Shell Canada Limited

application for the approval of

MUSKEG RIVER MINE PROJECT

Volume 4 • Environmental Impact Assessment

Biophysical and Historical Resources Cumulative Effects Assessment

submitted to
Alberta Energy and Utilities Board
and to
Alberta Environmental Protection

Calgary,
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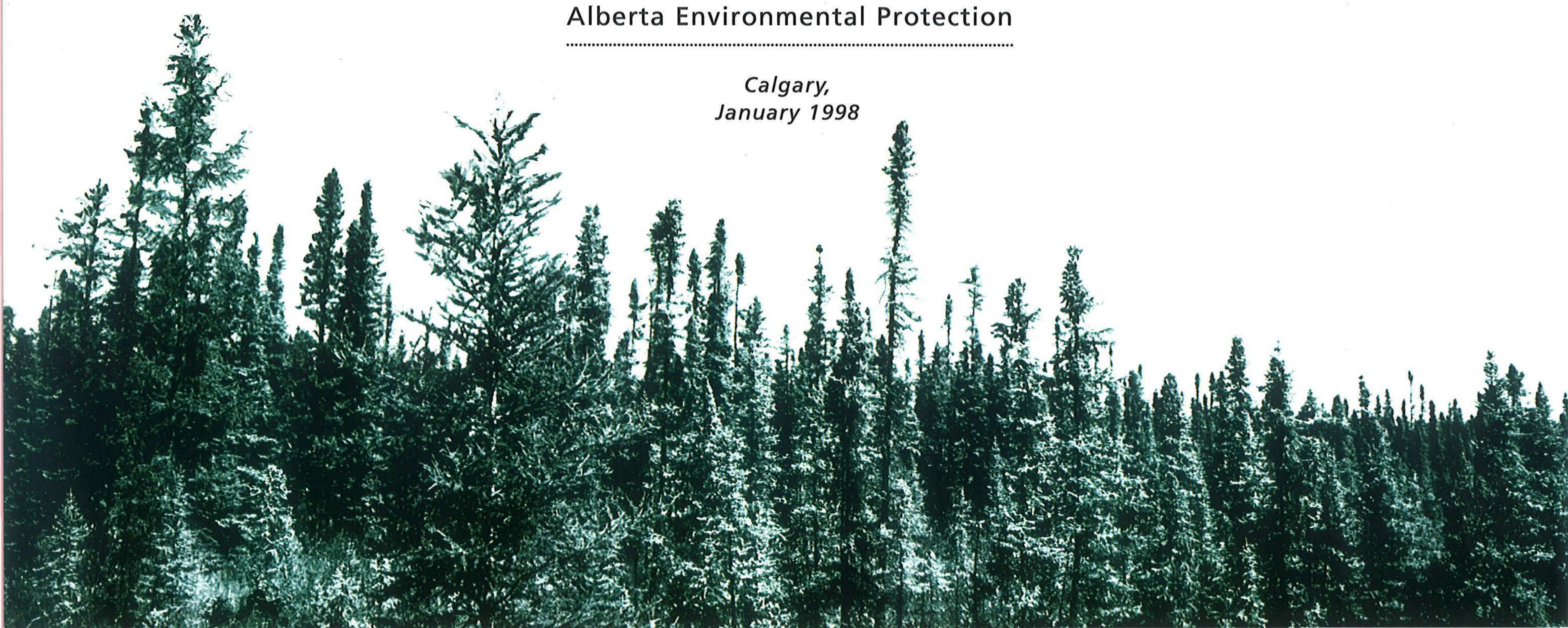

INTRODUCTION AND SUMMARY OF THE CUMULATIVE EFFECTS ASSESSMENT AND REGIONAL DEVELOPMENT REVIEW

The Muskeg River Mine Project (Project) Environmental Impact Assessment (EIA) is designed to provide relevant information to the regulators, public and other stakeholders about the potential effects of the Project under various scenarios. Shell has undertaken assessments of three development scenarios. These scenarios, which should encompass the range of potential effects hypothetically possible, include:

- the effects of the Project in combination with existing developments (Section E);
- the effects of the Project in combination with existing and approved developments (Section F); and
- the effects of the Project in combination with existing and approved developments, plus planned (publicly disclosed) developments (Section G).

The effects of the Project, in combination with existing developments is provided in Volume 3. The assessment of the potential impacts of the Project, in combination with existing developments in the region, is detailed within a local study area, which is defined to focus the assessment of the potential effects related to Project development. The residual impacts assessed for the Project are summarized in Section 10 of Volume 1, and detailed in Table A-2 (Section A) of Volume 2 of the Project Application.

The effects of the Project, in combination with existing and approved developments I provided in Volume 4 of the Project Application. Section F of the EIA includes the cumulative effects assessment (CEA) of the existing and approved (but not yet fully operational) developments plus the Project in a Regional Study Area (RSA) defined for the Project. The CEA involves evaluation of the potential effects of these combined developments on the RSA baseline environmental conditions, as defined in Volume 2 of the Project Application.

Section G of Volume 4 includes the assessment of a Regional Development Review (RDR). This RDR includes the results of the assessments completed in Section F coupled with consideration of the potential effects of planned developments. Once again, the potential effects of the combined developments on the baseline environmental conditions is considered within the RSA defined for the Project.

The methodologies used to assess and describe the effects varied according to the environmental component considered. The assessment methodologies are defined in Section E (Impact Assessment) with modifications required for the CEA or RDR detailed, as required, in Sections F and G.

To effectively understand the issues associated with an environmental impact assessment of the Project and other developments in the study area, Shell conferred with Provincial and Federal regulatory agencies as well as Project Stakeholders, including non-government organizations and the public. Specific guidance was provided through EIA Terms of Reference issued by AEP in November 1997.

Shell also is a participant in an oil sands industry initiated regional development review program. This program is designed to effectively evaluate the cumulative effect's associated with a probable development scenario for the oil sands region. This regional review initiative has involved regulatory agencies as well as regional stakeholders in program planning.

The Muskeg River Mine Project EIA is the first of a number of EIAs which will reflect participation in a coordinated regional approach to cumulative effects assessment and regional development review.

A component-specific summary of the EIA follows. The table following the overview details the residual impacts of the Muskeg River Mine Project under both the CEA and RDR scenarios. Details for specific EIA components under the CEA and RDR are provided in the respective sections in Section F and G of the EIA.

In summary, the predicted biophysical and historical resources impacts identified for the Muskeg River Mine Project are acceptable. The predicted impacts will have no significant, long-term effects on the environment, provided the recommended mitigation is undertaken. Details on the mitigation measures planned for the Project are provided in Table A-2 in Volume 2 of the Project Application.

COMPONENT-SPECIFIC SUMMARY OF THE EIA

Air Quality Impacts

Cumulative Effects Assessment

Maximum concentrations of emissions associated with mine pits and secondary combustion sources will occur close to the respective development areas (typically a few kilometres or less).

The CEA scenario will increase the area where the 0.25 keq/ha/a potential acid input (PAI) value is exceeded, from approximately 1,800 to 2,500 km^2. The Project contribution to this exceedance is approximately 30%. An additional 10 ppb maximum ozone concentration over the base case would still enable the 82 ppb guideline to be achieved.

Regional Development Review

The RDR scenario will increase the region where the 0.25 keq/ha/a PAI value is exceeded from 2,500 to 4,000 km^2. The Project contribution to this exceedance is approximately 11%. The continued increase in NO_x and VOC indicates a potential for ozone formation in the RSA due to precursor emissions. Under conditions favorable for the formation of ozone, there is the potential for the hourly guideline of 82 ppb to be exceeded. Shell, Syncrude and Suncor have recently initiated a program to model regional ground level ozone using a model expected to more accurately predict ozone concentrations.

Hydrogeology - Groundwater Impacts

Cumulative Effects Assessment

The cumulative impacts on Kearl Lake from drawdown, due to depressurization of the Basal Aquifer, are such that downward seepage from the lake will increase over both natural rates and the rate associated only with the Muskeg River Mine Project. This impact is not expected to extend to McClelland Lake. The complete recovery of groundwater levels in the Basal Aquifer is likely to take up to 30 years after completion of mining, however, groundwater levels will eventually recover. Therefore, the effects on Kearl Lake are reversible. Overall, the degree of concern related to cumulative effects of Basal Aquifer drawdown due to depressurization is considered to be low.

Regional Development Review

The residual impacts and degree of concern, considering proposed regional developments, is the same as for the cumulative effects assessment.

Surface Water Hydrology

Cumulative Effects Assessment

Combined developments associated with the CEA scenario will have negligible effects on the flows and water levels in Athabasca River both during operation and in the far future.

The combined developments will cause a small increase in sediment concentrations in the Muskeg River during operation, but will have negligible effects on channel erosion of the Muskeg River. Negligible increases in sediment concentrations and negligible increases in channel erosion will occur in the far future.

The reclaimed landscape and drainage systems will provide larger open-water areas of streams, wetlands and lakes, thus replacing the open-water areas lost during construction and operation.

The combined developments will cause small to moderate increases in the Muskeg River flows during the Project's operation and end pit lake management period. The combined developments will have only a small effect on the Muskeg River flows after closure.

Regional Development Review

The findings of the RDR are similar to the CEA scenario, except the developments will cause a small, instead of negligible, decrease in the flows and water levels in Athabasca River during operation. Negligible effects are projected for the far future.

Surface Water Quality

Cumulative Effects Assessment

Exceedances of toxicity guidelines for aquatic life are not predicted under the CEA scenario. There are two additional water quality guideline exceedances in the Athabasca River (benzo(a)anthracene at mean open-water flow and iron at 7Q10 flow). However, follow-up risk analysis in Section F11 and Section F12 did not identify these substances as a concern to wildlife or human health. No additional increases were predicted in levels of substances that exceeded guidelines in the Project Impact Assessment. In the Muskeg River, levels of nearly all substances that exceeded guidelines previously increased at both modelled flows, with six new substances predicted to exceed guidelines at 7Q10 flow. The additional developments included in the CEA will have a greater effect on the Muskeg River than on the Athabasca River, which reflects the different dilution capacities of these rivers. The degree of concern associated with these exceedances is negligible.

Greater temperature declines were predicted during the open-water season and the potential for slower seasonal warming and cooling is greater than predicted previously. However, the regulatory guideline for temperature is not predicted to be exceeded.

Due to the qualitative nature of the analysis, it is not possible to estimate differences in sediment polycyclic aromatic hydrocarbon (PAH) levels between the Impact Assessment and the CEA. Since pathways for PAHs to leave oil sands developments are limited, an impact on sediment PAH levels is unlikely.

The area affected by deposition of acidifying substances is greater than that identified during the Project Impact Assessment. This suggests that spring pH depression in sensitive waterbodies is a potentially important impact of combined developments in the RSA.

Regional Development Review

Concentrations of most substances exceeding guidelines in the RDR are identical to, or slightly higher than predicted concentrations in the CEA. Temperature declines predicted in the RDR are slightly greater than identified for the CEA, but remain below the guideline. The size of the area with potential spring pH depression in sensitive waterbodies is slightly larger for the RDR than that predicted for the CEA.

Aquatic Resources

Cumulative Effects Assessment

No tainting or accumulation of chemicals in fish are predicted as a result of combined developments. Neither are acute and chronic effects on fish expected. No effects on fish habitat in the Athabasca River are expected.

Negligible to Low effects on northern pike and Arctic grayling habitat in the Muskeg River are predicted due to predicted changes in flows and water temperature. Low effects on forage fish habitat are predicted in the RSA for the life of the developments. At each stage in the developments, habitat disturbed will be replaced with habitat of equivalent or better productivity. Habitat replaced through reclamation will result in a net gain in habitat for both forage and sport fish in the Far Future.

Regional Development Review

The results of the RDR for aquatic resources are the same as for the CEA.

Terrestrial Resource Impacts

Cumulative Effects Assessment

In the regional context, the terrestrial LSA comprises approximately 1% of the RSA. Within the RSA, approximately 0.4% will be developed by the Project.

Since no single macroterrain unit will be completely removed, the overall biodiversity at the macroterrain level will not be significantly altered. Soils and terrain that would be lost due the developments will be replaced with analogous forms. As a result of these developments, lands that have been rated as permanently or currently non-productive will be replaced with soils rated as low to moderate productivity.

Given the potential high level of imprecision in evaluating the acidifying emission and soil acidification linkages it was difficult to define residual impacts in a quantitative manner.

While there will be a loss of vegetative cover as a result of developing these projects, the loss will be offset through the reclamation programs. The residual impact on changes in biodiversity of terrestrial communities is low. The effects of air emissions on vegetative health in the RSA is expected to be of low concern. While fens represent approximately 65% of the RSA, the loss of bogs and fens for these developments is small (1.5%).

Although habitat loss was rated as moderate at the local level during operational stages, Shell intends to reclaim to equivalent or better habitat. This will result in an increase in habitat for upland species, e.g., moose and a decrease in habitat availability for wetland species, e.g., beavers. Effects on wildlife health due to changes to water, aquatic prey and plant quality was rated a Moderate degree of concern.

Regional Development Review

In reviewing the impacts on a regional development scale, planned projects were added to the existing and approved projects. The conclusions noted above are also directly applicable to those reached under the RDR evaluation.

Human Health Impacts

Cumulative Effects Assessment

No impacts to human health are predicted due to exposure to the Athabasca and Muskeg river waters.

Air emissions from vehicle fleet exhaust and VOCs from tailings settling ponds and mine surfaces for the combined developments could potentially increase the air concentrations predicted for Fort McMurray, Fort McKay and Fort Chipewyan, but the concentrations are expected to be well within the guidelines or acceptable limits. The resulting exposure ratios for the CEA, which do not differ significantly from those derived for Project Impact Assessment, are within acceptable levels.

Increased air emissions from regional developments may contribute to human inhalation exposure and chemical concentrations in plant tissues. However, there are currently no data available to evaluate this question further.

While the magnitude of chemical exposures to individuals living on reclaimed landscapes is not likely to increase due to combined developments, because of the larger area of reclaimed landscapes in the region, this exposure pathway is more likely to be realized.

It was inferred from other investigations that there is a potential for elevated noise levels to result in Fort McKay and the likelihood will increase with the added contribution of other regional developments. However, given the mobile nature of the noise sources and the capability to mitigate the noise levels through management of activities and/or use of noise barriers, the degree of concern was ranked as low.

Regional Development Review

No impacts to human health are predicted due to exposure to Muskeg and Athabasca river waters as a result of additional developments associated with the RDR.

The air emissions from vehicle fleet exhaust and VOCs from settling ponds and mine surfaces for the combined developments could potentially increase the air concentrations predicted for Fort McMurray, Fort Chipewyan and Fort McKay, but the concentrations are expected to be well within the guidelines or acceptable limits. The resulting exposure ratios for the RDR scenario do not differ significantly from those derived for the CEA and the Project Impact Assessment scenarios and are within acceptable levels.

As indicated in the CEA, further increased air emissions from regional developments may contribute to human inhalation and exposure as well as chemical concentrations in plant tissues. However, there are currently no data available to evaluate this question further.

While the magnitude of chemical exposures to individuals living on reclaimed landscapes is not likely to increase due to combined developments, because of the larger area of reclaimed landscapes in the region, this exposure pathway is more likely to be realized.

It was inferred from other investigations that there is potential for elevated noise levels to result in Fort McKay and the likelihood will increase with the added contribution of approved and planned developments. However, given the mobile nature of the noise sources and the capability to mitigate the noise levels through management of activities and/or use of noise barriers, the degree of concern was ranked as low.

Traditional Land Use and Non-Traditional Resource Use

Cumulative Effects Assessment

Timber resources will be adequately salvaged and forest capability will be equivalent to, or greater than predevelopment levels. Non-consumptive resource use will be reduced during construction and operations. Hunting and trapping potential will be reduced during construction and operations as a result of access restrictions and habitat disruption. Some fishing opportunities will be lost due to development.

Some ESAs may be affected by changes in terrain, vegetation and wildlife or changes in access. Provided that known ESAs are avoided to the extent possible, and that appropriate mitigation measures are used to further minimize impacts, the cumulative impacts associated with the various developments on ESAs will be minor.

A small proportion of recreational areas is expected to be lost due to the cumulative effects of various developments. Loss will result primarily from changes in access and changes in terrain, vegetation and wildlife. However, potential recreational sites in the RSA are numerous.

Regional Development Review

The same impacts and conclusions for the CEA scenario are applicable to the RDR scenario.

Historical Resources

The Project, together with oil sands developments in the immediate area, have greater potential to negatively effect historical resources than do other developments not situated in the landscape formed by the Glacial Lake Agassiz flood. This event is associated with a regionally unique prehistoric site distribution pattern.

Typically, identification of regional historical resources has been related to assessments completed for specific developments. Therefore, as was completed for the Project, assessments of impacts of developments on historical resources are best completed on an individual development basis, rather than under a cumulative effects assessment or regional development review.

Summary of Residual Impacts for CEA and RDR

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
AIR QUALITY ISSUES		
AQCEA-1 Will emissions from combined developments result in exceedances of ambient air quality guideline?	• The dispersion model predictions indicate that hourly and daily NO_2 concentrations should be less than the air quality guidelines. The annual average NO_2 concentrations, however, may exceed the guideline adjacent to the respective mines.	• The conclusions for the RDR are the same as for the CEA.
AQCEA-2 Will emissions from combined developments result in human health effects?	• The impact classification associated with these extrapolated concentration estimates is presented in the human health CEA.	• The impact classification associated with these extrapolated concentration estimates is presented in the human health section.
AQCEA-3 Will emissions from combined developments result in deposition of acid forming compounds that exceed target loadings?	• While the SO_2 emissions in the RSA are expected to be relatively stable (or perhaps even decrease), the RSA NO_X emissions are predicted to increase by about 40% over baseline levels. Of the increase from 78 to 110 t/d, the Muskeg River Mine Project accounts for 12 t/d. • The area where the PAI exceeds the 0.25 keq/ha/a target loading for sensitive ecosystem increases from 1,500 km^2 for the baseline emissions to 1800 km^2 with the addition of the project emissions. Under the CEA emissions scenario, the area further increases to 2,500 km^2.	• The RSA NO_X emissions are predicted to increase by about 150% over baseline levels. Of the increase from 78 to 195 t/d, the Muskeg River Mine Project accounts for 12 t/d. • The area where the PAI exceeds the 0.25 keq/ha/a target loading for sensitive ecosystem increases from 2,500 km^2 for the CEA emissions to 4,200 km^2 for the RDR emissions.
AQCEA-4 Will precursor emissions from combined developments result in the formation of ozone (O_3) concentrations that exceed air quality guidelines?	• Precursor NO_X and VOC emissions are estimated to increase by about 40 and 15%, respectively. The level of confidence for the VOC estimates, however, are lower than that for the NO_X emission estimates. • The estimated CEA NO_X emissions of 110 t/d are similar to those from urban areas such as Calgary (115 t/d) and Edmonton (151 t/d). The CEA VOC emissions of 50 t/d are less than one-half those from Calgary (120 t/d) and Edmonton (140 t/d). Photochemical modelling for these cities indicates a potential for downwind ozone values to exceed the guideline value of 82 ppb. • The previous application of the smog model to the RSA indicates a potential for the guideline value to be exceeded.	• precursor NO_X and VOC emissions are estimated to increase by about 150 and 30%, respectively. • There is a potential for downwind ozone values to exceed the guideline value of 82 ppb. • Shell will participate in an industry indicated study (with Syncrude and Suncor) to undertake more refined photochemical modelling using the recent VOC data and a more up-to-date photochemical model.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
	• Shell will participate in an industry initiated study (with Syncrude and Suncor) to undertake more refined photochemical modelling using more recent VOC data and more up-to-date photochemical model.	
HYDROGEOLOGICAL ISSUES		
GWCEA-1: Will Combined Developments Result in a Drawdown of Water Levels in the Basal Aquifer and Cause a Loss of Water From Important Lakes?	• The impact is expected to be limited to Kearl Lake. • The cumulative impacts on Kearl Lake from drawdown, due to depressurization of the Basal Aquifer, are such that downward seepage from the lake will increase over both natural rates and the rate associated only with the Muskeg River Mine Project. This impact is not expected to extend to McClelland Lake. The complete recovery of groundwater levels in the Basal Aquifer is likely to take up to 30 years after completion of mining, however, groundwater levels will eventually recover.	• Any additional production of groundwater from the Basal Aquifer due to other proposed developments will not have any additional effect on the downward seepage from Kearl Lake, since the analysis in the CEA already represents the upper limit for vertical seepage. • In the presence of other regional developments such as the Mobil Kearl Mine and SOLV-EX developments, the maximum downward seepage from Kearl Lake would be the same as the combined effect of the Muskeg River Mine and Aurora developments. That is, downward seepage from Kearl Lake would increase to 63 mm/year from 24 mm/year representing natural (pre-mining) conditions. Seepage of 63 mm/year represents about 14% of the mean annual precipitation received by the lake.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
SURFACE WATER ISSUES		
SWCEA-1: Will combined developments in the Muskeg River basin result in effects on the Muskeg River flows, sediment concentrations and channel regime?	• During construction and operation phases of the oil sands developments, the combined developments will cause small to large increases (4% to 23%) in the Muskeg River flows, primarily as a result of muskeg drainage, overburden dewatering, and transfer of the MFT to the end pit lake during reclamation of the Muskeg River Mine Project. • In far future, the average river flows in Muskeg River will increase slightly because the reclaimed surfaces will have different runoff characteristics from the natural basins. • During construction and operation phases of the oil sands developments, the increased Muskeg River flows will cause an increase in the streamflow sediment concentration by 0.2 to 1.2 mg/L and will cause a negligible increase in the channel erosion rate. • In the far future, the small increase in the Muskeg River flows will cause negligible changes in the river streamflow sediment concentration and channel regime.	• During construction and operation phases of the oil sands developments, the combined developments will cause small to large increases (4% to 23%) in the Muskeg River flows, primarily as a result of muskeg drainage, overburden dewatering, and a transfer of the MFT to the end pit lakes during mine reclamation. • In far future, the average river flows in Muskeg River will be similar to the natural conditions • During construction and operation phases of the oil sands developments, the increased Muskeg River flows will cause an increase in the streamflow sediment concentration by 0.2 to 1.2 mg/L and will cause a negligible increase in the channel erosion rate. • In the far future, there will be negligible changes in the river streamflow sediment concentration and channel regime.
SWCEA-2: Will combined developments result in effects on Athabasca River flows?	• During construction and operation phases of the oil sands developments, the regional developments will cause negligible changes to the mean flow conditions on Athabasca River. • After closure of all the oil sands developments, the regional developments will cause negligible changes to the mean flow conditions on Athabasca River.	• During construction and operation phases of the oil sands developments, the combined developments will cause small changes to the mean flow conditions on Athabasca River. • As determined in the CEA, after closure of all the oil sands projects, the developments will cause negligible changes to the mean flow conditions on Athabasca River.
SWCEA-3: Will combined developments result in effects to the open-water areas including lakes and streams?	• During construction and operation phases of the oil sands developments, the developments will permanently remove 464 ha of the natural open-water areas at the development areas. • After closure of all the oil sands developments, closure drainage systems at the reclaimed development areas will create 5,664 ha of new open-water areas.	• During construction and operation phases of the oil sands developments, the developments will permanently remove 852 ha of the natural open-water areas. • After closure of all the oil sands developments, closure drainage systems at the reclaimed mine sites will create 8,534 ha of new open-water areas which will replace the existing open-water areas lost to mine development.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
WATER QUALITY ISSUES		
WQCEA-1: Will Operational and Reclamation Water Releases From Combined Developments Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers?	• The combined developments considered in the CEA will cause exceedances of water quality guidelines for a number of metals, in addition to natural exceedances by certain metals. Although, exceedances of human health water quality guidelines were predicted to occur for two PAH compounds during initial high EPL discharges and in the Far Future, follow-up risk analysis in Section F11 and Section F12 did not identify these compounds as a concern to wildlife and human health.	• Concentrations of most substances exceeding guidelines in the RDR are identical to, or slightly higher than predicted concentrations in the CEA.
WQCEA-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?	• No exceedances of toxicity guidelines were predicted.	• No exceedances of toxicity guidelines were predicted
WQCEA-3: Will Operational and Reclamation Water Releases From Combined Developments Alter the Temperature Regime of the Muskeg River?	• Temperature fluctuations in the Muskeg River, as a result of changing flow regimes, will remain within temperature guidelines. However, uncertainties remain regarding potential effects on seasonal warming and cooling of river water and changes in diurnal temperature fluctuation. • Greater temperature declines were predicted during the open-water season in the CEA than in the Impact Assessment and the potential for slower seasonal warming and cooling is greater than predicted in the Impact Assessment.	• Compared to impact predictions in the CEA, temperature declines predicted in the RDR are slightly larger, but within temperature guidelines.
WQCEA-4: Will Muskeg and Overburden Dewatering Activities From Combined Developments Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?	• Dissolved oxygen impacts from muskeg drainage waters are not anticipated to occur.	• No further concern is evident compared to the CEA.
WQCEA-5: Will PAHs in Operational and Reclamation Water Releases From Combined Developments Accumulate in Sediments and Be Transported Downstream?	• PAH accumulation in sediments is not anticipated to occur due to limited available pathways, although uncertainties remain regarding release rates of PAHs from oil sands developments.	• Although impacts on sediment PAH levels are unlikely, this issue remains a potential concern related to oil sands developments. Due to the qualitative nature of the analysis, it is not possible to estimate differences in sediment PAH levels between the RDR, CEA and those identified in the impact assessment in the CEA in Section F5.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
WQCEA-6: Will Acidifying Emissions From Combined Developments Result in Changes in Water Quality?	• Acidification of waterbodies due to air emissions cannot be evaluated with a high degree of certainty at this time due to limited data on sensitivity of surface waters in the RSA to acidification. Although year-round acidification of surface waters in the RSA is highly unlikely, available data suggest that spring pH depression in sensitive waterbodies is a potential impact that should be examined further. • The predicted size of the area affected by deposition of acidifying substances, based on air quality modelling, will be 39% larger in the CEA than in the Impact Assessment. The Project is accountable for approximatley 36% of this increase.	• Compared to impact predictions in the CEA, the size of the potentially affected area identified, as predicted by air quality modelling for the RDR, increases by 68%. The Project is accountable for less than 1% of this increase.
AQUATIC RESOURCES ISSUES		
ARCEA-1: Will activities from the combined developments change fish habitat?	• No impacts on northern pike or Arctic grayling habitat are predicted. • No negative effects are predicted for longnose sucker habitat. • For the CEA, loss of forage fish habitat (1.7%) is predicted in the RSA. The Project contributes less than 0.1% of this impact. At each stage in the developments, habitat disturbed will be replaced with habitat of equivalent or better productivity. Forage fish habitat replaced through reclamation will result in a net gain (20% more that currently exists) in habitat for both forage fish and sport fish in the Far Future.	• No impacts on northern pike of Arctic grayling habitat are predicted. • No negative effects are predicted for longnose sucker habitat. • For the RDR, loss of forage fish habitat (3.1%) is predicted in the RSA. This loss elevated over the CEA where the loss is about 1.7%. The Project contributes less than 0.1% of this impact. At each stage in the developments, habitat disturbed will be replaced with habitat of equivalent or better productivity. Forage fish habitat replaced through reclamation will result in a net gain (30% more that currently exists) in habitat for both forage fish and sport fish in the Far Future.
ARCEA-2: Will operational and reclamation water releases from combined developments result in acute or chronic effects on fish?	• No acute or chronic effects on fish as a result of changes in temperature, dissolved oxygen, sediment or water quality are predicted.	• No acute or chronic effects on fish as a result of changes in temperature, dissolved oxygen, sediment or water quality were predicted.
ARCEA-3: Will operational and reclamation water releases from combined developments result in changes to fish tissue quality?	• No tainting or accumulation of chemicals in fish are predicted.	• No tainting or accumulation of chemicals in fish are predicted.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
ARCEA-4: Will operational and reclamation water releases from combined developments result in changes in fish abundance?	• No changes in fish abundance are expected as a result of acute and chronic effects, change in access or habitat.	• No changes in fish abundance are expected as a result of acute and chronic effects, change in access or habitat.
ECOLOGICAL LAND CLASSIFICATION ISSUES		
ELCCEA-1: Will activities from combined developments result in a loss or alteration of ELC units and diversity?	• In this CEA, the total losses to macroterrain units are 22,598 ha or 2.1% of the RSA. The Project will contribute 4,343 ha or 0.4% of the loss in the RSA.	• The combined developments will remove 40,633 ha or 3.9% of macroterrain units in the RSA. The Project will contribute less than 0.1% to this reduction. The total number of macroterrain units will not decrease and therefore, the diversity will not change.
TERRAIN AND SOILS ISSUES		
TSCEA-1: Will combined developments alter the quantity and distribution of terrain and soil units?	• During construction and operations phases the combined developments will cause a loss of 2.1% of the natural terrain and soil units in the RSA. The phased nature of development and reclamation will mediate the concern. • Reclamation of the developed areas with reconfigured terrain units covered by a reclamation soil mixture will produce very Positive impacts by increasing the diversity of terrain units.	• During the construction and operation phases of the combined developments will cause a loss of 3.9% of the natural terrain and soil units in the RSA. • This is a worst case perspective as it is unlikely that all sites will be developed to their maximum extent concurrently. The phased nature of development and reclamation will mediate the degree of concern. • Reclamation of the developed areas and existing disturbed areas with reconfigured terrain units covered by a reclamation soil mixture will produce very Positive impacts by increasing the diversity of terrain units.
TSCEA-2: Will combined developments alter soil capability and sensitivity?	• As a result of alterations in the quantity and distribution of soil and terrain units between the pre-development and closure landscapes, changes in soil capability will be produced. These are estimated to be: Positive in direction. The positive direction of change is the result of significant areas of non-productive class 4 and 5 land being reclaimed to low and moderately productive classes 2 and 3. • Operational activities of the developments will increase the levels of potentially acidifying emissions released into the RSA air shed. Associated with this is a low level of certainty as the PAI-soil acidification linkage is ill-defined.	• As a result of alterations in the quantity and distribution of soil and terrain units between the pre-development and closure landscapes, changes in soil capability will be produced. The Positive direction of change is the result of significant areas of non-productive class 4 and 5 land being reclaimed to low and moderately productive classes 2 and 3. • Operational activities of the developments will increase the levels of potentially acidifying emissions released into the RSA air shed.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
TERRESTRIAL VEGETATION ISSUES		
TVCEA-1: Will the combined developments, their reclamation and closure, result in a loss or alteration of vegetation communities?	• Loss of vegetation communities (28,642 ha or 2.8%) is predicted in the RSA. The Project contributes 4,343 or 0.4% of this impact. • All disturbed areas will be revegetated in accordance with reclamation plans. There will be a small increase in upland communities.	• Loss of vegetation communities (34,163 ha or 3.2%) is predicted in the RSA. The Project contributes 807 or 0.1% of this impact. • The RDR reclamation will increase terrestrial vegetation by 6.4% to 312,011 ha or 29.7% of the RSA.
TVCEA-2: Will the combined developments result in a change in vegetation diversity?	• There may be a short-term reduction in diversity within the RSA.	• There may be a short-term reduction in diversity within the RSA.
TVCEA-3: Will air emissions from combined developments result in a change to vegetation health?	• Vegetation health is not expected to be affected.	• Vegetation health is not expected to be affected.
WETLANDS ISSUES		
WTCEA-1: Will combined developments, their reclamation and closure, result in a loss or alteration of wetlands?	• The total loss of wetlands from the combined developments is 54,834 ha or 5.2% of the RSA. The Project's contribution to this loss is 6.1% under the CEA.	• The total loss of wetlands from the combined developments is 67,126 ha or 6.4% of the RSA. The Project's contribution to this loss is 5.0% under the RDR.
WTCEA-2: Will reclamation and closure of combined developments result in replacement of wetlands?	• Reclamation activities and reforestation will result changes to the distribution of wetland types in the RSA. Overall, fens and bogs will be reduced by 1.5% but marshes will increase by 0.3 % in the RSA.	• Overall, fens and bogs will be reduced by 2.6%, but marshes will increase by 0.1% in the RSA.
WILDLIFE ISSUES		
WCEA-1: Will the combined developments impact wildlife habitat?	• During the construction and operation phases of the oil sands developments, the combined developments will cause relatively small (1.2 - 3.1% of the RSA) losses of wildlife habitat due to site clearing and disturbance. The phased nature of site clearing and progressive reclamation will mitigate the cumulative effects of habitat loss. • Eventual reclamation of all sites should result in equivalent habitat capability for wildlife within the region.	• During the construction phase of the oil sands developments, the combined developments will cause relatively small (3.2 - 6.2% of the RSA) losses of wildlife habitat due to site clearing and disturbance.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
WCEA-2: Will changes to water, aquatic prey and plant quality from combined developments affect wildlife health?	• During operation of combined developments, no significant health impacts were identified for wildlife health from exposures to water from the Athabasca or Muskeg rivers; however, there is some uncertainty regarding the chronic toxicity of naphthenic acids. This prediction is not significantly different from that predicted for the Muskeg River Project. • Following closure in the far future when equilibrium conditions have been established for all combined developments, a potential impact associated with chemicals in plants has been identified in the CEA. The residual impact is likely to be enhanced in the CEA, relative to the impact predicted for the Muskeg River Mine Project in so far as there is a greater likelihood on a regional basis for this exposure pathway to be realized, but likely without an increase in exposure magnitude.	• The same conclusion reached in the CEA with respect to the uncertainty of the chronic toxicity of naphthenic acids is applicable to the RDR.
HUMAN HEALTH ISSUES		
HHCEA-1: Will water quality changes from combined developments affect human health?	• During operation and closure, no significant human health impacts were identified; however there is some uncertainty regarding the chronic toxicity of naphthenic acids and the potential exposure pathways. The resulting impact prediction for the CEA is not significantly different from that predicted for the Muskeg River Project.	• No significantly increased exposures predicted due to RDR.
HHCEA-2: Will air quality changes from combined developments affect human health?	• During operation of the combined developments, no significant impacts to human health were identified from the following emission sources: mine fleet exhausts, fugitive emissions from tailings settling ponds, fugitive emissions from mine surfaces and background sources of PAH in residential communities.	• During operation of the regional developments, no significant impacts were identified to human health from the following emission sources: mine fleet exhausts, fugitive emissions from tailings settling ponds, fugitive emissions from cut mine surfaces, and background sources of PAHs in residential communities.
HHCEA-3: Will changes to air and water quality from combined developments affect human health?	• During operation, no significant impacts are expected. However, there is some uncertainty regarding the chronic toxicity of naphthenic acids and exposures to airborne emissions from upgrader stack sources, as discussed for HHCEA-1.	• During operation, no significant impacts were identified for human health through this multimedia exposure pathway. However, there is some uncertainty regarding the chronic toxicity of naphthenic acids as discussed for HHCEA-1.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
HHCEA-4: Will changes to plant and game meat quality from combined developments affect human health?	1. During operation and closure phases of the Muskeg River Mine Project, no significant impacts were identified for human health as a result of consumption of native plants or wild game. Increased air emissions predicted for the CEA scenario may contribute to an increase in chemical concentrations in plant and game tissues. Quantitative estimates of future tissue concentrations are unavailable to assess the impact.	• During operation and closure phases of the Muskeg River Mine Project, no significant impacts were identified for human health as a result of consumption of native plants or wild game. Increased air emissions predicted for the RDR scenario may contribute to an increase in chemical concentrations in plant tissues. A potential impact is therefore predicted for the RDR. Quantitative estimates of future plant tissue concentrations are unavailable to quantify the impact further.
HHCEA-5: Will equilibrium concentrations of residual chemicals in water and select local food items following reclamation of all developments affect human health?	• Following closure in the far future when equilibrium conditions have been established for all combined developments, a potential impact associated with chemicals in plants has been identified in the CEA. The residual impact is likely to be enhanced in the CEA, relative to the impact predicted for the Muskeg River Mine Project in so far as there is a greater likelihood on a regional basis for this exposure pathway to be realized, but likely without an increase in exposure magnitude.	• Following closure in the far future when equilibrium conditions have been established for all combined developments, a potential impact associated with chemicals in plants has been identified in the RDR. The residual impact is likely to be enhanced in the RDR, relative to the impact predicted for the Muskeg River Mine Project and those predicted in Section F12, in so far as there is a greater likelihood on a regional basis for this exposure pathway to be realized, but likely without an increase in exposure magnitude.
HHCEA-6: Will noise from combined developments during construction and operation unduly affect people who reside in the region?	• During construction and operation, truck and shovel operations of combined developments may cause periodic exceedances of permissible sound levels in Fort McKay. The residual impacts identified in the CEA are not significantly different from those predicted for the Muskeg River Mine Project , due to the mobile nature of noise sources, the ability to mitigate and the remoteness of several developments to Fort McKay.	• The residual impacts identified in the RDR are not significantly different from those predicted for the Muskeg River Mine Project and those predicted in the CEA, due to the mobile nature of noise sources, the ability to mitigate and the remoteness of several developments to Fort McKay.
RESOURCE USE ISSUES		
RUCEA-1: Will Combined Development Result in a Change in Surface and Mineral Extraction Use?	• Mitigation measures will reduce the impact to the surface disposition. However, some of the disposition (in this case the Athabasca River Valley) will still be affected.	• No effects were identified for the Project in the RDR over those discussed in Section F14.
RUCEA-2: Will Combined Developments Result in a Change in ESAs?	• The Kearl Lake ESA may be affected by changes in terrain, vegetation, or wildlife or by changes in access. Provided that this ESA is avoided to the extent possible and that appropriate mitigation measures are used to further minimize impacts, the cumulative impacts associated with the developments on this ESA will be minor.	• The Kearl Lake wildlife movement corridor may be affected by changes in terrain, vegetation and wildlife or changes in access. Provided that appropriate mitigation measures are used to further minimize impacts, the impacts associated with the various developments on ESAs will be minor.

Key Question/Environmental Issue	Cumulative Effects Assessment (CEA)	Regional Development Review (RDR)
RUCEA-3: Will Combined Developments Result in a Change in Forestry Resource Use?	• Some areas of merchantable timber will be lost due to project development. This impact cannot be mitigated. However, the degree of concern is **Low**, as these areas represent a very small portion of the total AAC. • In the long-term, forest production will be equal to, or greater than that which existed prior to the developments.	• Some areas of merchantable timber will be lost due to development. This impact cannot be mitigated. However, the magnitude of the impact is expected to be Low, as these areas represent a very small portion of the total AAC. • In the long-term, forest production will be equal to, or greater than that which existed prior to the developments.
RUCEA-4: Will Combined Developments Result in a Change in Hunting, Trapping, Fishing and Berry Picking?	• There will be a decrease in berry picking activities due to loss of berry picking habitat and restricted access. There are no mitigation measures for site clearing and restricted access. Following closure, however, important berry picking habitat can be restored and developed sites are returned to equivalent or greater capability. • A small proportion of hunting sites and some trapping areas will be lost due to changes in access and changes in wildlife abundance and distribution. Following closure, hunting opportunities will be similar to, or greater than that which existed prior to development. • Some fishing opportunities will be lost due to development of projects. In particular, restricted access will lead to reduced fishing opportunities and this impact cannot be mitigated. Following closure, fishing opportunities will be similar to, or greater than that which existed prior to development.	• A small proportion of hunting sites will be lost due to changes in access and changes in wildlife abundance and distribution. Following closure, hunting opportunities will be similar to, or greater than that which existed prior to development. • As indicated in the CEA, important berry picking habitat can be restored by careful restoration of the site, and many disturbed sites can be returned to equivalent or greater capability. • Some trapping areas may be lost as a result of project development (i.e., site clearing and restricted access). This impact cannot be mitigated. However, the loss in trapping opportunities should only exist during the life of the project under consideration. As well, trappers can be reimbursed for the loss of revenue. • Some fishing opportunities will be lost due to development of projects. In particular, restricted access will lead to reduced fishing opportunities, and this impact cannot be mitigated. Following closure, fishing opportunities will be similar to, or greater than that which existed prior to development.
RUCEA-5: Will Combined Developments Result in a Change in Non-Consumptive Recreational Use?	• Recreational areas along the Athabasca and Muskeg Rivers may be affected by changes in access and changes in terrain, vegetation and wildlife.	• The conclusion reached for the RDR and the same in the CEA.

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SYMBOLS AND ABBREVIATIONS	
7Q10	Lowest 7-day consecutive flow that occurs, on average, once every 10 years
″	Inch
<	Less than
>	Greater than
%	Percent
°C	Temperature in degrees Celsius
°F	Temperature in degrees Fahrenheit
$k	Thousand dollars
µg/L	Micrograms per litre
$\mu g/m^3$	Micrograms per cubic metre
AAC	Annual Allowable Cut
ABDC	Aboriginal Business Development Committee
AEOSRD	Alberta Energy Oil Sands and Research Division
AEP	Alberta Environmental Protection
AEP-LFS	Alberta Environmental Protection - Land and Forest Service
AEPEA	Alberta Environmental Protection and Enhancement Act
AEUB	Alberta Energy and Utilities Board
Al-Pac	Alberta-Pacific Ltd.
AMD	Air Monitoring Directive
AOSERP	Alberta Oil Sands Environmental Research Program
AOSTRA	Alberta Oil Sands Technical Research Authority
API	American Petroleum Institute
APL	Alberta Power Limited
ARC	Alberta Research Council
asl or ASL	Above sea level
ATP	AOSTRA Taciuk Process
avg.	Average
bbl	Barrel, petroleum (42 U.S. gallons)
bpcd	Barrels per calendar day
BCM	Bank cubic metres
BCY	Bank cubic yards
BOD	Biochemical Oxygen Demand

SYMBOLS AND ABBREVIATIONS	
C	Carbon
C&R	Conservation and Reclamation
Ca	Calcium
$CaCO_3$	Calcium carbonate
CCME	Canadian Council of Ministers of the Environment
$CaSO_4$	Calcium sulphate
CANMET	Canada Centre for Mineral and Energy Technology
cd	Calendar day
CEA	Cumulative effects assessment
CEC	Cation exchange capacity
CEPA	Canadian Environmental Protection Act
ch	Calendar hour
CHWE	Clark Hot Water Extraction
CLI	Canada Land Inventory
cm	Centimetre
cm^2	Square centimetres
cm/s	Centimetres per second
CO_2	Carbon dioxide
COD	Chemical oxygen demand
COH	Co-efficient of haze
Conif.	Coniferous
CONRAD	Canadian Oil Sands Network for Research and Development
Consortium	Fine Tailings Fundamentals Consortium
CPUE	Catch per unit of effort
CSA	Canadian Standards Association
CSEM	Continuous Stack Emissions Monitor
CT	Consolidated Tailings
CWQG	Canadian Water Quality Guidelines
d	Day
DBH	Diametre at breast height
Decid.	Deciduous
DL	Detection limit
DEM	Digital elevation model
DO	Dissolved oxygen
DRU	Diluent Recovery Unit

SYMBOLS AND ABBREVIATIONS	
EC	Effective Concentration
e.g.	For example
EIA	Environmental Impact Assessment
ELC	Ecological Land Classification
elev	Elevation
EPA	Environmental Protection Agency (U.S.)
EPL	End Pit Lake
ER	Exposure ratio
FEM	Finite Element Modelling
FGD	Flue Gas Desulphurization
FMA	Forest Management Agreement
ft.	Feet
$ft.^3$	Cubic feet
g	Grams
g/cc	Grams per cubic centimetre
GC/FID	Gas Chromatography/Flare Ionization Detection
GC/MS	Gas Chromatography/Mass Spectrometry
GDP	Gross Domestic Product
GIS	Geographic Information System
GJ	Gigajoules
GLC	Ground Level Concentration
Golder	Golder Associates Ltd.
h	Hour
ha	Hectares
HQ	Hazard quotient
HSI	Habitat suitability index
H_2S	Hydrogen sulphide
HU	Habitat unit
ibid.	In the same place
i.e.	That is
IC	Inhibiting concentration
ICP	Inductively coupled argon plasma atomic emission spectrometric analysis
IR	Infrared spectrophotometric analysis
IRIS	Integrated Risk Information System
IRP	Integrated Resource Plan

SYMBOLS AND ABBREVIATIONS	
k or K	Thousand
kg	Kilogram
kg/d	Kilograms per day
kg/ha	Kilograms per hectare
kg/h	Kilograms per hour
KIRs	Key Indicator Resources
km	Kilometre
km^2	Square kilometres
km^3	Thousand cubic metres
KV	Kilovolt
L or l	Litre
LC/MS	Liquid Chromatography/Mass Spectrometry
LGHR	Low grade heat recovery
lb/hr	Pounds per hour
LC	Lethal concentration
LOAEL	Lowest observed adverse effect level
LOEL	Lowest observed effect level
LSA	Local Study Area
m	Metre
M	Million
m/s	Metres per second
m^2	Square metres
m^3	Cubic metres
m^3/ha	Cubic metres per hectare
m^3/cd	Cubic metres per calendar day
m^3/d	Cubic metres per day
m^3/hr	Cubic metres per hour
m^3/s	Cubic metres per second
Mm^3	Million cubic metres
meq	Milliequivalents
MFT	Mature Fine Tails
mg	Milligrams
mg/kg/d	Milligrams per kilogram body weight per day
mg/L	Milligrams per litre
MJ	Megajoule
MLA	Member of the Legislative Assembly
mm	Millimetre

SYMBOLS AND ABBREVIATIONS	
Mobil	Mobil Oil Canada
MP	Member of Parliament
mS/cm	millisiemens per centimetre
MVA	Megavolt amperes
MW	Megawatt
N	Nitrogen
N/A or n/a	Not applicable
NAQUADAT	Alberta Environmental Historical Water Database
n.d.	No date
N.D.	No data
No.	Number
NOAEL	No observed adverse effect level
NOEL	No Observable Effect Level
NO_x	Oxides of nitrogen
NPRI	National Pollutant Release Inventory
NRBS	Northern River Basin Study
O & G	Oil and Grease
OSEC	Oil Sands Environmental Coalition
OSLO	Other Six Lease Owners
OSWRTWG	Oil Sands Water Release Technical Working Group
P	Phosphorus
PAH	Polycyclic aromatic hydrocarbons
PANH	Polycyclic Aromatic nitrogen heterocycles
PASH	Polycyclic aromatic sulphur heterocycles
PM_{10}	Particulate matter $\leq$ 10 microns in diameter
$PM_{2.5}$	Particulate matter $\leq$ 2.5 microns in diameter
PMF	Probable maximum flood
ppb	Parts per billion
ppm	Parts per million
psi	Pounds per square inch
Q	Quarter (i.e., 3 months of a year)
QA/QC	Quality Assurance/Quality Control
RSA	Regional Study Area

SYMBOLS AND ABBREVIATIONS	
RAQCC	Regional Air Quality Coordinating Committee
RfD	Reference dose
RsD	Risk Specific dose
RRTAC	Reclamation Research Technical Advisory Committee
s	Second
S	Sulphur
SAGD	Steam Assisted Gravity Drainage
SAR	Sodium absorption ratio
scf/d	Standard cubic feet per day
SCO	Synthetic crude oil
SEC	Supplementary Emission Control
SFR	Sand to fines ratio
SLC	Screening level criteria
SO_2	Sulphur dioxide
SO_x	Sulphur oxides
SO_4	Sulphate
spp.	Species
Suncor	Suncor Energy Inc., Oil Sands
Syncrude	Syncrude Canada Ltd.
t	Tonne
t/cd	Tonnes per calendar day
t/d	Tonnes per day
TDS	Total dissolved solids
THC	Total hydrocarbons
TID	Tar Island Dyke
TIE	Toxicity identification evaluation
TKN	Total Kjeldahl Nitrogen
TOC	Total organic carbon
TofR	Terms of Reference
Ton	2000 pounds (Imperial)
Tonne	2205 pounds (Metric)
t/h	Tonnes per hour
TRV	Toxicity reference value
TSS	Total suspended solids
TV/BIP	Ratio of total volume removed to total volume of bitumen in place
Twp	Township

SYMBOLS AND ABBREVIATIONS	
$\mu g/m^3$	microgram per cubic metre
$\mu g/L$	microgram per litre
$\mu g/kg/d$	microgram per kilogram body weight per day
UTF	Underground test facility
USEPA	U.S. Environmental Protection Agency
USgpm	U.S. gallons per minutes
VOC	Volatile organic compound
Vol.	Volume
vs.	Versus
WET	Whole effluent toxicity
wt%	Weight percentage
y	Year

Section Title	Description	Cross-Reference	
		Volume	Section
Introduction	**Introduction**		
	identify for Shell and the public, information required by government agencies for EIA report	Terms of Reference	
Purpose	relevant impacts, mitigation options and residual impacts will be addressed	2 3	A E1
	impact predictions in terms of magnitude, frequency, duration, seasonal timing, reversibility, geographic extent.	2	A
	identify residual and cumulative impact and significance	1 2	10 A
	discuss mitigation measures, protection plans, monitoring or research programs, environmental performance objectives, anticipated regulatory requirements	1 2	10 A
Public Participation	EIA will be part of application to EUB	1	1
	Residents from:	1	12
	Fort McMurray		
	Fort McKay		
	Fort Chipewyan		
	communities of Wood Buffalo and		
	industrial, recreational, and environmental groups		
	public given opportunity to participate and express concerns		
	public notification of EIA given		
	Project Overview		
Proponent and Lease 13 History	provide proponent name and name of legal entity	1 2	1 A
	description of history of proposed development, resource characterization, environmental studies	1 2	1 A, B
Project Area and EIA Study Areas	includes all disturbed areas	2	D
	description of rationale and assumptions of Regional and Local Study Area boundaries including those related to cumulative effects	2	D1
	maps of study areas to include township and range lines	2	D1
	provide maps with lease boundaries, land tenure, facility locations	1	4
	include lakes, streams and other geographic information	1	4
Project Components and Development Schedule	overview of project components, mining operations, process facilities, buildings, transportation infrastructure, utilities, pipeline to Scotford and Scotford upgrader project	1 2	1,4,5,7,13 B
	development schedule including:	1 3	4,16 E16
	pre-construction		
	construction		
	operation		
	reclamation and		
	decommissioning		
	key factors controlling schedule	1	1,15
	describe major components to be applied for and constructed within 10 years	1	1,16
Project Need and Alternatives	analysis of need of project, including a no development scenario	1	1.1
	discuss an alternative means of doing project	1	1.1
	identify potential cooperative development opportunities	1	1.1
	summary of reasons for selecting project and major components	1	1

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Section Title	Description	Cross-Reference	
		Volume	Section
Regulatory Approval	identify regulatory approvals and legislation.	1	1
	consider municipal, provincial and federal governments	1	1
	identify government policies, resource management, planning or study initiatives pertinent to the Project and discuss implications	1	1
	Project Description		
General Information	describe mining, extraction and waste management components	1	4,5,6,7,8,9,16
	provide map of buildings, road access, pipeline routes, water pipelines, utility corridors, sand and waste disposal sites	1	1,4,8
	identify criteria and assumptions for locating facilities	1	4,8
	provide description and schedule of land clearing	1	4
	provide schedule for location and relocation of pit storage	1	4
	follow Oil Sands Subregional Integrated Resource Plan (IRP) setbacks for Athabasca, Muskeg and other tributaries	1 3	1 E16
Process Description	describe preparation and extraction processes	1	5
	provide material and energy balances	1	9
	basic flow diagrams	1	7,8,9
	describe technologies used and describe effects on water use, waste generation, chemical use, tailings, air emissions and bitumen recovery	1	6,7,8,16
	discuss alternative technologies considered	1	1,4,5,6
	hydrocarbon and sulphur balance and energy efficiency information	1	9
Mining Description	describe mining method	1	4
	discuss alternatives considered and environmental implications	1	3,4
	describe minimum ore grade selected and effect on tailings and fine tailings volumes, water requirements and long term reclamation	1	3,4
Utilities and Description	maps of utilities	1	7
	discuss amount of energy needed and source	1	7
	discuss options considered for thermal and electric power and environmental implications	1	7
	describe road access and needs for upgrading and new roads	1	7
	discuss the need for access management	5	
	provide results of consultation with local road authority	5	
	describe methodology and projected frequency for traffic on Highway 63 and Ft. Chipewyan winter road	5	
	discuss mitigation	5	
	discuss cooperation with other oil sand and industry operators	5	
	describe access through Lease 13	1	7
	describe location, volume and source for road construction material	1	7
	describe utility and pipeline stream and river crossings	1	7
Air Emissions Management	indicate type, rate and source of air emissions, include construction and vehicle pool	1 3	16 E2.2
	identify emission and fugitive emission points on site plan	3	E2.2.3 E2.2.5 E2.2.6
	describe monitoring and control systems	3	E2
	describe Shell's existing monitoring and involvement in RAQCC and CASA	1 3	12 E2
	estimate greenhouse gases	2 3	D2.7 E2.2.7 E2.7.1
	describe greenhouse gas management plan and place emission estimates in context with total emissions provincially and nationally	2 3	D2.7 E2.7.1

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Section Title	Description	Cross-Reference	
		Volume	Section
Water Supply and Management	describe process water and chemical requirements	1	8,16
	discuss water efficiency designs considered for all aspects of the project including, emergency operation designs	1 3	8 E4
	describe source of water and options considered	1	8
	discuss seasonal variability of water use, diversion and impacts	1	8
	describe nature, location, volume, quality and fluctuations of effluents	1	8
	show locations of water intakes and associated facilities treatment plants	1	8
	provide a water management plan and water balance, address site run-off and containment, groundwater protection and depressurization	1 3	8 E3
	describe wastewater treatment and disposal	1	8
	include water balance for life of project	1	8
	describe alternatives to minimize wastewater	1	8
	describe alternatives to minimize change in Muskeg River and tributary flows	1 3	8 E4
Waste Management	describe management plan for tailings, overburden, other mining wastes and camp.	1	4,6
	include plans to minimize fine tailings production	1	4,6
	identify all on-site disposal areas on site plan	1	4,6
	indicate strategy for disposal areas, their location and timing	1	4,6
	include plans to minimize above ground storage of overburden and tailings	1	4,6
	describe waste management strategy on-site industrial landfills, estimate quantity and composition of routine landfill wastes	1	16
	describe waste minimization and recycling plans	1	16
	describe waste management strategy for hazardous wastes, provide quantity and composition of hazardous wastes	1	16
	describe storage and handling methods proposed	1	16
	Environmental Impact Assessment Methodology		
Assessment Requirements	provide information on the environmental resources and resource uses that could be affected by the project	2	D
	provide sufficient information to predict positive and negative impacts	2,3,4	all sections
	extent impacts can be mitigated by planning, project design, construction techniques, operational practices, and reclamation techniques	3 2	all sections A
	quantify impacts in terms of spatial, temporal and cumulative effects	3	all sections
	sources of information will be reviewed and discussed	2,3,4	all sections
	limitations will be discussed	3	all sections
	information sources will include: • EIA studies	2,3,4	all sections
	• operating experience from current oil sands operations		
	• industry study groups		
	• traditional knowledge		
	• government sources		
	undertake studies where additional information is needed	Baseline Reports 2	all sections
	broad-based examination of ecosystem components, including previous environmental assessment work	2 3,4	D E,F,G
	describe and rationalize the selection of key components and indicators examined:	2 3	D E

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Section Title	Description	Cross-Reference	
		Volume	Section
	• For each environmental parameter	2	D
	• describe existing locations and comment if available data are sufficient to assess impacts and mitigative measures	2 3	D E
	• identify environmental disturbance from previous activities that have become part of baseline conditions	2	D
	• describe the nature and significance of environmental effects and impacts associated with development activities	3,4	E,F,G
	• present an environmental protection plan (EPP) to mitigate negative impacts, discuss key elements	2 3,4	A E,F,G
	• identify residual impacts and significance	3,4	E,F,G
	• present a plan to identify possible effect and impacts, monitor environmental impacts and manage environmental changes to demonstrate the project is operating in a environmentally sound manner	2 3 4	A E F,G
	• present recommendations for environmental protection or mitigation which may require joint government, industry and community resolution	2 3 4	A E F,G
Cumulative Environmental Effects Assessment	assess cumulative environmental effects for the project	4	F,G
	• define study and time boundaries, give rationale and assumptions	4	FG
	• consider environmental effects of other existing and proposed projects (public disclosure stage) or reasonably foreseeable activities in the region	3,4	E,F,G
	• demonstrate that any information of data from previous oil sands and other development projects is appropriate, supplement where required and consider all relevant environmental components	3,4	E,F,G
	• explain the approach and methods used to identify and assess cumulative impacts	3,4	E,F,G
	provide a record of all assumptions, confidence in data and analysis to support conclusions	2 3,4	D E,F
Climate, Air Quality and Noise	discuss baseline air quality and climate of area	2	D2.4,2.5 D4
	identify components of project and effect on local and regional air quality	3	E2
	document appropriate air quality parameters including NO_x, VOCs, ground level ozone, TRS, total hydrocarbons, acidifying emissions, and particulates	2 3	D2.2 D2.5 E2
	model ground-level ozone as part of joint industry cumulative effects assessment	3 4	E2.6 F2
	estimate ground levels of appropriate air quality parameters	3	E2.3, E2.4
	discuss changes to ambient particulate levels or acidic depositional patterns	2 3	D2.6, E2.5
	justify and identify limitations of models used	Appendix II	
	identify potential for decreased air quality	3	E2
	discuss implications on environmental protection and public health	3	E9,E11 E12
	discuss interactive effects of co-exposure of receptors to emissions and discuss limitation in present understanding of this subject	3	E12.7 E12.11
	discuss how impacts will be mitigated	3	E2
	identify a program to monitor air quality	3	E2

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Section Title	Description	Cross-Reference	
		Volume	Section
	identify project components that will increase noise, discuss mitigation	3	E12.11
	assess cumulative effects of air quality in the study area	4	F2, F12,G2, G12
Geology, Terrain and Soils	describe and map bedrock and surficial geology, topography and drainage patterns in study area	1 2	2 D4
	relate bedrock and surficial geology to regional areas (e.g., Susan Lake Moraine)	1	2
	assess and map changes due to projects construction, operation and reclamation	3 4	E8 F8
	describe and map soil types and distribution	2	D8
	provide an assessment and map of pre and post-disturbance land capability	2 3	D8 E8,E16
	develop soils reclamation management plan	3	E16
	describe availability and suitability of soils for reclamation	3	E8,E16
	outline criteria for salvaging soils	1 3	16 E16
	identify areas for soil salvage and stockpiling and estimate volumes	3	E16
	identify soil constraints and limitations on reclamation.	1 3	16 E8
	identify activities that may potentially contaminate soils	3	E8
	collect baseline information to enable ecological land classification (ELCs)	2	D7
	describe impacts on ELCs	3	E7
Vegetation and Forest Resources	describe and map vegetation communities	2 Baseline Reports	D9
	identify rare, threatened or endangered species	2 3	D9.6 E9.7
	identify amount of land and types of vegetation communities to be disturbed	3	E9.7.4 E10.8.3
	describe mitigative measures	3	E9.9
	evaluate forest and peatlands/wetlands outlined in Alberta Vegetation Standards (AVI) Manual Version 2.2	2	D9,D10
	describe impact on commercial forestry	3	E14, E16
	assess development and mitigation affect on peatlands/wetlands cumulatively	3 4	E10 F10,G10
	identify and evaluate potential impacts, including cumulative impacts (in context of Draft Wetlands Policy for Alberta)	3 4	E10 F10,G10
	illustrate, on a conceptual end land use map, type and distribution of proposed reclaimed vegetation	1 3	16 E16
Wildlife	describe wildlife habitat types and use	2	D11
	identify rare and endangered species, habitat requirements and seasonal habitat use in significant areas	2	D11
	describe and map significant local habitat, seasonal habitat use, winter and summer range, and movement corridors for moose and other key indicator species	Golder 1998b 3	Golder 1998b E11.6.3
	comment on the sensitivity of key species and habitat to impacts	3	E11.6
	discuss regional and temporal effect and potential return to pre-disturbance conditions	3 3 4	E11.12 E11.15 F11,G11
	provide a mitigation plan	3	E11
	identify and discuss monitoring programs to assess impacts of project and mitigation plans	3	E11

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Section Title	Description	Cross-Reference	
		Volume	Section
	assess cumulative effects on wildlife (and wildlife health)	3 4	E11 F11,G11
Surface Hydrology	describe pre and post project surface hydrology	2 3	D4 E4
	identify potential impacts on local and regional hydrology	3 4	E4 F4
	include impacts on thermal regime of surface water of Muskeg River and associated tributaries	3	E5.7
	describe alterations to timing, volume, and duration of peak flows including the western portion of Lease 13 and future development on Lease 13 east, as appropriate	3	E4.4
	describe design and plans to protect Muskeg and tributaries, include location and dimensions of buffers	3	E4.3 E4.6 E4
	describe monitoring program to assess water management	3	E4,E5
	describe the design parameters for all water management plans and facilities required within duration of Water Resources Act (WRA) approval	1 3	16 E4.3
	describe and discuss with respect to other projects including cumulative effects	3 4	E5 F5,G5
	identify wastewater effluents, mine depressurized water and runoff in terms of source, volume, and seasonal timing	3	E3,E4.4
	describe management plans, mitigation measures and monitoring programs	3	E4
	discuss probable maximum flood and precipitation and influence on project design and contingency plans	3	E4.3 E4.9
Groundwater	discuss the groundwater regime	2 3 4	D3 E3 F3,G3
	summarize existing databases including flow patterns, groundwater quality, and regional interactions	2	D3
	describe effects on existing groundwater including water quality, quantity and thermal regime.	3 4	E3.6,E3.7 F3,G3
	discuss effects on basal aquifer	3 Appendix	E3.5, E3.6 E3.7
	discuss relationship between groundwater and surface water	3 4	E3.5,E3.6 E3.7,E4 F3
	describe monitoring programs and mitigative measures	3 4	E3 F3
	describe surficial and upper bedrock groundwater regimes	2	D3
Water Quality	describe baseline conditions	2	D5
	identify activities influencing water quality (before, during, after)	3	E5
	describe potential impacts with respect to location, magnitude, duration and extent, and significance	3	E5
	describe mitigation measures during construction, operation and reclamation	3	E5
	discuss seasonal variation and effects	3	E5.5 E5.6 E5.7
	describe monitoring program to assess water management system for collection, handling, treatment and discharge	3	E5.5.4 E5.6.4
	assess cumulative effects	4	F5,G5

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Section Title	Description	Cross-Reference	
		Volume	Section
	predict water quality conditions in Muskeg, Athabasca and other water bodies down stream of project	3	E5.5 E5.6
	compare predicted and existing water quality to Alberta Ambient Surface Water Quality Interim Guidelines, relevant US EPA guidelines, and Canadian Water Quality Guidelines	2 3	D5 E5
	consider the recommended procedure for using existing guidelines described in "Alberta Environmental Protection Protocol for Determining Water Quality Guideline Use"	3	E5
	discuss implications for short and long term water quality, resource use and aquatic resources	3 4	E5,E14 F5,F14
Aquatic Resources	describe fish resources including species composition, distribution, relative abundance, movements and life history parameters	2 Appendix VI Golder 1997d	D6
	describe and map appropriate fish habitat of Athabasca, Muskeg and tributaries affected by project	2 Golder 1997d, Golder 1998a	D6
	describe impacts to fish and fish habitat because of changes in water quality, water quantity, substrate and hydrology	3	E6.5 E6.6 E6.8
	discuss nature, extent, duration, magnitude and significance of impacts	3	E6.5.3, E6.6.3, E6.7.3, E6.8.3
	describe relevance to existing or potential domestic, recreational or commercial fishery	3	E14.12
	identify critical or sensitive habitats such as spawning, rearing and overwintering areas	2 Golder 1997d	D6
	describe existing information base, any deficiencies in information and studies proposed to evaluate the status of fish and aquatic resources	3	E6.5.4 E6.6.4 E6.7.4 E6.8.4
	identify, provide rationale and selection criteria for key indicator species	2 3	D1 E6.3
	identify impacts on fish and fish habitat from project construction and operation	3	E6.5 E6.6 E6.8
	assess cumulative effects in the on fish and fish habitats	4	F6,G6
	discuss cooperative mitigation strategies	4	F6,G6
	discuss design, construction and operation factors to protect fish resources	3	E6.5.2
	identify proposed mitigation and compensation plans for each impact and specific site identified	3	E6.5 E6.6 E6.7 E6.8
	identify residual impacts on fish and fish habitat, discuss significance to local and regional fisheries	3	E6.5.3 E6.6.3 E6.7.3 E6.8.3, E14.12
	discuss how development and mitigation will address "no net loss"	3	E6.5.2
	identify monitoring programs to address impacts and mitigation	3	E6.10

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Section Title	Description	Cross-Reference	
		Volume	Section
	discuss potential for fish tainting, survival of eggs and fry, chronic and acute health effects, and stress on populations from contaminants, sedimentation, and habitat changes	3	E6.5 E6.6 E6.7 E6.8
	Reclamation/Mine Closure		
	provide a reclamation plan describing anticipated land capability and end land use, land stability, erosion control, revegetation, development phasing, pit backfill sequencing, and time frames	1 3	16 E16
	describe how the final landform is incorporated into mine planning	3	E16
	describe implications to water quality and other ecosystem components of the technology selected for managing fine tailings and alternative technologies	3	E16.6
	describe management and disposal of water and processing wastes	3	E16.4
	describe how reclamation plan addressed IRP and other government policies	3	E16
	describe impacts on biodiversity	3	E9, E10, E16.6
	compare pre-disturbed and anticipated species list	3	E9, E11
	describe differences in type, size, variety or distribution of terrestrial and aquatic landscape units on wildlife habitat, traditional uses, aesthetics, recreation, or forestry	3	E16.5
	describe physical and biological parameters to be monitored and evaluated	3	E16.8
	outline key milestones and progress measures	1 3	16 E16.4
	describe plans to demonstrate success	3	E16.2
	review reclamation research and experience	3	E16.8
	describe future research initiatives to further reclamation technology	3	E16.8
	Land Use		
	identify aboriginal traditional land uses	3	E15
	identify existing land uses	2	D14, D15
	identify potential impacts on all land uses and possible mitigation	3	E14, E15
	identify area that are potential sites for special status	2	D13, D14
	Public Health and Safety Issues		
	describe aspects that may have pubic health implications	3	E12
	describe measures to minimize adverse health effects	3	E12
	describe monitoring	3	E12
	describe plans to participate in Alberta Oil Sands Community Exposure Health Effects Assessment Program	3	E12.7
	provide outline of emergency response plan	3	E12.10
	describe mitigation plans to ensure worker and public safety	3	E12.10
	include prevention and safety for wildfires, chemical releases and water and fluid holding structure failures	3	E12.10
	Public Consultation		
Public Consultation	document public consultation program	1 2	12 C
	describe method for dissemination of information to public	1	12
	describe type of information disseminated	1	12
	describe level and nature of response	1	12
	describe consultative process	1	12
	show how public input was obtained and addressed	1	12
	describe and document concerns expressed by public	1	12
	describe actions to address issues and concerns	1	12

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Section Title	Description	Cross-Reference	
		Volume	Section
	describe how resolutions of issues and concerns were incorporated into Project development, mitigation and monitoring	1	12
	describe plans to maintain the process after EIA review	1	12
	ensure proper public forum for expressing views during ongoing development, operation and reclamation	1	12
	Socio-Economic		
Socio-Economic Assessment	describe existing socio-economic conditions	5	4, Appendix
	define mitigation measures	5	5.1
	impacts of region with respect to: • local employment and training • opportunities and procurement • local services and infrastructure • timing and size of workforce • population changes	5	5.1
	Shell policy re. local hire, purchase	5	5.1
	Outline plans to work with local residents and business re employment and contracting opportunities	5	5.1.6
	evaluate cumulative impacts on local services and infrastructure	5	6
	Historical Resources		
	consult Alberta Community Development and Aboriginal communities, specifically Fort McKay, to establish process to assess historical, archaeological and palaeontological significance	2 3	D13, D15 E13, E15.4
	complete a field investigation which meets requirements of Alberta Community Development	3	E13
	develop appropriate mitigation plans	3	E13

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F CUMULATIVE EFFECTS ASSESSMENT

This section of the Muskeg River Mine Project (Project) EIA is the cumulative effects assessment of existing and approved developments plus the Project, to the extent information is known and available to the end of 1997. Included are predictions about how these combined developments could affect environmental resources and resource use in the Project Regional Study Area (RSA).

This cumulative effects assessment is followed by a Regional Development Review (Section G), which describes the potential effect of the Project in combination with existing, approved and publicly disclosed developments in the RSA.

F1 CUMULATIVE EFFECTS ASSESSMENT (CEA) - METHODOLOGY

F1.1 Introduction

This section of the Muskeg River Mine Project (Project) EIA provides information as required by the Project Terms of Reference (TofR) issued on November 7, 1997 (AEP 1997). Specifically, the following is addressed:

Assess cumulative environmental effects for the Project:

- define study and time boundaries, give rationale and assumptions;
- consider environmental effects of other existing and proposed projects (public disclosure stage) or reasonably foreseeable activities in the region;
- demonstrate that any information or data from previous oil sands and other development projects is appropriate, supplement where required and consider all relevant environmental components;
- explain the approach and methods used to identify and assess cumulative impacts; and
- provide a record of all assumptions, confidence in data and analysis to support conclusions.

Discussions on environmental baseline components for the Project were provided in Section D, while the potential impacts of the Project on the environment were detailed in Section E of this EIA.

CEA Definition

The cumulative effects of the Muskeg River Mine Project are assessed under the following premises:

- There must be an environmental effect related to the Muskeg River Mine Project;
- The environmental effect must be demonstrated to operate cumulatively with the environmental effect from other developments or activities; and
- The other developments or activities have been or will be carried out and cannot be hypothetical.

The assessment of the effects of development include consideration of two scenarios:

1. Muskeg River Mine Project Cumulative Effects Assessment (CEA) - predicts the cumulative effects from the Project plus existing and approved developments (Tables F1-1) in the Regional Study Area (RSA). This scenario is detailed in Section F of the EIA (Volume 4 of the Application).

2. Regional Development Review (RDR) - predicts the effects from the Project plus existing, approved and planned (publicly disclosed) developments. This scenario is detailed in Section G of the EIA (Volume 4 of the Application).

Table F1-1 details the developments included in each of the scenarios.

F1.2 CEA Framework

The impact assessment methodology, described in Section E1 of this EIA, is based on the incremental impact of the Project on the environment over and above the existing (baseline) conditions. Although this analysis is technically "cumulative" since it considers other existing developments, it is referred to in this document as the impact assessment of the Muskeg River Mine Project.

Cumulative effects assessments are defined for the purposes of this EIA as providing similar analyses to the impact assessment but extending the scope to consideration of the effects of additional developments which are approved within or near the RSA, but not yet fully in operation. It is important to consider these projects to fully understand the potential incremental impacts of the Muskeg River Mine Project. The analyses follow the same approach as the impact assessment analyses with reference to key questions and linkage diagrams. A detailed description of this approach is provided in Section E1.

A regional development review has been provided in Section G of this EIA in response to the Alberta EUB and local community's desire for a better understanding of potential long-term developments. Although the consideration of the effects of these potential developments is not technically part of a cumulative effects assessment, because at this point they are speculative, the information in this document will assist the Board, AEP and regional government agencies in better understanding potential future issues in the region.

Cumulative effects result from the combination of environmental impacts from a number of individual activities. These impacts may be the result of

Table F1-1 Impact Assessment Scenarios

DEVELOPMENT	**Section D Environmental Baseline**	**Section E Impact Assessment**	**Section F Cumulative Effects Assessment**	**Section G Regional Development Review**
	BASELINE Conditions to the end of 1997	**BASELINE +** ***Muskeg River Mine Project***	**BASELINE + Muskeg River Mine Project +** ***APPROVED DEVELOPMENTS***	**BASELINE + Muskeg River Mine Project + Approved Developments +** ***PUBLICLY DISCLOSED DEVELOPMENTS***
EXISTING	**Suncor Lease 86/17**	Suncor Lease 86/17	Suncor Lease 86/17	Suncor Lease 86/17
	Syncrude Mildred Lake	Syncrude Mildred Lake	Syncrude Mildred Lake	Syncrude Mildred Lake
	Suncor Steepbank	Suncor Steepbank	Suncor Steepbank	Suncor Steepbank
	Gibsons Petroleum	Gibsons Petroleum	Gibsons Petroleum	Gibsons Petroleum
	SOLV-EX	SOLV-EX	SOLV-EX	SOLV-EX
	Municipalities	Municipalities	Municipalities	Municipalities
	Pulp mills for water quality	Pulp mills for water quality	Pulp mills for water quality	Pulp mills for water quality
	Forestry	Forestry	Forestry	Forestry
	Pipelines/roadways/ others	Pipelines/roadways/ others	Pipelines/roadways/ others	Pipelines/roadways/others
THE PROJECT		**Muskeg River Mine Project**	Muskeg River Mine Project	Muskeg River Mine Project
APPROVED			**Syncrude Aurora North and South Mines**	Syncrude Aurora North and South Mines
			Suncor Steepbank Mine and Fixed Plant Expansion	Suncor Steepbank Mine and Fixed Plant Expansion
			Forestry	Forestry
DISCLOSED				**Suncor Project Millennium - Upgrader and Mine**
				Shell Lease 13 East Mine
				Syncrude Project 21 Mildred Lake Upgrader Expansion
				Mobil Kearl Mine and Upgrader
				Petro-Canada MacKay River - In-situ
				JACOS Hangingstone - In-situ
				Gulf Surmont - In-situ
				Major pipelines, utility corridors and roadways

a number of developments within a geographic area, or may be the result of a number of developments occurring over time. Although impacts of an individual activity may be acceptable, the combined impacts of several developments may be unacceptable.

Section F of this EIA contains a review of the existing and approved developments, including consideration of the currently available information on the schedule for the approved (but perhaps not yet fully operational) developments. The level of detail known about the approved developments varies with their stage of development and assumptions have been made on the currently available data. This data and the development assumptions are described in this section. Detailed assumptions are provided, as required, in the component sections that follow.

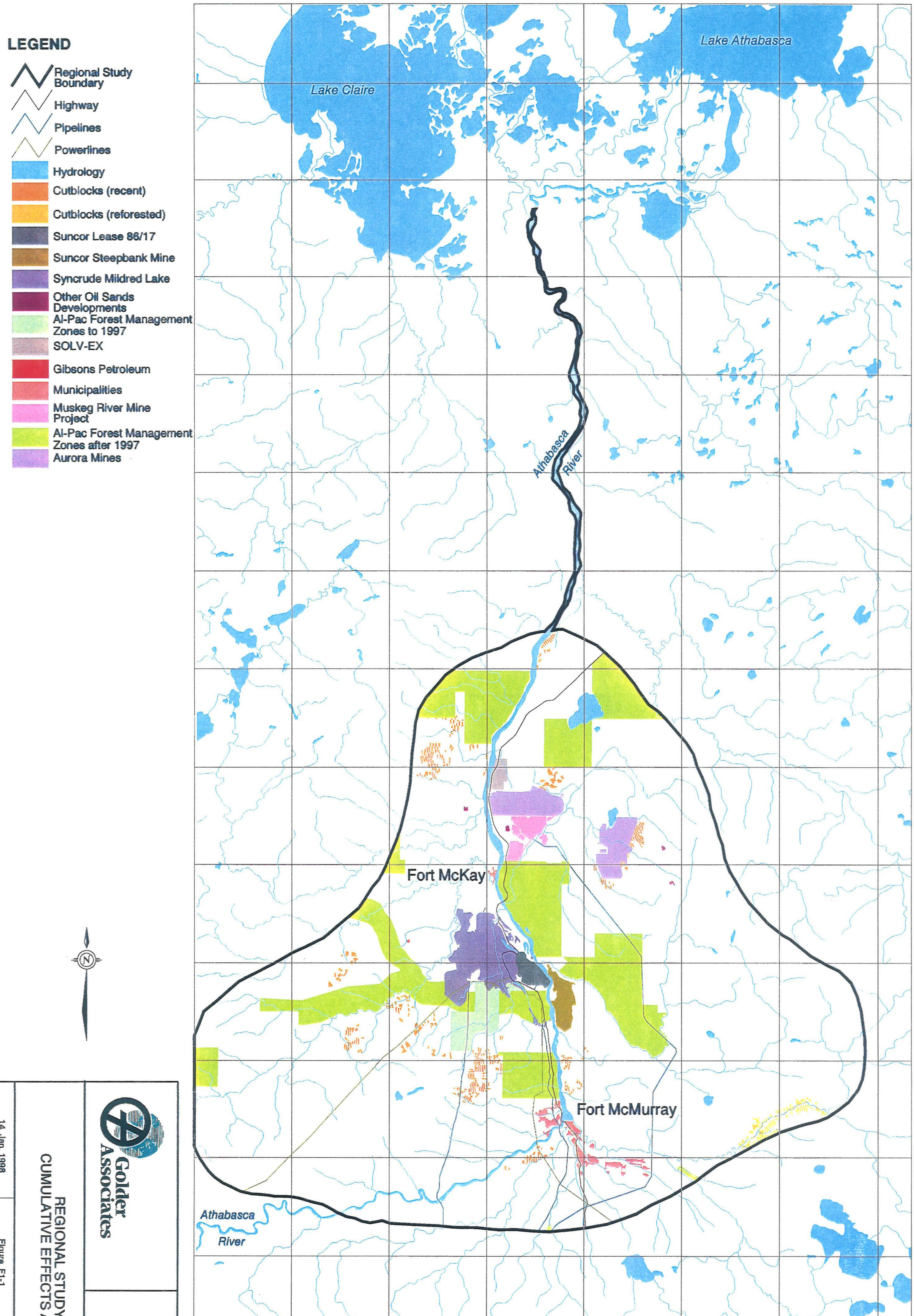
F1.3 Regional Study Area

The Regional Study Area (RSA) for the environmental, historic and land use components of the Project EIA and CEA is based on the RSA used for the Suncor Energy Inc. Steepbank Mine and Syncrude Canada Ltd. Aurora Mine EIAs (Suncor 1996, BOVAR 1996a). This study area, as shown in Figure F1-1, provides the basis for addressing cumulative effects resulting from the Project and from regional development. Through maintenance of the same RSA, results are directly comparable among development EIAs and consistency is maintained. In addition, there has been no significant additions to water or air emissions from existing or recently approved developments between the time the boundaries of the RSA were established in 1996 and the announcement of the Muskeg River Mine Project in 1997. Therefore, retaining the RSA boundary is justified.

One slight difference between the Project RSA and that for the Steepbank and Aurora EIAs is the inclusion of a longer, downstream portion of the Athabasca River, ending at the confluence with the Embarras River. This extension was added for the purpose of ensuring potential regional effects on surface water quality were adequately addressed.

Some other variations to the base RSA for this Project were made depending on the specific EIA component being addressed. For example the RSA for human health cumulative effects encompasses a region of up to 100 km radius from the oil sands development area and includes the communities of Fort McMurray, Fort McKay and Fort Chipewyan.

The environmental RSA boundaries were originally selected using an ecosystem-based approach, as defined by BOVAR Environmental (1996a). In summary, this approach included consideration of three criteria, airshed,



SOURCE: Al-Pac, Conor Pacific, Golder Associates Ltd., Mobil, Petro-Canada, RADARSAT International, Suncor, Syncrude, Norwest

5 0 5 10 15 20 25
Kilometres

MAP PROJECTION:
UTM
Zone 12
NAD 83 (GRS 1980)

Golder Associates

SHELL CANADA LIMITED

REGIONAL STUDY AREA - CUMULATIVE EFFECTS ASSESSMENT

14 Jan. 1998

Figure F1-1

PRODUCED BY: K. Quine
REVIEWED BY:

watershed and landscape (ecological land classification), all of which are discussed briefly below.

Airshed Criterion

The production of acidifying emissions by the Muskeg River Mine Project will be very low. Although low from the Project, the production of these emissions on a regional basis is of concern for the oil sands development area. Therefore, the cumulative effects of emissions from the Project need to be addressed in the context of emissions from existing or planned oil sands facilities in the region. Air quality modelling of concentrations and depositions was used to set the geographic extent of the potential and direct or indirect impacts of air emissions on water, soil and vegetation (BOVAR 1996a).

Watershed Criterion

Watersheds provide an ecological basis for defining a boundary for water-related impacts to aquatic resources, vegetation, soil and wildlife habitat utilization (BOVAR 1996a). The Project RSA includes watersheds of rivers and streams in the vicinity of the current and planned developments. The major rivers included in the watershed criterion were the Muskeg River, Steepbank River, MacKay River and the Athabasca River, from a point in the south where the Clearwater River enters the Athabasca River near Fort McMurray, to the confluence with the Embarras River in the north.

Landscape (Ecological Land Classification) Criterion

Ecological land classification (ELC) considerations used to delineate the RSA were described in BOVAR Environmental (1996a). In summary, the ELC considerations involved focus on ecodistricts, or subdivisions of the mid-boreal mixedwood ecoregion, as described by Strong (1992). The outer boundaries of those ecodistricts aligned with the oil sands development area were used to set the RSA boundary from a landscape perspective.

F1.4 Baseline (Existing) Conditions

Baseline conditions for the CEA include consideration of the following developments, as listed in Table F1-1 and shown on Figure F1-1. The production from the oil sands developments under the baseline conditions is shown in Table F1-2.

Table F1-2 Athabasca Oil Sands Production - Baseline Conditions

Development	Bitumen Production (bbl/day)	Synthetic Crude Production (bbl/day)
Suncor Lease 86/17 (Tar Island)	102,000	85,000
Syncrude Mildred Lake	250,000	210,000
Gibsons Petroleum	2,000	0
Total	**354,000**	**295,000**

F1.4.1 Suncor Energy Inc., Oil Sands - Lease 86/17

The Suncor Lease 86/17 development includes an open-pit oil sands mine, extraction and upgrading operation. Suncor also operates a utilities plant on Lease 86/17. The currently approved production from the Lease 86/17 operation is 85,000 barrels per day (bpd) of upgraded product.

The fundamental assumptions associated with the Lease 86/17 development include:

- progressive mining and reclamation activities for approved lease areas;
- production of air emissions from the operation of the mine, extraction plant, upgrader and utilities plant;
- implementation of consolidated tailings (CT) technology for mature fine tailings (MFT) management;
- use of water from the Athabasca River; and
- discharge of effluents to the Athabasca River via an industrial wastewater treatment system.

F1.4.2 Syncrude Canada Ltd. Mildred Lake

The Syncrude Mildred Lake development includes an open-pit oil sands mine, extraction and upgrading operation. Syncrude also operates a utilities plant at Mildred Lake. The currently production from the Mildred Lake operation is 210,000 barrels per day (bpd) of upgraded product.

Syncrude received approval in 1994 for a capacity increase to 300,000 bpd of synthetic crude from the Mildred Lake upgrader.

The fundamental assumptions associated with the Mildred Lake development include:

- progressive mining and reclamation activities for approved lease areas;
- production of air emissions from the operation of the mine, extraction plant, upgrader and utilities plant;
- employment of a water-capped fine tails lake as well as composite tailings (CT) technology for MFT management; and
- use of water from the Athabasca River.

F1.4.3 Suncor Steepbank Mine/ Fixed Plant Expansion

The Suncor Steepbank Mine/Fixed Plant Expansion development was approved in 1997 as a new mine to replace diminishing reserves on Lease 86/17. The Steepbank Mine will feed Suncor's extraction and upgrading facility on Lease 86/17. The Steepbank Mine was preceded by a 1996 approval of Suncor's Fixed Plant Expansion project, which expanded Suncor's approved bitumen upgrading capacity from 79,500 bpd of upgraded product to 105,000 bpd. The Steepbank Mine approval included authorization for the construction of a bridge across the Athabasca River from the current Lease 86/17 operation to the new mine on the east side of the Athabasca River.

The status of the Steepbank Mine and Fixed Plant Expansion projects included within the baseline for this CEA was restricted to: the bridge construction; some site preparation for the new mine/operation on the east side of the Athabasca River; and the first phase of the upgrading expansion (to 85,000 bpd).

F1.4.4 Gibsons Petroleum In-Situ Development

The Gibsons Petroleum development includes the operation of a steam assisted gravity drainage (SAGD) operation formerly known as the AOSTRA Underground Test Facility. Production from the facility is approximately 2,000 bpd of bitumen.

This development is considered in the CEA from the point of view of air quality and terrestrial considerations. All water is obtained from, and disposed to groundwater systems.

F1.4.5 SOLV-EX Development

The SOLV-EX development has included initiation of a mining and processing operation. The development was approved, but actual production of bitumen has been limited. The development recently changed owners and activities are suspended. The assumptions for this development:

- progressive mining and reclamation activities for approved lease area; and

- production of air emissions from the operation of the mine and processing (as per approved limits).

F1.4.6 Municipalities

The municipalities included in the CEA include the main areas within the RSA, including Fort McMurray and Fort McKay. The municipalities, which were assessed through remote sensing, are considered in this CEA from the point of view of:

- residents (human health);
- surface disturbance (terrestrial); and
- resource use.

F1.4.7 Pulp Mills

Water quality impacts assessed in the CEA included consideration of the potential influence of pulp mills located upstream on the Athabasca River. These potential influences are included through establishment of water quality background conditions for the Athabasca River on entry to the oil sands development area.

F1.4.8 Forestry

Forestry activities for the RSA are based on the forest management plans for Al-Pac and Northland Forest Products. Forestry considerations centre around the harvesting of timber resources. Therefore, these considerations involve no reclassification of existing soils or terrain. Forest cutblocks for the existing (baseline) conditions are allocated into two groups:

- existing old revegetated cut blocks; and
- recent cutblocks (other than Al-Pac).

F1.4.9 Pipelines, Power Right of Ways and Roadways

Pipelines, power right-of-ways and roadways primarily involve impacts to vegetative cover, although roadways may impact terrain units. For this CEA, it has been assumed that no reclassification of the existing soils or terrain is required. It is also assumed that during the operational life of pipeline corridors, herbaceous vegetation is established although establishment of woody species is discouraged. Following abandonment of the linear corridors, invasion of woody species from the adjacent vegetation communities ensures compatible vegetative cover.

Linear corridors in the baseline activities for the RSA include:

- pipelines servicing the oil sands development area, including the Albersun gas pipeline to Suncor, the Simmons gas pipeline to Syncrude, a spur line to the Gibsons Petroleum facility, the Alberta Energy oil pipeline from Syncrude Mildred Lake, the Suncor oil pipeline from Lease 86/17, and another natural gas pipeline that services the Fort McMurray area;

- one major power line right of way services the oil sands development area and Fort McMurray; and

- major roadways include Highway 63, from the point where it enters the RSA south of Fort McMurray to its northern point at the Lougheed Bridge near Fort McKay, Highway 963, which runs north from the Lougheed Bridge, the winter road to Fort Chipewyan (area within the RSA) and the gravel road from Highway 63 to the Gibsons Petroleum development.

Existing development areas not included in the CEA are linear disturbances such as seismic lines, which have a disturbance area below a width of 10m.

F1.5 Approved Projects

In addition to the existing regional developments, it is recognized for the CEA that there are other developments in the oil sands area. These developments have received regulatory approval but are not yet fully operational. These approved developments may result in additional environmental impacts in the RSA. The approved developments included in the CEA are detailed in Table F1-1, with development locations shown in Figure F1-1. The production from the existing and planned oil sands developments is summarized in Table F1-3.

Table F1-3 Athabasca Oil Sands Production - Baseline, Approved and Muskeg River Mine Project Developments

Oil Sands Development	Capacity K bbl/day [a]	Expected Production (2007)	
		Bitumen (bbl/day)	Synthetic Crude (bbl/day)
Suncor			
- Tar Island + Steepbank Mine	125 (B)	125,000	---
- Tar Island Upgrader	105 (S)	---	105,000
Syncrude			
- Mildred Lake Mine	270 (B)	160,000 [b]	---
- Aurora Mines	400 (B)	200,000	---
- Mildred Lake Upgrader	300 (S)	---	300,000
Shell Muskeg River Mine Project	150 (B)	150,000	---
Gibsons Petroleum	---	2,000	---
Total		**637,000**	**405,000**

[a] B = Bitumen; S = Synthetic Crude Products.
[b] Potential bitumen sales not included.

F1.5.1 Syncrude Canada Ltd. Aurora North and South Mines

The Syncrude Aurora North and South Mine developments include mining and bitumen extraction operations on the east side of the Athabasca River. The details used in the assessment of these developments are based on an application for regulatory approval (Syncrude 1996, BOVAR 1996a).

The Aurora North Mine will be located north of the Muskeg River Mine Project, while the Aurora South Mine will be east of the Project (Figure F1-1). The fundamental assumptions associated with the Aurora North and South Mine developments include:

- progressive mining and reclamation activities for approved lease areas;
- on-site bitumen extraction to produce a froth that will be transported by pipelines to the Mildred Lake facility;
- other pipelines to support the Aurora developments including natural gas, diesel and hot water (pipelines located in the same corridor as the froth lines);
- production of air emissions from the operation of the mine and extraction plant;
- implementation of CT technology for MFT management; and
- use of water from the Mildred Lake facility.

The production from the Aurora North and Aurora South mines will either replace or supplement current Syncrude production at the Mildred Lake facility. The Syncrude Aurora North Mine, as detailed in the Aurora Mine Application (Syncrude 1996), received an EUB board decision late in 1997.

This mining and extraction operation will eventually result in production of 200,000 bpd of bitumen from the North Mine.

The Syncrude Aurora South Mine, also as detailed in the Aurora Mine Application (Syncrude 1996), will be located east of the Shell Lease 13. This project received a decision by the EUB board, but an AEP approval was not applied for since the proposed commencement date is not until 2008. Eventual production from the Aurora South Mine is 200,000 bpd.

F1.5.2 Suncor Steepbank Mine

The Suncor Steepbank Mine development, which was approved in 1997 as a new mine to replace the diminishing reserves on Lease 86/17, is also included within the approved, but not fully developed, scenario. Details on the operation of the Steepbank Mine are taken from the project application (Suncor 1996a). As noted in the existing project description, approval for the mine was preceded by approval in 1996 of an expansion of Suncor's upgrading operation (Fixed Plant Expansion). Full operation of the Steepbank Mine and the Fixed Plant Expansion will produce 105,000 bpd of synthetic crude products.

The fundamental assumptions associated with the Steepbank Mine and Fixed Plant Expansion developments include:

- progressive mining and reclamation activities for approved lease areas;
- production of air emissions from the operation of the mine, remote extraction and hydrotransport operation; and
- use of CT technology for mature fine tailings (MFT) management.

F1.5.3 Forestry

Forestry activities for the RSA are based on the approved forest management plans for Al-Pac and Northland Forest Products. These plans include the 1998 Annual Operating Plan and the twenty year operating plan produced in 1995. Forestry considerations centre around the harvesting of timber resources. Therefore, forestry considerations involve no reclassification of existing soils or terrain, rather they are restricted to impacts on terrestrial vegetation. Forest cutblocks for the approved development scenario are allocated into two groups:

- Al-Pac cutblocks; and
- future cutblocks.

F1.6 Environmental Parameter Summary

Table F1-4 summarizes some of the major environmental parameters considered for existing and approved oil sands developments. Additional details on these parameters, as well as additional parameters are discussed in the relevant component discussions in Section F.

Table F1-4 Environmental Parameters for Existing, Approved and the Muskeg River Mine Project Developments

Development	Development Area (ha)	Water Withdrawal (1,000 m^3)	Air Emissions (t/d)	
			SO_2	NO_x
Suncor Lease 86/17	3,369	59,801	51	36
Syncrude Mildred Lake	23,244	67,961	200[a]	37
Steepbank Mine	3,234	[b]	[c]	[c]
Aurora North and South	15,171	[d]	[e]	23
Muskeg River Mine Project	4,343	55,100	0	12
SOLV-EX	2,088	5,000	4	2
Gibsons Petroleum	22	0	0.06	0.23

(a) Based on data provided by Syncrude in December 1997 for actual operation. SO_2 emissions could increase to 220 t/d based on approved Syncrude capacity.
(b) Withdrawal requirements included in Suncor's existing approval.
(c) Values for Steepbank Mine included in Lease 86/17 numbers.
(d) Withdrawal requirements included in Syncrude's existing approval.
(e) Value for Aurora Mines included in Mildred Lake number.

F1.7 Preliminary Schedule

The schedules for existing and approved developments are described, as relevant, in the component sections.

F1.8 Key Questions

Component specific CEA key questions have been developed, similar to the approach applied for the Muskeg River Mine Project environmental impact assessment (Section E of the EIA). They derive from issues identified by government agencies, local communities and other stakeholders.

These key questions focus the effects assessment on the primary cumulative effects issues associated with the Project. The key questions for cumulative effects are identical for both the Project CEA and RDR.

Table F1-5 lists the CEA key questions.

New linkage diagrams were not developed for the cumulative effects assessments as the linkages defined for the Project impact assessment generally remain valid.

F1.9 Impact Description and Degree of Concern

The impact description criteria and degree of concern definitions, as defined in Section E1, also apply for the CEA.

Table F1-5 Summary of CEA Key Questions for the Muskeg River Mine Project

Question Number	Key Question
Air Quality	
AQCEA-1	Will emissions from combined developments result in exceedances of ambient air quality guidelines?
AQCEA-2	Will emissions from combined developments result in human health effects?
AQCEA-3	Will emissions from combined developments result in the deposition of acid forming compounds that exceed target loadings?
AQCEA-4	Will the precursor emissions from combined developments result in the formation of ozone (O_3) concentrations that exceed air quality guidelines?
Hydrogeology - Groundwater	
GWCEA-1	Will combined developments result in a drawdown of water levels in the Basal Aquifer and cause a loss of water from important lakes?
Surface Water Hydrology	
SWCEA-1	Will combined developments in the Muskeg River basin result in effects on the Muskeg River flows, sediment concentrations and channel regime?
SWCEA-2	Will combined developments result in effects on Athabasca River flows?
SWCEA-3	Will combined developments result in effects to the open-water areas including lakes and streams?
Surface Water Quality	
WQCEA-1	Will operational and reclamation water releases from combined developments result in water quality guideline exceedances in the Athabasca and Muskeg rivers?
WQCEA-2	Will operational and reclamation water releases from combined developments result in toxicity guideline exceedances in the Athabasca and Muskeg rivers?
WQCEA-3	Will operational and reclamation water releases from combined developments alter the temperature regime of the Muskeg River?
WQCEA-4	Will muskeg and overburden dewatering activities from combined developments reduce dissolved oxygen concentrations to unacceptable levels in the Muskeg River?
WQCEA-5	Will PAHs in operational and reclamation water releases from combined developments accumulate in sediments and be transported downstream?
WQCEA-6	Will acidifying emissions from combined developments result in changes in water quality?

Question Number	Key Question
Aquatic Resources	
ARCEA-1	Will activities from combined developments change fish habitat?
ARCEA-2	Will operational and reclamation water releases from combined developments result in acute or chronic effects on fish?
ARCEA-3	Will operational and reclamation water releases from combined developments result in changes to fish tissue quality?
ARCEA-4	Will operational and reclamation water releases from combined developments result in changes in fish abundance?
ELC	
ELCCEA-1	Will activities from combined developments result in a loss or alteration of ELC units and diversity?
Terrain and Soils	
TSCEA-1	Will combined developments alter the quantity and distribution of terrain and soil units?
TSCEA-2	Will combined developments alter soil capability and sensitivity?
Terrestrial Vegetation	
TVCEA-1	Will combined developments, their reclamation and closure, result in a loss or alteration of vegetation communities?
TVCEA-2	Will combined developments result in a change in vegetation diversity?
TVCEA-3	Will air emissions from combined developments alter vegetation health?
Wetlands	
WTCEA-1	Will combined developments, their reclamation and closure, result in a loss or alteration of wetlands?
Wildlife	
WCEA-1	Will combined developments impact wildlife habitat?
WCEA-2	Will changes to water, aquatic prey and plant quality from combined developments affect wildlife health?
Human Health	
HHCEA-1	Will water quality changes from combined developments affect human health?
HHCEA-2	Will air quality changes from combined developments affect human health?
HHCEA-3	Will changes to air and water quality from combined developments affect human health?
HHCEA-4	Will changes to plant and game meat quality from combined developments affect human health?
HHCEA-5	Will equilibrium concentrations of residual chemicals in water and select local food items following reclamation of combined developments affect human health?
HHCEA-6	Will noise from combined developments during construction and operation unduly affect people who reside in the region?
Resource Use	
RUCEA-1	Will combined developments result in a change in surface and mineral extraction use?
RUCEA-2	Will combined developments result in a change in ESAs?
RUCEA-3	Will combined developments result in a change in forestry resource use?
RUCEA-4	Will combined developments result in a change in hunting, trapping, fishing and berry picking?
RUCEA-5	Will combined developments result in a change in non-consumptive recreational use?
Traditional Land Use	
TLUCEA-1	Will combined developments result in a change in Traditional Land Use?

F2 AIR QUALITY CUMULATIVE EFFECTS ASSESSMENT

F2.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project plus existing and approved developments on air quality in the Regional Study Area (RSA). The following developments are included in this CEA.

- Suncor Lease 86/17
- Suncor Steepbank Mine/Fixed Plant Expansion
- Syncrude Aurora North and South
- Syncrude Mildred Lake
- SOLV-EX
- Muskeg River Mine Project

The air quality predictions presented in this section are used to assess impacts on aquatic resources (Section F6), soils (Section F8), vegetation (Section F9) and human health (Section F12).

F2.1.1 Emission Projections

Table F2-1 provides a summary of the type and magnitude of the emissions associated with the CEA developments. SO_2 emissions result from upgrading (Syncrude and Suncor) and metal extraction (SOLV-EX) facilities only, and NO_x and THC emissions result from all operations (no THC estimates were available for SOLV-EX).

The combined total sulphur dioxide (SO_2) emission of 252 t/d does not include flaring and other upset events. The current SO_2 emission of 272 t/d includes 29 t/d from these type of events, leaving 243 t/d from non-upset sources. As such, the proposed SO_2 emission of 252 t/d is similar to that associated with the baseline emission scenario.

When compared to the baseline emission estimates provided in Table F2-1, the total hydrocarbon (THC) emissions associated with the CEA scenario are expected to increase by about 15% while the oxides of nitrogen (NO_x) emissions are expected to increase by about 40%. The level of confidence for the NO_x emission estimates is greater as they are directly related to fuel consumption while the VOC emissions are based on the extrapolation from other fugitive emission estimates.

Table F2-1 Summary of SO_2, NO_x and THC Emissions Associated With the CEA Emission Scenario.

Development	SO_2[(a)] (t/d)	NO_x[(a)] (t/d)	THC[(a)] (t/d)
Muskeg River Mine Project	0	12	4
Syncrude Mildred Lake [(b)]	197	37	51
Suncor Lease 86/17 and Steepbank	51	36	14
Syncrude Aurora North	0	13	6
Syncrude Aurora South	0	10	6
SOLV-EX	4	2	-
Other (from Table D2-1)	0.3	2	5
Combined Total Emissions	252	110	50
Baseline (from Table D2-1)	272	78	44

(a) SO_2 = sulphur dioxide, NO_x = oxides of nitrogen, THC = total hydrocarbon.

(b) Based on data provided by Syncrude in December 1997. SO_2 emissions could be up to 220 t/d based on approved Syncrude capacity.

F2.2 Potential Linkages and Key Questions

Figure E2-1 (Section E2) shows the linkage diagram for Project activities and potential changes in air quality associated with the Project. Generally, the same linkages and key questions apply to the CEA with the exception that Greenhouse gas emissions are not addressed. These emissions are usually discussed on a corporate basis.

The key questions for the air quality CEA include:

AQCEA-1: **Will Emissions From Combined Developments Result in Exceedances of Ambient Air Quality Guidelines?**

AQCEA-2: **Will Emissions From Combined Developments Result in Human Health Effects?**

AQCEA-3: **Will Emissions From Combined Developments Result in the Deposition of Acid Forming Compounds That Exceed Target Loadings?**

AQCEA-4: **Will the Precursor Emissions From Combined Developments Result in the Formation of Ozone (O_3) Concentrations That Exceed Air Quality Guidelines?**

F2.3 Approach and Methods

The general approach to assess potential cumulative impacts is consistent with that described in Section E2.2.

The impact assessment for the Muskeg River Mine Project was undertaken for the Local Study Area. In contrast, the Air Quality CEA is undertaken for the Regional Study Area.

F2.4 Analysis and Results

F2.4.1 Key Question AQCEA-1: Will Emissions From Combined Developments Result in Exceedances of Ambient Air Quality Guidelines?

The CEA scenario will result in the SO_2 and NO_x emissions indicated in Table F2-1 as well as CO and PM_{10} emissions. An evaluation of the Project emissions indicated a Negligible degree of concern for SO_2 and CO and a Low to Moderate degree of concern for NO_2 and PM_{10}. The Project concentration predictions indicated maximum concentrations from mine pits and secondary stacks and from the approved developments will occur relatively close to the respective development areas.

To provide an indication of the combined operation of multiple oil sands developments, the CEA focuses on NO_x emissions. The evaluation is based on NO_x predictions presented in Section E2 of this EIA, and on those presented in the Aurora North and South EIA (Syncrude Canada Ltd. and BOVAR 1997). The predictions are presented in the Table F2-2.

Table F2-2 Predicted Maximum Ambient NO_x and NO_2 Concentrations ($\mu g/m^3$)

Maximum	Baseline (LSA)	Project (LSA)	Project + Baseline	Combined (RSA)
Hourly				
NOx ($\mu g/m^3$)	995	1,580	1,580	2,202
NO_2 ($\mu g/m^3$)	149	207	207	270
NO_2 Guideline ($\mu g/m^3$)	400	400	400	400
Daily				
NOx ($\mu g/m^3$)	313	672	675	1,017
NO_2 ($\mu g/m^3$)	81	117	117	151
NO_2 Guideline ($\mu g/m^3$)	200	200	200	200
Annual				
NOx ($\mu g/m^3$)	32	156	159	214
NO_2 ($\mu g/m^3$)	32	65	65	71
NO_2 Guideline ($\mu g/m^3$)	60	60	60	60

The baseline values in the table refer to the predictions for the LSA, depicted in Section D2.6. The maximum values in the immediate vicinity of the respective baseline sources (e.g., Suncor and Syncrude) will be greater and similar to those associated with the Project. The 'Combined' values are obtained from the Aurora Mine submissions (Syncrude Canada Ltd. and BOVAR 1997) and include the overlapping effects of NO_x emissions from the Aurora North, Aurora South, Muskeg River Mine

Project, Shell Lease 13 East, Mobil Kearl Mines and NO_x emissions from the Syncrude Mildred Lake and Suncor main stacks. These predictions indicate:

- Maximum NO_x and NO_2 concentrations are predicted to occur adjacent to each mine. While maximum NO_x values can increase with increasing emissions, the amount of available ozone reduces the relative NO_2 increase.
- For example, while the maximum hourly average NOx concentration increases from 995 to 2,202 $\mu g/m^3$ with increasing development, the corresponding NO_2 concentration increases from 149 to 270 $\mu g/m^3$. The NO_2 values are within the 400 $\mu g/m^3$ guideline for NO_2.
- The maximum daily average NO_2 concentration increases from 81 to 151 $\mu g/m^3$ with increasing development and this maximum value is within the corresponding 200 $\mu g/m^3$ guideline.

The dispersion model predictions indicate that hourly and daily NO_2 concentrations should be less than the air quality guidelines. The annual average NO_2 concentrations, however, may exceed the guideline adjacent to the respective mines.

F2.4.2 Key Question AQCEA-2: Will Emissions From Combined Developments Result in Human Health Effects?

Analysis

Maximum hourly, daily and annual average concentrations of emissions from the Muskeg River Mine Project were predicted for the communities of Fort McKay, Fort McMurray and Fort Chipewyan. The evaluation focused on emissions from the mine fleet exhausts, fugitive emissions from the mine surface and fugitive emissions from the tailings settling ponds.

Similar emissions are expected from other mines and tailings ponds. As a first level indication of potential air concentrations that could occur in these communities, the Muskeg River Mine predictions were scaled on the basis of bitumen production. The CEA bitumen production is about five times that proposed for the Muskeg River Mine Project. Therefore, the expected concentrations in the communities from similar source types would be five times larger than those presented for the Project in Tables E2-18, E2-19 and E2-20.

The following discussion allows the combined effect of these emissions to be placed in perspective. Specifically, the discussion compares the NO_x, NO_2, and benzo(a)pyrene (BaP) predictions to representative background values.

Table F2-3 provides annual average NO_2 and NO_x concentrations that have been observed in remote rural and regional locations in Alberta and compares them to dispersion model predictions in the communities under review. The Muskeg River values are from Section E2 of this EIA and the Aurora North and South Mine predictions were from supplemental information filed in support of the Syncrude application (BOVAR 1997). The adjusted Aurora values reflect changes in the modelling approach based on comparing model predictions with observations.

Table F2-3 Comparison of Observed Rural Background and Predicted NO_x Concentrations

Location	Source	Period	NO_2 (μg/m³)	NO_x (μg/m³)
Fortress Mountain	Acid Deposition Research Program	1985-1987	2.3	-
Violet Grove	West Central Airshed Society	1996	5.1	6.0
Royal Park	AEP	1995	21	27
Fort McMurray	AEP	1995	17	29

Predicted NO_x Concentrations

Emission Sources	Fort McKay	Fort McMurray	Fort Chipewyan
Muskeg River Mine Fleet	2.79	0.83	0.28
Muskeg River Plant Sources	0.23	0.14	0.03
Total Project	3.02	0.97	0.31
Aurora North and South Mines	10.00	3.30[a]	1.00[a]
Adjusted Aurora North and South Mines	5.60	1.90[a]	0.56[a]

[a] Assumed, based on the same ration as for the Project.

Table F2-4 provides an estimation of annual average NO_2 concentrations that could occur in the respective communities due to various emission scenarios. In this comparison, all NO_x was conservatively assumed to occur as NO_2.

The Fort McMurray baseline includes local sources, current Suncor and Syncrude sources, and pristine background values. The Fort Chipewyan baseline of 5 μg/m³ was selected as being typical for remote Alberta locations. The Fort McKay value was assumed to be an average of the Fort McMurray and Fort Chipewyan values.

The implication of the multiplicative factor of five to extrapolate the Muskeg River Mine values to the CEA emission scenario is as follows:

- Ambient concentrations in Fort McKay could increase by about 100% over current baseline conditions.

- Ambient concentrations in Fort McMurray could increase by about 20% over current baseline conditions.
- Ambient concentrations in Fort Chipewyan could increase by about 30% over current baseline conditions.

For the example provided, the predicted annual average values in the communities are well below the 60 μg/m^3 even if one conservatively assumes complete conversion from NO to NO_2.

Table F2-4 Estimated Annual Average NOx Concentrations (μg/m^3) in the Selected Communities Due to CEA Emissions

	Baseline	Project	Baseline + Project	CEA=5* Project	Baseline + CEA	NO_2 Guideline
Fort McKay	15	3.0	18.0	15.0	30.0	60
Fort McMurray	29	1.0	30.0	5.0	34.0	60
Fort Chipewyan	5	0.3	5.3	1.5	6.5	60

Benzo(a)pyrene (BaP) is frequently used as a surrogate reflecting general PAH concentrations in the atmosphere. Table F2-5 compares the annual average BaP concentrations observed at AEP monitoring sites (1995) with the limited RSA observations conducted as part of the AOSERP monitoring program (Strosher 1978). The AOSERP values are limited to one to four samples at each site for May 1977. Urban values appear to range from 0.1 to 0.2 ng/m^3. The rural Royal Park value (0.01ng/m^3) is about one-tenth the urban values and is closer to the values observed as part of the AOSERP program. Greater values at the AOSERP sites would be expected during the winter.

Table F2-5 Comparison of Annual Average BaP

Location (1995)	BaP (ng/m^3)
Edmonton downtown	0.20
Edmonton residential	0.24
Edmonton industrial	0.12
Calgary downtown	0.17
Calgary residential	0.09
Calgary industrial	0.21
Fort Saskatchewan	0.09
Royal Park	0.01

Location (1997)	BaP (ng/m^3)
Birch Mountain	0.008 0.002 0.002
Bitumount	0.001 0.001 0.007
Mannix	0.007
Fort McMurray	0.001 0.008 0.008 0.006

For the purposes of additional comparison, 1992 BaP concentrations in Alert, NWT ranged up to 0.0017 ng/m^3 during the summer (mean summer = 0.001 ng/m^3) and up to 0.089 ng/m^3 during the winter (mean winter = 0.020 ng/m^3) (Fellin et al., 1992). The summer values reflect natural background while the winter values reflect long-range transport from mid-latitude sources (e.g. Siberia). The summer values are consistent with the AOSERP measurements.

The BC MOE undertook a PAH monitoring program in the community of Cranbrook during the winters of 1986 and 1987 to determine the effects of wood smoke emission on the community (Crozier and Manna 1988). The values observed in Cranbrook ranged up to 12.3 ng/m^3; in comparison, values ranged up to 0.34 ng/m^3 at a background site. The high value was attributed to wood smoke. Non-winter values were typically up to 0.01 ng/m^3.

Table F2-6 provides estimations of annual average BaP concentrations that could occur in the respective communities due to various emission scenarios. A uniform background value of 0.01ng/m^3 was assumed for all sites. The estimated BaP concentrations do not appear to increase significantly due to CEA BaP emissions (10% at Fort McKay, 3% at Fort McMurray and 1% at Fort Chipewyan). The Cranbrook measurements, however, indicate that the baseline could be higher if wood burning is significant in any of these communities. The estimated BaP concentrations do not appear to change significantly due to CEA emissions.

Table F2-6 Estimated Annual Average BaP Concentrations (ng/m^3) in the Selected Communities Due to CEA Emissions [(a)]

	Baseline	Project	Baseline + Project	CEA = 5* Project	Baseline + CEA
Fort McKay	0.01	0.00015	0.01015	0.01075	0.01075
Fort McMurray	0.01	0.000044	0.010044	0.00022	0.01022
Fort Chipewyan	0.01	0.000015	0.010015	0.000075	0.010075

(a) No guideline value for BaP concentrations.

Residual Impact Classification

The human health effects from these projected CEA concentrations are discussed in Section F12. As such, the impact classification associated with these emissions is also presented in Section F12.

Certainty

The certainty associated with the predictions provided in the tables are associated with the predictions for the Muskeg River Mine Project (Section E2) and with the extrapolation of these predictions to the region.

The emission estimates from the Project sources, in order of decreasing certainty, are mine diesel exhausts, mine surface VOC and TRS emissions and tailings pond VOC and TRS emissions. On an annual basis, the VOC and TRS emissions are likely overestimated. The models are expected to provide realistic concentration estimates in the communities (within a factor of two) based on the provided emission values.

The extrapolation assumes the predicted concentrations can be scaled according to the bitumen production capacity. This scaling can vary from mine to mine as the level activity, size of the mine and the associated tailings pond characteristics may have some variability. This scaling approach does not include VOC, TRS and PAH emissions from non-mining and non-extraction sources and, as such, the concentrations may be underestimated. The two examples provided for NO_x and BaP, however, implicitly concluded these other sources in the baseline term.

F2.4.3 Key Question AQCEA-3: Will Emissions From Combined Developments Result in the Deposition of Acid Forming Compounds That Exceed Target Loadings?

The baseline SO_2 and NO_x emissions result in Potential Acid Input (PAI) values that exceed the proposed target loading for sensitive ecosystems (0.25 keq/ha/a). The maximum value and the extent of the PAI exceedance increased with the addition of the Muskeg River Mine Project NO_x emissions. SO_2 emissions from the Project are negligible.

Based on the existing emissions listed in Table D2-1 and the emissions in Table F2-1, SO_2 emissions are projected to remain in the 250 t/d range, while NO_x emissions are projected to increase from 78 to 110 t/d.

The SO_2 deposition, NO_x deposition and the PAI were calculated for the regional airshed (RSA) using the CALPUFF modelling approach that was used for Sections D2 and E2. As indicated in Section D1.1, the RSA is defined by an area approximately 160 by 140 km centred over the location of the current Suncor and Syncrude upgraders.

Sulphate Equivalent Deposition

The deposition of SO_2 emissions will occur as SO_2 and SO_4^{2-} and is expressed as SO_4^{2-} equivalent/ha/a. Near the sources, the primary deposition occurs as SO_2, while more distant from the sources, the proportion of SO_4^{2-} deposition increases.

Figure F2-1 shows the sulphate deposition due to the CEA emission scenario. The maximum sulphate deposition (both wet and dry) of 19 kg SO_4^{2-}/ha/a and is predicted to occur in the vicinity of the existing sources. The deposition pattern is similar to that associated with the existing sources.

Nitrate Equivalent Deposition

The deposition of NO_x emissions will occur as NO_2, HNO_3 and NO_3^- and is expressed as NO_3^- equivalent/ha/a. Near the sources, the primary deposition occurs as NO_2 and more distant from the source, the proportion of HNO_3 and NO_3^- increases.

Figure F2-2 shows the nitrate equivalent deposition associated with the existing and Muskeg River Mine Project sources. The maximum nitrate deposition value (both wet and dry) of 40 kg NO_3^-/ha/a is predicted to occur adjacent to the current Syncrude Mildred Lake site and the Muskeg River Mine Project.

Figure F2-3 shows the nitrate equivalent deposition (both wet and dry) due to the CEA emission scenario. The maximum values are predicted to occur in the vicinity of each mine. The maximum nitrate deposition of 46 kg NO_3^-/ha/a is predicted to occur in the vicinity of the Syncrude Mildred Lake, Muskeg River Mine Project and Syncrude Aurora North developments.

Potential Acid Input

The PAI will depend on the sulphate equivalent deposition, the nitrate equivalent deposition and the background values.

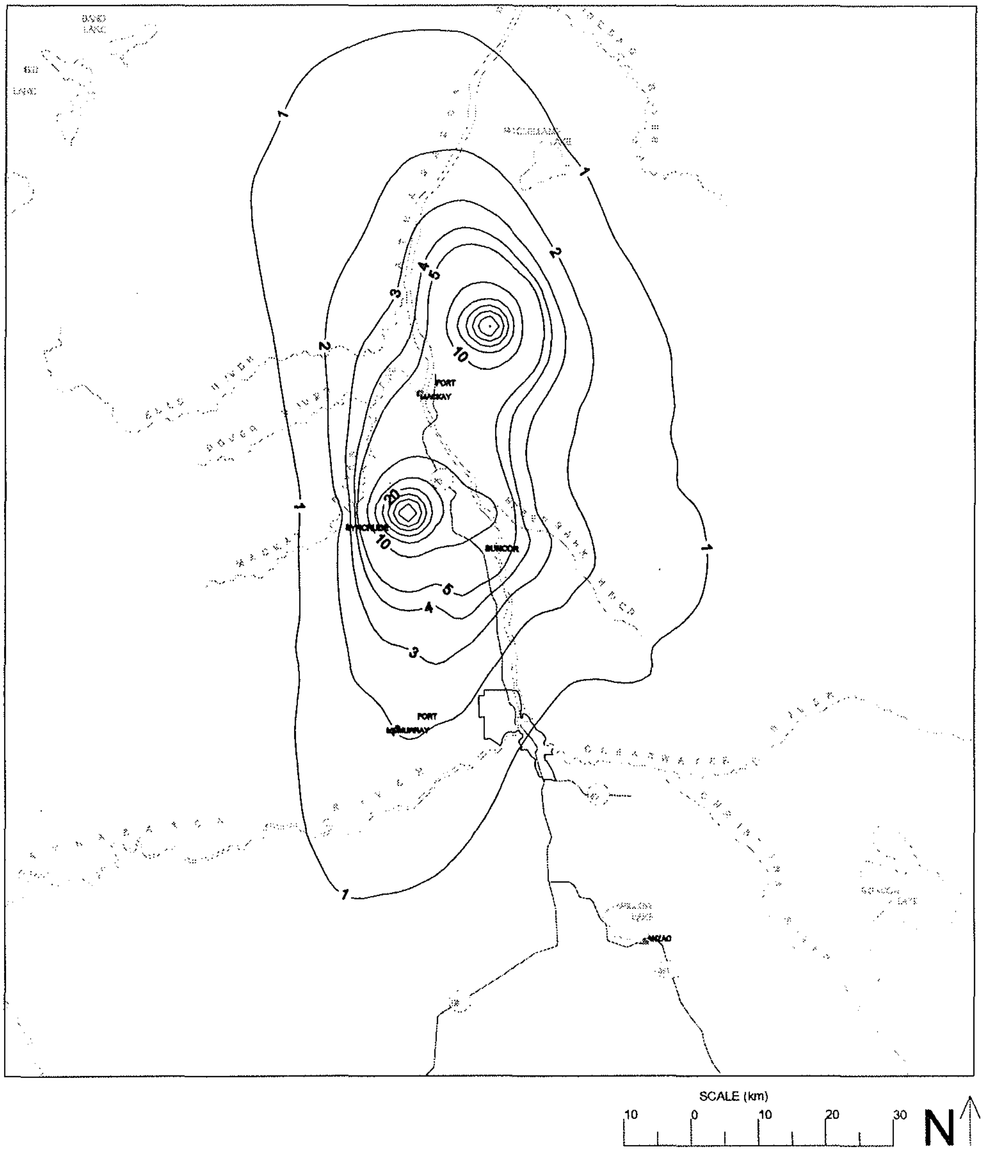
Figure F2-4 shows the PAI associated with the baseline sources and the Muskeg River Mine Project. PAI (wet, dry and background) values in excess of 0.75 keq/ha/a are predicted to occur in the vicinity of the Syncrude Mildred Lake and Muskeg River Mine Project developments.

Figure F2-1 Predicted Sulphate Equivalent Deposition (kg SO_4^{2-}/ha/a) in the RSA due to CEA Sources

c:\data\7316259\calpuff\modruns\output\mannix7i\sulfate.srf 01/08/98

Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Suncor	SO_2 = 51 t/d
	Syncrude	SO_2 = 197 t/d
	SOLV-EX	SO_2 = 4 t/d
	Muskeg River Mine	SO_2 =0 t/d
Target:	No target	

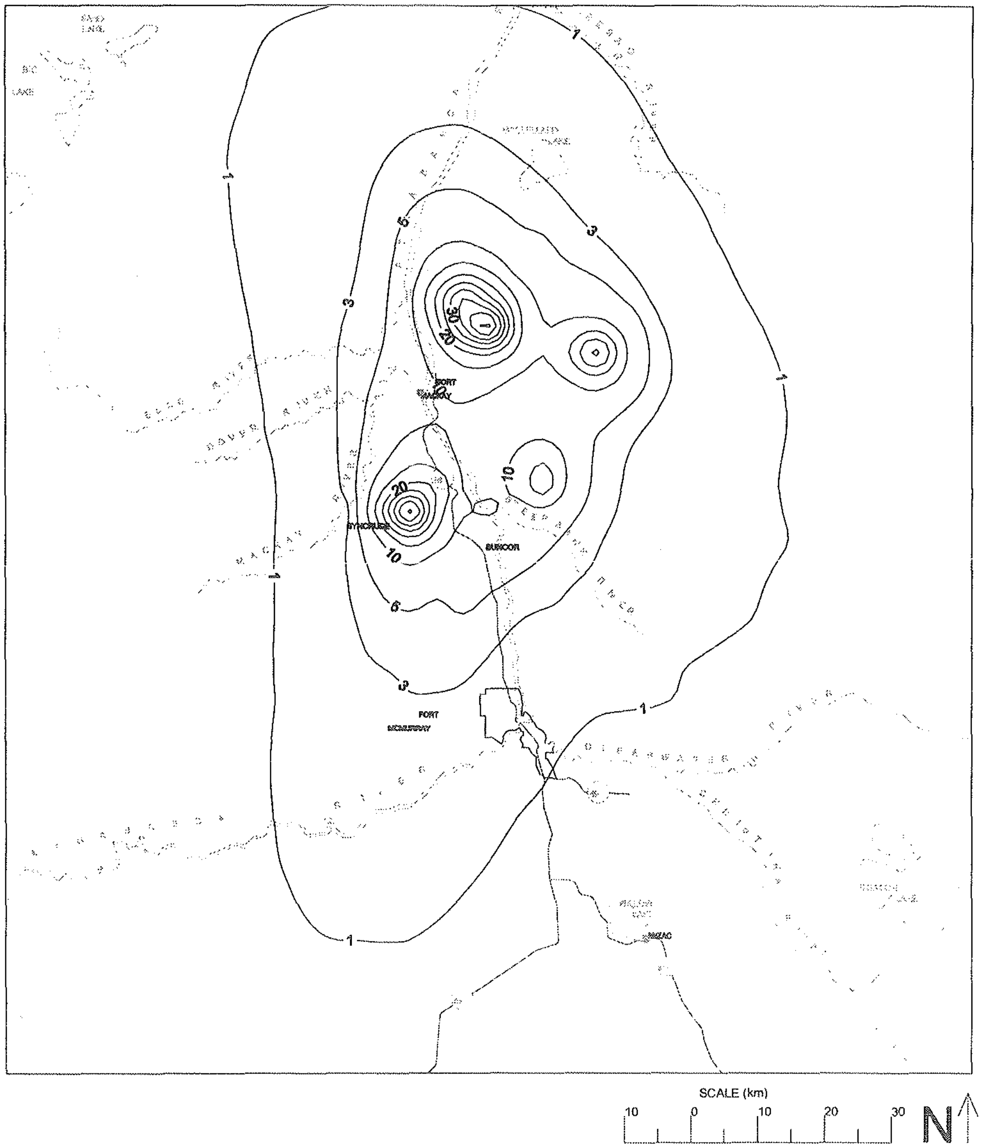
Figure F2-2 Predicted Nitrate Equivalent Deposition (kg NO_3^-/ha/a) in the RSA due to Baseline and Muskeg River Mine Project Sources



c:\data\7316259\calpuff\modruns\output\mannix7i\nitrate.srf 01/08/98

Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Suncor	NO_x = 39 t/d
	Syncrude	NO_x = 37 t/d
	Muskeg River Mine	NO_x = 12 t/d
Target:	No target	

Figure F2-3 Predicted CEA Nitrate Equivalent Deposition (kg NO_3^-/ha/a) in the RSA due to CEA Sources



c:\data\7316259\calpuff\modruns\output\mannix8d\nitrate.srf 01/14/98

Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Suncor	NO_x = 36 t/d
	Syncrude	NO_x = 37 t/d
	Muskeg River Mine	NO_x = 12 t/d
	Aurora Mines	NO_x = 23 t/d
	SOLV-EX	NO_x = 1 t/d
Target:	No target	

Figure F2-4 Predicted Potential Acid Input (keq/ha/a) in the RSA due to Baseline and Project Sources

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Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Suncor	SO_2 = 51 t/d
	Syncrude	SO_2 = 197 t/d
	Suncor	NO_x = 39 t/d
	Syncrude	NO_x = 37 t/d
	Muskeg River Mine	NO_x = 12 t/d
Targets:	0.25, 0.50 and 1.0 keq/ha/a	

Figure F2-5 shows the PAI due to the CEA emission scenario. The maximum values show the influence of the NO_x emissions associated with the mine fleet emissions. PAI of values in excess of 0.9 keq/ha/a are predicted to occur in the vicinity of the Mildred Lake, Suncor and Muskeg River developments.

For both the existing and CEA emission scenarios, the maximum PAI exceeds target loading criteria that have been proposed for ecosystems with differing sensitivities. Table F2-7 identifies these criteria and the areas associated with exceedances of these criteria. The effect of the CEA scenario is to increase the region where the 0.25 keq/ha/a value is exceeded from 1,800 to 2,500 km^2. For the 0.50 keq/ha/a target loading, the area is increased from 190 km^2 to 315 km^2. For the purposes of comparison, the Muskeg River Project operating in isolation, would result in the 0.25 keq/ha/a being exceeded over 40 km^2.

Table F2-7 Comparison of Area That Exceeded Selected PAI Criteria

Emission Scenario	Baseline	Project	Baseline and Project	CEA
SO_2 emissions (t/d)	254	0	254	252
NO_x emissions (t/d)	76	12	88	110
Area > 1 keq/ha/a (km^2)	0	0	0	0
Area > 0.50 keq/ha/a (km^2)	155	< 1	190	315
Area > 0.25 keq/ha/a (km^2)	1,500	40	1,800	2,500

Residual Impact Classification

The impact classifications associated with the predicted deposition of acidifying compounds are presented in the appropriate receptor sections (Section F5-Water Quality, Section F6-Aquatic Resources, Section F7-ELC, Section F8-Terrain and Soils and Section F10-Wetlands).

Certainty

The certainty associated with the predictions provided in these figures corresponds to those associated with the predictions for the Muskeg River Mine Project (Section E2). The CALPUFF model predicts sulphate depositions of 3 to 5 kg SO_4^{2-}/ha/a and nitrate depositions of about 1 kg NO_3^-/ha/a in Fort McMurray. The estimated wet sulphate and nitrate depositions in Fort McMurray due to existing sources are 3.2 kg SO_4^{2-}/ha/a and 1.1 kg NO_3^-/ha/a, respectively. While this comparison does not include the dry contribution, it does provide an indication of agreement. When compared to provincial scale predictions, the CALPUFF model predicts much larger deposition values (Section D2.6.4).

Figure F2-5 Predicted Potential Acid Input (keq/ha/a) in the RSA due to CEA Sources

c:\data\7316259\calpuff\modruns\output\mannix8d\acid.srf 01/14/98

Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Suncor	SO_2 = 51 t/d
	Syncrude	SO_2 = 197 t/d
	SOLV-EX	SO_2 = 3 t/d
	Suncor	NO_x = 36 t/d
	Syncrude	NO_x = 37 t/d
	Muskeg River Mine	NO_x = 12 t/d
	Aurora Mines	NO_x = 23 t/d
	SOLV-EX	NO_x = 1 t/d
Targets:	0.25, 0.50 and 1.0 keq/ha/a	

F2.4.4 Key Question AQCEA-4: Will the Precursor Emissions From Combined Developments Result in the Formation of Ozone (O_3) Concentrations That Exceed Air Quality Guidelines?

The production of ozone requires simultaneous NO_x emissions, VOC emissions and sufficient solar intensity to initiate reaction formation mechanisms. While precursor NO_x emissions from the CEA can be defined with some confidence, precursor VOC emissions are more difficult to characterize because of their fugitive nature. The prediction of photochemical O_3 production results in two challenges: the characterization of VOC emissions and the selection of an appropriate photochemical model.

Syncrude recently conducted a monitoring program and updated the VOC emission profile associated with their operations. Much of this information can be extrapolated to other oil sands operations to refine regional VOC emission estimates. This information, however, was not available at the time the Muskeg River Mine Project EIA was prepared.

The SMOG model was applied to the oil sands area in 1993 to predict photochemical ozone production due to precursor emissions. AEP recommended the use of the SMOG model for this type of application in their 1989 draft air modelling guidelines. Discussions with AEP indicate more up-to-date models are preferable for photochemical modelling.

Shell proposes to participate in an industry initiative with Syncrude and Suncor in using the updated VOC emission profile and a more recent photochemical model to predict the potential for photochemical ozone production. These studies are expected to be completed in the spring of 1998.

The ozone assessment due to CEA precursor emissions, in the interim, is based on inference. This CEA compares the oil sands regional precursor emissions with those from Calgary and Edmonton. This comparison allows conclusions obtained from the application of models to these urban centres to be extrapolated to the oil sands region. The CEA assessment also summarizes the previous SMOG predictions for the region.

Comparison to Urban Centres

Studies have been undertaken in Alberta to evaluate ozone formation downwind of large urban airsheds. Therefore, it is useful to compare the ozone precursor emissions from these centres with those from the oil sands area. This allows conclusions from the urban centres to be extrapolated to the oil sands area. Unfortunately, neither Environment Canada nor Alberta Environmental Protection has an emission inventory on an urban airshed basis. Notwithstanding this limitation, emissions from Edmonton and Calgary were estimated from 1990 provincial values as follows:

- Motor vehicle emissions (i.e., diesel and gasoline fueled heavy duty trucks, light duty trucks and light duty vehicles) were prorated on the basis of population.

- Residential and commercial fuel consumption assumes summer conditions (i.e., 15% of the annual fuel use is for non-space heating purposes).

- Selected industries were prorated to the two urban centres based on Edmonton having one quarter of the "Other Chemicals" emissions; one-third of the "Petroleum Refining", "Petrochemical Industry" and "Other Industry" emissions; and one half of the "Cement and Concrete Manufacture" emissions. Calgary was assumed to have one-third of the "Other Industry Emissions" emissions.

Similar assumptions were made to estimate VOC emissions from the Alberta totals for these two urban centres.

Table F2-8 compares the estimated NO_x and VOC emission from the urban airsheds with those from the Fort McMurray regional airshed. Calgary and Edmonton NO_x emissions are currently estimated to be greater than the baseline and CEA NO_x emissions in the RSA. The estimated VOC emissions in the Fort McMurray regional airshed are estimated to be between one-third and one-half those associated with the urban centres. In the absence of detailed modelling for the RSA, the observations and modelling associated with the urban centres provides an indication potential effects even though there are differences with the VOC emissions.

Studies associated with the evaluation of the Edmonton and Calgary airsheds include:

- Angle and Sandhu (1989) found that NO_x emissions in Edmonton and Calgary typically act as a sink rather than a source for ozone. This leads to ozone concentrations downwind of the urban areas that are less than the background rural values. However, under stagnant air flow conditions, they indicated that increased ozone concentrations at mid-day can occur further downwind of these cities.

- Gladstone et al. (1991) applied a photochemical box model to predict ozone concentrations downwind of Calgary and Edmonton. They found downwind ozone concentrations can be greater than the rural values due to photochemical production. The natural occurrence of VOC compounds such as isoprene plays a significant role in the production of ozone. They found that under stagnant conditions, the photochemical production of ozone can produce ambient values that are in excess of the 82 ppb guideline.

The extrapolation of these studies indicate that under similar conditions, there is a potential for ozone formation in the RSA due to precursor emissions.

Table F2-8 Comparison of NO_x and VOC Emissions for Various Airsheds

	NO_x (t/d)	VOC (t/d)
Oil Sands RSA		
Baseline	78	44
Baseline and Project	90	48
CEA	110	50[a]
Provincial		
Edmonton (Summer)	151	140
Calgary (Summer)	115	120
Alberta (Annual)	1,333	1,747

[a] The CEA VOC emissions are reduced due to improvements associated with the Suncor Steepbank Project.

Previous Modelling for the Oil Sands Area

As part of another study, the photochemical model SMOG was applied for a hypothetical meteorological condition (i.e., northerly summer time air flow) to evaluate the potential for ozone production downwind of oil sands sources. The model was applied to NO_x emission scenarios that ranged from 59 to 114 t/d and for anthropogenic VOC emission scenarios that ranged from 28 to 63 t/d. The predicted ozone concentrations were about 10 ppb larger for the higher emission scenarios than those for the lower emission scenarios.

Over the last four years, the maximum observed ozone concentration in Fort McMurray has averaged 67 ppb. An additional 10 ppb would increase the maximum value to near the 82 ppb guideline. The SMOG modelling therefore supports the urban modelling results in that there is a potential for ozone values in Fort McMurray to exceed the 82 ppb guideline.

Residual Impact Classification

Table F2-9 classifies the impacts associated with increased emissions of ozone precursors. Given the high relative increase in NO_x emissions in the RSA, the overall degree of concern is sufficient to warrant further investigation. Shell, in conjunction with Suncor and Syncrude, will undertake a more refined estimate of photochemical formation of ozone based on a more recently developed modelling approach and on updated VOC emissions.

Certainty

Updated modelling with more refined emission data will help produce predictions with a higher confidence level.

Table F2-9 Classification of Regional Air Quality Impacts Associated with Key Question A-4 (Ozone Production)

Direction	Negative due to increased NO_x emissions
Magnitude	To be determined
Geographic Extent	Regional
Duration	Plant life (duration of emissions)
Reversibility	Reversible
Frequency	Infrequent and intermittent. Requires warm temperatures, strong solar intensity and stagnant conditions

F2.5 Summary of Impacts

Table F2-10 provides a summary of the key questions that were addressed as part of the air quality CEA. The classification of the effects associated with air emissions is undertaken in the human health and respective environmental sections. An industry initiated study will determine the effects associated with the photochemical production of ozone.

Table F2-10 Summary of Air Quality CEA

Key Question	CEA Results
AQCEA-1: Will emissions from combined developments result in exceedances of ambient air quality guidelines?	• SO_2, CO and PM_{10} emissions have a low to negligible degree of concern under the CEA scenario. NO_2 concentrations for daily and hourly predictions should be less than air quality guidelines. Annual average NO_2 concentrations may exceed the guideline in areas adjacent to the mines.
AQCEA-2: Will emissions from combined developments result in human health effects?	• Human health effects were based on annual NO_2, VOC and PAH predictions in Fort McKay, Fort McMurray and Fort Chipewyan. The CEA values estimated the largest increase for NO_2 in Fort McKay, but the predicted values in the communities are well below the guideline. • The impact classification associated with these extrapolated concentration estimates is presented in the human health section.
AQCEA-3: Will emissions from combined developments result in deposition of acid forming compounds that exceed target loadings?	• While the SO_2 emissions in the RSA are expected to be relatively stable (or perhaps even decrease), the RSA NO_x emissions are predicted to increase by about 40% over baseline levels. Of the increase from 78 to 110 t/d, the Muskeg River Mine Project accounts for 12 t/d. • The CALPUFF model predicts that the potential acid input (PAI) will increase as a result of these increased NO_x emissions. • The area where the PAI exceeds the 0.25 keq/ha/a target loading for sensitive ecosystem increases from 1500 km^2 for the baseline emissions to 1,800 km^2 with the addition of the project emissions. Under the CEA emissions scenario, the area further increases to 2,500 km^2. • For areas that are better buffered, the 0.50 keq/ha/a target loading can be used, and the respective areas of exceedance are 155 km^2 (baseline), 190 km^2 (baseline and project) to 315 km^2 (CEA).

Key Question	CEA Results
	• The impact classification associated with these predictions is presented in the respective terrestrial and aquatic sections.
AQCEA-4: Will precursor emissions from combined developments result in the formation of ozone (O_3) concentrations that exceed air quality guidelines?	• Precursor NO_x and VOC emissions are estimated to increase by about 40 and 15%, respectively. The level of confidence for the VOC estimates, however, are lower than that for the NO_x emission estimates. • The estimated CEA NO_x emissions of 110 t/d are similar to those from urban areas such as Calgary (115 t/d) and Edmonton (151 t/d). The CEA VOC emissions of 50 t/d are less than one-half those from Calgary (120 t/d) and Edmonton (140 t/d). Photochemical modelling for these cities indicates a potential for downwind ozone values to exceed the guideline value of 82 ppb. • The previous application of the SMOG model to the RSA indicates a potential for the guideline value to be exceeded. • Shell will participate in an industry initiated study (with Syncrude and Suncor) to undertake more refined photochemical modelling using more recent VOC data and more up-to-date photochemical model. Until this is conducted, the magnitude of the effect is classified as "to be determined".

F3 HYDROGEOLOGY CUMULATIVE EFFECTS ASSESSMENT

F3.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on hydrogeology (groundwater) in the Regional Study Area (RSA). For the purposes of examining the key question described below, the following developments, as shown in Figure F1-1, were included in this CEA:

- SOLV-EX
- Muskeg River Mine Project
- Syncrude Aurora North
- Syncrude Aurora South

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

The hydrogeology predictions presented in this section are used to assess impacts on surface water hydrology (Section F4) and water quality (Section F5).

F3.2 Approach and Methods

The calculations of drawdown due to Basal Aquifer depressurization for the Muskeg River Mine Project were discussed in Section E3.5. The cumulative effects of Basal Aquifer drawdown from the Aurora North and South developments can be included by applying the principle of superposition. That is, the total drawdown at any point in a confined aquifer, due to pumping of multiple wells, is equal to the sum of the individual drawdowns that would correspond to each well pumping independently (Freeze and Cherry 1979, p. 327). Applied to the cumulative effect of depressurization at Kearl Lake, the total drawdown at Kearl Lake, from all depressurization operations, will be equal to the sum of the individual drawdowns from each operation.

F3.3 Potential Linkages and Key Questions

The potential linkages for the assessment of impacts of the project on hydrogeology were defined in Section E3. These linkages apply to the CEA under one key question.

GWCEA-1: Will Combined Developments Result in a Drawdown of Water Levels in the Basal Aquifer and Cause a Loss of Water From Important Lakes?

F3.4 Analysis and Results

F3.4.1 Key Question GWCEA-1: Will Combined Developments Result in a Drawdown of Water Levels in the Basal Aquifer and Cause a Loss of Water From Important Lakes?

From the hydrogeology impact analysis, drawdown of the Basal Aquifer was shown to increase the downward seepage of water from Kearl Lake. No impact on McClelland Lake was expected, since published geological maps of the area show that the Basal Aquifer is absent beneath McClelland Lake. Isadore's Lake is much closer to the Muskeg River Mine Project than to the Aurora mines Project, and the impact analysis conducted for Isadore's Lake already represents an extreme case. Therefore, the Aurora Mine development is not expected to have any impact on Isadore's Lake. Consequently, the focus of this hydrogeology cumulative impacts assessment is on the cumulative effects of Basal Aquifer depressurization on Kearl Lake.

Analysis of Key Question

Under natural conditions, Kearl Lake, which is assumed to have an elevation of 334 meters above sea level (masl), is separated from the Basal Aquifer by approximately 80 m of low permeability oil sands, fine-textured Cretaceous sediments and Quaternary deposits. Consequently, under natural conditions, the groundwater level in the Basal Aquifer, approximately 315 masl, is 19 m lower than the lake level. Therefore, there is a downward-directed vertical hydraulic gradient of 0.24, with downward seepage from the lake at a rate of 15 mm/year, assuming a hydraulic conductivity of 2 x 10-9 m/s for the intervening oil sands.

Basal Aquifer depressurization from the Muskeg River Mine Project is expected to produce a drawdown of approximately 18 m beneath Kearl Lake, which is situated approximately 12 km from the Project mine pit. Drawdown of this magnitude will increase the vertical hydraulic gradient beneath Kearl Lake to 0.46, which corresponds to a downward seepage rate of 29 mm/year, an increase of 14 mm/year.

Basal Aquifer depressurization for the Aurora Mine developments is expected to cause an additional drawdown of 60 m beneath Kearl Lake. This will give a total drawdown of 78 m in the Basal Aquifer, corresponding to a hydraulic head of 237 m. This gives a head difference of 97 m over a thickness of only 80 m of intervening oil sands, fine-textured Cretaceous sediments and Quaternary deposits. This suggests that desaturation of the Basal Aquifer beneath Kearl Lake may occur, in which case the downward vertical hydraulic gradient for practical purposes become unity. This represents a limiting condition for downward leakage from Kearl, since further drainage of the Basal Aquifer will not increase the vertical hydraulic gradient beyond unity.

Assuming that such conditions arise, and the vertical hydraulic gradient becomes unity, then the maximum downward seepage from Kearl Lake would be 63 mm/year. This represents about 14% of mean annual precipitation received by the lake.

Residual Impact Classification and Degree of Concern

The cumulative impacts of drawdown, due to depressurization of the Basal Aquifer on Kearl Lake, are such that downward seepage from the lake will increase over both natural rates and the rate associated only with the Muskeg River Mine Project. The direction of the residual impact is considered to be negative relative to the natural condition, and the magnitude of impact low to moderate. The impact is expected to be limited to Kearl Lake, so the geographic extent is considered to be local. The complete recovery of groundwater levels in the Basal Aquifer is likely to take up to 30 years after closure, therefore the duration of the impact is long-term. Groundwater levels will eventually recover, and therefore the water losses are reversible. However, while the lowered heads persist, the increased seepage will occur continuously and year-round, so the frequency is high. Overall, the degree of concern related to cumulative effects of Basal Aquifer drawdown due to depressurization is considered to be low.

F3.5 Summary of Impacts

Key Question	CEA Results
GWCEA-1: Will Combined Developments Result in a Drawdown of Water Levels in the Basal Aquifer and Cause a Loss of Water From Important Lakes?	• The cumulative impacts on Kearl Lake from drawdown, due to depressurization of the Basal Aquifer, are such that downward seepage from the lake will increase over both natural rates and the rate associated only with the Muskeg River Mine Project. This impact is not expected to extend to McClelland Lake. The complete recovery of groundwater levels in the Basal Aquifer is likely to take up to 30 years after completion of mining, however, groundwater levels will eventually recover. Therefore, the effects on Kearl Lake are reversible.

Key Question	CEA Results
	The direction of the residual impact is considered to be negative relative to the natural condition, and the magnitude of impact low to moderate. The impact is expected to be limited to Kearl Lake, so the geographic extent is local. The complete recovery of groundwater levels in the Basal Aquifer is likely to take up to 30 years after completion of mining, therefore the duration of the impact is long-term. Groundwater levels will eventually recover, and therefore the water losses from Kearl Lake are reversible. However, while the lowered heads persist, the increased seepage will occur continuously and year-round, so the frequency is high. Overall, the degree of concern related to cumulative effects of Basal Aquifer drawdown due to depressurization is considered to be **Low**.

F4 SURFACE WATER HYDROLOGY CUMULATIVE EFFECTS ASSESSMENT

F4.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on surface water hydrology in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- Syncrude Aurora North and South
- Syncrude Mildred Lake
- SOLV-EX
- Muskeg River Mine Project

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

The surface water hydrology predictions presented in this section are used to assess impacts on water quality (Section F5), aquatics (Section F6) and wetlands (Section F10).

F4.2 Approach and Methods

The approach used to assess potential cumulative impacts on surface water hydrology was consistent with that described for the surface water hydrology impact assessment in Section E4.

F4.3 Potential Linkages and Key Questions

Figures E4-1 to E4-3 (Section E4) show the linkage diagrams for Project activities and potential changes in surface water hydrology associated with the Project. Generally the same linkages and key questions apply to the CEA.

The CEA key questions are formulated to address the key issues. These key questions provide a framework for systematically analyzing the key issues, presenting the results of the CEA analysis, and assessing the cumulative effects. The CEA key questions are listed below.

SWCEA-1: Will Combined Developments in the Muskeg River Basin Result in Effects on the Muskeg River Flows, Sediment Concentrations and Channel Regime?

SWCEA-2: Will Combined Developments Result in Effects on Athabasca River Flows?

SWCEA-3: Will Combined Developments Result in Effects to the Open-Water Areas Including Lakes and Streams?

F4.4 Analysis and Results

F4.4.1 Key Question SWCEA-1: Will Combined Developments in the Muskeg River Basin Result in Effects on the Muskeg River Flows, Sediment Concentrations and Channel Regime?

Mining Schedules and Production Rates

The mining schedules for the three oil sands developments in the Muskeg River basin are listed in Table F4-1. Each mining schedule includes the beginning of construction, the beginning of operation and the completion of reclamation or the end of mining.

Table F4-1 Proposed Mining Schedules

Development	Beginning of Construction	Beginning of Operation	End of Operation
Aurora Mine North	1998	2001	2040
Aurora Mine South	2006	2009	2050+
Muskeg River Mine	1999	2002	2030

Based on these schedules, the Aurora Mine North will be the first to commence construction in the Muskeg River basin in year 1998, and the Aurora Mine South will be the last to be developed, beginning in year 2009. The Muskeg River Mine will be the first mine to be reclaimed and closed (2030), while the Aurora Mine South will be the last mine to be reclaimed and closed (2050).

Selection of Time Snapshots

Figure F4-1 shows the total area of muskeg drainage and overburden dewatering for the CEA projects, the combined area of closed-circuit operations, and the average changes in the Muskeg River flows. Detailed mine plans for the Aurora North and Muskeg River Mines provide an accurate basis for defining these areas during the lives of these mines. The area for the Aurora South Mine was estimated based on preliminary plans.

The variable changes of the Muskeg River flows as shown in Figure F4-1, provided a basis for identifying four time snapshots for the cumulative effects assessment. Figures F4-2 and F4-3 illustrate the areas of mine developments and the drainage systems for these time snapshots. The rationale for selection of these time snapshots is discussed below.

- **Year 2007:** This time snapshot was selected for assessing a maximum increase in the Muskeg River flows because of muskeg drainage and overburden dewatering area, which will reach a maximum of about 19.0 km^2 in year 2007. The combined closed-circuit area will be about 43.8 km^2 in that year.

- **Year 2020:** This time snapshot represents a condition when all of the oil sands developments in the Muskeg River basin will be in full production and the total closed-circuit area will nearly reach the maximum. The total area of muskeg drainage and overburden dewatering will reduce to about 6.2 km^2 in year 2020, while the combined closed-circuit operation will reach an area of about 105 km^2.

- **Year 2030:** This time snapshot represents a condition when the end pit lake (EPL) from the Muskeg River Mine will discharge waters from reclaimed surfaces to the Muskeg River. This time snapshot is used to capture the effect of the mature fine tails (MFT) transfer from the tailings settling pond to the end pit lake, resulting in a large temporary release of water from the lake to the Muskeg River.

- **Far Future Equilibrium Conditions:** This represents the closure conditions when a dynamic equilibrium will be established in the Muskeg River basin. This provides a time frame for quantifying the long-term effects of the oil sands developments.

The end pit lake management period for the Muskeg River Mine will be from 2023 to 2030. The MFT will be transferred from the tailings settling pond to the end pit lake over four years from 2027 to 2030, near the end of this management period. This transfer will temporarily increase the Muskeg River flows.

Analysis for Flows

Estimates of Muskeg Drainage Discharges

The areas of muskeg drainage and assumed muskeg depths for estimating the drainage discharges for the three oil sands developments in the Muskeg River basin, is presented in Table F4-2.

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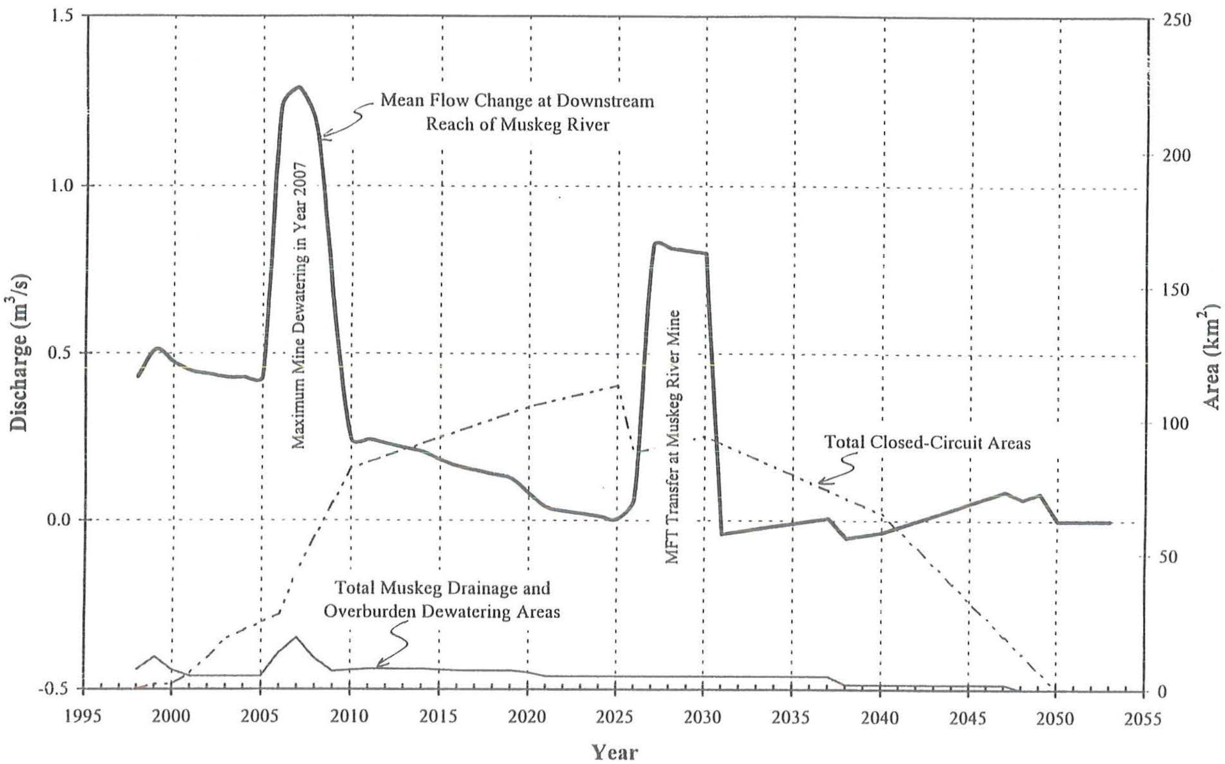

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PREDICTED MUSKEG RIVER DISCHARGES, CLOSED-CIRCUIT AREAS AND DEWATERING AREAS 1995-2055

19 JAN 98	Figure F4-1	DRAWN BY: RFM

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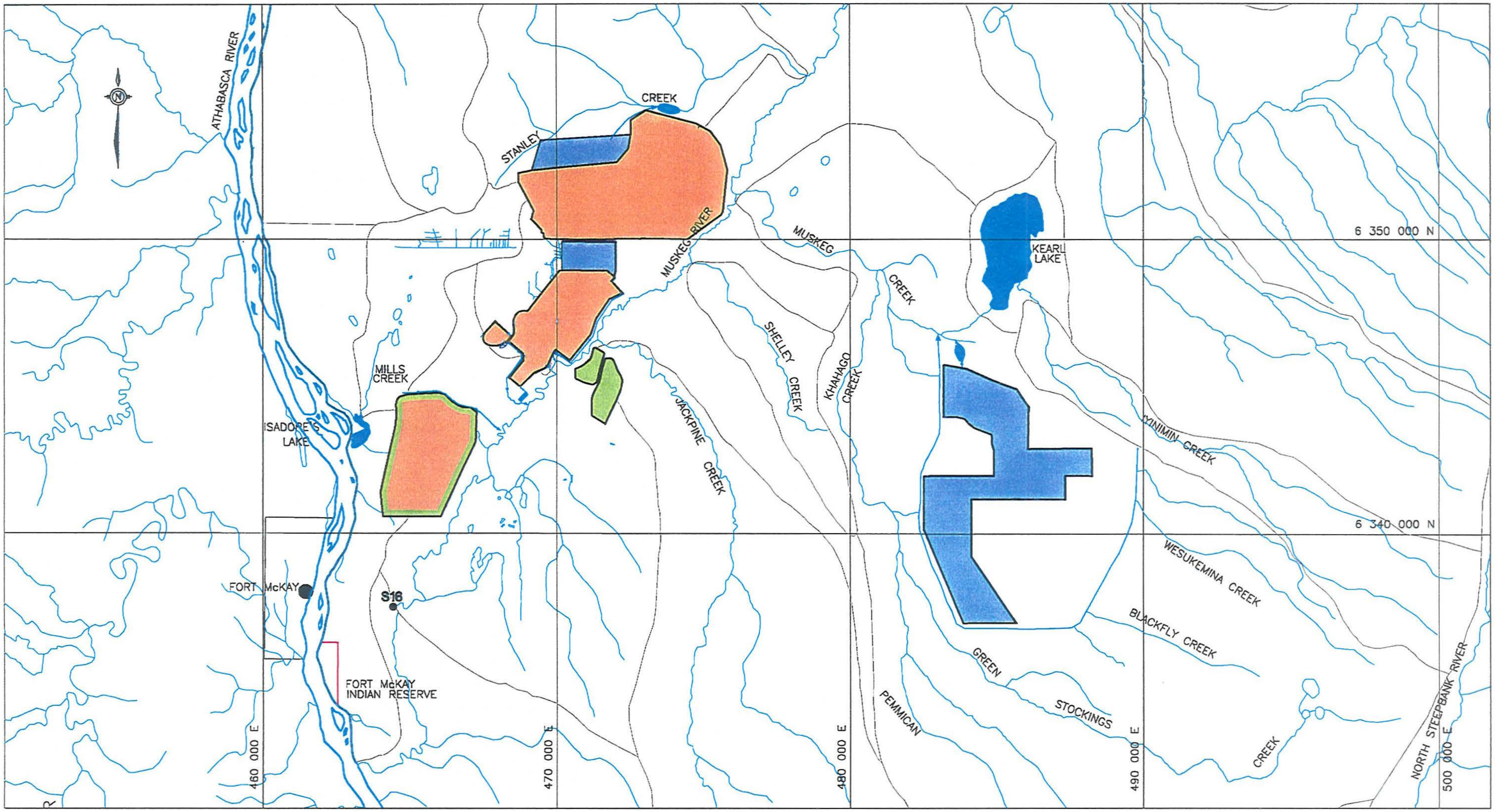

LEGEND

- PERMANENT STREAM
- DIVERSION OR DRAINAGE CHANNEL
- EXISTING OR END PIT LAKE
- S16 MONITORING NODE
- SUB-BASIN BOUNDARY
- CLOSED CIRCUIT AREA
- CLEARED AND DEWATERED AREA
- RECLAIMED AREA

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I 84A AND 84H FROM RESOURCE DATA DIVISION ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 2 4 6 8 10km

SCALE 1:200,000

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COMBINED OIL SANDS DEVELOPMENTS IN THE MUSKEG RIVER BASIN - YEAR 2007

11 JAN 1998	Figure F4-2	DRAWN BY: RFM

F4 - 5

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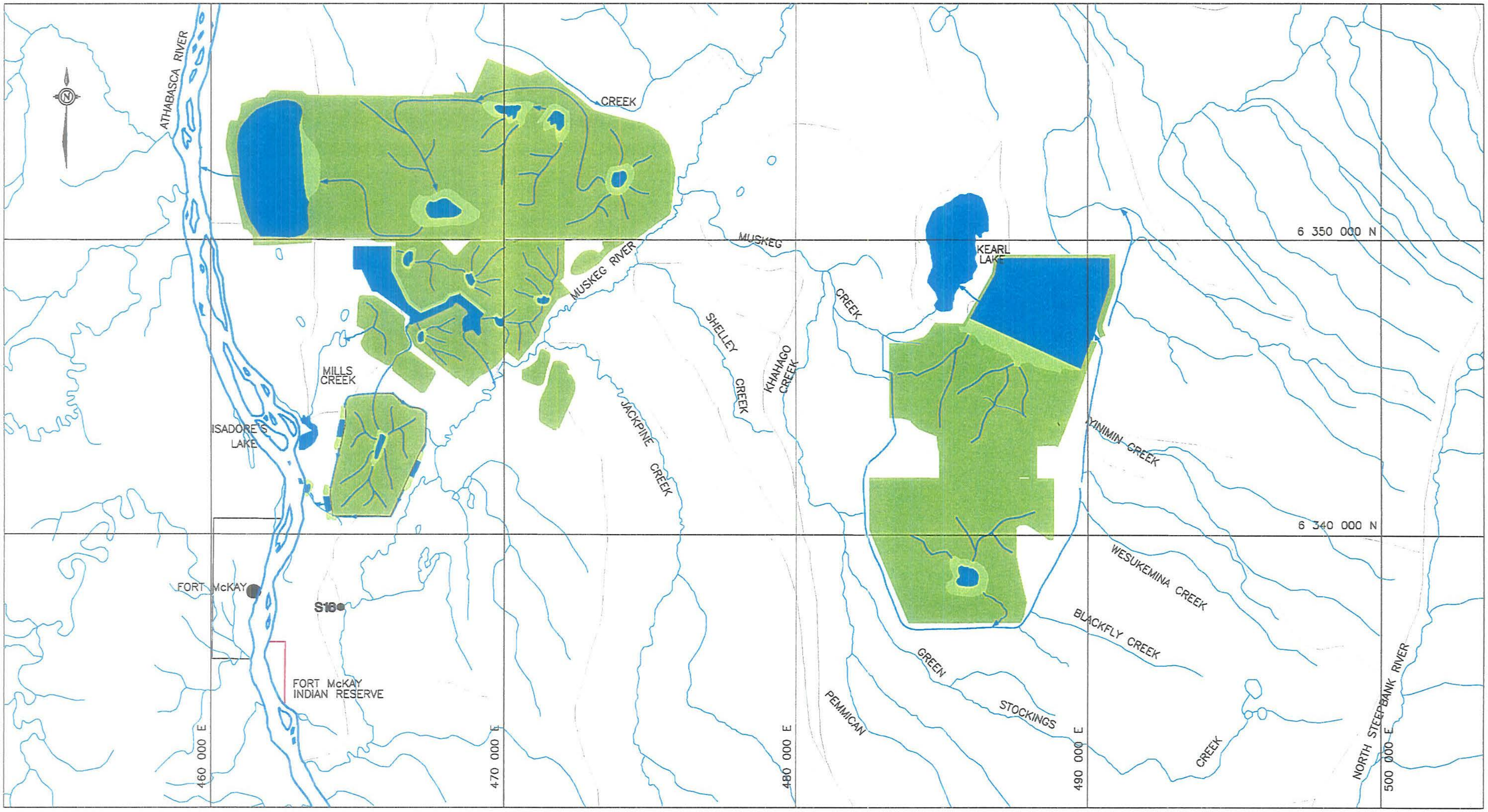

LEGEND

- PERMANENT STREAM
- DIVERSION OR DRAINAGE CHANNEL
- EXISTING OR END PIT LAKE
- S16 MONITORING NODE
- SUB-BASIN BOUNDARY
- CLOSED CIRCUIT AREA
- CLEARED AND DEWATERED AREA
- RECLAIMED AREA

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 2 4 6 8 10km
SCALE 1:200,000

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CLOSURE RECLAMATION DRAINAGE FAR FUTURE

16 JAN 1998	Figure F4-3	DRAWN BY: RFM

Table F4-2 Summary of Muskeg Drainage Areas and Muskeg Depths

Development	Assumed Muskeg Depth	Area of Muskeg Drainage
Aurora North Mine	1.5 m	7.3 km^2 during construction in year 1998. 1.5 km^2 in each year following construction until 3 years prior to mine closure.
Aurora South Mine	1.5 m	8.6 km^2 during construction in year 2006. 5.6 km^2 during construction in year 2007. 0.9 km^2 in each year following construction until 3 years prior to mine closure.
Muskeg River Mine	1.5 m	3.1 km^2 during construction in year 1999. 1.4 to 2.6 km^2 for each year from year 2000 to 2020.

Muskeg drainage water yield per unit area was estimated based on the following assumptions:

- Drainable water storage in the muskeg layer is assumed to be 60% of the muskeg depth. For example, the water storage that can be drained by gravity in 1.5 m depth of muskeg is 0.9 m.

- 40% of the muskeg water storage plus 0.17 m water yield from precipitation during the 6-month open-water season will be released for each of the first two years of drainage by ditching. For example, the water storage released the first year from the 1.5 m depth of muskeg is 0.36 m, which together with the 0.17 m yield from precipitation means the total annual water yield is 0.53 m.

- The remaining 20% of the muskeg water storage will be released in the third year when the material is placed in reclamation material storage areas. For example, the water storage released in the third year from the 1.5 depth of muskeg, is 0.18 m.

Table F4-3 summarizes the muskeg drainage discharges estimated for the selected time snapshots during construction and operation.

Table F4-3 Estimates of Total Muskeg Drainage Discharges

Time Snapshot	Area of Muskeg Drainage (km^2)	Total Drainage Discharge (m^3/s)
2007	19.0	0.350
2020	6.2	0.140
2030	4.8	0.110

Estimates of Overburden Dewatering Rates

The overburden dewatering rate is a function of drainage area and hydraulic conductivity of overburden materials. Table F4-4 summarizes the estimates of overburden dewatering rates for the selected time snapshots during mining construction and operation.

Table F4-4 Estimates of Total Overburden Dewatering Rates

Time Snapshot	Total Dewatering Rate (m^3/s)
2007	1.06
2020	0.23
2030	0.19

These total overburden dewatering rates were estimated based on data presented in the Aurora EIA (BOVAR 1996a) and in Section E3 of this EIA.

The overburden dewatering rates for the Aurora Mines are higher than the Muskeg River Mine Project, because the hydraulic conductivities of the overburden materials for the Aurora Mines are higher than those estimated for the Muskeg River Mine Project. In addition to ditch dewatering, groundwater well dewatering techniques will be used for some areas of the Aurora Mines. Therefore, it was assumed that the overburden dewatering discharges from the Aurora Mines will occur in both the ice-cover and open-water seasons. However, the overburden dewatering technique for the Muskeg River Mine Project was assumed to be ditching only. Therefore, the dewatering discharges were assumed to mainly occur in the open-water season.

Estimates of Mine Seepage Rates

Mine water seepage includes perimeter seepage from in-pit and external tailings sand storage areas to natural receiving streams. Materials for in-pit storage include CT and sand. The external tailings sand storage areas include tailings settling ponds and some residual fine tailings trapped between layers of sand. Table F4-5 presents the seepage estimates for the selected time snapshots.

Table F4-5 Estimates of Total Mine Seepage Rates

Time Snapshot	Perimeter CT Seepage Rate (m^3/s)	Tailings Settling Pond Seepage Rate (m^3/s)	CT Upward Flux (m^3/s)
2007	0.0	0.007	0.0
2020	0.0	0.013	0.0
2030	0.0	0.341	0.04
Far Future	0.07	0.342	0.0

These total seepage rates are estimated based on data presented in the Aurora EIA (BOVAR 1996a) and in Section E3 of the Project EIA.

There will be no CT perimeter seepage discharges to receiving streams from the Muskeg River Mine Project because the in-pit CT surface elevations for the Project will be lower than original ground levels. All CT perimeter seepage discharges to receiving streams will occur at the Aurora Mines because the CT surface elevations of these mines will be higher than original ground levels.

Perimeter ditches around the reclaimed tailings settling pond at the Muskeg River Mine Project will be constructed to route a portion of the seepage water to shallow lakes and wetlands for biological treatment before release to receiving streams. This will minimize the direct discharge of the sand seepage water to recieving streams.

Seepage water discharges from the overburden disposal areas will be relatively small and are not expected to adversely affect water quality of receiving streams. CT storage areas will contain CT upward porewater release. However, these upward fluxes will not be released to receiving streams during Project operation and will be negligible in the far future because CT consolidation slow to very low levels.

Estimates of Surface Runoff from Natural and Reclaimed Areas

The adopted methodology for simulating surface runoff from natural and reclaimed areas using the HSPF hydrologic model and for deriving the hydrologic parameters are presented in Section E4. Based on these hydrologic parameters derived for various land types, the surface runoff inflows to the Muskeg River were estimated based on the composition of various land types contributing runoff to the river at the selected time snapshots. Table F4-6 lists the types of surface areas contributing runoff to Muskeg River at Node S16 at the selected time snapshots.

Table F4-6 Drainage Areas of Different Land Types of Muskeg River at Node S16 for Each Time Snapshot

Land Type	Estimated Area for Each Specified Time Snapshot (km²)				
	Existing	2007	2020	2030	Far Future
Natural Upland	745	745	745	745	745
Natural Lowland	648	582	531	526	493
Overburden Disposal Area	0	2.2	3.4	3.4	9.1
Closed-Circuit Area	0	44	105	94	0
Reclaimed Sand on CT	0	0	0	6.8	6.8
Reclaimed Overburden on CT	0	0	0	6.3	6.3
Reclaimed Sand on Overburden	0	0	0	3.9	3.9
Reclaimed Tailings Settling Pond	0	0	0	10	51
Constructed Wetlands	0	0	0	1.8	9.2
Shallow Lakes and End Pit Lake	0	0	0	3.9	15.5

Results of the Cumulative Effects Analysis

The results of the cumulative effects of the three oil sands developments on the Muskeg River flows are presented in Table F4-7. A detailed analysis of these effects for each time snapshot follows:

- **Year 2007:** In year 2007, the mean annual discharge of the Muskeg River will be increased by 24%, primarily as a result of muskeg drainage and overburden dewatering discharge from the Aurora Mines. The mean open-water season discharge will be increased by 19%, and the mean ice-cover season discharge will be increased by 91%. The low flows will be largely increased due to the muskeg drainage and overburden dewatering. For example, the open-water 7Q10 low flow will be increased by about seven times, and the mean annual 30-day low flow will be increased by about six times. These levels of cumulative effects on the Muskeg River flows are relatively High.

- **Year 2020:** In year 2020, the mean annual and open-water discharges on the Muskeg River will be increased slightly by 2%, because the effect of flow reduction by closed-circuit operation will be offset by the effect of flow increase by muskeg drainage and overburden dewatering. The drainage and dewatering will actually increase the mean ice-cover flow and the river low flows. For example, the open-water 7Q10 low flow will increase by about three times, and the mean annual 30-day low flow will increase by 99%. Therefore, the combined effects on the mean Muskeg River flows in year 2021 will be small while the effects on the river low flow conditions could be relatively High.

Table F4 - 7 Cumulative Effects of the Oil Sands Developments in the Muskeg River Basin on Muskeg River Flows at Node S16

Year	Existing Drainage Area (km^2)	Future Area (km^2)				Mean Annual Seepage and Dewatering Discharges (m^3/s)										
						Muskeg Drainage[a]		Overburden Dewatering[a]		Perimeter CT Seepage		Upward CT Flux		Sand Storage Seepage[b]		
															Muskeg River Mine	
		Undisturbed Area	Reclaimed Area[d]	Closed Circuit Area	Total Drainage Area	Aurora Mines	Muskeg River Mine	Aurora Mines[b]	Muskeg River Mine	Aurora Mines[b]	Muskeg River Mine	Aurora Mines[b]	Muskeg River Mine	Aurora Mines	Collected In Ditches	Not Collected in Ditches
2007	1393	1327	2.9	43.8	1349	0.306	0.041	1.037	0.024	0	0	0	0	0	0	0.007
2020	1393	1276	5.3	105.2	1288	0.108	0.032	0.219	0.008	0	0	0	0	0	0	0.013
2030[e]	1393	1271	16.9	94.2	1293	0.109	0	0.189	0	0	0	0	0.04	0.338	0	0.0033
Far Future	1393	1238	129.3	0.0	1367	0	0	0	0	0.066	0	0	0	0.338	0.027	0.0035

Year	Streamflow Discharge (m^3/s)																	
	Annual Mean Discharge			Mean Open-Water Discharge[c]			Mean Ice-Cover Discharge[c]			Open-Water 7Q10 Discharge			Ice-Cover 7Q10 Discharge			Mean 30Q Discharge		
	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference	Existing	Future	Difference
2007	5.28	6.53	24%	8.21	9.74	19%	1.11	2.12	91%	0.281	2.058	632%	0.052	1.094	2005%	0.225	1.263	462%
2020	5.28	5.36	2%	8.21	8.28	1%	1.11	1.28	15%	0.281	0.793	182%	0.052	0.281	441%	0.225	0.446	99%
2030[e]	5.28	6.28	19%	8.21	9.78	19%	1.11	1.62	46%	0.281	2.290	715%	0.052	0.619	1091%	0.225	0.802	257%
Far Future	5.28	5.37	2%	8.21	8.11	-1%	1.11	1.47	33%	0.281	0.697	148%	0.052	0.483	829%	0.225	0.835	271%

[a]: Muskeg drainage and overburden dewatering at Muskeg River Mine will occur in the open-water season.

[b]: Overburden dewatering at Aurora North and South, perimeter CT seepage, CT upward flux, sand storage seepage will occur throughout the year.

[c]: The "open-water" season is defined as the period from mid-April to mid-November inclusive. The "ice-cover" season is defined as the period from mid-November to mid-April.

[d]: Reclaimed area includes end pit lakes and wetlands.

[e]: Mean annual mature fine tailings (MFT) transfer rate of 0.618 m3/s from the Muskeg River Mine was added to each future open-water surface runoff discharge component.

- **Year 2030:** In year 2030, the mean annual and open-water discharges on the Muskeg River will increase by 19% because of the effect of the MFT transfer from the tailings settling pond to the end pit lake at the Muskeg River Mine Project. This transfer could also theoretically increase the open-water 7Q10 low flow by about eight times. The transfer will not affect the mean ice-cover flows because it will only occur during the open-water season. However, the continuing overburden dewatering from the other mines will increase the mean ice-cover discharge by about 46% and the mean 30-day low flow by about 3.5 times.

- **Far Future Equilibrium Conditions:** In the far future, the mean annual flow on the Muskeg River will be increased slightly by 2%. However, the mean open-water flow will be reduced by 1% and the mean ice-cover flow will increase by 33%. The relatively large increase in the mean ice-cover flow is mainly due to the presence of the end pit lakes and the seepage water from the reclaimed sand and CT storage areas, which also cause relatively large increases in both open-water and ice-cover low flows. For example, the open-water 7Q10 low flow could theoretically increase by about 2.5 times, and the mean annual 30-day low flow could increase by about 3.5 times. Therefore, the combined closure landscape will have small effects on the mean annual Muskeg River flow, but could cause a relatively large increase in the low flows.

Analysis for Sediment Concentrations and Channel Regime

Streamflow Sediment Concentrations

An increase in the Muskeg River flows is expected to occur during the early years of mine developments in the Muskeg River basin (year 1998 to about year 2015) as shown in Figure F4-1. For the worst-case time snapshot in year 2007, the mean annual Muskeg River discharge will increase by about 24%. The end pit lake release to Muskeg River from the Muskeg River Mine Project will increase the river flows by about 15% for about four years from 2027 to 2030. Table F4-8 lists the estimated average increase of the Muskeg River flows and the increased streamflow sediment concentrations estimated, based on the relationship presented in Section D4 (Surface Water Hydrology Baseline).

Table F4-8 shows that the Muskeg River streamflow sediment concentrations will increase by 0.2 to 1.2 mg/L or 2 to 13%. These levels of increase are rated to be Low to Moderate.

Table F4-8 Estimated Increases in Muskeg River Flows and Sediment Concentrations

Period	Average Increase of Mean Annual Discharge (m^3/s)	Percent Increase of Mean Annual Discharge	Average Increase of Streamflow Sediment Concentration (mg/L)	Percent Increase of Streamflow Sediment Concentration
1998 to 2005	0.5	9%	0.5	5%
2006 to 2008	1.2	23%	1.2	13%
2009 to 2026	0.2	4%	0.2	2%
2027 to 2030	0.8	15%	0.8	8%
after 2030	Negligible	Negligible	Negligible	Negligible

Note: The baseline mean annual discharge of the Muskeg River is 5.3 m^3/s, and the baseline mean annual streamflow sediment concentration of the Muskeg River is about 9.5 mg/L.

Channel Regime

Table F4-9 presents the volumes of eroded channel materials caused by the increases in river flows and channel erosion rates, which were estimated based on the increased streamflow sediment concentrations shown in Table F4-8.

Table F4-9 Estimated Volumes of Eroded Channel Materials

Period	Average Increase of Streamflow Sediment Concentration (mg/L)	Mean Annual Discharge (m^3/s)	Average Increase in Channel Erosion Rate (mg/s)	Volume of Eroded Materials (m^3)
1998 to 2005	0.5	5.8	2900	276
2006 to 2008	1.2	6.5	7800	278
2009 to 2026	0.2	5.5	1100	223
2027 to 2030	0.8	6.1	4900	233
Total				**1010**

The total volume of eroded channel materials from 1998 to 2030 was estimated to be about 1,010 m^3. The reach of the Muskeg River to be affected by the combined oil sands developments is estimated to be about 60 km. The average dimension of the river channel is 20 m (width) x 1 m (depth). The total eroded materials represent an increase in the perimeter depth by about 0.8 mm for the 33 year period, which is about 0.003% of the total perimeter length. This level of erosion is Negligible. Therefore, the increased river flows caused by the oil sands developments in the Muskeg River basin will have a Negligible effect on the river channel regime.

Classification and Degree of Concern of the Cumulative Effects

Based on the above detailed analysis of the cumulative effects of the combined oil sands developments on the Muskeg River flows, sediment concentrations and channel regime, the cumulative effects are classified and the degree of concern of the cumulative effects are rated in Tables F4-10 and F4-11.

Table F4-10 Classification and Degree of Concern of Cumulative Effects on the Muskeg River Flows

Parameter	During Construction and Operation	After Closure
Direction	Negative	Negative
Magnitude	Low to High	Low
Geographic Extent	Local	Local
Duration	Medium-Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Moderate***	***Low***

Table F4-11 Classification and Degree of Concern of Cumulative Effects on the Muskeg River Sediment Concentrations and Channel Regime

Parameter	During Construction and Operation	After Closure
Direction	Negative	Negative
Magnitude	Negligible	Negligible
Geographic Extent	Local	Local
Duration	Medium-Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Negligible***	***Negligible***

The degree of concern of the cumulative effects on the Muskeg River flows is rated as Moderate throughout the life of the oil sands developments in the Muskeg River basin. The degree of concern on the changes in the river flows after mine closure is rated as Low. The degree of concern of the cumulative effects on the Muskeg River sediment concentrations and channel regime is rated as Negligible.

F4.4.2 Key Question SWCEA-2: Will Combined Developments Result in Effects on Athabasca River Flows?

Water Withdrawal and Return Flows on Athabasca River

Existing Effects

Water allocations to current license holders and applicants for water withdrawal from the Athabasca River and its tributary streams and return flows are summarized in Table F4-12 based on the updated data and information collected from the Water Rights Branch of AEP. The collected data included applicant name, intake location, sources, stated purpose, annual allocation and maximum withdrawal rate for all current licenses and existing license applications for water withdrawals from the Athabasca River and its tributary streams.

Table F4-12 shows the net water allocation, which is defined as water withdrawal minus return flow. The total water withdrawal by the existing licenses and license applications is about 400 Mm^3. The total net water allocation is about 179 Mm^3, which compares to a mean annual water yield of about 20,200 Mm^3 measured on the Athabasca River at the WSC gauging station below Fort McMurray for the period of record 1957 to 1995, and about 20,550 Mm^3 estimated for the river location below the confluence with the Muskeg River as shown in Table F4-13.

The total net water allocation of 179 Mm^3 represents a reduction in Athabasca River flows ranging from an average of 0.5% in summer and 3.3% in winter, based on the flows recorded below Fort McMurray. The mean annual reduction in flows of the Athabasca River is 0.9%, based on the flows measured below Fort McMurray.

The existing and approved oil sands developments in the region include Syncrude Mildred Lake Mine, Suncor Lease 86/17 Mine, Suncor Steepbank Mine, Syncrude Aurora North and South Mines and SOLV-EX. The total net water allocation for the existing and approved oil sands developments is about 82 Mm^3, which represents about 46% of the total net water allocation in the Athabasca River basin. This allocation represents a reduction in annual Athabasca River flows of about 0.4%, and a reduction in the seasonal river flows ranging from 0.3% in summer to 1.5% in winter. These effects are rated as small.

Incremental Effects of the Muskeg River Mine Project

The mean annual water withdrawal requirements of the Muskeg River Mine Project from the Athabasca River were analyzed and the results were presented in the study entitled "Water Management Plan for the Muskeg River Mine Project" (Golder 1997j). This analysis showed that the Muskeg River Mine Project will cause a negligible incremental effect on the mean flow conditions of the Athabasca River.

Table F4 - 12 Existing Water Allocations in the Athabasca River Basin

Purpose	Existing Licenses and License Applications for Water Allocations [d]							Existing Net Water Allocations as a Percentage of Mean Athabasca River Flows [c]				
	Existing Licenses (dam³)	Interim Licenses (dam³)	Exploration Permits (dam³)	Permit/ License Applications (dam³)	Total Withdrawals (dam³)	Return Flows (dam³)	Net Water Allocations (dam³)	Winter (Jan - Mar) (%)	Spring (Apr - Jun) (%)	Summer (Jul - Sep) (%)	Fall (Oct - Dec) (%)	Annual (Jan - Dec) (%)
Agricultural [a]	889	7	0	15	911	148	763	0.014	0.003	0.002	0.007	0.004
Domestic[a]	19	1	0	0	21	0	21	0.0004	0.0001	0.0001	0.0002	0.0001
Industrial[a]	185 382	6 847	0	31	192 259	127 904	64 355	1.193	0.211	0.193	0.553	0.318
Irrigation[b]	2 568	58	0	15	2 641	1 381	1 260	0.000	0.008	0.008	0.000	0.006
Municipal[a]	31 164	8 050	0	0	39 214	34 679	4 536	0.084	0.015	0.014	0.039	0.022
Other Use[a]	641	1 348	0	16	2 005	1 250	755	0.014	0.002	0.002	0.006	0.004
Storage Only[a]	26 899	857	0	2 849	30 605	5 077	25 528	0.473	0.084	0.077	0.219	0.126
Sub - Total	**247 562**	**17 168**	**0**	**2 926**	**267 657**	**170 439**	**97 217**	**1.78**	**0.32**	**0.30**	**0.82**	**0.48**
Syncrude:[a] Existing	63 463	4 498	0	0	67 961	0	67 961	1.259	0.223	0.204	0.584	0.336
Suncor:[a] Existing	59 801	0	0	0	59 801	50 639	9 162	0.170	0.030	0.027	0.079	0.045
Solv - Ex	0	5 000	0	0	5 000	62	4 938	0.092	0.016	0.015	0.042	0.024
Sub - Total	**123 263**	**9 498**	**0**	**0**	**132 761**	**50 701**	**82 060**	**1.52**	**0.27**	**0.25**	**0.70**	**0.41**
TOTALS	**370 825**	**26 666**	**0**	**2 926**	**400 418**	**221 140**	**179 277**	**3.30**	**0.59**	**0.54**	**1.53**	**0.89**

(a) Consumption assumed to be distributed equally over the four seasons

(b) Consumption assumed to be distributed equally over the spring and summer seasons only. No consumption in the fall and winter seasons.

(c) Based on discharges recorded from 1957 to 1995 at the Athabasca River below Fort McMurray streamflow monitoring station operated by the Water Survey Canada.

(d) 1 dam^3 = 1 000 m^3

Table F4-13 Annual and Seasonal Discharges of the Athabasca River (Period of Record 1957 to 1995)

Period	Locations Along Athabasca River			
	Below Fort McMurray		Below Confluence with Muskeg River	
	Discharge (m^3/s)	Water Yield (Mm^3)	Discharge (m^3/s)	Water Yield (Mm^3)
January to March	171	1,330	174	1,352
April to June	966	7,595	982	7,721
July to September	1,056	8,394	1,073	8,533
October to December	369	2,933	375	2,982
Annual	641	20,216	652	20,550

Cumulative Effects

The cumulative effects of the net water allocations on the Athabasca River flows are summarized in Table F4-14. The total reduction in Athabasca River flows caused by the developments in the Athabasca River basin is small. The total reduction in the river mean flow is about 1.2%, and the reduction in the river 7Q10 low flow is about 6.4%.

Table F4-14 Combined Effects of Water Allocations of the Existing, Approved and Planned Developments

	Net Water Allocation as a Percentage of the Athabasca River Flows[a]		
Flow Parameter	Existing Effects (179 Mm^3/yr)	Incremental Effects by the Muskeg River Mine Project (55 Mm^3/yr)	Cumulative Effects (234 Mm^3/yr)
Mean Winter Flow (January to March)	3.3%	1.0 %	4.3%
Mean Spring Flow (April to June)	0.6%	0.2 %	0.8%
Mean Summer Flow (July to September)	0.5%	0.2 %	0.7%
Mean Fall Flow (October to December)	1.5%	0.5 %	2.0%
Mean Annual Flow	0.9%	0.3 %	1.2%
Annual 7Q10 Low Flow	4.9%	1.5 %	6.4%

(a) The percent reduction is based on the estimated flows of the Athabasca River below its confluence with the Muskeg River.

Basin Water Yields Caused by Oil Sands Developments on Athabasca River

Mine Water Releases

Mine water releases to natural receiving streams affect both water quantity and quality in receiving streams. These water discharges during construction, operation and after closure of the oil sands developments include the following:

- muskeg drainage
- overburden dewatering
- tailings settling pond seepage
- CT porewater seepage
- sewage

Existing Effects

Table F4-15 shows the estimated mine water releases from existing and approved oil sands developments. The total water discharges from the existing and approved oil sands developments range from about 0.04 to 0.72 m^3/s. The discharges will peak around year 2030 and will reduce in the far future to about 0.41 m^3/s.

Incremental Effects

Future mine water releases from the Muskeg River Mine Project are presented in Section E4 for various time snapshots during construction and operation and after clousre. Table F4-16 summarizes these releases for four time snapshots for comparison with those releases from the existing and approved projects presented in Table F4-15. The incremental releases from the project are expected to range from 0.027 to 0.077 m^3/s.

Cumulative Effects

Table F4-17 summarizes the cumulative effects of all water releases from the existing, approved and proposed oil sands development. The present combined water discharge is about 0.04 m^3/s, and the total water discharge will reach a maximum of about 0.8 m^3/s around year 2030.

Table F4-15 Mine Water Releases from the Existing and Approved Oil Sands Developments

Development	Time	Mine Water Discharges to Natural Receiving Streams (m^3/s)			
		Muskeg Drainage and Overburden Dewatering	Seepage	Sewage	Total
Mildred Lake	Present	0	Negligible	0.0048	0.0048
	2010	0	Negligible	0.0048	0.0048
	2020	0	Negligible	0.0048	0.0048
	2030	0	Negligible	0.0048	0.0048
	Far Future	0	Negligible	0	0
Lease 86/17	Present	0.013	0.020	0.0016	0.034
	2010	0	0.048	0.0016	0.050
	2020	0	0.21	0.0016	0.21
	2030	0	0.071	0.0016	0.073
	Far Future	0	0.071	0	0.071
Aurora North Mine	Present	0	0	0	0
	2010	0.28	0	0	0.28
	2020	0.22	0	0	0.22
	2030	0.08	0.12	0	0.20
	Far Future	0	0.12	0	0.12
Aurora South Mine	Present	0	0	0	0
	2010	0.11	0	0	0.11
	2020	0.11	0	0	0.11
	2030	0.22	0.21	0	0.43
	Far Future	0	0.21	0	0.21
Steepbank Mine	Present	0	0	0	0
	2009	0.0048	0.0022	0	0.007
	2020	0.0048	0.0057	0	0.011
	2030	0	0.0057	0	0.0057
	Far Future	0	0.0057	0	0.0057
SOLV-EX	Present	0	0	0	0
	2010	0.024	0	0.0003	0.024
	2020	0.024	0	0.0003	0.024
	2030	0	0	0	0
	Far Future	0	0	0	0
Total	**Present**	**0.013**	**0.020**	**0.0064**	**0.039**
	2009/2010	**0.42**	**0.050**	**0.0067**	**0.48**
	2020	**0.36**	**0.22**	**0.0067**	**0.59**
	2030	**0.30**	**0.41**	**0.0064**	**0.72**
	Far Future	**0**	**0.41**	**0**	**0.41**

From: Syncrude Aurora EIA Report (BOVAR 1996a) and Suncor Steepbank Mine Application (Suncor 1996a).
Note snapshot years in BOVAR (1996a) did not include 2007.

Table F4-16 Water Releases from the Muskeg River Mine Project

Time	Water Discharges to Natural Receiving Streams (m^3/s)			
	Muskeg Drainage and Overburden Dewatering	Seepage	Sewage	Total
2010	0.067	0.010	0	0.077
2020	0.034	0.015	0	0.049
2030	0	0.027	0	0.027
Far Future	0	0.027	0	0.027

Table F4-17 Cumulative Mine Water Discharges from the Oil Sands Projects

Time	Mine Water Discharges to Natural Receiving Streams (m^3/s)			
	Muskeg Drainage and Overburden Dewatering	Seepage	Sewage	Total
Present	0.013	0.02	0.0064	0.039
2010	0.49	0.06	0.0067	0.56
2020	0.39	0.24	0.0067	0.64
2030	0.30	0.44	0.0064	0.75
Far Future	0	0.44	0	0.44

Reduction of Surface Water Yield Caused by Closed-Circuit Systems

Reduction of surface water yield caused by closed-circuit areas of the oil sands developments during operations is expected to have a small effect on Athabasca River flows, because the maximum combined closed-circuit area of the oil sands developments will represent a small percentage of the total drainage area of the Athabasca River in the RSA. Table F4-18 presents the existing, incremental and cumulative maximum closed-circuit areas and maximum reductions in surface water yield to receiving streams. The probable staggering of mining schedules was not considered for this analysis to provide a conservative estimate of the cumulative effects.

The maximum drainage area reduction caused by combined developments of the oil sands developments will be 403 km^2. This represents about 0.3% of the Athabasca River drainage area below the confluence with the Muskeg River. This maximum closed-ciruit area would result in a maximum reduction of about 0.86 m^3/s in mean annual discharge of the Athabasca River. This represents about 0.1% reduction of the mean river discharge and about 0.8% of the 7Q10 low flow. These levels of reduction are considered to be Negligible.

Table F4-18 Maximum Mine Closed-Circuit Areas and Reduction in Surface Water Yield

Effects	Oil Sands Development	Ultimate Closed-Circuit Area (km^2)	Maximum Reduction in Average Water Yield (m^3/s)
Existing Effects[a]	Mildred Lake	161	0.31
	Lease 86/17	32	0.10
	Aurora North Mine	70	0.14
	Aurora South Mine	69	0.13
	Steepbank Mine	34	0.11
	SOLV-EX	4	0.01
	Sub-Total	**370**	**0.80**
Incremental Effects[2]	Muskeg River Mine	33	0.06
Cumulative Effects	**All Projects**	**403**	**0.86**

(a) Source of data: Aurora Mine EIA (BOVAR 1996a) and Suncor Steepbank Mine Application (Suncor 1996a).
(b) Mean annual water yield based on 61 mm for natural lowland areas and 101 mm for natural upland areas.

Changes in Surface Water Yield After Mine Closure

Reclaimed mine sites permanently change the basin water yield characteristics relative to natural conditions. Table F4-19 presents the estimated annual water yield from each of the reclaimed mine sites and the changes from the natural conditions. This table shows that the combined change to the mean annual water yield is about -4%. This level of reduction is considered to be small.

Table F4-19 Estimated Mean Annual Water Yield from Reclaimed Mine Sites

Effects	Oil Sands Project	Reclaimed Area (km^2)	Water Yield (m^3/s)	Change from Natural Conditions (%)
Existing Effects	Mildred Lake [a]	161	0.30	-2
	Lease 86/17 [a]	32	0.13	+24
	Aurora North Mine[a]	70	0.08	-42
	Aurora South Mine[a]	69	0.08	-42
	Steepbank Mine[a]	34	0.11	0
	SOLV-EX[a]	4	0.01	0
	Sub-Total	**370**	**0.71**	**-15**
Incremental Effects[b]	Muskeg River Mine[b]	33	0.10	+40
Cumulative Effects	**All Projects**	**403**	**0.81**	**-4**

(a) Source of data: Aurora Mine EIA (BOVAR 1996a) and Suncor Steepbank Mine Application (Suncor 1996a).
(b) Based on results from Section E4.

Analysis of Combined Effects on the Athabasca River Flows During Construction and Operation of Oil Sands Developments

The maximum mine water release will be about 0.8 m^3/s during construction and operation of the oil sands developments. This represents about 0.1% of the mean annual discharge of the Athabasca River and about 0.7% of the annual 7Q10 low flow. These levels of increase are Negligible.

The maximum reduction in the Athabasca River flows caused by the total basin water allocation (total withdrawal minus total return flow) is estimated to be 7.4 m^3/s. The maximum reduction in surface runoff inflow to the Athabasca River caused by the combined closed-circuit areas of the oil sands developments is estimated to be about 0.9 m^3/s. The maximum combined reduction caused by the net water allocation and closed-circuit areas is conservatively estimated to be about 8.3 m^3/s without considering the progressive reclamation of the mine sites and mine water release during construction and operation.

It is important to note that the maximum allowable (licensed) river withdrawals are not representative of normal conditions. For example, average withdrawals by the Muskeg River Mine Project through its 20-year mine life would be only 47% of the licensed withdrawal, which is based on the water demand during years one and two when the water demands are the greatest. Both Syncrude and Suncor have similar variations in water withdrawal requirements throughout their mining operations, with the exception of requirements for filling end pit lakes. At the end of mining, it is expected that withdrawals will be made during the high flow season from June to September to fill the end pit lakes at the Syncrude and Suncor Mines. Since these withdrawals will be made during the high flow season, they will not affect the low flows.

Therefore, the mean water withdrawal through the mine life is a more reasonable basis for assessing cumulative effects on the Athabasca River flows. The peak water demands by the various oil sands developments are unlikely to coincide because the developments are staggered in time and thus the peak demand during the initital years of operation are unlikely to coincide.

If a typical ratio (0.5) of average river withdrawal to licensed river withdrawal for the oil sands operations is assumed, then the typical net river withdrawals of combined existing, approved and proposed oil sands projects (1.3 m^3/s) and non-oil-sands operations (3.1 m^3/s) would be about 4.4 m^3/s. The typical reduction caused by the net water allocation and closed-circuit areas would be about 5.3 m^3/s. This represents about 0.8% of the mean annual flow in Athabasca River and about 5% of the annual 7Q10 low flow. The level of reduction in flows is considered to be Negligible based on the mean flow conditions, and the cumulative effects on the 7Q10 low flow are considered to be Low.

After Closure of the Oil Sands Developments

After reclamation and closure of all the regional oil sands developments, the mean total annual surface runoff discharge from the reclaimed surfaces will be reduced by about 0.03 m^3/s relative to natural conditions. This level of reduction will have Negligible effects on the Athabasca River flows, although the seasonal distribution of these inflows will be different from the natural conditions. This seasonal change will have Negligible effects on the seasonal flows of the Athabasca River, because the total reclaimed surface area will represent 0.3% of the total drainage area of the Athabasca River below the confluence with the Muskeg River.

Classification and Degree of Concern of the Cumulative Effects

The cumulative effects of the combined developments on the Athabasca River flows in the RSA are classified and rated as shown in Table F4-20, based on the results of the above detailed analysis.

Combined developments in the Athabasca River basin will have Negligible effects on the average river flow conditions during the life of the oil sands developments. The degree of concern of the cumulative effects of the oil sands developments on the Athabascar River flows is rated as Negligible throughout the life of the developments.

Table F4-20 Classification and Degree of Concern of the Cumulative Effects on the Athabasca River Flows

Parameter	During Construction and Operation of the Oil Sands Developments	After Closure of the Oil Sands Developments
Direction	Negative	Neutral
Magnitude	Negligible	Negligible
Geographic Extent	Regional	Regional
Duration	Medium-Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Negligible***	

F4.4.3 Key Question SWCEA-3: Will Combined Developments Result in Effects to the Open-Water Areas Including Lakes and Streams?

Analysis of the Cumulative Effects

Some of the regional developments, particularly the oil sands developments, require permanent removal of natural open-water areas including lakes, ponds and streams. These types of open-water areas will be lost because of site clearing, infrastructure development, mine pit development, storage of muskeg and overburden materials, and development of the tailings settling ponds. The reduction of open-water areas will be the greatest near the end of mining when the closed-circuit operations will reach a maximum.

However, reclamation of the oil sands developments will create new drainage systems consisting of drainage channels, wetlands and lakes. This will result in an increase in the open-water areas on the oil sands development areas.

Effects of the Existing and Approved Oil Sands Developments

The maximum losses of the open-water areas caused by the existing and approved oil sands developments are listed in Table F4-21. The lost areas are compared with the existing total open-water area of lakes and streams in the RSA, which is about 27,700 ha estimated based on the satellite imagery produced by Radarsat International in 1996 and the provincial NTS maps.

Table F4-22 shows that the maximum loss of the open-water areas during construction and operation of the existing and approved oil sands developments represents about 1.5% of the total open-water area in the RSA. After reclamation, large areas of channels, lakes and wetlands will be developed as part of the closure landscape. These newly created open-water areas represent about 18% of the existing open-water areas in the RSA. This represents a 16.5% increase from the baseline conditions.

Table F4-21 Losses and Gains of Open-Water Areas Caused by the Existing and Approved Oil Sands Projects

Development	During Construction and Operation		After Mine Closure	
	Maximum Loss of Open-Water Areas (ha)[a]	Percent of Total Open-Water Area in the RSA	New Open-Water Area (ha)[b]	Percent of Total Open-Water Area in the RSA
Mildred Lake	-30	-0.11%	+1,760	+6.4%
Lease 86/17	0	0%	+248	+0.9%
Steepbank Mine	-231	-0.83%	+231	+0.8%
SOLV-EX	0	0%	+31	+0.1%
Aurora North Mine	-52	-0.18%	+1,383	+5.0%
Aurora South Mine	-124	-0.45%	+1341	+4.8%
Total	**-437**	**-1.58%**	**+4,994**	**+18.0%**

(a) Based on data from the Aurora EIA report (BOVAR 1996a), Syncrude (1997) and Suncor Steepbank Mine Application (Suncor 1996a).

(b) Based on data from the Aurora EIA report (BOVAR 1996a) and Suncor Steepbank Mine Application (Suncor 1996a).

Table F4-22 shows that the maximum loss of the open-water areas during construction and operation of the existing and approved oil sands developments represents about 1.5% of the total open-water area in the RSA. After reclamation, large areas of channels, lakes and wetlands will be developed as part of the closure landscape. These newly created open-water areas represent about 18% of the existing open-water areas in the RSA. This represents a 16.5% increase from the baseline conditions.

Table F4-22 Effects of the CEA Developments on the Open-Water Areas in the RSA

During Construction and Operation		After Mine Closure	
Maximum Loss of Open-Water Area (ha)	Percent of Total Open-Water Area in the RSA	New Open-Water Area (ha)	Percent of Total Open-Water Area in the RSA
-464	- 1.7%	+ 5,664	+20%

Incremental Effects of the Muskeg River Mine Project

The maximum loss of open-water areas during construction and operation of the Muskeg River Mine Project will be 27 ha, as discussed in Section E4. This represents about 0.1% of the existing open-water areas in the RSA. This is considered to be negligible. After reclamation, 670 ha of new channels, lakes and wetlands will be added to the closure landscape. This will result in a 2% increase to the existing open-water areas in the RSA.

Effects of the Oil Sands Projects Developments

Table F4-22 summarizes the cumulative changes in the open-water areas in the RSA. The total loss of natural open-water areas in the RSA will be about 464 ha, which is about 1.7% of the existing open-water areas in the RSA. This level of reduction is considered to be small. After reclamation and closure of all the oil sands developments in the far future, the newly created open-water areas will total about 5,664 ha, which is about 20% of the existing open-water areas in the RSA. The net increase of the total open-water areas will be about 19%. This level of increase is considered to be relatively High.

Table F4-22 Effects of the CEA Developments on the Open-Water Areas in the RSA

During Construction and Operation		After Mine Closure	
Maximum Loss of Open-Water Area (ha)	Percent of Total Open-Water Area in the RSA	New Open-Water Area (ha)	Percent of Total Open-Water Area in the RSA
-464	- 1.7%	+ 5,664	+20%

Classification and Degree of Concern of the Cumulative Effects

The effects of the oil sands developments on the changes of the open-water areas including lakes and streams in the RSA are classified and rated in Table F4-23 based on the results of the above detailed analysis.

Table F4-23 Classification and Degree of Concern of the Effects on the Changes of the Open-Water Areas in the RSA

Parameter	Construction and Operation	Closure
Direction	Negative	Neutral to Positive
Magnitude	Low	High
Geographic Extent	Regional	Regional
Duration	Medium-Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Low***	

The oil sands developments will permanently remove the natural open-water areas on the developement areas. The degree of concern of the effects during mining construction and operation is rated Low in the RSA. However, reclamation of the oil sands mine sites will replace existing open-water areas lost to mine development and increase the total open-water areas in the RSA relative to the existing conditions. The degree of concern of the effects after mine closure is rated as Negligible.

F4.5 Summary of Impacts

The assessment results of the cumulative effects on the surface water hydrology are summarized in Table F4-24.

Table F4-24 Summary of CEA on Surface Water Hydrology for the Existing, Approved and Muskeg River Mine Developments

Key Question	CEA Results
SWCEA-1: Will combined developments in the Muskeg River basin result in effects on the Muskeg River flows, sediment concentrations and channel regime?	• During construction and operation phases of the oil sands developments, the combined developments will cause small to large increases (4% to 23%) in the Muskeg River flows, primarily as a result of muskeg drainage, overburden dewatering, and transfer of the MFT to the end pit lake during reclamation of the Muskeg River Mine Project. The degree of concern of the cumulative effects is rated **Moderate**. • In far future, the average river flows in Muskeg River will increase slightly because the reclaimed surfaces will have different runoff characteristics from the natural basins. The degree of the cumulative effects concern is rated **Low**.

Key Question	CEA Results
	• During construction and operation phases of the oil sands developments, the increased Muskeg River flows will cause an increase in the streamflow sediment concentration by 0.2 to 1.2 mg/L and will cause a negligible increase in the channel erosion rate. The degree of concern of the cumulative effects is rated **Negligible**. • In the far future, the small increase in the Muskeg River flows will cause negligible changes in the river streamflow sediment concentration and channel regime. The degree of concern of the cumulative effects is rated **Negligible**.
SWCEA-2: Will combined developments result in effects on Athabasca River flows?	• During construction and operation phases of the oil sands developments, the regional developments will cause negligible changes to the mean flow conditions on Athabasca River. The degree of concern of the cumulative effects is rated **Negligible**. • After closure of all the oil sands developments, the regional developments will cause negligible changes to the mean flow conditions on Athabasca River.
SWCEA-3: Will combined developments result in effects to the open-water areas including lakes and streams?	• During construction and operation phases of the oil sands developments, the developments will permanently remove 464 ha of the natural open-water areas at the development areas. • After closure of all the oil sands developments, closure drainage systems at the reclaimed development areas will create 5,664 ha of new open-water areas which will replace the open-water areas lost to development.

F5 SURFACE WATER QUALITY CUMULATIVE EFFECTS ASSESSMENT

F5.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on surface water quality in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, were included in this CEA:

- Suncor Lease 86/17
- Suncor Steepbank
- Syncrude Aurora North
- Muskeg River Mine Project
- upstream pulp mills
- Syncrude Mildred Lake
- SOLV-EX
- Syncrude Aurora South
- upstream municipalities

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

The water quality predictions presented in this section are used to assess impacts on aquatic resources (Section F6), wildlife (Section F11) and human health (Section F12).

F5.2 Approach and Methods

The approach used to assess potential cumulative impacts on surface water quality is consistent with that described in the Surface Water Quality Impact Assessment, as described in Section E5.

The methods used to address the key questions for this CEA were generally the same as those described in Section E5. The water quality and temperature models were expanded to include the additional developments considered in the CEA and new snapshots were selected for the analysis (see below). Additional details of the models (i.e., those not addressed in Appendix V of Section E5, in Volume 3 of the Muskeg River Mine Project EIA) are provided in Appendix XII. Model input data (flow rates and water chemistry) for additional developments included in the CEA were obtained from the Aurora and Steepbank EIAs (BOVAR 1996a, Golder 1996f).

F5.2.1 Activities and Water Releases That May Affect Surface Water Quality

Activities and water releases associated with the Project and existing oil sands developments that may affect surface water quality were discussed in Section E5. Those activities and water releases were also considered to apply to the additional oil sands developments included in this CEA (i.e., Syncrude Aurora North and South, and Suncor Steepbank mines). Specific water quality and flow data for approved developments were obtained from recent EIAs (BOVAR 1996a, Golder 1996f).

F5.2.2 Assumptions Specific to the CEA

During assessment of the combined effects of the Project and the Aurora Mines in the Muskeg River basin, certain mitigative measures were discussed with Syncrude Canada Ltd. These measures would minimize the impact of reclamation waters in the Muskeg River basin.

Syncrude agreed that controls to minimize seepage flows to the Muskeg River at closure are feasible and that Syncrude will implement such controls as appropriate, consistent with their commitments in the Aurora EIA (BOVAR 1996a). Syncrude noted that there are several ways to mitigate impacts during low-flow periods, if that proves necessary. Examples include maintaining and enhancing the perimeter ditch around the reclaimed tailings settling pond with wetlands and leaving a cut-off key in place at closure.

Effective mitigative controls were assumed during the water quality modelling for all developments included in the CEA.

F5.2.3 Time Snapshots Modelled

Selection of the worst-case time snapshots for water quality modelling was based on the magnitude of combined water discharge rates in the Muskeg River basin from oil sands developments included in the CEA.

This approach was considered conservative, since the highest concentration of developments in the RSA will occur in the Muskeg River basin, where the lowest dilution capacity in surface waters would also occur. Discharges to the Athabasca River from upstream sources are expected to be highly diluted before they reach the confluence of the mouth of the Muskeg River. This, coupled with the large dilution capacity of the Athabasca River, suggests that the potential for impairment of water quality is considerably greater in the Muskeg River than in the Athabasca River.

The following snapshots were selected for this CEA:

- Year 2007, representing the highest rate of operational discharges from developments in the Muskeg River basin;
- Year 2030, representing the highest rate of reclamation discharges from the Project; and

- Far Future, representing the steady-state reclaimed condition for all oil sands developments in the RSA.

F5.3 Potential Linkages and Key Questions

Figure E5-1 (Section E5) shows the linkage diagram for Project activities and potential changes in water quality associated with the Project. Generally, the same key questions and linkages apply to the CEA, with exceptions discussed below.

The key questions related to accidental releases (WQ-7) and end pit lake (EPL) water quality (WQ-6) are not considered to be relevant for this CEA for the following reasons:

- It is considered highly improbable that accidental releases would occur simultaneously from more than one of the developments considered in the CEA. In addition, it is anticipated that all oil sands operations will develop state-of-the-art design features and spill response plans to minimize impacts. Therefore, accidental releases do not need to be considered on a cumulative basis.

- Evaluation of the EPL key question in Section E5 demonstrated that EPL water associated with the Project is expected to be non-toxic and that engineered solutions exist that would ensure this result was obtained. It was assumed that the same condition could be achieved in all EPLs in the region; hence, it is unnecessary to consider this question on a cumulative basis. However, as before, discharges from all EPLs were considered during the CEA under key question WQCEA-1, in terms of combined effects on water quality of the Muskeg and Athabasca rivers.

The key questions for the Surface Water Quality CEA include the following:

WQCEA-1: Will Operational and Reclamation Water Releases From Combined Developments Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers?

WQCEA-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?

WQCEA-3: Will Operational and Reclamation Water Releases From Combined Developments Alter the Temperature Regime of the Muskeg River?

WQCEA-4: Will Muskeg and Overburden Dewatering Activities From Combined Developments Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?

WQCEA-5: Will PAHs in Operational and Reclamation Water Releases From Combined Developments Accumulate in Sediments and Be Transported Downstream?

WQCEA-6: Will Acidifying Emissions From Combined Developments Result in Changes in Water Quality?

F5.4 Analysis and Results

F5.4.1 Key Question WQCEA-1: Will Operational and Reclamation Water Releases From Combined Developments Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers?

Analysis of Potential Linkages

Linkage Between Operational and Reclamation Water Releases and Exceedances of Water Quality Guidelines in the Athabasca and Muskeg Rivers

As discussed in Section E5, operational and reclamation waters have the potential to cause exceedances of water quality guidelines (Table V-3, Appendix V, Volume 3) in receiving waters. Therefore, this linkage is valid.

Analysis of Key Question

The results of water quality modelling are presented in Appendix XII for each snapshot and flow condition in the Athabasca and Muskeg rivers for all modelled substances. The summary tables below provide results only for substances that were predicted to exceed water quality guidelines and, thus, show the highest concentrations predicted for all snapshot years simulated. In addition, an indication of the spatial extent of the guideline exceedance is provided in the summary tables for the Athabasca River. The results are subsequently discussed under "Significance of Water Quality Guideline Exceedances."

Summary tables for the Athabasca River provide the following information for substances that were predicted to exceed guidelines:

- the existing concentration upstream of Fort McMurray, as measured during baseline studies or monitoring;

- the effects of existing and approved developments, as modelled substance concentrations at the 10% mixing zone boundary of Muskeg River water in the Athabasca River; and

- the effects of existing and approved developments plus the incremental increase caused by the Project, as modelled substance concentrations at the 10% mixing zone boundary of Muskeg River water in the Athabasca River.

Summary tables for the Muskeg River provide the following information for substances that were predicted to exceed guidelines:

- the existing substance concentration upstream of Node 16 in the Muskeg River, as measured during baseline studies;

- the effects of approved developments, as modelled substance concentrations at Node 16; and

- the effects of approved developments plus the incremental increase caused by the Project, as modelled substance concentrations at Node 16.

Mean Open-Water Flow in Athabasca River

Model results indicate that during mean open-water flow, compliance with most water quality guidelines is achieved during all time snapshots (Tables XII-6 and XII-8). Table F5-1 shows the concentrations of substances that are predicted to exceed water quality guidelines. Dispersion model contour plots of arsenic and benzo(a)anthracene concentrations are presented for snapshots with the greatest spatial extent of guideline exceedances (2007 and Far Future, respectively) in Figures XII-14 and XII-15.

Annual 7Q10 Flow in Athabasca River

Tables XII-5 and XII-7 provide predictions of substance concentrations at annual 7Q10 flow in the Athabasca River. Table F5-2 shows concentrations of substances that exceed guidelines at annual 7Q10 flow in the Athabasca River. Dispersion model contour plot of iron concentrations is presented for year 2007 in Figure XII-13.

Table F5-1 Maximum Predicted Substance Concentrations Compared With Water Quality Guidelines at Mean Open-Water Flow in the Athabasca River

Substance	Existing[a]	CEA		Guideline[d]	Comment on CEA
		Approved[b]	Project [c]		
aluminum (mg/L)	0.68	0.68	0.68	0.1 C	guideline exceedances for all snapshots due to existing river conditions
arsenic (mg/L)	0.001	0.002	0.002	0.01 C 0.000018 HC	guideline exceedances for all snapshots due to existing river conditions, but concentrations increase below Muskeg River (maximum spatial extent of exceedance: 40 km long reach downstream of Muskeg River; 15% of river width)
benzo(a)anthracene (mg/L)	0	0.0000046	0.000005	0.0000028 HC	guideline exceedances in 2030 and Far Future due to sand and CT seepage (maximum spatial extent of exceedance: 75 km long reach downstream of Muskeg River; 18% of river width)
iron (mg/L)	3.0	3.0	3.0	0.3 C 0.3 HNC	guideline exceedances for all snapshots due to existing river conditions
manganese (mg/L)	0.4	0.4	0.4	0.05 C 0.05 HNC	guideline exceedances for all snapshots due to existing river conditions
mercury (mg/L)	0.0001	0.0001	0.0001	0.000012 C 0.00014 HNC	guideline exceedances for all snapshots due to existing river conditions

(a) Existing concentration upstream of Fort McMurray, from Golder (1997d).
(b) Existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(c) Muskeg River Mine Project plus existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(d) A = Acute, C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Table F5-2 Maximum Predicted Substance Concentrations Compared With Water Quality Guidelines at Annual 7Q10 Flow in the Athabasca River

Substance	Existing[a]	CEA		Guideline[d]	Comment on CEA
		Approved[b]	Project [c]		
iron (mg/L)	0.17	0.43	0.44	0.3 C	guideline exceedance in 2007 due to releases of muskeg and overburden waters (maximum spatial extent of exceedance: 65 km long reach downstream of Muskeg River; 15% of river width)
manganese (mg/L)	0.1	0.1	0.1	0.05 C	guideline exceedances for all snapshots due to existing river conditions
mercury (mg/L)	0.0001	0.0001	0.0001	0.000012 C	guideline exceedances for all snapshots due to existing river conditions

(a) Existing concentration upstream of Fort McMurray, from Golder (1997d).
(b) Existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(c) Muskeg River Mine Project plus existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(d) A = Acute, C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Mean Open-water Flow in Muskeg River

Tables XII-2 and XII-4 provide predictions of substance concentrations at mean open-water flow in the Muskeg River. Table F5-3 includes the concentrations of substances that were predicted to exceed water quality guidelines.

Table F5-3 Maximum Predicted Substance Concentrations Compared With Water Quality Guidelines at Mean Open-Water Flow in the Muskeg River

Substance	Existing[a]	CEA		Guideline[d]	Comment on CEA
		Approved[b]	Project[c]		
aluminum (mg/L)	0.05	0.12	0.25	0.1 C	guideline exceedance in 2007 as a result of dewatering; guideline exceedances in 2030 and Far Future due to EPL discharge and sand and CT seepage, respectively. Most of the aluminum associated with particulate material and not bioavailable, reflecting existing river conditions
arsenic (mg/L)	0.003	0.005	0.005	0.01 C 0.000018 HC	guideline exceedances for all snapshots due to existing river conditions
benzo(a)anthra-cene (mg/L)	0	0.000036	0.000037	0.0000028 HC	guideline exceedance in 2030 and Far Future due to EPL discharge and sand and CT seepage, respectively
benzo(a)pyrene (mg/L)	0	0.0000044	0.0000044	0.0000028 HC	guideline exceedance in 2030 and Far Future due to EPL discharge and sand and CT seepage, respectively
iron (mg/L)	0.8	1.6	1.6	0.3 C 0.3 HNC	guideline exceedances for all snapshots as a result of existing river conditions; highest concentration in 2007 due to muskeg and overburden dewatering
manganese (mg/L)	0.04	0.15	0.15	0.05 C 0.05 HNC	guideline exceedances for all snapshots; highest concentration in 2007 due to muskeg and overburden dewatering
mercury (mg/L)	0.0001	0.000095	0.000095	0.000012 C 0.000014 HNC	guideline exceedances for all snapshots due to existing river conditions

(a) Existing concentration, from Golder (1997d).
(b) Approved developments (Aurora North, Aurora South).
(c) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South).
(d) A = Acute, C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Annual 7Q10 Flow in Muskeg River

Tables XII-1 and XII-3 provide predictions of substance concentrations at annual 7Q10 flow in the Muskeg River. Table F5-4 summarizes exceedances of water quality guidelines.

Table F5-4 Maximum Predicted Substance Concentrations Compared With Water Quality Guidelines at Annual 7Q10 Flow in the Muskeg River

Substance	Existing[a]	CEA		Guideline[d]	Comment on CEA
		Approved[b]	Project [c]		
aluminum (mg/L)	0.04 (<0.01 - 0.42)	1.1	1.1	0.1 C	guideline exceedances for all snapshots; most of the aluminum is associated with particulate material and not bioavailable, reflecting existing river conditions
arsenic (mg/L)	0.0029 (<0.0004 - 0.001)	0.019	0.019	0.01 C	guideline exceedance in 2007, due to muskeg and overburden dewatering
boron (mg/L)	0.06	1.96	1.95	0.5 C	guideline exceedance during Far Future, due to sand and CT seepage; slight decrease in concentration with increasing development due to increased river drainage area
cadmium (mg/L)	0.0006 (<0.002-0.003)	0.004	0.004	0.0018	guideline exceedance during Far Future, due to sand and CT seepage
chromium (mg/L)	0.0052 (<0.0004-0.006)	0.022	0.022	0.011C 0.016 A	guideline exceedance during 2007 and 2030, due to muskeg and overburden dewatering and EPL water discharge, respectively; guideline is for chromium VI, while predictions are for total chromium
copper (mg/L)	0.002 (<0.001-0.004)	0.010	0.010	0.007	guideline exceedances for all snapshots; highest concentration in 2007, due to muskeg and overburden dewatering
iron (mg/L)	2.42 (1.9 - 2.9)	5.9	6.0	0.3 C	guideline exceedances for all snapshots; highest concentration in 2007, due to muskeg and overburden dewatering
manganese (mg/L)	0.55 (0.43 - 0.66)	0.8	0.8	0.05 C	guideline exceedances for all snapshots
mercury (mg/L)	0.0001 (<0.0001 - 0.0005)	0.000018	0.00017	0.000012 C	guideline exceedance in Far Future, as a result of existing river conditions; slight decrease in concentration with increasing development due to increase in available dilution water
zinc (mg/L)	0.0215 (0.001-0.21)	0.20	0.20	C 0.19 A	guideline exceedance in 2007 and 2030, due to muskeg and overburden dewatering and EPL water discharge, respectively

(a) Existing concentration, from Golder (1997d).
(b) Approved developments (Aurora North, Aurora South).
(c) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South).
(d) A = Acute, C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Significance of Water Quality Guideline Exceedances

The following substances were predicted to exceed water quality guidelines in the Athabasca and Muskeg rivers:

- aluminum
- arsenic

- benzo(a)anthracene group
- benzo(a)pyrene group
- boron
- cadmium
- chromium
- copper
- iron
- manganese
- mercury
- zinc

There are several lines of evidence that suggest that these exceedances, where they are predicted to occur, are of limited consequence to the environmental quality of waters. These are briefly outlined below.

Of the substances identified above, aluminum, arsenic, iron, manganese and mercury frequently exceed water quality guidelines under natural, background conditions in the RSA; cadmium occasionally exceeds the chronic guideline in Muskeg River tributaries and copper occasionally exceeds the chronic and acute guidelines in the Athabasca River (Section D5; Environmental Setting - Surface Water Quality). Moreover, predicted concentrations of these metals from combined developments generally fall into the natural ranges in watercourses in the RSA, as summarized in Section D5. Naturally elevated levels of metals are usually not considered to be of concern in surface waters.

Frequently, a large fraction of total metals is associated with suspended sediments and is thus not in a bioavailable form. The dissolved fraction may be considered an approximation of the bioavailable portion of total metals. The proportion of total metals composed of the dissolved form was calculated for a number of metals using recent data collected in the Athabasca River and the Muskeg River basin (Section D5.5, "Relationship Between Total and Dissolved Metal Levels in Surface Waters"). These calculations showed that only 7 to 14% of aluminum and variable (low to moderate) percentages of arsenic, copper, iron, manganese and zinc were in the dissolved form (Table D5-11). The majority of boron was in the dissolved form and no conclusions could be drawn for cadmium, chromium and mercury due to low sample sizes. Dissolved fractions were typically lower in the Athabasca River, which usually carries a greater suspended sediment load.

The guideline exceedance by chromium is unlikely to be of significance, because the guideline exceeded is for the hexavalent form and total chromium concentration was modelled. Typically, the concentration of hexavalent chromium is a small fraction of total chromium.

Overall, the available metals data suggest that for the majority of metals that were predicted to exceed water quality guidelines, the bioavailable fraction will likely be considerably lower than suggested by predicted total metal concentrations.

The predicted concentrations of substances that tend to be bound to particulates are conservative, since no reduction in these metals was assumed during modelling, even though most of the particulates would settle in sedimentation ponds, EPLs and wetlands, or would be trapped as seepage waters travel through the ground. As well, modelling was carried out using conservative, worst-case assumptions regarding concentrations of substances in release waters and flows of release waters. Therefore, actual concentrations will likely be lower than those predicted, with the exception of periods of extreme low flow.

Benzo(a)anthracene and benzo(a)pyrene groups were predicted to exceed the human health water quality guidelines. However, it is anticipated that these PAHs would also be tightly bound to particulates and would settle out in EPLs, or be trapped by soil particles as seepages move through the ground (this aspect is discussed further under Key Question WQCEA-5). The predicted guideline exceedances by benzo(a)anthracene and benzo(a)pyrene groups were brought forward for further screening under the human health section (Section F12). The analysis in Section F12 indicates that the risks posed by these compounds to human health are very low during the periods modelled.

Based on the above information, it is concluded that exceedances of water quality guidelines due to water releases from the combined developments included in the CEA have limited potential to affect the environmental quality of receiving waters, despite the water quality guideline exceedances predicted by modelling.

Residual Impact Classification and Degree of Concern

The predicted impacts of combined operational and reclamation water releases, as defined by their contribution to exceedances of water quality guidelines, are classified in Table F5-5.

Table F5-5 Residual Impact Classification and Degree of Concern for Water Quality Guideline Exceedances

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Exceedances of guidelines at mean open-water flow in the Athabasca River	Negative	Low	Local	Medium-Term	Reversible	Medium	Low
Exceedances of guidelines at annual 7Q10 flow in the Athabasca River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Exceedances of guidelines at mean open-water flow in the Muskeg River	Negative	Low	Local	Medium-Term	Reversible	Medium	Low
Exceedances of guidelines at annual 7Q10 flow in the Muskeg River	Negative	Low	Local	Medium-Term	Reversible	Medium	Low

F5.4.2 Key Question WQCEA-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?

Analysis of Potential Linkages

Linkage Between Operational Water Releases and Exceedances of Toxicity Guidelines

As discussed in Section E5, operational waters do not have the potential to cause toxicity in receiving waters. Therefore, this linkage is invalid.

Linkage Between Reclamation Water Releases and Exceedances of Toxicity Guidelines

As discussed in Section E5, reclamation waters have the potential to cause exceedances of toxicity guidelines (Table V-3, Appendix V, Volume 3) in receiving waters. Therefore, this linkage is valid.

Analysis of Key Question

Athabasca River

Model results indicate that during mean open-water and annual 7Q10 flows, compliance with Whole Effluent Toxicity (WET) guidelines will be achieved. The values shown in Table F5-6 represent the highest numbers predicted for acute and chronic toxicity for all snapshot years simulated.

Dispersion model contour plots of TU values are presented in Figures XII-7 to XII-12.

Table F5-6 Maximum Predicted TU Values in the Athabasca River

Substance	Existing[a]	CEA		Guideline[d]	Comment on CEA
		Approved[b]	Project [c]		
Annual 7Q10 Flow					
acute toxicity (TUa)	0	0.01	0.01	0.3 A	Acute toxicity guideline not exceeded
chronic toxicity (TUc)	0	0.02	0.02	1.0 C	Chronic toxicity guideline not exceeded
Mean Open Water Flow					
acute toxicity (TUa)	0	0.002	0.002	0.3 A	Acute toxicity guideline not exceeded
chronic toxicity (TUc)	0	0.006	0.006	1.0 C	Chronic toxicity guideline not exceeded

(a) River assumed to be non-toxic upstream of oil sands operations.
(b) Existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(c) Muskeg River Mine Project plus existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(d) A = Acute, C = Chronic.

Muskeg River

Model results indicate that during mean open-water and annual 7Q10 flows, compliance with WET guidelines will be achieved. The values shown in Table F5-7 represent the highest TU values predicted for all snapshot years simulated.

Table F5-7 Maximum Predicted TU Values in the Muskeg River

Substance	Existing[a]	CEA		Guideline[d]	Comment on CEA
		Approved[b]	Project [c]		
Annual 7Q10 Flow					
acute toxicity (TUa)	0	0.28	0.27	0.3 A	Acute toxicity guideline not exceeded
chronic toxicity (TUc)	0	0.74	0.73	1.0 C	Chronic toxicity guideline not exceeded
Mean Open Water Flow					
acute toxicity (TUa)	0	0.02	0.02	0.3 A	Acute toxicity guideline not exceeded
chronic toxicity (TUc)	0	0.04	0.04	1.0 C	Chronic toxicity guideline not exceeded

(a) River assumed to be non-toxic upstream of oil sands operations.
(b) Approved developments (Aurora North, Aurora South).
(c) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South).
(d) A = Acute, C = Chronic.

Residual Impact Classification and Degree of Concern

The predicted impacts of operational and reclamation water releases on toxicity in receiving waters are classified in Table F5-8.

Table F5-8 Residual Impact Classification and Degree of Concern for WET Guideline Exceedances

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Exceedances of WET guidelines at mean open-water flow in the Athabasca River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Exceedances of WET guidelines at annual 7Q10 flow in the Athabasca River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Exceedances of WET guidelines at mean open-water flow in the Muskeg River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Exceedances of WET guidelines at annual 7Q10 flow in the Muskeg River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible

F5.4.3 Key Question WQCEA-3: Will Operational and Reclamation Water Releases From Combined Developments Alter the Temperature Regime of the Muskeg River?

Analysis of Key Question

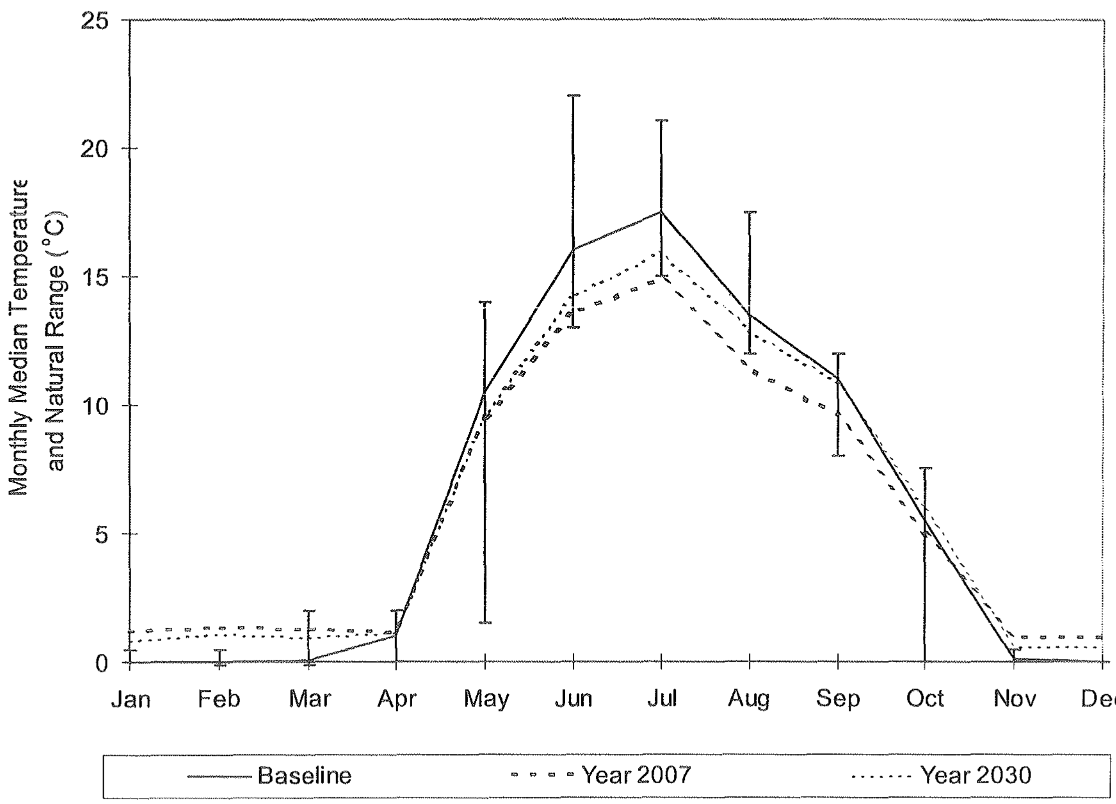
Results of temperature modelling suggest that water releases included in this CEA have the potential to alter the temperature regime of the Muskeg River.

In 2007, river water temperature was predicted to increase slightly (by about 1°C) in the winter and decrease by a maximum of 2.6°C during the open-water season (Figure F5-1). The primary cause of these predicted changes is muskeg dewatering. The maximum predicted temperature change of 2.6°C is below the currently available temperature guideline of <3°C change. Hence, the predicted changes in river water temperature in 2007 are classified as negligible.

Less pronounced changes were predicted in river water temperature in 2030 (Figure F5-1). This year represents a relatively short period, during which mature fine tails (MFT) will be added to the Project end pit lake (EPL) during the open-water season. The maximum predicted temperature change of 1.8°C in 2030 is also below the temperature guideline. Hence, the predicted temperature changes in 2030 are also classified as negligible.

The Far Future scenario was not modelled during this analysis. During this period, water balance in the RSA was predicted to be close to natural (Section F4 - Surface Water Hydrology CEA), indicating the lack of potential effects on stream temperatures. Therefore, any changes in water temperature in the Far Future are also classified as negligible.

Figure F5-1 Predicted Monthly Median Water Temperatures in the Muskeg River at Node S16 Compared With the Baseline Temperature Regime of the Lower Muskeg River



In addition to the predicted absolute temperature changes described above, water releases from oil sand developments may also cause slower seasonal warming and cooling of river water. The available data are insufficient to conduct a detailed analysis of this aspect. Although the expected changes in rates of warming and cooling are minor based on Figure F5-1, they may be mitigated by longer retention of muskeg and overburden drainage waters prior to discharge and adjusting discharge rates from EPLs during critical periods. Because of the uncertainty regarding the predicted rates of seasonal warming and cooling, the magnitude of this impact is classified as low.

Daily (diurnal) temperature variation of river water may also be affected downstream of EPLs. Since the temperature of EPL water would fluctuate less within a day than river water temperature, a general reduction in the amplitude of daily temperature fluctuation may be expected downstream of EPLs. The available baseline data are insufficient to assess the magnitude of this potential effect. However, based on the expected lengths of the EPL discharge channels (typically >1 km), some diurnal fluctuation may develop, which may offset any potential effects. Therefore, the magnitude of this impact is expected to be low.

Residual Impact Classification and Degree of Concern

The predicted impacts of mine activities on the temperature regime of the Muskeg River were classified as shown in Table F5-9.

Table F5-9 Residual Impact Classification and Degree of Concern for Change in Thermal Regime of the Muskeg River

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Cooling in open-water season	Neutral	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Slower seasonal warming and cooling	Neutral	Low	Regional	Medium-Term	Reversible	Medium	Low
Reduced diurnal fluctuation	Neutral	Low	Regional	Medium-Term	Reversible	High	Low

Certainty

Factors regarding certainty discussed in Section E5.7 (key question WQ-3) are also applicable to this assessment.

F5.4.4 Key Question WQCEA-4: Will Muskeg and Overburden Dewatering Activities From Combined Developments Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?

Analysis of Key Question

As discussed in Section E5, the limited oxygen depleting capacity of muskeg waters, anticipated design features and availability of simple mitigation options suggest that lowering of winter dissolved oxygen levels in the Muskeg River will be unlikely during the period with the highest release rates of operational waters.

Residual Impact Classification and Degree of Concern

The predicted impact of dewatering activities on dissolved oxygen levels of the Muskeg River are classified as shown in Table F5-10. It is not expected that dewatering activities will result in an unacceptable lowering of dissolved oxygen levels in the Muskeg River.

Table F5-10 Residual Impact Classification and Degree of Concern for Change in Dissolved Oxygen Concentrations

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Lowered dissolved oxygen levels	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible

Certainty

Although recent muskeg drainage data were used in this analysis, questions remain regarding the representativeness of the data.

F5.4.5 Key Question WQCEA-5: Will PAHs in Operational and Reclamation Water Releases From Combined Developments Accumulate in Sediments and Be Transported Downstream?

Analysis of Potential Linkages

Linkage Between PAHs in Operational and Reclamation Waters and PAH Accumulation and Transport in Sediments

The validity of the linkage between operational and reclamation waters and PAH levels in sediments is uncertain due to lack of relevant data. Therefore, the linkage is classified as uncertain.

Analysis of Key Question

There is no additional information to that presented in Section E5 to address this key question. However, the arguments presented in Section E5 also apply to the CEA.

Based on the weight of evidence provided in Section E5, it is unlikely that PAHs released from combined oil sands developments will result in substantial accumulation in sediments of surface waters.

Residual Impact Classification and Degree of Concern

The predicted impacts of PAH releases resulting from the combined developments on sediment levels are classified in Table F5-11.

Table F5-11 Residual Impact Classification and Degree of Concern for PAH Accumulation in Sediments

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
PAH accumulation in sediments	Negative	Negligible to Low	Regional	Medium-Term	Reversible	High	Negligible to Low

Certainty

The information suggests that it is unlikely that PAHs would be released by oil sands operations at levels that would cause biological effects. However, our understanding of this issue is limited, which highlights the necessity of further, cooperative studies, sponsored by all oil sands developments in the RSA, to address this issue.

F5.4.6 Key Question WQCEA-6: Will Acidifying Emissions From Combined Developments Result in Changes in Water Quality?

Analysis of Potential Linkages

Linkage Between Acidifying Emissions and Changes in Water Quality

Modelled values for annual potential acid input (PAI) from combined developments exceed the interim Critical Load of 0.25 keq/ha/a in an approximately 60 x 30 km area corresponding to the combined footprint of all developments included in the CEA (Section F2 - Air Quality CEA). Based on this predicted exceedance, this linkage is valid.

Analysis of Key Question

Based on its water chemistry and its large dilution capacity, the Athabasca River is not sensitive to acidification. Schindler (1996) designated the Firebag, Steepbank and Muskeg rivers as acid-sensitive and reported moderate pH depressions in the Firebag and Steepbank rivers during the spring snowmelt period in 1989 and 1990. There are no known acid-sensitive lakes within the area where air quality modelling predicted an exceedance of the interim Critical Load, though a number of acid-sensitive lakes were identified by Saffran and Trew (1996) just east of this area. In addition, there are numerous ponds and small streams within the area of exceedance for which water chemistry data are not available. The sensitivity of ponds to acidification cannot be assessed with certainty, but available data suggest that small streams may be similar to the Muskeg River in terms of acid-sensitivity.

The available information is insufficient to definitively evaluate the potential for acidification of sensitive waterbodies within the RSA. As noted above, there is a large number of potentially sensitive waterbodies in this area, including the Steepbank and Muskeg rivers, small streams and ponds. Based on seasonal water chemistry of the Muskeg and Steepbank rivers, Kearl Lake and small tributaries of the Athabasca and Muskeg rivers (Golder 1996b and Section D5 - Environmental Setting - Surface Water Quality), year-round acidification of surface waters is highly unlikely in the RSA, even considering the exceedance of the Critical Load predicted from the combined emissions from oil sands developments included in the CEA. Since spring pH depression has been observed in some of these waterbodies under baseline conditions, its continued occurrence and a potential increase in its severity cannot be ruled out.

Residual Impact Classification and Degree of Concern

The predicted impacts of acidifying emissions on surface waters are classified as shown in Table F5-12.

Table F5-12 Residual Impact Classification and Degree of Concern for Changes in Surface Water Quality Caused by Acidifying Emissions

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Year-round acidification of surface waters	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Spring pH depression in sensitive waterbodies	Negative	Low	Regional	Medium-Term	Reversible	Medium	Low

Certainty

The limited available data do not allow definitive conclusions regarding acidification of surface waters, suggesting that this issue should be examined further. Because it is a regional issue, the required studies should be sponsored by all oil sands developments in the RSA.

F5.5 Summary of Impact Predictions

The residual impacts predicted by this CEA are generally similar to those predicted in the Impact Assessment (Section E5). Exceptions include key questions WQCEA-1 (water quality guideline exceedances), WQCEA-3 (change in temperature regime of the Muskeg River) and WQCEA-6 (acidification). As expected, predicted impacts are more severe in the CEA than in the Impact Assessment. Residual impacts are summarized in Table F5-13 and differences in the severity of predicted impacts between the Impact Assessment and the CEA are described.

Predicted impacts on the temperature regime of the Muskeg River, sediment PAH levels and acid-sensitive waterbodies are subject to considerable uncertainty. To provide more precise predictions for these impacts, it would be necessary to conduct more detailed analyses on the regional scale, which are outside of the scope of this assessment.

Table F5-13 Summary of Surface Water Quality CEA

Key Question	CEA Results
WQCEA-1: Will Operational and Reclamation Water Releases From Combined Developments Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers?	• The combined developments considered in the CEA will cause exceedances of water quality guidelines for a number of metals, in addition to natural exceedances by certain metals. Exceedances of human health water quality guidelines were predicted to occur for two PAH compounds during initial high EPL discharges and in the Far Future. Follow-up risk analysis in Section F11 and Section F12 did not identify these compounds as a concern to wildlife and human health. The direction of impact is Negative, the magnitude Negligible to Low, the geographic extent is Local, the duration Medium-Term, Reversible, of Medium frequency and the overall degree of concern for water quality guideline exceedances is rated **Low**. • In the CEA, there are two additional guideline exceedances in the Athabasca River (benzo(a)anthracene at mean open-water flow and iron at 7Q10 flow), but no additional increases were predicted in levels of substances that exceeded guidelines in the Impact Assessment. In the Muskeg River, levels of nearly all substances that exceeded guidelines in the Impact Assessment increased at both modelled flows (by up to two-fold in most cases) and six new substances were predicted to exceed guidelines at 7Q10 flow, in addition to those identified in the Impact Assessment.
WQCEA-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?	• No exceedances of toxicity guidelines were predicted. The degree of concern for toxicity guideline exceedances is **Negligible**.
WQCEA-3: Will Operational and Reclamation Water Releases From Combined Developments Alter the Temperature Regime of the Muskeg River?	• Temperature fluctuations in the Muskeg River, as a result of changing flow regimes, would remain within acceptable ranges. However, uncertainties remain regarding potential effects on seasonal warming and cooling of river water and changes in diurnal temperature fluctuation. The degree of concern for cooling of river water in the open-water season is rated **Negligible**; the degree of concern for effects on rates of seasonal warming and cooling is rated **Low**; and the degree of concern for effects on diurnal temperature fluctuation is **Low**. • Greater temperature declines were predicted during the open-water season in the CEA than in the Impact Assessment and the potential for slower seasonal warming and cooling is greater than predicted in the Impact Assessment.
WQCEA-4: Will Muskeg and Overburden Dewatering Activities From Combined Developments Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?	• Dissolved oxygen impacts from muskeg drainage waters are not anticipated to occur. Therefore, the degree of concern for reduction of dissolved oxygen concentrations is **Negligible**.

Key Question	CEA Results
WQCEA-5: Will PAHs in Operational and Reclamation Water Releases From Combined Developments Accumulate in Sediments and Be Transported Downstream?	• PAH accumulation in sediments is not anticipated to occur due to limited available pathways, though uncertainties remain regarding release rates of PAHs from oil sands developments. The degree of concern for PAH accumulation in sediments is rated **Negligible to Low**. • Although severe impacts on sediment PAH levels are unlikely, this issue remains a potential concern related to oil sands developments. Due to the qualitative nature of the analysis, it is not possible to estimate differences in sediment PAH levels between the Impact Assessment and the CEA.
WQCEA-6: Will Acidifying Emissions From Combined Developments Result in Changes in Water Quality?	• Acidification of waterbodies due to air emissions cannot be evaluated with certainty at this time due to limited data on sensitivity of surface waters in the RSA to acidification. Although year-round acidification of surface waters in the RSA is highly unlikely, available data suggest that spring pH depression in sensitive waterbodies is a potential impact that should be examined further. The degree of concern for year-round acidification is **Negligible**; and the degree of concern for spring pH depression is **Low**. • The predicted size of the area affected by deposition of acidifying substances is considerably larger in the CEA than in the Impact Assessment.

F6 AQUATIC RESOURCES CUMULATIVE EFFECTS ASSESSMENT

F6.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on aquatic resources in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- Muskeg River Mine Project
- upstream municipalities
- Syncrude Mildred Lake
- SOLV-EX
- Syncrude Aurora North and South
- upstream pulp mills

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

The aquatic resources predictions presented in this section were also used to assess impacts on human health (Section F12 - fish tissue chemical concentrations) and resource use (Section F14 - fish abundance).

F6.2 Approach and Methods

The approach used to assess potential cumulative impacts on aquatic resources was consistent with that described for the aquatic resources impact assessment, as described in Section E6.5.

Time Snapshots

The time snapshots used for the aquatic resources CEA are based on potential worst-case conditions that vary depending on the key question that is being examined (Table F6-1).

For examining changes in fish habitat in the Muskeg and Athabasca rivers, time snapshots are based on the highest potential for changes in flows (See Section F4). For direct loss of fish habitat, maximum losses for each development are calculated and no specific time snapshot was used. Habitat restored or enhanced during reclamation is presented for Far Future.

For effects on fish (acute or chronic effects, tissue quality), the snapshots are the same as those used for Surface Water Quality: 2007, 2030 and Far Future (Section F5). The Muskeg River developments were the driver for selecting worse-case snapshots for the surface water quality and aquatic resources CEAs because of the high concentration of developments in the

Muskeg River basin, and hence, the highest potential for effects on water quality. The year 2007 was based on the highest combined operational discharges associated with the Project and other developments in the Muskeg River basin. The highest reclamation discharges from developments in the Muskeg River basin were predicted for 2030. Far future represents the steady state reclaimed conditions for all oil sands developments in the RSA.

Table F6-1 Summary of Time Snapshots for Aquatic Resources CEA

Time Snapshot	Rationale
2007	• largest increases in flows in Muskeg River as a result of dewatering (effects on habitat) • highest potential for temperature, channel regime, dissolved oxygen changes in Muskeg River (effects on habitat) • highest withdrawals from Athabasca River (effects on habitat)
2020	• most closed circuit operations in place (i.e., most potential for decrease in flows; effects on habitat)
2030	• highest potential for water quality changes (effects on fish) • provides continuity with impact assessment
Far Future	• to examine residual effects after reclamation • provides continuity with impact assessment • seepages from combined developments are highest

F6.3 Potential Linkages and Key Questions

Figures E6-1 and E6-2 show the linkage diagrams for potential changes in aquatic resources for the Project. Generally, the same linkages and key questions that were posed in the impact assessment section apply to the CEA for Aquatic Resources, with one exception.

The key question that relates to the viability of an aquatic ecosystem in the Project's end pit lake does not apply to the CEA since it is site specific. However, water quality of the end pit lake and its potential effect on fish in the Muskeg and Athabasca rivers is addressed through water quality modelling. As well, fish habitat gains from end pit lakes from the Project and other developments were included in the habitat assessment.

The key questions for the aquatic resources CEA include:

ARCEA-1: Will Activities From Combined Developments Change Fish Habitat?

ARCEA-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Acute or Chronic Effects on Fish?

ARCEA-3: Will Operational and Reclamation Water Releases From Combined Developments Result in Changes to Fish Tissue Quality?

ARCEA-4: Will Operational and Reclamation Water Releases From Combined Developments Result in Changes in Fish Abundance?

F6.4 Analysis and Results

F6.4.1 Key Question ARCEA-1: Will Activities From Combined Developments Change Fish Habitat?

Analysis of Potential Linkages

As discussed in Section E5, the following linkages are valid:

- changes in areas of lakes and streams and fish habitat; and
- changes in thermal regime and fish habitat.

As discussed in Section E6, the following linkages are invalid:

- change in dissolved oxygen level and fish habitat;
- change in sediment loading and fish habitat and benthic invertebrates;
- channel regime and fish habitat;
- changes in flows and fish habitat; and
- changes in water quality and benthic invertebrate.

Linkage Between Changes in Flows and Levels of Receiving Streams and Fish Habitat

Changes in flows in the Muskeg and Athabasca rivers were assessed in Section F4.2 and F4.3, respectively (Surface Water Hydrology). Potential linkages between changes in flows and levels and fish habitat are assessed separately for each waterbody.

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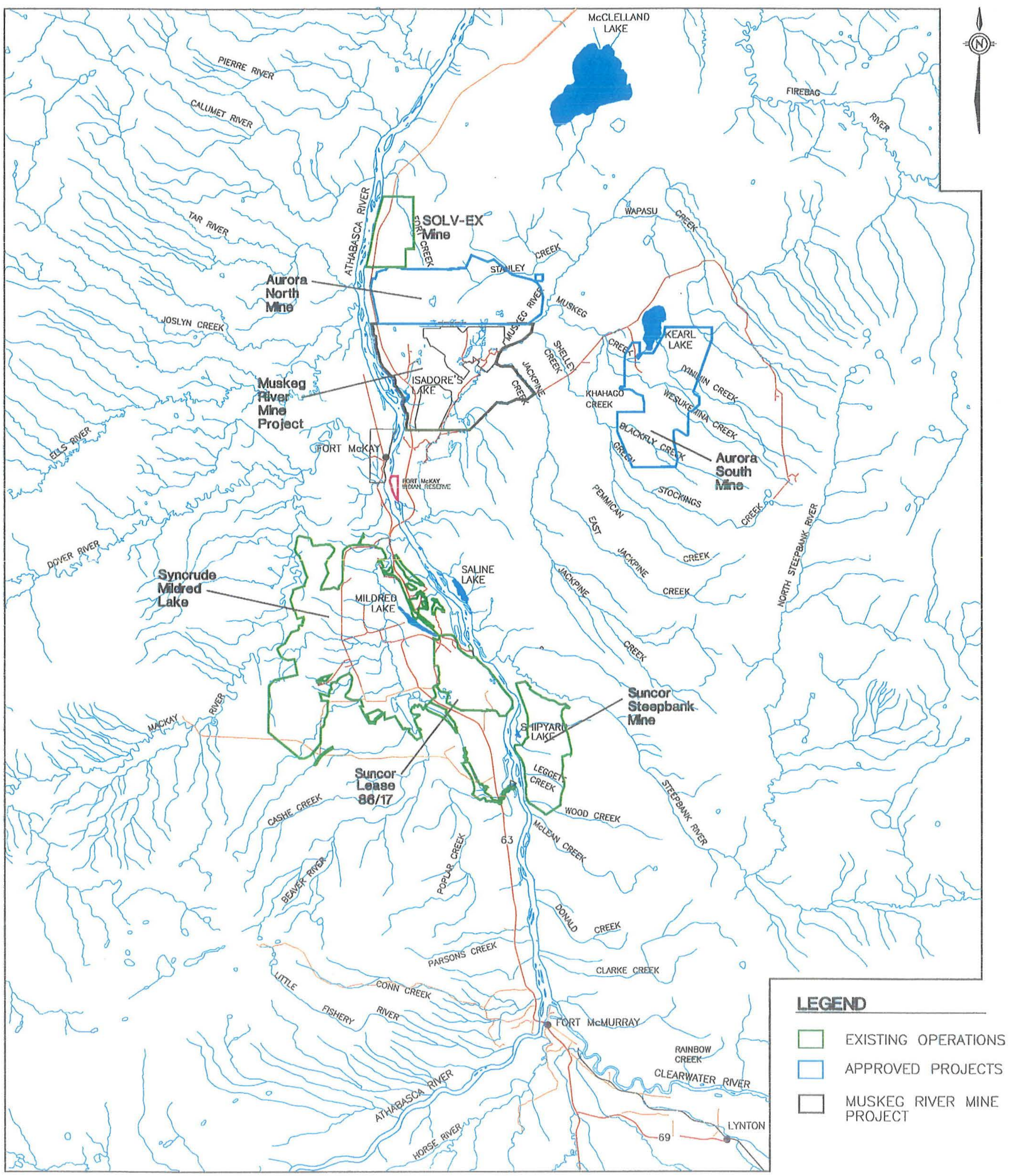

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

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EXISTING AND APPROVED DEVELOPMENTS IN RSA

15 JAN 98	Figure F6-1	DRAWN BY: CG

Athabasca River

Changes in flows in the Athabasca River were assessed in Section F4.3 (Key Question SWCEA-1). Water withdrawals from the Project and from all combined developments are shown in Table F4-14. Since measurable changes in Athabasca River flows were predicted, this linkage is valid for fish habitat.

Muskeg River

As discussed in Section E6, a linkage exists between changes in flows in the Muskeg River and fish habitat. Changes in flows, depths and velocity in the Muskeg River were quantified in the Surface Water Hydrology CEA (Key Question SWCEA-1; Section E4.2) and summarized in Tables F6-2 to F6-6 for various flow conditions.

Table F6-2 Mean Open Water Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)			D (m)			V (m/s)		
	Existing	Future[(a)]	Difference (%)	Existing	Future[(a)]	Difference (%)	Existing	Future[(a)]	Difference (%)
2007	8.21	9.74	18.6	0.63	0.70	12.2	0.73	0.77	5.6
2020	8.21	8.28	0.9	0.63	0.63	0.6	0.73	0.73	0.3
2030	8.21	9.78	19.1	0.63	0.71	12.6	0.73	0.77	5.7
Far Future	8.21	8.11	-1.2	0.63	0.62	-0.8	0.73	0.73	-0.4

[(a)] Predicted as a result of the Aurora North and South and Muskeg River Mine Projects in the Muskeg River Basin.

Table F6-3 Mean Ice-Cover Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)			D (m)			V (m/s)		
	Existing	Future[(a)]	Difference (%)	Existing	Future[(a)]	Difference (%)	Existing	Future[(a)]	Difference (%)
2007	1.11	2.12	91.0	0.23	0.29	25.5	0.39	0.48	22.9
2020	1.11	1.28	15.3	0.23	0.24	4.3	0.39	0.41	4.6
2030	1.11	1.62	45.9	0.23	0.26	12.9	0.39	0.44	12.8
Far Future	1.11	1.47	32.4	0.23	0.26	9.1	0.39	0.42	9.3

[(a)] Predicted as a result of the Aurora North and South and Muskeg River Mine Projects in the Muskeg River Basin.

Table F6-4 Open-Water 7Q10 Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)			D (m)			V (m/s)		
	Existing	Future[(a)]	Difference (%)	Existing	Future[(a)]	Difference (%)	Existing	Future[(a)]	Difference (%)
2007	0.281	2.058	632	0.18	0.29	57.4	0.25	0.47	88.4
2020	0.281	0.793	182	0.18	0.22	16.8	0.25	0.35	39.1
2030	0.281	2.29	715	0.18	0.30	64.8	0.25	0.49	95
Far Future	0.281	0.697	148	0.18	0.21	13.6	0.25	0.33	33.5

[(a)] Predicted as a result of the Aurora North and South and Muskeg River Mine Projects in the Muskeg River Basin.

Table F6-5 Mean 30Q Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)			D (m)			V (m/s)		
	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)
2007	0.225	1.263	461	0.18	0.24	34.5	0.23	0.40	73.1
2020	0.225	0.496	120	0.18	0.20	9.1	0.23	0.30	28.6
2030	0.225	0.802	256	0.18	0.22	19.2	0.23	0.35	49.8
Far Future	0.225	0.835	271	0.18	0.22	20.3	0.23	0.35	51.8

[a] Predicted as a result of the Aurora North and South and Muskeg River Mine Projects in the Muskeg River Basin.

Table F6-6 Annual 7Q10 Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)			D (m)			V (m/s)		
	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)	Existing	Future[a]	Difference (%)
2007	0.052	1.094	2004	0.17	0.23	36.8	0.15	0.39	164
2020	0.052	0.281	440	0.17	0.18	8.2	0.15	0.25	71.0
2030	0.052	0.619	1090	0.17	0.20	20.1	0.15	0.32	120
Far Future	0.052	0.483	829	0.17	0.20	15.3	0.15	0.30	103

[a] Predicted as a result of the Aurora North and South and Muskeg River Mine Projects in the Muskeg River Basin.

Analysis of Key Question

The following linkages are assessed in terms of their potential effects on fish habitat:

- flows and fish habitat in the Athabasca and Muskeg rivers; and
- thermal regime and fish habitat in the Muskeg River.

Athabasca River

Flows

Concerns have been raised about the potential for water withdrawals from the Athabasca River to affect fish habitat. These concerns mainly relate to fish habitat availability in the winter when flows are low and withdrawals could reduce the quality or quantity of fish habitat. The extent of fish over-wintering in the Athabasca River is not known. Investigations are currently underway as part of the oil sands Regional Aquatics Monitoring Program (RAMP) to determine whether two of the KIRs, walleye and lake whitefish, over-winter in the Athabasca River within the oil sands area.

The tools available for determining instream flow needs for fish are not generally applicable to a large river such as the Athabasca River. There are three approaches used in Alberta to determine instream flow needs for fish. The first, called the Tessman Modification of the Tennant method, is typically used to scope potential conflicts between instream flow needs for protection of the aquatic ecosystem and water demands for other uses (Tessman 1980). It is a simple, office technique that is based on hydrologic records. The second approach uses some indicator of river hydraulics to estimate instream flow needs (e.g., the effects of river stage on wetted perimeter). The third approach typically uses detailed hydraulic models and fish habitat preference information to determine the relationship between flow and habitat availability for fish.

Unfortunately, none of the methods has been refined for use in large northern rivers, particularly for the harsh winter months. The Tessman method, the only method for which data are currently available, typically indicates zero allowable withdrawal for winter months whenever the flows drop below the mean monthly flow. In fact, the results of the Tessman analysis indicate that the mean monthly flow should not be decreased in the Athabasca River from December through March (Table F6-7). A more sophisticated analysis could be conducted to better define minimum instream flows; however, this would be a substantial task which should be considered regionally.

Table F6-7 Results of the Tessman Scoping Analysis for Instream Flow Needs

Month	Mean Monthly Flow	Recommended Minimum Monthly Flow
January	179	179
February	163	163
March	171	171
April	513	258
May	1,057	423
June	1,328	531
July	1,412	565
August	991	396
September	766	306
October	570	258
November	332	258
December	204	204

The maximum percentage withdrawal from combined developments is 6.4% of 7Q10 flows (Table F4-14). However, under more usual conditions in the winter (mean winter flow) the cumulative withdrawals are about 4.3%. This decrease in Athabasca River flows is unlikely to cause an impact on fish habitat due to the large flow of the river.

In summary, during the winter months, water withdrawals at low flow are relatively small. This is unlikely to cause impacts on fish habitat. During the remainder of the year, the Tessman analysis indicates there is abundant water in the Athabasca River to meet both instream flow needs and the mean annual net withdrawal of water from the river by combined developments.

Muskeg River

Changes in the Muskeg River habitat from combined developments include increased flow and a decline in summer temperature. The largest change in temperature relative to baseline was predicted to occur in 2007, when rates of overburden and muskeg dewatering will be the highest. During this period, a decrease of up to 2.6°C in mean monthly summer temperatures and an increase of about 1°C in mean monthly winter temperatures were predicted to occur (Figure F5-2). In 2030, mid-summer declines are predicted to be about 1.8°C and winter temperatures may increase by up to 1°C. No changes in Muskeg River water temperature are expected in the Far Future.

These physical changes to the Muskeg River are analyzed relative to habitat requirements and suitability for each KIR using the same approach as for the impact assessment.

Northern Pike

Temperature

Figure F6-2, which compares existing versus predicted water temperatures in the Muskeg River indicates a drop in habitat suitability for northern pike from 0.9 to 0.7 Hence, if temperature of the Muskeg River were to decrease by 2.6°C, habitat would be less suitable for northern pike.

Flows

Predicted changes in flows in the Muskeg River for the CEA would have the same effects on northern pike habitat as described in E6.

Summary of Changes in Northern Pike Habitat

Changes in water temperature may have a low impact on habitat suitability for northern pike. Higher flows during low flow periods may improve access and habitat availability for northern pike.

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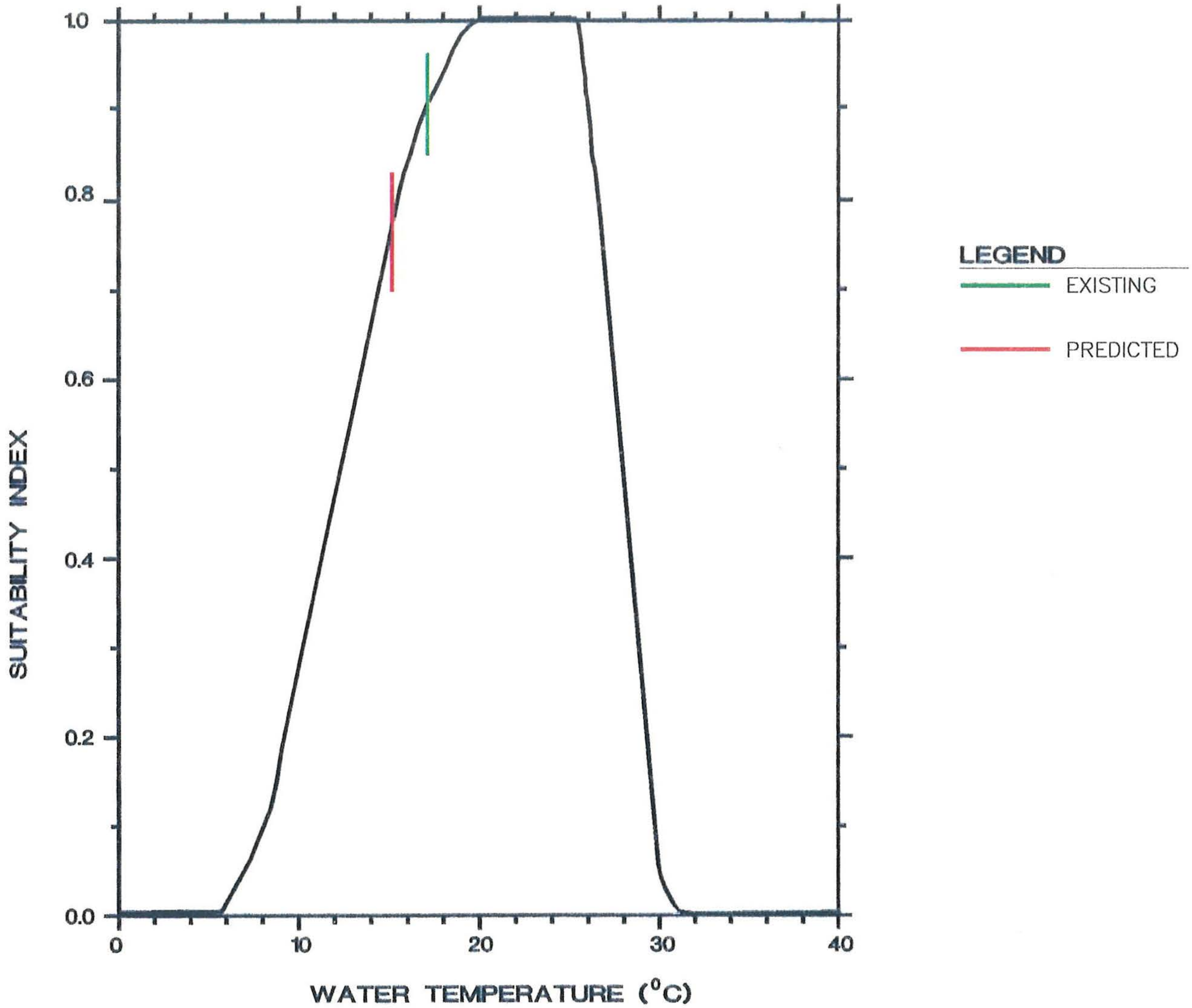

HABITAT SUITABILITY INDEX MODEL FOR NORTHERN PIKE (INSKIP 1982)
NOTE: HSI MODEL REPRESENTS MAXIMAL WEEKLY AVERAGE TEMPERATURE OF THE SURFACE LAYER.

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EXISTING AND PREDICTED WATER TEMPERATURE IN THE MUSKEG RIVER COMPARED WITH HSI INDEX FOR NORTHERN PIKE

16 JAN 1998	Figure F6–2	DRAWN BY: TM/DC

Arctic Grayling

Temperature

Figure F6-3 shows that Arctic grayling habitat suitability would not be affected if temperatures in the Muskeg River were to decline by up to 2.6°C.

Flows

Average velocity in spawning areas, percent downstream spawning habitat, annual frequency of spring spawning access to tributary streams and occurrence of winter habitat are variables that are related to flow.

There are negligible changes in depths of the river during mean open-water conditions (Table F6-2). Therefore, effects on availability of spawning habitat (i.e., the proportion of riffles) in the Muskeg River would not be expected.

Velocities predicted during 2007 (the time snapshot with the largest change) were compared with the HSI for velocity in spawning areas during spawning and embryo development (Figure F6-4). During mean open-water conditions a slight decline in habitat suitability would be expected. During low flow conditions (open-water 7Q10, 30Q10) habitat suitability does not change and both existing and predicted velocities are within the most suitable range (HSI = 1) for Arctic grayling.

Summary of Changes in Arctic Grayling Habitat

In summary, changes in temperature would not likely have implications for Arctic grayling habitat. Flow changes may cause a slight decline in suitability during mean open-water flow conditions.

Longnose Sucker

Temperature

Declines in water temperature during the summer would improve habitat suitability for longnose sucker (Figure F6-5).

Flows

Figure F6-6 indicates that predicted velocities for mean open-water flow conditions are suitable for longnose sucker spawning (HSI = 1). During low flow conditions (open water 7Q10, 30Q10) habitat suitability for longnose sucker would be improved.

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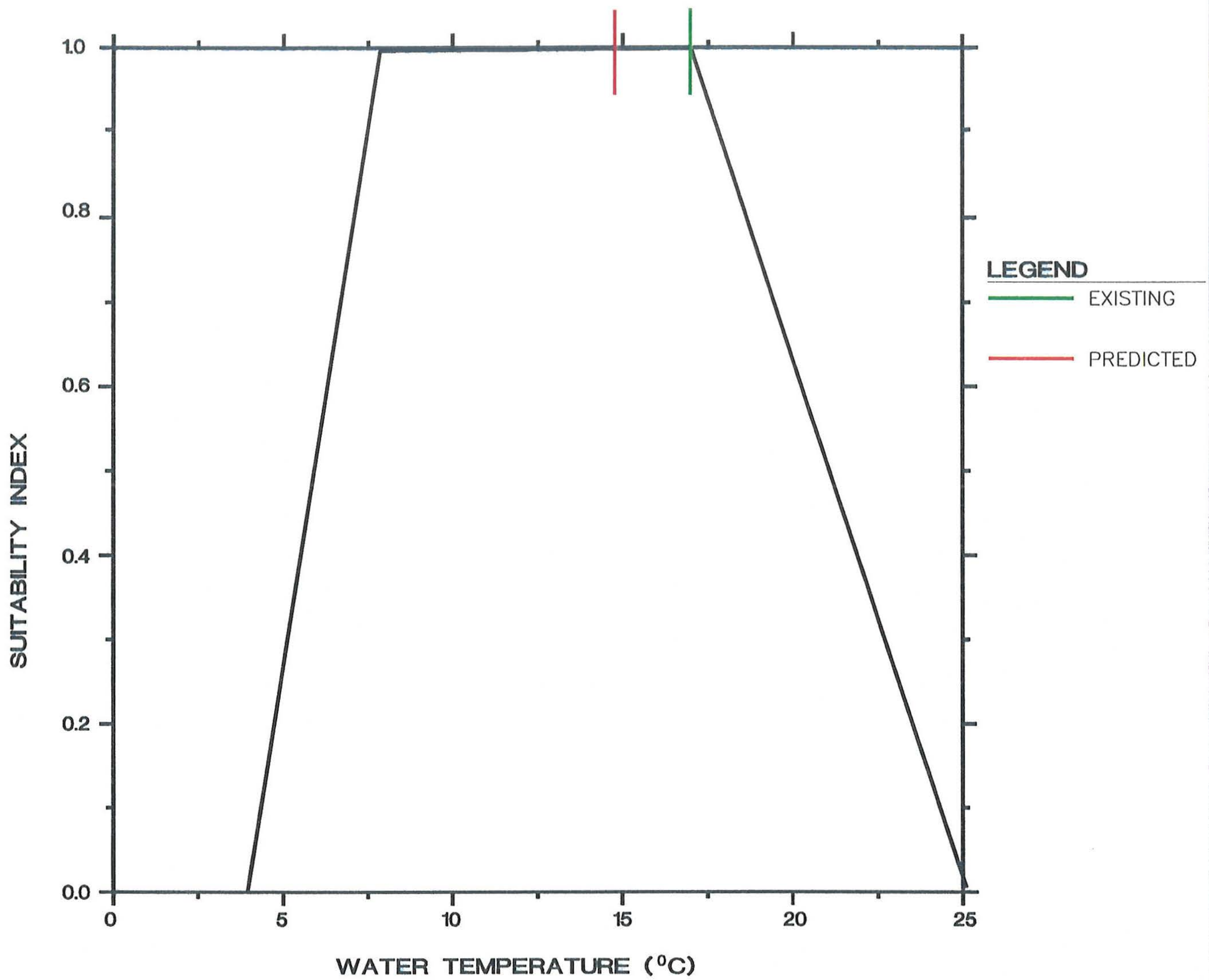

HABITAT SUITABILITY INDEX MODEL FOR ARCTIC GRAYLING (HUBERT ET AL. 1985)
NOTE; HSI MODEL REPRESENTS AVERAGE MAXIMUM WATER TEMPERATURE DURING THE WARMEST PERIOD OF THE YEAR IN SPAWNING STREAMS.

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EXISTING AND PREDICTED WATER TEMPERATURE IN THE MUSKEG RIVER COMPARED WITH HSI INDEX FOR ARCTIC GRAYLING		
09 JAN 1998	Figure F6-3	DRAWN BY: TM/DC

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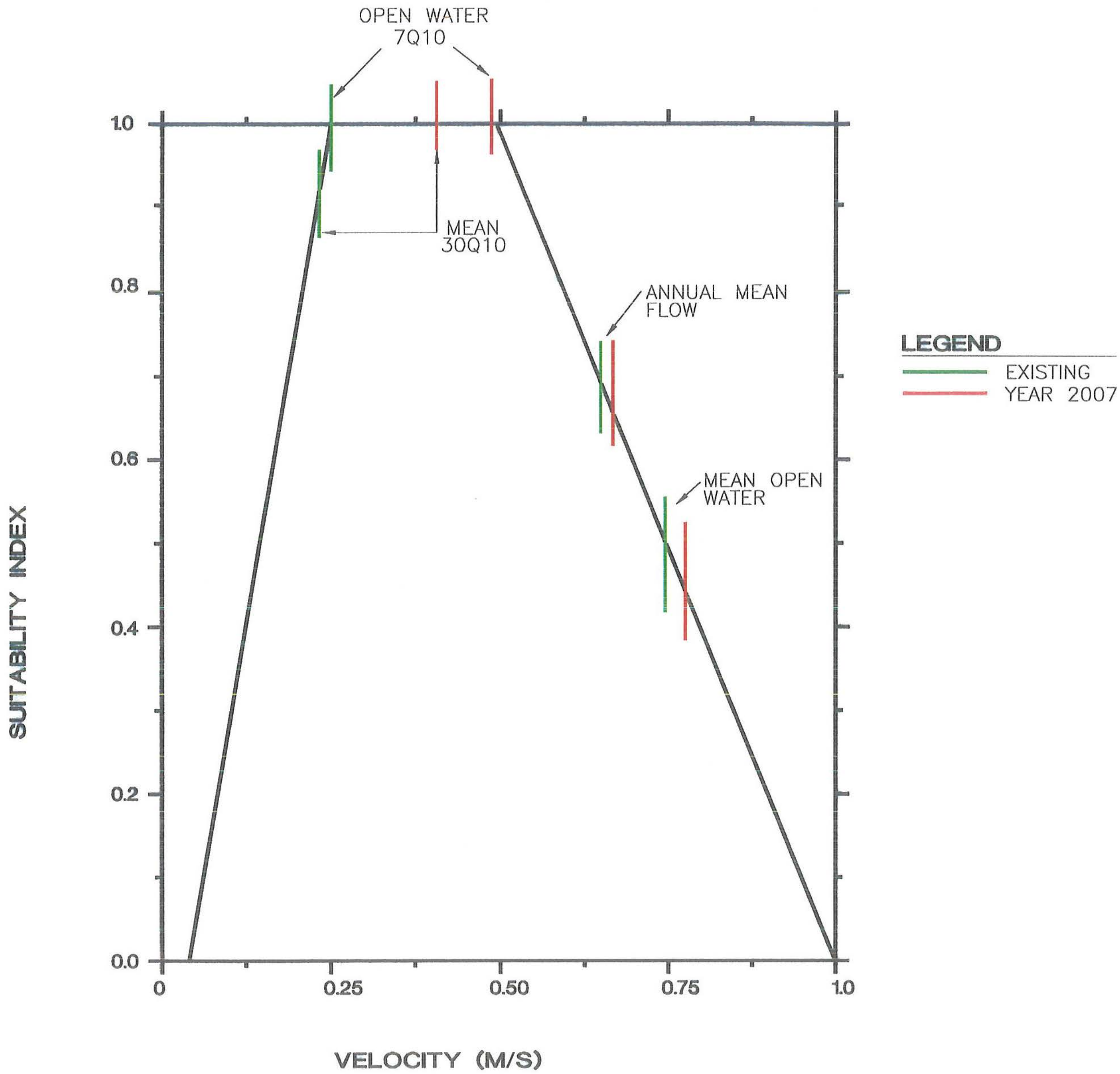

HABITAT SUITABILITY INDEX MODEL FOR ARCTIC GRAYLING (HUBERT ET AL. 1985)

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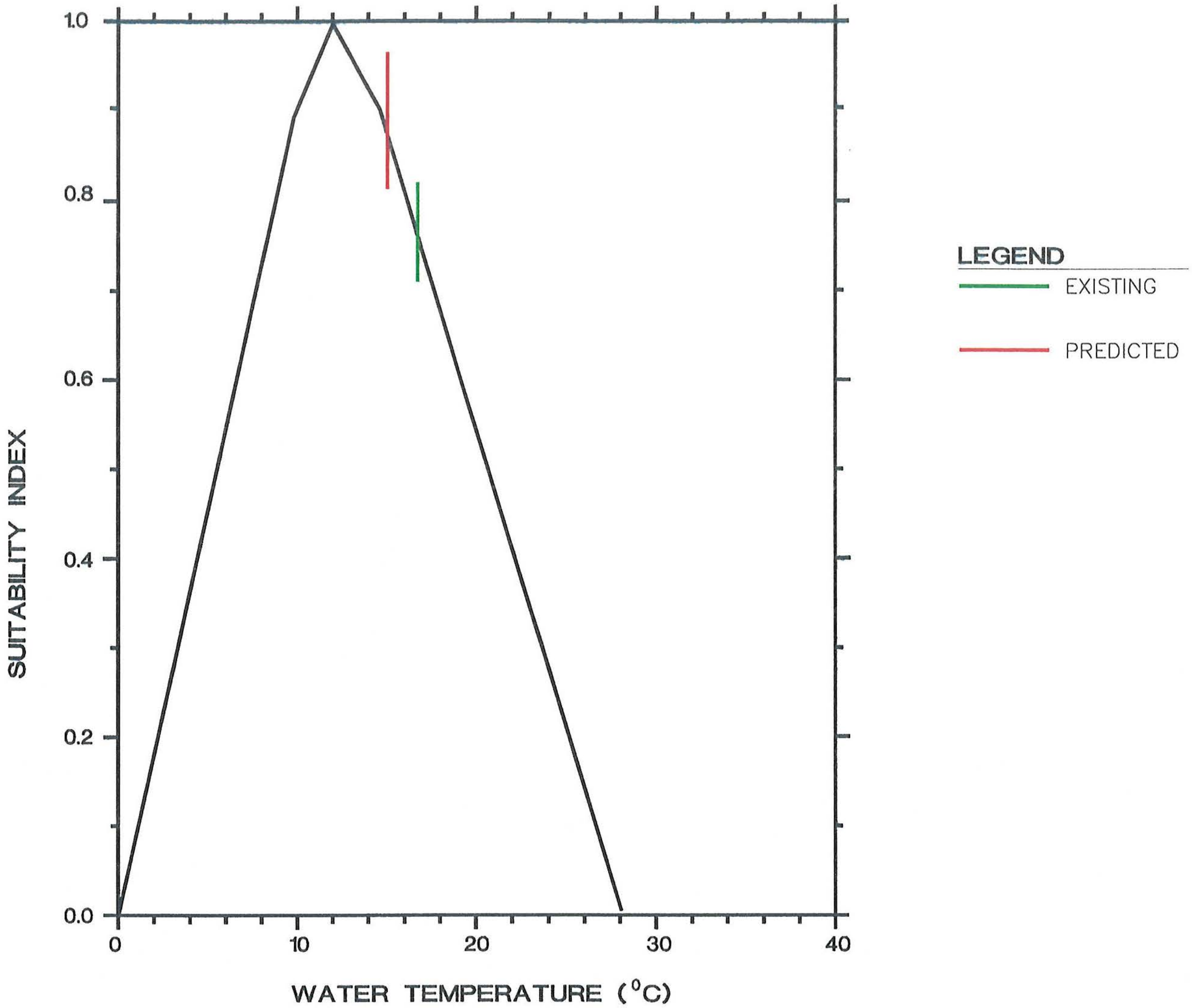
FUTURE AND EXISTING CURRENT VELOCITY WITHIN SPAWNING HABITAT COMPARED WITH HSI INDEX FOR ARCTIC GRAYLING

08 JAN 98	Figure F6-4	DRAWN BY: TM/DC



HABITAT SUITABILITY INDEX MODEL FOR LONGNOSE SUCKER (EDWARDS 1983)
NOTE: HSI MODEL REPRESENTS MEAN WATER TEMPERATURE DURING THE SUMMER.

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EXISTING AND PREDICTED WATER TEMPERATURE IN THE MUSKEG RIVER COMPARED WITH HSI INDEX FOR LONGNOSE SUCKER

09 JAN 1998	Figure F6–5	DRAWN BY: TM/DC

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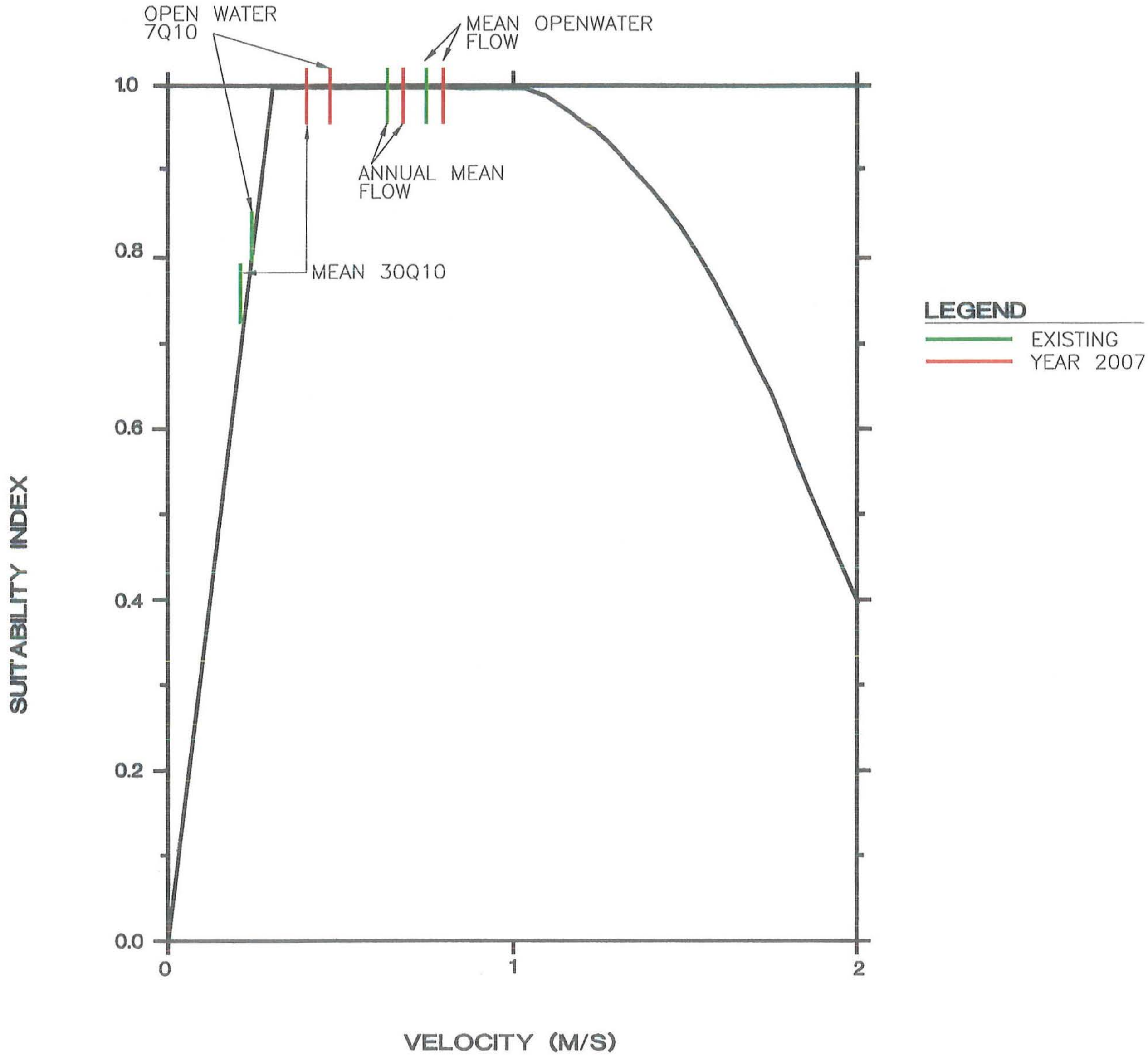

HABITAT SUITABILITY INDEX MODEL FOR LONGNOSE SUCKER (EDWARDS 1983)

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FUTURE AND EXISTING CURRENT VELOCITY WITHIN SPAWNING HABITAT COMPARED WITH HSI INDEX FOR LONGNOSE SUCKER

08 JAN 98	Figure F6-6	DRAWN BY: TM/DC

Summary of Habitat Changes for Longnose Sucker

Physical changes in the Muskeg River from combined developments would likely improve longnose sucker habitat for temperature and flow parameters.

Forage Fish Guild

Flow and temperature changes in the Muskeg River are unlikely to affect forage fish habitat quality as described in Section E6.

Habitat Loss from Small Streams, Lakes and Ponds

Most of the predicted habitat loss in the RSA is in small tributary streams. No direct losses of critical fish habitat are predicted in the region. Important tributaries to the Athabasca River such as the Muskeg and Steepbank rivers will not be directly affected by the combined developments (Figure F6-1). Based on the current plans for combined developments, only forage fish habitat will be affected.

Existing fish habitat disturbance due to Syncrude's Mildred Lake facility includes alterations to Ruth Lake, Mildred Lake, Poplar Creek and the Beaver River Drainage. Reclamation of the Mildred Lake Facility has been initiated and will be completed by 2025 (BOVAR 1996a).

No disturbance of fish habitat in Suncor's existing Lease 86/17 area has been recorded. The SOLV-EX project is not expected to effect fish habitat.

Predicted habitat disturbance from the Project is limited to several small lakes/ponds and the man-made Alsands Drain.

Two small tributaries to the Athabasca River and a small tributary to Shipyard Lake will be affected by the Steepbank Mine development. These tributaries provide forage fish habitat in their lower reaches (Golder 1996b).

Habitat affected by Aurora North includes a portion of Stanley Creek and some small ponds, both of which are considered forage fish habitat (BOVAR 1996a). Similarly, the streams affected by Aurora South (Iyinimin, Wesukemina, Blackfly and Muskeg creeks) contain forage fish habitat but are not known to support sport fish populations (BOVAR 1996a).

Changes in areas of lakes and streams in the RSA are presented in Section F4 (Tables F4-22 and F4-23). The total loss of lakes and streams is 464 ha, which is 1.7% of the total river, lake and stream area in the RSA. Habitat loss would not occur simultaneously as the development of approved oil sands developments will be staggered. For both the Aurora and Steepbank

Mines, the operators are committed to replacing any disturbed habitat with equal or better habitat. The assumption in this assessment is that all approved developments will commit to no net loss of the productive capacity of fish habitat in the RSA. As shown in Table F6-8, about 5,664 ha of waterbodies would be created through reclamation (16.5% more than currently exists). Hence, there will be a net gain in fish habitat. Figure F6-1 shows the footprints of existing and approved developments in relation to waterbodies in the RSA. Changes in areas of waterbodies from existing and approved developments are described in the Surface Water Hydrology CEA (Table F4-21).

Table F6-8 Habitat Losses and Gains from Combined Developments

Time Period	Existing[(a)]	Approved[(b)]	Project[(c)]	CEA[(d)]	Comment
Construction and Operation	-30 ha	-407 ha	-27 ha	-464	small tributary streams, shallow wetlands/lakes
Closure	+2,270 ha	+2,724 ha	+670 ha	+5,664	includes wetlands/shallow lakes, streams and end pit lakes, most habitat gained is in the form of end pit lakes

[(a)] Existing developments - Syncrude Mildred Lake, Suncor Lease 86/17.
[(b)] Approved - Syncrude Aurora North and South, SOLV-EX.
[(c)] Project - Muskeg River Mine Project.
[(d)]CEA - Project plus existing and approved.

Residual Impact Classification and Degree of Concern

Residual impacts are classified in Table F6-9. The predicted effect on forage fish habitat classified as low magnitude since it is less than 10%. Habitat loss for forage fish will be replaced at different times depending on the development. However, all oil sands operators will likely commit to no net loss of fish habitat and will replace disturbed habitat with like habitat of equivalent productivity.

No impacts on longnose sucker habitat are expected to occur. Classifications for northern pike, and Arctic grayling are rated negligible to low since both slight positive and negative effects may occur. These impacts are rated short to medium-term since changes in temperature and flow would occur over a short period (during maximum dewatering, and to a lesser extent in 2030).

Table F6-9 Residual Impact Classification and Degree of Concern for Cumulative Effects on Fish Habitat in Muskeg River

KIRs	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Forage Fish Guild	Negative	Low	Regional	Medium-Term	Reversible	Once	Low
Longnose Sucker	Positive	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Arctic Grayling	Negative	Negligible to Low	Local	Short to Medium-Term	Reversible	Intermittent	Low
Northern Pike	Negative	Negligible to Low	Local	Short to Medium-Term	Reversible	Intermittent	low

For the Athabasca River, the results of the analysis indicate that it is unlikely that water withdrawals will affect fish habitat in the winter. Hence, a negligible impact is expected. Follow-up investigations may be needed to confirm this prediction. During open-water there will be no effect on fish habitat.

Certainty

Predictions of effects on habitat in the Muskeg River are conservative and moderately certain. Flow calculations are based on preliminary plans for developments in the Muskeg River basin. It is unlikely that dewatering for these developments will overlap substantially. Hence, predicted flow changes are likely higher than will actually occur. Similarly, temperature predictions do not account for modifying effects of being held in sedimentation ponds or travel through channels from end pit lakes to the Muskeg River. Hence, the conservatism built into the analysis suggests that the temperature results reflect worse case conditions.

The prediction that changes in flow in the Athabasca River will not effect fish habitat is moderate in certainty. Radiotelemetry studies of KIR species could provide information on the extent of use of the Athabasca River for over-wintering. If additional investigations of in-stream flow needs are deemed necessary, then this issue should be dealt with on a regional basis.

F6.4.2 Key Question ARCEA-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Acute or Chronic Effects on Fish?

Analysis of Key Question

Results of analyses summarized above indicate that the linkage between operational and reclamation water releases and acute and chronic effects on fish is invalid. Hence, no acute or chronic effects on fish are expected.

Residual Impact Classification and Degree of Concern

No acute and chronic effects on fish are predicted.

Certainty

The above predictions are based on a number of assumptions, each of which affects the level of certainty. Most importantly, the toxicity of reclamation waters to be produced by all existing and approved oil sands operations were assumed to be equal to those of Suncor's currently-produced reclamation waters. Additionally, toxicity measured in laboratory tests was assumed to apply to field conditions. Additional assumptions were applied during modelling, which also affect the realism of the assessment.

F6.4.3 Key Question ARCEA-3: Will Operational and Reclamation Water Releases From Combined Developments Result in Changes to Fish Tissue Quality?

Analysis of Key Question

As discussed in Section E6.7, tainting and bioaccumulation of chemicals in fish tissue are not expected as a result of existing and approved developments.

Residual Impact Classification and Degree of Concern

No impacts on fish tissue quality are expected.

Certainty

As described in E6.8.4, conclusions regarding the potential for tainting of fish tissue via exposure to CT waters are based on previous investigations and the assumed presence of very low concentrations of tainting compounds. There is moderate certainty in these predictions.

F6.4.4 Key Question ARCEA-4: Will Operational and Reclamation Water Releases From Combined Developments Result in Changes in Fish Abundance?

Potential Linkages

As discussed in Section E6.8, the following linkages are invalid:

- change in access and fish abundance; and
- acute and chronic effects on fish and fish abundance.

Linkage Between Change in Fish Habitat and Fish Abundance

Change in fish habitat on a regional basis is rated as low for forage fish habitat, negligible for longnose sucker and negligible to low for Arctic grayling and northern pike. Conservatism built in to both water quality and water quantity models suggests that predicted flow and temperature changes are likely worst-case and that actual changes in habitat will be less than predicted.

The small effect on forage fish habitat is not expected to cause a decrease in fish abundance since it affects small proportion of habitat within the RSA. Additionally, many of the forage fish populations in these habitats are not accessible to predator fish species.

Analysis of Key Question

Based on analysis of linkages no changes in fish abundance are predicted.

Residual Impact Classification and Degree of Concern

Changes in fish abundance are predicted to be negligible.

Certainty

The certainty of conclusions about fish abundance is limited by uncertainty and conservatism of habitat predictions. As well there is uncertainty related to extrapolations from habitat to populations of fish in the field. This uncertainty is related to both losses and gains of habitat. As well, gains in habitat are only generally defined at this time. The exact amount of fish habitat created and the species and populations that it will support will be further defined as developments are reclaimed. The predicted 20% increase in habitat could result in an increased abundance of fish.

F6.5 Summary of Impacts

Impacts on aquatic resources from the CEA are summarized in Table F6-10.

Table F6-10 Summary of Impacts on Aquatic Resources

Key Question	CEA Results
ARCEA-1: Will activities from the combined developments change fish habitat?	• Predicted increases in flows in the Muskeg River are expected to have slight (< 0.1 habitat suitability) impacts on Arctic grayling habitat and result in slight improvements in northern pike habitat. Declines in temperature during summer are predicted to have low impacts (from 0.9 to 0.75 HSI) on northern pike habitat. These predictions are conservative: temperature and flow changes are unlikely to be as much as predicted. No impacts on northern pike of Arctic grayling habitat were predicted as a result of the Project. • CEA impacts on Arctic grayling and northern pike habitat are rated as Negative in direction, Negligible to Low in magnitude, Local in extent, Short to Medium-Term in duration, Reversible, and Intermittent in frequency. The degree of concern is **Low**. In the Far Future no impacts on Arctic grayling or northern pike habitat are predicted. • No negative effects are predicted for longnose sucker habitat. • For the CEA, loss of forage fish habitat (1.7%) is predicted in the RSA. The Project contributes less than 0.1% of this impact. The cumulative impact on forage fish habitat is Negative in direction, Low in magnitude, Regional in extent, Medium-Term in duration, Reversible, and Once in frequency. The degree of concern is **Low**. At each stage in the developments, habitat disturbed will be replaced with habitat of equivalent or better productivity. Forage fish habitat replaced through reclamation will result in a net gain (20% more that currently exists) in habitat for both forage fish and sport fish in the Far Future.
ARCEA-2: Will operational and reclamation water releases from combined developments result in acute or chronic effects on fish?	• No acute or chronic effects on fish as a result of changes in temperature, dissolved oxygen, sediment or water quality were predicted. The degree of concern is **Negligible**.
ARCEA-3: Will operational and reclamation water releases from combined developments result in changes to fish tissue quality?	• No tainting or accumulation of chemicals in fish are predicted. The degree of concern is **Negligible**.
ARCEA-4: Will operational and reclamation water releases from combined developments result in changes in fish abundance?	• No changes in fish abundance are expected as a result of acute and chronic effects, change in access or habitat. The degree of concern is **Negligible**.

F7 ECOLOGICAL LAND CLASSIFICATION CUMULATIVE EFFECTS ASSESSMENT

F7.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on ecological land units in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Municipalities
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Muskeg River Mine Project
- Pipelines, utility corridors and roadways

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

F7.2 Approach and Methods

The approach used to assess potential cumulative effects on the ecological land classification (ELC) component was consistent with the approach described for the ELC Impact Assessment in Section E7.

Key Indicator Resources

There are no Key Indicator Resources (KIRs) specific to ELC.

F7.3 Potential Linkages and Key Questions

Figures E7-1 and E7-2 show the linkage diagram for Project activities and potential changes in the ELC component. The same linkage diagrams apply to the CEA. The key questions from Section E7 of the EIA have been combined to the following question.

ELCCEA-1: Will Activities From Combined Developments Result in a Loss or Alteration of ELC Units and Diversity?

F7.4 Analysis and Results

F7.4.1 Key Question ELCCEA-1: Will Activities From Combined Developments Result in a Loss or Alteration of ELC Units and Diversity?

Linkage between Site Clearing and Loss of ELC

The major contributors to baseline disturbances for ELC in the RSA (Table F7-1) include oil sands developments from Suncor, Syncrude, Gibsons Petroleum, and SOLV-EX. Other disturbances include roadways, municipalities, gravel pits and powerlines. Forestry operations by Alberta Pacific Forest Industries (Al-Pac) and Northlands, and pipelines, will not impact macroterrain only vegetation (F9) and wetlands (F10). Approximately 54,055 ha or 5.2% of the RSA is currently subject to these developments. Existing oil sands developments, in which site clearing involves the direct removal of landforms, account for 2.7% of the RSA with 2.2% occurring from Syncrude's Mildred Lake operation. Pipelines, roadways and municipalities collectively occupy 0.6% of the RSA. Therefore, the total baseline disturbances that will affect macroterrain is 34,541 ha or 3.3% of the RSA. Approved developments include Syncrude's Aurora Mine North and South (15,171 ha or 1.4%) and Suncor's Steepbank Mine (3,084 or 0.3%). The Muskeg River Mine Project contribution to overall land disturbance is 4,343 or 0.4% of the RSA. These developments are further described in Section F1 and are shown in Figure F1-1 of this EIA.

Table F7-1 Combined Developments Considered for ELC Cumulative Effects Assessment within the RSA

Baseline/Existing	Area (ha)	Percent (%)
Suncor Lease 86/17	3,369	0.3
Syncrude Mildred Lake	23,244	2.2
Suncor Steepbank (to end of 97)	150	<0.1
Gibsons Petroleum	22	<0.1
SOLV-EX	2,088	0.2
municipalities	4,002	0.4
pipelines/roadways/others	1,666	0.2
Sub-total	**34,541**	**3.3**
Muskeg River Mine Project	**4,343**	**0.4**
Approved Projects		
Syncrude Aurora North and South	15,171	1.4
Suncor Steepbank	3,084	0.3
Sub-total	**18,255**	**1.7**
Total Developed Area	**52,796**	**5.0**
Regional Study Area	**1,051,411**	**100.0**

Impact Analysis

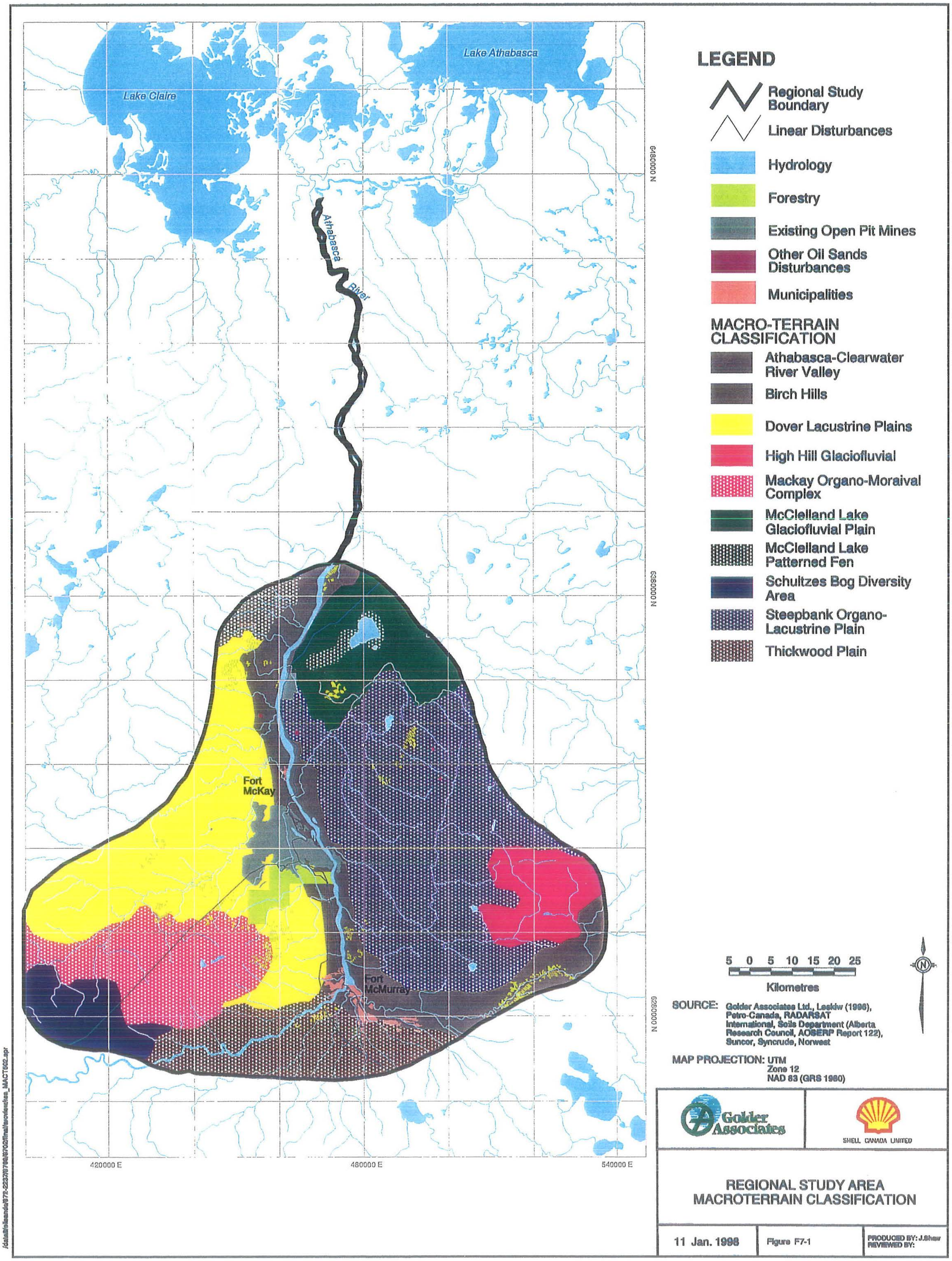
The analysis of potential linkages indicates that the valid linkage necessary for determining cumulative losses or alteration of ELC types at the macroterrain level involves site clearing during development. For oil sands developments, site clearing involves the direct removal of landforms, and associated soils and vegetation communities. Forestry disturbances will not affect macroterrain units. Forestry disturbances are included in CEA assessment for vegetation (F9) and wetlands (F10).

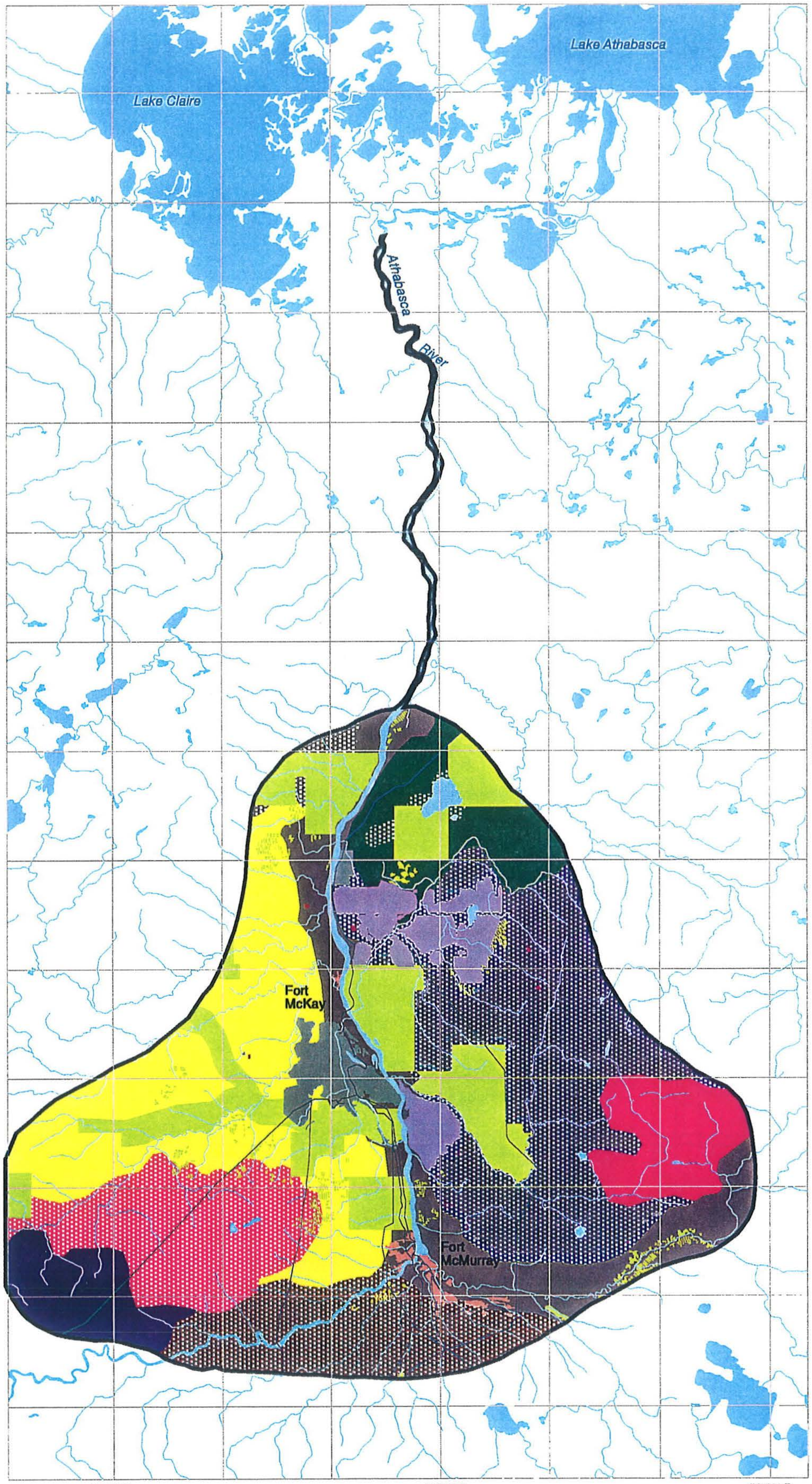
There are 10 macroterrain units in the RSA. A detailed description of each macroterrain type is found in the Baseline Ecological Land Classification Document (Golder 1997l). Figure F7-1 shows baseline regional macroterrain while Figure F7-2 shows the macroterrain with combined developments.

Baseline developments have affected 34,541 ha or 3.3% of the RSA. This represents the total baseline disturbances and is expressed as Reclaimed Units (3,600 ha) and Disturbance (30, 941 ha) in Table F7-2.

Combined developments will impact three macroterrain units within the RSA, namely, Athabasca Clearwater River Valley, McClelland Lake Glaciofluvial Plain and Steepbank Organo-Lacustrine Plain (Table F7-2). Combined developments will affect 2,446 ha (0.2%) of the Athabasca Clearwater River Valley macroterrain unit within the RSA. The Muskeg River Mine will remove 472 ha of macroterrain units and the approved developments will remove 1,974 ha. The McClelland Lake Glaciofluvial Plain macroterrain unit will be affected to the extent of 4,722 ha or 0.4% of the RSA. This represents a loss of 3.3% of the total unit. The Project will alter 412 ha of this macroterrain unity and approved developments will alter the remaining 4,482 ha. The Steepbank Organo-Lacustrine Plain is the macroterrain unit most affected by cumulative developments in the RSA. The total loss is 15,430 ha or 1.5% of the RSA. The Project will reduce the unit's area by 3,459 ha, while the approved developments will impact 11,971 ha. The total area disturbed including baseline, Project and approved developments is 51,471 ha or 4.9% of RSA. This area will be reclaimed to new macroterrain units.

This CEA scenario represents the worst case, as all developments do not occur simultaneously. Additionally, phased reclamation will also occur for each development scenario. Thereby reducing the total area under development at any one time.


Lake Claire
Lake Athabasca
Athabasca River
Fort McKay
Fort McMurray
6480000 N
6380000 N
6280000 N
420000 E
480000 E
540000 E
LEGEND
Regional Study Boundary
Linear Disturbances
Hydrology
Forestry
Existing Open Pit Mines
Other Oil Sands Disturbances
Municipalities
MACRO-TERRAIN CLASSIFICATION
Athabasca-Clearwater River Valley
Birch Hills
Dover Lacustrine Plains
High Hill Glaciofluvial
Mackay Organo-Moraival Complex
McClelland Lake Glaciofluvial Plain
McClelland Lake Patterned Fen
Schultzes Bog Diversity Area
Steepbank Organo-Lacustrine Plain
Thickwood Plain
5 0 5 10 15 20 25
Kilometres
SOURCE: Golder Associates Ltd., Leskiw (1996), Petro-Canada, RADARSAT International, Soils Department (Alberta Research Council, AOSERP Report 122), Suncor, Syncrude, Norwest
MAP PROJECTION: UTM Zone 12 NAD 83 (GRS 1980)
Golder Associates
SHELL CANADA LIMITED
REGIONAL STUDY AREA MACROTERRAIN CLASSIFICATION
11 Jan. 1998
Figure F7-1
PRODUCED BY: J.Shaw
REVIEWED BY:



LEGEND

- Regional Study Boundary
- Linear Disturbances
- Hydrology
- Forestry
- Existing Open Pit Mines
- Other Oil Sands Disturbances
- Proposed In-situ
- Municipalities
- Proposed Open Pit Mine

MACRO-TERRAIN CLASSIFICATION

- Athabasca-Clearwater River Valley
- Birch Hills
- Dover Lacustrine Plains
- High Hill Glaciofluvial
- Mackay Organo-Moraival Complex
- McClelland Lake Glaciofluvial Plain
- McClelland Lake Patterned Fen
- Schultzes Bog Diversity Area
- Steepbank Organo-Lacustrine Plain
- Thickwood Plain

5 0 5 10 15 20 25
Kilometres

SOURCE: Golder Associates Ltd., Leskiw (1996), Petro-Canada, RADARSAT International, Soils Department (Alberta Research Council, AOSERP Report 122), Suncor, Syncrude, Norwest

MAP PROJECTION: UTM
Zone 12
NAD 83 (GRS 1980)

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REGIONAL STUDY AREA MACROTERRAIN CLASSIFICATION CUMULATIVE EFFECTS ASSESSMENT

11 Jan. 1998	Figure F7-2	PRODUCED BY: K. Quine REVIEWED BY:

Table F7-2 Direct Losses/Alteration of Existing Macroterrain Within the RSA

Macroterrain	Baseline RSA[a]		Muskeg River Mine Project				Approved Developments				CEA[c]	
			Change[b]		Far Future		Change		Far Future		Final Landscape	
	Total (ha)	%	Total (ha)	% RSA	Total (ha)	% RSA	Total (ha)	% RSA	Total ha	% RSA	Total (ha)	% RSA
Athabasca-Clearwater River Valley	144,788	13.8	472	<0.1	0	0.0	1,974	0.2	0	0.0	142,342	13.5
Birch Hills	15,350	1.5	0	0.0	0	0.0	0	0.0	0	0.0	15,350	1.5
Dover Lacustrine Plains	228,999	21.8	0	0.0	0	0.0	33	0.0	0	0.0	228,999	21.8
High Hill Glaciofluvial	33,163	3.2	0	0.0	0	0.0	0	0.0	0	0.0	33,163	3.2
MacKay Organo-Morainal Complex	102,157	9.7	0	0.0	0	0.0	0	0.0	0	0.0	102,157	9.7
McClelland Lake Glaciofluvial Plain	71,941	6.8	412	<0.1	0	0.0	4,310	0.4	0	0.0	67,219	6.4
McClelland Lake Patterned Fen	10,172	1.0	0	0.0	0	0.0	0	0.0	0	0.0	10,172	1.0
Schultz's Bog Diversity Area	42,997	4.1	0	0.0	0	0.0	0	0.0	0	0.0	42,997	4.1
Steepbank Organo-Lacustrine	275,427	26.2	3,459	0.4	0	0.0	11,971	1.1	0	0.0	259,997	24.7
Thickwood Plain	91,876	8.7	0	0.0	0	0.0	0	0.0	0	0.0	91,876	8.7
Existing Developments												
Reclamation Units[d]	3,600	0.3	0	0.0	4,343	0.4	0	0.0	18,255	1.7	51,471	4.9
Disturbed[e]	30,941	2.9	0	0.0	0	0.0	0	0.0	0	0.0	5,668	0.5
Infrastructure					0		420	<0.1	420	<0.1	420	<0.1
Total	**1,051,411**	**100.0**	**4,343**	**0.4**	**4,343**	**0.4**	**18,255**	**0.0**	**18,255**	**1.7**	**1,015,411**	**100.0**

(a) Undeveloped macroterrain units plus existing developed area.
(b) Incremental changes to undeveloped terrain units.
(c) Cumulative effect of Project and Approved Developments on Baseline conditions.
(d) Newly created macroterrain units (revegetated tailings sand, overburden storage areas, etc.).
(e) Areas under development (does not include forestry, because forestry does not impact macroterrain).

Biodiversity

A discussion of biodiverisity and how it was assessed for the Project EIA was provided in Section E7.5. The CEA assessment showed that no macroterrain units will be completely removed by the combined developments. Therefore, the overall biodiversity at the macroterrain level will not be significantly be altered by developments in the RSA. Moreover, within macroterrain units, the vegetation diversity, discussed in F9, does not change substantially as a result of the combined developments or reclamation activities.

Residual Impact Classification and Degree of Concern

Table F7-3 details the residual impact classification and degree of concern for macroterrain units. reclaimed macroterrain units, on development closure, will be 51,471 ha. The residual impacts of 5,668 ha (or 0.5% of the RSA) includes highways, roadways, pipelines, municipalities and gravel pits. In summary, the direction is Negative, the magnitude is Low, Regional in geographic extent and the degree of concern is Low.

Table F7-3 Residual Cumulative Impact Summary for Macroterrain Units

Macroterrain Types	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Athabasca-Clearwater River Valley	Negative	Low	Regional	Long-Term	Irreversible	Long-Term	Low
McClelland Lake Glaciofluvial Plain	Negative	Low	Regional	Long-Term	Irreversible	Long-Term	Low
Steepbank Organo-Lacustrine Plain	Negative	Low	Regional	Long-Term	Irreversible	Long-Term	Low

F7.5 Summary of Impacts

Table F7-4 Summarizes the Impacts of The CEA Results on Ecological Land Classification

Table F7-4 Summary of Impacts on Ecological Land Classification

Key Question	CEA Results
ELCCEA-1: Will activities from combined developments result in a loss or alteration of ELC units and diversity?	• In this CEA, the total losses are 22,598 ha or 2.1% of the RSA. The Project will contribute 4,343 ha or 0.4% of the loss in the RSA • The CEA impact on diversity to vegetation communities is Negative in direction, Low in magnitude, Regional in geographic extent, Short-Term in duration and the degree of concern is **Low**.

F8 TERRAIN AND SOILS CUMULATIVE EFFECTS ASSESSMENT

F8.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on terrain and soils in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank
- SOLV-EX
- Muskeg River Mine Project
- Forestry
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Municipalities
- Pipeline/Roadways/Others

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

F8.2 Approach and Methods

The approach used to assess potential cumulative impacts on terrain and soils was consistent with that described for the Terrain and Soils Impact Assessment, as described in Section E8. The only variation was extending the scope to cover the developments included in the CEA. Note that due to the coarser level of analysis for the RSA, area and percentage values may not be identical between Sections E and F.

F8.3 Potential Linkages and Key Questions

Figure E8-1 (Section E8) shows the linkage diagram for Project activities and potential changes to terrain and soils associated with the Project. Generally the same linkages and key questions apply to the CEA although key questions TS-1 and TS-2 have been combined as TSCEA-1 and key question TS-3 rephrased and expanded in scope as TSCEA-2.

TSCEA-1: Will Combined Developments Alter the Quantity and Distribution of Terrain and Soil Units?

TSCEA-2: Will Combined Developments Alter Soil Capability and Sensitivity?

F8.4 Analysis and Results

F8.4.1 Key Question TSCEA 1: Will Combined Developments Alter the Quantity and Distribution of Terrain and Soil Units?

Analysis of terrain and soil units at the RSA level was conducted in the following manner:

- preliminary digital files of soil maps for the region (Turchenek and Lindsay 1982) were acquired and additional information required to encompass the eastern portion of the RSA was incorporated; and
- once the soil mapping was complete, terrain units were derived by combining all soil types having similar genetic characteristics into common groups (e.g., all soil series with eolian parent materials became eolian terrain units).

Table F7-1 provides details of the baseline conditions and approved developments in the RSA plus the Project.

For the purposes of this analysis, Forestry development was assumed to have a negligible impact on terrain and soils. Unlike open pit mining, the disturbances resulting from Forestry are largely superficial and transitory in nature. Therefore, this variable was not considered in the CEA analysis.

Data from Syncrude's Aurora Mine and Suncor's Steepbank Mine Applications were used to determine the vegetation communities, forest soil capabilities and terrain which would be found in the respective mines. Data from Suncor's Steepbank Mine Application provided similar data for Suncor's Lease 86/17. Data for Syncrude's Mildred Lake facility were extrapolated from the Aurora Mine Application.

Table F8-1 shows the derivation and extent of the terrain units in the RSA, while Figure F8-1 illustrates their distribution. Table F8-2 outlines the distribution of RSA soil units, which are illustrated in Figure F8-2.

Table F8-1 Terrain Units of the Muskeg River Mine Project RSA, Baseline Conditions[(a)]

Terrain Unit	Soil Series [(b)]	Area, ha	Area, % of RSA
Bog (B)	Kenzie 1	224,204	21.3
Shallow Bog (Bs)	Kenzie 2; Mikkwa 1and 2	264,554	25.6
Eolian (E)	Heart 4, 5 and 6	36,949	3.5
Fen (N)	Eaglesham 1	37,854	3.6
Fluvial (F)	Chipewyan 1; Mamawi 1 and 2; McMurray 1 and 2; Namur 1 and 2	51,586	4.9
Glaciofluvial (Fg)	Bitumount 1; Firebag 1, 2 and 3; Mildred 1 and 2; Ruth Lake 1	141,236	13.4
Glaciofluvial & Glaciolacustrine, medium over Morainal/Till (LFg)	Livock 1	25,925	2.5
Glaciolacustrine over Morainal/Till (Lg1/M)	Algar 1, Dover 1, Joslyn 1, Steepbank 1	151,936	13.2
Glaciolacustrine (Lg2)	Kearl 1	729	0.1
Morainal/Till, fine (M1)	Buckton 1, Horse River 1, Legend 1, Surmont 1	13,273	1.2
Morainal/Till, coarse (M2)	Kinosis 1	36,291	3.4
Rough Broken (RB)	Rough Broken	52,277	5.0
Total, Terrain Units		1,036,814	97.7
AIM[(c)]		10,164	1.0
NWL[(d)]		4434	0.4
Total, Non-terrain		14,598	1.4
Total		**1,051,411**	**100.0**

[(a)] All data from Turchenek and Lindsay (1982)
[(b)] Soil Series - these are the names used in Turchenek and Lindsay (1982).
[(c)] AIM - disturbed lands and cultural features.
[(d)] NWL - open water, rivers, streams and lakes.

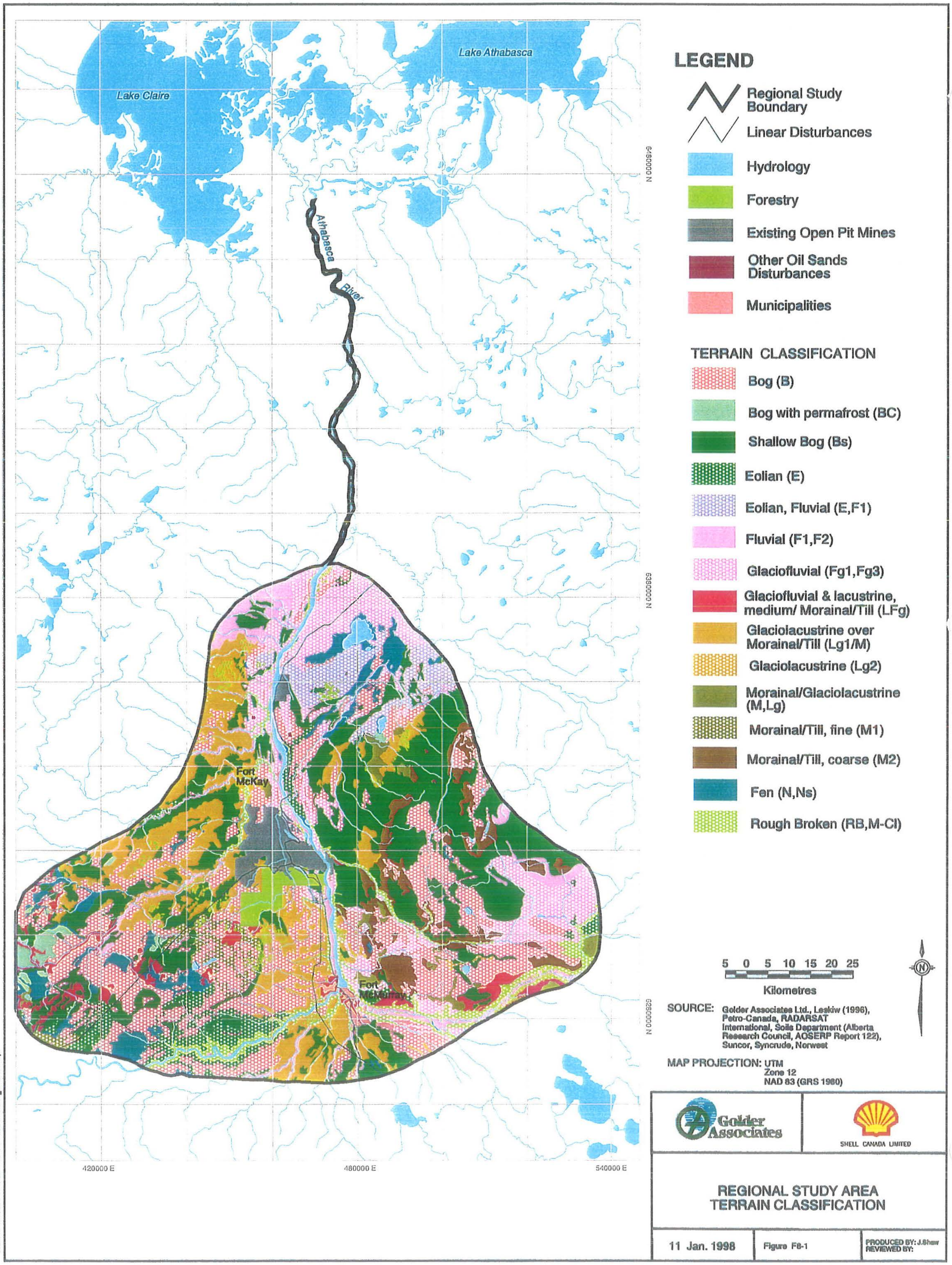
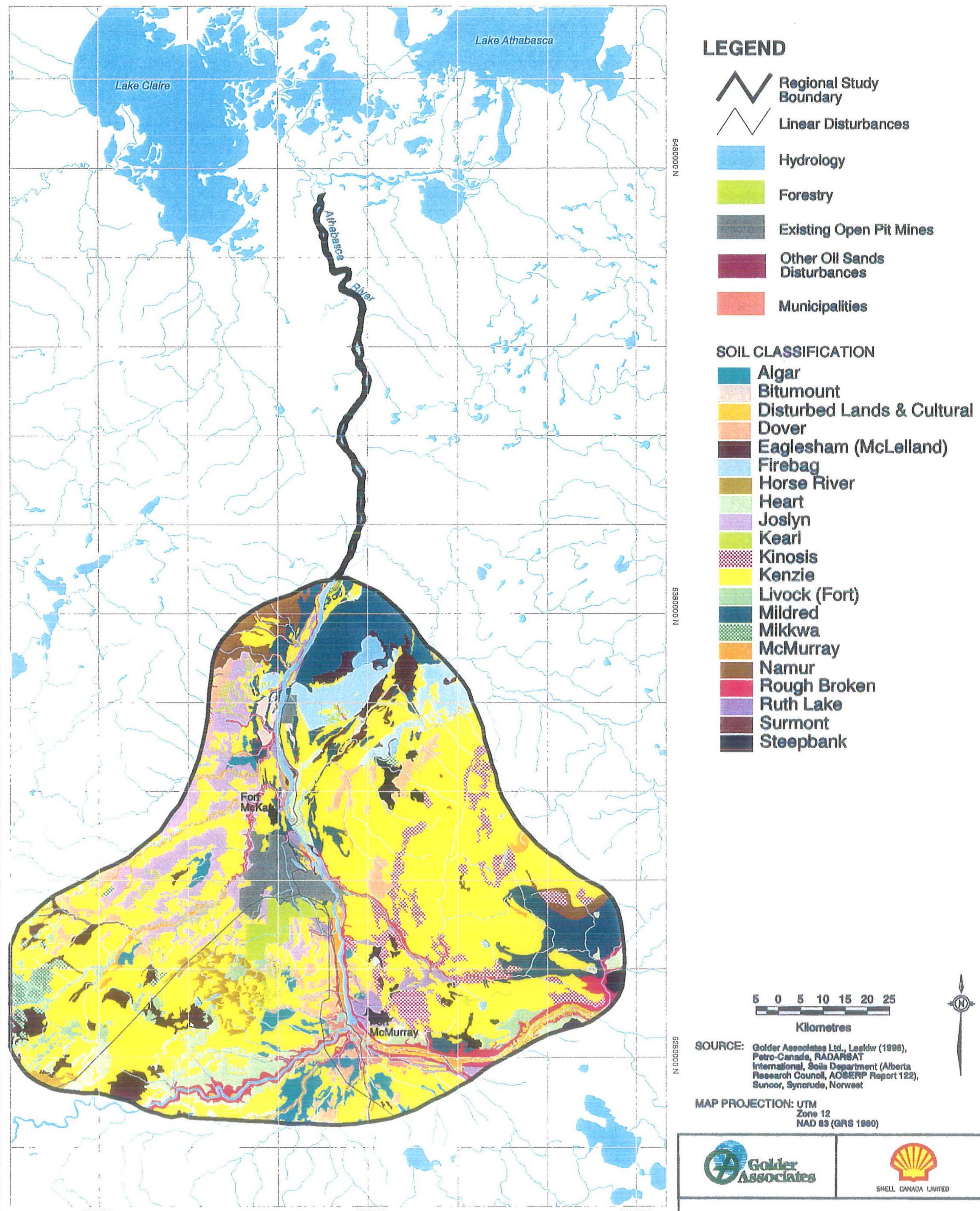

LEGEND
Regional Study Boundary
Linear Disturbances
Hydrology
Forestry
Existing Open Pit Mines
Other Oil Sands Disturbances
Municipalities
TERRAIN CLASSIFICATION
Bog (B)
Bog with permafrost (BC)
Shallow Bog (Bs)
Eolian (E)
Eolian, Fluvial (E,F1)
Fluvial (F1,F2)
Glaciofluvial (Fg1,Fg3)
Glaciofluvial & lacustrine, medium/ Morainal/Till (LFg)
Glaciolacustrine over Morainal/Till (Lg1/M)
Glaciolacustrine (Lg2)
Morainal/Glaciolacustrine (M,Lg)
Morainal/Till, fine (M1)
Morainal/Till, coarse (M2)
Fen (N,Ns)
Rough Broken (RB,M-Cl)
Lake Athabasca
Lake Claire
Athabasca River
Fort McKay
Fort McMurray
6480000 N
6380000 N
6280000 N
420000 E
480000 E
540000 E
5 0 5 10 15 20 25
Kilometres
SOURCE: Golder Associates Ltd., Leskiw (1996), Petro-Canada, RADARSAT International, Soils Department (Alberta Research Council, AOSERP Report 122), Suncor, Syncrude, Norwest
MAP PROJECTION: UTM Zone 12 NAD 83 (GRS 1980)
Golder Associates
SHELL CANADA LIMITED
REGIONAL STUDY AREA TERRAIN CLASSIFICATION
11 Jan. 1998
Figure F8-1
PRODUCED BY: J.Shaw
REVIEWED BY:

Table F8-2 Soils of the Muskeg River Mine Project RSA, Baseline Conditions[a]

Soil Series/Map Unit	Area (ha)	Area (% of RSA)
Algar	24,390	2.3
Bitumount	3,503	0.3
Dover	39,058	3.7
Eaglesham (McLelland)[b]	37,854	3.6
Firebag	31,941	3.0
Horse River	13,049	1.2
Heart	36,949	3.4
Joslyn	75,114	7.1
Kearl	729	0.1
Kinosis	36,291	3.5
Kenzie	479,910	45.6
Livock (Fort)[c]	25,925	2.4
Mildred	84,063	8.1
Mikkwa	8,848	0.9
McMurray	33,680	3.2
Namur	17,906	1.7
Rough Broken	52,277	5.0
Ruth Lake	20,729	2.0
Steepbank	13,374	1.3
Surmont	224	0.02
Total, Soil Units	1,036,813	98.42
AIM[d]	10,164	1.0
NWL[e]	4,434	0.4
Total, Non-soil Units	14,598	1.4
Total	**1,051,411**	**100.0**

(a) All data from Turchenek and Lindsay (1982).
(b) Eaglesham (McLelland) - this soil series was named McLelland in the LSA to conform with the Alberta soil names file (Golder 1997m).
(c) Livock (Fort) - Livock soils were classified as the Fort series in the LSA.
(d) AIM - disturbed lands and cultural features.
(e) NWL - open water, rivers, streams and lakes.



REGIONAL STUDY AREA
SOIL CLASSIFICATION

11 Jan. 1998 | Figure F8-2 | PRODUCED BY: J.Shaw
REVIEWED BY:

Analysis of the Key Question

The impacts associated with the CEA development scenario on the terrain and soil units in the RSA are shown in Tables F8-3 and F8-4, respectively. It is critical to note that the values in these Tables reflect the actual areas of terrain and soil units, respectively, that have been affected by the developments to date and so will not add up to the same areas as noted in Table F7-1 (maximum permitted development areas).

Since the terrain units were developed by combining soil units, an analysis of the development impacts applies equally to both variables. As shown in Tables F8-3 and F8-4; existing disturbances make up 30,941 ha/0.8% of the RSA, the total maximum disturbance directly attributable to the Project is another 4343 ha/0.4% and the combined developments will account for a further 18,255 ha/1.7 % of the RSA for a total of 53,539 ha/5.1%. The Project will, therefore, comprise approximately 8% of the area disturbed in the CEA scenario, or 19% when existing disturbances are not considered. In the closure landscape the entire Project area and the areas associated with the combined developments will have been entirely reclaimed and so have no long-term unremediated impacts. As outlined in Tables F8-3 and F8-4, the major impacts of the Project will be the organic soils making up the bog and fen terrain units. For comparative purposes the CEA scenario also shows the major impacts to be on these units with substantial areas of glaciofluvial and glaciolacustrine or morainal units also affected.

Natural soils will be removed during the construction phase of development and upon closure will be replaced by a reclamation soil mix (see Section E8 of this EIA for details). This mixture will not be identical to the naturally occurring soils but will provide an adequate growth medium for revegetation of terrestrial species on approximately 77% of the site, the remaining 23% will be reclaimed as wetlands and open water. Similarly, when the Project and all approved developments are considered, it is estimated that approximately 77% of the disturbed areas will be reclaimed for terrestrial species regrowth and the remaining 23% as wetlands or open water. Ultimately, there will be changes in the types and distribution of terrain and soils units found in 2.1% of the RSA but permanent removal from the ecosystem will be negligible (i.e., possibly roadways that may be left in place and/or other unspecified infrastructure).

Table F8-3 Terrain Units of the Muskeg River Mine Project RSA, Considering Combined Development

	Baseline[a]		Muskeg River Mine Project				CEA[c]							
			Impact[b]		Far Future		Impact[b]		Far Future		Final Landscape		Changes in Baseline [b]	
Terrain Unit	(ha)	% RSA	(ha)	RSA %	(ha)	% RSA	(ha)	% RSA	(ha)	% RSA	(ha)	% RSA	(ha)	% RSA
Bog (B)	219,383	21.3	2,350	0.2	0	0.0	4,393	0.4	0	0.0	214,990	20.4	-4,393	-0.4
Shallow Bog (Bs)	260,660	25.1	511	0.0	0	0.0	5,794	0.6	0	0.0	254,866	24.2	-5,794	-0.6
Eolian (E)	36,225	3.5	761	0.1	0	0.0	761	0.1	0	0.0	35,464	3.4	-761	-0.1
Fluvial (F)	51,314	4.9	1	0.0	0	0.0	206	0.0	0	0.0	51,108	4.9	-206	0.0
Glaciofluvial (Fg)	137,524	13.3	404	0.0	0	0.0	4,166	0.4	0	0.0	133,358	12.7	-4,166	-0.4
Glaciofluvial & Glaciolacustrine (LFg)	23,965	2.5	0	0.0	0	0.0	136	0.0	0	0.0	23,829	2.3	-136	0.0
Glaciolacustrine over Morainal (Lg1/M)	143,511	14.5	5	0.0	0	0.0	5,550	0.5	0	0.0	137,961	13.1	-5,550	-0.5
Glaciolacustrine(Lg2)	728	0.1	0	0.0	0	0.0	0	0.0	0	0.0	728	0.1	0	0.0
Morainal/Till, fine(M1)	13,228	1.3	0	0.0	0	0.0	0	0.0	0	0.0	13,228	1.3	0	0.0
Morainal/Till, coarse (M2)	36,265	3.5	0	0.0	0	0.0	106	0.0	0	0.0	36,158	3.4	-106	0.0
Fen, Shallow Fen (N,Ns)	37,807	3.6	300	0.0	0	0.0	740	0.1	0	0.0	37,067	3.5	-740	-0.1
NWL(d)	4,434	0.4	0	0.0	0	0.0	0	0.0	0	0.0	4,434	0.4	0	0.0
Rough Broken	51,826	5.0	11	0.0	0	0.0	745	0.1	0	0.0	51,081	4.9	-745	-0.1
Infrastructure	0	0.0	0	0.0	0	0.0	0	0.0	420	0.0	420	<0.1	420	<0.1
Reclaimed, terrestrial	3,600	0.3	0	0.0	3,363	0.3	0	0.0	17,349	1.7	39,387	3.7	35,788	3.4
Reclaimed, wetland and open water		0.0	0	0.0	980	0.1	0	0.0	4,829	0.5	11,663	1.1	11,663	1.1
AIM(e)	30,941	0.8	0	0.0	0	0.0	0	0.0	0	0.0	5,668	0.5	-25,273	-2.4
TOTAL	**1,051,411**	**100.0**	**4,343**	**0.4**	**4,343**	**0.1**	**22,598**	**2.1**	**22,598**	**2.1**	**1,051,411**	**100.0**	**0**	**0.0**

(a) Undeveloped, developed and reclaimed areas.
(b) Incremental changes.
(c) Cumulative impacts from Project and Approved Projects (does not include forestry, as forestry operations do not change terrain).
(d) NWL = open water, rivers, streams and lakes.
(e) AIM = disturbed lands and cultural features.

Table F8-4 Soils of the Muskeg River Mine Project RSA, Considering Combined Development

Soils Code	Baseline RSA[a]		Muskeg River Mine				CEA[c]				Final Landscape		Changes in baseline[b]	
			Impact [b]		Far Future		Impact [b]		Far Future					
	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%
Alger	24,279	2.3	0	0.0	0	0.0	0	0.0	0	0.0	24,279	2.3	0	0.0
Bitumen	3,419	0.3	0	0.0	0	0.0	338	<0.1	0	0.0	3,081	0.3	-338	<0.1
Dover	38,698	3.7	5	<0.1	0	0.0	2,353	0.2	0	0.0	36,345	3.5	-2,353	-0.2
Eaglesham (Mc)[d]	37,808	3.6	300	<0.1	0	0.0	740	0.1	0	0.0	37,068	3.5	-740	-0.1
Firebag	31,778	3.0	0	0.0	0	0.0	692	0.1	0	0.0	31,086	3.0	-692	-0.1
Horse River	13,004	1.2	0	0.0	0	0.0	0	0.0	0	0.0	13,004	1.2	0	0.0
Heart	36,227	3.4	761	0.1	0	0.0	761	0.1	0	0.0	35,466	3.4	-761	-0.1
Joslyn	67,245	6.4	0	0.0	0	0.0	0	0.0	0	0.0	67,245	6.4	0	0.0
Kearl	728	0.1	0	0.0	0	0.0	0	0.0	0	0.0	729	0.1	0	0.0
Kinosis	36,265	3.4	0	0.0	0	0.0	106	<0.1	0	0.0	36,159	3.4	-106	<0.1
Kenzie	471,337	44.8	2,861	0.3	0	0.0	9,874	0.9	0	0.0	461,463	43.9	-9,874	-0.9
Livock (Fort)[e]	23,964	2.3	0	0.0	0	0.0	136	<0.1	0	0.0	23,828	2.3	-136	<0.1
Mildred	83,475	7.9	403	<0.1	0	0.0	2,606	0.2	0	0.0	80,869	7.7	-2,606	-0.2
Mikkwa	8,848	0.8	0	0.0	0	0.0	413	<0.1	0	0.0	8,435	0.8	-413	<0.1
McMurray	33,408	3.2	1	0.0	0	0.0	206	<0.1	0	0.0	33,202	3.2	-206	<0.1
Namur	17,906	1.7	0	0.0	0	0.0	0	0.0	0	0.0	17,906	1.7	0	0.0
Rough Broken	51,734	4.9	11	<0.1	0	0.0	746	0.1	0	0.0	50,988	4.8	-746	-0.1
Ruth Lake	18,715	1.8	0	0.0	0	0.0	431	<0.1	0	0.0	18,284	1.7	-431	<0.1
Surmont	224	0.0	0	0.0	0	0.0	0	0.0	0	0.0	224	0.0	0	0.0
Steepbank	13,374	1.3	0	0.0	0	0.0	3,196	0.3	0	0.0	10,179	1.0	-3,195	-0.3
Reclaimed Soil	3,600	0.3	0	0.0	3,363	0.3	0	0.0	17,349	1.9	39,387	3.7	35,787	3.4
Reclaimed Wetlands	0	0.0	0	0.0	980	0.1	0	0.0	4,829	0.3	11,663	1.1	11,663	1.1
Total Soil Units	**1,106,036**	**96.6**	**4,343**	**0.4**	**4,343**	**0.4**	**22,598**	**2.1**	**22,178**	**2.2**	**1,040,889**	**99.0**	**24,853**	**2.4**
AIM Total[f]	30,941	2.9	0	0.0	0	0.0	0	0.0	0	0.0	5,668	0.5	-25,273	-2.4
NWL[g]	4,434	0.4	0	0.0	0	0.0	0	0.0	0	0.0	4,434	0.4	0	0.0
Infrastructure	0	0.0	0	0.0	0	0.0	0	0.0	420	0.0	420	0.0	420	0.0
Total, Non-Soil	**35,375**	**3.4**	**0**	**0.0**	**0**	**0.0**	**0**	**0.0**	**420**	**0.0**	**10,522**	**1.0**	**-24,853**	**-2.4**
TOTAL	**1,051,411**	**100.0**	**4,343**	**0.4**	**4,343**	**0.4**	**22,598**	**2.1**	**22,598**	**2.2**	**1,051,411**	**100.0**	**0**	**0.0**

(a) Undeveloped, developed and reclaimed areas.
(b) Incremental changes.
(c) Cumulative impacts from project and approved projects (does not include forestry as operations do not alter soil).
(d) McLelland in the LSA.
(e) Fort in LSA.
(f) AIM - disturbed lands and cultural features.
(g) NWL - open water, rivers, streams and lakes.

Residual Impacts and Degrees of Concern

Upon closure, those terrain and soil units that have been disturbed by development are generally reclaimed to analogous but not identical forms. Therefore, if assessed in an absolute sense this would be classed as a loss of terrain and soil when in fact it is primarily a change in type and distribution of the units, as shown in Tables F8-3 and F8-4.

For the naturally occurring terrain and soil units, the residual impacts and degrees of concern would be identical; as would be the affects of the Project alone and developments considered in the scenario. As shown in Table F8-5 the negative impacts on the natural terrain and soil units would be completely offset by the positive impacts on reclaimed terrain and soil units. Therefore, at closure, the overall net impact of both the Project and the developments in the CEA scenario will be negligible with a negligible degree of concern.

Table F8-5 Residual Impacts and Degrees of Concern - Terrain and Soil Units

	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Level of Certainty	Degree of Concern
Natural Units	Negative	Low	Regional	Long-Term	Irreversible	Low	High	Moderate
Reclaimed Units	Positive	Low	Regional	Long-Term	Irreversible	Low	High	Moderate

F8.4.2 Key Question TSCEA-2: Will Combined Developments Alter Soil Capability and Sensitivity?

This question addresses two discrete soil parameters - soil capability, defined as the potential to support forest ecosystems, and soil sensitivity, defined as the susceptibility of a soil to acidifying inputs.

Soil Capability

Soil capability for the RSA was evaluated in the same manner as for the LSA, a detailed description of this method may be found in Section E8 of this EIA. Table F8-6 details the extent of soils in the RSA that fall within the five capability classes outlined by Leskiw (1997), their distribution is shown in Figure F8-3. Table F8-7 shows the changes in capability class areas in the RSA due to the Project and CEA developments.

Analysis of the Key Question

The impacts on forest capabilities in the RSA by development are shown in Table F8-7; however, since the impact of the Project is somewhat different in nature than those of the approved developments, the two components are best reviewed separately.

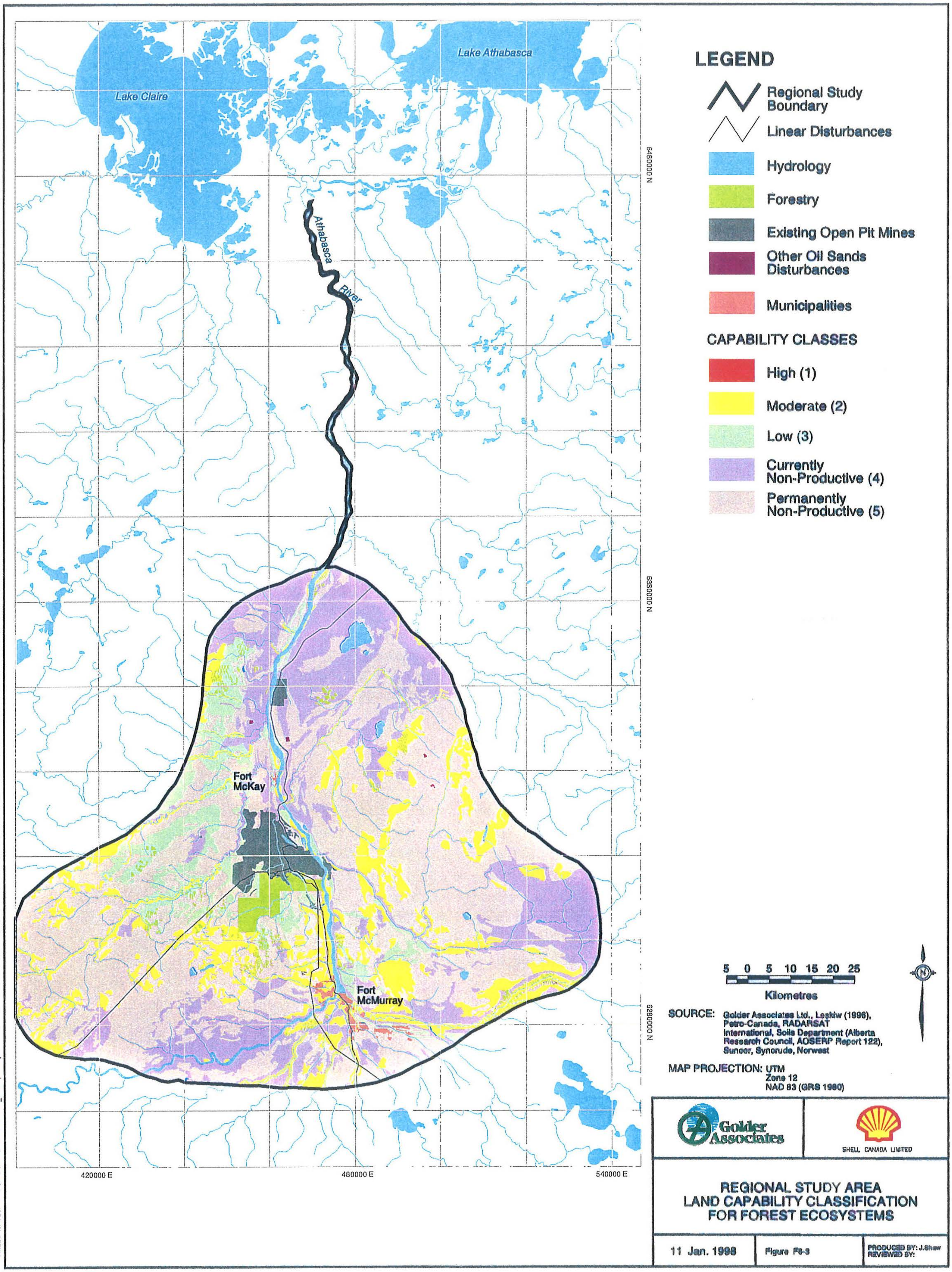

Lake Athabasca
Lake Claire
Athabasca River
Fort McKay
Fort McMurray
6480000 N
6380000 N
6280000 N
420000 E
460000 E
540000 E
LEGEND
Regional Study Boundary
Linear Disturbances
Hydrology
Forestry
Existing Open Pit Mines
Other Oil Sands Disturbances
Municipalities
CAPABILITY CLASSES
High (1)
Moderate (2)
Low (3)
Currently Non-Productive (4)
Permanently Non-Productive (5)
5 0 5 10 15 20 25
Kilometres
SOURCE: Golder Associates Ltd., Leskiw (1996), Petro-Canada, RADARSAT International, Soils Department (Alberta Research Council, AOSERP Report 122), Suncor, Syncrude, Norwest
MAP PROJECTION: UTM
Zone 12
NAD 83 (GRS 1980)
Golder Associates
SHELL CANADA LIMITED
REGIONAL STUDY AREA
LAND CAPABILITY CLASSIFICATION
FOR FOREST ECOSYSTEMS
11 Jan. 1998
Figure F8-3
PRODUCED BY: J.Shaw
REVIEWED BY:

Table F8-6 Soil Capabilities for Forest Ecosystems in the RSA

Capability Class	Area, ha	Area, % of RSA
Class 1[(a)]	0	0.0
Class 2	145,337	13.8
Class 3	88,548	8.4
Class 4	210,560	20.0
Class 5	567,991	54.0
AIM[(b)]	30,941	2.9
NWL[(c)]	4,434	0.4
Infrastructure	0	0.0
Existing Reclamation	3,600	0.3
Total	**1,051,411**	**100.0**

(a) No soils in the RSA were rated as Class 1.
(b) Disturbed lands and cultural features.
(c) Open water, rivers, streams and lakes.

As shown in Table F8-7 there are 30,941 ha of existing disturbed lands and another 3,600 ha of reclaimed lands which cannot be placed in a capability class; however, since 25,273 ha of the former and all of the latter will ultimately be returned to productive status they must be considered herein. The impact of the Project will be on 1175 ha of class 4 (14% of the CEA impact) and 3,161 ha of class 5 (28% of CEA impact) lands currently rated as non-productive. All of the former and 2188 ha of the latter will reclaimed to low productivity class 3 land. For context, at closure class 2 land will increase by 7,097 ha; class 3 by 17,102 ha; and class 4 by 2,477 ha while class 5 will decrease by 1,297 ha and presently existing disturbances by 25,273 ha.

Residual Impacts and Degrees of Concern

Land capability for forest ecosystems is a function of the combined interactions of terrain and soil, hence alterations in these components will alter the capabilities. Evaluation of the data in Table F8-7 allows the assignment of the residual impacts and degrees of concern displayed in Table F8-8. At closure the impacts of both the Project and the CEA scenario will be an overall enhancement of forest capabilities in the RSA, existing disturbed soils and those in currently non-productive classes 4 and 5 will be reclaimed to low productivity class 3 and moderately productive class 2 lands.

Table F8-7 Changes in the Distribution of Soil Capability Classes due to Combined Development

Class	Baseline RSA[a]		Muskeg River Mine Impact[b]		Muskeg River Mine Far Future		CEA[c] Impact[b]		CEA[c] Far Future		Final Landscape		Changes in baseline[b]	
	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%	(ha)	RSA%
1	0	0.0	0	0.0	0	0.0	0	0.0	50	0.0	150	0.0	150	0.0
2	145,337	13.8	7	0.0	0	0.0	2,732	0.3	3,701	0.4	153,059	14.6	7,722	0.7
3	88,548	8.4	0	0.0	3,363	0.3	431	0.0	8,710	0.8	107,910	10.3	19,362	1.8
4	210,560	20.0	1,175	0.1	0	0.0	8,214	0.8	3,741	0.4	212,602	20.2	2,042	0.2
5	567,991	54.0	3,161	0.3	444	0.0	11,221	1.1	2,952	0.3	564,144	53.7	-3,847	-0.4
Disturbed Land (AIM)[d]	30,941	2.9	0	0.0	0	0.0	0	0.0	0	0.0	5,668	0.5	-25,273	-2.4
All Water (NWL)[e]	4,434	0.4	0	0.0	536	0.1	0	0.0	3,024	0.3	7,458	0.7	3,024	0.3
Infrastructure	0	0.0	0	0.0	0	0.0	0	0.0	420	0.0	420	0.0	420	0.0
Existing Reclamation	3,600	0.3	0	0.0	0	0.0	0	0.0	0	0.0	0	0.0	-3,600	-0.3
TOTAL	**1,051,411**	**100.0**	**4,343**	**0.4**	**4,343**	**0.4**	**22,598**	**2.1**	**22,598**	**2.1**	**1,051,411**	**100.0**	**0**	**0.0**

(a) Undeveloped plus revegetated land (not classified).
(b) Incremental changes.
(c) Cumulative effects of project and approved developments (does not include forestry as forestry operation does not change forest capability).
(d) AIM: disturbed lands and cultural features.
(e) NWL: open water, rivers and stream channels - data from Turchenek and Lindsay (1982); therefore, less than remotely sensed areas in Sections F9 and F10.

Table F8-8 Residual Impacts and Degrees of Concern for Forest Capabilities Due to Combined Developments.

Capability Class	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Level of Certainty	Degree of Concern
1	Negligible	Low	Regional	Long-Term	Irreversible	Low	High	Negligible
2	Positive	Low	Regional	Long-Term	Irreversible	Low	High	
3	Positive	Low	Regional	Long-Term	Irreversible	Low	High	
4	Positive	Low	Regional	Long-Term	Irreversible	Low	High	
5	Negative	Low	Regional	Long-Term	Irreversible	Low	High	Moderate
Disturbed	Negative	Low	Regional	Long-Term	Irreversible	Low	High	Moderate

Soil Sensitivity

The second parameter, soil sensitivity, is evaluated in the context of the capacity of the soils in the RSA to resist the acidifying effects of anthropogenic inputs, i.e., emissions from industrial sources. Generally the potentially acidifying emissions in studies of this nature are oxides of sulfur (SO_x) and oxides of nitrogen (NO_x).

Holowaychuk and Fessenden (1987) have classified and mapped potential susceptibility of soils in the province to acid deposition as well as providing assessments of the capacities of both the surface soils and substrates to buffer acid inputs. Since the mapping and evaluations were done at a scale of 1:2,000,000, the degree of generalization involved is necessarily broad, however, the trends presented are valid. More than 50% of the RSA is covered by organic soils that are inherently acidic and have a low buffering capacity. Therefore, these soils may be considered to have a high sensitivity to acidic inputs.

The rest of the RSA is made up of mineral soils which, except for those along the major river valleys, are rated as being moderately resistant to acidification. For this assessment all the soils east of the Athabasca River are rated as being highly susceptible to acidifying inputs whereas the majority of those west of the Athabasca River are rated as moderately susceptible (Holowaychuk and Fessenden 1987). When the substrate is considered, the majority of the RSA east of the Athabasca River is rated as having a medium potential to neutralize acidic inputs whereas most the of the area west of the river is rated as having a high potential, i.e., the characteristics of the surficial geology enhance significantly the capacity of the soils to neutralize acidic deposition (Holowaychuk and Fessenden 1987).

With respect to the buffering capabilities of mineral substrates underlying the organic deposits in the RSA some further comments are in order. Since many of the organic deposits are on the order of 1 metre in depth, or greater, the contribution of the subsoil with respect to offsetting acidic inputs at the surface is questionable. What is more certain is that the removal or buffering of these inputs is highly dependent on the rate of flow and chemical composition of the surface and near surface water. Mesotrophic fens are characterized by significant rates of recharge due to horizontal flow, these waters may influence potential acidification by: flushing out concentrations of acidic ions and/or, replacing mobilized bases with dissolved cations. Substrate materials are unlikely to have much impact on surface acidic inputs until, and unless, they are incorporated in the reclamation soil mixture applied to the reconfigured terrain features and, obviously, this will affect only the development areas and be highly contingent on the specific characteristics of those materials - generalizations would therefore be misleading.

Analysis of the Key Question

The assessment of soil sensitivities, buffering capabilities and potential acidification is not straightforward. "The impacts of acidic deposition on aquatic and terrestrial ecosystems are difficult to predict, because the effects are exceedingly complex, subtle and long-term. Furthermore, every ecosystem has a different inherent capacity to resist acidification." (Cheng and Angle 1993, p. 1). A variety of parameters must be taken into account when endeavoring to evaluate the potential effects of anthropogenic emissions on soil properties, including:

- the composition and volumes of the emissions;
- the distribution of the sources, assuming more than one point source;
- the capacity of the atmosphere to neutralize acidic ions (Cheng and Angle [1993] and White [1983] have noted, "Alberta's atmosphere has a high concentration of ammonia which reacts with sulfurous ions to neutralize them - an atmospheric buffering effect.");
- Long Range Transport of Atmospheric Pollutants (LRTAP) - it is estimated that up to 50% of locally produced emissions are advected out of the immediate vicinity, therefore a direct emission to deposition correlation is not possible;
- seasonal variations in wind direction and velocity, atmospheric stability and precipitation scavenging (wet versus dry); and
- the time scale under consideration; Bloom and Grigal (1985) use initial, plus 100, 200 and 500 year scenarios in modelling of soil responses to acidic deposition.

All of these variables introduce their own degrees of uncertainty when attempting to complete a CEA of acidic emissions on potentially sensitive soils. Substantial background discussions on emission impacts may be found in Section E8 and Section F2 (Air Quality) of this EIA.

The World Health Organization has proposed critical loading factors for potential acid input (PAI) for sensitive ecosystems of 0.25 keq/ha/a and 0.50 keq/ha/a for moderately sensitive ecosystems (WHO 1994). Using these values in conjunction with data from Section F2 of the RSA for baseline and approved development scenarios (Figure F8-4) respectively, one may draw some reasonable but qualitative conclusions. As indicated in Figure F8-4, and described in Section E8, PAI values in the immediate vicinity of the existing and approved developments either do at present or will, once the facilities are in operation, exceed the critical loading benchmarks. It follows, therefore, that potential soil acidification would have the greatest likelihood of occurring in these same areas. However, it must be emphasized that the PAI values are for operational maxima, whereas in reality they will be phased in as the various developments come on-stream, then cease completely at the end of development.

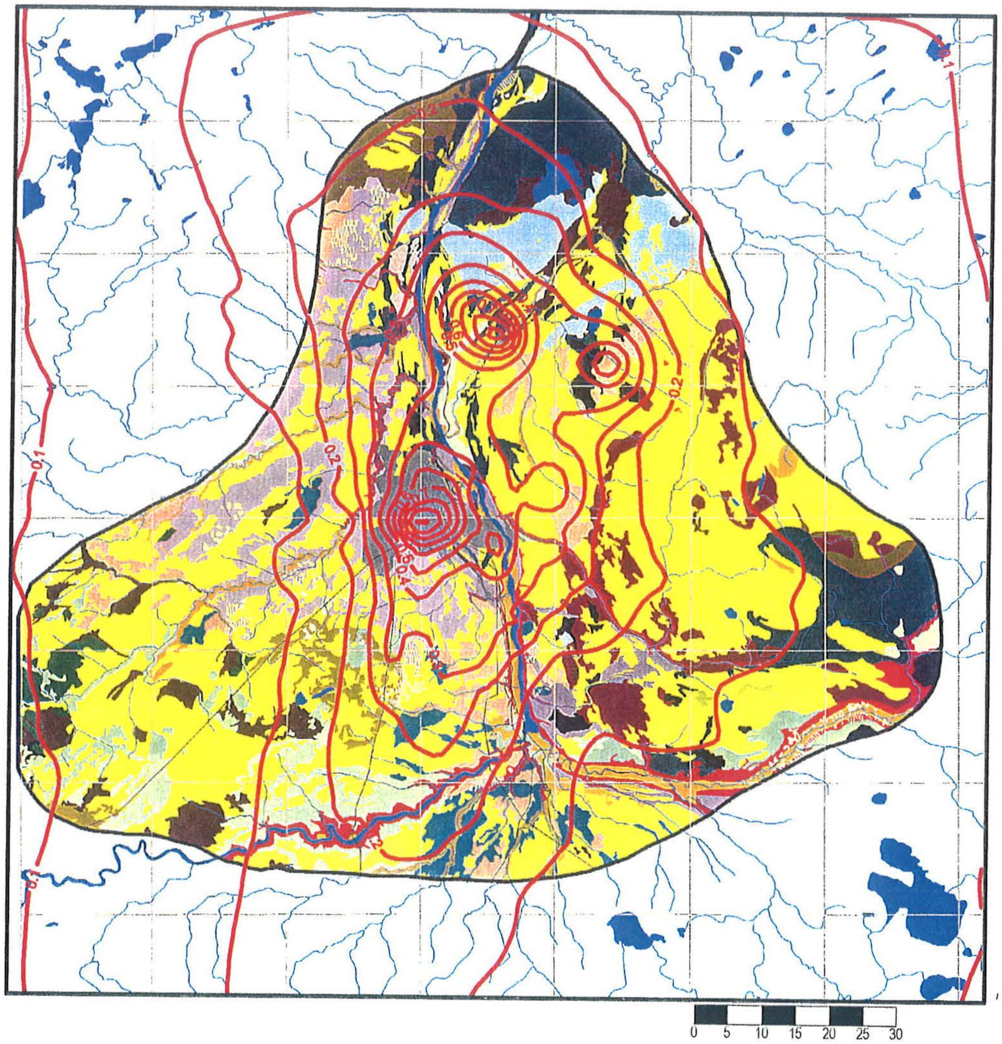
F8.4.3 Key Question TSCEA-2: Will Combined Developments Alter Soil Capability and Sensitivity?

As discussed at length in Section F2 - Air Quality, it is estimated that Project emissions will increase the area within which the 0.25 keq/ha/a loading factor is surpassed from 150,000 ha to 180,000 ha and for the full CEA scenario the area increases further to 250,000 ha. Therefore direct Project attributable impacts will encompass an additional 30,000 ha or 2.9% of the RSA. These and comparable data for the 0.50 keq/ha/a area are shown in Table F8-9.

Table F8-9 PAI Emissions in the RSA

PAI Criteria	Baseline ha/%RSA	Baseline + Project ha /%RSA	Baseline + Project + Approved ha/%RSA
>0.25 keq/ha/a	150,000/14.3	180,000/17.1	≈ 50,000/23.8
>0.50 keq/ha/a	15,500/1.5	19,000/1.8	31,500/13.0

One of the key unknown relationships in this sort of assessment is the length of time required for sustained acidic inputs to have measurable impacts on soil properties - as noted above, Bloom and Grigal (1985) looked at intervals in the hundreds of years in this context. The second, and equally critical, unknown variable is that the level of correlation between PAI and soil acidification is speculative at best. Roberts and Reiger 1989 (cited in BOVAR 1996a, Aurora Mine EIA) indicate that despite high predicted estimated acidity levels (EA has been replaced by PAI as a measurement parameter), no trends suggesting soil acidification which might be attributed to development-related activities have been found in northeastern Alberta.



5 0 5 10 15 20 25
Kilometres

SOURCE: Golder Associates Ltd., Leskiw (1996), Petro-Canada, RADARSAT International, Soils Department (Alberta Research Council, AOSERP Report 122), Suncor, Syncrude, Norwest

MAP PROJECTION: UTM
Zone 12
NAD 83 (GRS 1980)

LEGEND

- PAI Isopleths
- Regional Study Boundary
- Linear Disturbances
- Hydrology
- Forestry
- Existing Open Pit Mines
- Other Oil Sands Disturbances
- Municipalities

SOIL CLASSIFICATION

- Algar
- Bitumount
- Disturbed Lands & Cultural
- Dover
- Eaglesham (McLelland)
- Firebag
- Horse River
- Heart
- Joslyn
- Kearl
- Kinosis
- Kenzie
- Livock (Fort)
- Mildred
- Mikkwa
- McMurray
- Namur
- Rough Broken
- Ruth Lake
- Surmont
- Steepbank

Golder Associates

SHELL CANADA LIMITED

RSA BASELINE SOIL CLASSIFICATION WITH ANNUAL POTENTIAL ACID INPUT (PAI) - CEA

16 Jan. 1998 | Figure F8-4 | PRODUCED BY: J.Shaw REVIEWED BY:

Residual Impacts and Degrees of Concern

Given the potentially high level of imprecision in evaluating the acidifying emission-PAI-soil acidification linkages and required input time frames it is difficult to define either residual impacts or degrees of concern in a quantitative manner. Potential acid inputs are discussed at length in Section F2, the assessment of residual impacts and degrees of concern that follow are based on the estimated affects these input levels may have on soils. Table F8-10 provides the residual impacts and degrees of concern associated with the Project.

Table F8-10 Residual Impacts and Degrees of Concern Associated With Potential Soil Acidification Due to the Project

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Level of Certainty	Degree of Concern
Soil acidification Potential	Negative	Low	Regional	Project life	Irreversible	Continuous	Low	Low to - Moderate

Since the PAI to soil acidification relationship is poorly defined, the degree of concern associated with potential soil acidification due to Project emissions is Low to Moderate.

Table F8-11 provides similar data for the CEA scenario.

Table F8-11 Residual Impacts and Degrees of Concern Associated With Potential Soil Acidification Due to the Project and Approved Developments

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Level of Certainty	Degree of Concern
Soil acidification Potential	Negative	Moderate	Regional	Project life	Irreversible	Continuous	Low	Moderate to High

F8.5 Summary of Impacts

Table F8-12 summarizes the predicted impacts and corresponding concern levels identified in the cumulative effects assessment for terrain and soils.

Table F8-12 Summary of Predicted Impacts

Key Question	CEA Results
TSCEA 1: Will combined developments alter the quantity and distribution of terrain and soil units ?	• During construction and operations phases the combined developments will cause a loss of 2.1% of the natural terrain and soil units in the RSA, the impacts associated with this are estimated to be: Negative in direction, Low in magnitude, Regional in extent, of Long-Term duration, Irreversible, Low in frequency with a High level of certainty. This will generate a **Moderate** degree of concern. • This is a worst case perspective as it is unlikely that all sites will be developed to their maximum extent concurrently. The phased nature of development and reclamation will mediate the degree of concern. • Reclamation of the developed areas with reconfigured terrain units covered by a reclamation soil mixture will produce very Positive impacts by increasing the diversity of terrain units.
TSCEA 2: Will combined developments alter soil capability and sensitivity ?	• As a result of alterations in the quantity and distribution of soil and terrain units between the pre-development and closure landscapes, changes in soil capability will be produced. These are estimated to be: Positive in direction. The positive direction of change is the result of significant areas of non-productive class 4 and 5 land being reclaimed to low and moderately productive classes 2 and 3. • Operational activities of the developments will increase the levels of potentially acidifying emissions released into the RSA air shed. The impacts are estimated to be: Negative in direction, Moderate in magnitude, Regional in extent, lasting for the specific project lifespans, Irreversible, continuing in frequency (for the duration of production) with a **Moderate** to **High** degree of concern. Associated with this is a low level of certainty as the PAI-soil acidification linkage is ill-defined.

F9 TERRESTRIAL VEGETATION CUMULATIVE EFFECTS ANALYSIS

F9.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on terrestrial vegetation in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- Muskeg River Mine Project
- Gibsons Petroleum
- Municipalities
- Syncrude Mildred Lake
- Syncrude Aurora North and South
- SOLV-EX
- Forestry
- Pipelines, roadways and others

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

F9.2 Approach and Methods

The approach used to access ELCs for the CEA is consistent with Section E. The methodology employed to map and assess vegetation diversity is described in Section E9. This vegetation assessment includes all developments described in Section F7 (ELCs) as well as Forestry developments, which were not included in Sections F7 or F8 (Terrain and Soils).

Mapping

Vegetation was mapped using Landsat imagery and a geographical information system (GIS) to allow the relative abundance of plant communities to be compared within the RSA. By superimposing baseline, the Muskeg River Mine Project and approved development plans over the existing vegetation polygons, the distribution and amounts of each plant community affected can be quantified and an assessment of significance made using the criteria previously described. Similarly, by superimposing the successive reclamation activities onto the combined development area, the progression of revegetation can be quantified and monitored.

This classification is at a coarser scale than completed for the local study area, which is reflected in slight differences in area calculations for baseline and impact values for the Project.

Landsat Thematic Mapper Satellite imagery was collected for two areas ("scenes") July 1994 and July 1996 respectively. The majority of RSA was covered with the more recent 1996 imagery; however, due to cloud cover constraints small portions in the north and south of the RSA were covered by the 1994 imagery. A supervised classification of the imagery was undertaken that included the selection of a number of "training" or test areas determined from information collected from aerial photographs, Alberta Phase 3 Forest Inventory Maps, Alberta Vegetation Inventory Maps (AVI), Vegetation Maps produced for oil sands projects, Soil Inventory Maps of the Alberta Oil Sands Environmental Research Program (AOSERP) and a 1997 field investigation. An accuracy assessment of the classified imagery based on field data collected in July 1997 indicated a final overall accuracy of 80% (Golder 1997n: Terrestrial Vegetation Baseline Report).

Biodiversity Measurements

Vegetation diversity was measured using the same methodology as detailed in Section E9.

F9.3 Potential Linkages and Key Questions

TVCEA-1: **Will Combined Developments, Their Reclamation and Closure, Result in a Loss or Alteration of Vegetation Communities?**

TVCEA-2: **Will Combined Developments Result in a Change in Vegetation Diversity?**

TVCEA-3: **Will Air Emissions From Combined Developments Result in a Change in Vegetation Health?**

F9.4 Analysis and Results

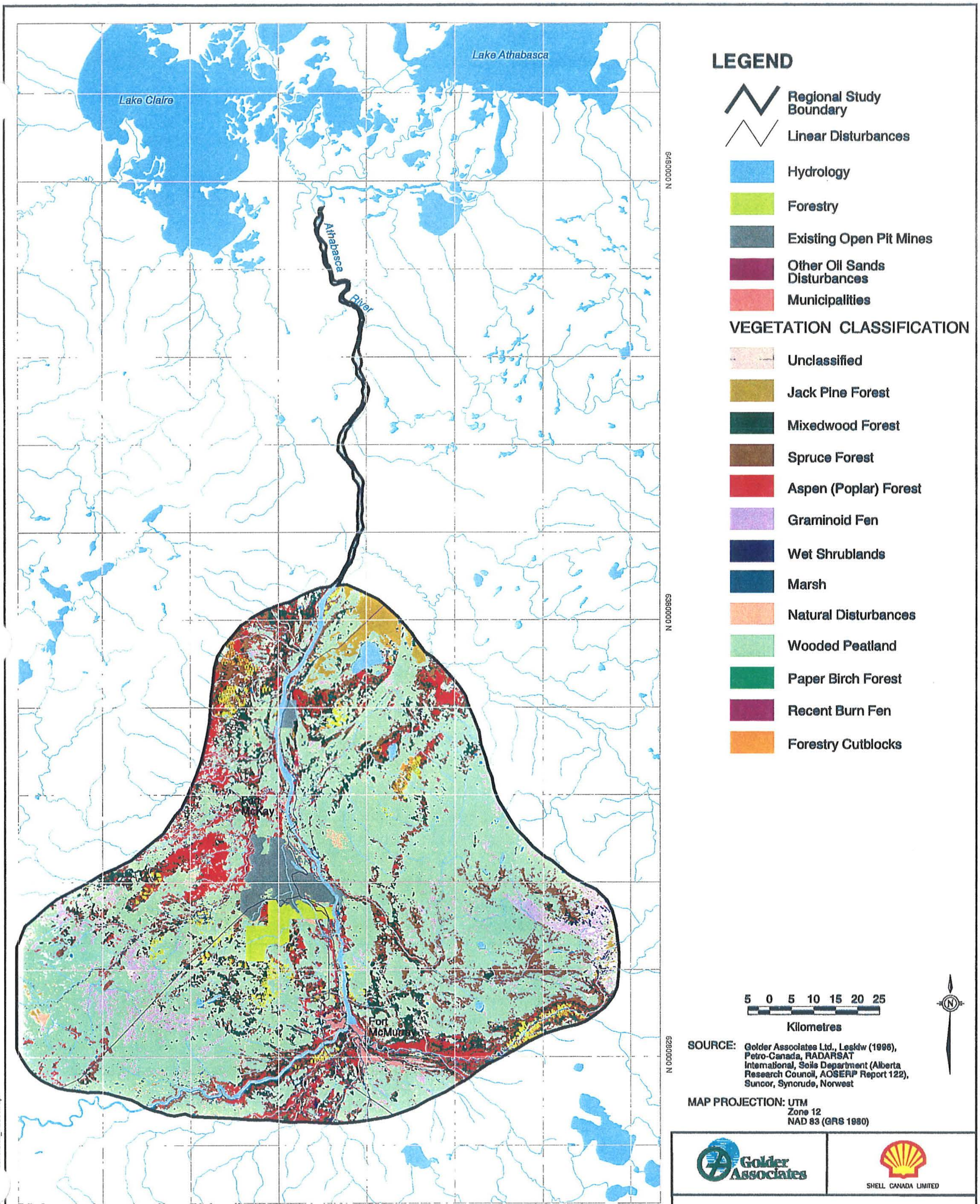
F9.4.1 Key Question TVCEA-1: Will Combined Developments Result in a Loss or Alteration of Vegetation Communities?

Analysis of Potential Linkages

The linkages are consistent with Section E9. Hydrogeology, however, is not a valid linkage for this CEA. The effects of hydrogeology (i.e., surficial aquifer drawdown) is best assessed on an individual project basis. Figure F9-1 shows the vegetation communities in the RSA.

Analysis of Key Question

The developments addressed in the RSA for the CEA scenarios are shown in Table F7-1.



REGIONAL STUDY AREA
VEGETATION CLASSIFICATION

11 Jan. 1998 | Figure F9-1 | PRODUCED BY: J.Shaw REVIEWED BY:

Loss/Alteration of Plant Communities

The vegetation resources of the RSA will be affected by the combined developments direct and losses and alterations. The vegetation types (ecosite phases) currently occupying the RSA and those that will be cleared for the Project and approved Developments are shown in Table F9-1.

Direct Losses/Alterations

There are approximately 6,409 ha which could not be classified through Landsat Imagery in the RSA (Table F9-1). Approximately 30,941 ha has been previously disturbed within the RSA, through anthropogenic disturbances, accounting for approximately 5.2% of the RSA (Table F9-1). An additional 3,600 ha are in reclamation stages. Existing forestry disturbances occupy 13,443 ha or 1.3% of the RSA. Therefore, the total baseline disturbance to vegetation is 47,984 ha or 4.3% of the RSA. This baseline disturbance could not be separated to pre-development vegetation classes due to lack of information.

Construction of the Project will result in the clearing of 4,343 ha (0.4% of the RSA). Approved developments (including forestry) will contribute 84,054 ha or 8.0% with a combined cumulative impact of approximately 88,397 ha or 8.4%.

Forestry disturbances, which account for 65,799 ha of the CEA, are predicted to be reclaimed to the same ecosite phases as predisturbance. Oil sands developments account for 22,598 ha in the RSA and is predicted to reclaim some permanently lost wetland classes such as fens and bogs to some upland vegetation types.

Within Upland (terrestrial) plant communities, the greatest impacts occur within the blueberry and low-bush cranberry ecosites (b1,b3,d2), where 11,285 ha will be cleared (1.1% of the RSA). The Project accounts for 648 ha, or 0.1% of this loss and approved developments will contribute 0.2%. A total of 17,030 ha or 1.6% of the RSA will be reclaimed to these ecosite phases. This will increase the baseline amount of blueberry and low-bush cranberry ecosite phases (b1,b3,d2) to 121,054 ha (11.5%) from 115,309 ha (11.0%) (or an increase of 5745 ha).

Lichen-jack pine (a1 with some b4) will be reduced by 2,928 ha (0.3). The Project will not affect this ecosite phase, however, it will reclaim 596 ha to this type. The combined developments will reclaim a total of 4,455 ha, or 0.4% in the RSA. This will increase baseline Lichen-jack pine from 15,278 ha (1.5%) to 16,805 ha or 1.6% in the RSA.

Blueberry-aspen-white birch (b2) will be reduced by 190 ha. The Project will not affect this ecosite phase. However, the project will reclaim 102 ha of this ecosite phase. Overall, baseline blueberry-aspen-white birch (b2)

Table F9-1 Baseline, Developed and Post-Clsoure Terrestrial Vegetation and Land Cover Types in the RSA

Wetland Types		Baseline		Muskeg River Mine Project				CEA				Final Landscape	
				Impacts		Far Future		Impacts		Far Future			
Map Codes	Ecosite Phases	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
a1 with some b4	Lichen Jack Pine	15,278	1.5	0	0.0	596	0.1	2,928	0.3	4,455	0.4	16,805	1.6
b1,b3,d2	Blueberry Pj-Aw, Aw-Sw; Low-bush cranberry Aw-Sw	115,309	11.0	648	0.1	1,019	0.1	11,285	1.1	17,030	1.6	121,054	11.5
b2	Blueberry Aw(Bw)	1,132	0.1	0	0.0	102	0.0	190	<0.1	584	0.1	1,526	0.1
d1	Low-bush cranberry (Aw)	81,511	7.8	39	<0.1	96	0.0	7,056	0.7	7,519	0.7	81,974	7.8
d3,e3	Low-bush cranberry Sw, Dogwood Sw	76,084	7.2	120	<0.1	1,550	0.1	7,120	0.7	8,905	0.8	77,869	7.4
e1,e2	Dogwood Pb-Aw, Pb-Sw	4,039	0.4	0	0.0	0	0.0	63	<0.1	354	<0.1	4,330	0.4
	Sub-Total (Terrestrial Vegetation)	293,353	27.9	807	0.1	3,363	0.3	28,642	2.8	38,847	3.7	303,558	28.9
	Sub-Total (Wetlands)	684,449	65.1	3,344	0.3	0	0	54,834	5.2	42,116	4.0	671,731	63.9
	Anthropogenic Disturbances	30,941	2.9	175	<0.1	0	0.0	33,133	3.2	1,349	0.1	30,032	2.9
	Forestry Disturbance	13,443	1.3	0	0.0	0	0.0	15,474	1.5	658	0.1	12,070	1.1
	Reclaimed Unit	3,600	0.3	0	0.0	0	0.0	3,600	0.3	0	0.0	3,600	0.3
	Sub-Total (Disturbances)	47,984	4.6	175	<0.1	0	0.0	52,273	5.0	2,007	0.2	45,702[(a)]	4.3
	Water	19,216	1.8	17	<0.1	536	0.1	454	<0.1	3,444	0.3	22,206	2.1
	Wetlands	0	0.0	0	0.0	444	<0.1	0	0.0	1,385	0.1	1,385	0.1
	Infrastructure	0	0.0	0	0.0	0	0.0	0	0.0	420	<0.1	420	0.0
	Unclassified	6,409	0.6	0	0.0	0	0.0	178	<0.1	178	<0.1	6,409	0.6
	Total	**1,051,411**	**100.0**	**4,343**	**0.4**	**4,343**	**0.4**	**136,381**	**13.0**	**88,397**	**8.4**	**1,051,411**	**100.0**

(a) Most of this area will be reclaimed; not defined in this table as reclamation types are not available will increase due to reclamation from 1,132 ha at baseline to 1,526 ha (0.1%) in the RSA.

Baseline low-bush cranberry-aspen (d1) accounts for 81,511 ha or 7.8 in the RSA. The Project will clear only 39 ha and the combined developments will clear 7,056 ha, or 0.7% of the RSA. The Project will reclaim 96 ha and combined developments 7,519 ha, thereby increasing the amount of low-bush cranberry-aspen (d1) in the RSA by 463 ha to 81,974 ha, or 7.8%.

Baseline Low-bush cranberry-white spruce (d3) and dogwood-white spruce represent 4,039 ha or 0.4% in the RSA. The Project will clear 120 ha with combined developments clearing a total of 7,120 ha (0.7%). The Project, therefore, contributes only a small proportion of this loss. However, the Project will reclaim 1,550 ha with combined developments reclaiming a total of 8,905 ha. Baseline Low-bush cranberry-white spruce (d3) and dogwood-white spruce will therefore increase to 77,869 or 7.4% of the RSA.

Baseline dogwood balsam poplar-aspen and balsam poplar-white spruce (e1,e2) is 4,039 ha or 0.4% of the RSA. The Project will not affect this ecosite phase, however, other developments will clear 63 ha and reclaim 354 ha. Dogwood balsam poplar-aspen and balsam poplar-white spruce (e1,e2) will increase from 4,049 ha at baseline to 4,330 ha in the Final Landscape.

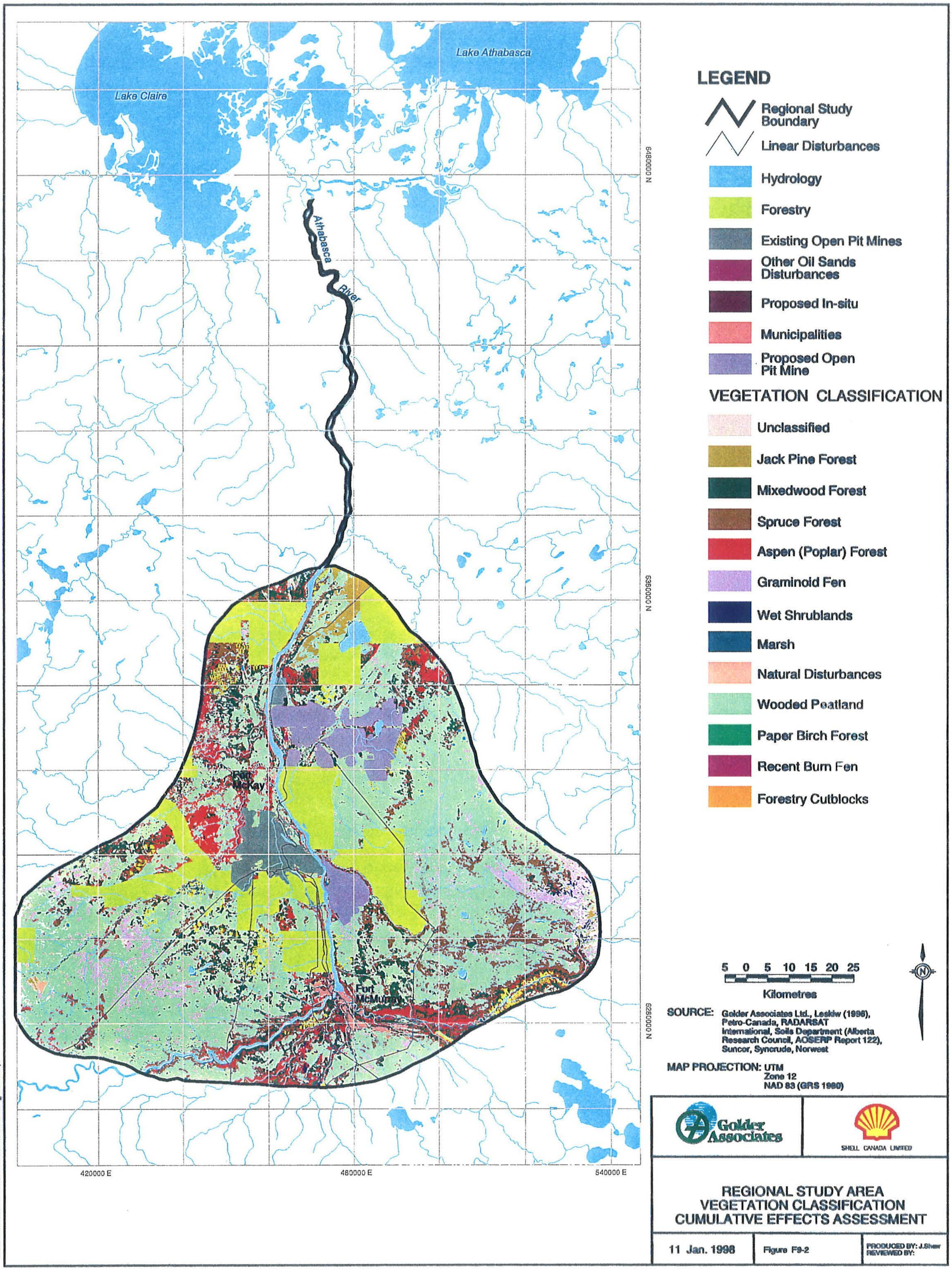
In general, the direct impacts to the vegetation resources do not cumulatively represent a significant reduction. Some vegetation types such as fens and bogs will represent a permanent loss of some of that resource, however several upland ecosite phases will be replaced during reclamation. In addition, loss/alteration to vegetation will be phased over the construction and operation phases of development.

As development proceeds, so sequential reclamation and revegetation will take place to minimize the area of disturbance at any one time and to initiate revegetation in conjunction with development conservation and reclamation (C&R) plans. Reclamation and revegetation will therefore result in a series of multi-aged vegetation communities at a variety of successional stages. This is important for wildlife habitat utilization and resource use.

The effects of existing Project and approved developments on the vegetation in the RSA is shown in Figure F9-2.

Old-Growth Forests

The RSA supports very few forest communities classified as "old-growth". This conclusion is based on field inventory results and a search of forest age


Lake Athabasca
Lake Claire
Athabasca River
Fort McKay
Fort McMurray
6480000 N
6360000 N
6280000 N
420000 E
480000 E
540000 E
LEGEND
Regional Study Boundary
Linear Disturbances
Hydrology
Forestry
Existing Open Pit Mines
Other Oil Sands Disturbances
Proposed In-situ
Municipalities
Proposed Open Pit Mine
VEGETATION CLASSIFICATION
Unclassified
Jack Pine Forest
Mixedwood Forest
Spruce Forest
Aspen (Poplar) Forest
Graminoid Fen
Wet Shrublands
Marsh
Natural Disturbances
Wooded Peatland
Paper Birch Forest
Recent Burn Fen
Forestry Cutblocks
5 0 5 10 15 20 25
Kilometres
N
SOURCE: Golder Associates Ltd., Leskiw (1996), Petro-Canada, RADARSAT International, Soils Department (Alberta Research Council, AOSERP Report 122), Suncor, Syncrude, Norwest
MAP PROJECTION: UTM Zone 12 NAD 83 (GRS 1980)
Golder Associates
SHELL CANADA LIMITED
REGIONAL STUDY AREA
VEGETATION CLASSIFICATION
CUMULATIVE EFFECTS ASSESSMENT
11 Jan. 1998
Figure F9-2
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REVIEWED BY:

records maintained by Alberta Environmental Protection (AEP). Tree age criteria for old-growth forests has been defined for this area as outlined in Section E9.

The two forest communities most likely to support old-growth forests included aspen-white spruce forests and lichen-jack pine forests. These are described in Section E9. A description of commerical forestry under the CEA is provided in Section F14 - Resource Use.

Rare or Endangered Terrestrial Plant Species or Communities

Rare plants often require unique habitat types, a number of which were observed in the RSA including the Project. Rare plants are found to a limited extent in upland locations depending upon the species requirements (Table E9-4). Cumulative effects to rare plants are discussed in Section F10 - Wetlands.

Traditional Plants (Food, Medicinal and Spiritual)

A description of traditional plants is provided in Section E9. Due to the generalized vegetation classification of the RSA and the widespread habitat requirements, traditional plants identified may be found in multiple ecosite phases within the RSA. Accordingly, many of the plants can potentially be found over large areas within the RSA.

As most of the traditional plants are widespread in the RSA losses associated with the Muskeg River Mine Project and combined developments are equally distributed across all species. Many wetlands ecosites, such as wooded fens, are lost because of oil sands developments; however, the wide distribution and abundance of fens within the RSA (65%) will result in a negligible loss in traditional plants within the RSA.

Residual Impact Classification and Degree of Concern

A total of 28,642 ha of terrestrial vegetation will be removed to develop the Muskeg River Mine Project and other developments. A total of 38,847 ha will be reclaimed by the combined developments. This will increase baseline terrestrial vegetation from 293,353 ha (27.9%) to 303,558 ha (28.9%) in the RSA.

The impact to terrestrial vegetation is Low in magnitude, Regional in geographical extent, Short-Term in duration and of a Low degree of concern.

F9.4.2 Key Question TVCEA-2: Will Combined Developments Result in a Change in Vegetation Diversity?

Analysis of Key Question

Table F9-3 provides a general regional vegetation patch size or "polygon" summary. Patch size (Table F9-3) will not be affected by the Project alone. Average patch size for Lichen Jack Pine will decrease by 1.293 ha as a result of the CEA. The range in patch size will not be affected. Average patch size for Blueberry-Low-Bush Cranberry (b1, b3, d2) will decrease by approximately 0.5 ha from 21.5208 ha to 26.0155 ha. Average patch size for Dogwood (e1, e2) will increase by approximately 1.1 ha. Overall, patch size for terrestrial vegetation does not change substantially such that regional vegetation diversity.

Residual Impact Classification and Degree of Concern

The residual impact classification of changes in biodiversity of terrestrial vegetation communities for the combined developments is Negative in direction, Low in magnitude, Regional in extent and of Short-Term duration. The degree of concern is Low.

Pre-development biodiversity indices (e.g., patch size), along with end land use objectives assisted in the design of the final reclamation plan.

F9.4.3 Key Question TVCEA-3: Will Air Emissions From Combined Developments Result in a Change in Vegetation Health?

Analysis of Potential Linkages

A discussion of the key air emission inputs are discussed in the Air Quality Cumulative Effects Section (F2) of this EIA. The linkages are consistent with Section E9.

Analysis of Key Question

As discussed in Section E9, airborne emissions from oil sands operations can have both short and long-term effects on vegetation vigour and health. Short-term exposure effects are usually restricted to a localized area and can include chlorosis or necrosis of plant tissues that can decrease growth rates or eventually result in plant mortality. Long-term effects can occur over a much larger area (RSA) and may result from the accumulation of contaminants in plant tissues, either by direct absorption into plant tissues from the air, or indirectly through deposition into the soil and into the roots.

Table F9-3 Patch size of Terrestrial Vegetation at Baseline and CEA

Map Code	Ecosite Phase	Baseline Patch Size (ha)			CEA Patch Size (ha)			Change in Patch Size (ha)		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
a1 (with some b4)	Lichen Jack Pine	0.0280	7063.5690	110.2352	0.0280	7063.5690	108.9422	<0.0001	<0.0001	1.2930
b1,b3,d2	Blueberry Pj-Aw, Aw-Sw; Low-bush cranberry Aw-Sw	0.0020	4090.2970	26.5208	<0.0001	4090.2970	26.0155	0.0020	<0.0001	0.5053
b2	Blueberry Aw(Bw)	0.0620	80.7980	8.9449	0.0620	80.7980	8.1382	<0.0001	<0.0001	0.8067
d1	Low-bush cranberry (Aw)	0.0010	10659.2700	37.4836	<0.0001	10659.2720	37.6221	0.0010	-0.0020	-0.1385
d3,e3	Low-bush cranberry Sw, Dogwood Sw	<0.0001	2587.1970	18.7199	<0.0001	2587.1970	18.6862	<0.0001	<0.0001	0.0337
e1,e2	Dogwood Pb-Aw, Pb-Sw	0.0040	45.1250	8.1036	0.0040	45.1250	9.1961	<0.0001	<0.0001	-1.0925

Sulphur Dioxide (SO_2) and oxides of Nitrogen (NO_x)

NO_x emissions are predicted to increase as a result of the Muskeg River Mine Project and combined developments in the RSA (Air Quality Impact Assessment, Section E2.2). According to the Air Quality Section (F2) higher emissions are predicted to occur in the vicinity of the existing sources. These areas will be cleared as a result of oil sands development and therefore air emissions will have limited effects on vegetation communities. Outside the immediate vicinity of oil sands developments, an assessment of the effects to vegetation communities is best discussed on an individual project basis and is not discussed in this CEA assessment.

Potential Acid Input (PAI)

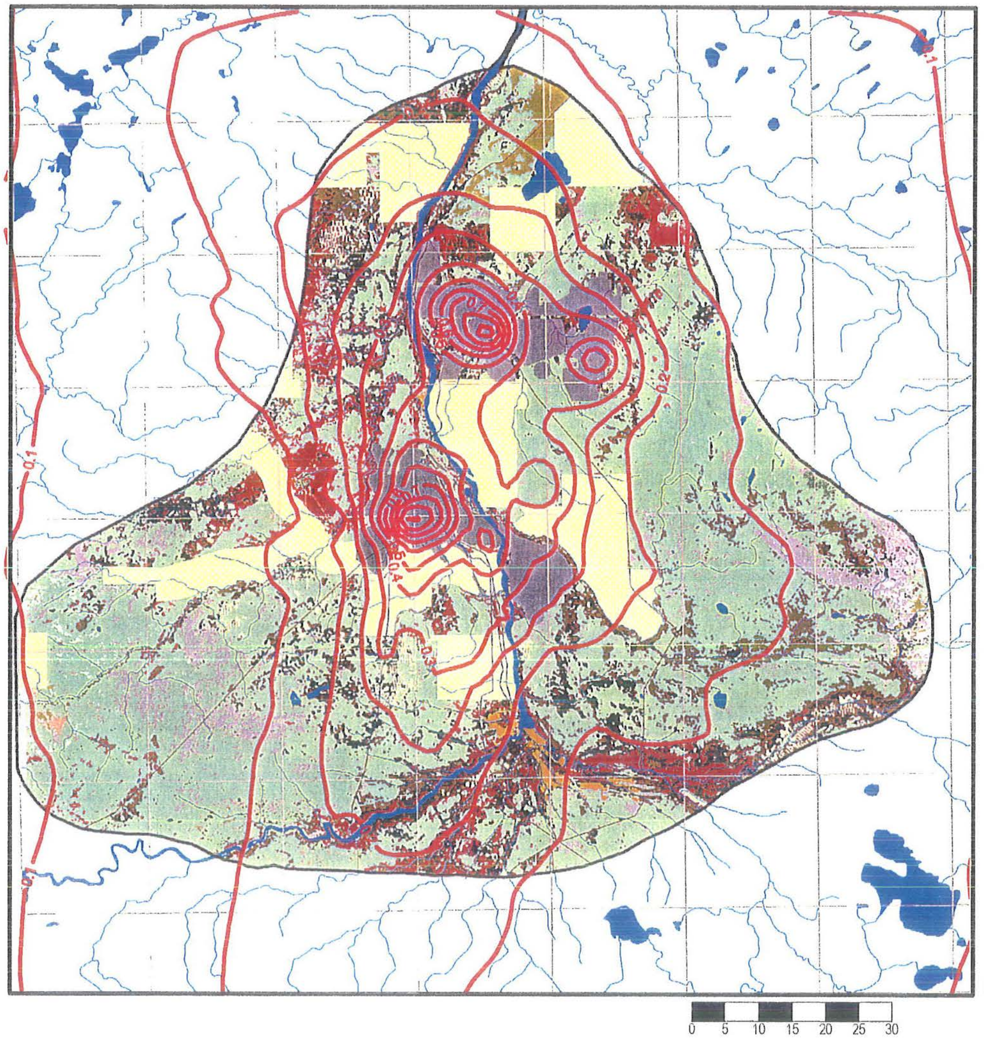
Deposition of acid forming substances can affect vegetation in northern Alberta environments as discussed in Malhotra and Blauel (1980), Torn et al. (1987), Treshow (1984) and Legg et al (1988). Vegetation communities that are sensitive to acidic deposition are primarily those growing on soil with low buffering capacity such as peatlands (see Section E8).

Sources of acidifying emissions associated with the Project and combined developments include SO_2 and NO_x emissions result in Potential Acid Input (PAI).

Modelled values for annual PAI exceed the interim Critical Load of 0.25 keq/ha/yr in an area of 1,530 to 3,470 km diameter, primarily surround the oil sands development area (Figure F9-3). The World Health Organization (1994) has proposed PAI critical loading factor of 0.25 keq/ha/a for sensitive ecosystems and 0.5 keq/ha/a for moderately sensitive ecosystems. Predicted PAI values exceeding 0.5 keq/ha/a are centered on plat sites which do not support vegetation communities (Figure F9-5). The vegetation communities occurring within the 0.25 keq/ha/a predicted isopleths are primarily wooded fens or peatlands (Figure F9-3). However, studies have not found any trends of peatland or soil acidification in northeastern Alberta (BOVAR 1996a). Therefore, the relationship between acid emissions and peatland is currently undetermined.

Residual Impact Classification and Degree of Concern

The effects of air emissions on vegetation health in the RSA as shown in Table F9-4, is expected to be Negative in direction, Undetermined in magnitude, Regional in extent and Short-Term duration. Additional information is required to further quantify this effect, although the degree of concern is considered to be Low.



LEGEND

- PAI Isopleths
- Regional Study Boundary
- Linear Disturbances
- Hydrology
- Forestry
- Existing Open Pit Mines
- Other Oil Sands Disturbances
- Proposed In-situ
- Proposed Open Pit Mine
- Municipalities

VEGETATION CLASSIFICATION

- Unclassified
- Jack Pine Forest
- Mixedwood Forest
- Spruce Forest
- Aspen (Poplar) Forest
- Graminoid Fen
- Wet Shrublands
- Marsh
- Natural Disturbances
- Wooded Peatland
- Paper Birch Forest
- Recent Burn Fen
- Forestry Cutblocks

5 0 5 10 15 20 25

Kilometres

SOURCE: Golder Associates Ltd., Leskiw (1996), Petro-Canada, RADARSAT International, Soils Department (Alberta Research Council, AOSERP Report 122), Suncor, Syncrude, Norwest

MAP PROJECTION: UTM
Zone 12
NAD 83 (GRS 1980)

Golder Associates

SHELL CANADA LIMITED

RSA BASELINE VEGETATION CLASSIFICATION WITH ANNUAL POTENTIAL ACID INPUT (PAI) - CEA

16 Jan. 1998	Figure F9-3	PRODUCED BY: J.Shaw REVIEWED BY:

Table F9-4 Residual Impact Classification for Air Emissions on Terrestrial Vegetation

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Acidification of plant communities	Negative	Undetermined	Regional	Short-Term	Reversible	Low	Low
Acidification of fens	Negative	Undetermined	Regional	Short-Term	Reversible	Low	Low

F9.5 Summary of Impacts

Table F9-5 summarizes the residual impacts for terrestrial vegetation under the CEA.

Table F9-5 Summary of Residual Impacts

Key Question	CEA Results
TVCEA-1: Will the combined developments, their reclamation and closure, result in a loss or alteration of vegetation communities?	• For the CEA, loss of vegetation communities (21,748 ha or 2.1%) is predicted in the RSA. The Project contributes 4,343 or 0.4% of this impact. • The CEA impact on loss or alteration of vegetation communities as Negative in direction, Low in magnitude, Regional in geographic extent, Short-term in duration, and the degree of concern is **Low.**
TVCEA-2: Will the combined developments result in a change in vegetation diversity?	• For the CEA, vegetation diversity is • The CEA impact on diversity to vegetation communities as Negative in direction, Low in magnitude, Regional in geographic extent, Short-term in duration, and the degree of concern is **Low.**
TVCEA-3: Will air emissions from combined developments result in a change to vegetation health?	• The CEA impact on diversity to vegetation communities as Negative in direction, Low in magnitude, Regional in geographic extent, Short-term in duration, and the degree of concern is **Low.**

F10 WETLANDS CUMULATIVE EFFECTS ASSESSMENT

F10.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on wetlands in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- Syncrude Aurora North and South
- Syncrude Mildred Lake
- SOLV-EX

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

F10.2 Approach and Methods

The cumulative effects (CEA) for the wetlands component of the Project focuses on two central issues within the RSA:

- the quantity and distribution of wetlands types which may be affected and changes in their diversity; and

- a description and assessment of combined landscape reclamation and replacement of wetlands communities.

Each issue was assessed for two scenarios; baseline conditions (existing developments) and baseline plus approved developments plus the Project.

F10.3 Potential Linkages and Key Questions

The key question regarding cumulative effects on wetlands is as follows:

WTCEA-1: Will Combined Developments, their Reclamation and Closure, Result in a Loss or Alteration of Wetlands?

F10.4 Analysis and Results

F10.4.1 Key Question WTCEA-1: Will Combined Developments, their Reclamation and Closure, Result in a Loss or Alteration of Wetlands?

Analysis of Potential Linkages

The linkages are consistent with Section E10. Hydrogeology effects, however are better assessed on an individual development basis.

Impact Analysis

The analysis of potential linkages indicates that the valid linkages necessary for determining cumulative losses or alteration of wetlands are site clearing during industrial development. For oil sands developments, site clearing involves the direct removal of landforms and associated soils and vegetation communities including wetlands. Forestry disturbances to wetlands should be minimal due to the lack of productive stands associated with bogs and fens in the RSA. Some alteration of wetlands may however, occur due to access to upland stands.

Table F10-1 shows the general distribution of land cover types in the RSA. Wetlands occupy 684,449 ha or 65.1% of the RSA, of which 3,344 ha (0.3%) will be affected by the Project. A further 51,490 ha (4.9%) will be affected by approved projects resulting in a total disturbance of 54,834 ha of wetlands or 5.2% of the RSA. The total disturbances predicted for the RSA is 88,397 ha, or 8.3%.

Table F10-1 Direct Losses/Alteration of Existing Terrestrial Vegetation, Wetlands, Lakes, Rivers and Other Areas Within the RSA

General Community Types	Baseline		Muskeg River Mine Project		Approved Developments		Total Loss	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Terrestrial Vegetation	293,353	27.9	807	<0.1	27,835	2.6	28,642	2.7
Wetlands	684,449	65.1	3,344	0.3	51,490	4.9	54,834	5.2
Lakes, Rivers, Streams	19,216	1.8	17	<0.1	437	<0.1	454	<0.1
Forest Disturbance	13,443	1.3	0	0	2,031	0.2	2,031	0.2
Developed or Unclassified	37,350	3.6	175	<0.1	2,261	0.2	2,436	0.2
Reclaimed Unit	3,600	0.3	0	0.0	0	0.0	0	0.0
TOTAL	**1,051,411**	**100.0**	4,343	0.4	**84,054**	7.9	**88,397**	8.3

Table F10-2 details the types of wetlands and the extent to which they are affected by development in the RSA.

Wetlands, bogs, fens, marshes, swamps and shallow open water, are the dominant community type lost to combined developments because they occupy 65.1% of the RSA. Wetlands are classified into four general types that include wooded fens and bogs, wooded fens and bogs that have been recently altered due to fire, shrubby fens, and marshes. The most dominant wetlands type in the region is wooded fens and bogs which occupy approximately 639,004 ha or 60.8%. One percent of this wetland type has been modified by fire and is located in the southeast of the RSA. Shrubby fens and marshes comprise less than 4% of the RSA (Table F10-2).

The Project will disturb 3,344 ha or 0.3% of wetlands in the RSA. The combined development (including the Project) will disturb 54,834 ha or 5.2% of the RSA. Combined developments will result in higher impacts to wooded fens and bogs (5.2%) with negligible (less than 1 percent) impacts to marshes and shrubby fens (Table F10-2).

An analysis of the predicted reclamation landscape following closure, including wetlands, is provided in the Closure Plans (such as that described for the Project in Section E16). Replacement of some wetlands communities, namely marsh, riparian shrub complexes and shallow open-water complexes, will occur within some mine reclamation areas upon closure. However, fens and bogs will not be replaced.

Table F10-2 also shows the amount and distribution of wetland types following final closure of the combined developments. The post-closure wetlands amounts were determined from the Steepbank Mine Closure Plan (Golder 1996i), Syncrude Aurora Mine Closure Plan (BOVAR 1996a) and the Muskeg River Mine Closure Plan (Section E16). Although Syncrude's Aurora Mine Closure Plan identified reclamation of fens, ecologically this is not a probable reclamation wetlands type. Accordingly, this area was reclassified as marsh (map code 11), a more probable reclamation wetlands type. In addition, closure plans identifying consolidated tailing wetlands were classified as marsh, which would include shallow open water. Overall the amount of wooded fens would be reduced in the final landscape by 1.5% of the RSA to 623,850 ha from 639,004 ha (baseline conditions). Graminoid fens (k3) will not be reclaimed. The majority of this area has been identified as reclaimed terrestrial vegetation, as discussed in Section F9. Marsh (11) will increase from 3,408 ha to 6,059 ha (0.6% of the RSA). This represents an increase of 77% for this wetlands type.

Table F10-2 Baseline, Developed and Post-Closure Wetlands in the RSA

Wetland Types		Baseline		Muskeg River Mine Project				CEA				Final Landscape	
				Impacts		Far Future		Impacts		Far Future			
Map Codes	Ecosite Phases	(ha)	(%)	(ha)	(%)	(ha)	(%)			(ha)	(%)	(ha)	(%)
j1,j2,k1,k2 and limited i1,i2	Wooded and Shrubby Fens and Bogs	639,004	60.8	3,315	0.3	0	0.0	53,584	5.1	38,430	3.7	623,850	59.3
j1,j2,k1,k2 with recent burn	Wooded and Shrubby Fens and Bogs (recently burned)	10,131	1.0	4	<0.1	0	0.0	96	0.0	86	0.0	10,121	1.0
k3	Graminoid fens	31,906	3.0	20	<0.1	0	0.0	745	0.1	540	0.1	31,701	3.0
l1	Marsh	3,408	0.3	5	<0.1	0	0.0	409	0.0	3060	0.3	6,059	0.6
	Sub-Total Wetlands	**684,449**	**65.1**	**3,344**	**0.3**	**0**	**0**	**54,834**	**5.2**	**42,116**	**4.0**	**671,731**	**63.9**
	Sub-Total (Terrestrial Vegetation)	**293,353**	**27.9**	**807**	**0.1**	**3,363**	**0.3**	**28,642**	**2.7**	**38,847**	**3.7**	**303,558**	**28.9**
	Anthropogenic Disturbances	30,941	2.9	175	<0.1	0	0.0	2,258	0.2	1,349	0.1	30,032	2.9
	Forestry Disturbance	13,443	1.3	0	0.0	0	0.0	2,031	0.2	658	0.1	12,070	1.1
	Reclaimed Unit	3,600	0.3	0	0.0	0	0.0	0	0.0	0	0.0	3,600	0.3
	Sub-Total (Disturbances)	**47,984**	**4.6**	**175**	**<0.1**	**0**	**0.0**	**4,289**	**0.4**	**2,007**	**0.2**	**45,702**	**4.3**
	Water	19,216	1.8	17	<0.1	536	0.1	454	<0.1	3,444	0.3	22,206	2.1
	Wetlands	0	0.0	0	0.0	444	<0.1	0	0.0	1,385	0.1	1,385	0.1
	Infrastructure	0	0.0	0	0.0	0	0.0	0	0.0	420	<0.1	420	0.0
	Unclassified	6,409	0.6	0	0.0	0	0.0	178	<0.1	178	<0.1	6,409	0.6
	Total	1,051,411	100.0	4,343	0.4	4,343	0.4	88,397	8.4	88,397	8.4	1,051,411	100.0

Reclamation will replace some wetlands types but not all. Fens and bogs cannot be reclaimed. Most wetlands communities lost from combined developments will be converted to terrestrial vegetation types such as jack pine (a1) and mixedwood (b1, b2, and b3), which will increase in overall distribution in the RSA. In summary, the total wetlands area in the final landscape scenario will be reduced by 12,718 ha from baseline conditions of 684,449 ha to 671,731 ha (Table F10-2). This represents a percentage change of 1.2% for the RSA as a whole. A proportion of these area will be reclaimed to upland vegetation types.

KIRs

Patterned Fens

The distribution of patterned fens in the RSA is difficult to determine due to the lack of detailed mapping and field observations. They are included in the Wooded Fens and Bogs Category for the purposes of this assessment (Table F10-2). Vitt et al. (1997) reported that the total number of patterned fens in the Central Mixedwood Natural Subregion is approximately 3,700 ha or 1.8%. As stated in Section E10, the Project will impact 1.9 ha of patterned fens. This represents <0.1% of patterned fens in the region. Due to the lack of field observations, it is difficult to determine the number of patterned fens affected by the combined developments. There are some notably large patterned fens in the RSA, such as McClelland Lake Fens which are currently protected from disturbance.

Fen wetlands communities have not been identified as potential reclamation communities, due to the length of time required for community development. As such, patterned fens disturbed during construction and operation will not be replaced.

Riparian Shrub Complex

Riparian wetlands include fens, marshes and swamps that occur along drainages such as the Athabasca River. At the regional scale, it is difficult to map these wetlands areas. Most of these wetlands, however, occur adjacent to rivers and streams that are protected from direct development impacts and thus, will not be affected by developments in the RSA.

Riparian shrublands are expected to increase as a result of reclamation of the combined developments. Amounts specific to the Project are detailed in Section E10. Although riparian shrublands are an obvious consequence of mine closure plans, it is difficult to quantify with available information.

Rare Plants

Field surveys conducted by Vitt et al. (1997), BOVAR (1996a) and Golder (1997o) identified 25 rare plant species within the RSA (Table F10-3). Of these 25 species, only three will be directly affected due to the combined development. The remaining 23 species are currently outside the combined development areas and are not threatened in the CEA scenario.

Table F10-3 Rare Plants Observed Within the RSA

Botanical Name	Common Name	Plot Location
Carex lacustris	lakeshore sedge	Project
Clintonia uniflora	corn lily	Project
Barbarea orthoceras	American winter cress	Project
Scirpus cyperinus	wool-grass	Project
Lycopus uniflorus	northern water-horehound	Project
Drosera anglica	Oblong-leaved sundew	Project
Coptis trifolia	goldthread	Project
Kalmia polifolia	northern laurel	Project
Monotropa uniflora	indian pipe	Project
Rhamnus alnifolia	alder-leaved buckthorn	Project
Carex tenuiflora	thin flowered sedge	Project
Sparganium fluctuans	n/a	Project
Nymphaea tetragona leibergii	small water-lily	Project
Carex hystricina	porcupine sedge	Project
Calypogeia muelleriana	n/a	Kearl Lake
Cephaloziella hampeana	n/a	McClelland Lake
Meesia longiseta	n/a	Fort McMurray
Pseudobryum cinclidiodes	n/a	Mariana Lake
Warnstorfia pseudostraminea	n/a	Thickwood Hills
Cardamine pratensis	n/a	Fort McMurray
Carex oligosperma	n/a	Kearl Lake
Drosera lineais	sundew	South of Hondo East of Fort McMurray
Juncus filiformis	n/a	Gregoire Lake
Lycopodium inundatum	n/a	Maybelle River
Polygala paucifolia	n/a	Fort McMurray

n/a = not applicable

Rare plant potential was assigned to each ecosite phase based on field observations and literature review (Table F10-4). Regional rare plant surveys have linked rare plants with fen ecosites (Westworth 1990). As such, all fens were ranked as having high rare plant potential, regardless of whether rare plants were identified within these ecosites.

Three of the general wetlands types within the RSA were found to have high rare plant potential (Table F10-4).

Rare plant potential lost from combined development is approximately 54,834 ha or 5.2% of the RSA. This value represents the total loss of fens and bogs in RSA. Typically, peat accumulations associated with fen and bog communities take several hundred years to develop. As such fens and bogs are very difficult to reclaim after oil sands development. Given suitable landform and drainage conditions, these communities may eventually re-establish; however, the long periods of time associated with their development renders them outside the scope of closure analysis. As such, no ecosites associated with either high or moderate rare plant potential will be re-established on reclamation landscapes.

Table F10-4 Wetlands Ecosite Phase Rare Plant Potential within the RSA

Map Code	Ecosite Phase	Rare Plant Potential[a]
j1,j2,k1,k2 and limited i1,i2	Wooded Fens and Bogs	H
j1,j2,k1,k2 with recent burn	Wooded Fens and Bogs (recently burned)	H
k3	Shrubby Fens	H
l1	Marsh	ID

[a] H = High, ID= Insufficient Data.

To improve the analysis of the rare plant potential ranking system, more detailed field investigations are required. For example, there is insufficient data for the ecosites identified in the RSA, to accurately assess rare plant potential.

The change in diversity of wetlands can be examined by looking at changes in wetlands type patch (or polygons) size from baseline conditions to CEA patch size (Table F10-5). For the most extensive wetlands type, the Wooded Fens and Bogs, there is an overall reduction in the average patch size from 385.9 ha in baseline conditions to 354.7 ha under the CEA scenario, or an average reduction by 31.2 ha (Table F10-5). Large patches of this wetlands type will therefore remain within the RSA, providing a basis for sustained wetlands diversity. A very minor change (reduction of 0.3 ha in patch size) is seen in the recently burned Wooded Fens and Bogs (Table F10-5). Similarly, the Graminoid fens (K3) and marsh (11) wetlands types see only minor reductions in average patch sizes (0.9 ha and 0.03 ha, respectively). The Project will not change the average regional wetlands patch size.

Table F10-5 Patch Size Change for Wetlands

Map Code	Ecosite Phase	Baseline Patch Size (ha)			CEA Patch Size (ha)			Change in Patch Size (ha)		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
j1,j2,k1,k2 and limited i1,i2	Wooded Fens and Bogs	<0.0001	239,044.3	386	<0.0001	230,528	354.8	<0.0001	-8,516	-31.2
j1,j2,k1,k2 with recent burn	Wooded Fens and Bogs (recently burned)	<0.0001	146	1.6	<0.0001	146.3	2.0	<0.0001	<0.0001	-0.4
k3	Graminoid Fens	0.001	7,923	35.2	0.001	7,923	34.3	<0.0001	<0.0001	-0.9
l1	Marsh	<0.0001	89	0.6	<0.0001	134.7	0.6	<0.0001	-46.0	-0.4

Residual Cumulative Impact Classification and Degree of Concern

The primary cumulative residual impacts on wetlands include:

- a change in dominant vegetation type from wetlands to upland communities;
- a decrease in areas of patterned fens;
- an increase in riparian shrub communities; and
- an increase in areas of ponds/wetlands and lakes.

Fens in the RSA, represent approximately 65% of the area. The loss of fens and bogs from combined developments is proportionally small (5.2%). The impacts to wetlands therefore are Negative in direction, Low in magnitude, Regional in geographical extent, Irreversible and of Low degree of concern.

These impacts are considered to be negative in direction for the patterned fen KIR with a Low magnitude of cumulative impact. The duration of impact is Long-Term, Irreversible and of Low frequency. The degree of concern is Low. For the riparian shrub complex, the direction of impact is Positive and the magnitude is Low. The geographic extent of the impact is Regional, of Long-Term duration, Reversible and Low in frequency.

The loss of KIRs, patterned fens and riparian shrubs are difficult to quantify at a regional scale. Important areas of these wetlands types, for example, patterned fens adjacent to McClelland Lake, are proposed for protection under the Special Places 2000 initiative.

Table F10-6 summarizes the residual impact classification associated with effects on wetlands from reclamation of combined developments.

Table F10-6 Residual Impact Classification on Wetlands in the RSA and Degree of Concern

Wetlands Type		Impact Assessment Criteria						
Map Codes	Ecosite Phases	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
j1,j2,k1,k2 and limited i1,i2	Wooded Fens and Bogs	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
j1,j2,k1,k2 with recent burn	Wooded Fens and Bogs (recently burned)	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
k3	Shrubby Fens	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
l1	Marsh	Negative	Low	Regional	Long-Term	Reversible	Low	Low

F10.5 Summary of Impacts

Table F10-7 summarizes the impact to wetlands under the CEA.

Table F10-7 Summary of Impacts on Wetlands

Key Question	CEA Results
WTCEA-1: Will the combined developments, their reclamation and closure, result in a loss or alteration of wetlands?	• The total loss to wetlands from the combined developments is 54,834 ha or 5.2% of the RSA. The Project's contribution to the loss of wetlands is 6.1% under the CEA. • Reclamation activities and reforestation will result in changes to the distribution of wetland types in the RSA. Overall, fens and bogs will be reduced by 1.5% but marshes will increase from 3,408 ha baseline to 6,059 ha in Final Landscape, an increase of 44% representing 0.6% of RSA. • Average patch sizes for wetlands associated with the Project will not affect the regional average patch size. • The CEA scenario will reduce average patch size for wooded fens and bogs by 31.2 ha.

F11 WILDLIFE CUMULATIVE EFFECTS ASSESSMENT

F11.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on wildlife in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Forestry
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Municipalities
- Pipelines, utility corridors and roadways

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

Discussion on the wildlife baseline for the Project were provided in Section D11, while the potential impacts of the Project on wildlife were detailed in Section E11 of this EIA.

F11.2 Approach and Methods

The Project CEA centres around two main wildlife issues:

- habitat quality and quantity; and
- wildlife health.

While other CEA issues concerning the synergistic effects of two or more impacts are possible (Smith 1994), few tools are available to quantitatively assess such effects for wildlife.

Methods for the wildlife CEA included HSI modeling (described in Section E11 and Golder 1998b) and wildlife risk assessment (described in Section E11).

Cumulative effects of habitat change included effects of vegetation clearing and sensory disturbance. For simplicity, effects of changes in hydrology on vegetation communities were disregarded because of limited information available for future projects.

HSI model results are presented for three Key Indicator Resources (KIRs). Data for the remaining KIRs is provided in the wildlife HSI modelling report (Golder 1998b). This report also evaluates cumulative impacts on wildlife movement corridors.

For wildlife habitat, due to the uncertainties involved with the potential reclamation programs for future projects, the temporal boundaries for the CEA were confined to the Construction Phase (1998-2002). This was considered to be a conservative approach as effects for that period represent the maximum cumulative effects possible and do not consider the positive impacts of reclamation.

For wildlife health, temporal boundaries included operation of the oil sands facilities (i.e., 2007, 2020), two years after closure of the Project (2030) and in the far future after closure of combined developments under equilibrium conditions.

F11.3 Potential Linkages and Key Questions

Figure E11-1 (Section E11) shows the linkage diagram for project activities and potential changes in wildlife associated with the Project. Generally the same linkages and key questions apply to the CEA.

The key questions for the wildlife CEA included:

WCEA-1: Will the Combined Developments Impact Wildlife Habitat?

WCEA-2: Will Changes to Water, Aquatic Prey and Plant Quality from the Combined Developments Affect Wildlife Health?

The same wildlife KIRs used for the EIA were used as potential indicators for the CEA (Section D1). Full details of the KIR selection process are found in BOVAR (1996a).

As not all KIRs are affected by the cumulative effects considered for the key questions, the following species were selected for the CEA:

- WCEA-1: moose, beaver, western tanagers; and
- WCEA-2: moose, snowshoe hares, black bears, beavers, ruffed grouse, dabbling ducks and other wildlife receptors previously evaluated for impacts to wildlife health in Section E11.

F11.4 Analysis and Results

F11.4.1 Key Question WCEA-1: Will the Combined Developments Impact Wildlife Habitat?

Existing and approved developments (excluding the Project) account for a loss of habitat of 1.1 to 2.5% for each KIR over baseline conditions (Table F11-1). The Project will result in an additional loss of 0.1 to 0.6% of the baseline HUs within the RSA. In total, some 1.2 to 3.1% of the RSA will be lost. It should be recognized that these figures represent worst case scenarios. The actual loss of habitat at any point in time will be less due to the phased nature of the developments and progressive reclamation. Habitat losses due to the Project represent 6.5 to 20.5% of the total loss.

Table F11-1 Cumulative Effects of Habitat Loss for KIRs in the RSA

KIR	HUs in RSA	Habitat Units (HUs) Lost (%) Existing and Approved Development	Muskeg River Mine Project	CEA	Change Attributed to Muskeg River Mine Project
moose	385,291	-2.5	-0.6	-3.1	20.5
beaver	105,408	-1.1	-0.1	-1.2	6.5
western tanager	127,278	-1.5	-0.3	-1.8	18.4

Mitigation for cumulative effects of habitat loss should include:

- ensuring that ELC unit abundance and distribution is maintained within the RSA; and
- ensuring that habitat connectivity is maintained (see Section F11.7).

A key factor in the mitigation for cumulative effects on wildlife will be the cooperation of the developers, residents and the various agencies with the mandate to manage the resource. Inter-agency and inter-industry cooperation is essential for proper ecosystem management (Grumbine 1994).

Analysis of Key Question

Cumulative, residual losses of wildlife habitat were considered to have a Low magnitude, because no KIR will experience losses of more than 3.1% of baseline HUs within the RSA. While the direction of the impacts are Reversible. In other words, eventual reclamation of the sites is expected to return them to an equivalent habitat capability. The geographic extent of the impacts can be considered to be Regional.

Residual Impact Classification and Degree of Concern

The degree of concern for KIRs was considered to be Moderate for the total impact scenario due to the regional and long-term nature of the impacts. The degree of concern for the incremental impacts of the Muskeg River Mine was considered to be Low due to the more localized geographic extent of the impacts. The impacts and degree of concern for the CEA is detailed in Table F11-2.

Table F11-2 Residual Impact of Combined Developments on Wildlife Habitat

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	High	Moderate

While the degree of concern is Moderate, reclamation is expected to return wildlife habitat to an equivalent capability over time.

F11.4.2 Key Question WCEA-2: Will Changes to Water, Aquatic Prey and Plant Quality From Combined Developments Affect Wildlife Health?

Analysis of Key Question

Water Quality

To evaluate the potential linkage between cumulative changes to water quality and wildlife health, a quantitative wildlife health risk assessment was conducted using methods described in Section E11.5.3 (Wildlife Impact Analysis, Risk Assessment Methods).

Potential receptors include both aquatic wildlife (i.e., water shrews, river otters, killdeer, and great blue herons) and terrestrial wildlife (i.e., moose, snowshoe hares, and black bears). These animals may be exposed through ingestion of Athabasca and Muskeg river water as a drinking water source.

Cumulative chemical concentrations were predicted for the Muskeg and Athabasca Rivers, according to the method described in Section F5 (Water Quality Cumulative Effects Assessment). Predicted cumulative concentrations were conservatively screened against receptor-specific Risk Based Concentrations (RBCs). No chemicals of concern in water were identified for the water shrew, river otter, killdeer, great blue heron or snowshoe hare. For moose and black bears, molybdenum was identified as a potential chemical of concern in water. Naphthenic acids were also identified as potential chemicals of concern, but due to the lack of chronic toxicity data for these substances, as discussed in Section E11.7 (Wildlife Impact Analysis for Key question W-2), these substances were not assessed in the CEA.

The predicted cumulative molybdenum concentrations in the Muskeg River were used as exposure concentrations to estimate daily intake rates for moose and black bears, using the same methodology as described in Section E11.7. Cumulative exposure ratios for moose and black bears remained less than 1.0 (i.e., Moose ER range = 0.00008 [in 2020] to 0.2 [in 2030]; Bear ER range = 0.007 [in 2020] to 0.18 [in 2030]), indicating that these predicted conservative exposures are well within acceptable limits. Therefore, no impacts to wildlife health are predicted due to cumulative water releases to the Muskeg River from combined developments.

Predicted chemical concentrations in the Athabasca River due to water releases from combined developments are less than predicted chemical concentrations in the Muskeg River for most chemicals due to increased dilution as a result of the larger water volume and flow rate of the Athabasca River compared with the Muskeg River. However, concentrations of aluminum, barium, beryllium, cadmium, chromium, copper, mercury and strontium are higher in the Athabasca River than the Muskeg River due to elevated natural baseline concentrations. However, predicted cumulative concentrations for these chemicals are still less than the applicable further evaluation in the risk assessment. Therefore, no impacts to wildlife health are predicted due to exposure to Athabasca River water affected by the Project, existing and approved developments.

Fish and Aquatic Invertebrate Quality

In the Project impact analysis for Key Question W-2 (Section E11.7), the impact analysis suggested predicted conservative exposures likely to be incurred by wildlife which consume local fish and aquatic invertebrates were well within acceptable limits.

With respect to cumulative effects, the minor increase in several waterborne chemicals in the Athabasca or Muskeg Rivers resulting from combined developments should not significantly increase the tissue concentrations of metals in fish or invertebrates. However, currently there are no data available to evaluate this exposure route further.

Plant Quality

In the Project impact analysis for this Key Question (Section E11.8), results of a limited vegetation sampling program indicated that oil sands operations do not appear to contribute to increases in chemical concentrations in plants. The impact analysis showed that predicted conservative exposures likely to incurred by wildlife which consume local plants were well within acceptable limits.

Intuitively, increased air emissions and deposition under the CEA are expected to increase chemical concentrations in plant tissues. However, currently there are no data available to evaluate this exposure route in the present EIA. It is anticipated further analysis will be possible within the context of subsequent EIAs.

Reclaimed Landscape

In the impact analysis for Key Question W-7 (Section E11.12), it was conservatively assumed that wildlife foraging ranges were confined to within the Project boundaries, despite the fact that the foraging ranges of many species will extend beyond the Project boundaries into un-impacted areas. Nevertheless, this conservative exposure scenario did not result in significant adverse effects to wildlife populations.

The results of the impact analysis for wildlife living for extended periods of time on the reclaimed Project site would be applicable to reclaimed landscapes for other regional developments. This assumes chemical releases from the reclaimed landscapes of other regional developments are not significantly greater than those predicted for the Project. A similar exposure scenario evaluated for the reclaimed landscape of the Steepbank Mine indicated a Low probability of potential impact to wildlife health (Golder 1996g).

Thus, chemical releases from multiple reclaimed landscapes within the region will not necessarily result in compounded exposures to wildlife foraging within any individual reclaimed area. Rather, due to the larger area of reclaimed landscapes in the Athabasca Oil Sands Region, there is a greater likelihood for wildlife to forage within a reclaimed area, and therefore this exposure scenario becomes more likely, although the exposure parameters modelled in this scenario are conservative.

Residual Impact Classification and Degree of Concern

For exposures to water during the operation phases of combined developments, no wildlife health impacts were identified. However, due to the uncertainty regarding the potential chronic effects of naphthenic acids, the magnitude of impact is rated as Low, rather than negligible. This finding is the same as that predicted for the Project.

For exposures on reclaimed landscapes, while the magnitude of the impact is considered to be Low, it is recognized that there is an increased likelihood on a regional basis for this exposure pathway to be realized. Therefore, the residual impact is likely to be enhanced in the CEA, relative to the impact predicted for the Project. The predicted enhancement is based on a greater likelihood of animals being exposed to chemicals on reclaimed landscapes. However, the magnitude of exposure and associated health risks for a given individual animal should not be increased in the CEA, relative to those predicted for the Project. Further data are necessary to substantiate this prediction. Table F11-3 reviews the impacts and degree of concern for the CEA.

Table F11-3 Residual Impact of Combined Developments on Wildlife Health

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	High	Moderate

Certainty

The assessment of potential impacts to local wildlife health from exposure to Athabasca and Muskeg river water was based on a number of highly conservative assumptions. Hence, the actual risks to wildlife health will likely be even lower than those suggested by ER estimates because of the multiple protective assumptions as outlined below:

- reasonable worst case exposure point concentrations in the Muskeg and Athabasca Rivers were used;
- exposure locations were set within the mixing zone of the Muskeg and Athabasca Rivers, downstream of all potential water discharges;
- exposure parameter values for wildlife receptors represent reasonable maximum exposure values;
- oral bioavailability was set to a maximum of 100%; and
- receptor-specific toxicity reference values were developed to be protective of wildlife under chronic exposure conditions.

However, there is some uncertainty associated with fish and aquatic invertebrate quality, plant quality and exposures on reclaimed landscapes.

F11.5 Summary of Impacts

Table F11-4 provides a summary of the residual impacts to wildlife under the CEA.

Table F11-4 Summary of Residual Impacts for Wildlife in the CEA

Key Question	CEA Results
WCEA-1: Will the combined developments impact wildlife habitat?	• During the construction phase of the oil sands developments, the combined developments will cause relatively small (1.2 - 3.1% of the RSA) losses of wildlife habitat due to site clearing and disturbance. These impacts are predicted to be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and High in frequency. The degree of concern for the cumulative effects is rated as **Moderate.** • These impacts represent a worst case scenario, as it is unlikely that all sites will be cleared to their maximum extent at the same time. The phased nature of site clearing and progressive reclamation will mitigate the cumulative effects of habitat loss. • Eventual reclamation of all sites should result in equivalent habitat capability for wildlife within the region.
WCEA-2: Will changes to water, aquatic prey and plant quality from combined developments affect wildlife health?	• During operation of combined developments, no significant health impacts were identified for wildlife health from exposures to water from the Athabasca or Muskeg rivers; however there is some uncertainty regarding the chronic toxicity of naphthenic acids. This prediction for the CEA is not significantly different from that predicted for the Muskeg River Project. • Following closure in the far future when equilibrium conditions have been established for all combined developments, a potential

Key Question	CEA Results
	impact has been identified in the CEA. The residual impact is likely to be enhanced in the CEA, relative to the impact predicted for the Muskeg River Mine Project, since there is a greater likelihood on a regional basis for this exposure pathway to be realized. However, the magnitude of exposure and associated health risks for a given individual animal should not be increased in the CEA, relative to the Project. The cumulative effects on wildlife health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Moderate,** reflecting the regional extent and the degree of uncertainty associated with impact predictions.

F12 HUMAN HEALTH CUMULATIVE EFFECTS ASSESSMENT

F12.1 Introduction

This cumulative effects assessment predicts the effects of the Muskeg River Mine Project (Project) plus baseline and approved developments on human health in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Pulp mills for water quality
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Municipalities
- Pipelines, utility corridors and roadways

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

Quantitative data were available to assess water quality and some aspects of air quality; however, due to uncertainty surrounding future developments that have been approved, assessment of other cumulative effects was restricted to a more qualitative nature.

Among the cumulative effects issues is the increasing urbanization of the area (i.e., the expected increase in the population of Fort McMurray). The expected increase in urbanization is a result of all regional developments and therefore has been targeted as an issue to be addressed by an industry association. While it is possible that increased urbanization may contribute to increases in vehicle emissions, traffic, roads, infrastructure development, water usage, sewage and solid waste disposal, its effect from a human health perspective is presently beyond the scope of this assessment. Increased urbanization is an issue addressed, in part, under the Socio-Economic Assessment (Volume 5 of the Application).

Cumulative effects assessment of the oil sands region is an evolving process, which will be built upon with each successive development application. As such, this section addresses the potential human health impacts associated with cumulative releases of water and air to the extent that the current database allows. The following key questions were defined to guide the analyses for the human health CEA.

F12.2 Approach and Methods

The approach used to assess potential cumulative impacts on human health was consistent with that described for the Human Health Impact Assessment, as described in Section E12.

F12.3 Potential Linkages and Key Questions

Figures E12-1 and E12-2 show the linkage diagrams for Project activities and potential changes in human health associated with the Project. Generally the same linkages and key questions apply to the CEA.

The key questions for the Human Health CEA include:

HHCEA-1: Will Water Quality Changes From Combined Developments Affect Human Health?

HHCEA-2: Will Air Quality Changes From Combined Developments Affect Human Health?

HHCEA-3: Will Changes to Air and Water Quality From Combined Developments Affect Human Health?

HHCEA-4: Will Changes to Plant and Game Meat Quality From Combined Developments Affect Human Health?

HHCEA-5: Will Equilibrium Concentrations of Residual Chemicals in Water and Select Local Food Items Following Reclamation of all Developments Affect Human Health?

HHCEA-6: Will Noise from Combined Developments During Construction and Operation Unduly Affect People Who Reside in the Region?

F12.4 Analysis and Results

F12.4.1 Key Question HHCEA-1: Will Water Quality Changes From Combined Developments Affect Human Health?

Analysis of Key Question

To evaluate the potential linkage between cumulative changes to water quality and human health, a quantitative human health risk assessment was conducted using methods described in Section E12.5 (Human Health Impact Analysis Methods). Key aspects of the risk assessment are discussed here; additional details are provided in Appendix X (Volume 3 of the Application).

Cumulative chemical concentrations were predicted for the Muskeg and Athabasca rivers, according to the method described in Section F5 (Water Quality Cumulative Effects Assessment). Predicted cumulative concentrations were conservatively screened against one-tenth of the Risk-Based Concentration (RBC). Refer to Appendix XIII for screening tables. The following seven chemicals were identified for further evaluation:

- benzo(a)pyrene
- benzo(a)anthracene
- boron
- cadmium
- lead
- molybdenum
- vanadium

In addition to these chemicals, baseline concentrations of arsenic appear to be naturally elevated in the Muskeg River because they exceeded the conservative RBC screening step. Beryllium was not detected in the Muskeg River under baseline conditions; however the detection limit exceeds the conservative RBCs. Although the Project will not contribute to increased concentrations of these chemicals, they were carried forward for further analysis in the cumulative effects assessment in light of interest articulated by regulators concerning elevated background chemical concentrations (Human and Ecological Health Component Focus Workshop, October 30, 1997).

Naphthenic acids were also identified as potential chemicals of concern, but due to the lack of chronic toxicity data for these substances, as discussed in Section E12 (Human Health Impact Analysis), these substances were not assessed in the CEA.

The predicted cumulative concentrations were used as exposure concentrations to estimate daily intake rates. The recreational and swimming scenarios, which are the same as those used in the impact analysis for the Muskeg River Mine Project, are described in Section E12.6.

Cumulative exposure ratio values for the swimming and recreational scenarios are presented in Tables F12-1 and F12-2.

Table F12-1 Exposure Ratio Values for the Swimming Scenario (Muskeg River Exposure)

Receptor/Chemical	2007	2020	2030	Far Future (Equilibrium)
Child				
Boron	0.0002	0.0002	0.002	0.0009
Cadmium	0.0001	0.0001	0.0004	0.0002
Lead	0.00007	0.00006	0.0002	0.00007
Molybdenum	0.00006	0.00003	0.009	0.001
Vanadium	0.00007	0.00007	0.0008	0.0001
Adult				
Boron	0.00002	0.00002	0.0002	0.00008
Cadmium	0.00009	0.000009	0.00003	0.00002
Lead	0.000003	0.000002	0.000007	0.000003
Molybdenum	0.000005	0.000003	0.0007	0.0001
Vanadium	0.000006	0.000006	0.00007	0.00001
Composite[a]				
benzo[a]pyrene	0[b]	0[b]	0.07	0.08
benzo[a]anthracene	0[b]	0[b]	0.02	0.04
Total PAHs	0[b]	0[b]	0.09	0.12

(a) ER = exposure ratio, which is the predicted exposure divided by the exposure limit. ERs for PAHs are based on a risk level of 1 in 100,000.

(b) No waterborne releases of benzo[a]pyrene or benzo[a]anthracene are expected until 2030; hence no risk is predicted for these chemicals (ER = 0). By the year 2030, waterborne releases of these chemicals are predicted to occur and ER values are presented for these scenarios.

Table F12-2 Exposure Ratio Values for the Recreational Scenario (Muskeg River)

Receptor/Chemical	2007	2020	2030	Far Future (Equilibrium)
Child				
Boron	0.008	0.008	0.07	0.03
Cadmium	0.004	0.004	0.01	0.007
Lead	0.003	0.003	0.009	0.003
Molybdenum	0.002	0.001	0.3	0.05
Vanadium	0.003	0.003	0.03	0.005
Adult				
Boron	0.003	0.003	0.02	0.01
Cadmium	0.001	0.001	0.005	0.002
Lead	0.0005	0.0004	0.002	0.0005
Molybdenum	0.0008	0.0004	0.11	0.02
Vanadium	0.009	0.009	0.01	0.002
Composite[a]				
benzo[a]pyrene	0[b]	0[b]	0.09	0.10
benzo[a]anthracene	0[b]	0[b]	0.03	0.06
Total PAHs	0[b]	0[b]	0.12	0.16

(a) ER = exposure ratio, which is the predicted exposure divided by the exposure limit. ERs for PAHs are based on a risk level of 1 in 100,000.

(b) No waterborne releases of benzo[a]pyrene or benzo[a]anthracene are expected until 2030; hence no risk is predicted for these chemicals (ER = 0). By the year 2030, waterborne releases of these chemicals are predicted to occur and ER values are presented for these scenarios.

All ER values for water exposure were less than 1.0, indicating that these predicted conservative exposures resulting from recreational activities (including occasional ingestion of water and swimming exposure) are well within acceptable limits. Therefore, no impacts to human health are predicted due to water releases under the cumulative effects scenario.

In addition to the chemicals evaluated above, baseline concentrations of arsenic are also naturally elevated in the Muskeg River. Although, beryllium was not measured in the Muskeg River, the detection limit of 0.001 mg/L exceeded the conservative screening step. For risk estimation, it was conservatively assumed that arsenic and beryllium behave as non-threshold carcinogens, and therefore the toxicity reference values selected for these substances are extremely low. The resultant cumulative ER values for the recreational scenario marginally exceeded 1.0 (i.e., ER = 3.3 to 5.5 for arsenic and 0.05 to 1.6 for beryllium), while ER values for the swimming scenario were less than 1.0. Combined developments are not expected to contribute to significant increases in concentrations of these chemicals in the Muskeg River. Arsenic and beryllium are natural constituents of the earth's crust and therefore may be found naturally in surface water. Typical background concentrations of arsenic in Canadian rivers range from 1 to 8 μg/L, and some rivers have reported concentrations as high as 50 μg/L (CCREM 1987). Predicted cumulative arsenic concentrations in the Muskeg River range from 3 to 5 μg/L, which is well within the normal range for Canadian rivers. It should be noted that predicted cumulative arsenic concentrations in the Muskeg River are much lower than the Canadian Drinking Water Guideline of 25 μg/L.

The average concentration of beryllium in Canadian surface fresh waters has been estimated to be less than 1 μg/L, but concentrations in Western Canada were reported to range up to 5 μg/L (CCREM 1987). Predicted cumulative beryllium concentrations in the Muskeg River range from 0.02 to 0.5 μg/L, which is within the range reported for surface waters in western Canada. There is no Canadian drinking water guideline for beryllium; however, U.S. EPA has specified a guideline of 4 μg/L. Predicted cumulative beryllium concentrations in the Muskeg River are lower than this drinking water guideline. For these reasons, the predicted cumulative concentrations of arsenic and beryllium in the Muskeg River are considered typical of background concentrations in Canadian rivers and acceptable for drinking water purposes.

Predicted chemical concentrations in the Athabasca River due to water releases from combined developments are less than predicted chemical concentrations in the Muskeg River for most chemicals due to increased dilution as a result of the larger water volume and flow rate of the Athabasca River compared with the Muskeg River. However, concentrations of aluminum, barium, beryllium, cadmium, chromium, copper, mercury and strontium are higher in the Athabasca River than the Muskeg River due to elevated baseline concentrations. Of these chemicals, only beryllium and cadmium exceed the conservative RBC screening step. For the reasons described previously, predicted beryllium concentrations are within the range of background concentrations in Canadian rivers and are considered acceptable for drinking water purposes. Similarly, predicted cadmium concentrations in the Athabasca River due to water releases from combined developments are considered acceptable since the ER value for cadmium based on recreational exposure to Athabasca River water was less than 1.0 (i.e., ER = 0.02). Therefore, no impacts to human health are predicted due to exposure to Athabasca River water affected by the Project, baseline and approved developments.

Residual Impact Classification and Degree of Concern

Based on the information assessed, no human health impacts were identified. However, due to the uncertainty regarding the potential chronic effects of naphthenic acids, the magnitude of impact is rated as low, rather than negligible. This results in a low degree of concern as shown in Table F12-3.

Table F12-3 Residual Impact Classification for Human Health Impacts Related to Water Quality Changes

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Low

The residual impact for the CEA is the same as that predicted for the Muskeg River Mine Project (Section E12). Currently there is an industry initiative to collect additional data to resolve the issue of chronic exposures.

Certainty

The assessment of potential impacts to users of the Athabasca and Muskeg rivers was based on a number of highly protective assumptions. Hence, the actual risks to human health will likely be even lower than those suggested by ER estimates because of the multiple protective assumptions as outlined below:

- reasonable worst case exposure point concentrations in the Muskeg and Athabasca rivers were used, assuming no decay or degradation of chemicals;
- exposure locations were set within the mixing zone of the Athabasca rivers, downstream of all potential water emissions;

- exposure parameter values for human receptors represent reasonable maximum exposure values;
- oral bioavailability was set to a maximum of 100%; and
- toxicity reference values adopted are protective of sensitive members of the population (e.g., seniors) under chronic exposure conditions.

F12.4.2 Key Question HHCEA-2: Will Air Quality Changes From Combined Developments Affect Human Health?

Analysis of Key Question

Cumulative ambient air concentrations of NO_2 in the communities of Fort McKay, Fort McMurray and Fort Chipewyan were predicted in Section F2 - Air Quality Cumulative Effects Assessment. The results of the air analysis indicated that predicted NO_2 concentrations in these communities would be compliant with applicable air quality criteria. Hence, NO_2 was not evaluated further in the Human Health CEA.

The Human Health CEA evaluates the potential for impacts to human health arising from the following emission sources from combined developments:

- petroleum hydrocarbon (including PAH) and VOC emissions from mine fleet exhaust;
- petroleum hydrocarbon (including PAH) emissions from tailings settling ponds; and
- petroleum hydrocarbon (including PAH) emissions from mine surfaces.

The CEA also includes an evaluation of background concentrations of carcinogenic PAHs in the communities of Fort McKay, Fort McMurray and Fort Chipewyan.

Air concentrations arising from mine fleet exhausts and fugitive emissions from the mine surface and the tailings settling pond of the Project will be increased as a result of air emissions from similar activities at other baseline and approved developments. As discussed in Section F2 (Air Quality Cumulative Effects Assessment), the combined air emissions of petroleum hydrocarbons and VOCs for baseline, approved developments and the Project could potentially increase the BaP concentrations predicted for Fort McMurray, Fort McKay and Fort Chipewyan by 3, 10 and 1% respectively (Table F2-6). The derivation of these increases is based on the total production capacity of the combined developments. Refer to Section F2 (Air Quality Cumulative Effects Assessment) for more details.

Since air concentrations could increase for Fort McMurray, Fort McKay and Fort Chipewyan, human exposure rates in these communities could also increase in the same proportion. Hence, for residents which spend all their time in their respective communities the estimated health risk could increase by a similar factor. However, in the case where the receptor is a community resident who may also work at the Muskeg River Mine, the exposure and health risk is not expected to increase in the same proportion. This is because the maximum on-site exposure concentrations are expected to be dominated by the on-site sources. Hence, for the worker component of the resident/worker receptor, the exposure and associated risk remains the same and only the residential component increases by the amounts previously noted. The resulting exposure ratio (ER) values for the CEA scenario are presented in Table F12-4. Refer to Appendix XIII.2 for further details.

The exposure ratios presented in Table F12-4 reflect the estimated increased exposure. The overall conclusions of the CEA respecting these sources do not significantly differ from those of the Project alone, as discussed previously in Section E12. The ER values are less than one for the child or composite receptor who receives all exposure from within the community. The ER values for aldehydes and total carcinogens are conservatively estimated to equal or marginally exceed one for residents who may also work on-site; however, this latter exposure is almost entirely due to the estimated worker component and is not reflective of the residential air quality. The worker exposure is also considered to be significantly conservative and may be less than indicated. It should be noted that acceptable exposure levels (occupational standards) are much higher for workers than the acceptable exposure levels for the general populations.

Table F12-4 Exposure Ratios (Sum ER) for the Inhalation Pathway

Chemical/Group	Fort McKay		Fort McMurray		Fort Chipewyan	
	Child[e]	Adult[f]	Child[e]	Adult[f]	Child[e]	Adult[f]
Non-Carcinogens						
aldehydes[a]	0.98	4.3	0.29	3.8	0.098	3.7
ketones[b]	0.00014	0.00044	0.000042	0.0004	0.000014	0.00038
aliphatics	0.021	0.12	0.0029	0.11	0.00082	0.1
aromatics[c]	0.014	0.079	0.0013	0.071	0.00034	0.07
PAH non-carcinogenic[d]	0.00017	0.000056	0.0000049	0.00005	0.0000017	0.000049
Carcinogens						
formaldehyde	0.32	1.1	0.095	0.89	0.032	0.84
acetaldehyde	0.017	0.057	0.0059	0.055	0.002	0.052
benzene	0.007	0.023	0.0021	0.02	0.0007	0.018
PAH carcinogenic[g]	0.0009	0.003	0.00027	0.0025	0.00009	0.0024
Total Carcinogens[h]	0.34	1.1	0.1	0.97	0.035	0.91

(a) modelled as acrolein.
(b) modelled as acetone.
(c) excludes benzene.
(d) ER values for all non-carcinogenic PAHs.
(e) denotes a child of 5-11 years for non-carcinogens, and composite resident for carcinogens.
(f) denotes an adult who resides in community and works at mine site.
(g) ER value for all carcinogenic PAHs combined, using B(a)P toxicity equivalent factors.
(h) the sum of all carcinogen ERs.

These cumulative health risk estimates reflect exposure to the combined air emissions of petroleum hydrocarbons and VOCs arising from the mine fleet exhausts and fugitive emissions from the mine surface and the tailings settling ponds for baseline and approved developments in addition to those of the Project. However, they do not include contributions from stack sources for these developments. The contribution from these sources has been estimated based on concentrations of benzo(a)pyrene measured at various locations in the RSA as part of the AOSERP monitoring program in May, 1977 (refer to Section F2 Air Quality Cumulative Effect Assessment for further details).

Based on the monitoring program data, background concentrations of benzo(a)pyrene in Fort McKay, Fort McMurray and Fort Chipewyan were assumed to be approximately 0.01 ng/m^3. Since the monitoring data from 1977 does not include emissions from Syncrude, which came on stream in 1978, the background concentration of benzo(a)pyrene was doubled to account for the increase in emissions (i.e., background benzo(a)pyrene = 0.02 ng/m^3). In order to determine the approximate background concentrations of other carcinogenic PAHs, it was assumed that the proportion of benzo(a)pyrene to total carcinogenic PAHs was the same as that predicted for vehicle fleet emissions (i.e., benzo(a)pyrene was assumed to account for 1/5 of total PAH emissions). Therefore, the total background concentration of PAHs was determined to be 0.1 ng/m^3 (i.e., 5 x 0.02 ng/m^3). This total PAH background concentration is approximately 17 times greater than the total PAH concentration predicted for emissions from mine surfaces, tailings settling ponds and the vehicle fleet of combined developments, as presented in Table F12-4. The resulting ERs for carcinogenic PAHs for child and adult receptors are presented in Table F12-5

Table F12-5 Exposure Ratios (Sum ER) for Carcinogenic PAHs From all Emission Sources

Fort McKay		Fort McMurray		Fort Chipewyan	
Child	**Adult**	**Child**	**Adult**	**Child**	**Adult**
0.015	0.051	0.0046	0.043	0.0015	0.041

The results indicate that even with the additional background emission sources, ER values are less than 1. Thus, no unacceptable impacts to human health are predicted for this scenario. The estimated health risk from the estimated increase in particulate matter arising from mine fleet exhaust has not been calculated in light of uncertainties surrounding such exposures (as previously noted in Section E12 Human Health). As a final note, airborne emissions of metals from stack sources of combined developments were not considered in the CEA, since the Muskeg River Mine Project is not a source of these emissions. Furthermore, pollution control technology employed in future upgrader stacks is expected to result in no net increase in airborne emissions from those sources.

Residual Impact Classification and Degree of Concern

In light of the foregoing conservative analyses, no unacceptable human health risks are predicted from changes in air quality arising from combined developments. Therefore, the degree of concern is negligible.

Certainty

The assessment of potential impacts to human health from the combined effects of airborne chemicals from the Muskeg Mine and other baseline and approved developments was based on a number of highly conservative assumptions inherent in the exposure analysis (described previously in Section E12 Human Health) and in the prediction of airborne chemical concentrations (described in Section F2 - 3 Air Quality Cumulative Effects Assessment).

F12.4.3 Key Question HHCEA-3: Will Changes to Air and Water Quality From Combined Developments Affect Human Health?

Analysis of Key Question

Due to concerns regarding combined chemical exposures from different sources, incremental risk estimates (ER values) for water and air were summed, resulting in a total ER value for each chemical. Table F12-6 presents the total ER values resulting from combined exposures. Refer to Appendix XIII.2 for further details.

Table F12-6 indicates the total carcinogenic health risk is defined by an ER of 6.3 and 7.1 for composite receptors who are residents or residents/workers, respectively. While these exceed the common reference value of 1, it is noted that virtually all of the health risk is associated with background (i.e., naturally occurring) waterborne arsenic and beryllium rather than the mine activities. These latter substances are actually within Canadian Drinking Water Guidelines.

Residual Impact Classification and Degree of Concern

The residual impacts identified for the multi-media exposure CEA are the same as those predicted for the Project. Due to the current uncertainties associated with the chronic toxicity of naphthenic acids in waterborne emissions, as discussed in the previous section, the impact and degree of concern is summarized in Table F12-7.

Table F12-6 Exposure Ratio Values for Children and Adults During Operation

Receptor/Chemical	Water	Air	All Sources
Child[a]			
arsenic[b]	5.5	0	5.5
beryllium[b]	0.5	0	0.5
boron	0.008	0	0.008
cadmium	0.004	0	0.004
lead	0.003	0	0.003
molybdenum	0.002	0	0.002
vanadium	0.003	0	0.003
acetaldehyde [b]	0	0.017	0.017
aldehydes [c]	0	0.98	0.98
aliphatics	0	0.021	0.021
aromatic [e]	0	0.014	0.014
benzene [b]	0	0.007	0.007
formaldehyde [b]	0	0.32	0.32
ketones [d]	0	0.00014	0.00014
PAH carcinogenic [b]	0	0.015	0.015
PAH non-carcinogenic [f]	0	0.000017	0.000017
Total Carcinogenic	*6.0*	*0.35*	*6.35*
Adult-Worker [g]			
arsenic [b]	5.5	0	5.5
beryllium [b]	0.5	0	0.5
boron	0.003	0	0.003
cadmium	0.001	0	0.001
lead	0.0005	0	0.0005
molybdenum	0.0008	0	0.0008
vanadium	0.0009	0	0.0009
acetaldehyde	0	0.057	0.057
aldehydes [c]	0	4.3	4.3
aliphatics	0	0.12	0.12
aromatic [e]	0	0.079	0.079
benzene [b]	0	0.023	0.023
formaldehyde	0	1.1	1.1
ketones [d]	0	0.00044	0.00044
PAH non-carcinogenic[f]	0	0.000056	0.000056
PAH carcinogenic [b]	0	0.051	0.051
Total Carcinogenic[h]	*6.0*	*1.1*	*7.1*

(a) the ER values which follow are for a child, except for carcinogens where they apply to a composite resident receptor.
(b) denotes a substance with carcinogenic effects.
(c) aldehydes modelled as acrolein.
(d) ketones modelled as acetone.
(e) aromatics exclude benzene.
(f) refers to the sum ER for grouped non-carcinogenic PAHs.
(g) the ER values which follow are for an adult, except for carcinogens where they apply to a composite resident receptor who works at the mine site.
(h) ER values listed are for Fort McKay, the highest values of the three communities.

Table F12-7 Residual Impact Classification for Human Health Impacts Related to Air and Water Quality Changes

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Low

Certainty

The points previously discussed concerning the certainty associated with cumulative effects to human health from changes to water and air quality also apply here.

F12.4.4 Key Question HHCEA-4: Will Changes to Plant and Game Meat Quality From Combined Developments Affect Human Health?

Analysis of Key Question

In the Project impact analysis for Key Question HH-3 (Section E12.8), results of a vegetation sampling program indicated that oil sands operations do not appear to contribute to increases in chemical concentrations in plants. Furthermore, the impact analysis showed that predicted conservative exposures likely to be incurred by residents who consume local plants were well within acceptable limits. The linkage between changes in game meat quality and human health was determined to be invalid, since there was no evidence of accumulation of Project-related chemicals in plant tissues that game animals would be ingesting.

With respect to cumulative effects, increased air emissions from the combined developments may contribute to an increase in chemical concentrations in plant tissues. However, there are currently no data available to evaluate this question further.

Residual Impact Classification and Degree of Concern

The residual impact, as shown in Table F12-8, will likely be enhanced in the CEA, relative to the impact predicted for the Project. Hence, the degree of concern is considered to be low, rather than negligible. There is a need for additional data to substantiate this prediction.

Table F12-8 Residual Impact Classification for Human Health Impacts Related to Changes in Plants and Game Meat Quality

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Low

F12.4.5 Key Question HHCEA-5: Will Equilibrium Concentrations of Residual Chemicals in Water and Select Local Food Items Following Reclamation of Combined Developments Affect Human Health?

Analysis of Key Question

In the Project impact analysis for the corresponding key question HH-6 (Section E12.11), no impacts to human health were predicted for virtually all chemicals evaluated. Two naturally elevated substances, arsenic and beryllium, may present marginally elevated health risks, consistent with present natural conditions, although the likelihood for adverse health effects is low.

The results of the impact analysis for a hypothetical hunter/trapper living for extended periods of time on the reclaimed Project site would be applicable to reclaimed landscapes of baseline and approved developments, assuming chemical releases from the reclaimed landscapes of other developments are not significantly greater than those predicted for the Project. Similar exposure scenarios evaluated for the reclaimed landscapes of the Steepbank and Aurora Mines indicated a low probability of potential impacts to human health (Golder 1996d, BOVAR 1996a).

For the reasons outlined above, the exposures derived by a hunter/trapper and his child from ingestion of plants and game animals on the reclaimed landscape of the Project were assumed to be similar for reclaimed landscapes of baseline and approved developments. However, exposures derived from water ingestion on the reclaimed landscape of the Project or other developments could be higher as a result of the cumulative contributions of release waters to drinking water sources, such as the Muskeg and Athabasca rivers. For this reason, the exposure scenario previously evaluated for key question HH-6 was re-evaluated using the predicted cumulative water concentrations in the Muskeg River for the hunter/trapper's drinking water exposure. The results of this assessment indicated marginally increased risk estimates (i.e., ER values) compared to the scenario evaluated in HH-6; however, ER values remained less than 1.0 for all chemicals, except arsenic and beryllium, as they were in the evaluation for key question HH-6 (Section E12.11). For the reasons discussed in Section F12.2, predicted cumulative concentrations of arsenic and beryllium in the Muskeg River are considered typical of background concentrations in Canadian rivers and acceptable for drinking water purposes.

Thus, chemical releases from multiple reclaimed landscapes within the region will not necessarily result in compounded exposures on any individual reclaimed area. Rather, due to the larger area of reclaimed landscapes in the Athabasca Oil Sands Region, there is a greater likelihood for a hypothetical hunter/trapper to live and hunt/trap in a reclaimed area. Therefore this exposure pathway becomes more likely, but the health risks are not significantly enhanced.

Residual Impact Classification and Degree of Concern

While the magnitude of the impact is considered to be low, it is recognized that there is an increased likelihood on a regional basis for this exposure pathway to be realized. Therefore, the residual impact is likely to be enhanced in the CEA relative to the impacts predicted for the Project, since there is a greater likelihood of individuals being exposed. However, the magnitude of exposure and associated health risks to a given individual are not expected to increase. The degree of concern is summarized in Table F12-9.

Table F12-9 Residual Impact Classification for Human Health Impacts Related to Chemicals in Food Items Following Reclamation

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Moderate

F12.4.6 Key Question HHCEA-6: Will Noise from Combined Developments During Construction and Operation Unduly Affect People Who Reside in the Region?

Analysis of Key Question

The potential impact of noise on background and permissible noise levels in Fort McKay was discussed previously in Section E12.11. The primary sources of noise from the Muskeg River operation are expected to be the truck and shovel operations. It was inferred from other investigations that there is a good potential for elevated noise levels to result in Fort McKay and the likelihood will increase with the added contribution of the Syncrude Aurora North Mine. However, given the mobile nature of the noise sources and the ability to mitigate the noise levels through management of activities and/or use of noise barriers, the degree of concern was ranked as low. The added contribution of the Suncor Steepbank Mine and Aurora South Mine to this scenario has not been measured; however given the remoteness of on-site machinery, it's contribution is likely insignificant. However, the potential for increased roadway traffic may contribute to elevated background noise and this can be effectively managed as noted above.

Residual Impact Classification

The residual impacts identified for the CEA are not significantly different from those predicted for the Project, due to the mobile nature of noise sources, the ability to mitigate and the remoteness of several developments to Fort McKay. In light of the above considerations the cumulative impact to ambient noise levels is summarized in Table F12-10.

Table F12-10 Residual Impact Classification for Noise

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Low

F12.5 Summary of Impacts

The summary of residual impacts on Human Health for the CEA is shown in Table F12-11.

Table F12-11 Summary of Human Health Residual Impacts for the CEA

Key Question	CEA Results
HHCEA-1: Will water quality changes from combined developments affect human health?	• During operation and closure, no significant health impacts were identified for human health; however there is some uncertainty regarding the chronic toxicity of naphthenic acids. The resulting impact prediction for the CEA is not significantly different from that predicted for the Muskeg River Project. The cumulative effects on human health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.
HHCEA-2: Will air quality changes from combined developments affect human health?	• During operation of the combined developments, no significant impacts were identified to human health from the following emission sources: mine fleet exhausts, fugitive emissions from tailings settling ponds, fugitive emissions from mine surfaces and background sources of PAHs in residential communities. The degree of concern is **Negligible**.
HHCEA-3: Will changes to air and water quality from combined developments affect human health?	• During operation, no significant impacts were identified for human health through this multimedia exposure pathway. However, there is some uncertainty regarding the chronic toxicity of naphthenic acids, as discussed for HHCEA-1. • The cumulative effects on human health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low.**

Key Question	CEA Results
HHCEA-4: Will changes to plant and game meat quality from combined developments affect human health?	• During operation and closure phases of the Muskeg River Mine Project, no significant impacts were identified for human health as a result of consumption of native plants or wild game. Increased air emissions predicted for the CEA scenario may contribute to an increase in chemical concentrations in plant tissues. A potential impact is therefore predicted for the CEA. Quantitative estimates of future plant tissue concentrations are unavailable to quantify the impact further. The cumulative effects on human health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.
HHCEA-5: Will equilibrium concentrations of residual chemicals in water and select local food items following reclamation of all developments affect human health?	• Following closure in the far future when equilibrium conditions have been established for all combined developments, a potential impact has been identified in the CEA. The residual impact is likely to be enhanced in the CEA, relative to the impact predicted for the Muskeg River Mine Project in so far as there is a greater likelihood on a regional basis for this exposure pathway to be realized, but likely without an increase in exposure magnitude. The cumulative effects on human health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Moderate**.
HHCEA-6: Will noise from combined developments during construction and operation unduly affect people who reside in the region?	• During construction and operation, truck and shovel operations of combined developments may cause periodic exceedances of permissible sound levels in Fort McKay. The residual impacts identified in the CEA are not significantly different from those predicted for the Muskeg River Mine Project , due to the mobile nature of noise sources, the ability to mitigate and the remoteness of several developments to Fort McKay. The cumulative effects will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.

F13 HISTORICAL RESOURCES CUMULATIVE EFFECTS ASSESSMENT

Effective assessment of the cumulative effects on historical resources of any series of proposed developments within a particular region is difficult because of the nature of the resources in question and the current state of knowledge about them. The great majority of historical resources in the lower Athabasca basin comprise the remains of occupations by nomadic hunter/gatherer groups that lived the region over the last 9,000 years. The historical resources are widely dispersed but are almost always concealed below a continuous cover of vegetation and/or shallow mineral sediment. Knowledge of their presence and character is only obtained upon completion of dedicated studies undertaken in advance of proposed developments.

It cannot be known in advance of specific studies what the effects of any particular development will be. Potential effects can only be compared in a quantitative way with those obtained from areas previously examined. A regional historical resource "population" against which the effects of impacts of a specific project can be measured, would only exist if that region had been completely inventoried. There are no regions in Alberta where inventories can be considered to be sufficiently complete to believe that extant historical resource "populations" can be defined. Without information on the extant resource "population" in a region, a cumulative effects analysis can only be impressionistic and subject to constant reevaluation as new information is obtained.

In considering impacts to historical resources, however, it must be appreciated that without regional developments (and the historical resource studies that accompany them), little of the prehistory of this region would be well-defined.

The pre-existing conditions and specific quantifiable effects of the Muskeg River Mine Project on historical resources were discussed in detail in Sections D13 and E13 of this EIA. Because of the inherent uncertainties of providing an effective analysis of the specific effects of the Project in combination with other existing and approved developments in the region, a historical resources CEA is not considered applicable for this EIA.

F14 RESOURCE USE CUMULATIVE EFFECTS ASSESSMENT

F14.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on Land Resource Use in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Forestry
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Municipalities
- Pipelines, utility corridors and roadways

Descriptions of these developments and the assumptions applicable to each for this CEA are detailed in Section F1.

This CEA was focused on the examination of incremental and total cumulative effects on land resource uses. The effects assessment considered how resources are affected by changes in soils, terrain, vegetation, wildlife and fisheries due to the Project, in combination with existing and approved developments in the RSA.

Developments will be phased over time. As well, each reclamation associated with forestry and oil sand activities will reduce the magnitude of impacts. In most cases, reclamation activities will enhance land resource use (e.g., forestry, berry picking, hunting).

F14.2 Approach and Methods

The approach for the evaluation of cumulative impacts was similar to the approach for the environmental impact evaluation (see Section E14.2). However, this assessment was based on the information provided in BOVAR's (1996) telephone survey. Quantitative comparisons were not possible because exact locations and spatial extent of preferred locations were not reported. As well, in the CEA, each residual impact was classified to magnitude and duration only.

F14.3 Potential Linkages and Key Questions

The potential linkages described for land resource use in Section E14 apply for the CEA. The key questions were modified by combining berrypicking, hunting, fishing and trapping into consumptive resource use. The key questions for the CEA include:

RUCEA-1: Will Combined Development Result in a Change in Surface and Mineral Extraction Use?

RUCEA-2: Will Combined Developments Result in a Change in ESAs?

RUCEA-3: Will Combined Developments Result in a Change in Forestry Resource Use?

RUCEA-4: Will Combined Developments Result in a Change in Hunting, Trapping, Fishing and Berry Picking?

RUCEA-5: Will Combined Developments Result in a Change in Non-Consumptive Recreational Use?

F14.4 Analysis and Results

F14.4.1 Key Question RUCEA-1: Will Combined Developments Result in a Change in Surface and Mineral Extraction Use?

Analysis of Key Question

Potential areas for surface dispositions throughout the RSA were shown in Figure D14-5. These areas are mainly concentrated along the Athabasca River and north of the Shell Lease 13. Of all the surface dispositions, only CNT 9601100, a Nominee for Special Places 2000, will be affected by combined developments. The developments which may have an impact are Alberta Pacific Forest Industries Forest Management Area, Suncor Steepbank, Suncor Lease 86/17, Aurora North, SOLV-EX, and the Muskeg River Mine. These developments may affect surface dispositions by removal of the habitat through site clearing. Surface dispositions are well documented and, during planning, attempts can be made to avoid these areas.

Residual Impact Classification and Degree of Concern

Mitigation measures will reduce the impact to the surface disposition. However, some of the disposition will still be affected. The impact is expected to be Moderate and of Long-Term duration. The degree of concern is Moderate.

F14.4.2 Key Question RUCEA-2: Will Combined Developments Result in a Change in ESAs?

Analysis of Key Question

There are a variety of ESAs within the RSA. To the extent possible, ESAs were considered during project development and attempts to minimize impacts, including avoiding these areas whenever possible, were implemented where possible. As well, mitigation measures such as reducing the total area cleared, maintaining native vegetation for cover and maintaining adequate buffer zones around rivers, lakes and other sensitive areas, further reduces impacts to ESAs.

The only ESA which will be directly affected by project development is Kearl Lake. Kearl Lake provides important waterfowl staging habitat, potential for rare plants and important moose habitat. Kearl Lake will mainly be affected by the Aurora South Mine. However, the Project may have an effect on the wildlife movement corridor to and from Kearl Lake.

Residual Impact Classification and Degree of Concern

Kearl Lake may be affected by changes in terrain, vegetation, or wildlife or by changes in access. Provided that this ESA is avoided to the extent possible and that appropriate mitigation measures are used to further minimize impacts, the cumulative impacts associated with the developments on this ESA will be minor. The magnitude is Low and the duration is Medium to Long-Term. The degree of concern is Low.

F14.4.3 Key Question RUCEA-3: Will Combined Developments Result in a Change in Forestry Resource Use?

Analysis of Key Question

Activities that may affect merchantable forests include oil sands mining, municipalities and various other developments. These activities may result in the loss of merchantable timber habitat and changes in access. Loss of merchantable timber may be minimized by salvaging merchantable timber during site clearing. However, once sites are developed, the footprint area is lost until reclamation. At that point, reforestation activities would occur.

The merchantable forest land area within the RSA consists of the vegetation communities within the following vegetation types:

- Jack Pine Forest
- Mixedwood Forest
- Spruce Forest
- Aspen Poplar Forest
- Paper Birch Forest

These vegetation units encompass an area of 300,000 ha. Approximately 30% of the RSA consists of merchantable timber. The greatest impact to the area of merchantable forest will be from timber harvesting. Alberta Pacific Forest Industries (Al-Pac) and Northland Forest Products will harvest close to 71,000 ha (or 14%) of the RSA in the next 30 years (BOVAR 1996a).

The Annual Allowable Cut (AAC) for the Al-Pac Forest Management Agreement (FMA) is 3,091,000 m^3/year. The AAC for Northland Forest Products is 210,200 m^3/year (BOVAR 1996a). The combined total AAC volume is 3,301,200 m^3/year. Annual average timber salvage from the Suncor Steepbank Mine and the SOLV-EX facility is less than 1% of the combined AAC (BOVAR 1996a). It is expected that the annual salvage of timber from the various developments will vary, but should be less than 2% of the Al-Pac's FMA and Northland Forest Products combined wood supply. Thus, timber salvage from the various developments in the area represent only a small percentage of the total AAC.

Aspen-White Spruce Forests

The aspen-white spruce forests are primarily found within dogwood ecosite phases (e1, e2) occupying an area of 4,039 ha or 0.4% (Table F14-1). Less than 0.1% loss to these communities are expected as a result of the combined developments. Other effects to productive forestry stands occur within aspen or white spruce dominated stands with the low bush cranberry (d3, d2), dogwood (e3), and blueberry (b1, b3) ecosite phase. The cumulative effects from combined CEA developments, therefore, represent an overall reduction in productive forest stands of approximately 38,847 ha or 3.7% of the RSA (Table F14-1). Reclamation, however, will increase productive forests by 100,015 ha, to a total of 303,558 ha or 28.9% of the RSA.

Table F14-1 Timber Productivity Ratings (TPR) of Terrestrial Vegetation (Ecosite Phases) Types Within the Local Study Area and Areas to be Cleared for the Muskeg River Mine Project

Vegetation Type			TPR [a]	RSA		CEA		Reclamation	
Vegetation Cover	Map Code	General Community Types		Area (ha)	% of RSA	Area (ha)	% of RSA	Area (ha)	% of RSA
Lichen Jack Pine	a1 with some b4	Lichen Pj	F-G	15,278	1.5	2,928	0.3	16,805	1.6
Blueberry Pj-Aw; Aw-Sw; Low-Bush Cranberry Aw-Sw	b1, b3, d2	Blueberry Pj-Aw, Aw-Sw, Sw-Pj; Low-Bush Cranberry AW-Sw	F - G	119,311	11.0	11,285	1.1	121,054	11.5
Blueberry Aw(Bw)	b2	Blueberry (Aw (Bw)	M - G	1,132	0.1	190	<0.1	1,526	0.1
Low-Bush Cranberry (Aw)	d1	Low-Bush Cranberry Aw	M - G	81,511	7.8	7,056	0.7	81,974	7.8
Low-Bush Cranberry Sw	d3, e3	Low-Bush Cranberry Sw; Dogwood Sw	M - G	76,383	7.3	7,120	0.7	77,867	7.4
	e1, e2	Dogwood Pb-AW; Pb-Sw	F - M	4,039	0.4	63	<0.1	4,330	0.41
	Sub-total	*Productive Forest*	*F-G*	*293,353*	*28*	*28,642*	*2.7*	*303,558*	*28.9*

Source: AVI Manual Version 2.2, 1996.
[a] TPR - G-Good, M-Moderate, F-Fair.

Lichen-Jack Pine Forests

The lichen-jack pine forests (a1) occupy approximately 15,278 or 1.5% of the RSA (Table F14-1).

The combined developments will clear 2,928 ha or 0.3%. This impact is the result of forestry and not oil sands development. Reclamation activities will result in a return 16,805 ha or 1.6% of the RSA to these forests.

Residual Impact Classification and Degree of Concern

Some areas of merchantable timber will be lost due to project development. This impact cannot be mitigated. However, the magnitude of the impact is expected to be Low, as these areas represent a very small portion of the total AAC. Duration of the impact will range from Medium to Long-Term, based on the projected lifespan of each development. The degree of concern is Low. In the far future there will be an increase in productive forest lands. In summary, the impact on old-growth forests of the Project and combined developments is Minimal. Therefore, the cumulative impact is defined as Neutral in direction and Negligible in magnitude.

So what is the verdict

F14.4.4 Key Question RUCEA-4: Will Combined Developments Result in a Change in Hunting, Trapping, Fishing and Berry Picking?

Analysis of Key Question

Existing and new developments within the RSA have the potential to disturb vegetation through loss of habitat and/or contamination. Loss of important berry producing shrubs and changes in access may affect recreational berry picking. The Muskeg River Valley, an important berry picking site as identified by BOVAR (1996c), will be affected by the Project and by the Aurora Mines. This berry picking site may be completely or partially lost, however, it can be reclaimed following closure of the developments and subsequent reclamation. Revegetation during reclamation can be focused toward vegetation species which have traditional and non-traditional medicinal, dietary, ritual, utensil and dye uses. As well, access to berry picking sites should be restored during reclamation and closure and may even be enhanced.

Hunting and trapping opportunities within the RSA will be incrementally affected by the Project. Effects are likely to be Negative during construction and operation but Positive following closure. Important hunting locations within the RSA include the Athabasca River Valley, the highway 963 Extension, and the oil sands lease area (BOVAR 1996c). These areas may be affected by various municipalities, Al-Pac, Suncor Steepbank, Suncor Lease 86/17, the Project, Aurora North, and SOLV-EX. Construction and operation of the developments may reduce hunting opportunities through changes in wildlife abundance and distribution and changes in access. It is expected that these hunting opportunities will be lost during the life of various developments. However, hunting opportunities may improve following closure and site reclamation. In addition, improved access following site closure may also lead to increases in hunting opportunities.

Registered fur management areas (RFMAs) within the RSA were identified in D14. Changes in wildlife abundance and diversity and changes in access may reduce trapping opportunities in the RSA and there are five traplines which may be affected (see Section D14.3.6). These traplines may be affected by Aurora North, SOLV-EX, the Project, various cutblocks, Al-Pac, and Aurora South. In particular, trapping opportunities will be reduced during development construction and operations. However, following closure and site reclamation, trapping opportunities may actually improve, especially with improved access.

Habitat loss due to existing and reasonably foreseeable developments ranges from 1.1 to 2.5% of the available game (moose) and furbearer (beaver) KIR HUs within the RSA (Table F11-1). The Muskeg River Mine Project will account for an additional 0.1 to 0.6% of the RSA being temporarily disturbed. Thus, the cumulative effects of existing and approved developments on game and furbearer species will range from 1.2 to 3.1%. These values represent the maximum decrease in hunting and trapping opportunities that could be accounted for by habitat change. Impacts are likely to be less due to the phasing of site clearing and reclamation activities.

Following development closure, habitat conditions for moose, black bears, beavers and ruffed grouse should rapidly improve within the Project area. Habitat for fishers and other late successional species will require more time for re-establishment to the pre-development state.

It should be noted that hunting and trapping will be restricted on the Project area during construction and operation for reasons of public and worker safety. Thus, hunting and trapping opportunities will decrease and will only return to the pre-development condition following closure.

Cumulative, residual losses to game and furbearer species were considered to have a Low magnitude as no KIR will experience losses of more than 3.1% of baseline HUs within the RSA due to existing, approved and the Muskeg River Mine developments. While the direction of the impacts during construction and operation of these developments is Negative, the impacts are Reversible, as reclamation of the sites is expected to return them to an equivalent habitat capability.

Preferred fishing locations which may be affected by various developments include the Athabasca and the Muskeg rivers. Developments which may affect these rivers include Al-Pac, Suncor Steepbank, Suncor Lease 86/17, the Project, Aurora North Mine and SOLV-EX.

Fish habitat may be altered as part of development. This, in turn, reduces fishing opportunities. As with other developments, restricted access during construction and operations may also reduce fishing opportunities. Reclamation of sites following closure improves fishing opportunities, especially through improved access.

Many developments comply with very stringent water quality and fish habitat guidelines. As well, significant measures are often undertaken to minimize impact. Thus, sport fish abundance and distribution is not expected to change as a result of development activities. Following closure, sport fish habitat may be enhanced over the creation of lakes, ponds and drainages. As well, access to important sport fishing locations is expected to improve.

Residual Impact Classification and Degree of Concern

There will be a decrease in berry picking activities due to loss of berry picking habitat and restricted access. There are no mitigation measures for site clearing and restricted access. Following closure, however, important berry picking habitat can be restored and developed sites are returned to equivalent or greater capability. The effects of the various developments on berry picking is expected to be of Low magnitude and of Medium duration. The degree of concern is Low.

Hunting and trapping opportunities within the RSA will be incrementally affected by the Project. Effects are likely to be Negative during construction and operation but Positive during reclamation. A small proportion of hunting sites and some trapping areas will be lost due to changes in access and changes in wildlife abundance and distribution. These impacts cannot be mitigated. However, hunting and trapping opportunities throughout the RSA are numerous. Thus, the impact is of Low magnitude and Medium to Long-Term in duration. The degree of concern is Low.

Some fishing opportunities will be lost due to development. In particular, restricted access will lead to reduced fishing opportunities and this impact cannot be mitigated. Cumulative effects for developments within the RSA is expected to be of Low magnitude and of Medium to Long-Term duration. The degree of concern is Low.

F14.4.5 Key Question RUCEA-5: Will Combined Developments Result in a Change in Non-Consumptive Recreational Use?

Analysis of Key Question

Non-consumptive recreational uses include camping, hiking, boating, wildlife viewing and snowmobiling. Important recreational areas for these activities were presented in Section D14.3.8. Of these important recreational areas, only the Athabasca River and the Muskeg River have the potential to be affected by combined developments. Al-Pac, SOLV-EX, Aurora Mines, the Project, Suncor Lease 86/17, Suncor Steepbank, various municipalities and cutblocks may all affect recreation on or near the Athabasca River. The Project and Aurora Mines may affect recreational activity on the Muskeg River.

Changes in access and changes in terrain, vegetation and wildlife due to project development may reduce recreational opportunities within the RSA. However, since many recreational areas are ESAs and recreational sites are numerous and scattered throughout the RSA, the cumulative effects of various developments is expected to be Low.

Residual Impact Classification and Degree of Concern

Recreational areas along the Athabasca and Muskeg Rivers may be affected by changes in access and changes in terrain, vegetation and wildlife. The impact is expected to be Low, as the impact to the rivers is expected to be low. The overall effect is expected to be Low in magnitude and Medium to Long-Term in duration. The degree of concern is Low.

F14.5 Summary of Impacts

Table F14-2 summarizes the residual impacts to resource use associated with the CEA.

Table 14-2 Summary of Impacts on Resource Use

Key Question	CEA Results
RUCEA-1: Will Combined Development Result in a Change in Surface and Mineral Extraction Use?	• Mitigation measures will reduce the impact to the surface disposition. However, some of the disposition will still be affected. The degree of concern is **Moderate**.
RUCEA-2: Will Combined Developments Result in a Change in ESAs?	• Kearl Lake may be affected by changes in terrain, vegetation, or wildlife or by changes in access. Provided that this ESA, is avoided to the extent possible and that appropriate mitigation measures are used to further minimize impacts, the cumulative impacts associated with the developments on this ESA will be minor. The degree of concern is **Low**.
RUCEA-3: Will Combined Developments Result in a Change in Forestry Resource Use?	• Some areas of merchantable timber will be lost due to project development. This impact cannot be mitigated. However, the degree of concern is Low, as these areas represent a very small portion of the total AAC.
RUCEA-4: Will Combined Developments Result in a Change in Hunting, Trapping, Fishing and Berry Picking?	• There will be a decrease in berry picking activities due to loss of berry picking habitat and restricted access. There are no mitigation measures for site clearing and restricted access. Following closure, however, important berry picking habitat can be restored and developed sites are returned to equivalent or greater capability. The effects of the various development on berry picking is expected to be of Low magnitude and of Medium duration. The degree of concern is **Low**. A small proportion of hunting sites and some trapping areas will be lost due to changes in access and changes in wildlife abundance and distribution. These impacts cannot be mitigated. However, hunting and trapping opportunities throughout the RSA are numerous. Thus, the degree of concern is **Low**.

Key Question	CEA Results
	• Some fishing opportunities will be lost due to development of projects. In particular, restricted access will lead to reduced fishing opportunities and this impact cannot be mitigated. Cumulative effects for projects within the RSA is expected to be of Low magnitude, of Medium to Long-Term duration. The degree of concern is **Low.**
RUCEA-5: Will Combined Developments Result in a Change in Non-Consumptive Recreational Use?	• Recreational areas along the Athabasca and Muskeg Rivers may be affected by changes in access and changes in terrain, vegetation and wildlife. The impact is expected to be low, as the impact to the rivers is expected to be low. The overall effect is expected to be Low in magnitude and Medium to Long-Term in duration. The degree of concern is **Low.**

F15 TRADITIONAL LAND USE CUMULATIVE EFFECTS ASSESSMENT

F15.1 Introduction

This cumulative effects assessment (CEA) predicts the effects of the Muskeg River Mine Project (Project) plus existing and approved developments on traditional land use in the Regional Study Area (RSA). The following developments, as shown in Figure F1-1, are included in the CEA:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Forestry
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Municipalities
- Pipelines, utility corridors and roadways

Descriptions of these developments and the assumptions for this CEA are detailed in Section F1.

F15.2 Approach and Methods

The basis for assessment of this question is a quantitative approach. This compares the area included within the stated traditional territory of the Fort McKay communities with the areas that would be lost either temporarily or permanently to existing, and approved developments within the RSA of the Project. This comparison is expressed as a simple percentage of the traditional lands to be affected.

F15.3 Potential Linkages and Key Questions

One key question has been established in consideration of this issue.

TLUCEA-1: Will Combined Developments Result in a Change in Traditional Land Use?

F15.4 Analysis and Results

F15.4.1 Key Question TLUCEA-1: Will Combined Developments Result in a Change in Traditional Land Use?

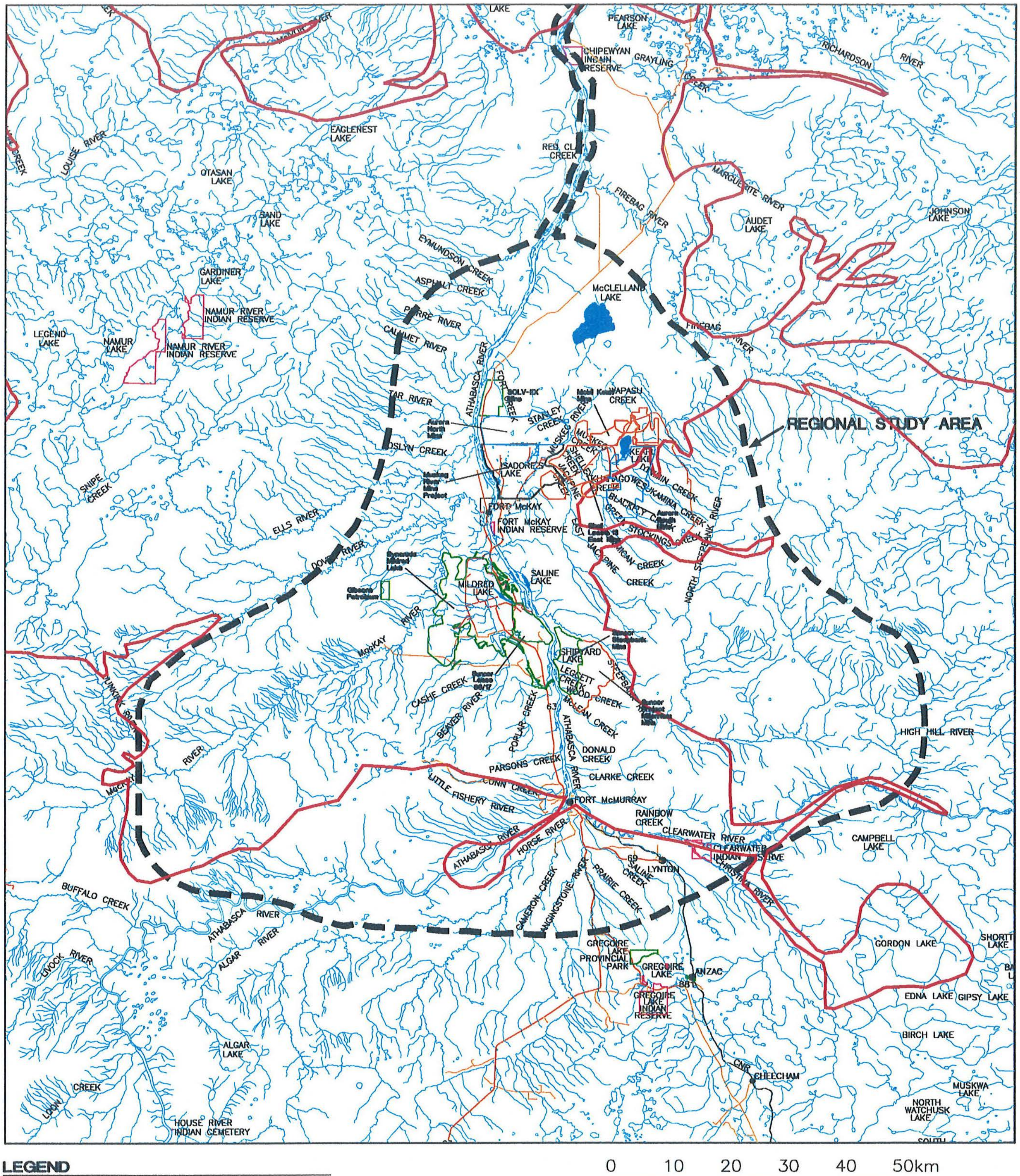
Analysis of Key Question

The Fort McKay communities (Communities) traditionally hunt, trap and conduct other traditional practices that are fundamental to the continuance of their distinct identity over a large area, which emcompasses the Project and other regional developments. This area has been defined in a document entitled 'From Where We Stand' (Fort McKay Tribal Administration 1982). The area illustrated in Figure 2 of that document (Fort McKay Hunting and Trapping Territory) has been calculated and its outline reproduced here in Figures F15-1 and F15-2. The area included within these boundaries forms the basis of a quantitative assessment undertaken of the potential combined effects of recently approved developments on the traditional practices conducted by the Fort McKay Communities. These communities include the Treaty Indians, both Chipweyan and Cree,and the Metis and Non-Status Indians who live in Fort McKay (Fort McKay Tribal Administration 1982, Fort McKay Firtst Nations 1994).

The area encompassed by these traditional lands has been compared with the areas represented by the existing and approved developments listed in Table F1-1 (see also Figure F15-2). As well, Table F15-1 includes area estimates for Forestry Management zones after 1997 (Figure G15-2), because they are considered approved developments for the purpose of this comparison. These data, when compared with the area identified as traditional use lands (Table F15-2) show that 10.4% of the lands considered to be the Communities' traditional lands would be affected by approved developments in combination with the Project and existing developments.

In considering this comparison, it should be noted that the traditional hunting and trapping lands illustrated in 'From Where We Stand' has a truncated northern boundary in the Lake Claire area. Traditional lands of the Fort McKay Communities may extend somewhat further north and may encompass more area than shown in Table F15-1. Activities that are conducted throughout this area are discussed in Section E15 of this EIA. The reader should consult that section, as well as the original documents referred to, for additional detail.

Also important to note is the fact that the Forestry calculations reflect only the RSA for the Project. Considerably larger areas would be affected within the Communities' Traditional lands outside the RSA, than is shown in the table.



LEGEND

- TRADITIONAL HUNTING AND TRAPPING TERRITORY
- EXISTING OPERATIONS
- APPROVED PROJECTS
- DISCLOSED PROJECTS
- MUSKEG RIVER MINE PROJECT

REFERENCE

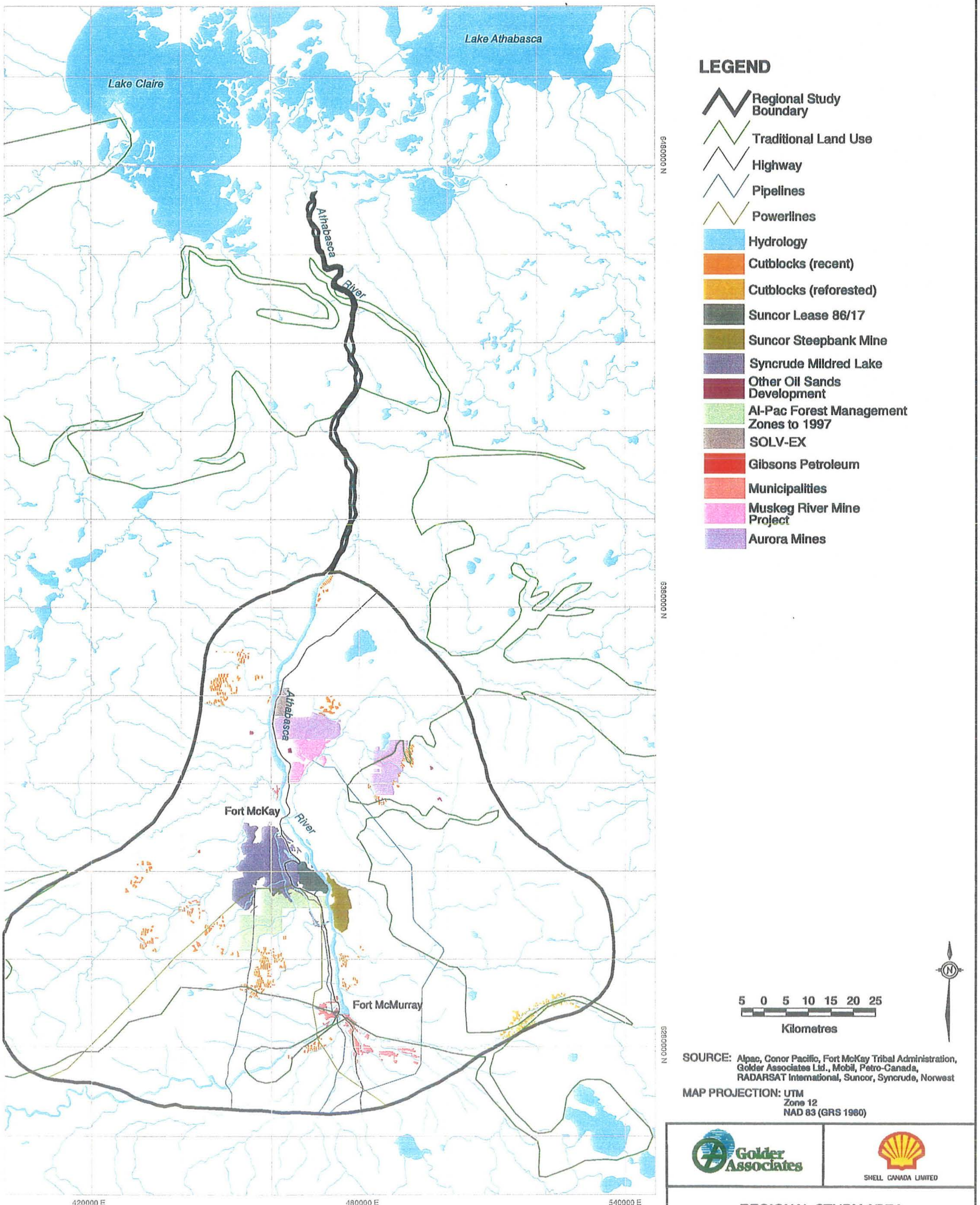
DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

SHELL CANADA LIMITED

AREA OF TRADTIONAL HUNTING (After "FROM WHERE WE STAND" 1983)

15 JAN 98	Figure F15–1	DRAWN BY: CG



SOURCE: Alpac, Conor Pacific, Fort McKay Tribal Administration, Golder Associates Ltd., Mobil, Petro-Canada, RADARSAT International, Suncor, Syncrude, Norwest

MAP PROJECTION: UTM
Zone 12
NAD 83 (GRS 1980)

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REGIONAL STUDY AREA
FORT MCKAY NATIONS TRADITIONAL LANDS
MUSKEG RIVER MINE
AND APPROVED OIL SANDS PROJECTS

10 Jan. 1998	Figure F15-2	PRODUCED BY: K. Quine REVIEWED BY:

Finally, it should also be noted that the areas listed in Table 15-1 represent maximum disturbance zones. Both forestry and oil sands developments will be phased such that only portions of each area will be disturbed at any one time. In addition, reclamation will be phased such that reclaimed land may be available for Traditional Land Use during various stages of development closure.

Table F15-1 Traditional Lands Compared With the Project, Existing and Approved Developments

Baseline	Area (km^2)	Approved Developments + Muskeg River Mine Project	Area (km^2)
Suncor 86/17	33.7	Aurora North	77.6
Syncrude Mildred Lake	232.4	Aurora South	74.2
Suncor Steepbank	1.5	Suncor Steepbank	30.8
SOLV-EX	20.9	Forestry after 1997	1,316.0
Gibsons	0.2	Muskeg River Mine Project	100.4
Municipalities	40.0		
Highways	4.3		
Pipelines	6.2		
Powerlines	4.2		
Others	2.0		
Forestry (Current and reforested)	195.2		
Total - Existing Developments	540.6	Total - Approved Developments + Muskeg River Mine	1,599.0
TOTAL Existing and Approved Projects			**2,139.6**

Table F15-2 Areas of Existing and Approved Developments in the Regional Study Area in Relation to the Traditional Land Use Areas

Areas	Area (km^2)	Traditional Lands Affected
Fort McKay Communities Traditional Lands	20,669.0	
Existing Developments	540.6	2.6%
Muskeg River Mine Project	100.4	0.5%
Total oil sand developments	521.7	2.5%
Total forestry	1,511.2	7.3%
Other developments	56.7	0.3%
Muskeg River Mine + Existing	641.0	3.1%
Muskeg River Mine + Existing + Approved	2,139.6	10.35%

The impacts of oil sands developments will depend on the lifespan of the developments involved and the character and the success of reclamation activities. Effective reclamation may enhance opportunities for Traditional Land Use after closure. In this respect it can be assumed that final landscape productivity will compare favorably with pre-Project conditions. Depending on which types of traditional resources are preferable, conditions favoring these resources can be incorporated into reclamation designs.

The effects of forestry activities will occur over a longer time frame and will affect larger areas within the region. The long-term effects of these activities will depend on the timing and character of vegetative regeneration. In many instances opportunities for continuing traditional land use practices may be enhanced by the re-vegetation procedures employed by the forestry industry.

The indirect affects of existing developments in combination with the Muskeg River Mine Project and other approved developments will stem from an increase in the non-aboriginal population in the region. The resulting increase in the non-traditional use of the landscape may compete with traditional uses.

In summary, the number of existing and approved developments within the RSA combined with the Project (including Forestry after 1997) will directly affect 10.1 % of the traditional use area of the Fort McKay Communities' traditional lands. The Project will account for 4.7% of the area encompassed by the existing and approved developments considered for the CEA within the RSA.

Outside the RSA additional proportions of the traditional use land base will be affected by longer term forestry related development and other activities not considered here. The effects of these approved developments in combination with the Project will be varied in magnitude and geographic extent depending on the specific land use practices or traditional resources to be affected. The duration of these effects will also vary depending on the lifespan of the operation. However, it may be possible to reverse the negative effects of the these developments.

Study is continuing, with the objective of providing additional regional level information, to clarify and further define specific aspects of the combined effects of existing and approved developments on the traditional land use practices of the Fort McKay Communities. This information would be provided in the next oil sands development application to be submitted for approval.

Residual Impact Classification

Residual impacts on the traditional land use practices of the Fort McKay Communities as a result of the Project in combination with existing and approved developments in the region would occur if opportunities for conduct of these practices are permanently precluded. Based on planning assumptions made elsewhere in this EIA, this concern would be effectively offset and the long-term effects of these projects would be classified as Low in magnitude and/or Reversible.

F15.5 Summary of Impact

Table F15-3 summarizes the impact on traditional land use under the CEA.

Table F15-3 Summary of Impacts on Traditional Land Use

Key Question	CEA Results
TLUCEA-1: Will combined developments result in a change in traditional land use?	• Oil sands developments and their auxiliary activities will result in negative effects on the traditional land use practices of the Fort McKay Communities. These effects will be Low in magnitude considering the proportion of the Communities' established traditional lands they would effect. They would be Localized in extent, Medium-Term in duration and are Reversible. The degree of concern is **Low.** • Forestry developments will also have Negative effects on traditional land use practices. These effects would be considered to be Moderate in magnitude considering the proportions of the Communities' traditional lands that they would affect. They would be Regional in extent over the Long-Term but localized to specific cut blocks and staging areas in the Short-Term. These effects would be Reversible. The degree of concern is **Moderate.** • Other types of developments typically involve much smaller areas and their negative impacts would be considered Negligible it terms of the proportion of the Communities' traditional lands to be affected. Only in the case of municipalities would these impacts be considered Permanent and Irreversible. • Over the life span of combined oil sands and forestry projects indirect Negative effects on traditional land use practices would be experienced as a result of an increase in non-traditional uses of the landscape which often complete with the traditional use patterns. The magnitude and duration of these effects cannot be accurately predicted but are assumed to be Reversible over the Long-Term.

G REGIONAL DEVELOPMENT REVIEW

This section of the Muskeg River Mine Project (Project) EIA is the regional development review, which includes consideration of the potential effects from the Project plus existing, approved and planned (publicly disclosed) developments, to the extent information is known and available to the end of 1997.

This assessment includes predictions about how the combined developments could affect environmental resources and resource use in the Regional Study Area for the Project.

G1 REGIONAL DEVELOPMENT REVIEW - METHODOLOGY

G1.1 Introduction

This section of the Muskeg River Mine Project (the Project) EIA provides a regional development review (RDR). This review provides a consideration of the potential effects from the Project plus existing, approved and planned (publicly disclosed) developments.

Although developments that have not advanced to the approval or application stage are not part of a cumulative effects assessment, Shell has committed to provide a consideration of the potential effects associated with planned developments. This regional development review will assist the AEUB, AEP and regional communities in understanding potential regional issues and help in regional planning. This information is also provided in accordance with the AEUB decision (No. D97-13) Syncrude Aurora Mine Decision, in which the Board wished to have additional information on regional issues placed before it.

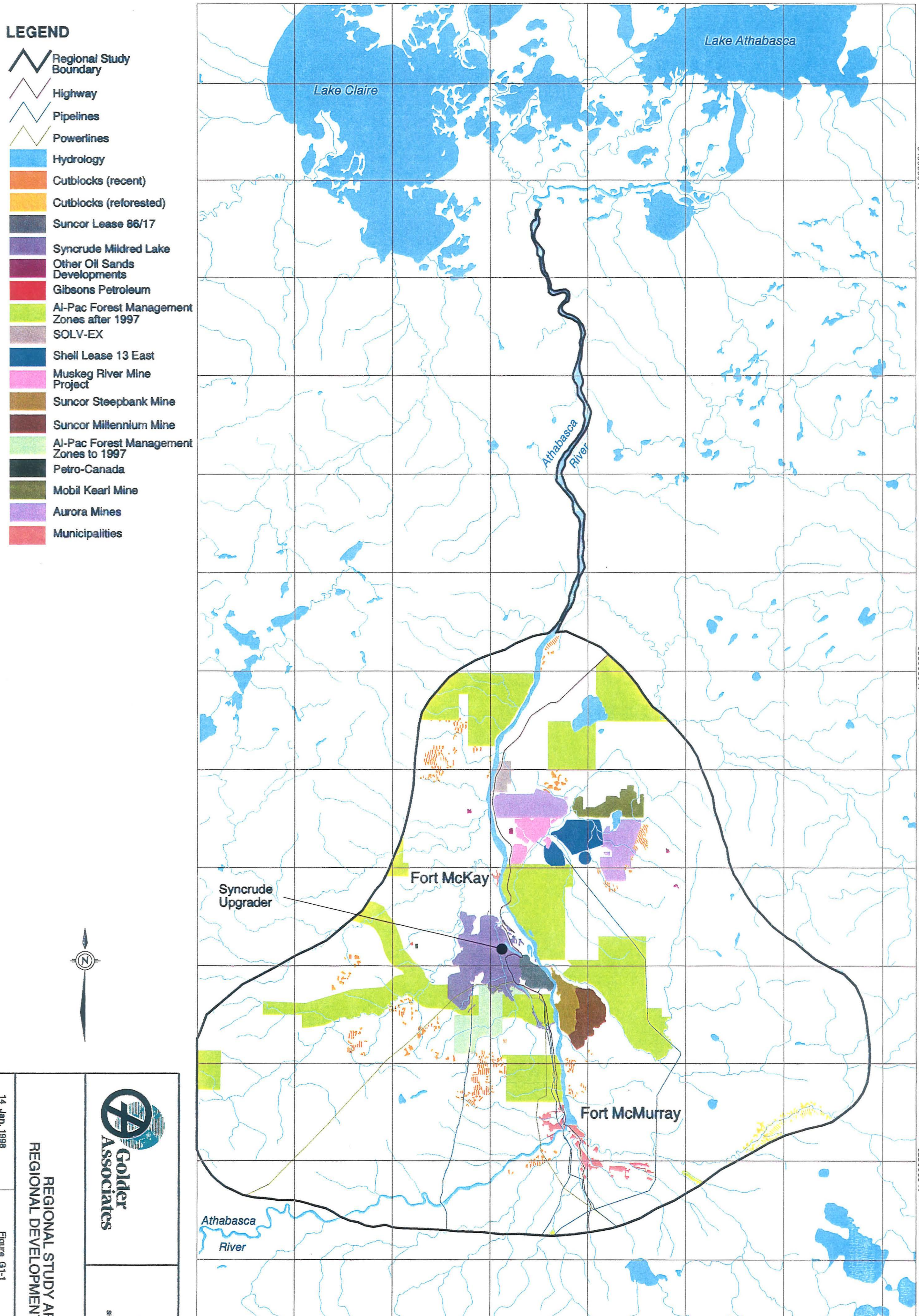
G1.2 Methods and Approach

The methodologies used to assess potential effects related to the RDR are the same as described for each component in Section E or F of this EIA. If additional methodologies were employed for a specific component, these are defined in the relevant component in Section G.

Section F of this EIA contains a review of the existing and approved developments, including consideration of the currently available information on the schedule for the approved (but perhaps not yet fully operational) developments.

G1.3 Planned Developments

In addition to the existing and approved developments, it is recognized that other planned oil sands developments have been publicly disclosed as of the end of 1997. Although these developments as yet have not been the subject of formal approval applications, if they were to proceed they may result in additional environmental impacts in the RSA. The planned developments included in the RDR, as well as existing and approved developments, are shown in Figure G1-1 and detailed in Table F1-1. Table G1-1 reviews the Athabasca Oil Sands production for the RDR.



SOURCE: Al-Pac, Conor Pacific, Golder Associates Ltd., Mobil, Petro-Canada, RADARSAT International, Suncor, Syncrude, Norwest

5 0 5 10 15 20 25

Kilometres

MAP PROJECTION:
UTM
Zone 12
NAD 83 (GRS 1980)

Golder Associates

SHELL CANADA LIMITED

REGIONAL STUDY AREA -
REGIONAL DEVELOPMENT REVIEW

14 Jan. 1998

Figure G1-1

PRODUCED BY: C. Anderson
REVIEWED BY:

The planned developments included in the RDR are reviewed below. The development details provided are based on publicly available information. Because these planned developments are in their early stages, the following conditions apply:

- there is uncertainty about whether they will proceed;
- a limited amount of information is available for the developments; and
- all must submit an application and undergo assessment to receive approval.

Table G1-1 Athabasca Oil Sands Production - Regional Development Review (Baseline, Approved, Muskeg River Mine Project + Planned Developments)

Oil Sands Development	Capacity K bbl/day	Expected Production (2010)	
		Bitumen (bbl/day)	Synthetic Crude (bbl/day)
Suncor			
- Tar Island + Fixed Plant Expansion + Steepbank Mine	125	125,000	105,000
- Project Millennium	125	125,000	105,000
Syncrude			
- Mildred Lake Mine	270	160,000 [a]	- - -
- Aurora Mines	400	400,000	- - -
- Project 21 Upgrader	480	- - -	480,000
Shell			
- Muskeg River Mine Project	150	150,000	- - -
- Lease 13 East	200	200,000	- - -
Mobil Kearl Mine	130	130,000	- - -
Mobil Upgrader	130	- - -	130,000
Gulf Surmont	100	100,000	- - -
Petro-Canada MacKay River	30	30,000	- - -
JACOS Hangingstone	10	10,000	- - -
Gibsons Petroleum	2	2,000	- - -
Total		**1,432,000**	**820,000**

[a] Potential bitumen sales not included.

G1.3.1 Suncor Energy Inc. Project Millennium

Suncor Project Millennium is proposed as an addition to the approved Lease 86/17, Fixed Plant Expansion and Steepbank Mine Projects. This development includes expansion of the Suncor mining operation on the east side of the Athabasca River, expansion of the upgrading facility on Lease 86/17 and development of primary extraction facilities on the east side of the Athabasca River.

Ultimate production from the combined Suncor developments is projected to be 210,000 bpd of upgraded products.

The fundamental assumptions associated with the Project Millennium development include:

- progressive mining and reclamation activities for approved lease areas;
- production of air emissions from the operation of the mine, extraction plant, upgrader and utilities plant;
- implementation of consolidated tailings (CT) technology for mature fine tailings (MFT) management;
- maintenance of water withdrawal rates from the Athabasca River, as for the Lease 86/17, Fixed Plant Expansion and Steepbank developments; and
- continuation of the discharge of effluent to the Athabasca River via an industrial wastewater treatment system, at the same rate as for the Lease 86/17, Fixed Plant Expansion and Steepbank Mine developments.

G1.3.2 Shell Canada Limited Lease 13 East Mine

The Shell Lease 13 East development will be located immediately east of the Muskeg River Mine Project. The current plan is for this development to be similar to the Project, with an ultimate bitumen production of 200,000 bpd day starting in 2010. It is assumed that a bitumen extraction facility similar to that proposed for the Project will be associated with the Lease 13 East development.

The fundamental assumptions associated with the Lease 13 East development include pro-rating the emissions from the Project, based on a production increase from 150,000 to 200,000 bpd for Lease 13 East. Other assumptions include:

- progressive mining and reclamation activities for approved lease areas;
- production of air emissions from the operation of the mine and extraction plant;
- shipment of the produced bitumen to an out-of-region upgrading facility;
- implementation of CT technology for MFT management; and
- use of water from the Athabasca River.

G1.3.3 Syncrude Canada Ltd. Project 21 Mildred Lake Upgrader Expansion

The expansion of the Syncrude upgrader was announced just prior to this submission This expansion increases the Syncrude upgrading capacity to 480,000 bpd from the currently approved level of 300,000 bpd. The fundamental assumptions associated with the Syncrude upgrader expansion include production of air emissions from the integrated operation of the existing upgrader and utilities plant together with the new modifications and additions to upgrading. Emission numbers, as provided by Syncrude, are detailed in Section G2.

G1.3.4 Mobil Oil Canada Properties Kearl Oil Sands Mine and Upgrader

The Mobil Kearl Mine, which will be located immediately northeast of the Shell Lease 13 East development area, is anticipated to have similar environmental impacts and mitigation measures as for the Muskeg River Mine Project. Preliminary information supplied by Mobil (Mobil 1997) indicates that this development will involve a truck and shovel mining operation, with bitumen upgrading using a warm water, non-caustic process. Projected development capacity of up to 130,000 bpd is scheduled to commence in 2003.

Final plans for a Mobil Kearl Mine upgrader within the RSA had not been announced at the time of preparation of this EIA. Mobil have discussed five possible locations for the upgrader in their discussions with project stakeholders. Although the upgrader location is still uncertain at the time of this submission, estimates where considered for emissions for a 130,000 bpd facility were used for this review.

The fundamental assumptions associated with the Kearl Mine and Upgrader development include:

- progressive mining and reclamation activities for approved lease areas, with methodologies similar to that described for the Muskeg River Mine Project;
- production of air emissions (SO_2 and NO_x) from the operation of the mine, extraction plant and upgrader, with emissions pro-rated from estimates for the Project;
- implementation of CT technology for MFT management, as described for the Project; and
- use of water from the Athabasca River.

G1.3.5 In-Situ Developments

The disclosed developments involved with in-situ extraction of bitumen include:

- Petro-Canada MacKay River Project
- JACOS Hangingstone
- Gulf Surmont

The impact of the in-situ developments will be related primarily to the groundwater, terrestrial and air emission environmental components. For the RDR, the considerations included air emissions and some minor terrestrial impacts. Based on available information, it is assumed that water supply and disposal for all in-situ developments will utilize groundwater resources that will not have an impact on the Project.

Petro-Canada MacKay River

The Petro-Canada MacKay River development was detailed in a public disclosure document (Petro-Canada 1997). The preliminary information for the project indicates a production of approximately 30,000 bpd of bitumen.

Information for the MacKay River development was incorporated into the air and terrestrial components of the RDR. Preliminary air quality design information has been provided by Petro-Canada related to the MacKay River development.

JACOS Hangingstone

Few details are available for the proposed Hangingstone in-situ development. The developer has stated initial targets are for a pilot development that will produce approximately 10,000 bpd of bitumen.

The JACOS development is considered for air quality assessment only. The estimated emissions are pro-rated based on data from the Petro-Canada MacKay River development.

Gulf Surmont

The Gulf Canada Resources Limited Surmont Commercial Oil Sands Project was publicly disclosed in October 1997 (Gulf 1997). The target production for the Surmont development is 100,000 bpd of bitumen. Since this development is located south of the RSA, the only consideration included in the Project RDR is related to air quality.

G1.3.6 Major Pipelines, Utility Corridors and Roadways

The disclosed developments which involve construction of pipelines include:

- Suncor IPL Wildrose Pipeline
- Shell product and diluent pipelines
- Additional regional natural gas supply pipeline

The locations of the proposed pipelines, except the Wildrose pipeline, are uncertain at this time. The total impact of existing and planned pipelines in the RSA is small (approximately 600 ha). Therefore, this total value for pipeline developments was included within the baseline.

Electrical power right of ways and roadways, as well as municipal area development, while they are assumed to be in the planning stage under planned developments, have not been documented. Because of this lack of information, no values were added for these developments under the RDR.

Linear disturbances primarily involve impacts to vegetative cover, although roadways may impact terrain units. As such, it has been assumed that no reclassification of the existing soils or terrain is required. It is also assumed that during the operational life of these corridors, herbaceous vegetation is established although establishment of woody species is discouraged. Following abandonment of the linear corridor, invasion of woody species from the adjacent vegetation communities ensures compatible vegetative cover.

G1.4 Environmental Parameter Summary

Table G1-2 summarizes some of the major environmental parameters considered for the major planned oil sands developments. Additional details on these parameters, as well as additional parameters are discussed in the relevant component discussions in Section G. Table F1-4 provides details on the existing and approved developments, as well as the Project.

Emission data used for modelling was provided to Shell by the various companies at the end of 1997. It is recognized that these projects are still in development stage and that the numbers may change as project definition improves.

Table G1-2 Environmental Parameters for Planned Developments

Development	Development Area (ha)	Water Withdrawal (1,000 m^3)	Air Emissions (t/d)	
			SO_2	NO_x
Suncor Project Millennium	5,437	[a]	51[b]	60[b]
Shell Lease 13 East	7,215	[a]	0	16
Syncrude Project 21 Upgrader	0	[a]	200[c]	83[c]
Mobil Kearl Mine and Upgrader	5,350	47,800[c]	5	13
Petro-Canada MacKay River	33	0	0	1
JACOS Hangingstone	n/a	0	0	0.3
Gulf Surmont	n/a	0	0	5

(a) Withdrawal requirements included in development's existing approval.
(b) Total for combined Suncor developments (Lease 86/17, Steepbank Mine, Fixed Plant Expansion and Project Millennium).
(c) Total for combined Syncrude developments (Mildred Lake, Aurora North and South, Project 21 Upgrader).
(d) Pro-rated from Muskeg River Mine Project value for 150,000 bbl/day production.
n/a = not available.

G1.5 Preliminary Schedule

The proposed schedule for the existing, approved and planned developments are detailed, as relevant, within the components in this section of the EIA.

G1.6 Potential Linkages and Key Questions

Linkage diagrams as defined for the Project impact assessment (Section E) remain valid for the RDR.

Component specific key questions for the RDR are the same as those described in Section F. Table F1-2 lists the key questions.

G1.7 Impact Description and Degree of Concern

The impact description criteria and degree of concern definitions, as defined in Section E1, also apply for the RDR.

G2 AIR QUALITY REGIONAL DEVELOPMENT REVIEW

G2.1 Introduction

This regional effects review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus baseline, approved and publicly disclosed developments on air quality in the Regional Study Area (RSA). The following developments are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- Syncrude Aurora North and South
- Suncor Project Millennium
- Syncrude Project 21 Upgrader Expansions
- Mobil Kearl Mine and Upgrader
- JACOS Hangingstone
- Syncrude Mildred Lake
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Petro-Canada MacKay River Project
- Gulf Surmont

The air quality predictions presented in this section are used to assess impacts on human health (Section G12), aquatic resources (Section G6), soils (Section G8) and vegetation (Section G9).

G2.1.1 Emissions

Table G2-1 provides a summary of the type and magnitude of the emissions associated with the RDR emissions. As these other facilities are either in the pre-design or design stages, the emission estimates provided in the table should be considered as preliminary. In some cases, emission estimates were extrapolated from one facility to another on the basis of production.

The combined total sulphur dioxide (SO_2) emission of 259 t/d does not include flaring and other upset events. The current SO_2 emission of 272 t/d includes 29 t/d from these type of events, leaving 243 t/d from non-flaring sources. As such, the SO_2 emissions are expected to remain essentially the same (with 10%) as for the baseline emission scenario.

Based on the emission estimates provided in Table G2-1, total hydrocarbon (THC) emissions are expected to increase by about 30% while the oxides of nitrogen (NO_x) emissions are expected to increase by about 150% (more than double). The level of confidence for NO_x emission estimates is greater as they are directly related to fuel consumption while the VOC emissions are based on the extrapolation of fugitive emission estimates, and in some cases updated values are not available.

Table G2-1 Summary of SO_2, NO_x and THC Emissions Associated With RDR Emission Scenario

Development	SO_2[a] (t/d)	NO_x[a] (t/d)	THC[a] (t/d)
Muskeg River Mine Project	0	12	4
Syncrude Mildred Lake and Upgrader Expansion	200	60	15
Suncor Lease 86/17, Steepbank and Millennium	51	63	14
Syncrude Aurora North	0	13	6
Syncrude Aurora South	0	10	7
SOLV-EX	4	1	-
Shell Lease 13 East Mine	0	16	4
Mobil Kearl Mine[b]	5	13	4
Petro-Canada MacKay River Project	0	1	0
Gulf Surmont Project	0.0	5	0.1
JACOS Hangingstone Project	0	0.3	0.0
Other Baseline (from Table D2-1)	0.3	2	5
Combined RDR Emissions	259	195	58
Baseline (1996) (from Table D2-1)	272	78	44

(a) SO_2 = sulphur dioxide, NO_x = oxides of nitrogen, THC = total hydrocarbon

(b) Based on project information received from Mobil in December 1997. This information is subject to change as project definition proceeds.

G2.2 Potential Linkages and Key Questions

Figure E2-1 (Section E2) shows the linkage diagram for Project activities and potential changes in air quality associated with the Project. Generally, the same linkages and key questions apply to the RDR with the exception that Greenhouse gas emissions are not addressed. This is because this emissions are usually discussed on a corporate basis.

The key questions for the air quality RDR include:

AQRDR-1: Will Emissions From Combined Developments Result in Exceedances of Ambient Air Quality Guidelines?

AQRDR-2: Will Emissions From Combined Developments Result in Human Health Effects?

AQRDR-3: Will Emissions From Combined Developments Result in the Deposition of Acid Forming Compounds That Exceed Target Loadings?

AQRDR-4: Will the Precursor Emissions From Combined Developments Result in the Formation of Ozone (O_3) Concentrations That Exceed Air Quality Guidelines?

G2.3 Analysis and Results

G2.3.1 Key Question AQRDR-1: Will Emissions From Combined Developments Result in Exceedances of Ambient Air Quality Guidelines?

The overlapping effects of mine emissions in the vicinity of the Aurora Mines, Muskeg River Mine, Shell Lease 13 East Mine and Kearl Mine developments was discussed in Section F2.4.1 with respect to NO_x emissions. The evaluation concludes that maximum predicted hourly and daily NO_x evaluations are less than the respective guidelines. The annual average, however, exceeded the guideline in areas adjacent to the respective mines.

G2.3.2 Key Question AQRDR-2: Will Emissions From Combined Developments Result in Human Health Effects?

Analysis

The health effects study focuses primarily on the extrapolation of predicted annual average VOC, TRS and PAH concentrations provided in Tables E2-18, E2-19 and E2-20. The expected concentrations associated with the RDR emission scenario was assumed to scale according to bitumen production. On this basis, the predicted concentrations in the communities are expected to be about eight times the values provided in the indicated tables.

Table G2-2 provides estimates of the maximum NO_x and benzo(a)pyrene (BaP) concentrations that could be expected from the RDR emission scenario using the same approach as Section F2.4.2.

The implication of the multiplative factor of eight to extrapolate the Project values to the RDR emission scenario is as follows:

- ambient concentrations in Fort McKay could increase by about 160% over current baseline conditions;
- ambient concentrations in Fort McMurray could increase by about 30% over current baseline conditions; and
- ambient concentrations in Fort Chipewyan could increase by about 50% over current baseline conditions.

For the example provided, the predicted annual average values in the communities are below the 60$\mu g/m^3$ guideline, even if one conservatively assumes complete conversion from NO to NO_2.

The estimated BaP concentrations for the RDR development are predicted to increase by about 12% in Fort McKay, 4% in Fort McMurray and 1.2% in Fort Chipewyan. The health implications for the Projects RDR air concentrations are discussed in Section G12.

Table G2-2 Predicted NOx and BaP Concentrations in the Selected Communities due to RDR Development

NO_x ($\mu g/m^3$)						
Community	Baseline	Project	Baseline +Project	RDR=8* Project	Baseline+ RDR	NO_2 Guideline
Fort McKay	15	3	17	24	39	60
Fort McMurray	29	1	30	8	37	60
Fort Chipewyan	5	0.3	5.3	2.4	7.4	60
BaP (ng/m^3)						
Community	Background	Project	Baseline+ Project	RDR=8* Project	Baseline+ RDR	Guideline
Fort McKay	0.01	0.00015	0.01015	0.0012	0.0112	None
Fort McMurray	0.01	0.000044	0.010044	0.00035	0.01035	None
Fort Chipewyan	0.01	0.000015	0.010015	0.00012	0.01012	None

Certainty

The same certainty considerations presented in Section F2.4.2 are applicable to this RDR key question.

G2.3.3 Key Question AQRDR-3: Will Emissions From Combined Developments Result in the Deposition of Acid Forming Compounds that Exceed Target Loadings?

Sulphate Equivalent Deposition

Figure G2-1 shows the sulphate equivalent deposition for the RDR emission scenario. The maximum sulphate deposition (both wet and dry) of 24 kg SO_4^{2-}/ha/a and is predicted to occur in the vicinity of the existing sources. While the deposition pattern is similar to that associated with the existing sources, there are slight changes due to an additional stack associated with the Syncrude Upgrader Expansion and the Mobil Kearl Mine Upgrader.

Figure G2-1 Predicted Sulphate Equivalent Deposition (kg SO_4^{2-}/ha/a) in the RSA due to RDR Sources

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Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Suncor	SO_2 = 51 t/d
	Syncrude	SO_2 = 200 t/d
	SOLV-EX	SO_2 = 4 t/d
	Mobil Kearl	SO_2 = 5 t/d
Target:	No target	

Nitrate Equivalent Deposition

Figure G2-2 shows the nitrate equivalent deposition for the RDR emission scenario. Maximum nitrate depositions in excess of 50 kg NO^{3-}/ha/a are predicted to occur in the vicinity of the Syncrude Mildred Lake, Muskeg River Mine Project and Syncrude Aurora North developments.

Potential Acid Input

Figure G2-3 shows the PAI for the RDR emission scenario. The maximum values show the influence of the NO_x emissions associated with the mine fleet emissions. PAI values in excess of 1.0 keq/ha/a are predicted to occur in the vicinity of the Syncrude Mildred Lake, Suncor and Muskeg River Mine Project developments.

Table G2-2 indicates proposed target loading criteria and the areas associated with exceedances of these criteria. The effect of the RDR scenario is to increase the region where the 0.25 keq/ha/a value is exceeded from 2,500 to 4,200 km². For the 0.50 keq/ha/a target loading, the area is increased from 315 to 980 km².

Table G2-3 Comparison of Area That Exceeded Selected PAI Criteria

Emission Scenario	Current from Section D	CEA from Section F	RDR
SO_2 emissions (t/d)	254	252	259
NO_x emissions (t/d)	78	110	195
Area > 1 keq/ha/a (km^2)	0	0	30
Area > 0.50 keq/ha/a (km^2)	155	315	980
Area > 0.25 keq/ha/a (km^2)	1,500	2,500	4,200

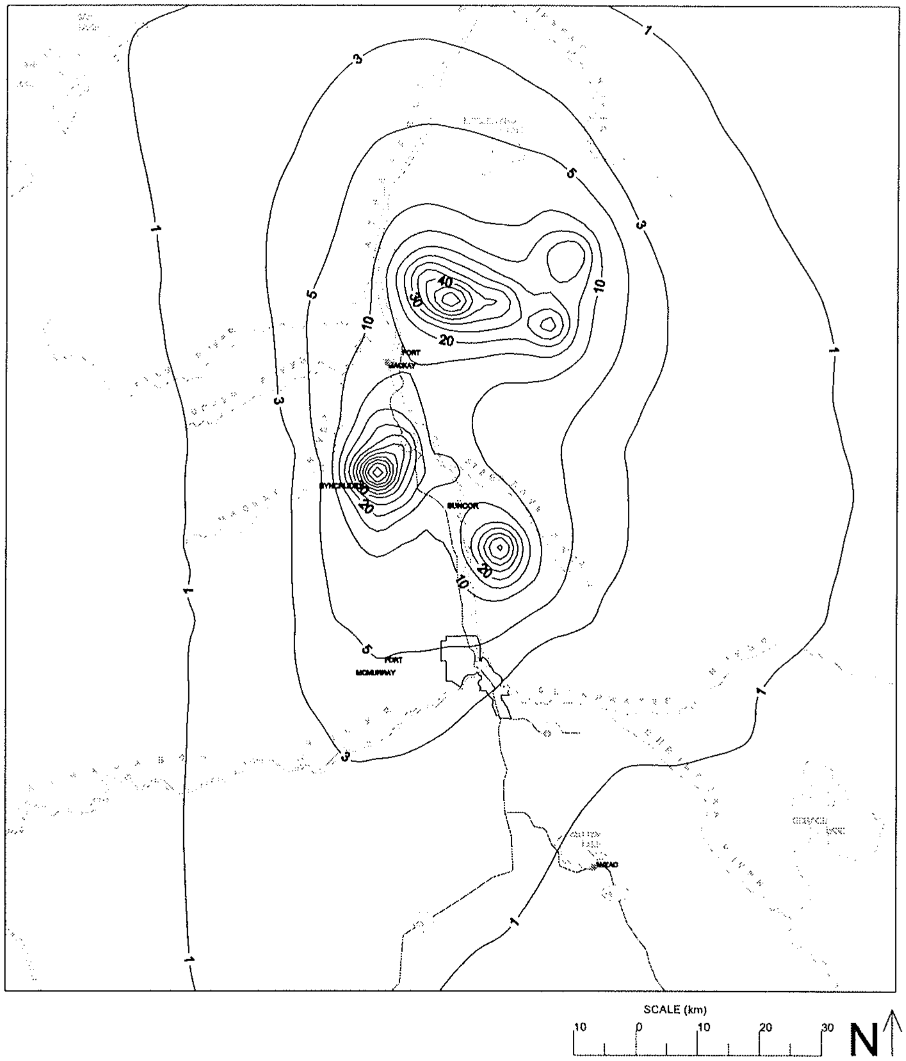
Residual Impact Classification

The impact classification associated with the predicted deposition of acidifying compounds are presented in the appropriate receptor scales (Section G5-Water Quality, Section G6-Aquatic Resources, Section G7-ELC, Section G8-Terrain and Soils and Section G10-Wetlands).

Certainty

The same certainty considerations presented in Section F2.4.3 are applicable to those RDR key questions. The areal extent exceeding 0.25 keq/ha/a is increased significantly in the RDR emission scenario. This is primarily due to the predicted dry deposition of NO_x. In the modelling approach, a number of assumptions relating to vegetation canopy process were made that could result in overprediction.

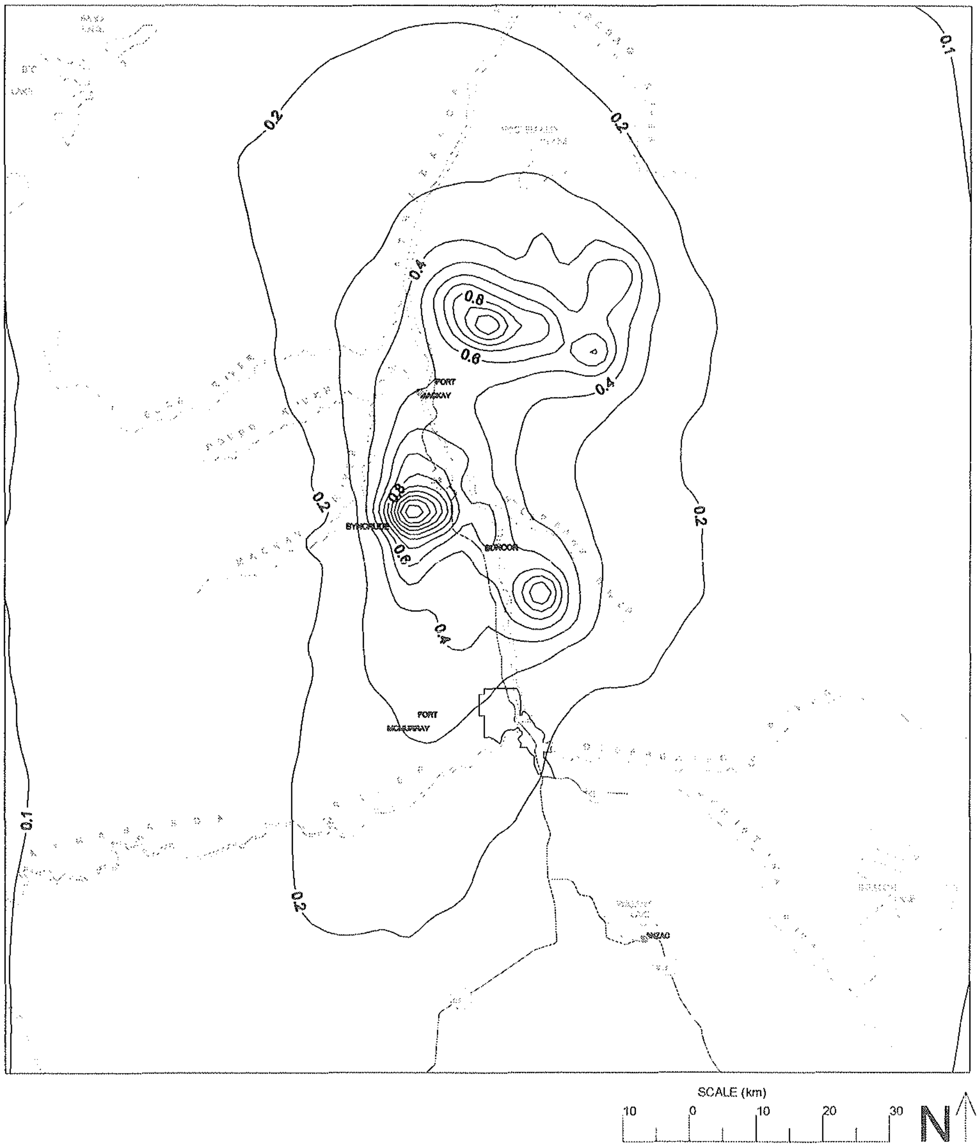
Figure G2-2 Predicted Nitrate Equivalent Deposition (kg NO_3^-/ha/a) in the RSA due to RDR Sources



c:\data\7316259\calpuff\modruns\output\mannix8g\nitrate.srf 01/14/98

Model:	CALPUFF	
Meteorology:	Mannix	
Sources:	Suncor	NO_x = 63 t/d
	Syncrude	NO_x = 60 t/d
	Muskeg River Mine	NO_x = 12 t/d
	Aurora Mines	NO_x = 23 t/d
	SOLV-EX	NO_x = 1 t/d
	Lease 13 East Mine	NO_x = 16 t/d
	Mobil Kearl	NO_x = 11 t/d
	Petro-Canada	NO_x = 1 t/d
	Gulf Surmont	NO_x = 5 t/d
Target:	No target	

Figure G2-3 Predicted Potential Acid Input (keq/ha/a) in the RSA due to RDR Sources



c:\data\7316259\calpuff\modruns\output\mannix8g\acid.srf 01/14/98

Model:	CALPUFF			
Meteorology:	Mannix			
Sources:	Suncor	SO_2 = 51 t/d	Aurora Mines	NO_x = 23 t/d
	Syncrude	SO_2 = 200 t/d	SOLV-EX	NO_x = 1 t/d
	SOLV-EX	SO_2 = 4 t/d	Mobil Kearl	NO_x = 13 t/d
	Mobil Kearl	SO_2 = 5 t/d	Lease 13 East Mine	NO_x = 16 t/d
	Suncor Millennium	NO_x = 63 t/d	Petro-Canada	NO_x = 1 t/d
	Syncrude Expansion	NO_x = 60 t/d	Gulf Surmont	NO_x = 5 t/d
	Muskeg River Mine	NO_x = 12 t/d		
Target:	0.25, 0.5 and 1.0 keq/ha/a			

G2.3.4 Key Question AQRDR-4: Will the Precursor Emissions From Combined Developments Result in the Formation of Ozone (O_3) Concentrations that Exceed Air Quality Guidelines?

Analysis

Table G2-4 compares the estimated NO_x and VOC emission from the urban airsheds with those from the RSA. For the RDR sources, the projected NO_x emissions exceed those associated with either urban centre. The estimated VOC emissions in the RSA regional airshed are about one-half those associated with the urban centres.

The continued increase in NO_x and VOC indicates a greater potential for photochemical ozone formation in the RSA. Previous SMOG model predicted ozone concentrations are about 10 ppb larger for the higher emission scenarios than that for the lower emission scenarios. Under conditions favorable for the formation of ozone, there is greater potential that the hourly guideline of 82 ppb will be exceeded.

Table G2-4 Comparison of NO_x and VOC Emissions for Various Airshed Scenarios

	NO_x (t/d)	VOC (t/d)
Oil Sands RSA		
Baseline	78	50
CEA	110	50
RDR	195	58
Provincial		
Edmonton (Summer)	151	140
Calgary (Summer)	115	120
Alberta (Annual)	1333	1747

Residual Impact Classification

Given the high relative increase in NO_x emissions in the RSA, the overall degree of concern is sufficient to warrant further investigation. Shell, in conjunction with Suncor and Syncrude, will undertake a more refined estimate of photochemical formation of ozone based on a more recently developed modelling approach and on updated VOC emissions.

Certainty

Updated modelling with more refined emission data will help produce predictions with a higher confidence level.

G2.4 Summary of Impacts

Table G2-5 provides a summary of the key questions that were addressed as part of the air quality RDR. The classification of the effects associated with air emissions is undertaken in the human health section and respective environmental sections. An industry indicated study will determine the effects associated with the photochemical production of ozone.

Table G2-5 Summary of Air Quality RDR

Key Question	RDR Results
AQRDR-1: Will emissions from combined developments result in exceedances of ambient air quality guidelines?	• The maximum predicted hourly and daily NO_x evaluations are less than the respective guidelines. The annual average exceeded the guidelines in areas adjacent to the respective mines.
AQRDR-2: Will emissions from combined developments result in human health effects?	• Human health effects were based on annual NO_2, VOC and PAH predictions in Fort MacKay, Fort McMurray and Fort Chipewyan. The RDR values were estimated to increase by about 12% in Fort McKay, 4% in Fort McMurray and 1% in Fort Chipewyan for BaP concentrations. • The impact classification associated with these extrapolated concentration estimates is presented in the human health section.
AQRDR-3: Will emissions from combined developments result in deposition of acid forming compounds that exceed target loadings?	• While the CO_2 emissions in the RSA are expected to be relatively stable (or perhaps even decrease), the RSA NO_x emissions are predicted to increase by about 150% over baseline levels. Of the increase from 78 to 195 t/d, the Muskeg River Mine project accounts for 12 t/d. • The CALPUFF model predicts that the potential acid input will increase as a result of these increased NO_x emissions. The area where the PAI exceeds the 0.25 keq/ha/a target loading for sensitive ecosystem increases from 1500 km^2 for the baseline emissions to 4200 km^2. For areas that are better buffered, the 0.50 keq/ha/a target loading can be used and the areas where this value is exceeded increases from 155 km^2 (baseline), to 980 km^2 (RDR). • The impact classification associated with these predictions is presented in the respective terrestrial and aquatic sections.
AQRDR-4: Will precursor emissions from combined developments result in the formation of ozone (O_3) concentrations that exceed air quality guidelines?	• Precursor NO_x and VOC emissions are estimated to increase by about 150 and 30%, respectively. The level of confidence of the VOC estimates, however, are lower than that from the NO_x emission estimates. • By inference, there is a potential for downwind ozone values to exceed the guideline value of 82 ppb. • Shell will participate in an industry indicated study (with Syncrude and Suncor) to undertake more refined photochemical modelling using the more recent VOC data and more up-to-date photochemical model. Until this is conducted, the magnitude of the effect is classified as "to be determined".

G3 HYDROGEOLOGY REGIONAL DEVELOPMENT REVIEW

G3.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and publicly disclosed developments on hydrogeology (groundwater) in the Regional Study Area (RSA). For the purposes of examining the key question described below, the following developments, as shown in Figure G1-1, were included in the RDR:

- SOLV-EX
- Syncrude Aurora North
- Syncrude Aurora South
- Muskeg River Mine Project
- Shell Lease 13 East
- Mobil Kearl Mine

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

The groundwater predictions presented in this section are used to assess impacts on surface water hydrology (Section G4) and water quality (Section G5).

G3.2 Potential Linkages and Key Question

Hydrogeology linkages and one key question, as described in Section F3, also apply to the RDR.

GWRDR-1: Will Combined Developments Result in a Drawdown of Water Levels in the Basal Aquifer and Cause a Loss of Water From Important Lakes?

G3.3 Analysis and Results

G3.3.1 Key Question GWRDR-1: Will Combined Developments Result in a Drawdown of Water Levels in the Basal Aquifer and Cause a Loss of Water from Important Lakes?

From the hydrogeology impact analysis (Section E3 and Section F3), drawdown of the Basal Aquifer from the Muskeg River Mine Project and Aurora North and South Projects was shown to increase the downward seepage of water from Kearl Lake. No impact on McClelland Lake was expected, since published geological maps of the area show that the Basal Aquifer is absent beneath McClelland Lake. Isadore's Lake is much closer to the Muskeg River Mine Project than to any other developments, and the impact analysis conducted for Isadore's Lake in Section E3 already represents an extreme case. Other mine developments are not expected to have any impact on Isadore's Lake. Consequently, the focus of assessment of any additional hydrogeologic impacts due to future regional developments is limited to effects of Basal Aquifer depressurization on Kearl Lake.

Analysis of Key Question

As discussed in section F3, the combined drawdown from the Muskeg River Mine Project and the Aurora North and South developments may lower the hydraulic head in the Basal Aquifer to the top of the aquifer, with some possibility of desaturation of the aquifer. That is, all available drawdown in the aquifer may be eliminated by depressurization from these developments. Under this limiting condition, the vertical hydraulic gradient reaches a practical maximum value of unity beneath Kearl Lake. This was the case evaluated in Section F3, and corresponds to the maximum leakage possible from the lake in response to lowering of head in the Basal Aquifer.

Any additional production of groundwater from the Basal Aquifer due to other proposed projects in the region will not have any additional effect on the downward seepage from Kearl Lake, since the analysis in Section F3 already represents the upper limit for vertical seepage.

Therefore, in the presence of other regional developments such as the Mobil Kearl Mine and SOLV-EX developments, the maximum downward seepage from Kearl Lake would be the same as the combined effect of the Muskeg River Mine and Aurora developments, as discussed in Section F3. That is, downward seepage from Kearl Lake would increase to 63 mm/year from 24 mm/year representing natural (pre-mining) conditions. Seepage of 63 mm/year represents about 14% of the mean annual precipitation received by the lake.

Residual Impact Classification and Degree of Concern

The classification of residual impacts and degree of concern, is the same as for the impact discussed in Section F3. The combined impacts of drawdown due to depressurization of the Basal Aquifer on Kearl Lake are such that downward seepage from the Lake will increase over both natural rates and the rate associated only with the Muskeg River Mine Project.

The direction of the residual impact is considered to be negative relative to the natural condition, and the magnitude of impact low to moderate. The impact is expected to be limited to Kearl Lake, so the geographic extent is considered to be local. The complete recovery of groundwater levels in the Basal Aquifer is likely to take up to 30 years after completion of mining, therefore the duration of the impact is long-term. Groundwater levels will eventually recover, and therefore the water losses from Kearl Lake are reversible. However, while the lowered heads persist, the increased seepage will occur continuously and year-round, so the frequency is high. Overall, the degree of concern related to RDR effects of Basal Aquifer drawdown due to depressurization is considered to be **Low**.

G3.4 Summary of Impacts

Key Question	RDR Results
GWRDR-1: Will Combined Developments Result in a Drawdown of Water Levels in the Basal Aquifer and Cause a Loss of Water From Important Lakes?	• Any additional production of groundwater from the Basal Aquifer due to other proposed projects in the region will not have any additional effect on the downward seepage from Kearl Lake, since the analysis in Section F3 already represents the upper limit for vertical seepage. • Therefore, in the presence of other regional developments such as the Mobil Kearl Mine and SOLV-EX developments, the maximum downward seepage from Kearl Lake would be the same as the combined effect of the Muskeg River Mine and Aurora developments. That is, downward seepage from Kearl Lake would increase to 63 mm/year from 24 mm/year representing natural (pre-mining) conditions. Seepage of 63 mm/year represents about 14% of the mean annual precipitation received by the lake. • The direction of the residual impact is considered to be negative relative to the natural condition, and the magnitude of impact low to moderate. The impact is expected to be limited to Kearl Lake, so the geographic extent is considered to be local. The complete recovery of groundwater levels in the Basal Aquifer is likely to take up to 30 years after completion of mining, therefore the duration of the impact is long-term. Groundwater levels will eventually recover, and therefore the water losses from Kearl Lake are reversible. However, while the lowered heads persist, the increased seepage will occur continuously and year-round, so the frequency is high. Overall, the degree of concern related to RDR effects of Basal Aquifer drawdown due to depressurization is considered to be **Low**.

G4 SURFACE WATER HYDROLOGY REGIONAL DEVELOPMENT REVIEW

G4.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and planned developments on surface water hydrology in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- Syncrude Aurora North and South
- Suncor Project Millennium
- Mobil Kearl Mine
- Syncrude Mildred Lake
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

The surface water hydrology predictions presented in this section are used to assess impacts on water quality (Section G5), aquatics (Section G6) and wetlands (Section G10).

G4.2 Potential Linkages and Key Questions

Figures E4-1 to E4-3 (Section E) show the linkage diagrams for the Project activities and potential changes in surface water hydrology associated with the Project. Generally, the same linkages and key questions apply to the RDR.

SWRDR-1: Will Combined Developments in the Muskeg River Basin Result in Effects on the Muskeg River Flows, Sediment Concentrations and Channel Regime?

SWRDR-2: Will Combined Developments Result in Effects on Athabasca River Flows?

SWRDR-3: Will Combined Developments Result in Effects to the Open-Water Areas Including Lakes and Streams?

G4.3 Analysis and Results

G4.3.1 Key Question SWRDR-1: Will Combined Developments in the Muskeg River Basin Result in Effects on the Muskeg River Flows, Sediment Concentrations and Channel Regime?

Mining Schedules and Production Rates

The mining schedules and daily production rates of the planned oil sands developments in the Muskeg River basin are listed in Table G4-1.

Table G4-1 Mining Schedules and Production Rates of the Planned Oil Sands Developments in the Muskeg River Basin

Development	Beginning of Construction	Beginning of Operation	End of Operation	Production Rate (barrels per day)
Lease 13 East Mine	2009	2012	2055	150,000
Kearl Mine	2000	2003	2040	130,000

Based on the schedules presented in Tables F4-1 and G4-1, the Aurora North Mine will be the first to commence construction in the Muskeg River basin in year 1998, and the Lease 13 East Mine will the last to be developed, beginning in year 2009. The Muskeg River Mine will be the first mine to be reclaimed and closed in year 2030, while the Lease 13 East Mine will be the last mine to be reclaimed and closed in year 2055.

Selection of Time Snapshots

Figure G4-1 shows the total area for the RDR developments of muskeg drainage and overburden dewatering, the combined area of closed-circuit operations, and the average changes in the Muskeg River flows. The areas for the Least 13 East and Kearl Mines were estimated based on the preliminary plans.

The variable changes of the Muskeg River flows shown in Figure G4-1 provided a basis for identifying four time snapshots for the cumulative effects assessment. Figures G4-2 and G4-3 illustrate the areas of mine developments and the drainage systems for these time snapshots. The rationale for selection of these time snapshots is similar to that presented in Section F4.2.2.

There will be an end pit lake management period for the Muskeg River Mine from 2023 to 2030. This transfer will temporarily increase the Muskeg River flows. It is assumed that the Lease 13 East Mine and Kearl Mine projects will have similar requirements for transfering mature fine tails (MFT) to the end pit lakes. Therefore, the end pit lake management of each project will cause similar increases in the Muskeg River flows. However, these effects will not be cumulative, because the MFT transfer periods of these projects will not occur at the same time, as shown in Table G4-2. Therefore, the effects of the end pit lake management for the other projects are not included in this cumulative effect assessment.

Table G4-2 Periods of MFT Transfer to End Pit Lakes

Development	Period of MFT Transfer to End Pit Lakes	
	Beginning	End
Muskeg River Mine	2027	2030
Kearl Mine	2037	2040
Lease 13 East Mine	2052	2055

Analysis of Key Questions on Flows

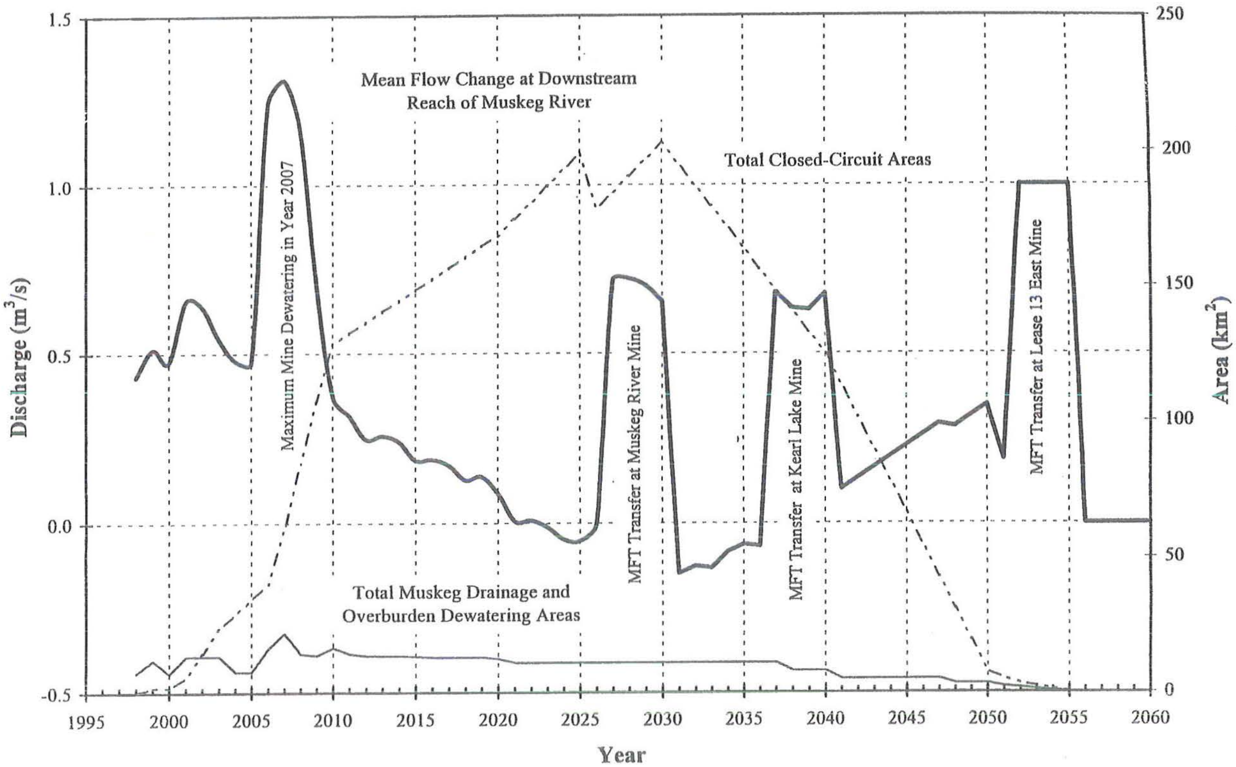
Estimates of Muskeg Drainage Discharges

The areas of muskeg drainage and assumed muskeg depths for estimating the drainage discharges for the Least 13 East Mine and Kearl Mine projects, is presented in Table G4-3.

Table G4-3 Summary of Muskeg Drainage Areas and Muskeg Depths

Development	Assumed Muskeg Depth	Area of Muskeg Drainage
Lease 13 East Mine	1.5 m	4.2 km^2 during construction in years 2009 and 2010. 2.4 km^2 during construction in year 2011. 1.6 km^2 in each year following construction until 3 years prior to mine closure.
Kearl Mine	1.0 m	8.6 km^2 during construction in year 2001. 2.9 km^2 at intervals of once every 3 years following construction, until 3 years prior to mine closure.

Table G4-4 summarizes the muskeg drainage discharges at the Lease 13 East Mine and Kearl Mine projects, which were estimated for the selected time snapshots during mine construction and operation using the estimation method presented in Section F4.2.4. The total muskeg drainage discharges from all the developments in the Muskeg River basin are presented in Table G4-5 based on the estimates in Tables F4-3 and G4-4.



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PREDICTED MUSKEG RIVER DISCHARGES, CLOSED-CIRCUIT AREAS AND DEWATERING AREAS 1995-2060

19 JAN 98	Figure G4-1	DRAWN BY: RFM

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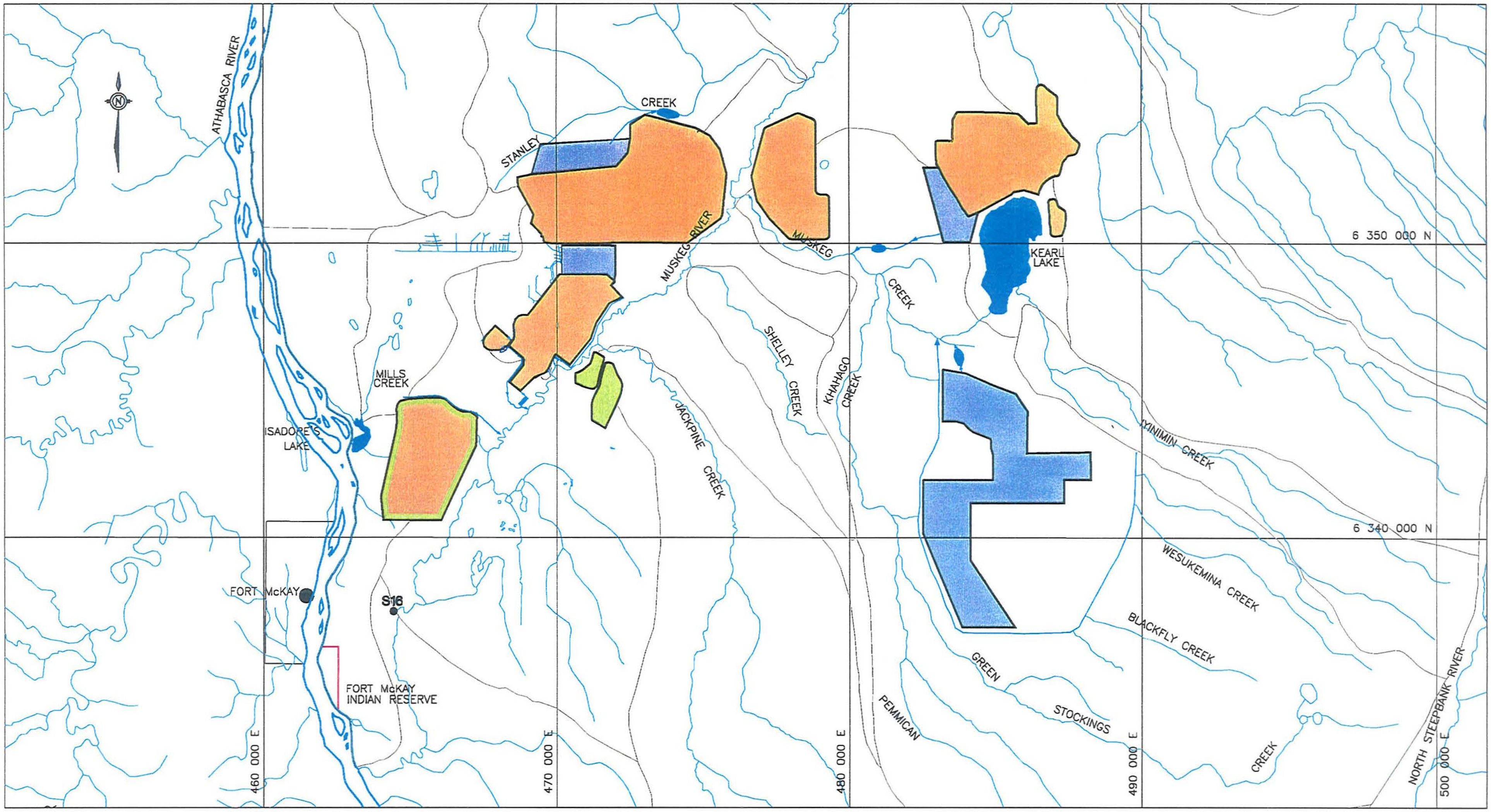

G4 - 5

LEGEND

- PERMANENT STREAM
- DIVERSION OR DRAINAGE CHANNEL
- EXISTING OR END PIT LAKE
- S16 MONITORING NODE
- SUB-BASIN BOUNDARY
- CLOSED CIRCUIT AREA
- CLEARED AND DEWATERED AREA
- RECLAIMED AREA

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 2 4 6 8 10km

SCALE 1:200,000

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COMBINED OIL SANDS DEVELOPMENTS IN THE MUSKEG RIVER BASIN - YEAR 2007

11 JAN 1998	Figure G4-2	DRAWN BY: RFM

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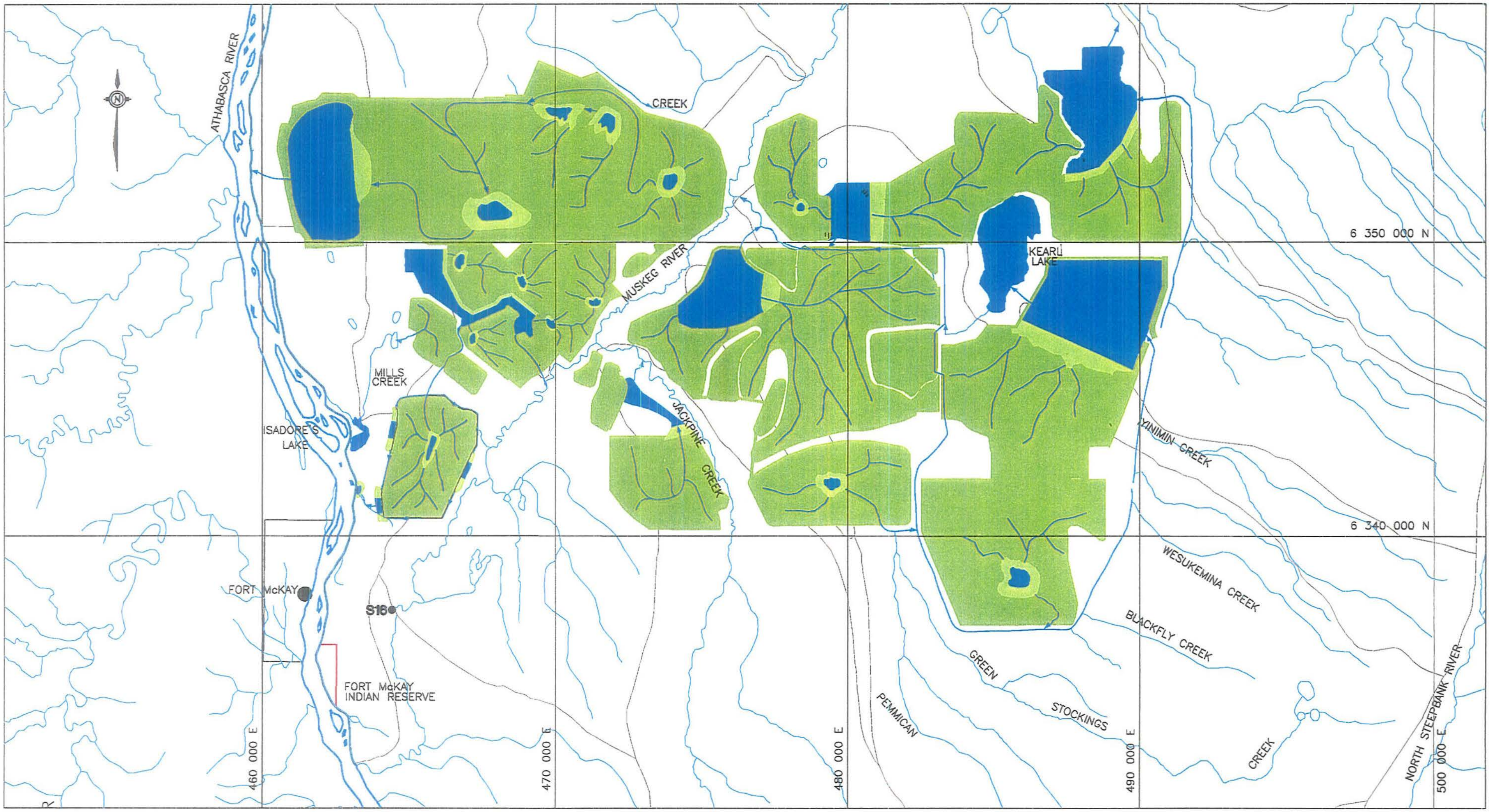

LEGEND

- PERMANENT STREAM
- DIVERSION OR DRAINAGE CHANNEL
- EXISTING OR END PIT LAKE
- S16 MONITORING NODE
- SUB-BASIN BOUNDARY
- CLOSED CIRCUIT AREA
- CLEARED AND DEWATERED AREA
- RECLAIMED AREA

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 2 4 6 8 10km

SCALE 1:200,000

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CLOSURE RECLAMATION DRAINAGE FAR FUTURE

11 JAN 1998	Figure G4-3	DRAWN BY: RFM

Table G4-4 Sums of Muskeg Drainage Discharges at the Lease 13 East Mine and Kearl Mine

Time Snapshot	Area of Muskeg Drainage (km^2)	Drainage Discharge (m^3/s)
2007	2.9	0.038
2020	6.1	0.11
2030	6.1	0.090

Table G4-5 Total of Muskeg Drainage Discharges from the Oil Sands Developments in the Muskeg River Basin

Time Snapshot	Total Area of Muskeg Drainage (km^2)	Total Drainage Discharge (m^3/s)
2007	21.9	0.38
2020	12.3	0.25
2030	10.9	0.20

Estimates of Overburden Dewatering Rates

Table G4-6 presents the estimates of overburden dewatering rates at the Lease 13 East Mine and Kearl Mine for the selected time snapshots during mining construction and operation. These dewatering rates were estimated based on the average dewatering rate per unit area for the Muskeg River Mine without accounting for the variation of overburden soils and their hydraulic conductivities at various project sites. The total overburden dewatering discharges from all the developments in the Muskeg River basin are presented in Table G4-7 based on the estimates in Tables F4-4 and G4-6.

Table G4-6 Sums of Overburden Dewatering Rates at the Lease 13 East Mine and Kearl Mine

Time Snapshot	Dewatering Rate (m^3/s)
2007	0.032
2020	0.067
2030	0.067

Table G4-7 Total Overburden Dewatering Discharges from the Oil Sands Developments in the Muskeg River Basin

Time Snapshot	Total Overburden Dewatering Discharge (m^3/s)
2007	1.09
2020	0.30
2030	0.26

Estimates of Mine Seepage Rates

Table G4-8 presents the estimates of mine seepage rates at the Lease 13 East Mine and Kearl Mine by prorating the mine seepage rates from the Muskeg River Mine. It is assumed that the in-pit CT storage areas at these planned developments will be constructed in the same manner as the Muskeg River Mine Project. Therefore, there will be no CT perimeter seepage discharges to Muskeg River from these two planned developments, because the in-pit CT surface elevations will be lower than the original ground levels.

Table G4-8 Sums of Mine Seepage Rates at the Lease 13 East Mine and Kearl Mine

Time Snapshot	Perimeter CT Seepage Rate (m^3/s)	Tailings Settling Pond Seepage Rate (m^3/s)	CT Upward Flux (m^3/s)
2007	0.0	0.006	0.0
2020	0.0	0.021	0.0
2030	0.0	0.027	0.0
Far Future	0.0	0.075	0.0

Similar to the Muskeg River Mine, it is assumed that perimeter ditches around the reclaimed tailings settling ponds at the two planned developments will be constructed to route some of the sand seepage water to shallow lakes and wetlands for biological treatment before release to receiving streams. This will minimize the direct discharge of the sand seepage water to receiving streams.

Estimates of Surface Runoff from Natural and Reclaimed Areas

Table G4-9 lists the types of surface areas contributing runoff to the Muskeg River at Node S16 for the selected time snapshots; including the approved and planned oil sands developments in the river basin.

Table G4-9 Types of Drainage Areas of Muskeg River at Node S16 for Each Time Snapshot

Land Type	Estimated Area for Each Specified Time Snapshot (km^2)				
	Existing	2007	2020	2030	Far Future
Natural Upland	745	745	745	745	745
Natural Lowland	648	563	461	391	382
Overburden Storage	0	2.2	6.7	12.2	41.7
Closed-Circuit Area	0	61	167	203	0
Reclaimed Sand Cap on CT	0	0	0	6.8	74
Reclaimed Overburden Cap on CT	0	0	0	6.3	6.3
Reclaimed Sand on Overburden	0	0	0	3.9	3.9
Reclaimed Tailings Settling Pond	0	0	0	10	73
Constructed Wetlands	0	0	0	1.8	14
Shallow Lakes and End Pit Lakes	0	0	0	3.9	26

Results of the RDR

The results of the RDR of the five oil sands developments on the Muskeg River flows are presented in Table G4-10. A detailed analysis of these effects for each time snapshot follows:

- **Year 2007:** In year 2007, the Kearl Mine will add negligible increases in the Muskeg River flows. The mean annual discharge of the Muskeg River will be increased by 24% primarily as a result of muskeg drainage and overburden dewatering discharge from the Aurora Mines. The low flows will be largely increased because of the muskeg drainage and overburden dewatering.

- **Year 2020:** In year 2020, the mean annual and open-water discharges on the Muskeg River will increase slightly by 1%, because the effect of flow reduction by closed-circuit operation will be offset by the effect of flow increase by muskeg drainage and overburden dewatering. The drainage and dewatering will actually increase the mean ice-cover flow and the river low flows. For example, the open-water 7Q10 will increase by about 3.7 times, and the mean annual 30-day low flow will increase by over 100%. Therefore, the combined effects on the mean Muskeg River flows in year 2020 will be small while the effects on the river low flow conditions will be relatively high.

  Year 2030: In year 2030, the mean annual and open-water discharges on the Muskeg River will increase moderately by 16% because of the effect of the MFT transfer from the tailings settling pond to the end pit lake at the Muskeg River Mine. This transfer will also increase the open-water 7Q10 low flow by about eight times. The transfer will not affect the ice-cover flows because it will only occur during the open-water season. However, the continuing overburden dewatering from the other mines will increase the mean ice-cover discharge by about 42% and the mean 30-day low flow by about five times. These effects are considered to be relatively high.

- **Far Future Equilibrium Conditions:** In far future, the mean annaul flow on the Muskeg River will be the same as the natural conditions. However, the mean open-water flow will reduce moderately by 3% and the mean ice-cover flow will increase by 34%. The relatively large increase in the mean ice-cover flow is mainly due to the presence of the end pit lakes and the seepage water from the reclaimed sand and CT storage areas, which also cause relatively large increases in both open-water and ice-cover low flows. For example, the open-water 7Q10 will increase by about 160%, and the mean annual 30-day low flow will increase by about 360%. Therefore, the combined closure landscape will have a negligible effect on the mean annual Muskeg River flow but will cause a relatively large increase in the low flows.

Analysis of Key Questions on Sediment Concentrations and Channel Regime

Streamflow Sediment Concentrations

Table G4-11 lists the estimated average increase of the Muskeg River flows, and the increased streamflow sediment concentrations estimated based on the relationship presented in Section D. The table shows that the Muskeg River streamflow sediment concentrations will increase by 0.2 to 1.2 mg/L or 2 to 13%. These levels of increase are rated low to moderate.

Table G4-11 Estimated Increases in Muskeg River Flows and Sediment Concentrations

Period	Average Increase of Mean Annual Discharge (m^3/s)	Percent Increase of Mean Annual Discharge	Average Increase of Streamflow Sediment Concentration (mg/L)	Percent Increase of Streamflow Sediment Concentration
1998 to 2005	0.5	9%	0.5	5%
2006 to 2008	1.2	23%	1.2	13%
2009 to 2026	0.2	4%	0.2	2%
2027 to 2030	0.7	13%	0.7	7%
2031 to 2036	-0.1	-2%	None	None
2037 to 2040	0.7	13%	0.7	7%
2041 to 2051	0.2	4%	0.2	2%
2052 to 2055	1.0	19%	1.0	11%
after 2055	Negligible	Negligible	Negligible	Negligible

Note: The baseline mean annual discharge of the Muskeg River is 5.3 m^3/s, and the baseline mean annual streamflow sediment concentration of the Muskeg River is about 9.5 mg/L.

Channel Regime

Table G4-12 presents the volumes of eroded channel materials caused by the increases in river flows and channel erosion rates, which were estimated based on the increased streamflow sediment concentrations shown in Table G4-11.

Table G4-12 Estimated Volumes of Eroded Channel Materials

Period	Average Increase of Streamflow Sediment Concentration (mg/L)	Mean Annual Discharge (m^3/s)	Average Increase in Channel Erosion Rate (mg/s)	Volume of Eroded Materials (m^3)
1998 to 2005	0.5	5.8	2900	276
2006 to 2008	1.2	6.5	7800	278
2009 to 2026	0.2	5.5	1100	223
2027 to 2030	0.7	6.0	4200	200
2031 to 2036	None	5.2	None	None
2037 to 2040	0.7	6.0	4200	200
2041 to 2051	0.2	5.5	1100	144
2052 to 2055	1.0	6.3	6300	300
Total				**1621**

The total volume of eroded channel materials from 1998 to 2055 was estimated to be about 1,621 m^3. The reach of the Muskeg River to be affected by the combined oil sands developments is estimated to be about 60 km long. The average dimension of the river channel is 20 m (width) x 1 m (depth). The total eroded materials represent an increase in the perimeter depth by about 1.2 mm for the 33 year period, which is about 0.006% of the total perimeter length. This level of erosion is negligible. Therefore, the increased river flows caused by the oil sands developments in the Muskeg River basin will have a negligible effect on the river channel regime.

Regional Impact Classification and Degree of Concern

Based on the above detailed analysis of the effects of the combined oil sands developments on the Muskeg River flows, sediment concentrations and channel regime, the effects are classified and the degree of concern of the effects are rated in Tables G4-13 and G4-14.

Table G4-13 Classification and Degree of Concern on the Muskeg River Flows

Parameter	During Construction and Operation	After Closure
Direction	Negative	Negative
Magnitude	Low to High	Low
Geographic Extent	Local	Local
Duration	Medium-Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Moderate***	***Negligible***

Table G4-14 Classification and Degree of Concern of on the Muskeg River Sediment Concentrations and Channel Regime

Parameter	During Construction and Operation	After Closure
Direction	Negative	Negative
Magnitude	Negligible	Negligible
Geographic Extent	Local	Local
Duration	Medium-Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Negligible***	***Negligible***

The degree of concern of the effects on the Muskeg River flows is rated as Moderate throughout the life of the oil sands developments in the Muskeg River basin. The degree of concern on the changes in the river flows after mine closure is rated as Negligible. The degree of concern of the effects on the Muskeg River sediment concentrations and channel regime through the lives of the oil sands developments is rated as Negligible.

G4.3.2 Key Question SWRDR-2: Will Combined Developments Result in Effects on Athabasca River Flows?

Water Withdrawal and Return Flows on Athabasca River

The planned oil sands developments included in the RDR are listed below:

- Shell Lease 13 East Mine
- Mobil Kearl Mine
- Suncor Project Millennium Mine
- Syncrude Upgrader

To estimate the water withdrawal requirements of these planned projects, the following assumptions were made based on the data and information available for this assessment.

- The required licensed river withdrawal for the Muskeg River Mine will be sufficient for the Lease 13 East Mine, due to similar production capacities of these two projects.

- The production capacity of the Kearl Mine project will be 130,000 barrels per day, which compares with the capacity of the Muskeg River Mine Project at 150,000 barrels per day. The required licensed river withdrawal for the Mobil Kearl Mine project was estimated to be 47.8 Mm^3 per year by prorating the required withdrawal volume (55.1 Mm^3 per year) for the Muskeg River Mine Project based on the ratio of the production capacities of these two developments.

- The existing license for Suncor will be sufficient for the operation of the proposed Project Millennium.

- The existing license for Syncrude will be sufficient for the operation of the upgrader.

The incremental effects of the planned projects will cause an additional reduction of the mean Athabasca River flow by 0.2% and the annual 7Q10 low flow by 1.4%. This level of reduction is considered to be negligible to low.

Effects of Combined Developments

The effects of the net water allocations from the existing, approved and planned developments on the Athabasca River flows are summarized in Table G4-15. These are based on the results presented in Table F4-14 and the incremental effects of the planned developments as discussed above. The total reduction in Athabasca River flows caused by all the developments in the Athabasca River basin is considered to be small. The total reduction in the river mean flow is about 1.4%, while the reduction in the river 7Q10 low flow is about 7.8%.

Table G4-15 Combined Effects of Water Allocations of All the Regional Developments

Flow Parameter	Net Water Allocation as a Percentage of the Athabasca River Flows[a]			
	Existing Effects (179 Mm^3/yr)	Incremental Effects by the Project (55 Mm^3/yr)	Incremental Effects by the Planned Developments (48 Mm^3/yr)	Combined Effects (282 Mm^3/yr)
Mean Winter Flow (January to March)	3.3%	1.0 %	0.9 %	5.2%
Mean Spring Flow (April to June)	0.6%	0.2 %	0.1 %	0.9%
Mean Summer Flow (July to September)	0.5%	0.2 %	0.1 %	0.8%
Mean Fall Flow (October to December)	1.5%	0.5 %	0.4 %	2.4%
Mean Annual Flow	0.9%	0.3 %	0.2 %	1.4%
Annual 7Q10 Low Flow	4.9%	1.5 %	1.4 %	7.8%

[a] The percent reduction is based on the estimated flows of the Athabasca River below its confluence with the Muskeg River.

Basin Water Yields Caused by the Oil Sands Developments on Athabasca River

Table G4-16 represents the mine releases from the planned oil sands developments based on the information and data available for this assessment. The incremental releases from these planned developments are expected to range from 0.26 to 0.72 m^3/s.

Table G4-16 Mine Water Releases from the Planned Oil Sands Developments

Development	Time	Mine Water Discharges to Natural Receiving Streams (m^3/s)			
		Muskeg Drainage and Overburden Dewatering	Seepage	Sewage	Total
Lease 13 East Mine	2010	0.18	0	0	0.18
	2020	0.11	0.010	0	0.12
	2030	0.11	0.016	0	0.13
	Far Future	0	0.045	0	0.045
Kearl Mine	2010	0.070	0.07	0	0.14
	2020	0.070	0.011	0	0.081
	2030	0.043	0.011	0	0.054
	Far Future	0	0.030	0	0.030
Suncor Millennium	2010	0.15	0.07	0	0.22
	2020	0.15	0.18	0	0.33
	2030	0	0.18	0	0.18
	Far Future	0	0.18	0	0.18
Total	**2010**	**0.40**	**0.14**	**0**	**0.54**
	2020	**0.33**	**0.39**	**0**	**0.72**
	2030	**0.15**	**0.21**	**0**	**0.36**
	Far Future	**0**	**0.26**	**0**	**0.26**

Table G4-17 summarizes the effects of all mine water releases from the existing, approved and planned oil sands developments based on the results presented in Tables F4-17 and G4-16. The present combined mine water discharge is about 0.04 m^3/s, and the total mine water discharge will reach a maximum of about 1.4 m^3/s around year 2020.

Table G4-17 Mine Water Discharges From the Combined Oil Sands Developments

Time	Mine Water Discharges to Natural Receiving Streams (m^3/s)			
	Muskeg Drainage and Overburden Dewatering	Seepage	Sewage	Total
Present	0.013	0.020	0.0064	0.039
2010	0.89	0.20	0.0067	1.10
2020	0.72	0.63	0.0067	1.36
2030	0.45	0.65	0.0064	1.11
Far Future	0	0.70	0	0.70

Reduction of Surface Water Yield Caused by Closed-Circuit Systems

Table G4-18 presents the incremental maximum closed-circuit areas and maximum reductions in surface water yield to receiving streams caused by the planned oil sands developments. The table also summarizes effects of all the regional oil sands developments by adding the incremental changes by the planned developments to those caused by the existing and approved oil sands developments. Staggering mining schedules were not considered for this analysis to provide a conservative estimate of the effects.

Table G4-18 Maximum Mine Closed-Circuit Areas and Reduction in Surface Water Yield

Effects	Development	Ultimate Closed-Circuit Area (km^2)	Maximum Reduction in Average Water Yield (m^3/s)
Incremental Effects of the Planned Oil Sands Projects[a]	Lease 13 East Mine	72	0.17
	Kearl Mine	53	0.10
	Project Millennium	47	0.15
	Sub-Total	172	0.42
Effects	**All Projects**	**575**	**1.28**

[a] Mean annual water yield based on 61 mm for natural lowland areas and 101 mm for natural upland areas.

The maximum drainage area reduction caused by combined developments of the oil sands developments will be 575 km^2. This represents about 0.4% of the Athabasca River drainage area below the confluence with the Muskeg River. This maximum closed-ciruit area would result in a maximum reduction of about 1.4 m^3/s in mean annual discharge of the Athabasca River. This represents about 0.2% reduction of the mean river discharge and about 1% of the 7Q10 low flow. These levels of reduction are considered to be negligible.

Changes in Surface Water Yield After Mine Closure

Table G4-19 presents the estimated annual water yield from each of the reclaimed mine sites of the planned developments and the changes from the natural conditions. This table also summarizes the effects by all the regional oil sands developments. The table shows that the combined change to the mean annual water yield is about 6%.

Table G4-19 Estimated Mean Annual Water Yield from Reclaimed Mine Sites

Effects	Oil Sands Project	Reclaimed Area (km^2)	Water Yield (m^3/s)	Percent Change from Natural Conditions
Incremental Effects of the Planned Oil Sands Projects	Lease 13 East Mine[a]	72	0.24	+40%
	Kearl Mine[a]	53	0.18	+40%
	Suncor Millennium [b]	47	0.15	0%
	Sub-Total	172	0.57	29%
Cumulative Effects	**All Projects**	**575**	**1.38**	**6%**

[a] Extrapolated from Muskeg River Mine based on the mining footprint areas.
[b] Extrapolated from Steepbank Mine based on the mining footprint areas.

Combined Effects on the Athabasca River Flows

During Construction and Operation of the Oil Sands Developments

The maximum mine water release will be about 1.4 m^3/s during construction and operation of the oil sands developments. This represents about 0.2% of the mean annual discharge of the Athabasca River and about 1.2% of the annual 7Q10 low flow. These levels of increase are negligible.

The maximum reduction in the Athabasca River flows caused by the total basin water allocation (total withdrawal minus total return flow) is estimated to be 8.9 m^3/s. The maximum reduction in surface runoff inflow to the Athabasca River caused by the combined closed-circuit areas of the oil sands developments is estimated to be about 1.3 m^3/s. The maximum combined reduction caused by the net water allocation and closed-circuit areas is conservatively estimated to be about 10.2 m^3/s without considering the progressive reclamation of the mine sites and mine water release during mine construction and operation.

If a typical ratio (0.5) of average river withdrawal to licensed river withdrawal for the oil sands operations is assumed based on the rationale presented in Section F4.3.4, the typical net river withdrawals of combined existing, approved and proposed oil sands projects (2.9 m^3/s) and non-oil-sands operations (3.1 m^3/s) would be about 6.0 m^3/s. The typical reduction caused by the net water allocation and closed-circuit areas would be about 7.3 m^3/s. This represents about 1% of the mean annual flow in Athabasca River and about 6% of the annual 7Q10 low flow. The level of reduction in the mean annual flow is considered to be small, and the effects on the 7Q10 low flow are considered to be moderate.

After Closure of the Oil Sands Developments

After reclamation and closure of all the regional oil sands developments, the mean total annual surface runoff discharge from the reclaimed surfaces will increase by about 0.1 m^3/s relative to natural conditions. This level of increase will have negligible effects on the Athabasca River flows, although the seasonal distribution of these inflows will be different from the natural conditions. This seasonal change will have negligible effects on the seasonal flows of the Athabasca River, because the total reclaimed surface area will represent 1% of the total drainage area of the Athabasca River below the confluence with the Muskeg River.

Residual Impact Classification and Degree of Concern

The effects of the combined developments on the Athabasca River flows in the RSA are classified and rated as shown in Table G4-20, based on the results of the above detailed analysis.

Table G4-20 Classification and Degree of Concern on the Athabasca River Flows for the RDR

Parameter	During Construction and Operation	After Closure
Direction	Negative	Neutral
Magnitude	Low	Negligible
Geographic Extent	Regional	Regional
Duration	Medium-Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Low***	

Combined developments in the Athabasca River basin will have small effects on the river mean flows during the life of the oil sands developments. The degree of concern of the effects on the river flows during mining construction and operation is rated Low. After closure, the regional oil sands developments will contribute Negligible changes to the Athabasca River flows, although other developments in the region may continue to affect the Athabasca River flows. Therefore, the degree of concern of the RDR after closure of the oil sands developments is rated as Negligible.

G4.3.3 Key Question SWRDR-3: Will Combined Developments Result in Effects to the Open-Water Areas Including Lakes and Streams?

Analysis of the Effects

Table G4-21 presents the future maximum loss of open-water areas during construction and operation of the planned oil sands developments and the open-water areas gained after closure of these mines. The maximum loss will represent about 1.4% of the existing open-water areas in the RSA. This is considered to be small. The open-water areas gained after closure of the mines will present a moderate 10% increase in the open-water areas in the RSA.

Table G4-21 Losses and Gains of the Open-Water Areas Caused by the Planned Oil Sands Developments

Development	During Construction and Operation		After Mine Closure	
	Maximum Loss of Open-Water Area (ha)	Percent of Total Open-Water Area in the RSA	New Open-Water Area (ha)	Percent of Total Open-Water Area in the RSA
Lease 13 East Mine[a]	-51	-0.18%	+1460	+5%
Kearl Mine[a]	-7	-0.03%	+1080	+4%
Project Millennium[b]	-330	-1.2%	+330	+1%
Total	**-388**	**-1.4%**	**+2870**	**+10%**

[a] Areas lost during construction and operation were estimated based on the mining footprint areas. The areas after reclamation were estimated by assuming that these two mines will be reclaimed the same manner as the Muskeg River Mine.
[b] Prorated based on the data for the Steepbank Mine and the ratio of the mining footprint areas between the Steepbank and Millennium Mines.

Effects of the Oil Sands Developments

Table G4-22 summarizes the changes in the open-water areas in the RSA based on the data in Tables F4-22 and G4-21. The total loss of natural open-water areas in the RSA will be about 852 ha, which is about 3.1% of the existing open-water areas in the RSA. This level of reduction is considered to be small. After reclamation and closure of all the oil sands developments in the far future, the newly created open-water areas will total about 8,534 ha, which is about 31% of the existing open-water areas in the RSA. The net increase of the total open-water areas will be about 28%. This level of increase is considered to be relatively high.

Table G4-22 Effects of the Combined Developments on the Open-Water Areas in the RSA

During Construction and Operation		After Mine Closure	
Maximum Loss of Open-Water Area (ha)	Percent of Total Open-Water Area in the RSA	New Open-Water Area (ha)	Percent of Total Open-Water Area in the RSA
-852	-3.1%	+8,534	+30.8%

Residual Impact Classification and Degree of Concern

The effects of the oil sands developments on the changes of the open-water areas including lakes and streams in the RSA are classified and rated in Table G4-23 based on the results of the above analysis.

Table G4-23 Classification and Degree of Concern on the Changes of the Open-Water Areas in the RSA

Parameter	Construction and Operation	Closure
Direction	Negative	Neutral to Positive
Magnitude	Low	High
Geographic Extent	Regional	Regional
Duration	Medium-Term	Long-Term
Reversibility	Reversible	Irreversible
Frequency	Continuous	Continuous
Degree of Concern	***Low***	

The oil sands projects will permanently remove the natural open-water areas at the development sites. The degree of concern of the effects during mining construction and operation is rated Low in the RSA. However, reclamation of the oil sands mine sites will replace existing open-water areas lost to mine development and increase the total open-water areas in the RSA relative to the existing conditions.

G4.4 Summary of Impacts

Table G4-24 summarizes the impacts to surface water under the RDR.

Table G4-24 Summary of Impacts on Surface Water

Key Question	RDR Results
SWRDR-1: Will combined developments in the Muskeg River basin result in effects on the Muskeg River flows, sediment concentrations and channel regime?	• During construction and operation phases of the oil sands developments, the combined developments will cause small to large increases (4% to 23%) in the Muskeg River flows, primarily as a result of muskeg drainage, overburden dewatering, and a transfer of the MFT to the end pit lakes during mine reclamation. The degree of concern is **Moderate**. • In far future, the average river flows in Muskeg River will be similar to the natural conditions. The degree of concern is **Negligible**. • During construction and operation phases of the oil sands developments, the increased Muskeg River flows will cause an increase in the streamflow sediment concentration by 0.2 to 1.2 mg/L and will cause a negligible increase in the channel erosion rate. The degree of concern is **Negligible**. • In the far future, there will be negligible changes in the river streamflow sediment concentration and channel regime. The degree of concern is **Negligible**.
SWRDR-2: Will combined developments result in effects on Athabasca River flows?	• During construction and operation phases of the oil sands developments, the combined developments will cause small changes to the mean flow conditions on Athabasca River. The degree of concern is **Low**. • After closure, all of the oil sands developments will cause negligible changes to the mean flow conditions on Athabasca River.

Key Question	RDR Results
SWRDR-3: Will combined developments result in effects to the open-water areas including lakes and streams?	• During construction and operation phases of the oil sands developments, the developments will permanently remove 852 ha of the natural open-water areas. The degree of concern is **Low.** • After closure of all the oil sands developments, closure drainage systems at the reclaimed mine sites will create 8,534 ha of new open-water areas which will replace the existing open-water areas lost to development.

G5 SURFACE WATER QUALITY REGIONAL DEVELOPMENT REVIEW

G5.1 Introduction

This Regional Development Review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and publicly disclosed developments on surface water quality in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Upstream pulp mills
- Syncrude Mildred Lake
- Syncrude Aurora North and South
- Suncor Project Millenium
- Mobil Kearl Mine
- Upstream municipalities

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

The water quality predictions presented in this section are used to assess impacts on aquatic resources (Section G6), wildlife (Section G11) and human health (Section G12).

G5.2 Potential Linkages and Key Questions

Figure E5-1 (Section E5) shows the linkage diagram for Project activities and potential changes in water quality associated with the Project. The same key questions and linkages apply to the RDR and Section F5. The key questions for the surface water quality RDR include:

WQRDR-1: Will Operational and Reclamation Water Releases From Combined Developments Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers?

WQRDR-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?

WQRDR-3: Will Operational and Reclamation Water Releases From Combined Developments Alter the Temperature Regime of the Muskeg River?

WQRDR-4: Will Muskeg and Overburden Dewatering Activities From Combined Developments Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?

WQRDR-5: Will PAHs in Operational and Reclamation Water Releases From Combined Developments Accumulate in Sediments and Be Transported Downstream?

WQRDR-6: Will Acidifying Emissions From Combined Developments Result in Changes in Water Quality?

G5.3 Analysis and Results

G5.3.1 Key Question WQRDR-1: Will Operational and Reclamation Water Releases From Combined Developments Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers?

Analysis of Potential Linkages

Linkage Between Operational and Reclamation Water Releases and Exceedances of Water Quality Guidelines in the Athabasca and Muskeg Rivers

As discussed in Section E5, operational and reclamation waters have the potential to cause exceedances of water quality guidelines (Table V-3, Appendix V, Volume 3) in receiving waters. Therefore, this linkage is valid.

Analysis of Key Question

Results of water quality modelling are presented in Appendix XII for each snapshot and flow condition in the Athabasca and Muskeg rivers for all modelled substances. The summary tables below provide results only for substances that were predicted to exceed water quality guidelines and, thus, show the highest concentrations predicted for all years simulated. In addition, an indication of the spatial extent of the guideline exceedance is provided for the Athabasca River.

Summary tables for the Athabasca River provide the following information for substances that were predicted to exceed guidelines:

- the existing concentration upstream of Fort McMurray, as measured during baseline studies or monitoring;
- the effects of existing and approved developments, as modelled substance concentrations at the 10% mixing zone boundary of Muskeg River water in the Athabasca River;

- the effects of existing and approved developments plus the incremental increase caused by the Project, as modelled substance concentrations at the 10% mixing zone boundary of Muskeg River water in the Athabasca River; and
- the effects of existing, approved and disclosed developments plus the incremental increase caused by the Project, as modelled substance concentrations at the 10% mixing zone boundary of Muskeg River water in the Athabasca River.

Summary tables for the Muskeg River provide the following information for substances that were predicted to exceed guidelines:

- the existing substance concentration upstream of Node 16 in the Muskeg River, as measured during baseline studies;
- the effects of approved developments, as modelled substance concentrations at Node 16;
- the effects of approved developments plus the incremental increase caused by the Project, as modelled substance concentrations at Node 16; and
- the effects of approved and publicly disclosed developments plus the incremental increase caused by the Project, as modelled substance concentrations at Node 16.

Mean Open-Water Flow in Athabasca River

Model results indicate that during mean open-water flow, compliance with most water quality guidelines is achieved during all time snapshots (Table XII-12). Table G5-1 shows the concentrations of substances that were predicted to exceed water quality guidelines. Dispersion model contour plots of arsenic and benzo(a)anthracene concentrations are presented for snapshots with the greatest spatial extent of guideline exceedances (2007 and Far Future, respectively) in Figures XII-23 and XII-24.

Annual 7Q10 Flow in Athabasca River

Table XII-11 provides predictions of substance concentrations at annual 7Q10 flow in the Athabasca River. Table G5-2 shows concentrations of substances that exceed guidelines at annual 7Q10 flow in the Athabasca River. Dispersion model contour plot of iron concentrations is presented for year 2007 in Figure XII-22.

Table G5-1 Maximum Predicted Substance Concentrations Compared With Water Quality Guidelines at Mean Open-Water Flow in the Athabasca River

Substance	Existing[a]	Approved[b]	Project[c]	RDR[d]	Guideline[e]	Comment on RDR
aluminum (mg/L)	0.68	0.68	0.68	0.68	0.1 C	guideline exceedances for all snapshots due to existing river conditions
arsenic (mg/L)	0.001	0.002	0.002	0.002	0.01 C 0.000018 HC	guideline exceedances for all snapshots due to existing river conditions, but concentrations increase below Muskeg River (maximum extent: 55 km long reach downstream of Muskeg River; 15% of river width)
benzo(a)anthracene (mg/L)	0	0.0000046	0.000005	0.000008	0.0000028 HC	guideline exceedances in 2030 and Far Future due to sand and CT seepage (maximum extent: >170 km long reach downstream of Project Millennium discharge, 32.5% of river width)
iron (mg/L)	3.0	3.0	3.0	3.0	0.3 C 0.3 HNC	guideline exceedances for all snapshots due to existing river conditions
manganese (mg/L)	0.4	0.4	0.4	0.4	0.05 C 0.05 HNC	guideline exceedances for all snapshots due to existing river conditions
mercury (mg/L)	0.0001	0.0001	0.0001	0.0001	0.000012 C 0.00014 HNC	guideline exceedances for all snapshots due to existing river conditions

(a) Existing concentration upstream of Fort McMurray, from Golder (1997d).
(b) Existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(c) Muskeg River Mine Project plus existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(d) Muskeg River Mine Project, plus existing Suncor and Syncrude operations, plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South), plus publicly disclosed developments (Suncor Project Millennium, Shell Lease 13 East, Mobil Kearl Mine).
(e) A = Acute, C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Mean Open-Water Flow in Muskeg River

Table XII-10 provides predictions of substance concentrations at mean open-water flow in the Muskeg River. Table G5-3 includes the concentrations of substances that were predicted to exceed water quality guidelines.

Table G5-2 Maximum Predicted Substance Concentrations Compared With Water Quality Guidelines at Annual 7Q10 Flow in the Athabasca River

Substance	Existing[a]	Approved[b]	Project[c]	RDR[d]	Guideline[e]	Comment on RDR
iron (mg/L)	0.17	0.43	0.44	0.47	0.3 C	guideline exceedance in 2007 due to releases of muskeg and overburden waters (maximum extent: >170 km long reach downstream Muskeg River; 25% of river width)
manganese (mg/L)	0.1	0.1	0.1	0.1	0.05 C	guideline exceedances for all snapshots due to existing river conditions
mercury (mg/L)	0.0001	0.0001	0.0001	0.0001	0.000012 C	guideline exceedances for all snapshots due to existing river conditions

(a) Existing concentration upstream of Fort McMurray, from Golder (1997d).
(b) Existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(c) Muskeg River Mine Project plus existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(d) Muskeg River Mine Project, plus existing Suncor and Syncrude operations, plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South), plus publicly disclosed developments (Suncor Project Millennium, Shell Lease 13 East, Mobil Kearl Mine).
(e) A = Acute, C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Table G5-3 Maximum Predicted Substance Concentrations Compared With Water Quality Guidelines at Mean Open-Water Flow in the Muskeg River

Substance	Existing[a]	Approved[b]	Project[c]	RDR[d]	Guideline[e]	Comment on RDR
aluminum (mg/L)	0.05	0.12	0.25	0.26	0.1 C	guideline exceedance in 2007 as a result of dewatering; guideline exceedances in 2030 and Far Future due to EPL discharge and sand and CT seepage, respectively. Most of the aluminum associated with particulate material and not bioavailable, reflecting existing river conditions
arsenic (mg/L)	0.003	0.005	0.005	0.006	0.01 C 0.000018 HC	guideline exceedances for all snapshots due to existing river conditions
benzo(a)anth-racene (mg/L)	0	0.000036	0.000037	0.00004	0.0000028 HC	guideline exceedance in 2030 and Far Future due to EPL discharge and sand and CT seepage, respectively
benzo(a)py-rene (mg/L)	0	0.0000044	0.0000044	0.0000048	0.0000028 HC	guideline exceedance in 2030 and Far Future due to EPL discharge and sand and CT seepage, respectively
iron (mg/L)	0.8	1.6	1.6	1.6	0.3 C 0.3 HNC	guideline exceedances for all snapshots as a result of existing river conditions; highest concentration in 2007 due to muskeg and overburden dewatering
manganese (mg/L)	0.04	0.15	0.15	0.16	0.05 C 0.05 HNC	guideline exceedances for all snapshots; highest concentration in 2007 due to muskeg and overburden dewatering
mercury (mg/L)	0.0001	0.000095	0.000095	0.000094	0.000012 C 0.000014 HNC	guideline exceedances for all snapshots due to existing river conditions

(a) Existing concentration, from Golder (1997d).
(b) Approved developments (Aurora North, Aurora South).
(c) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South).
(d) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South), plus publicly disclosed developments (Shell Lease 13 East, Mobil Kearl Mine).
(e) A = Acute, C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen.

Annual 7Q10 Flow in Muskeg River

Table XII-9 provides predictions of substance concentrations at annual 7Q10 flow in the Muskeg River. Table G5-4 summarizes exceedances of water quality guidelines.

Table G5-4 Maximum Predicted Substance Concentrations Compared With Water Quality Guidelines at Annual 7Q10 Flow in the Muskeg River

Substance	Existing[a]	Approved[b]	Project[c]	RDR[d]	Guideline[e]	Comment on RDR
aluminum (mg/L)	0.04 (<0.01 - 0.42)	1.1	1.1	1.1	0.1 C	guideline exceedances for all snapshots; most of the aluminum is associated with particulate material and not bioavailable, reflecting existing river conditions
arsenic (mg/L)	0.0029 (<0.0004 - 0.001)	0.019	0.019	0.019	0.01 C	guideline exceedance in 2007, due to muskeg and overburden dewatering
boron (mg/L)	0.06	1.96	1.95	1.95	0.5 C	guideline exceedance during Far Future, due to sand and CT seepage
cadmium (mg/L)	0.0006 (<0.002 - 0.003)	0.004	0.004	0.004	0.0018	guideline exceedance during Far Future, due to sand and CT seepage
chromium (mg/L)	0.0052 (<0.0004 - 0.006)	0.022	0.022	0.022	0.011C 0.016 A	guideline exceedance during 2007 and 2030, due to muskeg and overburden dewatering and EPL water discharge, respectively; guideline is for chromium VI, while predictions are for total chromium
copper (mg/L)	0.002 (<0.001- 0.004)	0.010	0.010	0.010	0.007	guideline exceedances for all snapshots; highest concentration in 2007, due to muskeg and overburden dewatering
iron (mg/L)	2.42 (1.9 - 2.9)	5.9	6.0	6.0	0.3 C	guideline exceedances for all snapshots; highest concentration in 2007, due to muskeg and overburden dewatering
manganese (mg/L)	0.55 (0.43 - 0.66)	0.8	0.8	0.8	0.05 C	guideline exceedances for all snapshots; highest concentration in 2007, due to muskeg and overburden dewatering
mercury (mg/L)	0.0001 (<0.0001 - 0.0005)	0.000018	0.00017	0.00016	0.000012 C	guideline exceedance in Far Future, as a result of existing river conditions; slight decrease in concentration with increasing development due to increase in available dilution water
zinc (mg/L)	0.0215 (0.001 -0.21)	0.20	0.20	0.20	C 0.19 A	guideline exceedance in 2007 and 2030, due to muskeg and overburden dewatering and EPL water discharge, respectively

(a) Existing concentration, from Golder (1997d).
(b) Approved developments (Aurora North, Aurora South).
(c) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South).
(d) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South), plus publicly disclosed developments (Shell Lease 13 East, Mobil Kearl Mine).
(e) A = Acute, C = Chronic, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen

Significance of Water Quality Guideline Exceedances

The same substances that were predicted to exceed water quality guidelines in Section F5, exceed guidelines in the RDR and their predicted concentrations are nearly identical. As explained in Section F5, there are several lines of evidence that suggest that these exceedances are of limited consequence to the environmental quality of waters where they were predicted to occur.

It is concluded that exceedances of water quality guidelines due to water releases from oil sands developments included in the RDR have limited potential to affect the environmental quality of receiving waters, despite the water quality guideline exceedances predicted by modelling.

Residual Impact Classification and Degree of Concern

The predicted impacts of operational and reclamation water releases from developments included in the RDR, as defined by their contribution to exceedances of water quality guidelines, are classified in Table G5-5.

Table G5-5 Residual Impact Classification and Degree of Concern for Water Quality Guideline Exceedances

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Exceedances of guidelines at mean open-water flow in the Athabasca River	Negative	Low	Local	Medium-Term	Reversible	Medium	Low
Exceedances of guidelines at annual 7Q10 flow in the Athabasca River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Exceedances of guidelines at mean open-water flow in the Muskeg River	Negative	Low	Local	Medium-Term	Reversible	Medium	Low
Exceedances of guidelines at annual 7Q10 flow in the Muskeg River	Negative	Low	Local	Medium-Term	Reversible	Medium	Low

G5.3.2 Key Question WQRDR-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?

Analysis of Potential Linkages

Linkage Between Operational Water Releases and Exceedances of Toxicity Guidelines

As discussed in Section E5, operational waters do not have the potential to cause toxicity in receiving waters. Therefore, this linkage is invalid.

Linkage Between Reclamation Water Releases and Exceedances of Toxicity Guidelines

As discussed in Section E5, reclamation waters have the potential to cause exceedances of toxicity guidelines (Table V-3, Appendix V, Volume 3) in receiving waters. Therefore, this linkage is valid.

Analysis of Key Question

Athabasca River

Model results indicate that during mean open-water and annual 7Q10 flows, compliance with whole effluent toxicity (WET) guidelines will be achieved. The values shown in Table G5-6 represent the highest numbers predicted for acute and chronic toxicity for all snapshot years simulated. Dispersion model contour plots of TU values are presented in Figures XII-14 to XII-19.

Table G5-6 Maximum Predicted TU Values in the Athabasca River

Substance	Existing[a]	Approved[b]	Project[c]	RDR[d]	Guideline[e]	Comment
Annual 7Q10 Flow						
acute toxicity (TUa)	0	0.01	0.01	0.02	0.3 A	Acute toxicity guideline not exceeded
chronic toxicity (TUc)	0	0.02	0.02	0.06	1.0 C	Chronic toxicity guideline not exceeded
Mean Open Water Flow						
acute toxicity (TUa)	0	0.002	0.002	0.008	0.3 A	Acute toxicity guideline not exceeded
chronic toxicity (TUc)	0	0.006	0.006	0.023	1.0 C	Chronic toxicity guideline not exceeded

(a) River assumed to be non-toxic upstream of oil sands operations.
(b) Existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(c) Muskeg River Mine Project plus existing Suncor and Syncrude operations plus approved developments (SOLV-EX, Suncor Steepbank, Aurora North, Aurora South).
(d) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South), plus publicly disclosed developments (Shell Lease 13 East, Mobil Kearl Mine, Suncor Project Millennium).
(e) A = Acute, C = Chronic.

Muskeg River

Model results indicate that during mean open-water and annual 7Q10 flows, compliance with WET guidelines will be achieved. The values shown in Table G5-7 represent the highest TU values predicted for all snapshot years simulated.

Table G5-7 Maximum Predicted TU Values in the Muskeg River

Substance	Existing[a]	Approved[b]	Project[c]	RDR[d]	Guideline[e]	Comment
Annual 7Q10 Flow						
acute toxicity (TUa)	0	0.28	0.27	0.27	0.3 A	Acute toxicity guideline not exceeded
chronic toxicity (TUc)	0	0.74	0.73	0.73	1.0 C	Chronic toxicity guideline not exceeded
Mean Open Water Flow						
acute toxicity (TUa)	0	0.02	0.02	0.02	0.3 A	Acute toxicity guideline not exceeded
chronic toxicity (TUc)	0	0.04	0.04	0.05	1.0 C	Chronic toxicity guideline not exceeded

(a) River assumed to be non-toxic upstream of oil sands operations.
(b) Approved developments (Aurora North, Aurora South).
(c) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South).
(d) Muskeg River Mine Project plus approved developments (Aurora North, Aurora South), plus publicly disclosed developments (Shell Lease 13 East, Mobil Kearl Mine).
(e) A = Acute, C = Chronic.

Residual Impact Classification and Degree of Concern

The predicted impacts of operational and reclamation water releases on toxicity in receiving waters are classified in Table G5-8.

Table G5-8 Residual Impact Classification and Degree of Concern for WET Guideline Exceedances

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Exceedances of WET guidelines at mean open-water flow in the Athabasca River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Exceedances of WET guidelines at annual 7Q10 flow in the Athabasca River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Exceedances of WET guidelines at mean open-water flow in the Muskeg River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Exceedances of WET guidelines at annual 7Q10 flow in the Muskeg River	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible

G5.3.3 Key Question WQRDR-3: Will Operational and Reclamation Water Releases From Combined Developments Alter the Temperature Regime of the Muskeg River?

Analysis of Potential Linkages

Linkage Between Operational and Reclamation Water Releases and Temperature Regime of the Muskeg River

Since flow of the Muskeg River will be affected by a number of oil sands developments in the RSA, the linkage between operational and reclamation water releases and temperature regime of the Muskeg River is classified as valid.

Analysis of Key Question

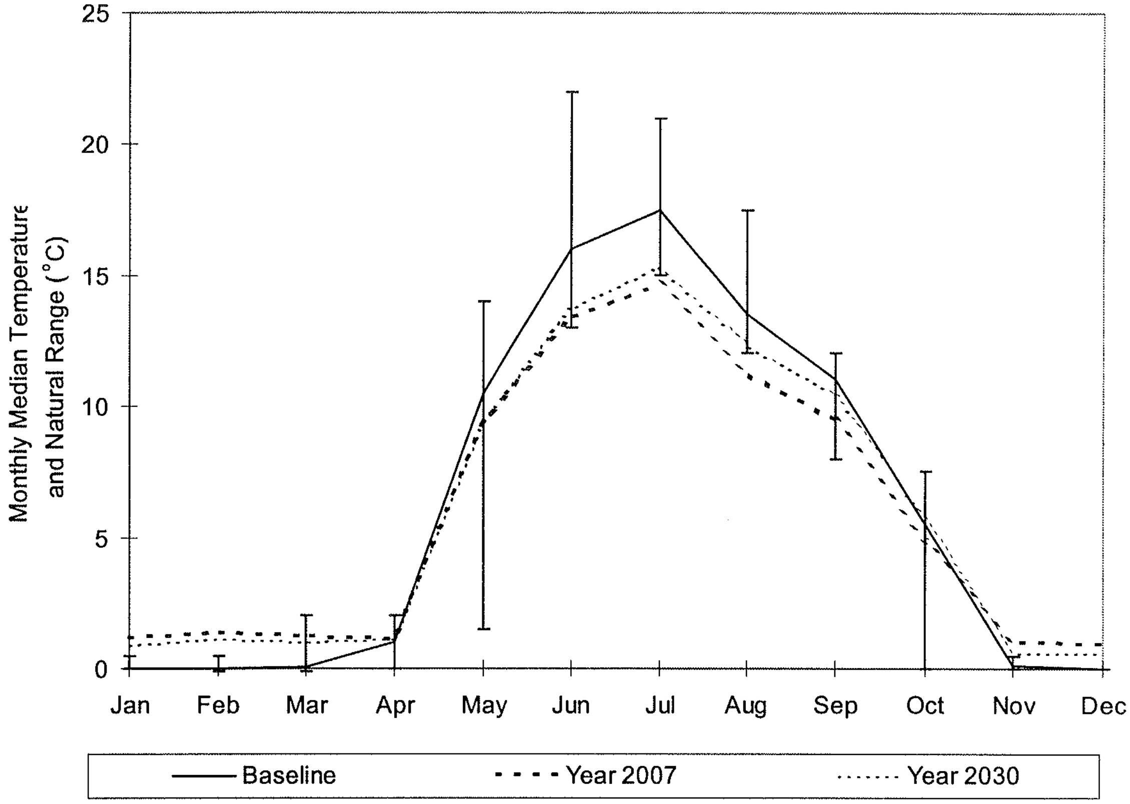
Results of temperature modelling suggest that water releases included in this RDR have the potential to alter the temperature regime of the Muskeg River.

In 2007, river water temperature was predicted to increase slightly (by about 1°C) in the winter and decrease by a maximum of 2.9°C during the open-water season (Figure G5-1). The primary cause of these predicted changes is muskeg dewatering. The maximum predicted temperature change of 2.9°C is slightly below the currently available temperature guideline of <3°C change. Hence, the predicted changes in river water temperature in 2007 are classified as negligible.

Less pronounced changes were predicted in river water temperature in 2030 (Figure G5-1). This year represents a relatively short period, during which mature fine tails (MFT) will be added to the Project EPL during the open-water season. The maximum predicted temperature change of 2.3°C in 2030 is also below the temperature guideline. Hence, the predicted temperature changes in 2030 are also classified as negligible.

The Far Future scenario was not modelled during this analysis. During this period, water balance in the RSA was predicted to be close to natural (Section G4), indicating the lack of potential effects on stream temperatures. Therefore, any changes in water temperature in the Far Future are also classified as negligible.

Figure G5-1 Predicted Monthly Median Water Temperatures in the Muskeg River at Node S16 Compared With the Baseline Temperature Regime of the Lower Muskeg River



In addition to the predicted absolute temperature changes described above, water releases from oil sand developments may also cause slower seasonal warming and cooling of river water and reduced daily (diurnal) temperature variation. These impacts are predicted to be similar for Section F and the RDR and are described in Section F5.4.3. Because of the uncertainty regarding theses impacts their magnitudes are classified as low.

Residual Impact Classification and Degree of Concern

The predicted impacts of mine activities on the temperature regime of the Muskeg River were classified as shown in Table G5-9.

Table G5-9 Residual Impact Classification and Degree of Concern for Change in Thermal Regime of the Muskeg River

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Cooling in open-water season	Neutral	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Slower seasonal warming and cooling	Neutral	Low	Regional	Medium-Term	Reversible	Medium	Low
Reduced diurnal fluctuation	Neutral	Low	Regional	Medium-Term	Reversible	High	Low

Certainty

Factors regarding certainty discussed in Section E5.7 (key question WQ-3) are also applicable to this assessment.

G5.3.4 Key Question WQRDR-4: Will Muskeg and Overburden Dewatering Activities From Combined Developments Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?

The information presented under key question WQCEA-4 is also applicable to this key question. Impacts of developments included in the RDR on dissolved oxygen concentrations in the Muskeg River are expected to be very similar to those of combined developments identified in Section F5.4.4.

G5.3.5 Key Question WQRDR-5: Will PAHs in Operational and Reclamation Water Releases From Combined Developments Accumulate in Sediments and be Transported Downstream?

The information presented under key question WQCEA-5 is also applicable to this key question. Impacts of developments included in the RDR on sediment PAH levels are expected to be very similar to those of combined developments identified in Section F5.4.5.

G5.3.6 Key Question WQRDR-6: Will Acidifying Emissions From Combined Developments Result in Changes in Water Quality?

The information presented under key question WQCEA-6 is also applicable to this key question. Impacts of acidifying emissions from developments included in the RDR on surface waters are expected to be similar to those of combined developments identified in Section F5.4.6, with the exception that the area of potential impacts in the RDR is predicted to be slightly larger.

G5.4 Summary of Impact Predictions

The residual impacts predicted by this RDR are very similar to those predicted in Section F5. Residual impacts are summarized in Table G5-10 and differences in the severity of predicted impacts between the RDR and Section F5 are described.

Predicted impacts on the temperature regime of the Muskeg River, sediment PAH levels and acid-sensitive waterbodies are subject to considerable uncertainty. To provide more precise predictions for these impacts, it would be necessary to conduct more detailed analyses on the regional scale, which are outside of the scope of this assessment.

Table G5-10 Summary of Surface Water Quality RDR

Key Question	RDR Results
WQRDR-1: Will Operational and Reclamation Water Releases From Combined Developments Result in Water Quality Guideline Exceedances in the Athabasca and Muskeg Rivers?	• The combined developments considered in the RDR will cause exceedances of water quality guidelines for a number of metals, in addition to natural exceedances by certain metals. Exceedances of human health water quality guidelines were predicted to occur for two PAH compounds during initial high EPL discharges and in the Far Future. Follow-up risk analysis in Section G11 and Section G12 did not identify these compounds as a concern to wildlife and human health. The overall degree of concern for water quality guideline exceedances is rated **Low**. • Concentrations of most substances exceeding guidelines in the RDR are identical to, or slightly higher than predicted concentrations in Section F5. The size of the area of exceedances in the Athabasca River predicted in the RDR is slightly larger for arsenic and more than two-fold larger for benzo(a)anthracene and iron than the area of exceedance predicted in the Section F5.
WQRDR-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Toxicity Guideline Exceedances in the Athabasca and Muskeg Rivers?	• No exceedances of toxicity guidelines were predicted. Therefore, the degree of concern for toxicity guideline exceedances is rated **Negligible**.
WQRDR-3: Will Operational and Reclamation Water Releases From Combined Developments Alter the Temperature Regime of the Muskeg River?	• Temperature fluctuations in the Muskeg River, as a result of changing flow regimes, would remain within acceptable ranges. However, uncertainties remain regarding potential effects on seasonal warming and cooling of river water and changes in diurnal temperature fluctuation. The degree of concern for cooling of river water in the open-water season is rated **Negligible**; the degree of concern for effects on rates of seasonal warming and cooling is rated **Low**; and the degree of concern for effects on diurnal temperature fluctuation is rated **Low**. • Compared to impact predictions in Section F5, temperature declines predicted in the RDR are slightly larger.
WQRDR-4: Will Muskeg and Overburden Dewatering Activities From Combined Developments Reduce Dissolved Oxygen Concentrations to Unacceptable Levels in the Muskeg River?	• Dissolved oxygen impacts from muskeg drainage waters are not anticipated to occur. Therefore, the degree of concern for reduction of dissolved oxygen concentrations is rated **Negligible**.

Key Question	RDR Results
WQRDR-5: Will PAHs in Operational and Reclamation Water Releases From Combined Developments Accumulate in Sediments and Be Transported Downstream?	• PAH accumulation in sediments is not anticipated to occur due to limited available pathways, though uncertainties remain regarding release rates of PAHs from oil sands developments. The degree of concern for PAH accumulation in sediments is rated **Negligible to Low**. • Although severe impacts on sediment PAH levels are unlikely, this issue remains a potential concern related to oil sands developments. Due to the qualitative nature of the analysis, it is not possible to estimate differences in sediment PAH levels between the RDR and those identified in Section F5.
WQRDR-6: Will Acidifying Emissions From Combined Developments Result in Changes in Water Quality?	• Acidification of waterbodies due to air emissions cannot be evaluated with certainty at this time due to limited data on sensitivity of surface waters in the RSA to acidification. Although year-round acidification of surface waters in the RSA is highly unlikely, available data suggest that spring pH depression in sensitive waterbodies is a potential impact that should be examined further. The degree of concern for year-round acidification is rated **Negligible**; and the degree of concern for spring pH depression is rated **Low**. • Compared to impact predictions in Section F5, the size of the potentially affected area identified in the RDR is slightly larger.

G6 AQUATIC RESOURCES REGIONAL DEVELOPMENT REVIEW

G6.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and publicly disclosed developments on aquatic resources in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- Syncrude Aurora North and South
- Suncor Project Millennium
- Mobil Kearl Mine
- Upstream Pulp Mills
- Syncrude Mildred Lake
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Upstream Municipalities

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

The aquatic resources predictions presented in this section were used to assess impacts on human health (Section G12 - fish tissue chemical concentrations) and resource use (Section G14 - fish abundance).

G6.2 Potential Linkages and Key Questions

Figures E6-1 and E6-2 show the linkage diagram for Project activities and potential changes in aquatic resources associated with the project. Generally the same linkages and key questions apply with the exception discussed below.

The key question that relates to the viability of an aquatic ecosystem in the Project's end pit lake does not apply to the RDR since it is site specific. However, water quality of the end pit lake and its potential effect on fish in the Muskeg and Athabasca rivers is addressed through water quality modelling. As well, fish habitat gains from end pit lakes from the Project and other developments were included in the habitat assessment.

The key questions for the aquatic resources RDR include:

ARRDR-1: Will Activities From Combined Developments Change Fish Habitat?

ARRDR-2: Will Operational And Reclamation Water Releases From Combined Developments Result in Acute or Chronic Effects on Fish?

ARRDR-3: Will Operational and Reclamation Water Releases From Combined Developments Result in Changes to Fish Tissue Quality?

ARRDR-4: Will Operational and Reclamation Water Releases From Combined Developments Result in Changes in Fish Abundance?

G6.3 Analysis and Results

G6.3.1 Key Question ARRDR-1: Will Activities From Combined Developments Change Fish Habitat?

Analysis of Potential Linkages

Linkage Between Changes in Areas of Lakes and Streams and Fish Habitat

Changes in areas of waterbodies from existing and approved developments are described in the Surface Water Hydrology CEA (Table F4-21). Area changes related to disclosed developments are presented in the Surface Water Hydrology RDR (Table G4-21).

Figure G6-1 shows the footprints of existing, approved and disclosed developments in relation to waterbodies in the RSA. Fish habitat affected by the Project and by existing and approved developments is described in Section F6.5.1.

The Mobil Kearl development will affect Wapasu Creek which is a tributary to the Muskeg River. Suncor's Project Millennium development will affect portions of Wood and McLean creeks, which are small tributaries to the Athabasca River. Khahago, Muskeg and Shelley creeks will be displaced by the Shell Lease 13 East development.

As with existing and approved developments, disclosed developments will not directly affect important tributaries to the Athabasca River such as the Muskeg and Steepbank rivers (Figure G6-1). Based on the current plans for combined developments, only forage fish habitat will be affected.

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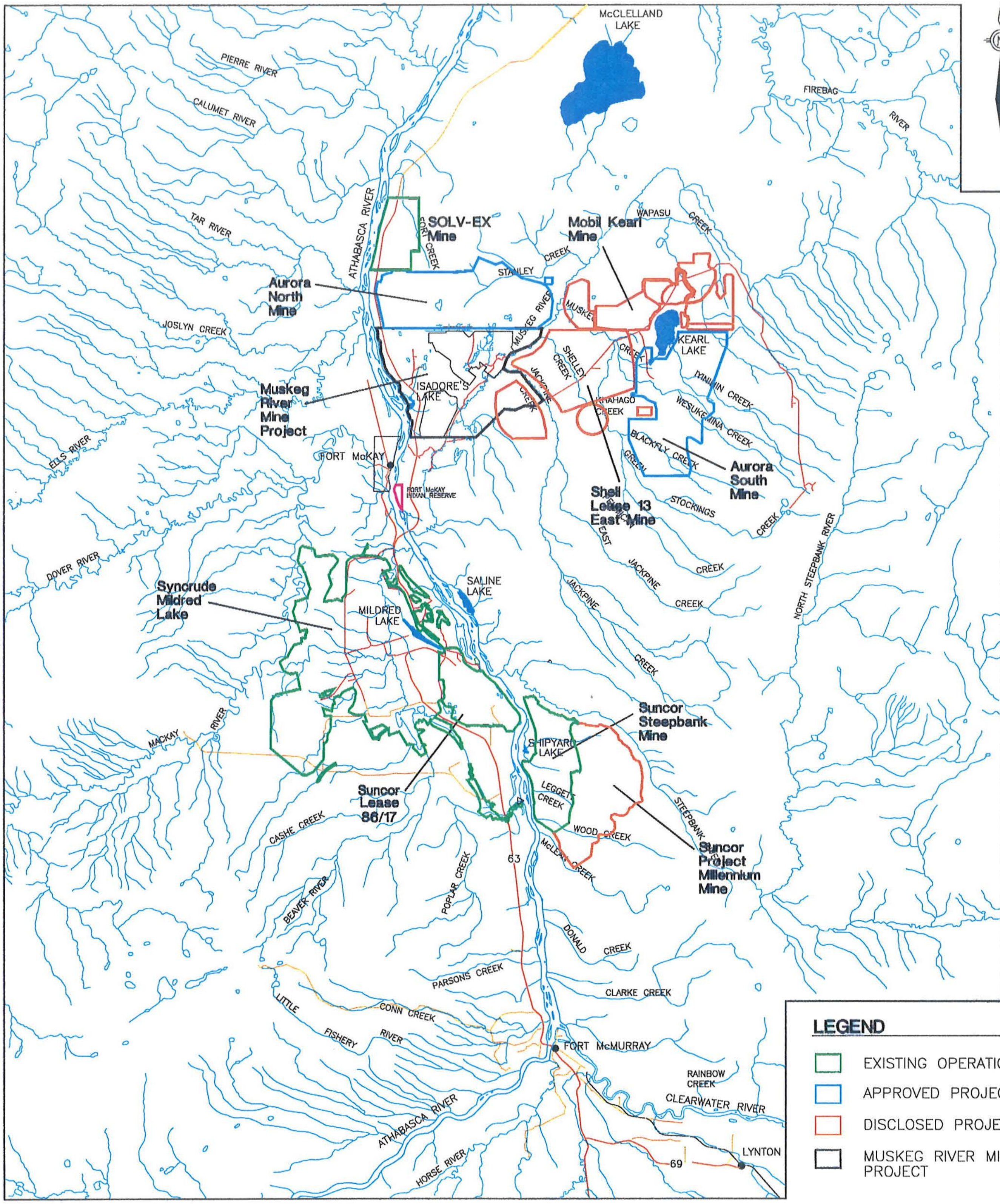


0 5 10 15 20 25km

SCALE 1:500,000

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

SHELL CANADA LIMITED

EXISTING, APPROVED AND DISCLOSED DEVELOPMENTS IN THE RSA

15 JAN 98	Figure G6-1	DRAWN BY: CG

The linkage between changes in areas of lakes and streams and fish habitat is valid for the forage fish Key Indicator Resource (KIR), but not for other KIRs since habitats that these species use are not expected to be affected.

Linkage Between Change in Dissolved Oxygen and Fish Habitat

The potential for a linkage between muskeg and overburden dewatering and changes in dissolved oxygen levels was assessed in the Water Quality CEA (Section F5.8) and is applicable to the RDR. Dewatering activities from the Project plus approved and disclosed Muskeg River basin developments are not expected to result in unacceptable lowering of oxygen levels. However, if monitoring indicated a potential problem then sedimentation ponds could be aerated to mitigate any effects. Hence, the linkage between dissolved oxygen levels and fish habitat is invalid.

Linkage Between Change in Sediment Loading and Fish Habitat

Estimated changes in sediment concentrations in the Muskeg River from combined developments are presented in the Surface Water Hydrology RDR (Section G4.2). The maximum change in sediment concentrations from combined developments is predicted to be less than 2 mg/L. This change in sediment levels is negligible and would not affect fish habitat. Therefore, the linkage between change in sediment loading and fish habitat is invalid.

Linkage Between Change in Flows and Levels of Receiving Streams and Fish Habitat

Change in flows in the Muskeg and Athabasca Rivers were assessed in Section G4.2 and G4.3, respectively (Surface Water Hydrology). Potential linkages between changes in flows and levels and fish habitat are assessed separately for each waterbody.

Athabasca River

Changes in flows in the Athabasca River from existing, approved and disclosed developments were assessed in Section G4. Since there will be measurable changes in Athabasca River flows, this linkage is valid for fish habitat.

Muskeg River

Changes in flows, depths and velocity in the Muskeg River were quantified in the Surface Water Hydrology RDR (Section G4.2) and are summarized in Tables G6-1 to G6-5 for various flow conditions. Since changes in flows were predicted to occur, this linkage is valid for fish habitat and will be analyzed further.

Table G6-1 Mean Open Water Flow Parameters on the Muskeg River at Node S16

'Year	Q (m^3/s)[a]			D (m)			V (m/s)[b]		
	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)
2007	8.21	9.80	19.4	0.63	0.71	12.7	0.73	0.77	5.8
2020	8.21	8.25	0.5	0.63	0.63	0.3	0.73	0.73	0.2
2030	8.21	9.58	16.7	0.63	0.70	11.0	0.73	0.77	5.0
Far Future	8.21	7.96	-3.0	0.63	0.61	-2.0	0.73	0.72	-1.0

(a) The relationship between mean depth of flow and discharge at Muskeg River near Fort McKay is defined by equation - Mean depth = 0.0006 X Discharge ^{2} + 0.0609 X Discharge + 0.1671.
(b) Flow velocity was defined as discharge per unit flow area. Flow area was calculated based on equation - Flow area+ 206695 X Discharge $^{0.6819}$.
(c) Predicted as a result of the oil sands developments in the Muskeg River Basin.

Table G6-2 Mean Ice-Cover Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)[a]			D (m)			V (m/s)[b]		
	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)
2007	1.11	2.11	90.1	0.23	0.29	25.2	0.39	0.48	22.7
2020	1.11	1.26	13.5	0.23	0.24	3.8	0.39	0.40	4.1
2030	1.11	1.49	34.2	0.23	0.26	11.7	0.39	0.43	11.7
Far Future	1.11	1.49	34.2	0.23	0.26	9.6	0.39	0.43	9.8

(a) The relationship between mean depth of flow and discharge at Muskeg River near Fort McKay is defined by equation - Mean depth = 0.0006 X Discharge ^{2} + 0.0609 X Discharge + 0.1671.
(b) Flow velocity was defined as discharge per unit flow area. Flow area was calculated based on equation - Flow area+ 206695 X Discharge $^{0.6819}$.
(c) Predicted as a result of the oil sands developments in the Muskeg River Basin.

Table G6-3 Open-Water 7Q10 Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)[a]			D (m)			V (m/s)[b]		
	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)
2007	0.281	2.197	682	0.18	0.30	61.8	0.25	0.48	92.4
2020	0.281	1.035	268	0.18	0.23	24.6	0.25	0.38	51.4
2030	0.281	2.59	822	0.18	0.32	74.2	0.25	0.51	103
Far Future	0.281	0.738	163	0.18	0.21	15.0	0.25	0.34	36.0

(a) The relationship between mean depth of flow and discharge at Muskeg River near Fort McKay is defined by equation - Mean depth = 0.0006 X Discharge ^{2} + 0.0609 X Discharge + 0.1671.
(b) Flow velocity was defined as discharge per unit flow area. Flow area was calculated based on equation - Flow area+ 206695 X Discharge $^{0.6819}$.
(c) Predicted as a result of the oil sands developments in the Muskeg River Basin.

Table G6-4 Mean 30Q Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)[a]			D (m)			V (m/s)[b]		
	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)
2007	0.225	1.266	463	0.18	0.24	34.6	0.23	0.40	73.2
2020	0.225	0.461	105	0.18	0.20	7.9	0.23	0.29	25.6
2030	0.225	1.151	412	0.18	0.24	30.8	0.23	0.39	68.1
Far Future	0.225	1.036	360	0.18	0.23	27.0	0.23	0.38	62.5

(a) The relationship between mean depth of flow and discharge at Muskeg River near Fort McKay is defined by equation - Mean depth = 0.0006 X Discharge ^{2} + 0.0609 X Discharge + 0.1671.
(b) Flow velocity was defined as discharge per unit flow area. Flow area was calculated based on equation - Flow area+ 206695 X Discharge $^{0.6819}$.
(c) Predicted as a result of the oil sands developments in the Muskeg River Basin.

Table G6-5 Annual 7Q10 Flow Parameters on the Muskeg River at Node S16

Year	Q (m^3/s)[a]			D (m)			V (m/s)[b]		
	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)	Existing	Future[c]	Difference (%)
2007	0.052	1.1	2015	0.17	0.23	37.1	0.15	0.39	164
2020	0.052	0.3	477	0.17	0.19	8.8	0.15	0.26	74.6
2030	0.052	0.643	1137	0.17	0.21	21.0	0.15	0.33	123
Far Future	0.052	0.529	917	0.17	0.20	17.0	0.15	0.31	109

(a) The relationship between mean depth of flow and discharge at Muskeg River near Fort McKay is defined by equation - Mean depth = 0.0006 X Discharge ^{2} + 0.0609 X Discharge + 0.1671.

(b) Flow velocity was defined as discharge per unit flow area. Flow area was calculated based on equation - Flow area+ 206695 X Discharge $^{0.6819}$.

(c) Predicted as a result of the oil sands developments in the Muskeg River Basin.

Linkage Between Changes in Channel Regime and Fish Habitat

No changes in channel regime and morphology due to changes in flows in the Muskeg River are expected due to combined developments (Section G4.2). Therefore, the linkage between channel regime and fish habitat is invalid.

Linkage Between Changes in Thermal Regime and Fish Habitat

The potential for changes in thermal regime in the Muskeg River from combined developments was assessed for 2007, 2030 and Far Future (Water Quality Section G5.7). The largest temperature changes relative to baseline conditions were predicted for 2007, when rates of overburden and muskeg dewatering will be the highest. During this period, a decrease of up to 2.9°C in mean monthly summer temperatures and an increase of about 1°C in mean monthly winter temperatures were predicted to occur (Figure G5-2). In 2030, less pronounced changes were predicted (maximum decline of 2.3°C) to occur in mid-summer and winter. No changes in temperature regime are predicted for the Far Future.

Based on the above information, the linkage between changes in thermal regime and fish habitat is valid.

Linkage Between Changes in Sediment Loading and Benthic Invertebrate Communities

Negligible changes in sediment levels are predicted for the Muskeg River. Therefore, the linkage between change in sediment loading and benthic invertebrate communities is invalid.

Linkage Between Changes in Flows and Benthic Invertebrate Communities

Changes in flows in the Athabasca River and lower Muskeg River were assessed in the Surface Water RDR (Sections G4.2 and G4.3). Changes in flows may affect benthic invertebrate communities if they are of sufficient magnitude to change current velocity beyond the natural range and permanently alter substratum composition.

The predicted reduction in discharge of the Athabasca River in winter is small (about 5.2% of mean winter flows). Because slightly lower flows would not affect benthic invertebrate habitat appreciably, the predicted reduction in flow is not considered significant for benthic invertebrates.

For the RDR, predicted increases in velocity in the Muskeg River are of similar magnitude as predicted for the CEA (Section F6.5). No effects on benthic invertebrates are expected.

Based on the above information this linkage is invalid.

Linkage Between Changes in Water Quality and Benthic Invertebrate Communities

Changes in water quality relevant to benthic invertebrate communities were assessed in the Water Quality RDR (Sections G5.5 and G5.6). Results are similar to those predicted for the CEA. No effects on benthic invertebrates are expected. This linkage is invalid.

Analysis of Key Question

A number of linkages between combined developments and fish habitat were assessed. The following linkages are invalid:

- dissolved oxygen and fish habitat and benthic invertebrates;
- sediment loading and fish habitat and benthic invertebrates;
- flows and benthic invertebrates;
- channel regime and fish habitat in the Athabasca River; and
- water quality and benthic invertebrates.

Hence, the following valid linkages will be assessed in terms of their potential effects on fish habitat:

- flows and fish habitat in the Athabasca and Muskeg rivers; and
- thermal regime and fish habitat in the Muskeg River.

Athabasca River

Flows

The maximum percentage withdrawal from the Athabasca River related to all combined developments is 7.8% of 7Q10 flows, which is slightly higher than the 6.4% decrease predicted for the CEA (Table G4-15). Under more usual conditions in the winter (mean winter flow) the RDR withdrawals are about 5.2% (compared to 4.3% for the CEA). Because differences in predicted flows between the RDR and the CEA are small, the information presented under ARCEA-1 is also applicable to this question (Section F6.5.2). Decreases in Athabasca River flows related to the RDR are unlikely to cause an impact on fish habitat due to the large discharge of the river.

In summary, during the winter months, water withdrawals at low flow are relatively small. This is unlikely to cause impacts on fish habitat. As discussed in Section F6.5.2, during the remainder of the year, the Tessman analysis indicates there is abundant water in the Athabasca River to meet both instream flow needs and the mean annual net withdrawal of water from the river. If more detailed investigations into instream flow needs for fish are required, then this issue should be dealt with on a regional basis.

Muskeg River

Changes in the Muskeg River habitat from combined developments include a maximum decline in summer temperature of about 2.9°C and increased flows. This temperature change has similar effects on habitat for the RDR as for the CEA.

Flow changes related to all combined developments are very similar to changes predicted for the CEA (Tables F6-2 to F6-6 and Tables G6-1 to G6-5). Depth changes are within 1 cm and velocity changes are identical except under open-water 7Q10 flows where the increase is slightly higher (0.01 m/s). Hence, effects on fish habitat would be the same as those predicted for the CEA (Section F6.4).

These physical changes to the Muskeg River are analyzed relative to habitat requirements and suitability for each KIR using the same approach as for the impact assessment (Section E6).

Northern Pike

Temperature

Similar effects on northern pike habitat are predicted for the RDR and the CEA. For the RDR a decrease in temperature from 2.9C in the Musekg River would result in a habitat suitability drop from 0.9 to 0.7.

Flows

Habitat changes related to flows are the same for the RDR as for the CEA (see Section F6.5.2).

Summary of Changes in Northern Pike Habitat

Changes in water temperature may have a low impact on suitability suitability for northern pike. Higher flows during low flow periods may improve access and habitat availability for northern pike.

Arctic Grayling

Temperature

Arctic grayling habitat suitability would not be affected if temperatures in the Muskeg River were to decline by up to 2.9°C. This result is the same as predicted for the CEA.

Flows

Flow-related habitat changes include a slight decline in habitat suitability during mean open-water conditions but no changes during low flow periods (Section F6.5.2).

Summary of Changes in Arctic Grayling Habitat

In summary, changes in temperature would not likely have implications for Arctic grayling habitat. Flow changes may cause a slight decline in suitability during mean open-water flow conditions.

Longnose Sucker

Temperature

Changes in temperature predicted for the RDR are similar to those predicted in the CEA. Declines in water temperature during the summer would improve habitat suitability for longnose sucker from 0.75 to 0.89 habitat suitability.

Flows

No change in suitability during mean flow conditions would be expected. During low flow conditions habitat suitability would be improved.

Summary of Habitat Changes for Longnose Sucker

Physical changes in the Muskeg River from the combined developments would likely improve longnose sucker habitat for temperature and flow parameters.

Forage Fish Guild

Flow and temperature changes in the Muskeg River are unlikely to affect forage fish habitat quality as described in E6.

Habitat Loss From Small Streams, Lakes and Ponds

Changes in areas of lakes and streams in the RSA is presented in Section F4 (Tables F4-22 and F4-23). The total loss of lakes and streams is 852 ha which is 3.1% of the total river, lake and stream area in the RSA. This is an increase of 388 ha over the CEA. Habitat loss would not occur simultaneously as the development of approved and planned new developments will be staggered. Hence, the estimate is conservative. In addition, for both the Aurora and Steepbank Mine the operators are committed to replacing any disturbed habitat with equal or better habitat (BOVAR 1996a, Suncor 1996a). The assumption in this assessment is that all disclosed oil sands projects will also commit to no net loss of the productive capacity of fish habitat in the RSA. Through reclamation about 8,534 ha of waterbodies would be created (30% more than currently exists), mostly in the form of end pit lakes but also as small streams and wetlands as shown in Table G6-6. Hence, there will be a net gain in fish habitat.

Table G6-6 Habitat Losses and Gains from Combined Developments

Time Period	Existing[a]	Approved[b]	Project[c]	Planned[d]	RDR[e]	Comment
Construction and Operation	-30 ha	-407 ha	-27 ha	-388 ha	-852 ha	small tributary streams, shallow wetlands/lakes
Closure	+2,270 ha	+2,724 ha	+670 ha	+2,870 ha	+8,534 ha	end pit lakes, small streams, shallow wetlands/lakes

(a) Existing developments - Syncrude Mildred Lake, Suncor Lease 86/17
(b) Approved - Syncrude Aurora North and South, SOLV-EX
(c) Project - Muskeg River Mine Project
(d) Planned - Mobil Kearl , Shell Lease 13 East, Project Millennium
(e) RDR - Project plus existing, approved and disclosed

Residual Impact Classification and Degree of Concern

Residual impacts are classified in Table G6-7. The predicted effect on forage fish habitat is considered low magnitude based on the loss of forage fish habitat which will be replaced at different times depending on the development. However, all oil sands operators will likely commit to no net loss of fish habitat and will replace disturbed habitat with like habitat of the same productivity.

No impacts on longnose sucker habitat are expected to occur. Classifications for northern pike, and Arctic grayling are rated negligible to low since both slight positive and negative effects may occur. These impacts are rated short to medium term since changes in temperature and flow would occur over a short period (during maximum dewatering in 2007 and again, to a lesser extent in 2030).

Table G6-7 Residual Impact Classification and Degree of Concern for Cumulative Effects on Fish Habitat in Muskeg River

KIRs	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Forage Fish Guild	Negative	Low	Regional	Medium-Term	Reversible	Once	Low
Longnose Sucker	Negative	Negligible	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Negligible
Arctic Grayling	Negative	Negligible to Low	Local	Short to Medium-Term	Reversible	Intermittent	Low
Northern Pike	Negative	Negligible to Low	Local	Short to Medium-Term	Reversible	Intermittent	Low

For the Athabasca River, the results of the analysis indicate that it is unlikely that water withdrawals will affect fish habitat in the winter. Hence, a Negligible impact is expected.

Certainty

Habitat predictions for the Muskeg River are moderately certain as described in Section F6.5.4.

The prediction that changes in flow in the Athabasca River will not effect fish habitat is moderate in certainty. Radiotelemetry studies of KIR species should give information on the extent of use of the Athabasca River for over wintering. If additional investigations into in-stream flow needs are deemed necessary, then this issue should be dealt with on a regional basis.

G6.3.2 Key Question ARRDR-2: Will Operational and Reclamation Water Releases From Combined Developments Result in Acute or Chronic Effects on Fish?

The information presented in E6. also applicable to this key question (see Section F6.6). Regional developments are not expected to result in acute or chronic effects on fish.

G6.3.3 Key Question ARRDR-3: Will Operational and Reclamation Water Releases From Combined Developments Result in Changes to Fish Tissue Quality?

As discussed in Section F6.7, tainting and bioaccumulation of chemicals in fish tissue are not expected as a result of the Project, existing and approved developments. Disclosed developments are not expected to result in tainting or bioaccumulation of chemicals in fish since water releases are similar in nature to existing and approved developments.

G6.3.4 Key Question ARRDR-4: Will Operational and Reclamation Water Releases From Combined Developments Result in Changes in Fish Abundance?

The information presented under key question ARCEA-4 (Section F6.8) is relevant to this key question. No impacts on fish abundance are expected as a result of combined developments. This prediction is moderately certain. Sources of uncertainty are outlined in Sections F6.5.4 and F6.8.4.

G6.4 Summary of Impacts

Table G6-8 summarizes the impacts on Aquatic Resources under the RDR.

Table G6-8 Summary of Impacts on Aquatic Resources

Key Question	RDR Results
ARRDR-1: Will activities from the combined developments change fish habitat?	• Predicted changes in Arctic grayling and northern pike are the same as for the CEA. Increases in flows in the Muskeg River are expected to have slight (< 0.1 habitat suitability) impacts on Arctic grayling habitat and result in slight improvments in northern pike habitat. Declines in temperature during summer are predicted to have low impacts (from 0.9 to 0.7 HSI) on northern pike habitat. No impacts on northern pike of Arctic grayling habitat were predicted as a result of the Project. • RDR impacts on Arctic grayling and northern pike habitat are rated as Negative in direction, Negligible to Low in magnitude, Local in extent, Short to Medium-Term in duration, Reversible, and Intermittent in frequency. The degree of concern is **Low**. These predictions are conservative: temperature and flow changes are unlikely to be as much as predicted. In the Far Future no impacts on Arctic grayling or northern pike habitat are predicted. • No negative effects are predicted for longnose sucker habitat. The degree of concern is **Negligible**. • For the RDR, loss of forage fish habitat (3.1%) is predicted in the

Key Question	RDR Results
	RSA. This loss elevated over the CEA where the loss is about 1.7%. The Project contributes less than 0.1% of this impact. The impact on forage fish habitat is Negative in direction, Low in magnitude, Regional in extent, Medium-Term in duration, Reversible, and Once in frequency. The degree of concern is **Low**. At each stage in the developments, habitat disturbed will be replaced with habitat of equivalent or better productivity. Forage fish habitat replaced through reclamation will result in a net gain (30% more that currently exists) in habitat for both forage fish and sport fish in the Far Future.
ARRDR-2: Will operational and reclamation water releases from combined developments result in acute or chronic effects on fish?	• No acute or chronic effects on fish as a result of changes in temperature, dissolved oxygen, sediment or water quality were predicted. The degree of concern is **Negligible**.
ARRDR-3: Will operational and reclamation water releases from combined developments result in changes to fish tissue quality?	• No tainting or accumulation of chemicals in fish are predicted. The degree of concern is **Negligible**.
ARRDR-4: Will operational and reclamation water releases from combined developments result in changes in fish abundance?	• No changes in fish abundance are expected as a result of acute and chronic effects, change in access or habitat. The degree of concern is **Negligible**.

G7 ECOLOGICAL LAND CLASSIFICATION REGIONAL DEVELOPMENT REVIEW

G7.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and publicly disclosed developments on ecological land units in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Petro-Canada MacKay River
- JACOS Hangingstone
- Pipelines, utility corridors and roadways
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Suncor Project Millennium
- Syncrude Upgrader
- Mobil Kearl Mine and Upgrader
- Gulf Surmont
- Municipalities

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

G7.2 Potential Linkages and Key Question

Figures E7-1 and E7-2 show the linkage diagram for Project activities and potential changes in the ecological land classification (ELC) component. The same linkages and key question, as reviewed in Section F7, apply to the RDR.

ELCRDR-1: Will Activities of Combined Developments Result in a Loss or Alteration of ELC Units and Diversity?

G7.3 Analysis and Results

G7.3.1 Key Question ELCRDR-1: Will Activities of Combined Developments Result in a Loss or Alteration of ELC Units and Diversity?

Linkage Between Site Clearing and Loss of ELC

The baseline disturbance for the RDR is 34,541 ha or 3.3% of the RSA. Combined regional developments, including the Project, will result in a clearing of 70,831 or 6.7% (Table G7-1) of the RSA. For oil sands developments, site clearing involves the direct removal of landforms, and associated soils and vegetation communities.

Table G7-1 Combined Developments Considered for RDR Within the RSA

Baseline/Existing	Area (ha)	Percent (%)
Suncor Lease 86/17	3,369	0.3
Syncrude Mildred Lake	23,244	2.2
Suncor Steepbank (to end of 97)	150	<0.1
Gibsons Petroleum	22	<0.1
SOLV-EX	2,088	0.2
municipalities	4,002	0.4
pipelines/roadways/others	1,666	0.2
Sub-total	**34,541**	**3.3**
Muskeg River Mine Project	**4,343**	**0.4**
Approved Projects		
Syncrude Aurora North and South	15,171	1.4
Suncor Steepbank (mining and production)	3,084	0.3
Sub-total	**18,255**	**1.7**
Total Developed Area	**52,796**	**5.0**
Disclosed Projects		
Suncor Project Millennium	5,437	0.5
Shell Lease 13 East	7,215	0.7
Syncrude Upgrader	n/a	0.0
Mobile Kearl Mine	5,350	0.5
Petro-Canada MacKay River	33	<0.1
JACOS	n/a	0.0
Gulf Surmont	n/a	0.0
Sub Total	**18,035**	**1.7**
Total Developed Area	**70,831**	**6.7**
Regional Study Area	**1,051,411**	**100.0**

Impact Analysis

The analysis of potential linkages indicates that the valid linkages necessary for determining cumulative losses or alteration of ELC types at the macroterrain level are site clearing during industry development. For oil sands developments, site clearing involves the direct removal of landforms, and associated soils and vegetation communities. Forestry disturbances will not affect macroterrain units but has been included in the RDR of vegetation (G9) and wetlands (G10).

There are 10 macroterrain units in the RSA. A detailed description of each macroterrain type is found in the Baseline Ecological Land Classification Document (Golder 1997l). Figure F7-1 shows baseline regional macroterrain units while Figure F7-2 shows the macroterrain units with combined developments.

The baseline disturbance to macroterrain units is 34,541 ha, which includes existing reclaimed units totalling 3,600 ha. The remaining

30,941 is disturbed (Table G7-2). Combined developments, including disclosed developments, will affect four macroterrain units within the RSA, namely, Athabasca Clearwater River Valley, Dover Lacustrine Plains, McClelland Lake Glaciofluvial Plain, and Steepbank Organo-Lacustrine Plain. Combined developments will affect 2,818 ha (0.3%) of the Athabasca Clearwater River Valley macroterrain unit within the RSA (Table G7-2). The Project will remove 472 ha. The Dover Lacustrine Plains will be reduced by 33 ha as a result of approved and planned development. The Project will not affect this unit. The McClelland Lake Glaciofluvial Plain macroterrain unit will be affected to the extent of 4,894 ha or 0.5% of the RSA. This represents a loss of 6.5 % of the total unit. The Project will alter 412 ha, while approved and planned developments will collectively affect 4,482 ha. The Steepbank Organo-Lacustrine Plain is the most affected macroterrain unit from developments in the RSA. The total loss of this unit is 32,888 ha or 3.1% of the RSA. The Project will affect 3,459 ha. The total loss to macroterrain units in the RSA including baseline is 73,849 or 7.0% of the RSA. Impacts totalling 5,668 ha result from municipalities, roadways and other. These are not expected to be reclaimed after development closure. All developments are not expected to occur simultaneously, therefore, this impact analysis represents the worst case scenario. In addition, phased reclamation for each development will minimize the regional impacts.

Biodiversity

No macroterrain units will be completely removed by the combined developments. Therefore, the overall biodiversity at the macroterrain level will not be significantly altered by developments in the RSA. Moreover, within macroterrain units, the vegetation diversity, as discussed in G9, does not change substantially because of the reclamation activities planned for the combined developments.

Residual Impact Classification and Degree of Concern

Table G7-3 details the residual impact classification and degree of concern for macroterrain units. Macroterrain units will be reclaimed by each development, however a residual impact of 5,668 ha is expected. This impact represents municipalities, roadways and other development that will persist into far future. In summary, the direction is Negative, the magnitude is Low, Regional in geographic extent and the degree of concern is Low.

Table G7-2 Direct Losses/Alteration of Existing Macroterrain Within the RSA

			Muskeg River Mine				RDR[c]						CEA		RDR	
	Baseline RSA[a]		Change[b]		Far Future		Change[b]		Far Future		Final Landscape		Changes from Baseline		Changes From Baseline	
	Total (ha)	%RSA	Total (ha)	%RSA	Total (ha)	%RSA	Total (ha)	%RSA	Total (ha)	%RSA	Total (ha)	%RSA	Total (ha)	%RSA	Total (ha)	%RSA
Athabasca	144,788	13.8	472	<0.1	0	0.0	2,818	0.3	0	0.0	141,498	13.5	-2,446	-0.2	-2,818	-0.3
Birch Hills	15,350	1.5	0	0.0	0	0.0	0	0.0	0	0.0	15,350	1.5	0	0.0	0	0.0
Dover Lacustrine Plains	228,999	21.8	0	0.0	0	0.0	33	<0.1	0	0.0	228,966	21.8	0	0.0	-33	<0.1
High Hill Glaciofluvial Plain	33,163	3.2	0	0.0	0	0.0	0	0.0	0	0.0	33,163	3.2	0	0.0	0	0.0
MacKay Organo-Moranial Complex	102,157	9.7	0	0.0	0	0.0	0	0.0	0	0.0	102,157	9.7	0	0.0	0	0.0
McClelland Lake Glaciofluvial Plain	71,941	6.8	412	<0.1	0	0.0	4,894	0.5	0	0.0	67,047	6.4	-4,722	-0.4	-4,894	-0.5
McClelland Lake Patterned Fen	10,172	1.0	0	0.0	0	0.0	0	0.0	0	0.0	10,172	1.0	0	0.0	0	0.0
Schultz's Bog Diversity Area	42,997	4.1	0	0.0	0	0.0	0	0.0	0	0.0	42,997	4.1	0	0.0	0	0.0
Steepbank Organo-Lacustrine Plain	275,427	26.2	3,459	0.3	0	0.0	32,888	3.1	0	0.0	242,539	23.1	-15,430	-1.5	-32,888	-3.1
Thickwood Plain	91,876	8.7	0	0.0	0	0.0	0	0.0	0	0.0	91,876	8.7	0	0.0	0	0.0
Existing Developments																
Reclamation Units[e]	3,600	0.3	0	0.0	4,343	0.4	0	0.0	40,213	3.8	69,085	6.6	47,451	4.6	65,485	6.2
Disturbed[d]	30,941	2.9	0	0.0	0	0.0	0	0.0	0	0.0	5,668	0.5	-25,273	-2.4	-25,273	-2.4
Infrastructure									420	<0.1	420	<0.1			420	<0.1
Grand Total	**1,051,411**	**100**	**4,343**	**0.4**	**4,343**	**0.4**	**40,633**	**3.9**	**40,633**	**3.9**	**1,051,411**	**100.0**	**0**	**0.0**	**0**	**0.0**

(a) Undeveloped macroterrain units plus existing developed area.
(b) Incremental changes to undeveloped macroterrain units.
(c) Cumulative effect of Project, approved and planned development in baseline conditions.
(d) Areas under development (does not include forestry as forestry does not impact macroterrain.
(e) Newly created macroterrain units (revegetated tailings sand, overburden storage areas, etc.).

Table G7-3 Residual Impact Summary for Macroterrain Units

Macroterrain Types	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Athabasca-Clearwater River Valley	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
Dover Lacustrine Plains	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
McClelland Lake Glaciofluvial Plain	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
Steepbank Organo-Lacustrine Plain	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
Thickwood Plain	Negative	Low	Regional	Long-Term	Irreversible	Low	Low

G7.4 Summary of Impact

Table G7-4 summarizes the impact of the RDR on Ecological Land Classification.

Table G7-4 Summary of Impacts on ELC

Key Question	RDR Results
ELCRDR-1: Will activities from the combined developments result in a loss or alteration of ELC units and Diversity?	• The combined developments will remove 73,849 ha or 3.9% of macroterrain units in the RSA. The Project will contribute less than 0.4% to this reduction. The total number of macroterrain units will not decrease and therefore, the diversity will not change. • The RDR impact on ELCs is Negative in direction, Low in magnitude, Regional in geographic extent, Short-term in duration, and the degree of concern is **Low.**

G8 TERRAIN AND SOILS REGIONAL DEVELOPMENT REVIEW

G8.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and publicly disclosed developments on terrain and soils in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1 are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Petro-Canada MacKay River
- JACOS Hangingstone
- Forestry
- Pipelines, utility corridors and roadways
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Suncor Project Millennium
- Syncrude Upgrader
- Mobil Kearl Mine and Upgrader
- Gulf Surmont
- Municipalities

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

The terrain and soil predictions presented in this section are used to assess impacts on vegetation (Section G9) and ecological land classifications (Section G7).

G8.2 Potential Linkages and Key Questions

Figures E8-1 and E8-2 (Section E8) show the linkage diagrams for Project activities and potential changes in terrain and soils associated with the Project. Generally the same linkages and key questions apply to the RDR.

TSRDR-1: Will Regional Developments Alter the Quantity and Distribution of Terrain and Soil Units?

TSRDR-2: Will Regional Developments Alter Soil Capability and Sensitivity?

G8.3 Analysis and Results

Table G7-1 outlines in detail the Projects considered in this RDR, the following points of clarification must be made to place the analyses in context:

- as discussed in Section F8, it was assumed that Forestry would have no impact on terrain and soils; therefore it was not considered in the analysis;

- the Syncrude Upgrader is to be located within the Mildred Lake footprint and so does not require addition area, it is incorporated here because it will increase the level of potentially acidifying emissions within the RSA; and

- the same reasoning holds for the Mobil Upgrader at the Kearl Mine while JACOS Hangingstone and Gulf Surmont fall ouside the spatial boundaries of the RSA, their emission plumes may impact soil within the RSA.

G8.3.1 Key Question TSRDR-1: Will Regional Development Alter the Quantity and Distribution of Terrain and Soil Units?

Analysis of terrain and soil units at the RSA level was conducted as described in Section F8.3.1, but expanded to cover the RDR scenario.

Analysis of the Key Question

The impacts associated with the RDR scenario for the RSA are shown in Tables G8-1 and G8-2 for terrain and soil units, respectively. Naturally occurring terrain and soil features will be removed during development construction but phased reclamation over the productive life spans of the various developments will produce a closure landscape wherein these have been replaced with reclamation substitutes. Examination of the data indicate that (1.7% of the RSA) over and above that discussed in Section F8 will be affected by the developments considered in the RDR scenario. The majority of this area, approximately 11,700 ha, are bog and shallow bog terrain units (primarily Kenzie soils) which will be converted to either reclaimed terrestrial or wetland areas in the closure landscape. At closure approximately 76% of the disturbed areas will be reclaimed for regrowth of terrestrial vegetation while the remaining 24% will be either reclaimed wetlands or open water areas.

Residual Impacts and Degrees of Concern

As discussed in Section F8, the areas disturbed by development will be reclaimed as similar but not identical landscapes. Evaluated in a strictly objective sense, this would be seen as a loss of soil and terrain when in fact it is more accurately a change in the types and distribution of the units.

Table G8-1 Terrain Units of the Muskeg River Mine Project, RDR Scenario

Terrain	Baseline RSA[a]		Muskeg River Mine Project Impact[b]		Muskeg River Mine Project Far Future		RDR[c] Impact[b]		RDR[c] Far Future		Changes From Baseline Final Landscape		Changes From Baseline CEA		Changes From Baseline RDR	
	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%
Bog	219,383	21.3	2,350	0.2	0	0.0	6,386	0.6	0	0.0	212,997	20.3	-4,393	-0.4	-6,386	-0.6
Shallow Bog	260,660	21.5	511	0.0	0	0.0	15,523	1.5	0	0.0	245,137	23.3	-5,794	-0.6	-15,523	-1.5
Eolian	36,225	3.5	761	0.1	0	0.0	761	0.1	0	0.0	35,454	3.4	-761	-0.1	-761	-0.1
Fluvial	51,314	4.9	1	0.0	0	0.0	287	0.0	0	0.0	51,027	4.9	-206	0.0	-287	0.0
Glaciofluvial	137,524	13.3	404	0.0	0	0.0	7,532	0.7	0	0.0	129,993	12.4	-4,166	-0.4	-7,532	-0.7
Glaciofluvial and Glaciolacustrine, medium, over Morainal Till	23,965	2.5	0	0.0	0	0.0	136	0.0	0	0.0	23,829	2.3	-136	0.0	-136	0.0
Glaciolacustrine over Morainal/Till	143,511	14.5	5	0.0	0	0.0	6,776	.6	0	0.0	136,737	13.0	-5,550	-0.5	-6,774	-0.6
Glaciolacustrine	728	0.1	0	0.0	0	0.0	0	0.0	0	0.0	728	0.1	0	0.0	0	0.0
Morainal/Till, fine	13,228	1.3	0	0.0	0	0.0	0	0.0	0	0.0	13,228	1.3	0	0.0	0	0.0
Morainal/Till, coarse	36,265	3.5	0	0.0	0	0.0	1,125	0.1	0	0.0	35,139	3.3	-106	0.0	-1,125	-0.1
Fen	37,807	3.6	300	0.0	0	0.0	1,350	0.1	0	0.0	36,457	3.5	-740	-0.1	-1,350	-0.1`
Rough Broken	51,826	5.0	11	0.0	0	0.0	757	0.1	0	0.0	51,069	4.9	-745	-0.1	-757	-0.1
Infrastructure	0	0.0	0	0.0	0	0.0		0.0	420	0.0	420	<0.1	420	<0.1	420	0.0
Reclaimed Terrestrial	3,600	0.3	0	0.0	3,363	0.3	0	0.0	33,163	3.2	53,360	5.1	35,788	3.4	49,760	4.7
Reclaimed Wetland and open water		0.0	0	0.0	980	0.1	0	0.0	7,050	.7	15,725	1.5	11.663	1.1	15,725	1.5
AIM [a]	30,941	0.8	0	0.0	0	0.0	0	0.0	0	0.0	5,668	0.5	-25,273	-2.4	-25,273	-2.4
NWL [b]	4,434	0.4	0	0.0	0	0.0	0	0.0	0	0.0	4,434	0.4	0	0.0	0	0.0
TOTAL	1,051,411	100.0	4,343	0.4	4,343	0.4	40,632	3.9	40,633	3.9	1,051,411	100.0	0	0.0	0	0.0

(a) AIM - Undeveloped, developed and reclaimed areas.
(b) NWL - Incremental changes.
(c) Total impacts from Project, approved projects and planned does not include forestry as operations do not impact terrain.

Table G8-2 Soils of the Muskeg River Mine Project, RDR Scenario

	Baseline RSA[e]		Muskeg River Mine Project				RDR[g]				Changes From Baseline[f]					
			Impact[f]		Far Future		Impact[f]		Far Future		Final Landscape		CEA		RDR	
Soils Series/Map Unit	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%	Total (ha)	%
Algar	24,279	2.3	0	0	0	0	14	0	0	0	24,265	2.3	0	0.0	-14	<0.1
Bitumount	3,419	0.3	0	0	0	0	468	<0.1	0	0	2,951	0.3	-388	<0.1	-468	<0.1
Dover	38,698	3.7	5	<0.1	0	0	3,271	0.3	0	0	35,427	3.4	-2,353	-0.2	-3,271	-0.3
Eaglesham (Mc)[a]	37,808	3.6	300	<0.1	0	0	1,350	0.1	0	0	36,458	3.5	-740	-0.1	-1,350	-0.1
Firebag	31,778	3.0	0	0	0	0	3,101	0.3	0	0	28,677	2.7	-692	-0.1	-3,101	-0.3
Horse River	13,004	1.2	0	0	0	0	0	0	0	0	13,004	1.2	0	0.0	0	0.0
Heart	36,227	3.4	761	0.1	0	0	761	0.1	0	0	35,466	3.4	-761	-0.1	-761	-0.1
Joslyn	67,245	6.4	0	0	0	0	19	0	0	0	67,226	6.4	0	0.0	-19	<0.1
Kearl	728	0.1	0	0	0	0	0	0	0	0	728	0.1	0	0.0	0	0.0
Kinosis	36,265	3.4	0	0	0	0	1,125	<0.1	0	0	35,140	3.3	-106	<0.1	-1,125	-0.1
Kenzie	471,337	44.8	2,861	0.3	0	0	21,597	2.1	0	0	449,740	42.8	-9,875	-0.9	-21,597	-2.1
Livock (Fort)[b]	23,964	2.3	0	0	0	0	136	<0.1	0	0	23,828	2.3	-136	<0.1	-136	<0.1
Mildred	83,475	7.9	404	<0.1	0	0	3,135	0.3	0	0	80,340	7.6	-2,606	-0.2	-3,135	-0.3
Mikkwa	8,848	0.8	0	0	0	0	413	<0.1	0	0	8,435	0.8	-413	<0.1	-413	<0.1
McMurray	33,408	3.2	1	0	0	0	287	<0.1	0	0	33,121	3.2	-206	<0.1	-287	<0.1
Namur	17,906	1.7	0	0	0	0	0	0	0	0	17,906	1.7	0	0.0	0	0.0
Rough Broken	51,734	4.9	11	<0.1	0	0	758	0.1	0	0	50,976	4.8	-746	-0.1	-758	-0.1
Ruth Lake	18,715	1.8	0	0	0	0	729	<0.1	0	0	17,986	1.7	-431	<0.1	-729	-0.1
Surmont	224	0.0	0	0	0	0	273	0	0	0	-49	0.0	0	0.0	-273	<0.1
Steepbank	13,374	1.3	0	0	0	0	3,196	0.3	0	0	10,179	1.0	-3,195	-0.3	-3,195	-0.3
Reclaimed Soils Terrestrial	3,600	0.3	0	0	3,363	0.3	0	0	33,163	3.2	53,360	5.1	35,788	3.4	49,760	4.7
Reclaimed Wetlands and Open-water	0	0.0	0	0	980	0.1	0	0	7,050	0.7	15,725	1.5	11,663	1.1	15,725	1.5
Total, Soil Units	**1,016,036**	**96.6**	**4,343**	**0.4**	**0**	**0.4**	**40,633.0**	**3.9**	**40,213**	**3.9**	**1,040,889**	**99.0**	**24,853**	**2.4**	**24,853**	**2.4**
AIM[c]	30,941	2.9	0	0	0	0	0	0	0	0	5,668	0.5	-25,273	-2.4	-25,273	-2.4
NWL[d]	4,434	0.4	0	0	0	0	0	0	0	0	4,434	0.4	0	0.0	0	0.0
Infrastructure	0	0.0	0	0	0	0	0	0	0	0.0	420	0.0	420		420	0.0
Total, Non-soil	**35,375**	**3.4**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**10,522**	**1.0**	**-24,853**	**0-2.4**	**24,853**	**-2.4**
Total	**1,016,036**	**100.0**	**4,343**	**0.4**	**4,343**	**0.4**	**40,633.0**	**3.9**	**40,633**	**3.9**	**1,051,411**	**100.0**	**0**	**0**	**0**	**0.0**

(a) Undeveloped, developed and reclaimed areas.
(b) Incremental changes.
(c) Cumulative impacts from project and approved projects (does not include forestry as operations do not alter soil).
(d) McLelland in the LSA.
(e) Undeveloped, developed and reclaimed areas.
(f) Incremental increase.
(g) Total impacts from Project, Approved Projects and disclosed developments does not include forestry as operations do not impact soils.

Residual impacts and degrees of concern for terrain and soils are identical so may be treated together for purposes of analysis as shown in Table G8-3.

Table G8-3 Residual Impacts and Degrees of Concern for Terrain and Soils of the RSA, RDR Scenario

	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Level of Certainty	Degree of Concern
Natural Units	Negative	Low	Regional	Long-term	Irreversible	Low	High	Moderate
Reclaimed Units	Positive	Low	Regional	Long-term	Irreversible	Low	High	Moderate

At closure, the residual impacts would be off-setting in a quantitative sense hence the final impact and degree of concern would be Negligible. Qualitative changes associated with these alterations are assessed for key question TSRDR-2.

G8.3.2 Key Question TSRDR-2: Will Regional Development Alter Soil Capability and Sensitivity?

This facet of the RDR addresses two discrete parameters - soil capability, defined as the potential to support forest ecosystems, and soil sensitivity, defined as the susceptibility of a soil to acidifying inputs.

Soil Capability

Soil capability for the RSA was evaluated in the same manner as for the LSA, a detailed description of this method may be found in Section E8 of this EIA.

Analysis of the Key Question

The baseline distribution of soil capabilities for forest ecosystems is shown in Table F8-6 and Figure F8-5. Table G8-4 shows the changes in capability class areas in the RSA for purposes of the RDR. As shown in Table G8-4 there is a significant change in the proportions of the various capability classes between the baseline and RDR closure landscapes. The major difference is the conversion of approximately 32,500 ha (3.1% of the RSA) from either existing disturbed or non-produtive class classes 4 and 5 lands to a low productivity class 3 rating. Of this change, approximately 13,000 ha (1.3% of the RSA) is the result of developments considered in the RDR scenario over and above those assessed in Section F8. This enahncement in overall productivity is the result of the reclamation soil mixture applied over the reconfigured terrain units in the closure landscape.

Table G8-4 Soil Capabilities for Forest Ecosystems in the RSA, RDR Scenario

CLASS	Baseline RSA[a]		Muskeg River Mine				RDR[c]				Changes From Baseline[b]			
			Change[b]		Far Future		Far Future		Final Landscape		CEA		RDR	
	Total (ha)	% RSA	Total (ha)	% RSA	Total (ha)	% RSA	Total (ha)	% RSA	Total (ha)	% RSA	Total (ha)	% RSA	Total (ha)	% RSA
1	0	0.0	0	0.0	0	0.0	50	0.0	150	0.0	150	0.0	150	0.0
2	145,337	13.8	7	0.0	0	0.0	3,701	0.4	150,691	14.3	7,772	0.7	5,354	0.5
3	88,548	8.4	0	0.0	3,363	0.1	22,683	2.2	121,066	11.5	19,362	1.8	32,518	3.1
4	210,560	20.0	1,175	0.1	0	1.1	3,741	0.4	208,924	19.9	2,042	0.2	-1,636	-0.2
5	567,991	54.0	3,161	0.3	444	2.2	4,793	0.5	553,638	52.7	-3,847	-0.4	-14,353	-1.4
Disturbed land+AIM	30,941	2.9	0	0.0	0	0.0	0	0.0	5,668	0.5	-25,273	-2.4	-25,273	-2.4
All water+NWL	4,434	0.4	0	0.0	536	0.0	5,245	0.5	9,679	0.9	3,024	0.3	5,245	0.5
Infrastructure	0	0.0	0	0.0	0	0.0	420	0.0	420	0.0	420	0.0	420	0.0
Existing Reclamation [d]	3,600	0.3	0	0.0	0	0.0	0	0.0	0	0.0	-3,600	-0.3	-3,600	-0.3
TOTAL	**1,051,411**	**100.0**	**4,343**	**0.4**	**4,343**	**3.9**	**40,633**	**3.9**	**1,051,411**	**100.0**	**0**	**0.0**	**-1,175**	**-0.1**

(a) Undeveloped plus revegetated land (not classified).
(b) Incremental change.
(c) Effects of projects approved and planned developments on baseline conditions, excludes forestry which does not affect soil capability.
(d) Newly reclaimed areas, capability ratings not assigned.

Residual Impacts and Degrees of Concern

Land capability for forest ecosystems is a function of the combined interactions of terrain and soil, hence alterations in these components will alter the capabilities. Evaluation of the data in Table G8-4 allows the assignment of the residual impacts and degrees of concern displayed in Table G8-5. At closure, the impacts of both the Project and the CEA scenario will be an overall enhancement of forest capabilities in the RSA. Existing disturbed soils and those in currently non-productive classes 4 and 5 will be reclaimed to low productivity class 3 and moderately productive class 2 lands. This should be interpreted as a significantly positive, qualitative alteration to forest capabilitiy in the RSA.

Table G8-5 Residual Impacts and Degrees of Concern for Forest Capabilities Due to Regional Development.

Capability Class	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Level of Certainty	Degree of Concern
1	Negligible	Low	Regional	Long-Term	Irreversible	Low	High	Negligible
2	Positive	Low	Regional	Long-Term	Irreversible	Low	High	
3	Positive	Low	Regional	Long-Term	Irreversible	Low	High	
4	Positive	Low	Regional	Long-Term	Irreversible	Low	High	
5	Negative	Low	Regional	Long-Term	Irreversible	Low	High	Moderate
Disturbed	Negative	Low	Regional	Long-Term	Irreversible	Low	High	Moderate

Soil Sensitivity

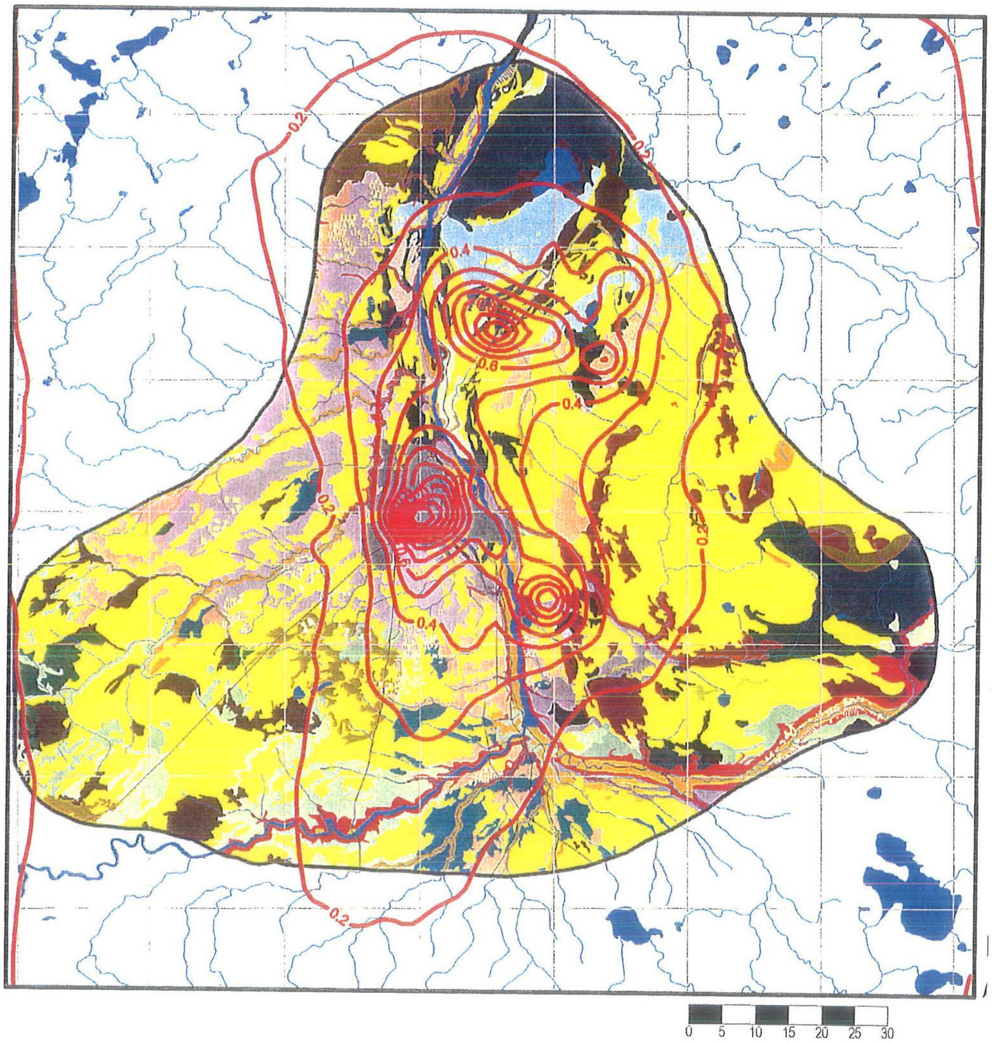
The second parameter, soil sensitivity, is evaluated in the context of the capacity of the soils in the RSA to resist the acidifying effects of anthropogenic inputs, i.e., emissions from industrial sources. Section F8 describes in detail the background issues and method of analysis used in evaluating this variable. The baseline emission scenarios is shown in Figure G8-1.

Analysis of the Key Question

Analysis for the RDR scenario is the same as outlined in Section F8.

Residual Impacts and Degrees of Concern

As outlined in Section F8, it is difficult to quantify either the residual impacts or degrees of concern with a high degree of certainty due to the precarious nature of the emission-acidification relationship. None the less it is possible to provide data which will permit a semiquantitative judgement of the impact potentials. Following Section G2, it is estimated that planned development emissions will increase the area within which the 0.25 keq/ha/a loading factor is exceeded from 250,000 ha to 420,000 ha as shown in Table G8-6. Based on these data the residual impacts and degrees of concern are evaluated in Table G8-7.



5 0 5 10 15 20 25

Kilometres

SOURCE: Golder Associates Ltd., Leskiw (1996), Petro-Canada, RADARSAT International, Soils Department (Alberta Research Council, AOSERP Report 122), Suncor, Syncrude, Norwest

MAP PROJECTION: UTM
Zone 12
NAD 83 (GRS 1980)

LEGEND

- PAI Isopleths
- Regional Study Boundary
- Linear Disturbances
- Hydrology
- Forestry
- Existing Open Pit Mines
- Other Oil Sands Disturbances
- Municipalities

SOIL CLASSIFICATION

- Algar
- Bitumount
- Disturbed Lands & Cultural
- Dover
- Eaglesham (McLelland)
- Firebag
- Horse River
- Heart
- Joslyn
- Kearl
- Kinosis
- Kenzie
- Livock (Fort)
- Mildred
- Mikkwa
- McMurray
- Namur
- Rough Broken
- Ruth Lake
- Surmont
- Steepbank

Golder Associates

SHELL CANADA LIMITED

RSA BASELINE SOIL CLASSIFICATION WITH ANNUAL POTENTIAL ACID INPUT (PAI) - RDR

16 Jan. 1998	Figure G8-1	PRODUCED BY: J.Shaw REVIEWED BY:

Table G8-6 Potential Acidifying Inputs for the RSA, RDR Scenario

PAI Criteria	Baseline ha/%RSA	Baseline + Project ha/% RSA	Baseline + Project + Approved ha/% RSA	RDR Scenario ha/RSA
> 0.25 keq/ha/a	150,000/14.3	180,000/17.1	250,000/23.8	42,000/40.0
>0.50 keq/ha/a	15,500/1.5	19,000/1.8	31,500/3.0	9,800/9.3

Table G8-7 Residual Impacts and Degrees of Concern Associated With Potential Soil Acidification in the RSA, RDR Scenario

Impact	Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Level of Certainty	Degree of Concern
Soil Acidification Potential	Negative	Low	Regional	Project Life	Irreversible	Continuous	Low	Moderate

It is estimated that the degree of concern associated with potential soil acidification resulting from Planned Developments be rated as High but emphasis must be placed on the Low level of certainty in the analysis.

G8.4 Summary of Impacts

Table G8-8 summarizes the residual impacts for Terrain and Soil under the RDR.

Table G8-8 Summary of Residual Impacts

Key Question	RDR Results
TSRDR 1: Will combined development alter the quantity and distribution of terrain and soil units?	• During the construction and operation phases of the combined developments will cause a loss of 3.9% of the natural terrain and soil units in the RSA, the impacts associated with this are estimated to be: Negative in direction, Low in magnitude, Regional in extent, of Long-term duration, Irreversible, Low in Frequency with a High level of certainty. This will generate a **Moderate** degree of concern. • This is a worst case perspective as it is unlikely that all sites will be developed to their maximum extent concurrently. The phased nature of development and reclamation will mediate the degree of concern. • Reclamation of the developed areas and existing disturbed areas with reconfigured terrain units covered by a reclamation soil mixture will produce very Positive impacts by increasing the diversity of terrain units.

Key Question	RDR Results
TSRDR 2: Will combined development alter soil capability and sensitivity?	• As a result of alterations in the quantity and distribution of soil and terrain units between the pre-development and closure landscapes, changes in soil capability will be produced. These are estimated to be: Positive in direction, Low in magnitude, Regional in extent, of Long-term duration, Irreversible low in frequency, of a high level of certainty and generate a **Moderate** degree of concern. The Positive direction of change is the result of significant areas of non-productive class 4 and 5 land being reclaimed to low and moderately productive classes 2 and 3. • Operational activities of the developments will increase the levels of potentially acidifying emissions released into the RSA air shed. The impacts are estimated to be: Negative in Direction, Moderate in magnitude, Regional in extent, lasting for the specific project life spans, Irreversible, Continuing in frequency (for the duration of production) with a **Moderate** to **High** degree of concern. Associated with this is a low level of certainty as the PAI-soil acidification linkage is ill-defined.

G9 TERRESTRIAL VEGETATION REGIONAL DEVELOPMENT REVIEW

G9.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (the Project) plus existing, approved and publicly disclosed (planned) developments on terrestrial vegetation in the RSA. The following developments, as shown in Figure G1-1, are included in the RDR.

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Petro-Canada MacKay River
- Gulf Surmont
- Municipalities
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Suncor Project Millennium
- Syncrude Upgrader
- JACOS Hangingstone
- Forestry
- Pipelines/ roadways/other

G9.2 Potential Linkages and Key Questions

The potential linkages for Project impacts on terrestrial vegetation were discussed in Section E9. Four key questions have been developed for the assessment of terrestrial vegetation in the RDR.

TVRDR-1: Will Combined Developments, Their Reclamation and Closure, Result in a Loss or Alteration of Vegetation Communities?

TVRDR-2: Will Combined Developments Result in a Change in Vegetation Diversity?

TVRDR-3: Will Air Emissions From Combined Developments Alter Vegetation Health?

G9.3 Analysis and Results

G9.3.1 Key Question TVRDR-1: Will Combined Developments, Their Reclamation and Closure, Result in a Loss or Alteration of Vegetation Communities?

Direct Losses/Alterations

The combined developments will result in direct losses and alteration to terrestrial vegetation (Table G9-1). A discussion detailing activities associated with these developments is detailed in F9.3. Baseline regional vegetation is shown in Figure F9-1, while Figure F9-2 shows vegetation within the development areas.

Within the Uplands (terrestrial) plant communities, the greatest impacts occur within the Blueberry and Low-Bush Cranberry ecosite phases (b1, b3, d2), where 14,249 ha will be cleared (1.4% of the RSA). The Project accounts for 648 ha, or 0.1% of this loss and planned and approved developments will contributed 1.3%. Low bush Cranberry-Aspen dominated will be reduced by 4,978 ha, or 0.8% of the RSA. The Project will contribute less than 0.1% to this loss. Reclamation will increase Low-Bush Cranberry by 21,288 ha. Baseline Low-Bush Cranberry will increase from 115,309 ha to 122,348 (11.5%) in RSA.

In general, the direct and indirect impacts to the vegetation resources do not represent a significant reduction. Some vegetation types such as fens and bogs will represent a permanent loss of that resource, however several upland ecosite phases will be replaced during reclamation. In addition, loss/alteration to vegetation will be phased over the construction and operation phases of development. Substantial increases in ecosite phases, for example, e3 (Dogwood-White Spruce) and b4 (Blueberry-White Spruce-Jack Pine) are foreseen following mine closures based on reclamation plans.

The RDR is present as the worst case scenario. Developments may not occur simultaneously and reclamation will be phased over time.

Indirect Losses/Alterations

Old-Growth Forests

Losses of old growth forests are detailed in Section F9.4 of this EIA. The two forest communities most likely to support old-growth forests included aspen-white spruce forests and lichen-jack pine forests. Losses to old growth cannot be predicted in this regional review and is better assessed on an individual project basis.

Aspen-White Spruce Forests

Loss of timber associated with this KIR is discussed in Section F9.4. Essentially the loss of productive stands are associated with all terrestrial vegetation types except A1. Therefore, the loss of potentially productive forests will approximate 34,163 ha or 3.2% of the RSA (Table G9-1). Reclamation is expected to increase productive forests from 293,353 ha to 312,011 ha (28.9%) in the RSA.

Table G9-1 Combined Losses/Alteration of Existing Vegetation, Rivers and Lakes Within the RSA

Vegetation Types		Baseline		Muskeg River Mine Project				CEA				RDR				Final Landscape	
				Impacts		Far Future		Impacts		Far Future		Impacts		Far Future			
Map Codes	Ecosite Phases	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)			(ha)	(%)
a1 with some b4	Lichen Jack Pine	15,278	1.5	0	0.0	596	0.1	2,928	0.3	4,455	0.4	3,005	0.3	6925	0.7	19198	1.6
b1,b3,d2	Blueberry Pj-Aw, Aw-Sw; Low-bush Cranberry Aw-Sw	115,309	11.0	648	0.1	1,.019	0.1	11,285	1.1	17,030	1.6	14,249	1.4	21288	2.0	122348	11.5
b2	Blueberry Aw(Bw)	1,132	0.1	0	0.0	102	0.0	190	<0.1	584	0.1	190	<0.1	1007	0.1	1,949	0.1
d1	Low-bush Cranberry (Aw)	81,511	7.8	39	<0.1	96	0.0	7,056	0.7	7,519	0.7	7,978	0.8	7916	0.8	81,449	7.8
d3,e3	Low-bush Cranberry Sw, Dogwood Sw	76,084	7.2	120	<0.1	1,550	0.1	7,120	0.7	8,905	0.8	8,678	0.8	15331	1.5	82,737	7.4
e1,e2	Dogwood Pb-Aw, Pb-Sw	4,039	0.4	0	0.0	0	0.0	63	<0.1	354	<0.1	63	<0.1	354	<0.1	4,330	0.4
	Sub-Total (Terrestrial Vegetation)	**293,353**	**27.9**	**807**	**0.1**	**3,363**	**0.3**	**28,642**	**2.8**	**38,847**	**3.7**	**34,163**	**3.2**	**52821**	**5.0**	**312,011**	**28.9**
	Sub-Total (Wetlands)	**684,449**	**65.1**	**3,344**	**0.3**	**0**	**0**	**54,834**	**5.2**	**42,116**	**4.0**	**67,126**	**6.4**	**42186**	**4.0**	**659,508**	**63.9**
	Anthropogenic Disturbances	30,941	2.9	175	<0.1	0	0.0	33,133	3.2	1,349	0.1	33,409	3.2	1349	0.1	30,032	2.9
	Forestry Disturbance	13,443	1.3	0	0.0	0	0.0	15474	1.5	658	0.1	15,474	1.5	658	0.1	12,070	1.1
	Reclaimed Unit	3,600	0.3	0	0.0	0	0.0	3600	0.3	0	0.0	3,600	0.3	420	<0.1	3,600	0.3
	Sub-Total (Disturbances)	**47,984**	**4.6**	**175**	**<0.1**	**0**	**0.0**	**52273**	**5.0**	**2,007**	**0.2**	**52,483**	**5.0**	**2007**	**0.2**	**45,702**	**4.3**
	Water	19,216	1.8	17	<0.1	536	0.1	454	<0.1	3,444	0.3	466	<0.1	5665	0.5	22,206	2.1
	Wetlands	0	0.0	0	0.0	**444**	<0.1	0	0.0	1,385	0.1	0	0.0	3155	0.3	1,385	0.1
	Infrastructure	0	0.0	0	0.0	0	0.0	0	0.0	420	<0.1	0	0.0	420	<0.1	420	0.0
	Unclassified	6,409	0.6	0	0.0	0	0.0	178	<0.1	178	<0.1	178	<0.1	178	<0.1	6,409	0.6
	Total	1,051,411	100.0	4,343	0.4	4,343	0.4	88,397	8.4		8.4	154,416	15.0	106432	10.1	1,051,411	100.0

Lichen-Jack Pine Forests

This KIR is discussed in Section F9.4. The total amount of Lichen-Jack Pine forests lost from combined developments is 3,005 ha, or 0.3% of the RSA. The Project will not affect this ecosite phase, however, reclamation will contribute an additional 596 ha. the Final Landscape is expected to increase Lichen Jack Pine in the RSA from 15,278 ha (1.5%) at baseline to 19,198 ha (1.6%).

Rare or Endangered Terrestrial Plant Species or Communities

A discussion of rare plants in the RSA is detailed in Section F9.4. Impacts to rare plants cannot be quantified for this Regional review. This is better assessed on an individual project basis.

Traditional Plants (Food, Medicinal and Spiritual)

Regional impacts to Traditional Plants is discussed in Section F9.4. Impacts on Traditional Plants cannot be quantified in this regional review. This is best assessed on an individual project basis. Due to the generalized vegetation classification of the RSA and the widespread habitat requirements, traditional plants identified may be found in multiple ecosite phases.

Residual Impact Classification and Degree of Concern

A total of 34,163 ha, or 3.2% of terrestrial vegetation will be removed from combined developments. This represents a Low magnitude, Short-Term in frequency and a Low degree of concern.

G9.3.2 Key Question TVRDR-2: Will Combined Developments Result in a Change in Vegetation Diversity?

Analysis of Key Question

Patch size of "polygon" size was assessed to determine impacts from combined developments in the RSA. The Project alone does not affect patch size in the RSA. Average patch size for Lichen Jack Pine is reduced from approximate 100 ha to 64 ha. This reduction indicates that large patches of 7,063 ha of Lichen Jack Pine will be reduced to approximately 2,877 ha. This is a relatively Low impact. Average patch size for other upland vegetation does not indicate a substantial change. It is predicted that phased reclamation may increase average patch size of Lichen Jack Pine.

Table G9-2 Patch Size for Terrestrial Vegetation for Baseline, CEA and RDR

Map Code	Ecosite Phase	Baseline Patch Size (ha)			RDR Patch Size (ha)			Change in Patch Size (ha)		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
a1 (with some b4)	Lichen Jack Pine	0.0280	7063.5690	110.2352	<0.0001	2877.3830	63.6938	0.0280	4186.1860	46.5414
b1,b3,d2	Blueberry Pj-Aw, Aw-Sw; Low-bush cranberry Aw-Sw	0.0020	4090.2970	26.5208	<0.0001	3469.8000	23.6963	0.0020	620.4970	2.8245
b2	Blueberry Aw(Bw)	0.0620	80.7980	8.9449	0.0620	23.3750	4.4989	<0.0001	57.4230	4.4460
d1	Low-Bush Cranberry (Aw)	0.0010	10659.2700	37.4836	<0.0001	4941.2790	35.5613	0.0010	5717.9910	1.9223
d3,e3	Low-Bush Cranberry Sw, Dogwood Sw	<0.0001	2587.1970	18.7199	<0.0001	3461.6130	19.8951	<0.0001	-874.4160	-1.1751
e1,e2	Dogwood Pb-Aw, Pb-Sw	0.0040	45.1250	8.1036	0.0040	110.7450	8.8446	<0.0001	-65.6200	-0.7410

Residual Classification and Degree of Concern

The residual impact classification of changes in diversity of terrestrial vegetation communities for the combined developments is Negative in direction, Low in magnitude, Regional in extent and of Short-Term duration. The degree of concern is Low. Lichen Jack Pine, however, does indicate a substantial change in average patch size. Therefore, for Lichen Jack Pine the magnitude is high, short term in duration, Regional in extent with a moderate level of concern.

G9.3.3 Key Question TVRDR-3: Will Air Emissions From Combined Developments Alter Vegetation Health?

Analysis of Key Question

Potential Acid Input (PAI)

Potential Acid Input (PAI) from combined developments, including fully disclosed, is predicted to centered around oil sands development areas. The World Health Organization (1994) has proposed a PAI critical loading factor of 0.25 keq/ha/a for sensitive ecosystems and 0.5 keq/ha/a for moderately sensitive ecosystems. The dominant vegetation communities occurring within isopleths of 0.25 keq/ha/a are wooded fens and bogs. The effects to this community type are not known, however studies have not found any discernible trend of peatland acidification in northeastern Alberta (BOVAR 1996a). Therefore, the relationship between acid emissions and peatlands is currently undetermined.

Residual Classification and Degree of Concern

The residual impact classification of acid emissions and vegetation health for the combined developments is Negative in direction, Undermined in magnitude, Regional in extent and of Short-Term duration. The degree of concern is Low.

Residual Classification and Degree of Concern

The residual impact classification for replacement of vegetation following reclamation and closure of the combined developments is Positive in direction, Low in magnitude, Regional in extent and of Short-Term duration.

G9.4 Summary of Impacts

Table G9-3 summarizes the residual impacts to terrestrial vegetation under the RDR.

Table G9-3 Summary of Residual Impacts

Key Question	RDR Results
TVRDR-1: Will the combined developments, their reclamation and closure, result in a loss or alteration of vegetation communities?	• For the RDR, loss of vegetation communities (34,163 ha or 3.2%) is predicted in the RSA. The Project contributes 807 or 0.1% of this impact. • The CEA impact on loss or alteration of vegetation communities as Negative in direction, Low in magnitude, Regional in geographic extent, Short-term in duration, and the degree of concern is **Low.** • The RDR reclamation will increase terrestrial vegetation by 6.4% to 312,011 ha or 29.7% of the RSA. This impact is Positive in direction, Low in magnitude, Regional in geographic extent, Short-term in duration, and the degree of concern is **Low.**
TVRDR-2: Will the combined developments result in a change in vegetation diversity?	• The RDR impact on diversity to vegetation communities as Negative in direction, Low in magnitude, Regional in geographic extent, Short-term in duration, and the degree of concern is **Low.**
TVRDR-3: Will air emissions from combined developments result in a change to vegetation health?	• The RDR impact on air emission to vegetation health as Negative in direction, Low in magnitude, Regional in geographic extent, Short-term in duration, and the degree of concern is **Low.**

G10 WETLANDS REGIONAL DEVELOPMENT REVIEW

G10.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and publicly disclosed (planned) developments on wetlands in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- Syncrude Aurora North and South
- Shell Lease 13 East
- Petro-Canada MacKay River
- Pipelines, roadways and utility corridors
- Syncrude Mildred Lake
- SOLV-EX
- Muskeg River Mine Project
- Syncrude Project 21 Upgrader
- Mobil Kearl Mine and Upgrader

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

G10.2 Potential Linkages and Key Question

The linkages are consistent with E10 and F10. The key question for the RDR is as follows:

WTRDR-1: Will Combined Developments, Their Reclamation and Closure Result in a Loss or Alteration of Wetlands?

Linkage between site clearing and wetlands

The combined oil sands and forestry developments will result in a clearing of 160,487 ha or 15.3% (Table G10-1) of the RSA. The combined development will affect a total of 79,972 ha or 7.6% of RSA wetlands. Therefore, direct removal of wetlands is a valid linkage.

G10.3 Analysis and Results

G10.3.1 Key Question WTRDR-1: Will Combined Developments, Their Reclamation and Closure Result in a Loss or Alteration of Wetlands?

The analysis of potential linkages indicates that the valid linkages necessary for determining losses or alteration of wetlands are site clearing during industry development. For oil sands projects, site clearing involves the direct removal of landforms, and associated soils and vegetation communities including wetlands.

Some forestry disturbances to wetlands will occur as a result of road construction for access to productive stands. Table G10-1 shows the distribution of wetlands and land cover types in the RSA.

Table G10-1 Direct Losses/Alteration of Existing Terrestrial Vegetation, Wetlands, Lakes, Rivers and Other Areas Within the RSA

General Community Types	Baseline		Muskeg River Mine Project		CEA		RDR	
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Terrestrial Vegetation	293,353	27.9	807	0.1	28,642	2.7	34,163	3.2
Wetlands	684,449	65.1	3,344	0.3	54,834	5.2	67,126	6.4
Lakes, Rivers, Streams	19,216	1.8	17	<0.1	454	<0.1	466	<0.1
Forest Disturbance	13,443	1.3	0	0	15,474	1.5	15,747	1.5
Developed or Unclassified	37,350	3.6	175	<0.1	52,451	5.0	52,626	5.0
Reclamation Unit	3,600	0.3	0	0.0	3,600	0.3	3,600	0.3
TOTAL	**1,051,411**	**100.0**	**4,343**	**0.4**	**136,381**	**13.0**	**172,982**	**16.5**

Direct Losses to Wetlands Resources

Wetlands, bogs, fens, marshes, swamps and shallow open water, are the dominant community type lost to developments because they occupy 65.1% of the RSA. Wetlands are classified into four general types that include wooded fens and bogs, wooded fens and bogs that have been altered due to fire, shrubby fens, and marshes. The most dominant wetlands type in the region is wooded fens and bogs. One percent of this wetlands type has been modified by fire and is located in the southeastern region of the RSA (Figure G1-1). Shrubby fens and marshes comprise less than 4% of the RSA.

The combined developments, including disclosed developments, will disturb 67,126 ha or 6.4% of wooded fens and bogs within the RSA. Disclosed developments including forestry, will disturb 63,354 ha or 5.9% in the RSA. Combined developments will impact 904 ha or 0.1% of shrubby fens and 651 ha or 0.1% of marshes in the RSA (Table G10-2). The Project will contribute a total of 3,344 ha to the total wetlands lost in the RSA.

Impact Analysis

An analysis of the predicted reclamation landscape following closure, including wetlands, is provided in the Mine Closure Plans (e.g., Section E16 for the Muskeg River Mine Project). Replacement of some wetlands communities, namely marsh, riparian shrub complexes and shallow open-water complexes, will occur within the development footprints upon closure. However, none of the fens or bogs disturbed during construction and operation will be replaced.

Fens and bogs disturbed by forestry are expected to be reclaimed to their pre-disturbance type.

Fens and bog communities, which account for 65% of the RSA, are not included in the vegetation communities suitable for establishment on reclaimed landscapes. Typically, peat accumulations integral to the structure of wetlands communities, such as fens, take several hundreds of years to develop. While it is not impossible that, given suitable landform and drainage conditions, these communities may re-establish, the long periods of time associated with their development renders them outside the scope of closure analysis. However, some marsh communities will be developed on reclaimed landscapes. Table G10-2 shows the replacement wetlands after closure of regional developments in the RSA.

Table F10-2 shows the amount and distribution of wetlands types at baseline and after closure of combined developments. The post-closure wetlands amounts were determined from the Steepbank Mine Closure Plan (Golder 1996i), Syncrude Aurora Mine Closure Plan (BOVAR 1996a) and the Muskeg River Mine Closure Plan (Section E16). Although Syncrude's Aurora Mine closure plan identified fens to be reclaimed, ecologically this is not a probable reclamation wetland type. Accordingly, this area was reclassified as marsh (l1), a probable reclamation wetland type. In addition, closure plans identifying consolidated tailing wetlands were classified as marsh, which would include shallow open water. Forestry activities are not expected to remove fens or bogs. Overall the amount of wooded fens remaining in the RSA is 611,652 ha or 58% within the RSA. Wooded fens and bogs modified by fire remaining in the RSA is 10,121 or 1.0%. Graminoid fens (k3) will not be reclaimed, the amount remaining is 31,634 or 3% of the RSA. Marsh (l1) communities are expected to increase from 3,408 ha to 6,101 ha or 0.6% in the RSA.

Residual Impact Classification and Degree of Concern

Fens in the RSA represent approximately 65% of the wetlands. The loss fens and bogs from combined developments is small (6.4% of the RSA). The impacts to wetlands therefore are Negative in direction, Negligible in magnitude, Regional in geographical extent, Not Reversible and of a Low degree of concern.

The loss of patterned fens and riparian shrubs are difficult to quantify at a regional scale. Protection of these wetland types, for example, patterned fens adjacent to McClelland Lake are proposed to be protected under the Special Places 2000 initiative, are initiated in the RSA.

Table G10-2 Baseline, CEA, RDR and Post-Closure Wetlands and Land Cover Types in the RSA

Vegetation Types		Baseline		Muskeg River Mine Project				CEA				RDR				Final Landscape	
				Impacts		Far Future		Impacts		Far Future		Impacts		Far Future			
Map Codes	**Ecosite Phases**	**(ha)**	**(%)**	**(ha)**	**(%)**	**(ha)**	**(%)**	**(ha)**	**(%)**	**(ha)**	**(%)**	**(ha)**	**(%)**	**(ha)**	**(%)**	**(ha)**	**(%)**
j1,j2,k1,k2 and limited i1,i2	Wooded and Shrubby Fens and Bogs	639,004	60.8	3,315	0.3	0	0.0	53,584	5.1	38,430	3.7	65,781	6.3	38,430	3.7	611,653	58.2
j1,j2,k1,k2 with recent burn	Wooded and Shrubby Fens and Bogs (recently burned)	10,131	1.0	4	<0.1	0	0.0	96	0.0	86	<0.1	96	<0.1	86	<0.1	10,121	1.0
k3	Graminoid fens	31,906	3.0	20	<0.1	0	0.0	745	0.1	540	0.1	812	0.1	540	0.1	31,634	3.0
l1	Marsh	3,408	0.3	5	<0.1	0	0.0	409	0.0	3060	0.3	437	<0.1	3,130	0.3	6,101	0.6
	Sub-Total Wetlands	**684,449**	**65.1**	**3,344**	**0.3**	**0**	**0**	**54,834**	**5.2**	**42,116**	**4.0**	67,126	6.4	42,186	4.0	**659,508**	**62.7**
	Sub-Total (Terrestrial Vegetation)	**293,353**	**27.9**	**807**	**0.1**	**3,363**	**0.3**	**28,642**	**2.8**	**38,847**	**3.7**	**34,163**	**3.2**	**52,821**	**5.0**	**312,011**	**28.9**
	Anthropogenic Disturbances	30,941	2.9	175	<0.1	0	0.0	33,133	3.2	1,349	0.1	33,409	3.2	1,349	0.1	30,032	2.9
	Forestry Disturbance	13,443	1.3	0	0.0	0	0.0	15474	1.5	658	0.1	15,474	1.5	658	0.1	12,070	1.1
	Reclaimed Unit	3,600	0.3	0	0.0	0	0.0	3600	0.3	0	0.0	3,600	0.3	420	<0.1	3,600	0.3
	Sub-Total (Disturbances)	**47,984**	**4.6**	**175**	**<0.1**	**0**	**0.0**	**52273**	**5.0**	**2,007**	**0.2**	**52,483**	**5.0**	**2,007**	**0.2**	**45,702**	**4.3**
	Water	19,216	1.8	17	<0.1	536	0.1	454	<0.1	3,444	0.3	466	<0.1	5,665	0.5	22,206	2.1
	Wetlands	0	0.0	0	0.0	444	<0.1	0	0.0	1,385	0.1	0	0.0	3,155	0.3	1,385	0.1
	Infrastructure	0	0.0	0	0.0	0	0.0	0	0.0	420	<0.1	0	0.0	420	<0.1	420	0.0
	Unclassified	6,409	0.6	0	0.0	0	0.0	178	<0.1	178	<0.1	178	<0.1	178	<0.1	6,409	0.6
	Total	1,051,411	100.0	4,343	0.4	4,343	0.4	88,397	8.4		8.4	154,416	15.0	106,432	10.1	1,051,411	100.0

The primary residual impacts include:

- a change in dominant vegetation type from wetlands to upland communities;
- a decrease in areas of patterned fens;
- an increase in riparian shrub communities; and
- an increase in areas of ponds/wetlands and lakes.

These impacts, as shown in Table G10-3, are considered to be Negative in direction for the patterned fen KIR with a Low in magnitude of cumulative impact. The duration of impact is Long-Term, Irreversible and of Low frequency. The degree of concern is Low. For the riparian shrub complex, the direction of impact is Positive and the magnitude is Low. The geographic extent of the impact is Regional, of Long-Term duration, Reversible and Low in frequency.

Table G10-3 Residual Impact Classification on Wetlands in the RSA and Degree of Concern

Wetlands Type		Impact Assessment Criteria						
Map Codes	**Ecosite Phases**	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Reversibility**	**Frequency**	**Degree of Concern**
j1,j2,k1,k2 and limited i1,i2	Wooded Fens and Bogs	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
j1,j2,k1,k2 with recent burn	Wooded Fens and Bogs (recently burned)	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
k3	Shrubby Fens	Negative	Low	Regional	Long-Term	Irreversible	Low	Low
l1	Marsh	Positive	Low	Regional	Long-Term	Reversible	Low	Low

Average patch size for wooded fens and bogs will decrease from approximately 386 to 354 ha as a result of the RDR scenario (Table G10-4). The Project alone will not affect patch size in the RSA. Recently burned fens and bogs will increase patch size from 1.60 ha to 2.682 ha. Marshes will decrease average patch size from 35 ha to approximately 32 ha. Overall, the diversity of wetlands in the RSA does not change substantially from combined development. The impact magnitude is Low, with a Low degree of concern.

Table G10-4 Wetland Patch Size for Baseline and RDR

Map Code	Ecosite Phase	Baseline Patch Size (ha)			RDR Patch Size (ha)			Change in Patch Size (ha)		
		Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
j1,j2,k1,k2 and limited i1,i2	Wooded Fens and Bogs	<0.0001	239044.3	385.9754	<0.0001	195437.4	353.5235	<0.0001	43606.9000	32.4519
j1,j2,k1,k2 with recent burn	Wooded Fens and Bogs (recently burned)	<0.0001	146.296	1.600119	<0.0001	961.926	2.682102	<0.0001	-815.6300	-1.0820
k3	Graminoid Fens	0.0010	7923.268	35.23209	0.0010	7923.268	31.68619	<0.0001	0.0000	3.5459
l1	Marsh	<0.0001	88.688	0.592432	<0.0001	134.709	0.60001	<0.0001	-46.0210	-0.0076

G10.4 Summary of Impacts

Table G10-5 summarizes the impacts for RSA wetlands under the RDR scenario.

Table G10-5 Summary of Impacts on Wetlands

Key Question	RDR Results
WTRDR-1: Will combined developments, their reclamation and closure result in a loss or alteration of wetlands?	• The total loss to wetlands from the combined developments is 67,126 ha or 6.4% of the RSA. The Project's contribution to this loss is 5.0% under the RDR. • The RDR impact on diversity to wetlands is Negative in direction, Low in magnitude, Regional in geographic extent, Short-Term in duration, and the degree of concern is **Low.**
WTRDR-2: Will reclamation and closure of combined developments result in a replacement of wetlands?	• Reclamation activities and reforestation will result in changes to the distribution of wetland types in the RSA. Overall, fens and bogs will be reduced by 2.6% but marshes will increase by 0.1% in the RSA. • The RDR impact on diversity to wetlands is Negative in direction, Low in magnitude, Regional in geographic extent, Short-Term in duration, and the degree of concern is **Low.**

G11 WILDLIFE REGIONAL DEVELOPMENT REVIEW

G11.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and planned (publicly disclosed) developments on wildlife in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Petro-Canada MacKay River
- JACOS Hangingstone
- Forestry
- Pipelines, utility corridors and roadways
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Suncor Project Millennium
- Syncrude Project 21 Upgrader
- Mobil Kearl Mine and Upgrader
- Gulf Surmont
- Municipalities

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

Discussion on the wildlife baseline for the Project were provided in Section D11, while the potential impacts of the Project on wildlife were detailed in Section E11 of this EIA.

G11.2 Potential Linkages and Key Questions

Figure E11-1 (Section E11) shows the linkage diagram for project activities and potential changes in wildlife associated with the Project. Generally the same linkages and key questions apply to the RDR.

The key questions for the wildlife RDR included:

WRDR-1: Will the Combined Developments Impact Wildlife Habitat?

WRDR-2: Will Changes to Water, Aquatic Prey and Plant Quality from the Combined Developments Affect Wildlife Health?

G11.3 Analysis and Results

G11.3.1 Key Question WRDR-1: Will the Combined Developments Impact Wildlife Habitat?

Incremental changes to wildlife habitat due to the RDR scenario and the Project are shown in Table G11-1.

Table G11-1 Cumulative Effects of Habitat Loss for KIRs in the RSA

KIR	HUs in RSA	Habitat Units (HUs) Lost (%)			
		Existing and Approved Development	Muskeg River Mine Project	Total Development	Change Attributed to Muskeg River Mine Project
moose	385,291	-5.6	-0.6	-6.2	10.2
beaver	105,408	-3.1	-0.1	-3.2	2.5
western tanager	127,278	-4.1	-0.3	-5.0	7.0

Existing, approved and planned developments (excluding the Project) account for a loss of habitat of 3.1 to 5.6% for each KIR over baseline conditions. The Project will result in an additional loss of 0.1 to 0.6% of the baseline HUs within the RSA. In total, disturbances for the RDR will range from 3.2 to 6.2% of baseline conditions. Changes attributed to the Project represent 2.5 to 10.2% of the total disturbances.

Analysis of Key Question

Cumulative, residual losses of wildlife habitat were considered to have a Low magnitude, because no KIR will experience losses of more than 3.1% of baseline HUs within the RSA. The direction of the impacts are Reversible as eventual reclamation of the sites is expected to return them to an equivalent habitat capability. The geographic extent of the impacts can be considered to be Regional.

Residual Impact Classification and Degree of Concern

The degree of concern for all KIRs was considered to be Moderate for the total impact scenario due to the regional and long-term nature of the impacts. The degree of concern for the incremental impacts of the Project was considered to be Low due to the more localized geographic extent of the impacts. The degree of concern for the total impact scenario is shown in Table G11-2.

Table G11-2 Residual Impact Classification on Wildlife Habitat and Degree of Concern

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	High	Moderate

G11.3.2 Key Question WRDR-2: Will Changes to Water, Aquatic Prey and Plant Quality From Combined Developments Affect Wildlife Health?

Analysis of Key Question

Water Quality

To evaluate the potential linkage between cumulative changes to water quality and wildlife health, a quantitative wildlife health risk assessment was conducted using methods described in Section E11.5.3.

Potential receptors include both aquatic wildlife (i.e., water shrews, river otters, killdeer and great blue herons) and terrestrial wildlife (i.e., moose, snowshoe hares and black bears). These animals may be exposed through ingestion of Athabasca and Muskeg river water as a drinking water source.

Cumulative chemical concentrations were predicted for the Muskeg and Athabasca rivers, according to the method described in Section E5. Predicted cumulative concentrations were conservatively screened against receptor-specific Risk Based Concentrations (RBCs). No chemicals of concern in water were identified for the water shrew, river otter, killdeer, great blue heron or snowshoe hare. For moose and black bears, molybdenum was identified as a potential chemical of concern in water. Naphthenic acids were also identified as potential chemicals of concern, but due to the lack of chronic toxicity data for these substances, as discussed in Section E11.7, these substances were not assessed in the RDR.

The predicted cumulative molybdenum concentrations in the Muskeg River were used as exposure concentrations to estimate daily intake rates for moose and black bears, using the same methodology as described in Section E11.7. RDR exposure ratios for moose and black bears remained less than 1.0 (i.e., Moose ER range = 0.0009 [in 2020] to 0.21 [in 2030]; Bear ER range = 0.0008 [in 2020] to 0.18 [in 2030]), indicating that these predicted conservative exposures are well within acceptable limits. Therefore, no impacts to wildlife health are predicted due to combined water releases to the Muskeg River from regional developments.

As discussed in Section F11, predicted chemical concentrations in the Athabasca River due to water releases from combined developments are less than or equal to predicted chemical concentrations in the Muskeg River for most chemicals and concentrations of all chemicals are less than wildlife risk-based concentrations. Therefore, no impacts to wildlife health are predicted due to exposure to Athabasca River water affected by the Project, existing, approved and disclosed developments.

Fish and Aquatic Invertebrate Quality

In the Project impact analysis for Key Question W-2 (Section E11.7), the impact analysis showed that predicted conservative exposures likely to be incurred by wildlife who consume local fish and aquatic invertebrates were well within acceptable limits.

Minor changes to the water quality of the Athabasca or Muskeg rivers, resulting from regional developments, should not significantly increase the tissue concentrations of metals in fish or invertebrates. However, no data were available to further evaluate this exposure route.

Plant Quality

In the impact analysis for this key question (Section E11.8), results of a vegetation sampling program indicated that oil sands operations do not appear to contribute to increases in chemical concentrations in plants. The impact analysis showed that predicted conservative exposures likely to be incurred by wildlife who consume local plants were well within acceptable limits.

Increased air emissions from the regional developments may contribute to an increase in chemical concentrations in plant tissues. However, currently there are no data available to evaluate this exposure route.

Reclaimed Landscape

The results of the analysis of this key question in Section F11 are also applicable to the RDR scenario. As discussed in Section F11.6, chemical releases from multiple reclaimed landscapes within the region will not necessarily result in compounded exposures on any individual reclaimed area. Rather, due to the larger area of reclaimed landscapes in the Athabasca oil sands region, there is a greater likelihood for wildlife to forage in a reclaimed area, and therefore this exposure pathway becomes more likely, although the exposure parameters in this scenario are conservative.

Residual Impact Classification and Degree of Concern

For exposures to water during the operation phases of combined developments, no wildlife health impacts were identified. However, due to the uncertainty regarding the potential chronic effects of naphthenic acids, the magnitude of impact is rated as Low, rather than negligible. This finding is the same as that predicted for the Project.

For exposures on reclaimed landscapes, while the magnitude of the impact is considered to be low, it is recognized that there is an increased likelihood on a regional basis for this exposure pathway to be realized. Therefore, the residual impact is likely to be enhanced in the RDR, relative to the impact predicted in Section F11. The predicted enhancement is based on a greater likelihood of animals being exposed to chemicals on reclaimed landscapes. However, the magnitude of exposure and associated health risks for a given individual animal should not be increased in the RDR, relative to the CEA. Further data are necessary to substantiate this prediction. The impact is shown in Table G11-3.

Table G11-3 Residual Impact Classification on Wildlife Health and Degree of Concern

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Moderate

Certainty

The assessment of potential impacts to local wildlife health from exposure to Athabasca and Muskeg river water was based on a number of highly conservative assumptions as outlined in Section F11.6.2. Hence, the actual risks to wildlife health will likely be even lower than those suggested by ER estimates because of the multiple protective assumptions. However, there is some uncertainty associated with fish and aquatic invertebrate quality, plant quality and exposures on reclaimed landscapes.

G11.4 Summary of Impacts

Table G11-4 summarizes the predicted impacts and corresponding concern levels identified in the RDR assessment for wildlife:

Table G11-4 Summary of RDR for Wildlife for the Existing, Approved, Planned and Muskeg River Mine Project Developments

Key Question	RDR Results
WRDR-1: Will the combined developments impact wildlife habitat?	• During the construction phase of the oil sands developments, the combined developments will cause relatively small (3.2 - 6.2% of the RSA) losses of wildlife habitat due to site clearing and disturbance. These impacts are predicted to be Negative in direction, Low in magnitude, Regional in geographic extent, Long-term in duration, Reversible and High in frequency. The degree of concern for the cumulative effects is **Moderate.** • These impacts represent a worst case scenario, as it is unlikely that

Key Question	RDR Results
	all sites will be cleared to their maximum extent at the same time. The phased nature of site clearing and progressive reclamation will mitigate the cumulative effects of habitat loss. • Eventual reclamation of all sites should result in equivalent habitat capability for wildlife within the region.
WRDR-2: Will changes to water, aquatic prey and plant quality from combined developments affect wildlife health?	• During operation of combined developments, no significant health impacts were identified for wildlife health from exposures to water from the Athabasca or Muskeg rivers; however there is some uncertainty regarding the chronic toxicity of naphthenic acids. This prediction for the RDR is not significantly different from that predicted for the Project. • Following closure in the far future when equilibrium conditions have been established for all combined developments, a potential impact has been identified in RDR. The residual impact is likely to be enhanced in RDR, relative to the impact predicted for the Muskeg River Mine Project, since there is a greater likelihood on a regional basis for this exposure pathway to be realized. However, the magnitude of exposure and associated health risks for a given individual animal should not be increased in the RDR, relative to the CEA. The cumulative effects on wildlife health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Moderate**, reflecting the regional extent and degree of uncertainty associated with impact predictions.

G12 HUMAN HEALTH REGIONAL DEVELOPMENT REVIEW

G12.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus baseline, approved and planned developments on human health in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Petro-Canada MacKay River
- JACOS Hangingstone
- Forestry
- Pipelines, utility corridors and roadways
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Suncor Project Millennium
- Syncrude Upgrader
- Mobil Kearl Mine and Upgrader
- Gulf Surmont
- Municipalities

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

The assessment of regional developments of the oil sands region is an evolving process, which will be built upon with each successive development application. As such, this section addresses the potential human health impacts associated with combined releases of water and air from the regional developments to the extent that the current database allows.

Quantitative data were available to assess water quality and some aspects of air quality; however, due to uncertainty surrounding future developments that have been approved, assessment of other cumulative effects was restricted to a more qualitative nature.

G12.2 Potential Linkages and Key Questions

Figures E12-1 and E12-2 show the linkage diagrams for Project Activities and potential changes in Human Health associated with the Project. Generally, the same linkages and key questions apply to the RDR.

The key questions for the Human Health RDR include:

HHRDR-1: Will Water Quality Changes From Combined Developments Affect Human Health?

HHRDR-2: Will Air Quality Changes From Combined Developments Affect Human Health?

HHRDR-3: Will Changes to Air and Water Quality From Combined Developments Affect Human Health?

HHRDR-4: Will Changes to Plant and Game Meat Quality From Combined Developments Affect Human Health?

HHRDR-5: Will Equilibrium Concentrations of Residual Chemicals in Water and Select Local Food Items Following Reclamation of Combined Developments Affect Human Health?

HHRDR-6: Will Noise From Combined Developments During Construction and Operation Unduly Affect People Who Reside in the Region?

G12.3 Analysis and Results

G12.3.1 Key Question HHRDR-1: Will Water Quality Changes From Combined Developments Affect Human Health?

Analysis of Key Question

To evaluate the potential linkage between changes to water quality as a result of regional developments and human health, a quantitative human health risk assessment was conducted using methods described in Section E12.5 (Human Health Impact Analysis Methods). Key aspects of the risk assessment are discussed here; additional details are provided in Appendix X (Volume 3 of the Application).

Chemical concentrations as a result of regional developments were predicted for the Muskeg and Athabasca rivers, according to the method described in Section F5 (Water Quality). Predicted concentrations were conservatively screened against one-tenth of the Risk-Based Concentration (RBC). Refer to Appendix XIII for screening tables. The following seven chemicals were identified for further evaluation:

- benzo(a)pyrene
- benzo(a)anthracene
- boron
- cadmium
- lead
- molybdenum
- vanadium

In addition to these chemicals, baseline concentrations of arsenic are also naturally elevated in the Muskeg River, because they exceeded the conservative RBC screening step. Beryllium was not detected in the Muskeg River under baseline conditions; however the detection limit exceeds the conservative RBCs. Although the Project will not contribute to increased concentrations of these chemicals, they were carried forward for further analysis in light of interest articulated by regulators concerning elevated background chemical concentrations (Human and Ecological Health Component Focus Workshop, October 30, 1997).

Naphthenic acids were also identified as potential chemicals of concern, but due to the lack of chronic toxicity data for these substances, as discussed in Section E12.6, these substances were not assessed in the RDR.

The predicted concentrations were used as exposure concentrations to estimate daily intake rates. The recreational and swimming scenarios are the same as those used in the impact analysis for the Muskeg River Mine Project and are described in Section E12.6 (Human Health Impact Analysis, key question HH-1).

Regional exposure ratio values for the swimming and recreational scenarios are presented in Tables G12-1 and G12-2.

Table G12-1 Exposure Ratio Values for the Swimming Scenario (Muskeg River Exposure)

Receptor/Chemical	2007	2020	2030	Far Future (Equilibrium)
Child				
Boron	0.0002	0.0002	0.002	0.0009
Cadmium	0.0001	0.0001	0.0004	0.0003
Lead	0.00007	0.00006	0.0002	0.00007
Molybdenum	0.00007	0.00004	0.009	0.001
Vanadium	0.00007	0.00007	0.0009	0.0001
Adult				
Boron	0.00002	0.00002	0.0002	0.00008
Cadmium	0.000009	0.000009	0.00003	0.00002
Lead	0.000003	0.000002	0.000008	0.000003
Molybdenum	0.000006	0.000003	0.0008	0.0001
Vanadium	0.000006	0.000006	0.00007	0.00001
Composite[(a)]				
benzo[a]pyrene	0[(b)]	0[(b)]	0.07	0.09
benzo[a]anthracene	0[(b)]	0[(b)]	0.02	0.05
Total PAHs	0[(b)]	0[(b)]	0.09	0.14

(a) ER = exposure ratio, which is the predicted exposure divided by the exposure limit. ERs for PAHs are based on a risk level of 1 in 100,000.

(b) No waterborne releases of benzo[a]pyrene or benzo[a]anthracene are expected until 2030; hence no risk is predicted for these chemicals (ER = 0). By the year 2030, waterborne releases of these chemicals are predicted to occur and ER values are presented for these scenarios.

Table G12-2 Exposure Ratio Values for the Recreational Scenario (Muskeg River)

Receptor/Chemical	2007	2020	2030	Far Future (Equilibrium)
Child				
Boron	0.008	0.008	0.07	0.03
Cadmium	0.004	0.004	0.01	0.009
Lead	0.003	0.003	0.01	0.003
Molybdenum	0.002	0.001	0.33	0.05
Vanadium	0.003	0.003	0.03	0.005
Adult				
Boron	0.003	0.003	0.03	0.01
Cadmium	0.001	0.001	0.005	0.003
Lead	0.0005	0.0004	0.002	0.0005
Molybdenum	0.0008	0.0005	0.11	0.02
Vanadium	0.0009	0.0009	0.01	0.002
Composite[(a)]				
benzo[a]pyrene	0[(b)]	0[(b)]	0.09	0.11
benzo[a]anthracene	0[(b)]	0[(b)]	0.03	0.07
Total PAHs	0[(b)]	0[(b)]	0.12	0.18

(a) ER = exposure ratio, which is the predicted exposure divided by the exposure limit. ERs for PAHs are based on a risk level of 1 in 100,000.

(b) No waterborne releases of benzo[a]pyrene or benzo[a]anthracene are expected until 2030; hence no risk is predicted for these chemicals (ER = 0). By the year 2030, waterborne releases of these chemicals are predicted to occur and ER values are presented for these scenarios.

All ER values for water exposure were less than 1.0, indicating that these predicted conservative exposures resulting from recreational activities (including occasional ingestion of water and swimming exposure) are well within acceptable limits. In addition, the predicted concentrations of arsenic and beryllium in the Muskeg and Athabasca rivers as a result of regional developments are considered typical of background concentrations in Canadian rivers and acceptable for drinking water purposes. Therefore, no impacts to human health are predicted due to water releases to the Muskeg River from regional developments.

As discussed in Section F12 (Human Health), predicted chemical concentrations in the Athabasca River due to water releases from regional developments are less than or equal to predicted chemical concentrations in the Muskeg River for most chemicals. Therefore, no impacts to human health are predicted due to exposure to Athabasca River water affected by the Project baseline, approved and planned developments.

Residual Impact Classification and Degree of Concern

Based on the information assessed, no human health impacts were identified. However, due to the uncertainty regarding the potential chronic effects of naphthenic acids, the degree of concern is rated as low, rather than negligible. This results in a low degree of concern is summarized in Table G12-3.

Table G12-3 Residual Impact to Human Health From Water Quality Changes

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Low

The residual impact for the RDR is the same that predicted for the Project (Section E12) and the CEA. Currently there is an industry initiative to collect additional data to resolve the issue of chronic exposures.

Certainty

The assessment of potential impacts to users of the Athabasca and Muskeg rivers was based on a number of highly protective assumptions as outlined in Section F12.3.2 (Human Health). Hence, the actual risks to human health will likely be even lower than those suggested by ER estimates because of the multiple protective assumptions.

G12.3.2 Key Question HHRDR-2: Will Air Quality Changes From Combined Developments Affect Human Health?

Analysis of Key Question

Regional ambient air concentrations of NO_2 were predicted for the communities of Fort McKay, Fort McMurray and Fort Chipewyan in Section G2 - Air Quality. The results of the air analysis indicated that predicted NO_2 concentrations in these communities would be compliant with applicable air quality criteria. Hence, NO_2 was not evaluated further in the Human Health RDR.

The Human Health RDR evaluates the potential for impacts to human health arising from the following emission sources from regional developments:

- petroleum hydrocarbon (including PAH) and VOC emissions from mine fleet exhaust
- petroleum hydrocarbon (including PAH) emissions from tailings settling ponds
- petroleum hydrocarbon (including PAH) emissions from cut mine surfaces

The RDR also includes an evaluation of background concentrations of carcinogenic PAHs in the communities of Fort McKay, Fort McMurray and Fort Chipewyan.

Air concentrations arising from mine fleet exhausts and fugitive emissions from the mine surface and the tailings settling pond of the Project will be increased as a result of air emissions from similar activities at other baseline, approved and planned developments. As discussed in Section G2 (Air Quality Regional Development Review), the combined air emissions of petroleum hydrocarbons and VOCs from baseline, approved and planned developments as well as the Project could potentially increase the BaP concentrations predicted for Fort McMurray, Fort McKay and Fort Chipewyan by 4, 12 and 1%, respectively. The derivation of these increases is based on the total production capacity of developments in the region. Refer to Table G2-2 (Section G2 - Air Quality Regional Development Review) for more details.

Since air concentrations could increase for Fort McMurray, Fort McKay and Fort Chipewyan, human exposure rates in these communities could also increase in the same proportion. Hence, for residents who spend all their time in their respective communities the estimated health risk could increase by a similar factor. However, in the case where the receptor is a community resident who may also work at the Project, the exposure and health risk is not expected to increase in the same proportion. This is because the maximum on-site exposure concentrations are expected to be dominated by the on-site sources. Hence, for the worker component of the resident/worker receptor, the exposure and associated risk remains the same and only the residential component increases by the amounts previously noted. The resulting exposure ratio (ER) values for the CEA scenario are presented in Table G12-4. Refer to Appendix XIII.2 for further details.

Table G12-4 Exposure Ratios (Sum ER) for Carcinogenic PAHs from all Emission Sources

Chemical/Group	Fort McKay		Fort McMurray		Fort Chipewyan	
	Child[e]	Adult[f]	Child[e]	Adult[f]	Child[e]	Adult[f]
Non-Carcinogens						
aldehydes[a]	1.6	4.7	0.47	3.9	0.16	3.7
ketones[b]	0.00022	0.00049	0.000066	0.00041	0.000022	0.00039
aliphatics	0.034	0.13	0.0046	0.11	0.0013	0.1
aromatics[c]	0.022	0.085	0.0021	0.072	0.00054	0.071
PAH non-carcinogenic[d]	0.000026	0.000058	0.0000079	0.000049	0.0000026	0.00046
Carcinogens						
formaldehyde	0.51	1.2	0.15	0.93	0.051	0.85
acetaldehyde	0.027	0.065	0.0094	0.058	0.0031	0.053
benzene	0.011	0.027	0.0033	0.021	0.0011	0.019
PAH carcinogenic[g]	0.0014	0.0034	0.00043	0.0026	0.00014	0.0024
Total Carcinogens[h]	0.55	1.3	0.16	1.0	0.055	0.92

(a) modelled as acrolein.
(b) modelled as acetone.
(c) excludes benzene.
(d) ER values for all non-carcinogenic PAHs.
(e) denotes a child of 5-11 years for non-carcinogens, and composite resident for carcinogens.
(f) denotes an adult who resides in community and works at mine site.
(g) ER value for all carcinogenic PAHs combined, using B(a)P toxicity equivalent factors.
(h) the sum of all carcinogen ERs.

The exposure ratios presented in Table G12-4 reflect the estimated increased exposure. The overall conclusions respecting these sources do not significantly differ from those of the Muskeg River Mine Project alone, as discussed previously in Section E12. The ER values are less than one for the child or composite receptor who receives all exposure from within the community. The ER values for aldehydes and total carcinogens are conservatively estimated to equal or marginally exceed 1 for residents who may also work on-site; however, this latter exposure is almost entirely due to the estimated worker component and is not reflective of the residential air quality. The worker exposure is also considered to be significantly conservative and may be less than estimated. It should be noted that acceptable exposure levels (occupational standards) are much higher for workers than the acceptable exposure levels for the general population.

These cumulative health risk estimates reflect exposure to combined air emissions of petroleum hydrocarbons and VOCs arising from mine fleet exhausts and fugitive emissions from mine surfaces and tailings settling ponds for baseline, approved and planned developments in addition to those of the Project. However, they do not include contributions from stack sources for these developments. The contribution from these sources has been estimated based on concentrations of benzo(a)pyrene measured at various locations in the RSA as explained in Section G2 Air Quality.

Following the same rationale previously described in Section F12.4.2, background exposure ratios (ERs) for total carcinogenic PAHs were predicted to be 17 times greater than the total PAH concentration from the vehicle fleet, tailings settling ponds and cut mine surfaces. The resulting ERs for carcinogenic PAHs for child and adult receptors are presented in Table G12-5.

Table G12-5 Exposure Ratios (Sum ER) for Carcinogenic PAHs from all Emission Sources

Fort McKay		Fort McMurray		Fort Chipewyan	
Child	**Adult**	**Child**	**Adult**	**Child**	**Adult**
0.024	0.058	0.0073	0.044	0.0024	0.041

Residual Impact Classification and Degree of Concern

The results indicate that even with the additional background emission sources, ER values are less than 1. Thus, no unacceptable impacts to human health are predicted for this scenario.

The predicted health risk from the estimated increased particulate matter arising from mine fleet exhaust has not been calculated in light of uncertainties surrounding such exposures (as previously noted in Section E12 Human Health). As a final note, airborne emissions of metals from stack sources of regional developments were not considered in the RDR, since the Muskeg River Mine Project is not a source of these emissions. Furthermore, pollution control technology employed in future upgrader stacks is expected to result in no net increase in airborne emissions from those sources.

Residual Impact Classification and Degree of Concern

In light of the foregoing conservative analysis, no unacceptable human health risks are predicted from changes in air quality arising from regional developments. Therefore the degree of concern is negligible.

Certainty

The assessment of potential impacts to human health from combined effects of airborne chemicals from the Muskeg River Mine and other baseline, approved and planned developments was based on a number of highly conservative assumptions inherent in the exposure analysis (described previously in Section E12 Human Health) and in the prediction of airborne chemical concentrations (described in Section G2 Air Quality Regional Development Review).

G12.3.3 Key Question HHRDR-3: Will Changes to Air and Water Quality From Combined Developments Affect Human Health?

Analysis of Key Question

Due to concerns regarding combined chemical exposures from different sources, incremental risk estimates (ER values) for water and air were summed, resulting in a total ER value for each chemical. Table G12-6 presents the total ER values resulting from combined exposures. Refer to Appendix HIII.2 for further details.

Table G12-6 indicates the total carcinogenic health risk is defined by an ER of 7.7 and 8.4 for composite receptors who are residents or residents/workers, respectively. While these exceed the common reference value of 1, it is noted that virtually all of the health risk is associated with background (i.e., naturally occurring) waterborne arsenic and beryllium rather than the mine activities. These latter substances are actually within Canadian Drinking Water Guidelines.

Table G12-6 Exposure Ratio Values for Children and Adults During Operation

Receptor/Chemical	Water	Air[h]	All Sources
Child[a]			
arsenic[b]	6.6	0	6.6
beryllium[b]	0.5	0	0.5
boron	0.008	0	0.008
cadmium	0.004	0	0.004
lead	0.003	0	0.003
molybdenum	0.002	0	0.002
vanadium	0.003	0	0.003
acetaldehyde [b]	0	0.027	0.027
aldehydes [c]	0	1.6	1.6
aliphatics	0	0.034	0.034
aromatic [e]	0	0.22	0.022
benzene [b]	0	0.011	0.011
formaldehyde [b]	0	0.51	0.51
ketones [d]	0	0.00022	0.00022
PAH carcinogenic [b]	0	0.024	0.024
PAH non-carcinogenic [f]	0	0.000026	0.000026
Total Carcinogenic	*7.1*	*0.57*	*7.67*
Adult-Worker [g]			
arsenic [b]	6.6	0	6.6
beryllium [b]	0.5	0	0.5
boron	0.003	0	0.003
cadmium	0.001	0	0.001
lead	0.0005	0	0.0005
molybdenum	0.0008	0	0.0008
vanadium	0.0009	0	0.0009
acetaldehyde	0	0.065	0.065
aldehydes [c]	0	4.7	4.7
aliphatics	0	0.13	0.13
aromatic [e]	0	0.085	0.085
benzene [b]	0	0.027	0.027
formaldehyde	0	1.2	1.2
ketones [d]	0	0.00049	0.00049
PAH non-carcinogenic[f]	0	0.000058	0.000058
PAH carcinogenic [b]	0	0.058	0.058
Total Carcinogenic[h]	*7.1*	*1.3*	*8.4*

(a) the ER values which follow are for a child, except for carcinogens where they apply to a composite resident receptor.
(b) denotes a substance with carcinogenic effects.
(c) aldehydes modelled as acrolein.
(d) ketones modelled as acetone.
(e) aromatics exclude benzene.
(f) refers to the sum ER for grouped non-carcinogenic PAHs.
(g) the ER values which follow are for an adult, except for carcinogens where they apply to a composite resident receptor who works at the mine site.
(h) ER values listed are for Fort McKay, the highest values of the three communities.

Residual Impact Classification and Degree of Concern

The residual impacts identified for the multi-media exposure RDR are the same as those predicted for the Project and the CEA. The current uncertainties associated with the chronic toxicity of naphthenic acids in waterborne emissions, as discussed previously, result in a residual impact and degree of concern, as summarized in Table G12-7.

Table G12-7 Residual Impact on Human Health From Multi-Media Exposure

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Low

Certainty

The points previously discussed concerning the certainty associated with cumulative effects to human health from changes to water and air quality also apply here.

G12.3.4 Key Question HHRDR-4: Will Changes to Plant and Game Meat Quality From Combined Developments Affect Human Health?

Analysis of Key Question

The results of the analysis of this key question in Section F12 are also applicable to the RDR. Increased air emissions from the regional developments may contribute to an increase in chemical concentrations in plant tissues. However, there are currently no data available to evaluate this question further.

Residual Impact Classification and Degree of Concern

The residual impact, as shown in Table G12-8, will likely be enhanced in the RDR relative to the impact predicted for the Project and the CEA. Hence, the degree of concern is considered to be Low.

Table G12-8 Residual Impact on Human Health From Changes to Plant and Game Meat Quality

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Low

G12.3.5 Key Question HHRDR-5: Will Equilibrium Concentrations of Residual Chemicals in Water and Select Local Food Items Following Reclamation of Combined Developments Affect Human Health?

Analysis of Key Question

The results of the analysis of this key question in Section F12 are also applicable to the regional scenario. As discussed in Section F12.7, chemical releases from multiple reclaimed landscapes within the region will not necessarily result in compounded exposures on any individual reclaimed area. Rather, due to the larger area of reclaimed landscapes in the Athabasca Oil Sands Region, there is a greater likelihood for a hypothetical hunter/trapper to live and hunt/trap in a reclaimed area, and therefore this exposure pathway becomes more likely, although the exposure parameters in this scenario are conservative.

Residual Impact Classification and Degree of Concern

While the magnitude of the impact is considered to be low, it is recognized that there is an increased likelihood on a regional basis for this exposure pathway to be realized. Therefore, the residual impact identified for the RDR is likely to be enhanced relative to the impact predicted for the Project and the impacts predicted in Section F12, since there is a greater likelihood of individuals being exposed. However the magnitude of exposure and associated health risks to a given individual are not expected to increase. Further data are necessary to substantiate these predictions. The residual impact and degree of concern is shown in Table G12-9.

Table G12-9 Residual Impact to Human Health From Residual Chemicals in Food Items Following Reclamation

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Moderate

G12.3.6 Key Question HHRDR-6: Will Noise From Combined Developments During Construction and Operation Unduly Affect People Who Reside in the Region?

Analysis of Key Question

The potential impact of noise on background and permissible noise levels in Fort McKay was discussed previously in section E12.11. The primary sources of noise from the Project operation are expected to be from the truck and shovel operations. It was inferred from other investigations that there is a good potential for elevated noise levels to result in Fort McKay and the likelihood will increase with the added contribution of the Syncrude Aurora North Mine. However, given the mobile nature of the noise sources and the ability to mitigate the noise levels through management of activities and/or use of noise barriers, the degree of concern was ranked as low.

In the present regional development review, the additional planned operations and noise sources other than truck and shovel activities (e.g., power house operations) will result in increased ambient noise. However, prediction of these levels and location is presently beyond the scope of this assessment due to lack of certainty in future developments at this time. Notwithstanding this uncertainty, the management of noise sources and mitigation of noise through use of natural barriers (e.g., treed areas, slopes) reduces the degree of concern associated with the impact.

Residual Impact Classification

The residual impacts identified for the RDR are not significantly different from those predicted for the Project and those predicted in Section F12, due to the mobile nature of noise sources, the ability to mitigate and the remoteness of several developments. In light of the above considerations the impact of ambient noise levels is shown in Table G12-10:

Table G12-10 Residual Impact on Human Health From Noise

Direction	Magnitude	Geographic Extent	Duration	Reversibility	Frequency	Degree of Concern
Negative	Low	Regional	Long-Term	Reversible	Medium	Low

G12.4 Summary of Impacts

Table G12-11 summarizes the predicted impacts and corresponding concern levels identified in the regional development review for human health.

Table G12-11 Summary of Predicted Impacts

Key Question	RDR Results
HHRDR-1: Will water quality changes from combined developments affect human health?	• During operation and closure, no significant health impacts were identified for human health; however there is some uncertainty regarding the chronic toxicity of naphthenic acids. The resulting impact prediction for the RDR is not significantly different from those predicted for the Muskeg River Project or those predicted in Section F12. The effects on human health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.
HHRDR-2: Will air quality changes from combined developments affect human health?	• During operation of the regional developments, no significant impacts were identified to human health from the following emission sources: mine fleet exhausts, fugitive emissions from tailings settling ponds, fugitive emissions from cut mine surfaces, and background sources of PAHs in residential communities. The degree of concern is **Negligible**.

Key Question	RDR Results
HHRDR-3: Will changes to air and water quality from combined developments affect human health?	• During operation, no significant impacts were identified for human health through this multimedia exposure pathway. However, there is some uncertainty regarding the chronic toxicity of naphthenic acids as discussed for HHCEA-1. • The effects on human health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low.**
HHRDR-4: Will changes to plant and game meat quality from combined developments affect human health?	• During operation and closure phases of the Muskeg River Mine Project, no significant impacts were identified for human health as a result of consumption of native plants or wild game. Increased air emissions predicted for the RDR scenario may contribute to an increase in chemical concentrations in plant tissues. A potential impact is therefore predicted for the RDR. Quantitative estimates of future plant tissue concentrations are unavailable to quantify the impact further. The effects on human health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.
HHRDR-5: Will equilibrium concentrations of residual chemicals in water and select local food items following reclamation of all developments affect human health?	• Following closure in the far future when equilibrium conditions have been established for all combined developments, a potential impact has been identified in the RDR. The residual impact is likely to be enhanced in the RDR, relative to the impact predicted for the Muskeg River Mine Project and those predicted in Section F12, in so far as there is a greater likelihood on a regional basis for this exposure pathway to be realized, but likely without an increase in exposure magnitude. The effects on human health will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Moderate.**
HHRDR-6: Will noise from combined developments during construction and operation unduly affect people who reside in the region?	• During construction and operation, truck and shovel operations of combined developments may cause periodic exceedances of permissible sound levels in Fort McKay. The residual impacts identified in the RDR are not significantly different from those predicted for the Muskeg River Mine Project and those predicted in Section F12, due to the mobile nature of noise sources, the ability to mitigate and the remoteness of several developments to Fort McKay. The effects will be Negative in direction, Low in magnitude, Regional in geographic extent, Long-Term in duration, Reversible and of Medium frequency. The degree of concern is **Low**.

G13 HISTORICAL RESOURCES REGIONAL DEVELOPMENT REVIEW

As discussed in Section F13, the assessment of development impacts on historical resources is best dealt with on a development-specific basis.

Section E13 provides a detailed review of the impacts of the Muskeg River Mine Project on historical resources.

G14 RESOURCE USE REGIONAL DEVELOPMENT REVIEW

G14.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and planned (publicly disclosed) developments on land resource use in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Petro-Canada MacKay River
- JACOS Hangingstone
- Forestry
- Pipelines, utility corridors and roadways
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Suncor Project Millennium
- Syncrude Upgrader
- Mobil Kearl Mine and Upgrader
- Gulf Surmont
- Municipalities

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

G14.2 Potential Linkages and Key Questions

The key questions and linkages detailed in Section F14 also apply to the RDR. The key questions for the land resource use RDR include:

RURDR-1: Will Combined Developments Result in a Change in Surface and Mineral Extraction Use?

RURDR-2: Will Combined Developments Result in a Change in ESAs?

RURDR-3: Will Combined Developments Result in a Change in Forestry Resource Use?

RURDR-4: Will Combined Development Result in a Change in Hunting, Trapping, Fishing and Berry Picking?

RURDR-5: Will Combined Developments Result in a Change in Non-Consumptive Recreational Use?

G14.3 Analysis and Results

Developments will be phased over time. As well, each reclamation associated with forestry and oil sands activities will reduce the magnitude of impacts. In most cases, reclamation activities will enhance land resource use (e.g., forestry, berry picking, hunting).

G14.3.1 Key Question RURDR-1: Will Combined Developments Result in a Change in Surface and Mineral Extraction Use?

No effects were identified for the Project in the RDR over those discussed in Section F14.

G14.3.2 Key Question RURDR-2: Will Combined Developments Result in a Change in ESAs?

Analysis of Key Question

There are a variety of ESAs within the RSA. To the extent possible, ESAs were considered during Project development and attempts to minimize impacts, including avoiding these areas whenever possible, were implemented where possible. As well, mitigation measures such as reducing the total area cleared, maintaining native vegetation for cover, and maintaining adequate buffer zones around rivers, lakes and other sensitive areas, further reduces impacts to ESAs. Kearl Lake, which provides habitat for waterfowl, moose and rare plants, may be affected by the Aurora South Mine, Mobil Kearl Mine, Shell Lease 13 East Mine and the Project.

Residual Impact Classification

The Kearl Lake wildlife movement corridor may be affected by changes in terrain, vegetation and wildlife or changes in access. Provided that appropriate mitigation measures are used to further minimize impacts, the impacts associated with the various developments on ESAs will be minor. The degree of magnitude is Low and the duration is of Medium to Long-Term. The degree of concern is Low.

G14.3.3 Key Question RURDR-3: Will Combined Developments Result in a Change in Forestry Resource Use?

Analysis of Key Question

Activities that may have an effect on merchantable forests include oil sands mining, the City of Fort McMurray and various other developments. These activities may result in the loss of merchantable timber habitat and changes in access. Loss of merchantable timber may be minimized to some extent in that merchantable timber will be salvaged during site clearing. However, once sites are developed, the footprint area is lost until closure and subsequent site reclamation. At that point, reforestation activities must occur. The entire process from site clearing through to reclamation and tree regeneration may take a long time.

The merchantable forest land area within the RSA consists of the vegetation communities within the following vegetation types:

- Jack Pine Forest
- Mixedwood Forest
- Spruce Forest
- Aspen Poplar Forest
- Paper Birch Forest

These vegetation units encompass an area of 300,000 ha. Approximately 30% of the RSA consists of merchantable timber. The greatest impact to the area of merchantable forest will be from timber harvesting. Alberta Pacific Forest Industries and Northland Forest Products will harvest close to 71,000 ha (or 14%) of the RSA in the next 30 years (BOVAR 1996a).

The Annual Allowable Cut (AAC) for the Alberta Pacific Forest Industries Forest Management Agreement (FMA) is 3,091,000 m^3/year, and the AAC for Northland Forest Products is 210,200 m^3/year (BOVAR 1996a). The combined total AAC volume is 3,301,200 m^3/year. Annual average timber salvage from the Suncor Steepbank Mine and the proposed SOLV-EX facility is less than 1% of the combined AAC (BOVAR 1996a). It is expected that the annual salvage of timber from the various projects will vary, but should be less than <2% of the Alberta-Pacific's FMA and Northland Forest Products combined wood supply. Thus, timber salvage from the various developments and proposed developments in the area represents only a small percentage of the total AAC.

The loss of potential productive forest for timber harvest under the RDR, as shown in Table G9-1, is 34,163 ha (3.2%). Following reclamation, an additional 18,658 ha of productive forest will be created, resulting in a total of 312,011 ha or 28.9% of the RSA.

Residual Impact Classification and Degree of Concern

Some areas of merchantable timber will be lost due to development. However, reclamation will result in an increase of productive forests. Therefore, the net effect is Positive.

G14.3.4 Key Question RURDR-4: Will Combined Developments Result in a Change in Hunting, Trapping, Fishing and Berry Picking?

Analysis of Key Question

Existing and new developments within the RSA have the potential to disturb vegetation through loss of habitat and/or contamination. Loss of important berry producing shrubs and changes in access may affect recreational berry picking. Important berry picking sites include the Muskeg River Valley. Berry picking along the Muskeg River Valley may be affected by Shell Lease 13 East, the Project, Aurora Mines and the Mobil Kearl Mine.

Some berry picking areas may be permanently lost due to changes in vegetation and/or changes in access. However, sites lost due to development can be subsequently reclaimed. Revegetation during reclamation can be focused toward vegetation species which have traditional and non-traditional medicinal, dietary, ritual, utensil and dye uses.

There will be a decrease in berry picking activities due to loss of berry picking habitat and restricted access. There are no mitigation measures for site clearing and restricted access. Following closure, however, important berry picking habitat can be restored by careful restoration of the site, and many disturbed sites can be returned to equivalent or greater capability. The effects of the development of various projects on berry picking is expected to be of Low magnitude and of Medium duration. The degree of concern is Low.

Important hunting locations within the RSA include the Athabasca River Valley. Construction and operation of various developments may reduce hunting opportunities through changes in wildlife abundance and distribution, and changes in access. It is expected that these hunting opportunities will be lost during the life of the developments. However, hunting opportunities may actually improve following site reclamation and closure. In addition, improved access following site closure may also lead to increases in hunting opportunities.

A small proportion of hunting sites will be lost due to changes in access and changes in wildlife abundance and distribution. These impacts cannot be mitigated. However, hunting opportunities throughout the RSA are numerous. Thus, the impact is of Low magnitude and Medium to Long-Term in duration. The degree of concern is Low.

Registered fur management areas (RFMAs) within the RSA were identified in D14 and are presented in Table G14-6. Changes in wildlife abundance and diversity and changes in access may reduce trapping opportunities in the RSA, and there are several traplines which may be affected (see Section D14.3.6). In particular, trapping opportunities will be reduced during construction and operation of developments. However, following site reclamation and closure, trapping opportunities may actually improve, especially with improved access. There are 4 RFMAs which may be affected by various developments; including the Project, Aurora North and South, and SOLV-EX.

Some trapping areas may be lost as a result of development (i.e., site clearing and restricted access). This impact cannot be mitigated. However, the loss in trapping opportunities should only exist during the life of the project under consideration. As well, trappers can be reimbursed for the loss of revenue. The cumulative effects on trapping is expected to be of Low magnitude and of Medium to Long-Term duration.

Preferred fishing locations include the Athabasca and Muskeg rivers. Fishing on these rivers may be affected by Al-Pac, Suncor Steepbank, Suncor Lease 86/17, the Project, Aurora Mines and SOLV-EX.

Within the RSA, fish habitat may be altered as part of development. This, in turn, reduces fishing opportunities. As with other developments, restricted access during construction and operations may also reduce fishing opportunities. Reclamation and closure of developments improves fishing opportunities, especially through improved access.

Approvals for most developments include very stringent water quality and fish habitat guidelines. As well, significant measures are often undertaken to minimize impact. Thus, sport fish abundance and distribution is not expected to change as a result of development activities. Following closure, sport fish habitat may be enhanced through the creation of lakes, ponds and drainages. As well, access to important sport fishing locations is expected to improve.

Some fishing opportunities will be lost due to development. In particular, restricted access will lead to reduced fishing opportunities, and this impact cannot be mitigated. The effects of developments within the RSA is expected to be of low magnitude and of Medium to Long-Term duration. The degree of concern is Low.

G14.3.5 Key Question RURDR-5: Will Combined Developments Result in a Change in Non-Consumptive Recreational Use?

Analysis of Key Question

Non-consumptive recreational uses include camping, hiking, boating, wildlife viewing, and snowmobiling. Important recreational areas for these activities were presented in Section D14.3.8. The list includes the Athabasca and Muskeg rivers which may be affected by the Project, Al-Pac, SOLV-EX, Aurora Mines, Suncor Lease 86/17, Suncor Steepbank, Shell Lease 13 East, Mobil Kearl Mine, cutblocks and municipalities.

Changes in access and changes in terrain, vegetation and wildlife due to development may reduce recreational opportunities within the RSA. However, since many of the recreational areas include ESAs, and recreational sites are numerous and scattered throughout the RSA, the effects of various developments is expected to be low.

Residual Impact Classification

A small amount of potential recreational areas is expected to be lost due to the effects of various developments. Loss will mostly result from changes in access and changes in terrain, vegetation, and wildlife. However, potential recreational sites in the RSA are numerous, thus the overall effect is expected to be Low in magnitude and Medium to Long-Term in duration.

G14.4 Summary of Impact

Table G14-1 summarizes the impact to Resource Use under the RDR.

Table G14-1 Summary of Impacts on Resource Use

Key Question	RDR Results
RURDR-1: Will Combined Development Result in a Change in Surface and Mineral Extraction Use?	• No effects were identified for the Project in the RDR over those discussed in Section F14. The degree of concern is **Moderate**.
RURDR-2: Will Combined Developments Result in a Change in ESAs?	• The Kearl Lake wildlife movement corridor may be affected by changes in terrain, vegetation and wildlife or changes in access. Provided that appropriate mitigation measures are used to further minimize impacts, the impacts associated with the various developments on ESAs will be minor. The degree of magnitude is Low and the duration is of Medium to Long-Term. The degree of concern is **Low**.
RURDR-3: Will Combined Developments Result in a Change in Forestry Resource Use?	• Some areas of merchantable timber will be lost due to development. However, reclamation will result in an increase in productive forest. Therefore, the net result is Positive.
RURDR-4: Will Combined Developments Result in a Change in Hunting, Trapping, Fishing and Berry Picking?	• A small proportion of hunting sites will be lost due to changes in access and changes in wildlife abundance and distribution. These impacts cannot be mitigated. However, hunting opportunities throughout the RSA are numerous. Thus, the impact is of Low magnitude and Medium to Long-Term in duration. The degree of concern is **Low**. • There will be a decrease in berry picking activities due to loss of berry picking habitat and restricted access. There are no mitigation measures for site clearing and restricted access. Following closure, however, important berry picking habitat can be restored by careful restoration of the site, and many disturbed sites can be returned to equivalent or greater capability. The effects of the development of various projects on berry picking is expected to be of Low magnitude and of Medium duration. The degree of concern is **Low**. • Some trapping areas may be lost as a result of project development (i.e., site clearing and restricted access). This impact cannot be mitigated. However, the loss in trapping opportunities should only exist during the life of the project under consideration. As well, trappers can be reimbursed for the loss of revenue. The cumulative effects on trapping is expected to be of Low magnitude and of varying duration. The degree of concern is **Low**. • Some fishing opportunities will be lost due to development of projects. In particular, restricted access will lead to reduced fishing opportunities, and this

Key Question	RDR Results
	impact cannot be mitigated. Cumulative effects of developments within the RSA is expected to be of Low magnitude and of Medium to Long-Term duration. The degree of concern is **Low**.
RURDR-5: Will Combined Developments Result in a Change in Non-Consumptive Recreational Use?	• A small amount of potential recreational areas is expected to be lost due to the cumulative effects of various developments. Loss will mostly result from changes in access and changes in terrain, vegetation, and wildlife. However, potential recreational sites in the RSA are numerous, thus the overall effect is expected to be Low in magnitude and Medium to Long-Term in duration. The degree of concern is **Low**.

G15 TRADITIONAL LAND USE REGIONAL DEVELOPMENT REVIEW

G15.1 Introduction

This regional development review (RDR) predicts the effects of the Muskeg River Mine Project (Project) plus existing, approved and publicly disclosed developments on traditional land use in the Regional Study Area (RSA). The following developments, as shown in Figure G1-1, are included in the RDR:

- Suncor Lease 86/17
- Suncor Steepbank Mine
- SOLV-EX
- Muskeg River Mine Project
- Shell Lease 13 East
- Petro-Canada MacKay River
- Municipalities
- Syncrude Mildred Lake
- Gibsons Petroleum
- Syncrude Aurora North and South
- Suncor Project Millennium
- Syncrude Project 21 Upgrader
- Forestry
- Pipelines, utility corridors and roadways

Descriptions of these developments and the assumptions applicable to each for this RDR are detailed in Section G1.

G15.2 Potential Linkages and Key Questions

The linkage diagrams for Project activities and potential changes in traditional land use associated with the Project, as discussed in Section E15, are valid for the RDR. One key question applies for the RDR of traditional land use.

TLURDR-1: Will Combined Developments Result in a Change in Traditional Land Use?

G15.3 Analysis and Results

G15.3.1 Key Question TLURDR-1: Will Combined Developments Result in a Change in Traditional Land Use?

Analysis of Key Question

Table G15-1 provides quantitative information relating to the overall size of the planned developments in combination with the areas encompassed by the Project, and the existing and approved developments in the RSA. These areas are compared with the area encompassed by the Traditional Hunting and Trapping territory of the Fort McKay communities (Communities) as defined in a document entitled 'From Where We Stand'

(Fort McKay Tribal Administration 1982, Figure 2). Figure G15-1 illustrates most of this area. This comparison indicates that approximately 11.2% of the lands considered to be the traditional use area of the Fort McKay Communities might be directly affected by the combined developments.

The developments included in this comparison are those listed in Table G1-1. These areas, including the traditional land use base as defined above, are illustrated in Figure G15-2.

Table G15-1 Areas of Existing, Approved and Planned Developments in the Regional Study Area

Existing and Approved Developments + Muskeg River Mine Project [(a)]	Area (km^2)	Publicly Disclosed Developments	Area (km^2)
Existing Developments	540.6	Shell Lease 13 East	72.2
Approved Developments[(b)]	1498.6	Suncor Project Millennium	54.4
Muskeg River Mine Project[(b)]	100.4	Mobil Kearl Mine	53.4
		Petro-Canada MacKay River	0.3
Total	2,139.6	Total	180.4
TOTAL - Existing, Approved, Muskeg River Mine Project and Planned Developments			**2,320.0**
Percentage of the Total Development Area compared with the Fort McKay Communities Traditional Use Lands (20,669 km^2)			11.2%

(a) From Table F15-1

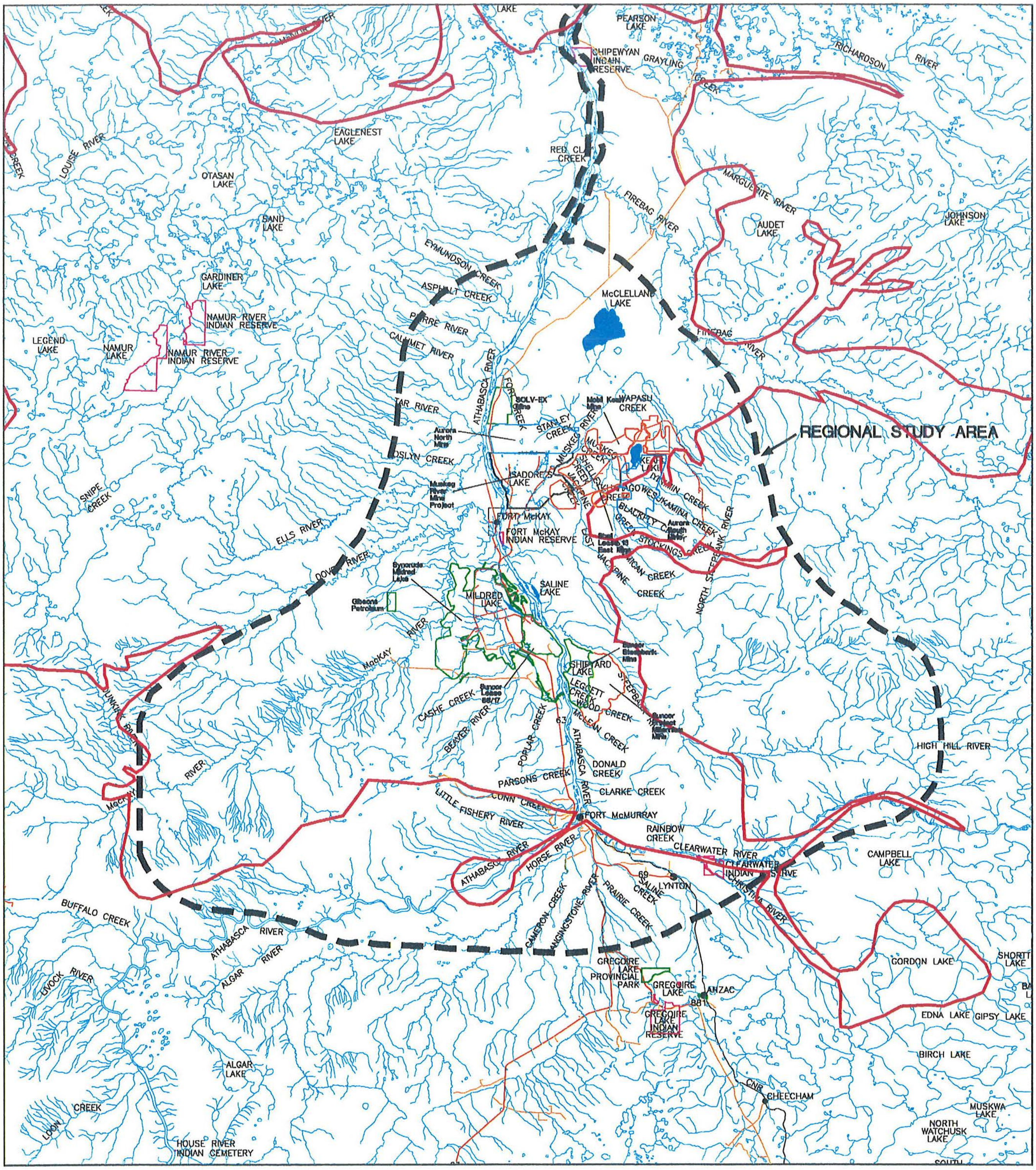
(b) Numbers represent total lease areas because of the assumption that access limitations are greater than development footprints.

The general effects of the oil sands developments and their auxiliary facilities are discussed briefly in Section F15 and are not repeated here. Traditional land use practices will not be possible during development and operations stages. Their re-institution after closure will depend on the nature of the reclamation procedures implemented, as well as the results of reclamation programs.

The values for existing developments include approved forestry developments after 1997, but only for the RSA defined for the Project. Outside this area, long term forestry developments will affect large portions of the traditional lands of the Communities.

Furthermore, the areas listed in Table G15-1 represent maximum disturbance zones. Development and reclamation activities within these areas will be staged, such that only portions of each will be disturbed at any one time, and reclaimed areas may be available for Traditional Land Use at other stages in the development plans.

In addition, these values do not consider the wide ranging but difficult to predict effects of increased non-traditional use of these lands. These non-traditional uses, which typically accompany developments, frequently compete with traditional uses.



LEGEND

- TRADITIONAL HUNTING AND TRAPPING TERRITORY
- EXISTING OPERATIONS
- APPROVED PROJECTS
- DISCLOSED PROJECTS
- MUSKEG RIVER MINE PROJECT

REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

0 10 20 30 40 50km

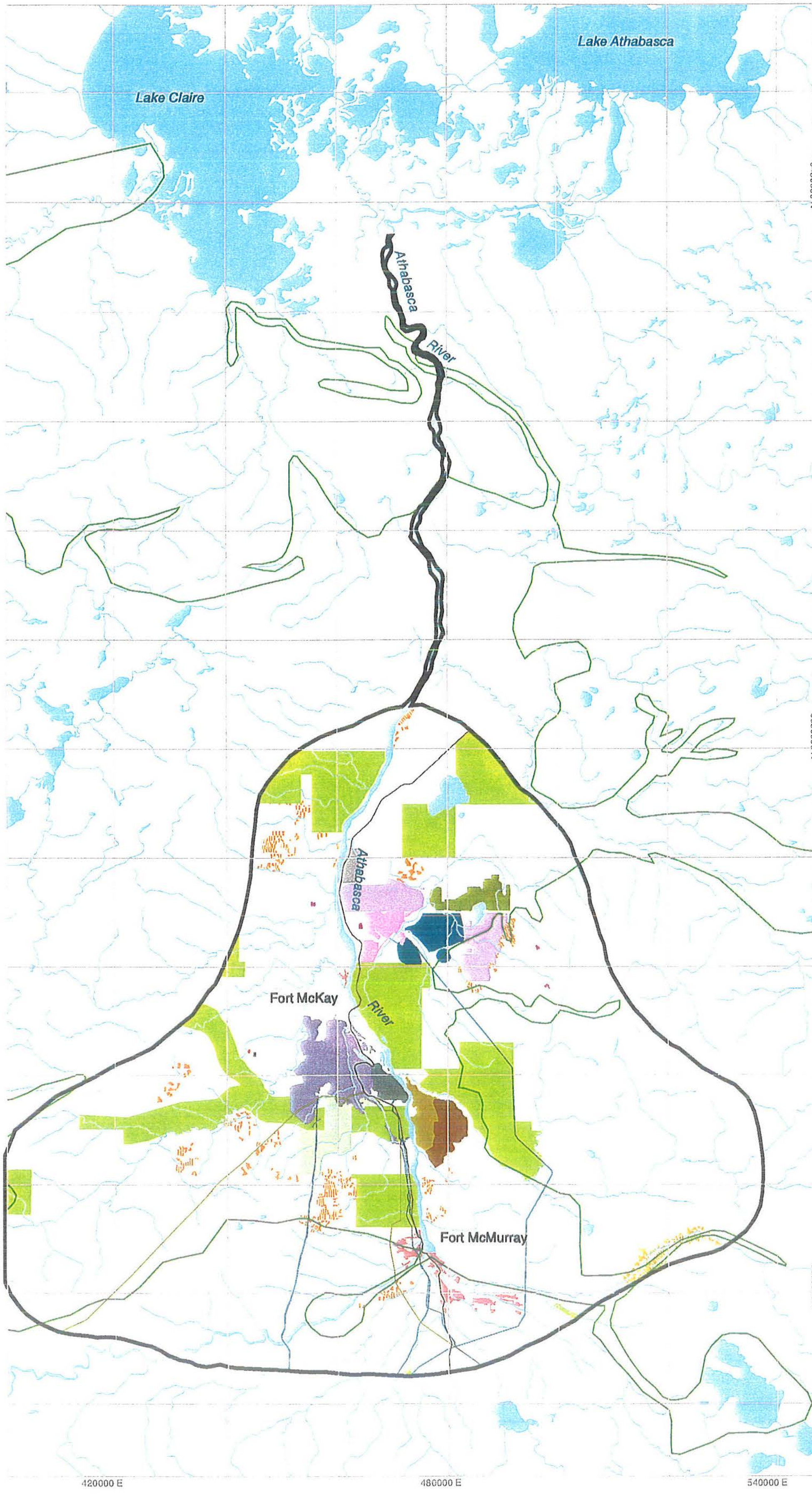
SCALE 1:1,000,000

Golder Associates

SHELL CANADA LIMITED

AREA OF TRADTIONAL HUNTING (After "FROM WHERE WE STAND" 1983)

15 JAN 98	Figure G15-1	DRAWN BY: CG



LEGEND

- Regional Study Boundary
- Traditional Land Use
- Highway
- Pipelines
- Powerlines
- Hydrology
- Cutblocks (recent)
- Cutblocks (reforested)
- Suncor Lease 86/17
- Syncrude Mildred Lake
- Other Oil Sands Developments
- Gibsons Petroleum
- Al-Pac Forest Management Zones after 1997
- SOLV-EX
- Shell Lease 13 East
- Muskeg River Mine Project
- Suncor Steepbank Mine
- Suncor Millennium Mine
- Al-Pac Forest Management Zones to 1997
- Petro-Canada
- Mobil Kearl Mine
- Aurora Mines
- Municipalities

5 0 5 10 15 20 25
Kilometres

SOURCE: Alpac, Conor Pacific, Fort McKay tribal Administration, Golder Associates Ltd., Mobil, Petro-Canada, RADARSAT International, Suncor, Syncrude, Norwest

MAP PROJECTION: UTM
Zone 12
NAD 83 (GRS 1980)

Golder Associates

SHELL CANADA LIMITED

REGIONAL STUDY AREA
FORT MCKAY NATIONS TRADITIONAL LANDS
REGIONAL DEVELOPMENT REVIEW

10 Jan. 1998	Figure G15-2	PRODUCED BY: K. Quine REVIEWED BY:

In summary, the effects of planned developments within the area encompassed by the Traditional Lands of the Communities, in combination with the Project and other existing and approved developments, will be varied in magnitude and geographic extent. The existing and approved developments considered for the CEA account for 92% of the lands considered for the RDR.

The duration of these effects will also vary depending on the lifespan of project operation. However it may be possible to reverse the negative effects of the these combined developments or even enhance the opportunities for continued traditional land use through appropriate closure planning and reclamation activities, for energy developments, and through consultation and cooperative planning in regard to forestry developments.

Residual Impact Classification

Residual impacts of the Project in combination with planned, existing and approved developments are the same as discussed in Section F15.2.

G15.4 Summary of Impacts

Table G15-2 summarizes the results of the RDR assessment for traditional land use.

Table G15-2 Summary of RDR on Traditional Land Uses for Existing, Approved, Planned and Muskeg River Mine Project Developments

Key Question	RDR results
TLURDR-1: Will combined developments result in a change in traditional land use?	• The summary of the effects of various development types on the traditional land use practices of the Communities is the same as provided in Table F15-3 The one change is that, in this scenario, oil sands development would affect a slightly higher proportion of the Communities' traditional lands. This increase would be Negative in direction but would not alter the Low magnitude classification applied to these effects as detailed in Table F15-3. The increase would extend the duration of these effects,but they would still be considered of Medium-Term. These effects would be Reversible. The degree of concern is **Low.**

APPENDIX XII

SURFACE WATER QUALITY MODELLING RESULTS FOR THE CUMULATIVE EFFECTS ASSESSMENT (CEA) AND REGIONAL DEVELOPMENT REVIEW (RDR)

XII-1 SURFACE WATER QUALITY MODELLING RESULTS FOR THE CUMULATIVE EFFECTS ASSESSMENT (CEA) AND REGIONAL DEVELOPMENT REVIEW (RDR)

XII-1.1 Water Quality Screening Assumptions

XII-1.1.1 Decay Rates

Decay rates used are as follows:

Substance	Seepage (1/yr)	Wetlands (1/yr)
benzo(a)anthracene	0.0013	0.54
benzo(a)pyrene	0.0017	0.70
acute toxicity	0.0065	2.43
chronic toxicity	-	2.43

XII-1.1.2 Model Configuration

Three of the water quality models described in Section E5 (i.e., end pit lake, small streams and Athabasca River models) were expanded to incorporate water flows associated with the additional mining operations included in the CEA and RDR. Modelling nodes for the CEA and RDR are shown in Figures XII-1 and XII-2, respectively. Figures XII-3 to XII-6 illustrate the water flows associated with each model node.

XII-1.2 Temperature Model

The temperature model was re-run to predict temperature changes in the Muskeg River due to water releases from the combined developments selected for the CEA and RDR. Flow data presented in Sections F4 (Surface Water Hydrology CEA) and G4 (Surface Water Hydrology RDR) were used for the CEA and RDR temperature modelling, respectively.

XII-1.3 Water Quality Modelling Results

XII-1.3.1 Muskeg River

Tables XII-1 to XII-4 summarize projected water quality in the Muskeg River during mean open water and annual 7Q10 flows for the CEA. Tables XII-9 and XII-10 describe Muskeg River water quality during the same flow conditions for the RDR.

XII-1.3.2 Athabasca River

Tables XII-5 to XII-8 summarize projected water quality in the Athabasca River during mean open water and annual 7Q10 flows for the CEA. Tables XII-9 and XII-10 describe Athabasca River water quality during the same flow conditions for the RDR. Figures XII-7 to XII-15 and Figures XII-16 to XII-24 illustrate dilution plumes in the Athabasca River for selected substances and toxic units for the CEA and RDR, respectively.

Table XII - 1 **Assessment of Water Quality in the Muskeg River During Annual 7Q10 Flow Conditions (CEA - Approved Developments)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.5	C	0.4	C	0.5	C	1.1	C
Ammonia - Total	0.9		0.9		0.9		1.8	
Antimony - Total	4.8E-04		4.1E-04		4.4E-04		2.6E-04	
Arsenic - Total	0.019	C	0.016	C	0.018	C	0.003	
Barium - Total	0.2		0.2		0.2		0.1	
Benzo(a)anthracene grp	0	-	0	-	0	-	6.3E-04	
Benzo(a)pyrene grp	0	-	0	-	0	-	7.7E-05	
Beryllium-Total	9.5E-04		8.2E-04		8.9E-04		2.4E-03	
Boron - Total	0.04		0.04		0.04		1.96	C
Cadmium - Total	2.8E-05		1.1E-04		6.8E-05		4.0E-03	C
Calcium	104	n.g.	100	n.g.	102	n.g.	83	n.g.
Chloride	0.3		1.0		0.6		23.4	
Chromium - Total	0.022	A C	0.020	A C	0.021	A C	0.005	
Conductivity	608	n.g.	590	n.g.	598	n.g.	2275	n.g.
Copper - Total	0.010	C	0.009	C	0.009	C	0.008	C
Dissolved Organic Carbon	11.3	n.g.	12.5	n.g.	11.9	n.g.	43.5	n.g.
Iron - Total	5.9	C	5.5	C	5.7	C	2.1	C
Lead - Total	0.002		0.002		0.002		0.003	
Lithium-Total	0.008		0.009		0.008		0.139	
Magnesium	13.2	n.g.	13.7	n.g.	13.5	n.g.	24.6	n.g.
Manganese - Total	0.8	C	0.8	C	0.8	C	0.2	C
Mercury - Total	4.6E-06		1.8E-05	C	1.1E-05		1.8E-05	C
Molybdenum - Total	2.9E-03		2.5E-03		2.7E-03		2.2E-01	
Naphthenic Acids	0	-	0	-	0	-	8.3	n.g.
Nickel - Total	0.0001		0.0002		0.0001		0.0045	
Phenolics - Total	0	-	0	-	0	-	0.005	
Selenium - Total	0.01		0.01		0.01		6.8E-04	
Silver - Total	0	-	0	-	0	-	2.9E-04	
Sodium	6.2	n.g.	7.3	n.g.	6.8	n.g.	526	n.g.
Strontium	0.2	n.g.	0.2	n.g.	0.2	n.g.	0.5	n.g.
Sulphate	3.2	n.g.	3.5	n.g.	3.3	n.g.	336	n.g.
Total Dissolved Solids	333	n.g.	329	n.g.	330	n.g.	1047	n.g.
Total PAHs	0	-	0	-	0	-	0.005	n.g.
Toxicity - acute	0	-	0	-	0	-	0.28	
Toxicity - chronic	0	-	0	-	0	-	0.74	
Vanadium - Total	0.005		0.004		0.004		0.032	
Zinc - Total	0.20	A C	0.17	C	0.18	C	0.06	

C = Chronic, A = Acute, n.g.=no guideline

Table XII - 2 **Assessment of Water Quality in the Muskeg River During Mean Open Water Flow Conditions (CEA - Approved Developments)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.12	C	0.07		0.08		0.11	C
Ammonia - Total	0.18		0.09		0.10		0.14	
Antimony - Total	7.3E-05		2.1E-05		3.0E-05		1.5E-05	
Arsenic - Total	0.005	HC	0.004	HC	0.004	HC	0.003	HC
Barium - Total	0.05		0.03		0.04		0.03	
Benzo(a)anthracene grp	0	-	0	-	0	-	3.6E-05	HC
Benzo(a)pyrene grp	0	-	0	-	0	-	4.4E-06	HC
Beryllium-Total	1.5E-04		4.2E-05		6.1E-05		1.4E-04	
Boron - Total	0.04		0.04		0.04		0.15	
Cadmium - Total	0.0002		0.0002		0.0002		0.0004	
Calcium	48.3	n.g.	41.2	n.g.	42.5	n.g.	40.7	n.g.
Chloride	2.7		3.0		2.9		4.3	
Chromium - Total	0.0037		0.0013		0.0018		0.0007	
Conductivity	321	n.g.	286	n.g.	292	n.g.	385	n.g.
Copper - Total	0.002		0.001		0.001		0.001	
Dissolved Organic Carbon	20.4	n.g.	21.6	n.g.	21.4	n.g.	23.3	n.g.
Iron - Total	1.6	C HNC	1.0	C HNC	1.1	C HNC	0.9	C HNC
Lead - Total	0.0006		0.0005		0.0005		0.0005	
Lithium-Total	0.006		0.006		0.006		0.014	
Magnesium	10.1	n.g.	9.7	n.g.	9.8	n.g.	10.4	n.g.
Manganese - Total	0.15	C HNC	0.07	C HNC	0.09	C HNC	0.05	
Mercury - Total	8.5E-05	C	9.6E-05	C	9.4E-05	C	9.5E-05	C
Molybdenum - Total	6.1E-04		3.2E-04		3.7E-04		1.3E-02	
Naphthenic Acids	3.4	n.g.	3.8	n.g.	3.8	n.g.	4.3	n.g.
Nickel - Total	0.0003		0.0004		0.0004		0.0006	
Phenolics - Total	0	-	0	-	0	-	0.0003	
Selenium - Total	0.0017		0.0005		0.0007		3.9E-05	
Silver - Total	0	-	0	-	0	-	1.7E-05	
Sodium	9.7	n.g.	10.2	n.g.	10.1	n.g.	39.8	n.g.
Strontium	0.08	n.g.	0.06	n.g.	0.07	n.g.	0.09	n.g.
Sulphate	4.3	n.g.	4.5	n.g.	4.4	n.g.	23.5	n.g.
Total Dissolved Solids	195	n.g.	179	n.g.	182	n.g.	221	n.g.
Total PAHs	0	-	0	-	0	-	0.0003	n.g.
Toxicity - acute	0	-	0	-	0	-	0.02	
Toxicity - chronic	0	-	0	-	0	-	0.04	
Vanadium - Total	0.001		0.001		0.001		0.002	
Zinc - Total	0.04		0.02		0.02		0.01	

C = Chronic, A = Acute, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen, n.g.=no guideline

Table XII - 3 **Assessment of Water Quality in the Muskeg River During Annual 7Q10 Flow Conditions (CEA - Approved Developments + Project)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.5	C	0.4	C	0.5	C	1.1	C
Ammonia - Total	0.9		0.9		0.9		1.7	
Antimony - Total	4.8E-04		4.1E-04		4.4E-04		2.5E-04	
Arsenic - Total	0.019	C	0.017	C	0.018	C	0.003	
Barium - Total	0.2		0.2		0.2		0.1	
Benzo(a)anthracene grp	0	-	0	-	0	-	6.3E-04	
Benzo(a)pyrene grp	0	-	0	-	0	-	7.4E-05	
Beryllium-Total	9.5E-04		8.3E-04		8.8E-04		2.3E-03	
Boron - Total	0.04		0.04		0.04		1.95	C
Cadmium - Total	2.7E-05		1.0E-04		7.2E-05		4.0E-03	C
Calcium	104	n.g.	100	n.g.	102	n.g.	82	n.g.
Chloride	0.3		1.0		0.7		22.9	
Chromium - Total	0.022	A C	0.020	A C	0.021	A C	0.005	
Conductivity	608	n.g.	590	n.g.	598	n.g.	2282	n.g.
Copper - Total	0.010	C	0.009	C	0.009	C	0.008	C
Dissolved Organic Carbon	11.3	n.g.	12.5	n.g.	12.0	n.g.	43.3	n.g.
Iron - Total	6.0	C	5.5	C	5.7	C	2.1	C
Lead - Total	0.002		0.002		0.002		0.003	
Lithium-Total	0.008		0.009		0.008		0.138	
Magnesium	13.2	n.g.	13.7	n.g.	13.5	n.g.	24.6	n.g.
Manganese - Total	0.8	C	0.8	C	0.8	C	0.2	C
Mercury - Total	4.6E-06		1.7E-05	C	1.2E-05		1.7E-05	C
Molybdenum - Total	2.9E-03		2.5E-03		2.6E-03		2.1E-01	
Naphthenic Acids	0	-	0	-	0	-	8.1	n.g.
Nickel - Total	0.0001		0.0002		0.0002		0.0042	
Phenolics - Total	0	-	0	-	0	-	0.005	
Selenium - Total	0.01		0.01		0.01		6.4E-04	
Silver - Total	0	-	0	-	0	-	2.7E-04	
Sodium	6.2	n.g.	7.3	n.g.	6.8	n.g.	528	n.g.
Strontium	0.2	n.g.	0.2	n.g.	0.2	n.g.	0.5	n.g.
Sulphate	3.2	n.g.	3.4	n.g.	3.3	n.g.	326	n.g.
Total Dissolved Solids	333	n.g.	329	n.g.	330	n.g.	1041	n.g.
Total PAHs	0	-	0	-	0	-	0.005	n.g.
Toxicity - acute	0	-	0	-	0	-	0.27	
Toxicity - chronic	0	-	0	-	0	-	0.73	
Vanadium - Total	0.005		0.004		0.004		0.031	
Zinc - Total	0.20	A C	0.17	C	0.18	C	0.06	

C = Chronic, A = Acute, n.g.=no guideline

Table XII - 4 **Assessment of Water Quality in the Muskeg River During Mean Open Water Flow Conditions (CEA - Approved Developments + Project)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.12	C	0.07		0.25	C	0.12	C
Ammonia - Total	0.18		0.09		0.11		0.14	
Antimony - Total	7.6E-05		2.3E-05		1.3E-04		1.5E-05	
Arsenic - Total	0.005	HC	0.004	HC	0.004	HC	0.003	HC
Barium - Total	0.05		0.03		0.05		0.03	
Benzo(a)anthracene grp	0	-	0	-	1.8E-05	HC	3.7E-05	HC
Benzo(a)pyrene grp	0	-	0	-	3.8E-06	HC	4.4E-06	HC
Beryllium-Total	1.5E-04		4.7E-05		5.2E-04		1.4E-04	
Boron - Total	0.04		0.04		0.36		0.16	
Cadmium - Total	0.0002		0.0002		0.0008		0.0004	
Calcium	48.6	n.g.	41.6	n.g.	50.2	n.g.	40.9	n.g.
Chloride	2.7		3.0		7.7		4.3	
Chromium - Total	0.0038		0.0015		0.0032		0.0007	
Conductivity	323	n.g.	287	n.g.	484	n.g.	391	n.g.
Copper - Total	0.002		0.001		0.003		0.001	
Dissolved Organic Carbon	20.4	n.g.	21.5	n.g.	25.8	n.g.	23.3	n.g.
Iron - Total	1.6	C HNC	1.0	C HNC	1.2	C HNC	0.9	C HNC
Lead - Total	0.0006		0.0005		0.0018		0.0006	
Lithium-Total	0.006		0.006		0.024		0.014	
Magnesium	10.1	n.g.	9.7	n.g.	11.3	n.g.	10.4	n.g.
Manganese - Total	0.15	C HNC	0.07	C HNC	0.10	C HNC	0.05	C HNC
Mercury - Total	8.5E-05	C	9.5E-05	C	9.0E-05	C	9.5E-05	C
Molybdenum - Total	6.2E-04		3.3E-04		8.7E-02		1.3E-02	
Naphthenic Acids	3.4	n.g.	3.8	n.g.	3.5	n.g.	4.2	n.g.
Nickel - Total	0.0003		0.0004		0.0022		0.0006	
Phenolics - Total	0	-	0	-	0.001		0.0003	
Selenium - Total	0.0018		0.0006		0.0008		3.8E-05	
Silver - Total	0	-	0	-	0.0001		1.6E-05	
Sodium	9.7	n.g.	10.2	n.g.	55.8	n.g.	41.2	n.g.
Strontium	0.08	n.g.	0.06	n.g.	0.20	n.g.	0.09	n.g.
Sulphate	4.3	n.g.	4.5	n.g.	83.1	n.g.	23.7	n.g.
Total Dissolved Solids	196	n.g.	179	n.g.	323	n.g.	223	n.g.
Total PAHs	0	-	0	-	0.0020	n.g.	0.0003	n.g.
Toxicity - acute	0	-	0	-	0.01		0.02	
Toxicity - chronic	0	-	0	-	0.02		0.04	
Vanadium - Total	0.001		0.001		0.011		0.002	
Zinc - Total	0.04		0.02		0.03		0.01	

C = Chronic, A = Acute, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen, n.g.=no guideline

Table XII - 5 **Assessment of Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions (CEA - Approved Developments)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.08		0.06		0.06		0.08	
Ammonia - Total	0.07		0.05		0.05		0.07	
Antimony - Total	2.1E-05	n.g.	8.0E-06	n.g.	8.5E-06	n.g.	6.4E-06	n.g.
Arsenic - Total	1.2E-03		7.0E-04		7.2E-04		4.8E-04	
Barium - Total	0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	8.3E-08	n.g.	4.7E-07	n.g.	4.7E-07	n.g.	1.3E-05	n.g.
Benzo(a)pyrene grp	2.2E-08	n.g.	1.4E-07	n.g.	1.4E-07	n.g.	1.7E-06	n.g.
Beryllium-Total	4.3E-05		1.6E-05		1.7E-05		4.9E-05	
Boron - Total	0.03		0.03		0.03		0.07	
Cadmium - Total	0.001		0.001		0.001		0.001	
Calcium	52.5	n.g.	50.9	n.g.	51.0	n.g.	50.7	n.g.
Chromium - Total	0.004		0.003		0.003		0.003	
Conductivity	407	n.g.	402	n.g.	402	n.g.	435	n.g.
Copper - Total	0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.1	n.g.	8.1	n.g.	8.1	n.g.	8.7	n.g.
Iron - Total	0.43	C	0.27		0.27		0.22	
Lead - Total	0.0001		0.0000		0.0000		0.0001	
Magnesium	13.9	n.g.	13.9	n.g.	13.9	n.g.	14.1	n.g.
Manganese - Total	0.1	C	0.1	C	0.1	C	0.1	C
Mercury - Total	0.0001	C	0.0001	C	0.0001	C	0.0001	C
Molybdenum - Total	0.0002		0.0004		0.0004		0.0049	
Naphthenic Acids	0.01	n.g.	0.03	n.g.	0.03	n.g.	0.22	n.g.
Nickel - Total	7.9E-06		1.8E-05		0.0000		0.0001	
Phenolics - Total	0.003		0.003		0.003		0.003	
Selenium - Total	0.0006		0.0003		0.0003		0.0001	
Silver - Total	1.6E-07		5.9E-07		5.9E-07		6.6E-06	
Sodium	16.1	n.g.	16.3	n.g.	16.3	n.g.	26.1	n.g.
Strontium	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.
Sulphate	39.7	n.g.	40.1	n.g.	40.1	n.g.	45.9	n.g.
Total Dissolved Solids	247	n.g.	245	n.g.	245	n.g.	259	n.g.
Total PAHs	1.6E-06	n.g.	9.3E-06	n.g.	9.3E-06	n.g.	1.2E-04	n.g.
Toxicity - acute	1.5E-04		8.0E-04		8.0E-04		0.01	
Toxicity - chronic	6.5E-04		2.1E-03		2.1E-03		0.02	
Vanadium - Total	0.002		0.002		0.002		0.003	
Zinc - Total	0.015		0.010		0.010		0.008	

C = Chronic, A = Acute, n.g.=no guideline

Table XII - 6 **Assessment of Water Quality in the Athabasca River During Mean Open Water Flow Conditions (CEA - Approved Developments)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.68	C	0.68	C	0.68	C	0.68	C
Ammonia - Total	0.03		0.02		0.02		0.03	
Antimony - Total	1.0E-05		3.3E-06		3.8E-06		2.0E-06	
Arsenic - Total	0.002	HC	0.001	HC	0.001	HC	0.001	HC
Barium - Total	0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	2.6E-07		3.2E-07		3.2E-07		4.6E-06	HC
Benzo(a)pyrene grp	6.1E-08		8.5E-08		8.5E-08		5.8E-07	
Beryllium-Total	0.001		0.001		0.001		0.001	
Boron - Total	0.04		0.04		0.04		0.05	
Cadmium - Total	0.001		0.001		0.001		0.001	
Calcium	33.1	n.g.	31.9	n.g.	32.0	n.g.	31.8	n.g.
Chromium - Total	0.004		0.004		0.004		0.004	
Conductivity	243	n.g.	237	n.g.	238	n.g.	249	n.g.
Copper - Total	0.004		0.004		0.004		0.004	
Dissolved Organic Carbon	10.1	n.g.	10.0	n.g.	9.9	n.g.	10.2	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.99	C HNC	2.99	C HNC
Lead - Total	0.0001		0.0001		0.0001		0.0001	
Magnesium	8.0	n.g.	7.9	n.g.	7.9	n.g.	8.0	n.g.
Manganese - Total	0.4	C HNC	0.4	C HNC	0.4	C HNC	0.4	C HNC
Mercury - Total	0.0001	C	0.0001	C	0.0001	C	0.0001	C
Molybdenum - Total	0.0003		0.0004		0.0004		0.0017	
Naphthenic Acids	0.48	n.g.	0.47	n.g.	0.45	n.g.	0.53	n.g.
Nickel - Total	0.0001		0.0001		0.0001		0.0001	
Phenolics - Total	0.002		0.002		0.002		0.002	
Selenium - Total	0.0004		0.0003		0.0003		0.0002	
Silver - Total	7.1E-07		9.3E-07		9.3E-07		2.2E-06	
Sodium	6.9	n.g.	7.3	n.g.	7.3	n.g.	10.6	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.22	n.g.	0.22	n.g.
Sulphate	19.4	n.g.	19.5	n.g.	19.5	n.g.	20.0	n.g.
Total Dissolved Solids	156	n.g.	153	n.g.	153	n.g.	158	n.g.
Total PAHs	4.9E-06	n.g.	6.1E-06	n.g.	6.1E-06	n.g.	4.1E-05	n.g.
Toxicity - acute	0.0004		0.001		0.001		0.002	
Toxicity - chronic	0.003		0.004		0.004		0.006	
Vanadium - Total	0.004		0.004		0.004		0.004	
Zinc - Total	0.015		0.012		0.012		0.011	

C = Chronic, A = Acute, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen, n.g.=no guideline

Table XII - 7 **Assessment of Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions (CEA - Approved Developments + Project)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.08		0.06		0.06		0.08	
Ammonia - Total	0.07		0.05		0.05		0.07	
Antimony - Total	2.2E-05	n.g.	8.2E-06	n.g.	8.5E-06	n.g.	6.4E-06	n.g.
Arsenic - Total	0.001		0.001		0.001		0.000	
Barium - Total	0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	8.3E-08	n.g.	4.7E-07	n.g.	9.2E-07	n.g.	1.4E-05	n.g.
Benzo(a)pyrene grp	2.2E-08	n.g.	1.4E-07	n.g.	1.6E-07	n.g.	1.8E-06	n.g.
Beryllium-Total	4.3E-05		1.7E-05		1.9E-05		5.3E-05	
Boron - Total	0.03		0.03		0.03		0.07	
Cadmium - Total	0.001		0.001		0.001		0.001	
Calcium	52.5	n.g.	50.9	n.g.	51.0	n.g.	50.8	n.g.
Chromium - Total	0.004		0.003		0.003		0.003	
Conductivity	408	n.g.	402	n.g.	404	n.g.	439	n.g.
Copper - Total	0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.2	n.g.	8.1	n.g.	8.1	n.g.	8.8	n.g.
Iron - Total	0.44	C	0.27		0.28		0.22	
Lead - Total	0.0001		0.0000		0.0000		0.0001	
Magnesium	13.9	n.g.	13.9	n.g.	13.9	n.g.	14.1	n.g.
Manganese - Total	0.1	C	0.1	C	0.1	C	0.1	C
Mercury - Total	0.0001	C	0.0001	C	0.0001	C	0.0001	C
Molybdenum - Total	0.0002		0.0004		0.0004		0.0050	
Naphthenic Acids	0.01	n.g.	0.03	n.g.	0.03	n.g.	0.23	n.g.
Nickel - Total	8.5E-06		1.9E-05		0.0000		0.0001	
Phenolics - Total	0.003		0.003		0.003		0.003	
Selenium - Total	0.0006		0.0003		0.0003		0.0001	
Silver - Total	1.7E-07		5.9E-07		5.9E-07		6.6E-06	
Sodium	16.1	n.g.	16.3	n.g.	16.7	n.g.	27.3	n.g.
Strontium	0.34	n.g.	0.34	n.g.	0.34	n.g.	0.34	n.g.
Sulphate	39.7	n.g.	40.1	n.g.	40.2	n.g.	46.2	n.g.
Total Dissolved Solids	247	n.g.	245	n.g.	246	n.g.	261	n.g.
Total PAHs	1.6E-06	n.g.	9.3E-06	n.g.	9.6E-06	n.g.	1.2E-04	n.g.
Toxicity - acute	1.5E-04		8.0E-04		9.1E-04		0.01	
Toxicity - chronic	6.5E-04		2.1E-03		2.4E-03		0.02	
Vanadium - Total	0.002		0.002		0.002		0.003	
Zinc - Total	0.016		0.010		0.010		0.008	

C = Chronic, A = Acute, n.g.=no guideline

Table XII - 8 **Assessment of Water Quality in the Athabasca River During Mean Open Water Flow Conditions (CEA - Approved Developments + Project)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.68	C	0.68	C	0.68	C	0.68	C
Ammonia - Total	0.03		0.02		0.02		0.03	
Antimony - Total	1.1E-05		3.7E-06		1.9E-05		2.0E-06	
Arsenic - Total	0.002	HC	0.001	HC	0.002	HC	0.001	HC
Barium - Total	0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	2.6E-07		3.1E-07		2.9E-06	HC	5.0E-06	HC
Benzo(a)pyrene grp	6.1E-08		8.5E-08		5.9E-07		6.1E-07	
Beryllium-Total	0.001		0.001		0.001		0.001	
Boron - Total	0.04		0.04		0.09		0.06	
Cadmium - Total	0.001		0.001		0.001		0.001	
Calcium	33.2	n.g.	32.0	n.g.	33.4	n.g.	31.9	n.g.
Chromium - Total	0.004		0.004		0.004		0.004	
Conductivity	243	n.g.	237	n.g.	267	n.g.	251	n.g.
Copper - Total	0.004		0.004		0.004		0.004	
Dissolved Organic Carbon	10.1	n.g.	10.0	n.g.	10.9	n.g.	10.3	n.g.
Iron - Total	2.99	C HNC	2.99	C HNC	2.99	C HNC	2.99	C HNC
Lead - Total	0.0001		0.0001		0.0003		0.0001	
Magnesium	8.0	n.g.	8.0	n.g.	8.2	n.g.	8.1	n.g.
Manganese - Total	0.4	C HNC	0.4	C HNC	0.4	C HNC	0.4	C HNC
Mercury - Total	0.0001	C	0.0001	C	0.0001	C	0.0001	C
Molybdenum - Total	0.0003		0.0004		0.0126		0.0017	
Naphthenic Acids	0.49	n.g.	0.49	n.g.	0.52	n.g.	0.54	n.g.
Nickel - Total	0.0001		0.0001		0.0003		0.0001	
Phenolics - Total	0.002		0.002		0.002		0.002	
Selenium - Total	0.0004		0.0003		0.0003		0.0002	
Silver - Total	7.1E-07		9.4E-07		1.8E-05		2.2E-06	
Sodium	6.9	n.g.	7.3	n.g.	13.7	n.g.	11.0	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.22	n.g.	0.22	n.g.
Sulphate	19.4	n.g.	19.5	n.g.	28.6	n.g.	20.1	n.g.
Total Dissolved Solids	156	n.g.	153	n.g.	175	n.g.	159	n.g.
Total PAHs	4.9E-06	n.g.	6.0E-06	n.g.	3.0E-04	n.g.	4.2E-05	n.g.
Toxicity - acute	0.0004		0.001		0.002		0.002	
Toxicity - chronic	0.003		0.003		0.005		0.006	
Vanadium - Total	0.004		0.004		0.005		0.004	
Zinc - Total	0.015		0.012		0.013		0.011	

C = Chronic, A = Acute, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen, n.g.=no guideline

Table XII - 9 **Assessment of Water Quality in the Muskeg River During Annual 7Q10 Flow Conditions (Regional Development Review)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.5	C	0.5	C	0.5	C	1.1	C
Ammonia - Total	0.9		0.9		0.9		1.6	
Antimony - Total	4.8E-04		4.2E-04		4.5E-04		2.2E-04	
Arsenic - Total	0.019	C	0.017	C	0.018	C	0.003	
Barium - Total	0.2		0.2		0.2		0.1	
Benzo(a)anthracene grp	0	-	0	-	0	-	6.3E-04	
Benzo(a)pyrene grp	0	-	0	-	0	-	7.2E-05	
Beryllium-Total	9.5E-04		8.4E-04		8.9E-04		2.3E-03	
Boron - Total	0.04		0.04		0.04		1.95	C
Cadmium - Total	2.7E-05		9.4E-05		6.4E-05		4.0E-03	C
Calcium	104	n.g.	101	n.g.	102	n.g.	81	n.g.
Chloride	0.3		0.9		0.6		22.5	
Chromium - Total	0.022	A C	0.020	A C	0.021	A C	0.005	
Conductivity	608	n.g.	593	n.g.	600	n.g.	2308	n.g.
Copper - Total	0.010	C	0.009	C	0.009	C	0.008	C
Dissolved Organic Carbon	11.3	n.g.	12.3	n.g.	11.9	n.g.	43.3	n.g.
Iron - Total	6.0	C	5.5	C	5.7	C	2.1	C
Lead - Total	0.002		0.002		0.002		0.003	
Lithium-Total	0.008		0.009		0.008		0.139	
Magnesium	13.2	n.g.	13.7	n.g.	13.4	n.g.	24.7	n.g.
Manganese - Total	0.79	C	0.76	C	0.77	C	0.22	C
Mercury - Total	4.5E-06		1.6E-05	C	1.1E-05		1.5E-05	C
Molybdenum - Total	2.9E-03		2.5E-03		2.7E-03		1.9E-01	
Naphthenic Acids	0	-	0	-	0	-	8.0	n.g.
Nickel - Total	0.0001		0.0002		0.0001		0.0038	
Phenolics - Total	0	-	0	-	0	-	0.005	
Selenium - Total	0.01		0.01		0.01		6.1E-04	
Silver - Total	0	-	0	-	0	-	2.5E-04	
Sodium	6.2	n.g.	7.2	n.g.	6.7	n.g.	537	n.g.
Strontium	0.2	n.g.	0.2	n.g.	0.2	n.g.	0.5	n.g.
Sulphate	3.2	n.g.	3.4	n.g.	3.3	n.g.	316	n.g.
Total Dissolved Solids	333	n.g.	329	n.g.	331	n.g.	1041	n.g.
Total PAHs	0	-	0	-	0	-	0.005	n.g.
Toxicity - acute	0	-	0	-	0	-	0.27	
Toxicity - chronic	0	-	0	-	0	-	0.73	
Vanadium - Total	0.005		0.004		0.005		0.029	
Zinc - Total	0.20	A C	0.18	C	0.18	C	0.06	

C = Chronic, A = Acute, n.g.=no guideline

Table XII - 10 **Assessment of Water Quality in the Muskeg River During Mean Open Water Flow Conditions (Regional Development Review)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.13	C	0.08		0.26	C	0.13	C
Ammonia - Total	0.2		0.1		0.1		0.1	
Antimony - Total	8.0E-05		3.2E-05		1.5E-04		1.5E-05	
Arsenic - Total	0.006	HC	0.004	HC	0.004	HC	0.003	HC
Barium - Total	0.05		0.04		0.05		0.03	
Benzo(a)anthracene grp	0	-	0	-	1.8E-05	HC	4.2E-05	HC
Benzo(a)pyrene grp	0	-	0	-	3.9E-06	HC	4.8E-06	HC
Beryllium-Total	1.6E-04		6.5E-05		5.5E-04		1.6E-04	
Boron - Total	0.04		0.04		0.37		0.17	
Cadmium - Total	0.0002		0.0002		0.0008		0.0005	
Calcium	49.2	n.g.	42.8	n.g.	52.0	n.g.	41.3	n.g.
Chloride	2.6		2.9		7.8		4.4	
Chromium - Total	0.0040		0.0019		0.0037		0.0008	
Conductivity	326	n.g.	294	n.g.	498	n.g.	409	n.g.
Copper - Total	0.002		0.001		0.003		0.001	
Dissolved Organic Carbon	20.3	n.g.	21.3	n.g.	25.7	n.g.	23.4	n.g.
Iron - Total	1.6	C HNC	1.1	C HNC	1.4	C HNC	0.9	C HNC
Lead - Total	0.0006		0.0005		0.0019		0.0006	
Lithium-Total	0.006		0.006		0.025		0.015	
Magnesium	10.1	n.g.	9.8	n.g.	11.5	n.g.	10.6	n.g.
Manganese - Total	0.16	C HNC	0.09	C HNC	0.12	C HNC	0.06	C HNC
Mercury - Total	8.4E-05	C	9.4E-05	C	8.8E-05	C	9.4E-05	C
Molybdenum - Total	6.5E-04		3.8E-04		9.1E-02		1.3E-02	
Naphthenic Acids	3.4	n.g.	3.7	n.g.	3.4	n.g.	4.1	n.g.
Nickel - Total	0.0003		0.0004		0.0022		0.0006	
Phenolics - Total	0	-	0	-	0.001		0.0003	
Selenium - Total	0.0019		0.0008		0.0011		4.1E-05	
Silver - Total	0	-	0	-	0.0001		1.7E-05	
Sodium	9.6	n.g.	10.1	n.g.	57.4	n.g.	45.2	n.g.
Strontium	0.08	n.g.	0.07	n.g.	0.21	n.g.	0.09	n.g.
Sulphate	4.3	n.g.	4.4	n.g.	86.1	n.g.	25.3	n.g.
Total Dissolved Solids	198	n.g.	182	n.g.	332	n.g.	231	n.g.
Total PAHs	0	-	0	-	0.0021	n.g.	0.0003	n.g.
Toxicity - acute	0	-	0	-	0.01		0.02	
Toxicity - chronic	0	-	0	-	0.02		0.05	
Vanadium - Total	0.001		0.001		0.012		0.002	
Zinc - Total	0.04		0.02		0.03		0.01	

C = Chronic, A = Acute, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen, n.g.=no guideline

Table XII - 11 **Assessment of Water Quality in the Athabasca River During Annual 7Q10 Flow Conditions (Regional Development Review)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.08		0.07		0.07		0.09	
Ammonia - Total	0.09		0.09		0.09		0.11	
Antimony - Total	2.8E-05	n.g.	1.9E-05	n.g.	1.7E-05	n.g.	1.4E-05	n.g.
Arsenic - Total	0.001		0.001		0.001		0.001	
Barium - Total	0.09		0.09		0.09		0.09	
Benzo(a)anthracene grp	3.3E-06	n.g.	8.9E-06	n.g.	9.0E-06	n.g.	2.2E-05	n.g.
Benzo(a)pyrene grp	9.9E-07	n.g.	2.7E-06	n.g.	2.7E-06	n.g.	4.0E-06	n.g.
Beryllium-Total	6.1E-05		5.0E-05		5.0E-05		8.6E-05	
Boron - Total	0.04		0.05		0.05		0.10	
Cadmium - Total	0.001		0.001		0.001		0.001	
Calcium	53.0	n.g.	51.7	n.g.	51.5	n.g.	51.2	n.g.
Chromium - Total	0.004		0.004		0.003		0.003	
Conductivity	413	n.g.	413	n.g.	414	n.g.	454	n.g.
Copper - Total	0.001		0.001		0.001		0.001	
Dissolved Organic Carbon	8.3	n.g.	8.4	n.g.	8.4	n.g.	9.1	n.g.
Iron - Total	0.47	C	0.31	C	0.29		0.23	
Lead - Total	0.0001		0.0001		0.0001		0.0002	
Magnesium	13.9	n.g.	13.9	n.g.	13.9	n.g.	14.2	n.g.
Manganese - Total	0.1	C	0.1	C	0.1	C	0.1	C
Mercury - Total	0.0001	C	0.0001	C	0.0001	C	0.0001	C
Molybdenum - Total	0.0029		0.0079		0.0080		0.0113	
Naphthenic Acids	0.24	n.g.	0.65	n.g.	0.65	n.g.	0.76	n.g.
Nickel - Total	6.1E-05		1.6E-04		0.0002		0.0002	
Phenolics - Total	0.003		0.003		0.003		0.003	
Selenium - Total	0.0007		0.0004		0.0003		0.0001	
Silver - Total	4.1E-06		1.1E-05		1.1E-05		1.6E-05	
Sodium	17.3	n.g.	19.4	n.g.	19.7	n.g.	31.1	n.g.
Strontium	0.34	n.g.	0.35	n.g.	0.35	n.g.	0.35	n.g.
Sulphate	42.2	n.g.	46.6	n.g.	46.6	n.g.	52.0	n.g.
Total Dissolved Solids	251	n.g.	253	n.g.	254	n.g.	270	n.g.
Total PAHs	6.7E-05	n.g.	1.8E-04	n.g.	1.8E-04	n.g.	2.7E-04	n.g.
Toxicity - acute	0.01		0.02		0.02		0.02	
Toxicity - chronic	0.02		0.05		0.05		0.06	
Vanadium - Total	0.002		0.003		0.003		0.003	
Zinc - Total	0.017		0.012		0.011		0.009	

C = Chronic, A = Acute, n.g.=no guideline

Table XII - 12 **Assessment of Water Quality in the Athabasca River During Mean Open Water Flow Conditions (Regional Development Review)**

Substance / Parameter	2007		2020		2030		Far Future	
	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds	mg/L	Exceeds
Aluminum - Total	0.68	C	0.68	C	0.68	C	0.68	C
Ammonia - Total	0.04		0.04		0.04		0.04	
Antimony - Total	1.4E-05		8.1E-06		2.4E-05		5.0E-06	
Arsenic - Total	0.002	HC	0.002	HC	0.002	HC	0.001	HC
Barium - Total	0.07		0.07		0.07		0.07	
Benzo(a)anthracene grp	1.4E-06		3.7E-06	HC	5.6E-06	HC	8.1E-06	HC
Benzo(a)pyrene grp	4.1E-07		1.1E-06		1.4E-06		1.5E-06	
Beryllium-Total	0.001		0.001		0.001		0.001	
Boron - Total	0.04		0.05		0.09		0.06	
Cadmium - Total	0.001		0.001		0.001		0.001	
Calcium	33.5	n.g.	32.5	n.g.	33.8	n.g.	32.1	n.g.
Chromium - Total	0.004		0.004		0.004		0.004	
Conductivity	246	n.g.	243	n.g.	272	n.g.	257	n.g.
Copper - Total	0.004		0.004		0.004		0.004	
Dissolved Organic Carbon	10.1	n.g.	10.1	n.g.	10.9	n.g.	10.4	n.g.
Iron - Total	3.00	C HNC	2.99	C HNC	2.99	C HNC	2.99	C HNC
Lead - Total	0.0001		0.0001		0.0003		0.0001	
Magnesium	8.1	n.g.	8.0	n.g.	8.3	n.g.	8.1	n.g.
Manganese - Total	0.4	C HNC	0.4	C HNC	0.4	C HNC	0.4	C HNC
Mercury - Total	0.0001	C	0.0001	C	0.0001	C	0.0001	C
Molybdenum - Total	0.0012		0.0033		0.0150		0.0041	
Naphthenic Acids	0.56	n.g.	0.67	n.g.	0.68	n.g.	0.71	n.g.
Nickel - Total	0.0001		0.0001		0.0004		0.0001	
Phenolics - Total	0.002		0.002		0.002		0.002	
Selenium - Total	0.0005		0.0003		0.0003		0.0002	
Silver - Total	1.7E-06		4.7E-06		2.1E-05		5.6E-06	
Sodium	7.3	n.g.	8.0	n.g.	14.7	n.g.	12.5	n.g.
Strontium	0.22	n.g.	0.22	n.g.	0.22	n.g.	0.22	n.g.
Sulphate	20.4	n.g.	22.3	n.g.	30.8	n.g.	22.4	n.g.
Total Dissolved Solids	158	n.g.	157	n.g.	178	n.g.	163	n.g.
Total PAHs	2.8E-05	n.g.	7.5E-05	n.g.	3.5E-04	n.g.	9.8E-05	n.g.
Toxicity - acute	0.003		0.008		0.008		0.008	
Toxicity - chronic	0.008		0.021		0.021		0.023	
Vanadium - Total	0.004		0.004		0.005		0.004	
Zinc - Total	0.016		0.013		0.014		0.012	

C = Chronic, A = Acute, HC = Human Health Carcinogen, HNC = Human Health Non-Carcinogen, n.g.=no guideline

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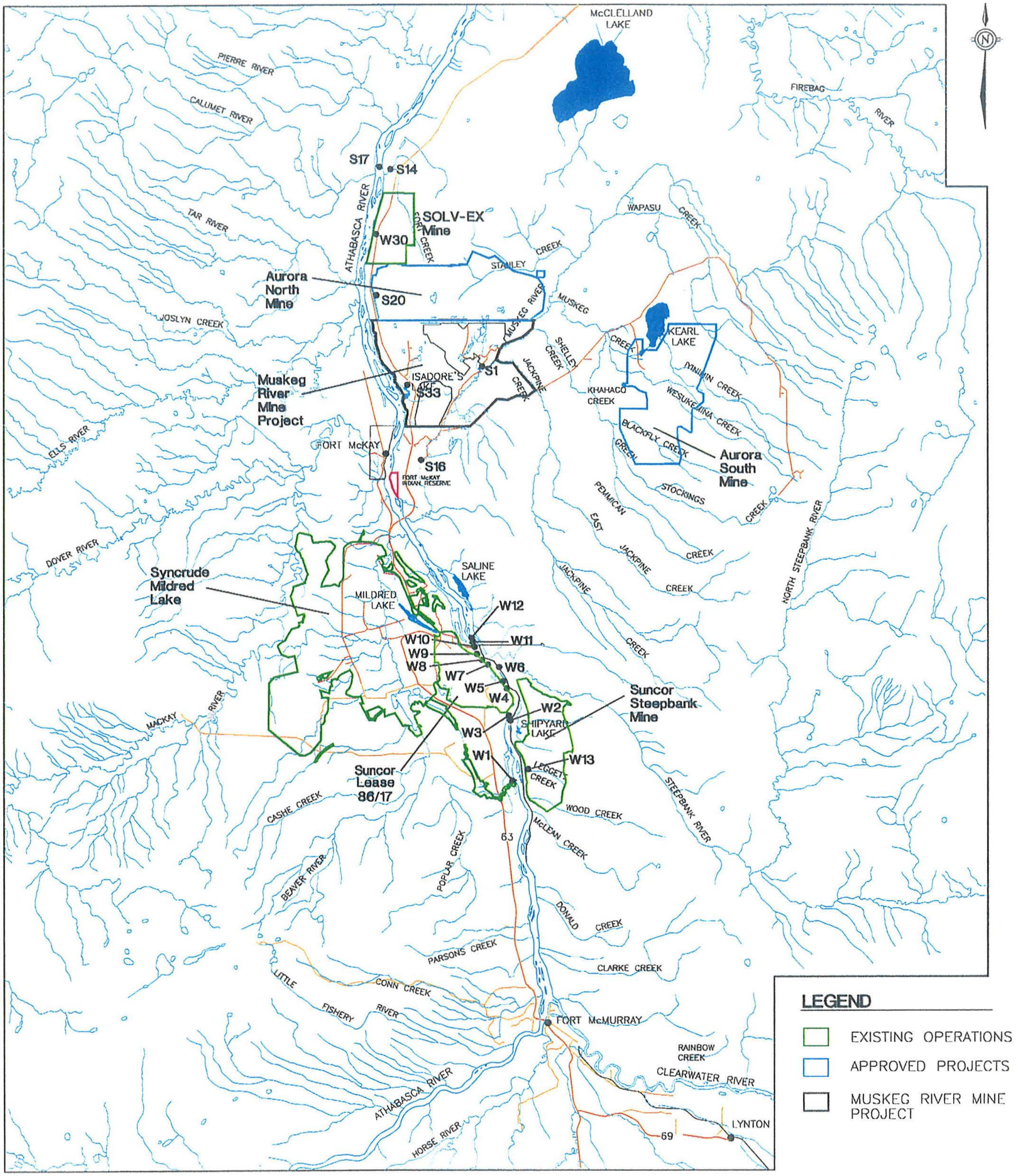

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REFERENCE

DIGITAL DATA SETS 74D, 74E, 74I
84A AND 84H FROM RESOURCE DATA DIVISION
ALBERTA ENVIRONMENTAL PROTECTION, 1997.

Golder Associates

SHELL CANADA LIMITED

WATER QUALITY MODELLING NODES FOR CUMULATIVE EFFECTS ASSESSMENT

15 JAN 98	Figure XII-1	DRAWN BY: CG

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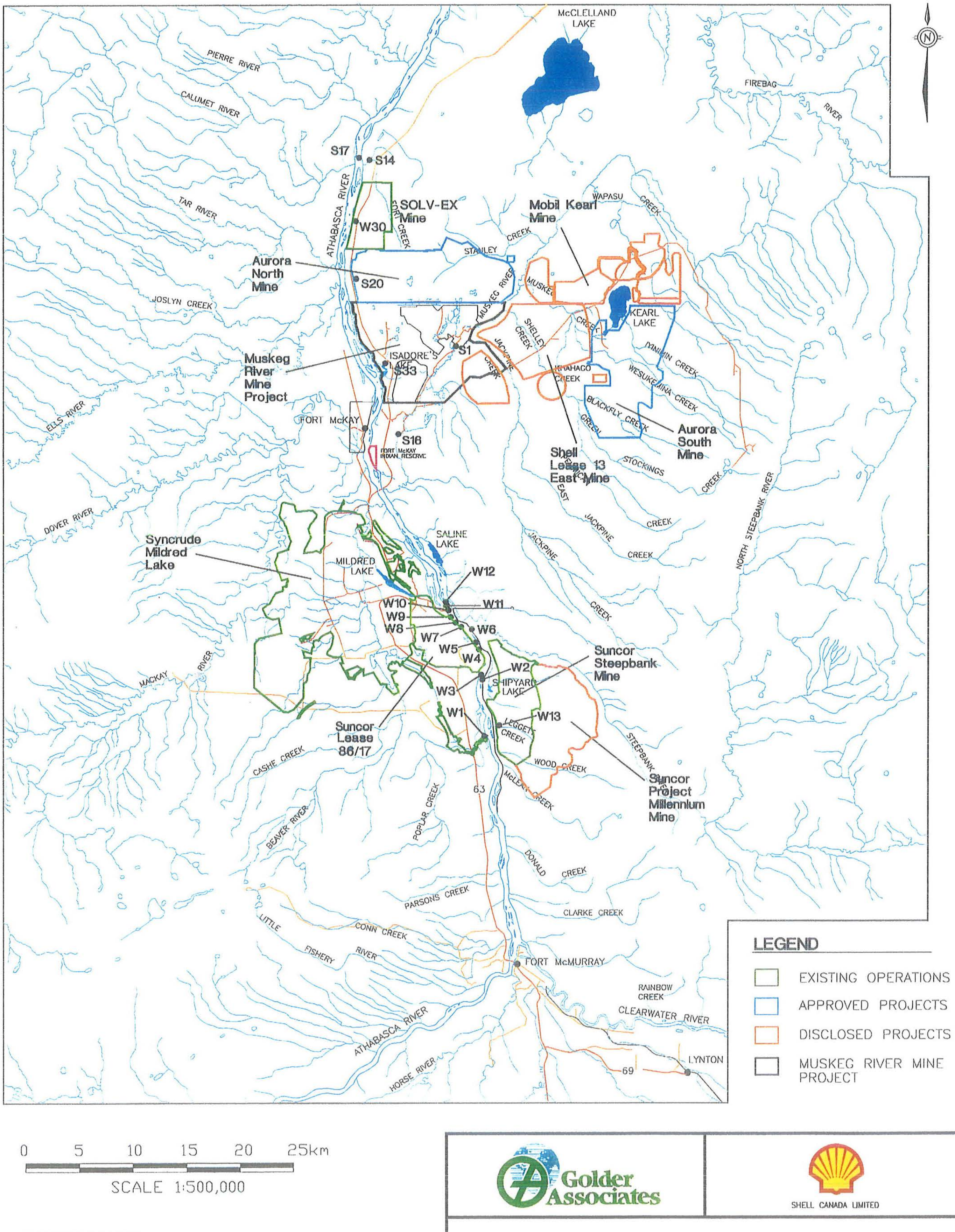

REFERENCE

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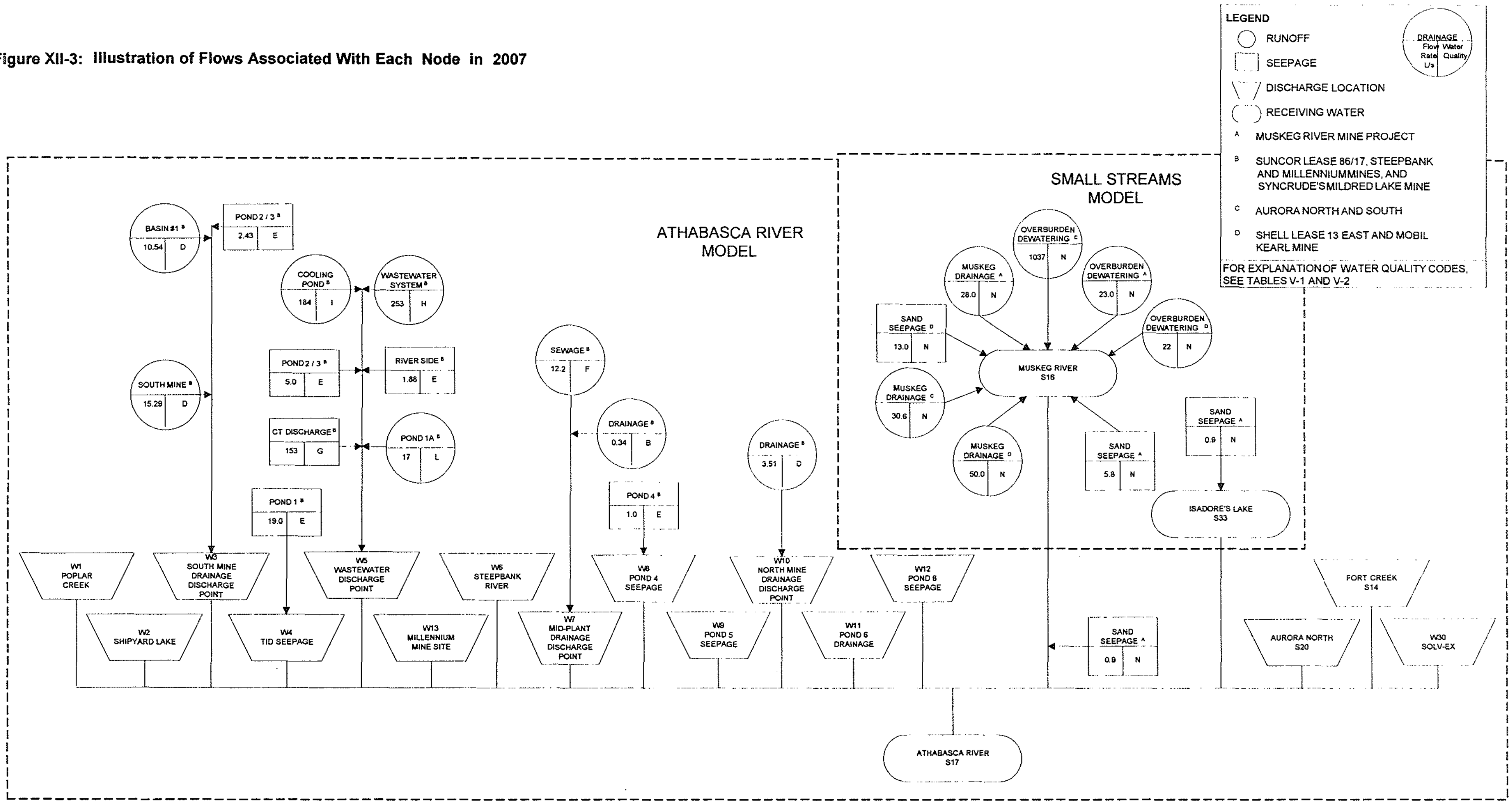
SHELL CANADA LIMITED

REGIONAL WATER QUALITY MODELLING NODES

15 JAN 98	Figure XII-2	DRAWN BY: CG

Figure XII-3: Illustration of Flows Associated With Each Node in 2007



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Date Last Revision: 16 Jan 98

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Figure XII-4: Illustation of Flows Associated With Each Node in 2020

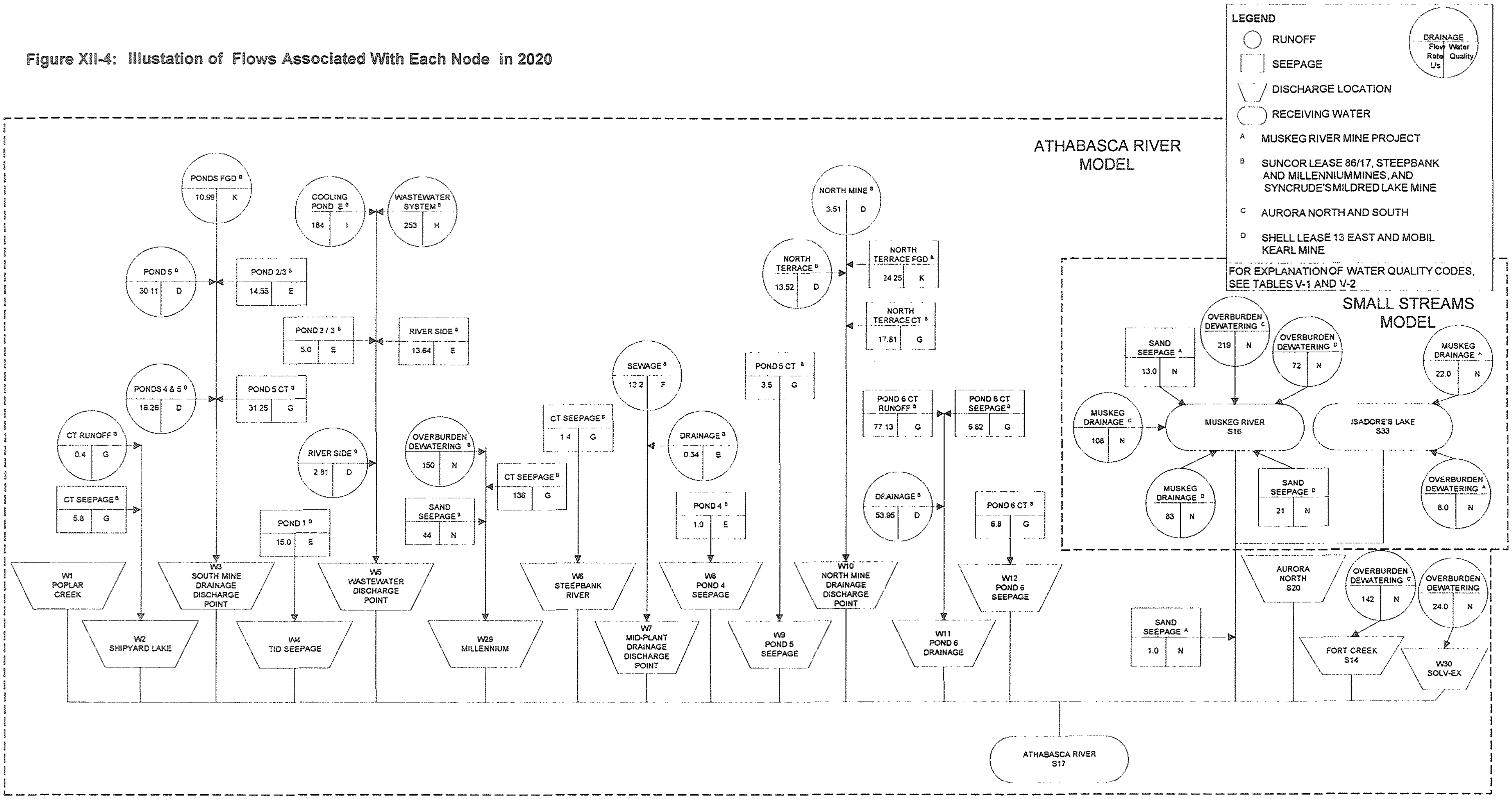

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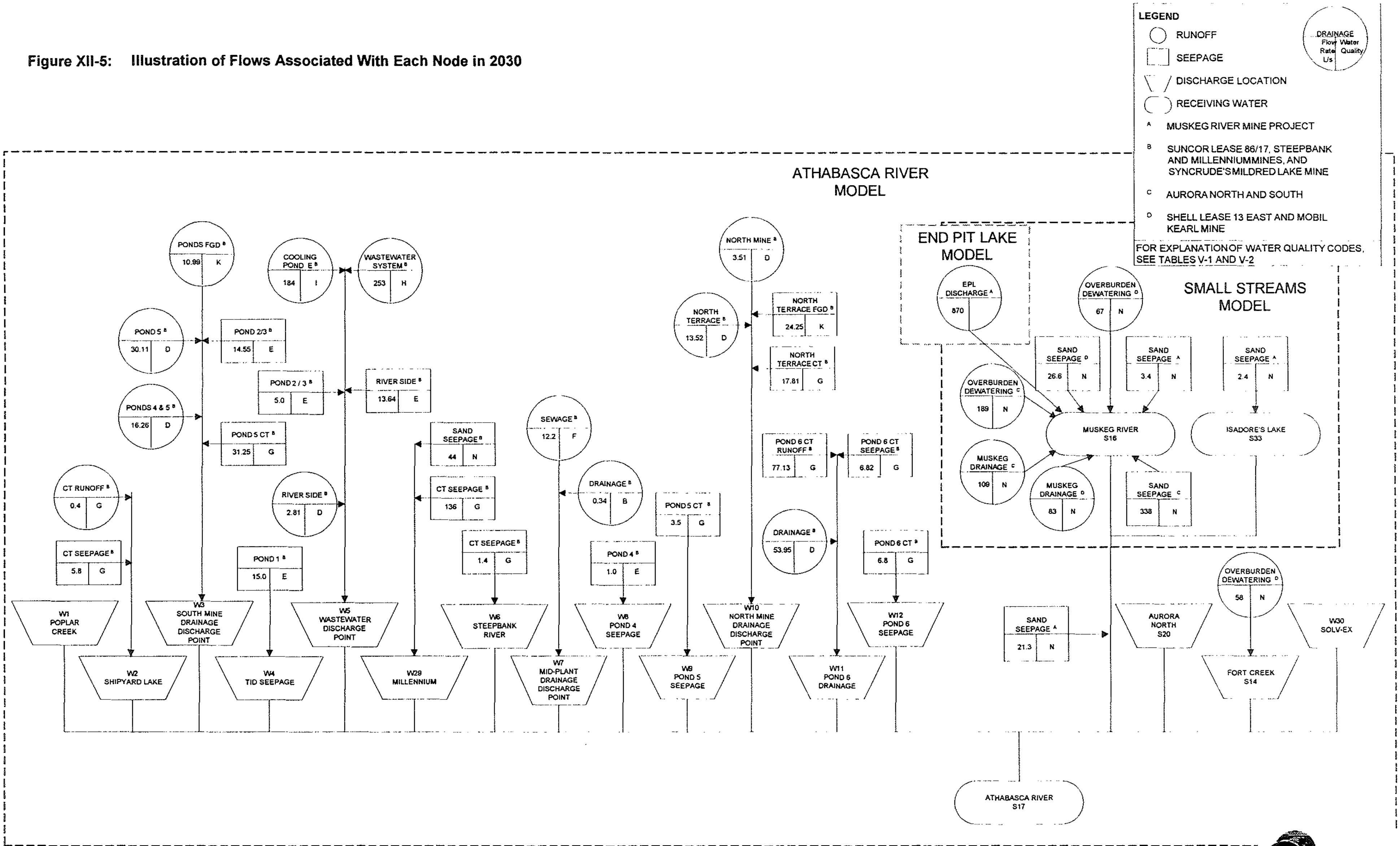
Figure XII-5: Illustration of Flows Associated With Each Node in 2030



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Date Last Revision: 16 Jan 98

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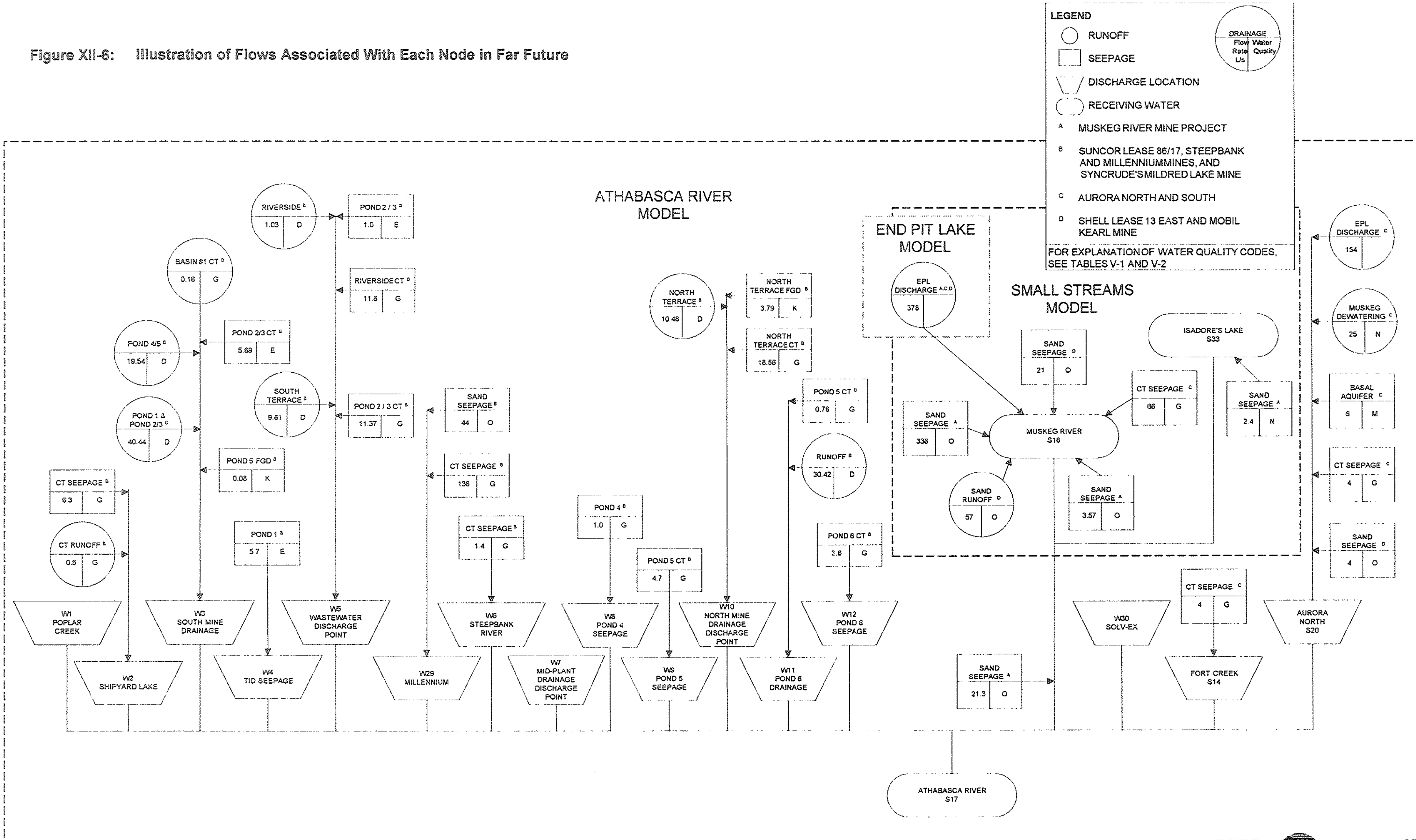
Figure XII-6: Illustration of Flows Associated With Each Node in Far Future



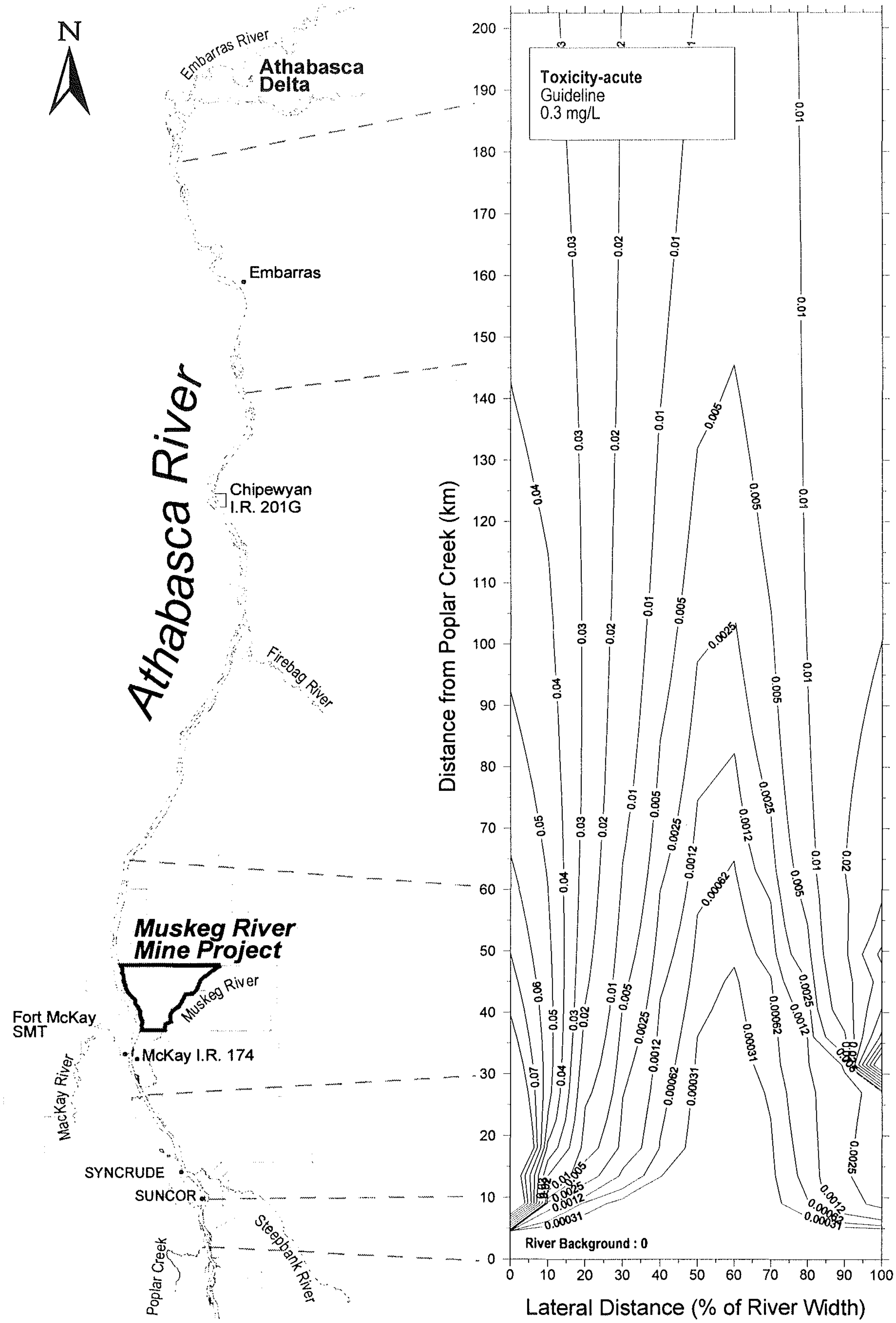


Figure XII-7 Muskeg River Mine Project Scenario Year: Far Future at 7Q10 Flow With Ice Cover (CEA)

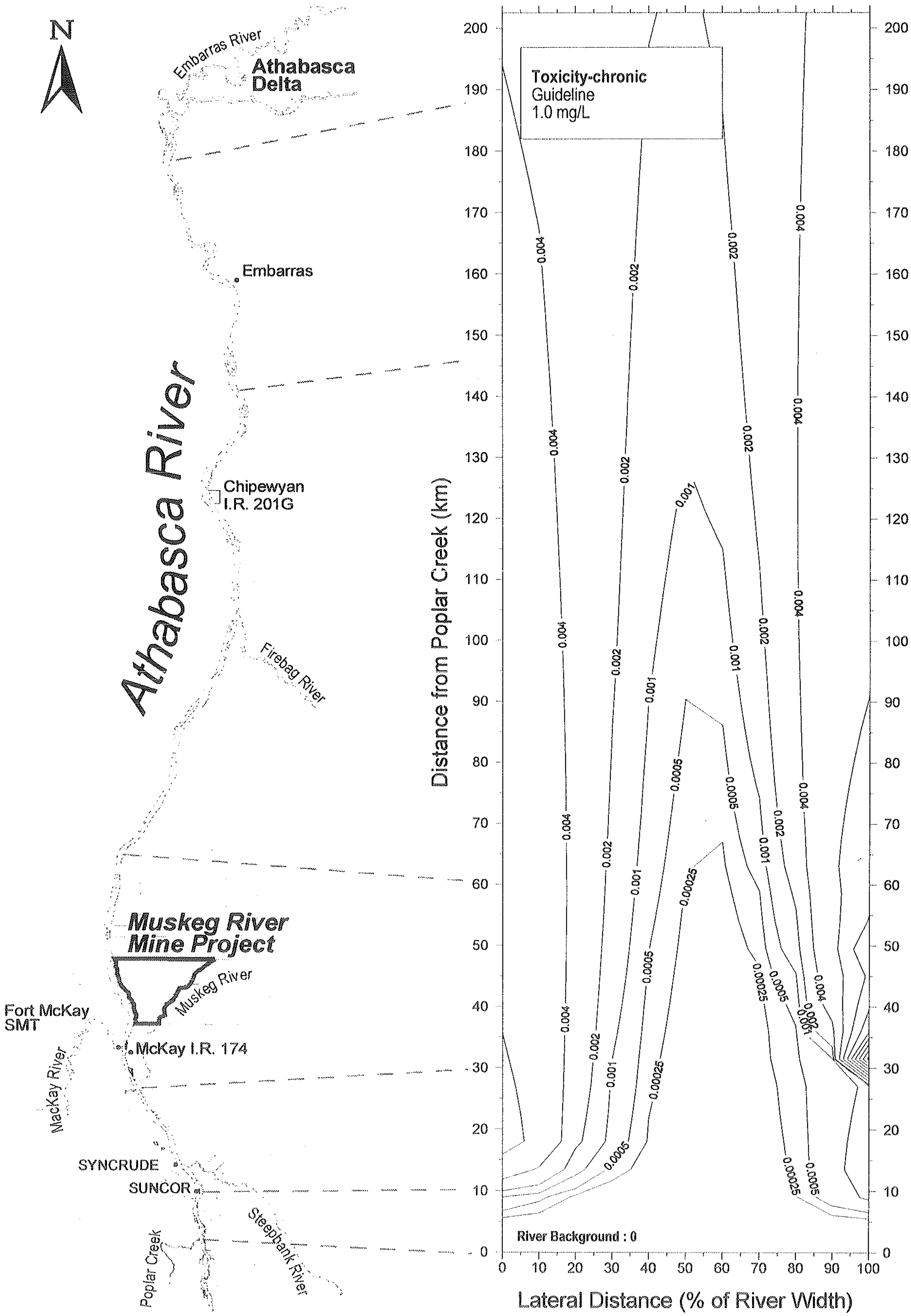


Figure XII-8 Muskeg River Mine Project Scenario Year: Far Future at 7Q10 Flow With Ice Cover (CEA)

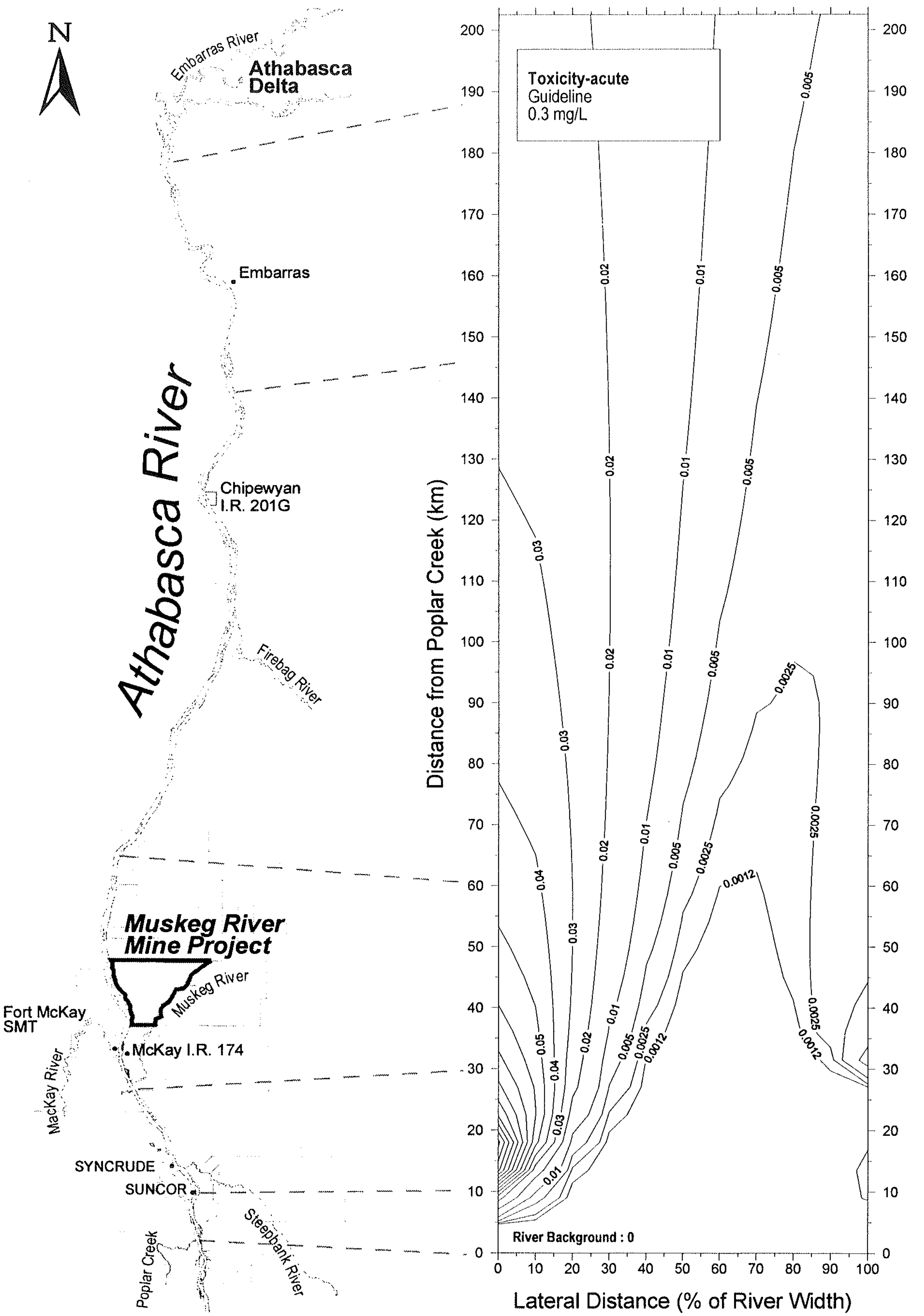


Figure XII-9 Muskeg River Mine Project Scenario Year: 2030 at Mean Open Water Flow (CEA)

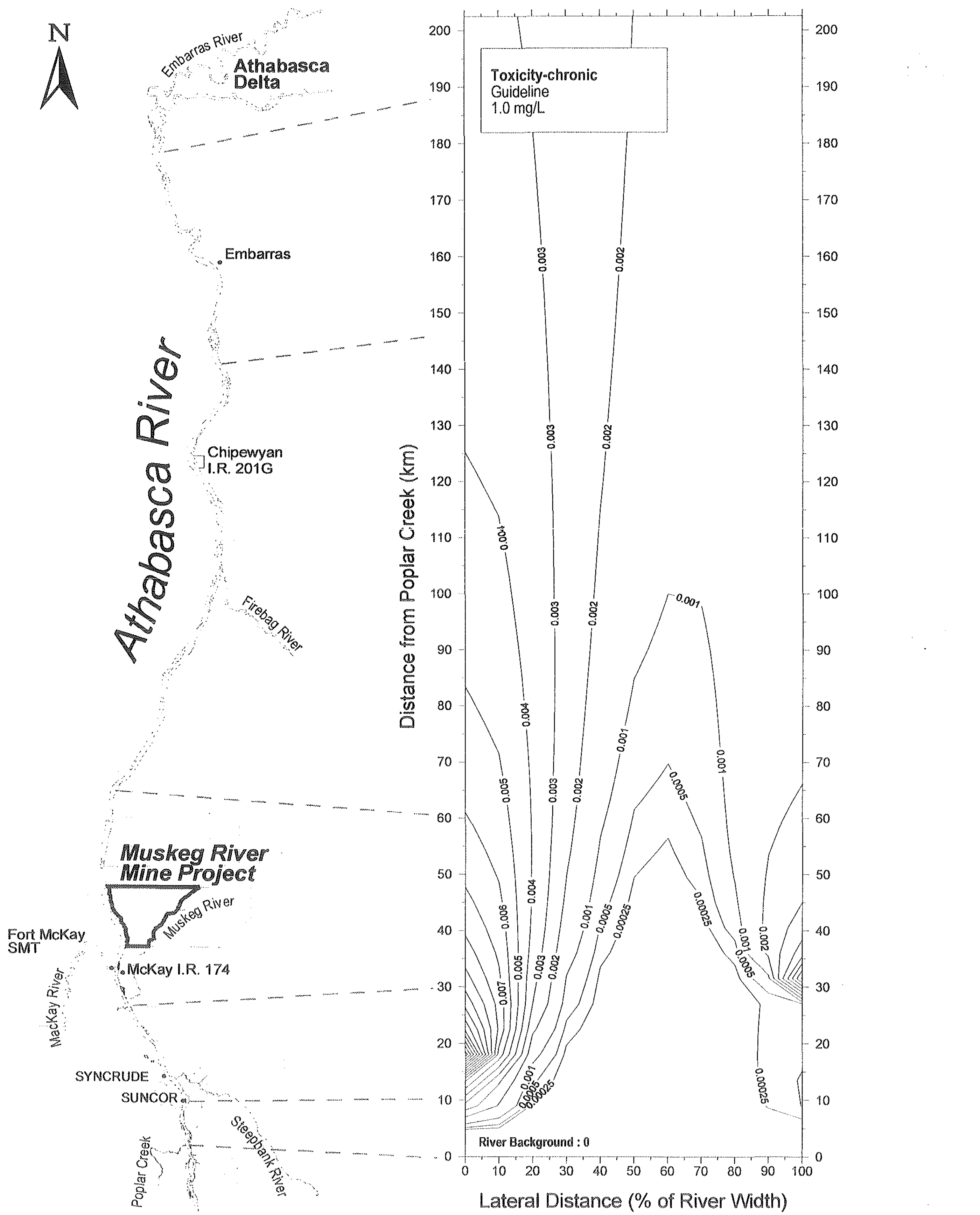


Figure XII-10 Muskeg River Mine Project Scenario Year: 2030 at Mean Open Water Flow (CEA)

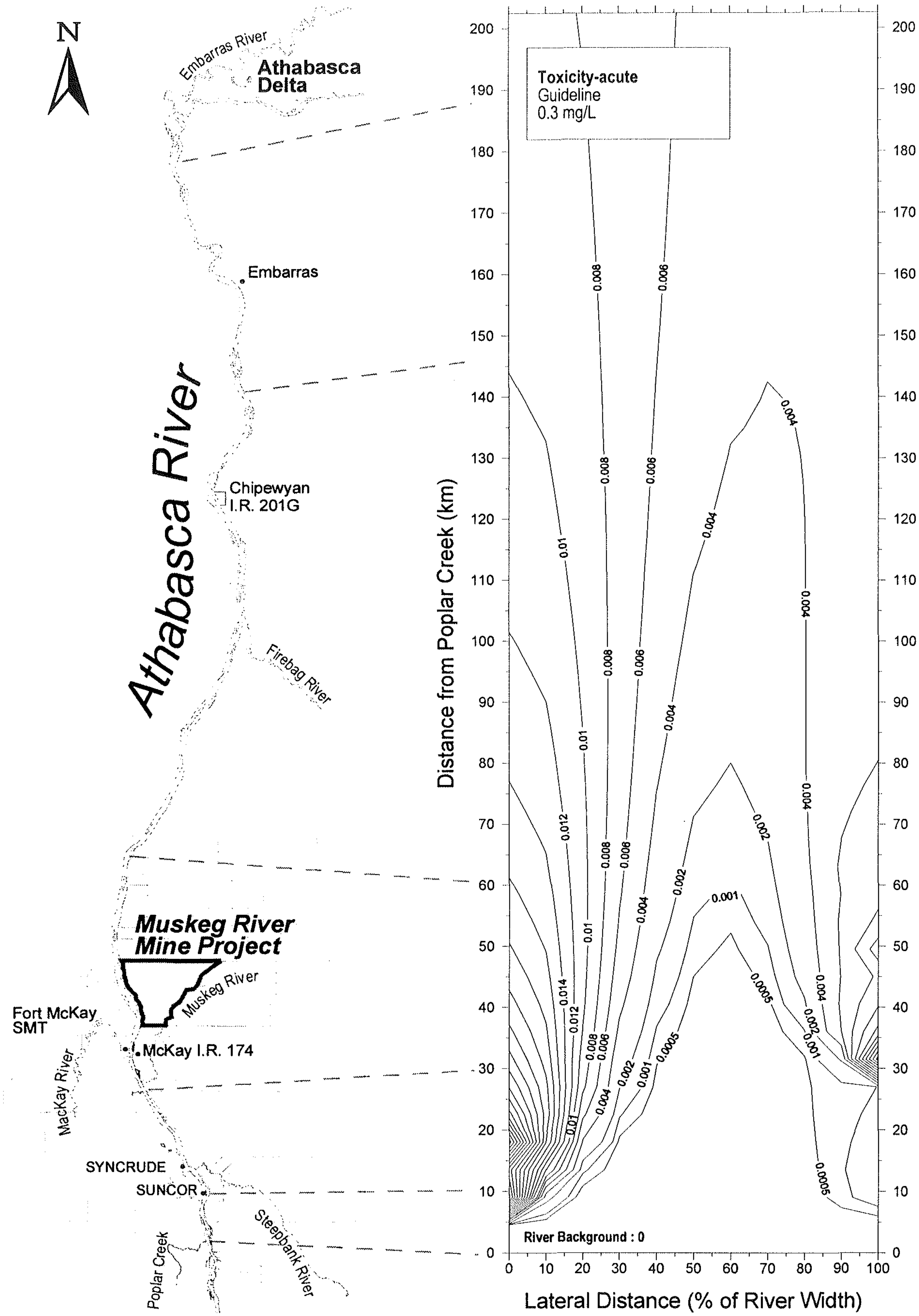


Figure XII-11 Muskeg River Mine Project Scenario Year: Far Future at Mean Open Water Flow (CEA)

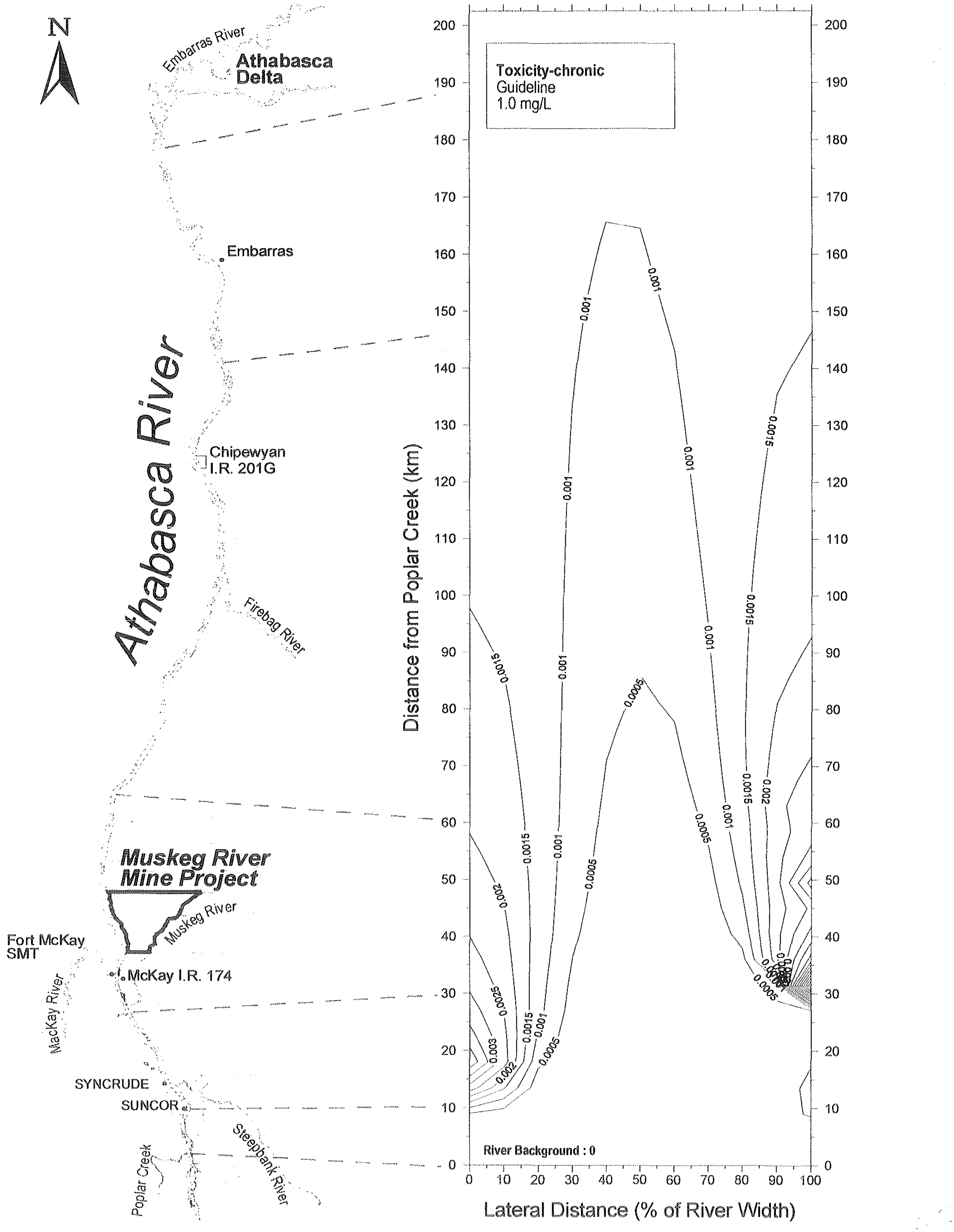


Figure XII-12 Muskeg River Mine Project Scenario Year: Far Future at Mean Open Water Flow (CEA)

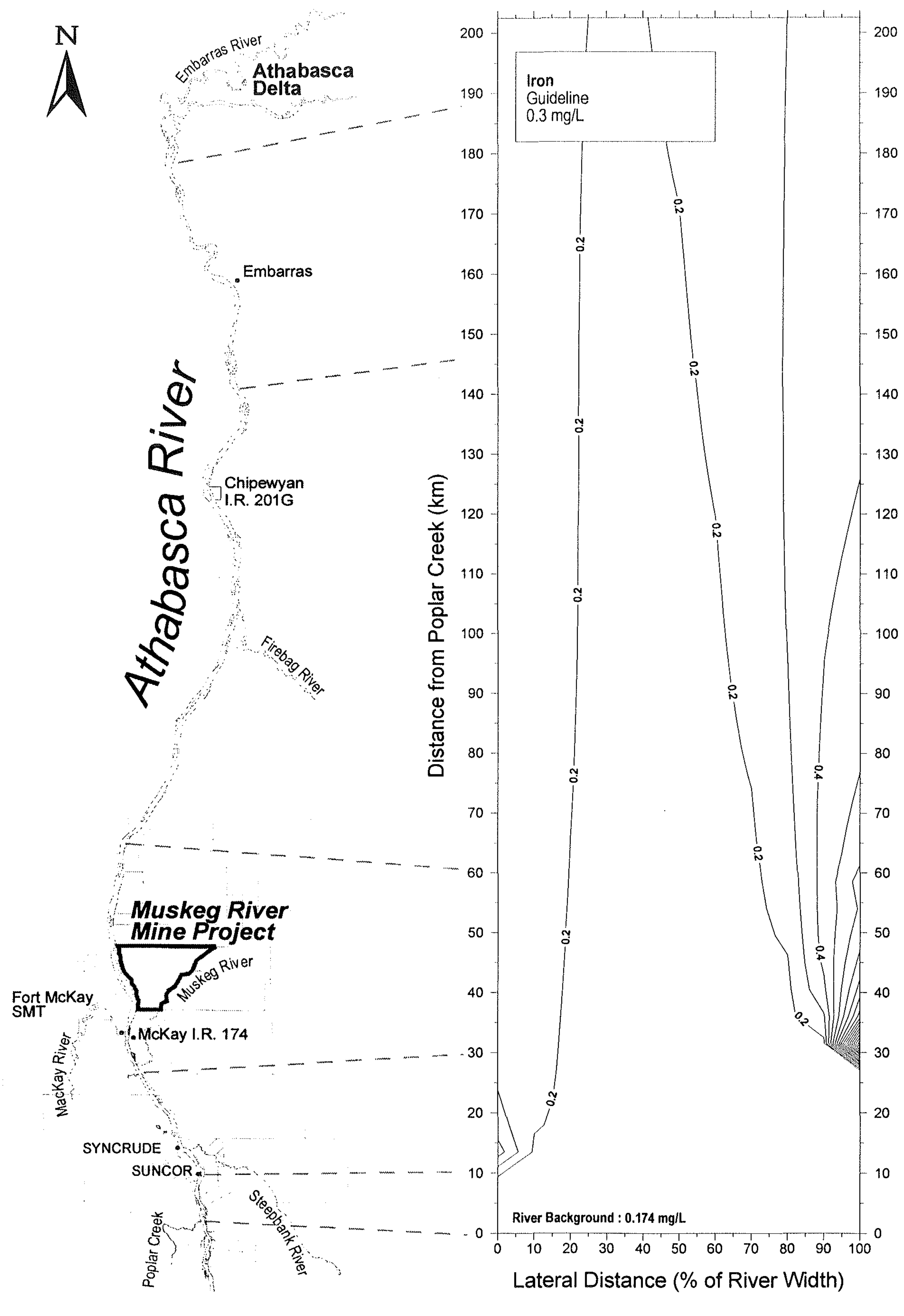


Figure XII-13 Muskeg River Mine Project Scenario Year: 2007 at 7Q10 Flow With Ice Cover (CEA)

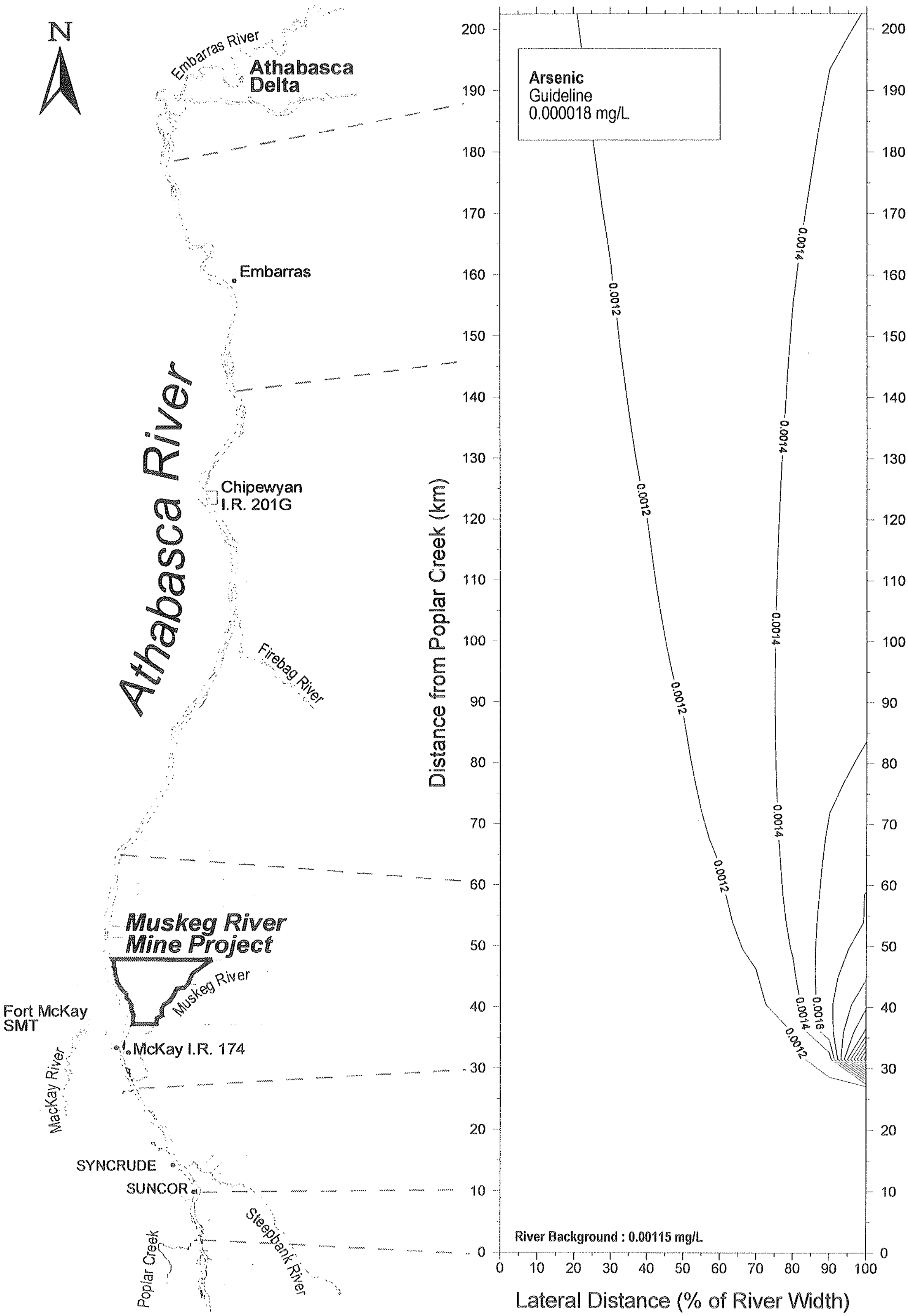


Figure XII-14 Muskeg River Mine Project Scenario Year: 2007 at Mean Open Water Flow (CEA)

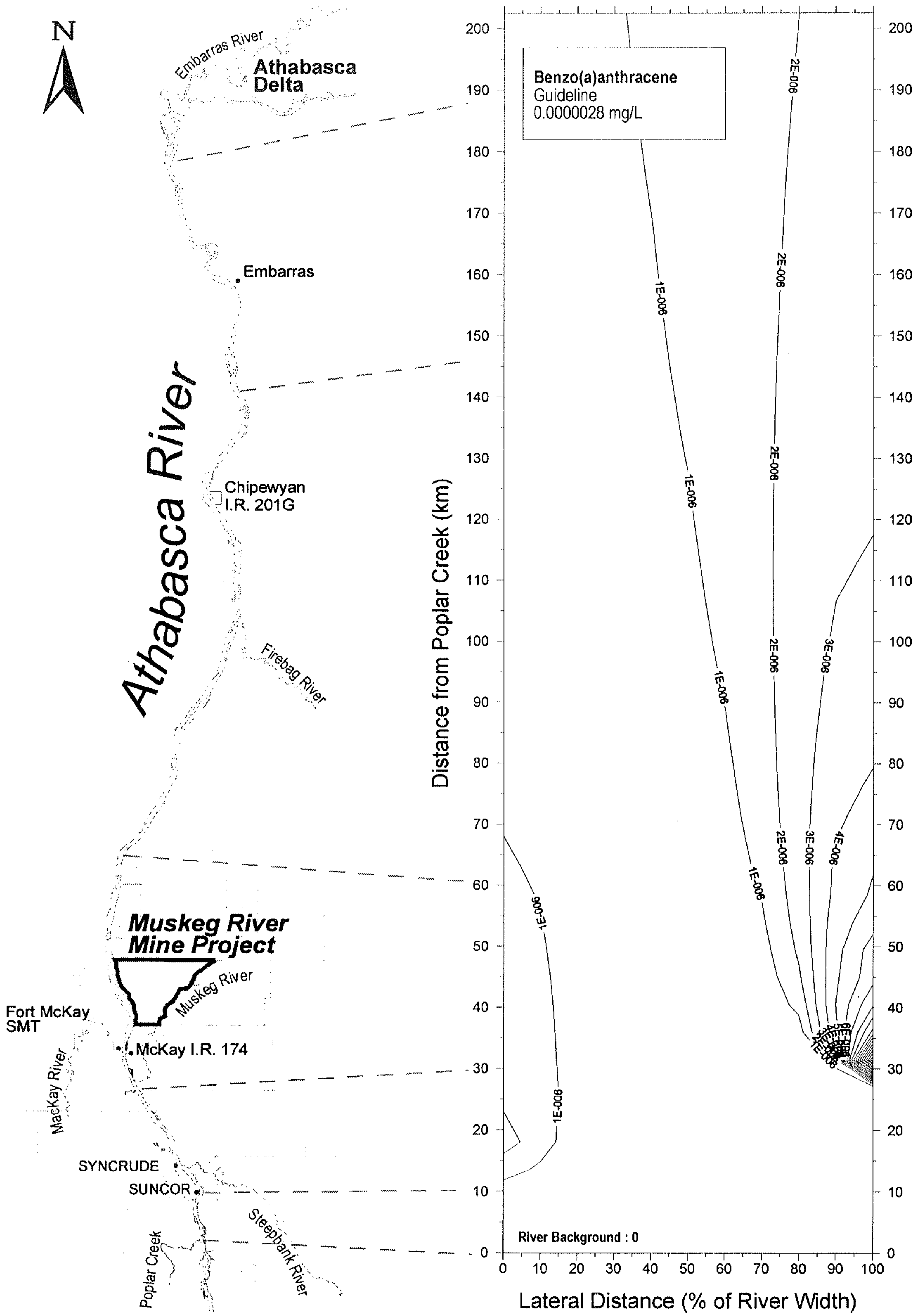


Figure XII-15 Muskeg River Mine Project Scenario Year: Far Future at Mean Open Water Flow (CEA)

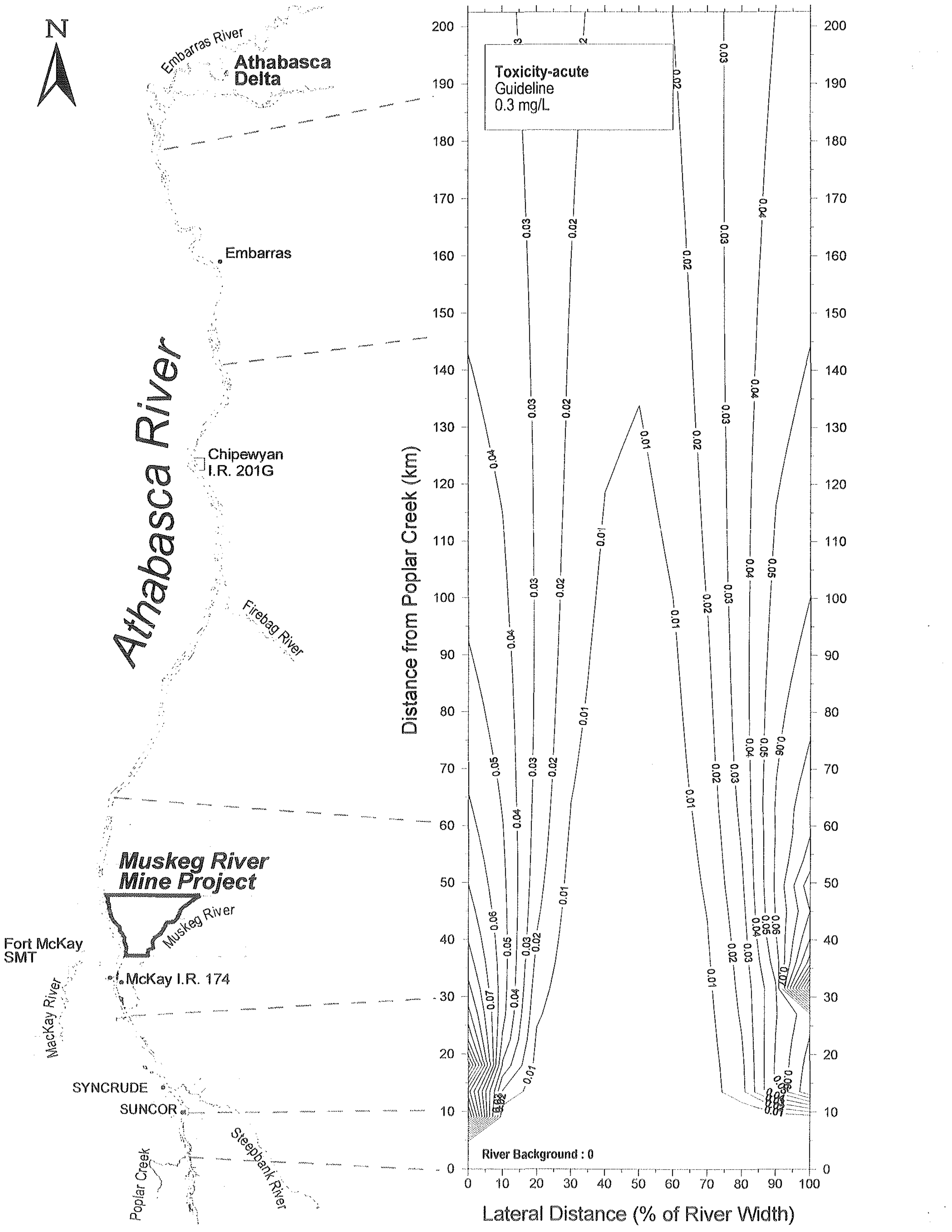


Figure XII-16 Muskeg River Mine Project Scenario Year: Far Future at 7Q10 Flow With Ice Cover (RDR)

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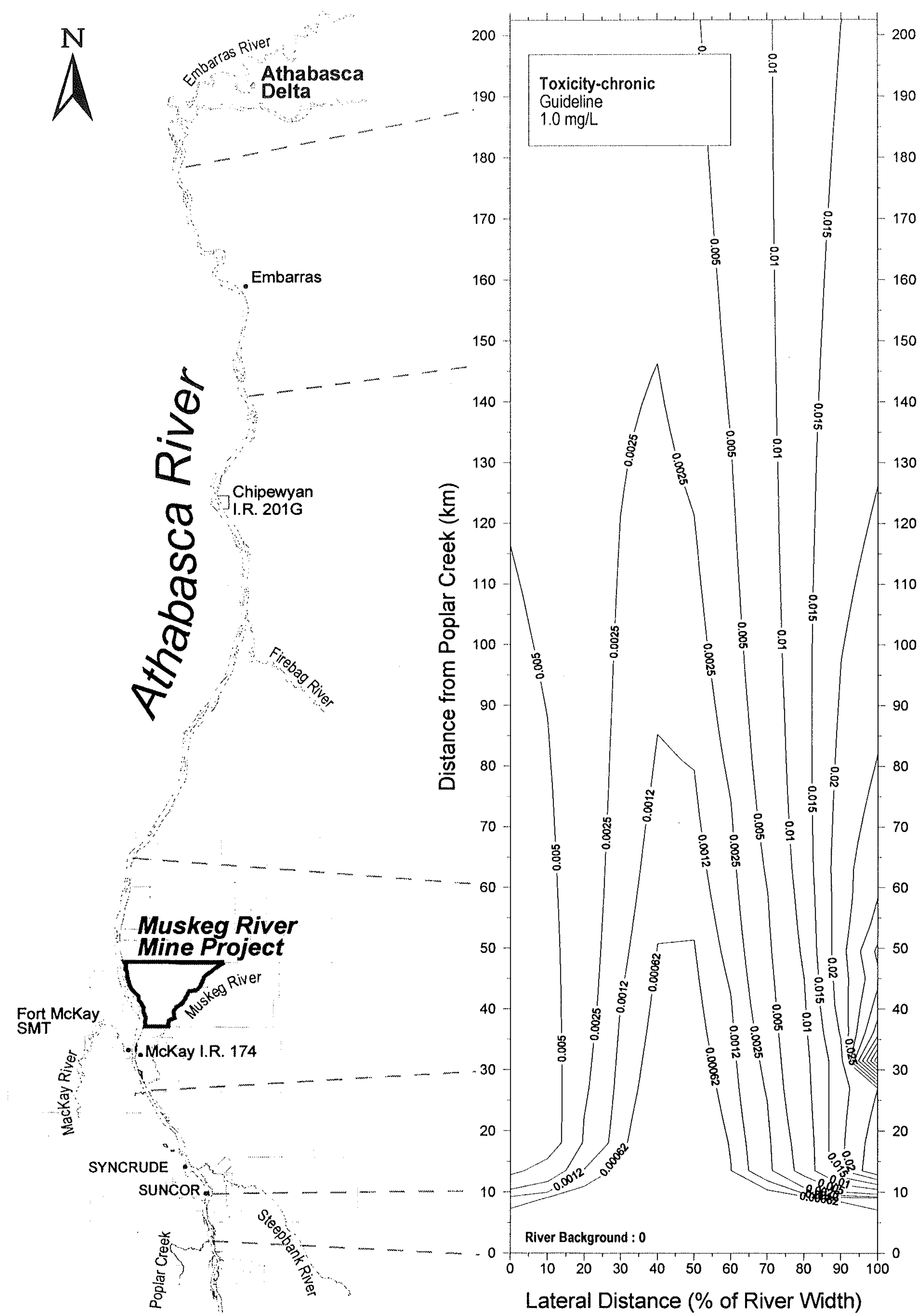

Figure XII-17 Muskeg River Mine Project Scenario Year: Far Future at 7Q10 Flow With Ice Cover (RDR)

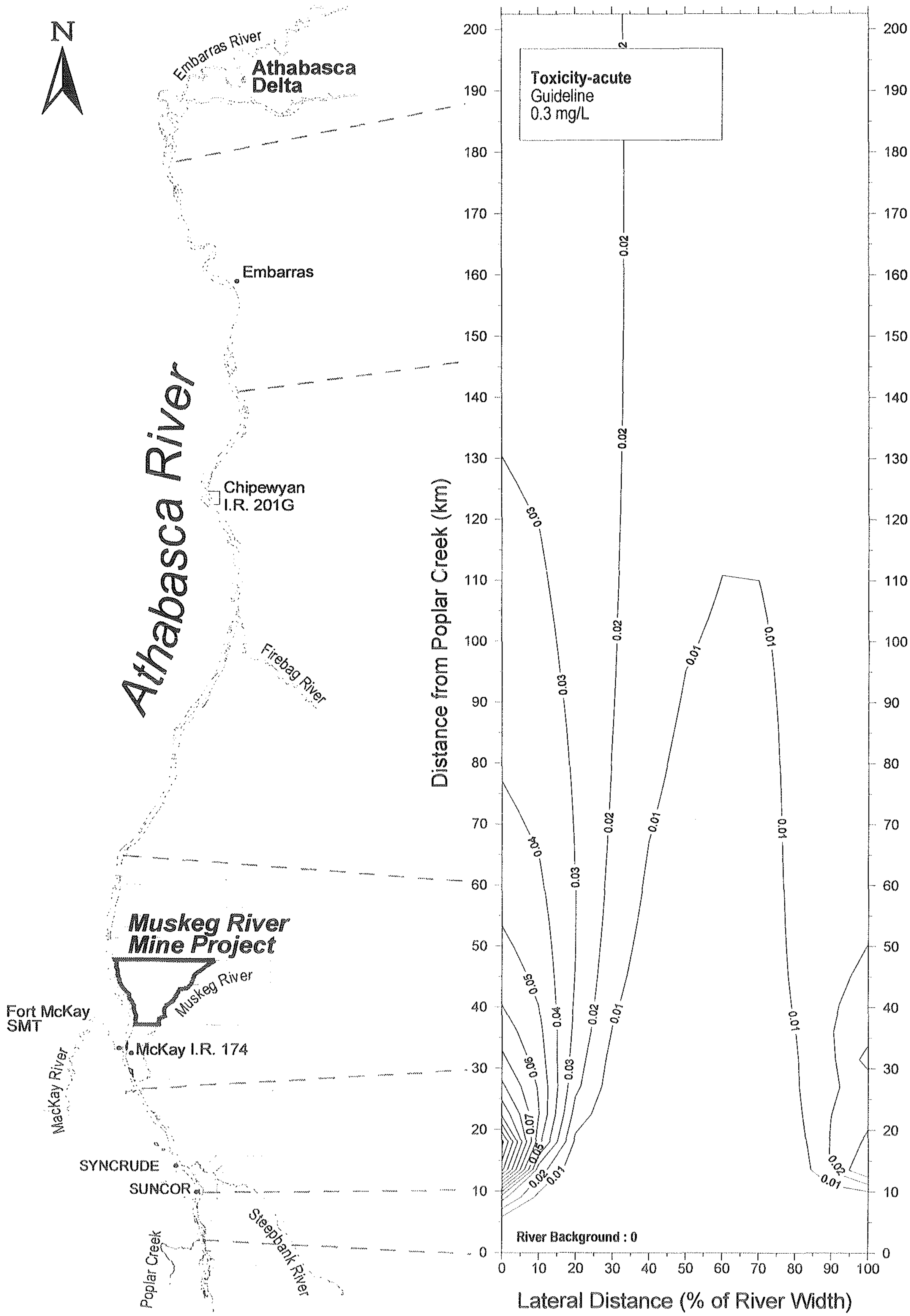

Figure XII-18 Muskeg River Mine Project Scenario Year: 2030 at Mean Open Water Flow (RDR)

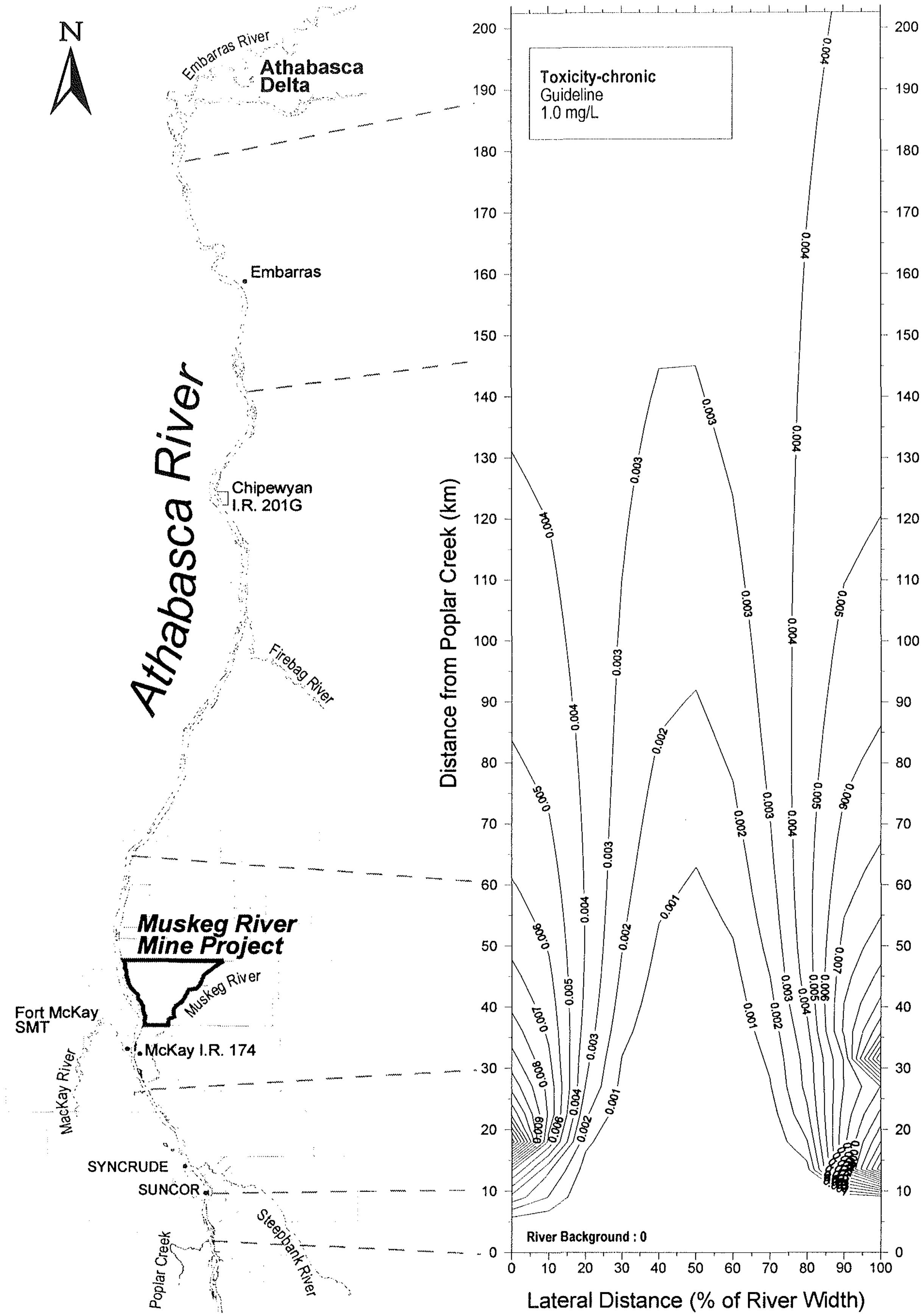

Figure XII-19 Muskeg River Mine Project Scenario Year: 2030 at Mean Open Water Flow (RDR)

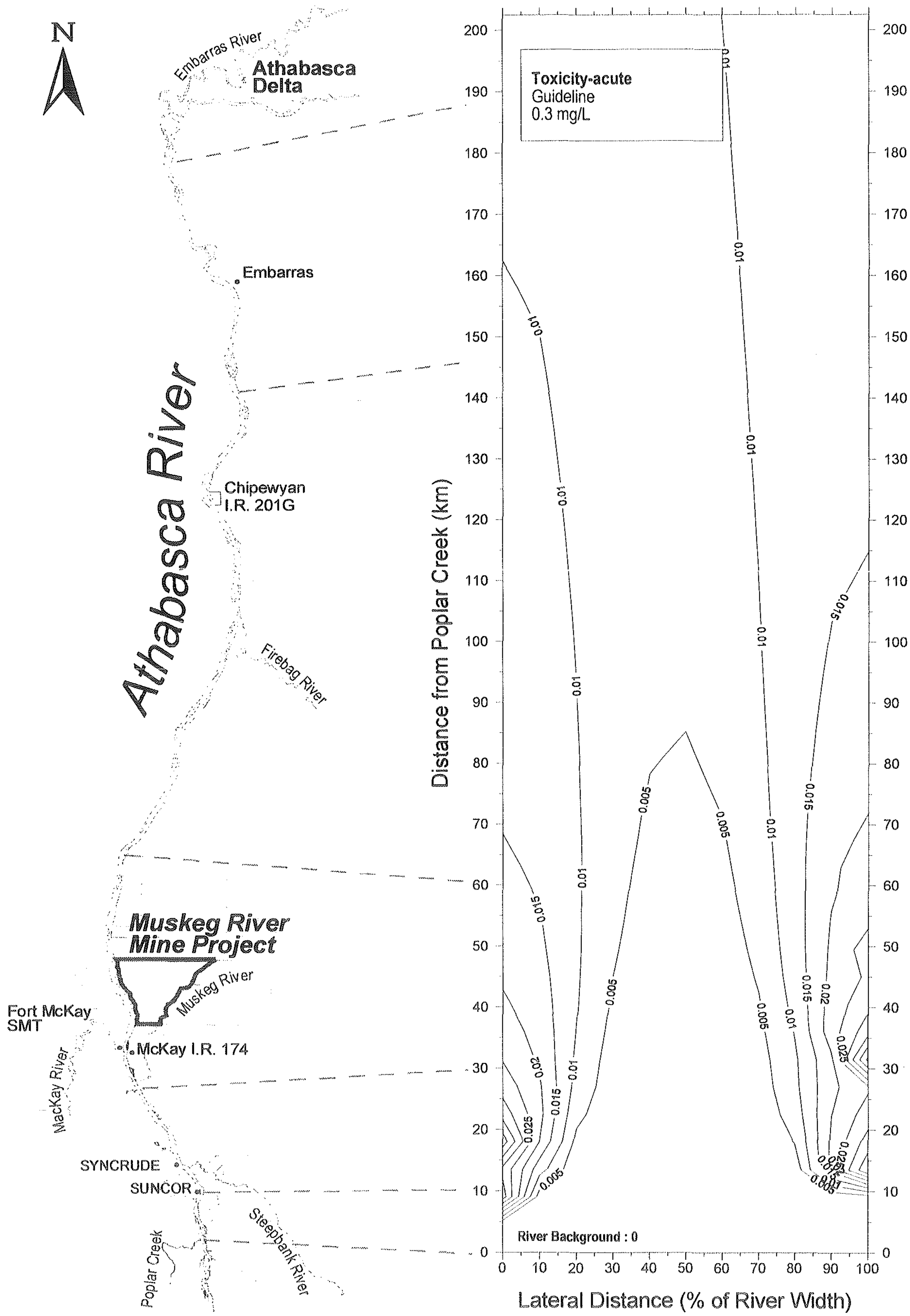

Figure XII-20 Muskeg River Mine Project Scenario Year: Far Future at Mean Open Water Flow (RDR)

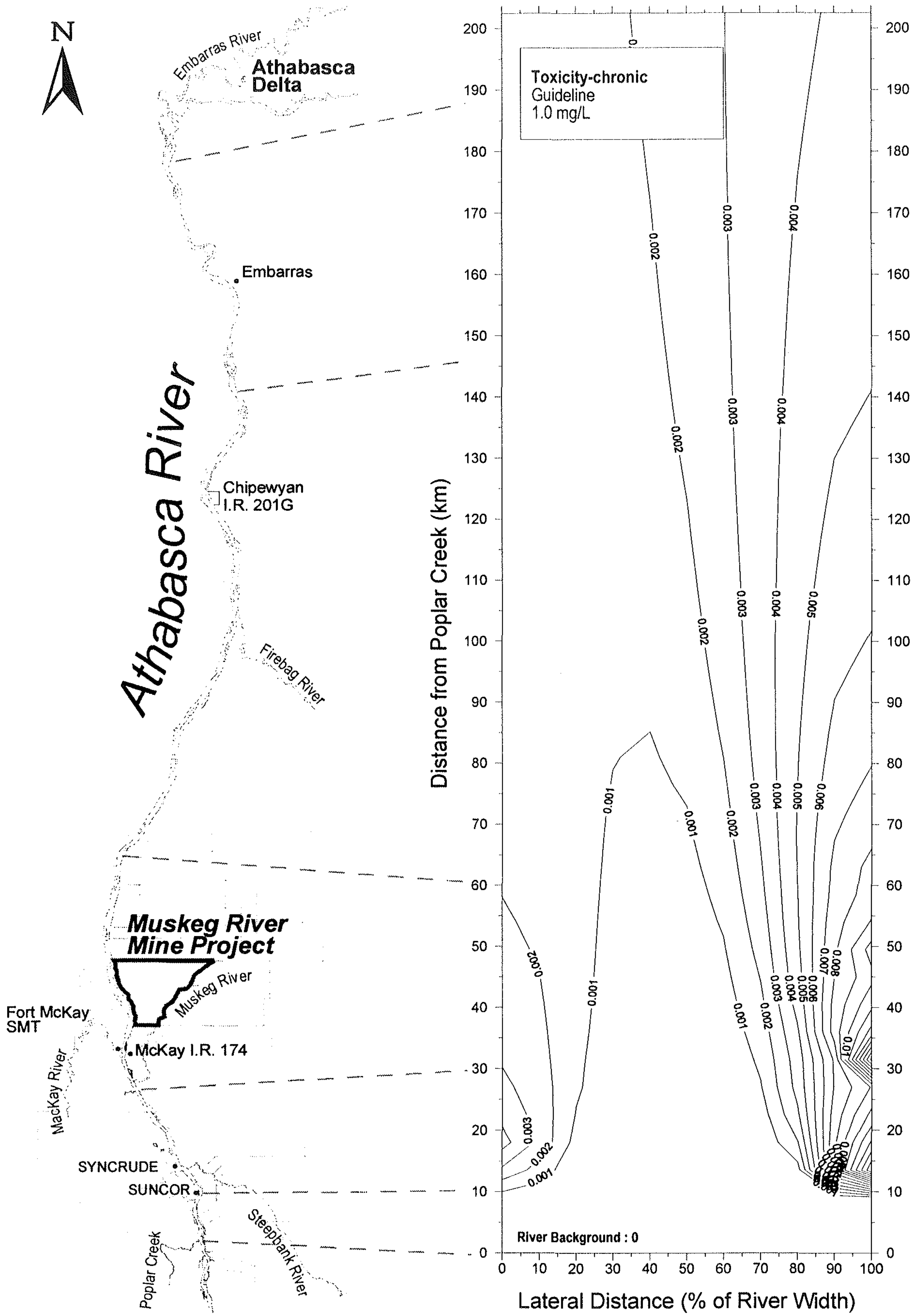

Figure XII-21 Muskeg River Mine Project Scenario Year: Far Future at Mean Open Water Flow (RDR)

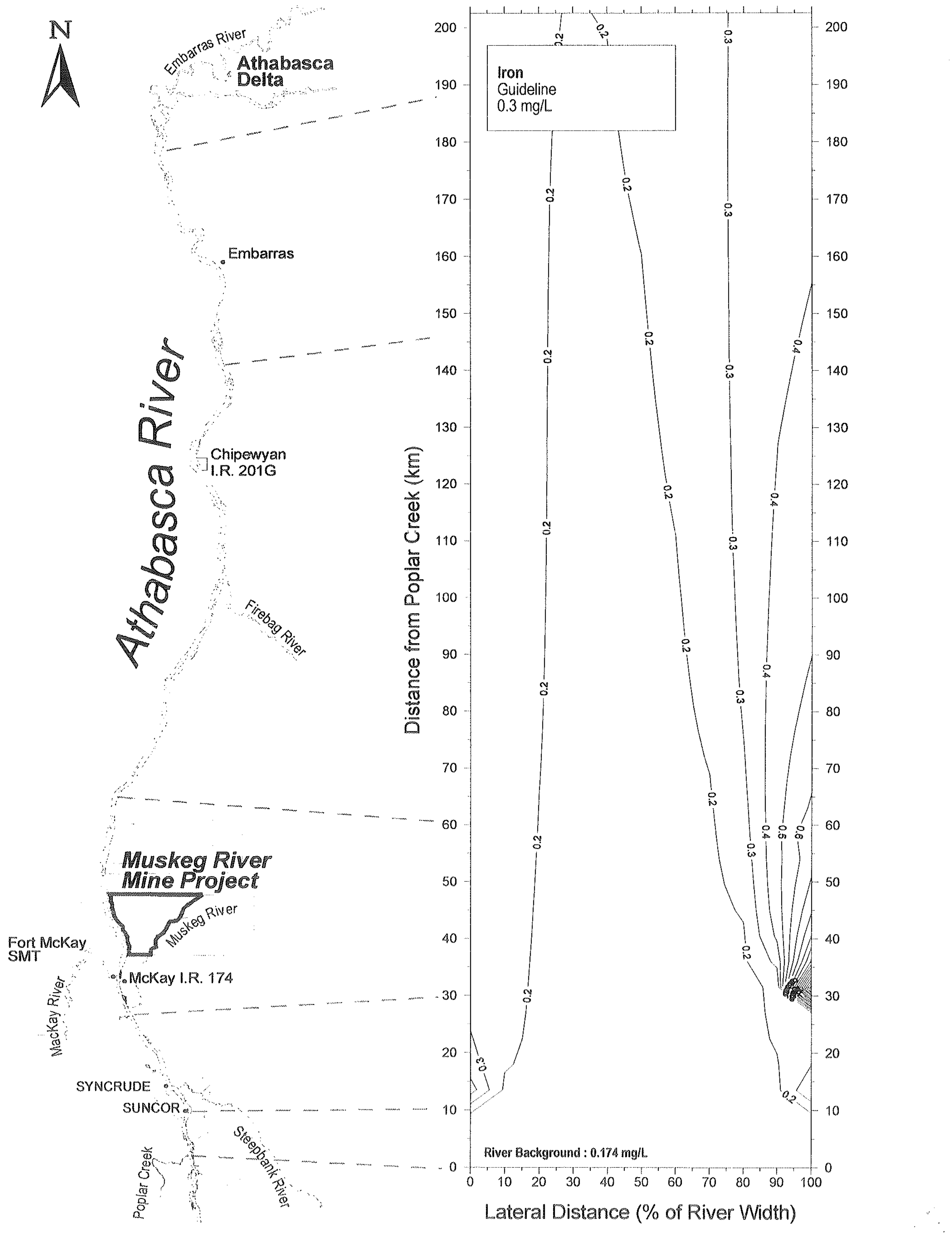

Figure XII-22 Muskeg River Mine Project Scenario Year: 2007 at 7Q10 Flow With Ice Cover (RDR)

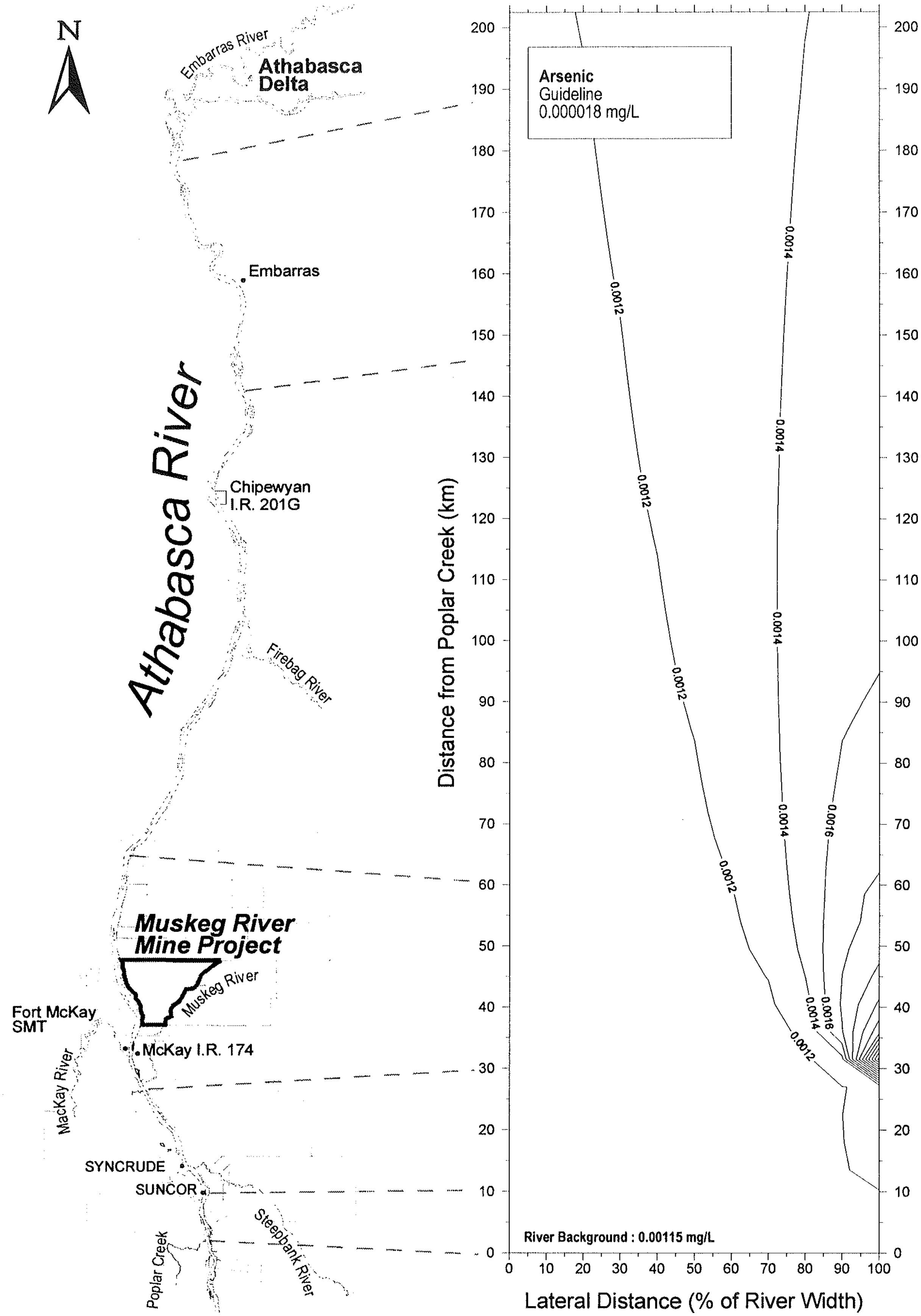

Figure XII-23 Muskeg River Mine Project Scenario Year: 2007 at Mean Open Water Flow (RDR)

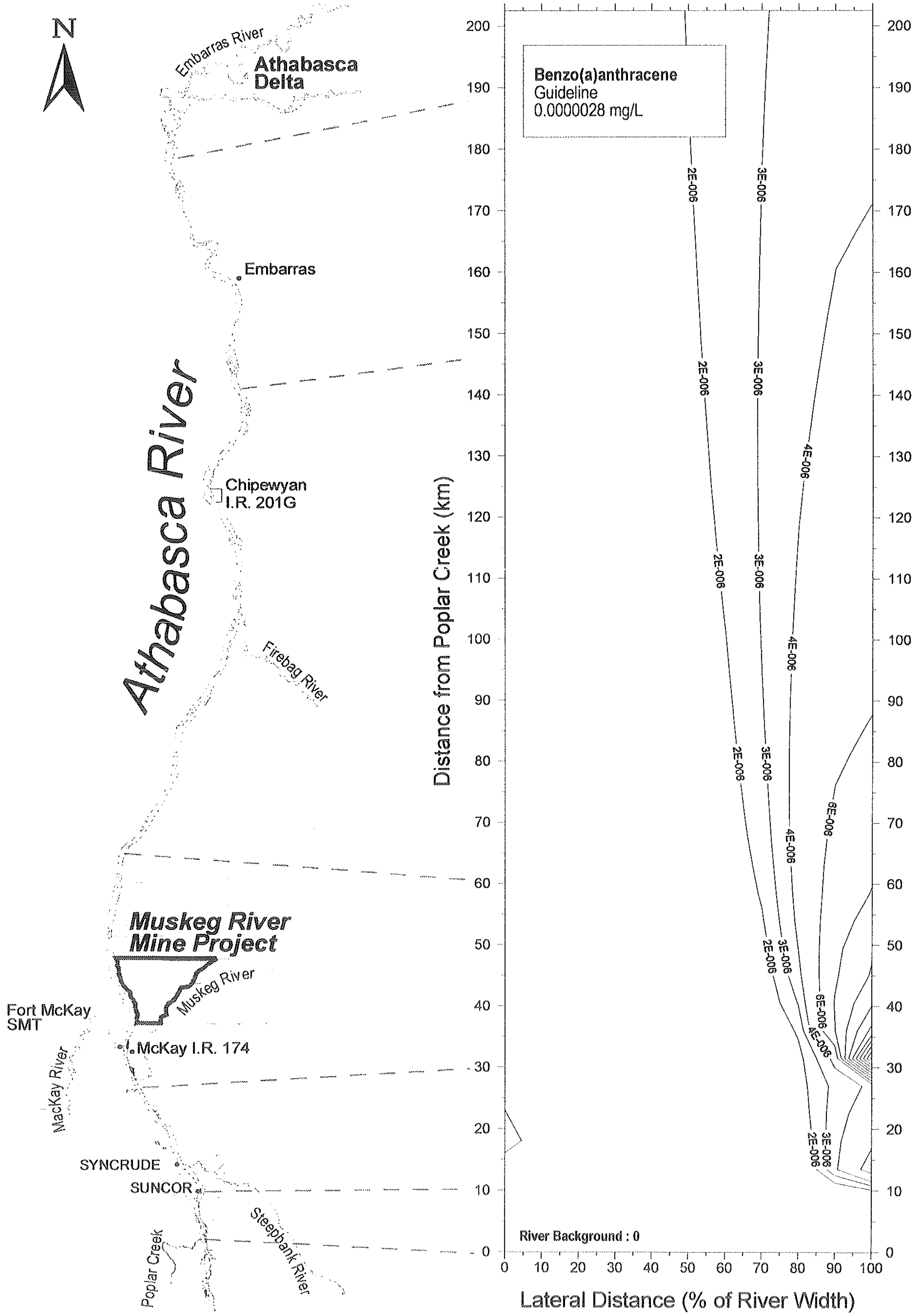

Figure XII-24 Muskeg River Mine Project Scenario Year: Far Future at Mean Open Water Flow (RDR)

APPENDIX XIII

HUMAN AND WILDLIFE HEALTH: CHEMICAL SCREENING

XIII HUMAN AND WILDLIFE HEALTH APPENDIX

XIII.1 Chemical Screening

The objective of screening chemicals is to focus the list of chemicals measured in various media (e.g., water, air, fish, plants, meat) to those chemicals that may be a concern because of their concentrations and their potential to cause adverse human or wildlife health effects. This list of chemicals of potential concern is used to assist in receptor and exposure pathway screening, and the chemicals identified here are carried forward into the Risk Analysis phase.

The methodology for chemical screening is described in detail in Appendix X. This appendix presents the chemical screening tables for the Human Health Cumulative Effects Assessment and Regional Development Review Sections (F12 and G12) and for wildlife health aspects of the Wildlife Cumulative Effects Assessment and Regional Development Review (Sections F11 and G11).

XIII.2 Risk Estimation Results for Airborne Exposures

Table XIII-11 provides the exposure ratios calculated for child and adult receptors exposed to airborne emissions from existing, approved and Muskeg River Mine developments (i.e., CEA). Table XIII-12 provides similar information for the RDR scenario (including existing, approved, planned and Muskeg River Mine developments).

Table XIII-1 Wildlife Health Screening Level Criteria for Consumption of Drinking Water

Chemicals	CCREM[a] (mg/L) (livestock)	BC MOE[b] (mg/L) (livestock/ wildlife)	Screening[c] Level Criteria (mg/L)
PAHs AND SUBSTITUTED PAHs			
Acenaphthylene	-[d]	-[d]	-[d]
Acenaphthene group[e]	-[d]	-[d]	-[d]
Benzo(a)anthracene group[e]	-[d]	-[d]	-[d]
Benzo(ghi)perylene	-[d]	-[d]	-[d]
Benzo(a)pyrene group[e]	-[d]	-[d]	-[d]
Biphenyl	-[d]	-[d]	-[d]
Dibenzothiophene group[e]	-[d]	-[d]	-[d]
Fluoranthene group[e]	-[d]	-[d]	-[d]
Fluorene group[e]	-[d]	-[d]	-[d]
Naphthalene group[e]	-[d]	-[d]	-[d]
Phenanthrene group[e]	-[d]	-[d]	-[d]
Pyrene	-[d]	-[d]	-[d]
SUBSTITUTED PANH COMPOUNDS			
Acridine group[e]	-[d]	-[d]	-[d]
Quinoline group[e]	-[d]	-[d]	-[d]
NAPHTHENIC ACIDS			
Naphthenic acids	-[d]	-[d]	-[d]
VOLATILES			
Carbon tetrachloride	-[d]	0.005	0.005
Chloroform	-[d]	-[d]	-[d]
Ethylbenzene	-[d]	-[d]	-[d]
Methylene chloride	-[d]	0.05	0.05
Toluene	-[d]	-[d]	-[d]
m-+p-xylenes	-[d]	-[d]	-[d]
o-xylene	-[d]	-[d]	-[d]

Table XIII-1 Wildlife Health Screening Level Criteria for Consumption of Drinking Water

Chemicals	CCREM[a] (mg/L) (livestock)	BC MOE[b] (mg/L) (livestock/ wildlife)	Screening[c] Level Criteria (mg/L)
PHENOLS			
Phenol	-[d]	-[d]	-[d]
2,4-Dimethylphenol	-[d]	-[d]	-[d]
m-cresol	-[d]	-[d]	-[d]
o-cresol	-[d]	-[d]	-[d]
INORGANICS			
Aluminum	5	5	5
Ammonia	-[d]	-[d]	-[d]
Antimony	-[d]	-[d]	-[d]
Arsenic	0.5	0.5	0.5
Barium	-[d]	-[d]	-[d]
Beryllium	0.1	0.1	0.1
Boron	5	5	5
Cadmium	0.02	0.02	0.02
Calcium	1000	1000	1000
Chloride	-[d]	-[d]	-[d]
Chromium	1	1	1
Cobalt	1	1	1
Copper	0.5	0.3	0.3
Cyanide	-[d]	-[d]	-[d]
Iron	-[d]	-[d]	-[d]
Lead	0.1	0.1	0.1
Lithium	-[d]	5	5
Magnesium	-[d]	-[d]	-[d]
Manganese	-[d]	-[d]	-[d]
Mercury	0.003	0.002	0.002

Table XIII-1 Wildlife Health Screening Level Criteria for Consumption of Drinking Water

Chemicals	CCREM[a] (mg/L) (livestock)	BC MOE[b] (mg/L) (livestock/ wildlife)	Screening[c] Level Criteria (mg/L)
Molybdenum	0.5	0.05	0.05
Nickel	1	1	1
Phosphorus	_[d]	_[d]	_[d]
Potassium	_[d]	_[d]	_[d]
Selenium	0.05	0.05	0.05
Silicon	_[d]	_[d]	_[d]
Silver	_[d]	_[d]	_[d]
Sodium	_[d]	_[d]	_[d]
Strontium	_[d]	_[d]	_[d]
Sulphate	1000	1000	1000
Tin	_[d]	_[d]	_[d]
Titanium	_[d]	_[d]	_[d]
Vanadium	0.1	0.1	0.1
Uranium	0.2	0.2	0.2
Zinc	50	50	50
Zirconium	_[d]	_[d]	_[d]

[a] Canadian Council of Resource and Environment Ministers Water Quality Guidelines for Livestock Drinking Water Quality (CCREM 1987).

[b] British Columbia Ministry of Environment Water Quality Criteria for the protection of livestock and/or wildlife (BCE Contam Sites Regulation, 1997).

[c] Screening Level Criteria are the lowest of the listed criteria values.

[d] No criterion.

[e] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X; Table X-1.

Table XIII-2 Comparison of Muskeg River Concentrations for Cumulative Effects Assessment to Background Concentrations and Wildlife Health Screening Level Criteria for Water

Chemical	Muskeg River Concentrations for CEA				Screening Level Criteria[b]	Background Muskeg River[c]	Comments
	2007 (max)[a] (mg/L)	2020 (max)[a] (mg/L)	2030 (max)[a] (mg/L)	Equilibrium (max)[a] (mg/L)	(mg/L)	(median) (mg/L)	
PAHs AND SUBSTITUTED PAHs							
Benzo(a)anthracene group[e]	0	0	1.80E-05	3.70E-05	-[d]	-[e]	No criterion
Benzo(a)pyrene group[e]	0	0	3.80E-06	4.40E-06	-[d]	-[e]	No criterion
NAPHTHENIC ACIDS							
Naphthenic acids	3.4	3.8	3.5	4.2	-[d]	4	No criterion; EXCEEDS BACKGROUND
INORGANICS							
Aluminum	0.12	0.07	0.25	0.12	5	0.05	Does not exceed.
Ammonia	0.18	0.09	0.11	0.14	-[d]	0.05	No criterion; EXCEEDS BACKGROUND[f]
Antimony	0.000076	0.000023	0.00013	0.000015	-[d]	-[e]	No criterion
Arsenic	0.005	0.004	0.004	0.003	0.5	0.0029	Does not exceed.
Barium	0.05	0.03	0.05	0.03	-[d]	0.03	No criterion; EXCEEDS BACKGROUND
Beryllium	0.00015	0.000047	0.00052	0.00014	0.1	-[e]	Does not exceed.
Boron	0.04	0.04	0.36	0.16	5	0.05	Does not exceed.
Cadmium	0.0002	0.0002	0.0008	0.0004	0.02	0.0002	Does not exceed.
Calcium	48.6	41.6	50.2	40.9	1000	38.4	Does not exceed.
Chloride	2.7	3	7.7	4.3	-[d]	3.1	No criterion; EXCEEDS BACKGROUND[f]
Chromium	0.0038	0.0015	0.0032	0.0007	1	0	Does not exceed.
Copper	0.002	0.001	0.003	0.001	0.3	0.001	Does not exceed.
Iron	1.6	1	1.2	0.9	-[d]	0.79	No criterion; EXCEEDS BACKGROUND[f]
Lead	0.0006	0.0005	0.0018	0.0006	0.1	0.0004	Does not exceed.
Lithium	0.006	0.006	0.024	0.014	-[d]	-[e]	No criterion
Magnesium	10.1	9.7	11.3	10.4	-[d]	9.6	No criterion; EXCEEDS BACKGROUND[f]
Manganese	0.15	0.07	0.1	0.05	-[d]	0.04	No criterion; EXCEEDS BACKGROUND[f]
Mercury	0.000085	0.000095	0.00009	0.000095	0.002	0.0001	Does not exceed.
Molybdenum	0.00062	0.00033	0.087	0.013	0.05	0.0002	EXCEEDS
Nickel	0.0003	0.0004	0.0022	0.0006	1	0.0004	Does not exceed.
Selenium	0.0018	0.0006	0.0008	0.000038	0.05	-[e]	Does not exceed.
Silver	0	0	0.0001	0.000016	-[d]	-[e]	No criterion
Sodium	9.7	10.2	55.8	41.2	-[d]	10.4	No criterion; EXCEEDS BACKGROUND[f]
Strontium	0.08	0.06	0.2	0.09	-[d]	0.06	No criterion; EXCEEDS BACKGROUND[f]
Sulphate	4.3	4.5	83.1	23.7	1000	4.52	Does not exceed.
Vanadium	0.001	0.001	0.011	0.002	0.1	0.0004	Does not exceed.
Zinc	0.04	0.02	0.03	0.01	50	0.011	Does not exceed.

(a) Maximum predicted cumulative concentration for years specified (cumulative effects scenario; Section F11)

(b) Screening level criteria were based on the lowest available criteria.

(c) Median concentrations in Muskeg River in 1997.

(d) No data or criterion.

(e) For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X, Table X-1.

(f) These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

Table XIII-3 Comparison of Muskeg River Concentrations for Cumulative Effects Assessment to Risk-Based Concentrations for Wildlife

Chemical	Muskeg River Concentrations for CEA 2007 (max)[a] (mg/L)	2020 (max)[a] (mg/L)	2030 (max)[a] (mg/L)	Equilibrium (max)[a] (mg/L)	RBC for[b] Water Shrew (mg/L)	RBC for[b] River Otter (mg/L)	RBC for[b] Killdeer (mg/L)	RBC for[b] Great Blue Heron (mg/L)	RBC for[b] Moose (mg/L)	RBC for[b] Snowshoe Har (mg/L)	RBC for[b] Black Bear (mg/L)	Comments
PAHs AND SUBSTITUTED PAHs												
Benzo(a)anthracene group[d]	0	0	1.80E-05	3.70E-05	8	3.1	10.2	22.4	1.7	4	2	Does not exceed.
Benzo(a)pyrene group[d]	0	0	3.80E-06	4.40E-06	0.8	0.3	0.05	0.1	0.2	0.4	0.2	Does not exceed.
NAPHTHENIC ACIDS												
Naphthenic acids	3.4	3.8	3.5	4.2	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]	No criterion
INORGANICS												
Aluminum	0.12	0.07	0.25	0.12	1.6	0.6	49.8	108.8	0.3	0.8	0.4	Does not exceed.
Antimony	0.000076	0.000023	0.00013	0.000015	0.1	0.04	-[c]	-[c]	0.02	0.05	0.02	Does not exceed.
Arsenic	0.005	0.004	0.004	0.003	0.1	0.04	10.2	22.4	0.02	0.05	0.03	Does not exceed.
Barium	0.05	0.03	0.05	0.03	8	3.1	2.3	5.1	1.7	3.9	2	Does not exceed.
Beryllium	0.00015	0.000047	0.00052	0.00014	1	0.4	-[c]	-[c]	0.2	0.5	0.3	Does not exceed.
Boron	0.04	0.04	0.36	0.16	41.7	16	-[c]	-[c]	9	20.4	10.5	Does not exceed.
Cadmium	0.0002	0.0002	0.0008	0.0004	1.4	0.5	0.7	1.4	0.03	0.1	0.03	Does not exceed.
Chromium	0.0038	0.0015	0.0032	0.0007	-[c]	-[c]	0.5	-[c]	1	2.4	1.2	Does not exceed.
Copper	0.002	0.001	0.003	0.001	22.6	8.7	9.5	20.8	4.9	11.2	5.8	Does not exceed.
Lead	0.0006	0.0005	0.0018	0.0006	11.9	4.6	1.7	3.8	2.6	5.9	3	Does not exceed.
Lithium	0.006	0.006	0.024	0.014	14	5.4	-[c]	-[c]	3.8	8.9	4.6	Does not exceed.
Manganese	0.15	0.07	0.1	0.05	131.1	50.3	21.3	32.9	28	64.3	33	Does not exceed.
Mercury	0.000085	0.000095	0.00009	0.000095	2	0.7	0.2	0.4	0.4	0.9	0.5	Does not exceed.
Molybdenum	0.00062	0.00033	0.087	0.013	0.2	0.1	1.6	968.6	0.04	0.1	0.05	EXCEEDS (moose, bear)
Nickel	0.0003	0.0004	0.0022	0.0006	59.6	22.9	35.1	3.5	12.8	29.3	15	Does not exceed.
Selenium	0.0018	0.0006	0.0008	0.000038	0.3	0.1	0.2	76.7	0.1	0.1	0.1	Does not exceed.
Silver	0	0	0.0001	0.000016	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]	No criterion
Strontium	0.08	0.06	0.2	0.09	392	150.4	-[c]	-[c]	83.8	192.2	98.7	Does not exceed.
Vanadium	0.001	0.001	0.011	0.002	0.3	0.1	5.2	15.9	0.1	0.1	0.1	Does not exceed.
Zinc	0.04	0.02	0.03	0.01	238.4	91.5	6.6	11.3	51	116.9	60	Does not exceed.

[a] Maximum predicted cumulative concentration for years specified (cumulative effects scenario; Section F11).
[b] RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)
Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.
[c] No data or criterion.
[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X, Table X-1.

Table XIII-4 Comparison of Cumulative Regional Development Muskeg River Concentrations to background Concentrations and Wildlife Health Screening Level Criteria for Water

Chemical	Muskeg River Concentrations for RDR				Screening Level Criteria[b]	Background Muskeg River[c]	Comments
	2007 (max)[a] (mg/L)	2020 (max)[a] (mg/L)	2030 (max)[a] (mg/L)	Equilibrium (max)[a] (mg/L)	(mg/L)	(median) (mg/L)	
PAHs AND SUBSTITUTED PAHs							
Benzo(a)anthracene group[e]	0	0	1.80E-05	4.20E-05	-[d]	-[e]	No criterion
Benzo(a)pyrene group[e]	0	0	3.90E-06	4.80E-06	-[d]	-[e]	No criterion
NAPHTHENIC ACIDS							
Naphthenic acids	3.4	3.7	3.4	4.1	-[d]	4	No criterion; EXCEEDS BACKGROUND
INORGANICS							
Aluminum	0.13	0.08	0.26	0.13	5	0.05	Does not exceed.
Ammonia	0.2	0.1	0.1	0.1	-[d]	0.05	No criterion; EXCEEDS BACKGROUND[f]
Antimony	0.00008	0.000032	0.00015	0.000015	-[d]	-[e]	No criterion
Arsenic	0.006	0.004	0.004	0.003	0.5	0.0029	Does not exceed.
Barium	0.05	0.04	0.05	0.03	-[d]	0.03	No criterion; EXCEEDS BACKGROUND
Beryllium	0.00016	0.000065	0.00055	0.00016	0.1	-[e]	Does not exceed.
Boron	0.04	0.04	0.37	0.17	5	0.05	Does not exceed.
Cadmium	0.0002	0.0002	0.0008	0.0005	0.02	0.0002	Does not exceed.
Calcium	49.2	42.8	52	41.3	1000	38.4	Does not exceed.
Chloride	2.6	2.9	7.8	4.4	-[d]	3.1	No criterion; EXCEEDS BACKGROUND[f]
Chromium	0.004	0.0019	0.0037	0.0008	1	0	Does not exceed.
Copper	0.002	0.001	0.003	0.001	0.3	0.001	Does not exceed.
Iron	1.6	1.1	1.4	0.9	-[d]	0.79	No criterion; EXCEEDS BACKGROUND[f]
Lead	0.0006	0.0005	0.0019	0.0006	0.1	0.0004	Does not exceed.
Lithium	0.006	0.006	0.025	0.015	-[d]	-[e]	No criterion
Magnesium	10.1	9.8	11.5	10.6	-[d]	9.6	No criterion; EXCEEDS BACKGROUND[f]
Manganese	0.16	0.09	0.12	0.06	-[d]	0.04	No criterion; EXCEEDS BACKGROUND[f]
Mercury	0.000084	0.000094	0.000088	0.000094	0.002	0.0001	Does not exceed.
Molybdenum	0.00065	0.00038	0.091	0.013	0.05	0.0002	EXCEEDS
Nickel	0.0003	0.0004	0.0022	0.0006	1	0.0004	Does not exceed.
Selenium	0.0019	0.0008	0.0011	0.000041	0.05	-[e]	Does not exceed.
Silver	0	0	0.0001	0.000017	-[d]	-[e]	No criterion
Sodium	9.6	10.1	57.4	45.2	-[d]	10.4	No criterion; EXCEEDS BACKGROUND[f]
Strontium	0.08	0.07	0.21	0.09	-[d]	0.06	No criterion; EXCEEDS BACKGROUND
Sulphate	4.3	4.4	86.1	25.3	1000	4.52	Does not exceed.
Vanadium	0.001	0.001	0.012	0.002	0.1	0.0004	Does not exceed.
Zinc	0.04	0.02	0.03	0.01	50	0.011	Does not exceed.

[a] Maximum predicted cumulative concentration for years specified (regional development review scenario; Section G11).

[b] Screening level criteria were based on the lowest available criteria.

[c] Median concentration in Muskeg River in 1997.

[d] No data or criterion.

[e] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X, Table X-1.

[f] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

Table XIII-5 Comparison of Cumulative Regional Dvelopment Muskeg River Concentrations to Risk-Based Concentrations for Wildlife

Chemical	Muskeg River Concentrations for RDR				RBC for [b]	RBC for [b]	RBC for [b]	RBC for [b]	RBC for [b]	RBC for [b]	RBC for [b]	Comments
	2007 (max)[a]	2020 (max)[a]	2030 (max)[a]	Equilibrium (max)[a]	Water Shrew	River Otter	Killdeer	Great Blue Heron	Moose	Snowshoe Hare	Black Bear	
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHs AND SUBSTITUTED PAHs												
Benzo(a)anthracene group[d]	0	0	1.80E-05	4.20E-05	8	3.1	10.2	22.4	1.7	4	2	Does not exceed.
Benzo(a)pyrene group[d]	0	0	3.90E-06	4.80E-06	0.8	0.3	0.05	0.1	0.2	0.4	0.2	Does not exceed.
NAPHTHENIC ACIDS												
Naphthenic acids	3.4	3.7	3.4	4.1	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]	No criterion
INORGANICS												
Aluminum	0.13	0.08	0.26	0.13	1.6	0.6	49.8	108.8	0.3	0.8	0.4	Does not exceed.
Antimony	0.00008	0.000032	0.00015	0.000015	0.1	0.04	-[c]	-[c]	0.02	0.05	0.02	Does not exceed.
Arsenic	0.006	0.004	0.004	0.003	0.1	0.04	10.2	22.4	0.02	0.05	0.03	Does not exceed.
Barium	0.05	0.04	0.05	0.03	8	3.1	2.3	5.1	1.7	3.9	2	Does not exceed.
Beryllium	0.00016	0.000065	0.00055	0.00016	1	0.4	-[c]	-[c]	0.2	0.5	0.3	Does not exceed.
Boron	0.04	0.04	0.37	0.17	41.7	16	-[c]	-[c]	9	20.4	10.5	Does not exceed.
Cadmium	0.0002	0.0002	0.0008	0.0005	1.4	0.5	0.7	1.4	0.03	0.1	0.03	Does not exceed.
Chromium	0.004	0.0019	0.0037	0.0008	-[c]	-[c]	0.5	-[c]	1	2.4	1.2	Does not exceed.
Copper	0.002	0.001	0.003	0.001	22.6	8.7	9.5	20.8	4.9	11.2	5.8	Does not exceed.
Lead	0.0006	0.0005	0.0019	0.0006	11.9	4.6	1.7	3.8	2.6	5.9	3	Does not exceed.
Lithium	0.006	0.006	0.025	0.015	14	5.4	-[c]	-[c]	3.8	8.9	4.6	Does not exceed.
Manganese	0.16	0.09	0.12	0.06	131.1	50.3	21.3	32.9	28	64.3	33	Does not exceed.
Mercury	0.000084	0.000094	0.000088	0.000094	2	0.7	0.2	0.4	0.4	0.9	0.5	Does not exceed.
Molybdenum	0.00065	0.00038	0.091	0.013	0.2	0.1	1.6	968.6	0.04	0.1	0.05	EXCEEDS (Moose and Black Bear)
Nickel	0.0003	0.0004	0.0022	0.0006	59.6	22.9	35.1	3.5	12.8	29.3	15	Does not exceed.
Selenium	0.0019	0.0008	0.0011	0.000041	0.3	0.1	0.2	76.7	0.1	0.1	0.1	Does not exceed.
Silver	0	0	0.0001	1.7e0-5	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]	-[c]	No criterion
Strontium	0.08	0.07	0.21	0.09	392	150.4	-[c]	-[c]	83.8	192.2	98.7	Does not exceed.
Vanadium	0.001	0.001	0.012	0.002	0.3	0.1	5.2	15.9	0.1	0.1	0.1	Does not exceed.
Zinc	0.04	0.02	0.03	0.01	238.4	91.5	6.6	11.3	51	116.9	60	Does not exceed.

(a) Maximum predicted cumulative concentration for years specified (regional development review scenario; Section G11)

(b) RBC = THQ x (NOEAL x body weight)/(ingestion rate x exposure frequency x bioavailability factor)

Note that for the screening assessment, the target hazard quotient (THQ) was conservatively set at 0.1 and exposure frequency and bioavailability factors were set at 1.0.

(c) No data or criterion.

(d) For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X, Table X-1.

Table XIII-6 Human Health Screening Level Criteria for Consumption of Drinking Water

Chemicals	HWC[a] Drinking Water Criteria (mg/L)	U.S. EPA[b] Drinking Water Criteria (mg/L)	BC MOE[c] Drinking Water Criteria (mg/L)	Screening Level[d] Criteria (mg/L)
PAHs AND SUBSTITUTED PAHs				
Acenaphthylene	-[e]	-[e]	-[e]	-[e]
Acenaphthene group[f]	-[e]	-[e]	-[e]	-[e]
Benzo(a)anthracene group[f]	-[e]	0.0001	-[e]	0.0001
Benzo(a)pyrene group[f]	0.00001	0.0002	0.00001	0.00001
Benzo(ghi)perylene	-[e]	-[e]	-[e]	-[e]
Biphenyl	-[e]	-[e]	-[e]	-[e]
Dibenzothiophene group[f]	-[e]	-[e]	-[e]	-[e]
Fluorene group[f]	-[e]	-[e]	-[e]	-[e]
Fluoranthene group[f]	-[e]	-[e]	-[e]	-[e]
Naphthalene group[f]	-[e]	-[e]	-[e]	-[e]
Phenanthrene group[f]	-[e]	-[e]	-[e]	-[e]
Pyrene	-[e]	-[e]	-[e]	-[e]
SUBSTITUTED PANH COMPOUNDS				
Acridine group	-[e]	-[e]	-[e]	-[e]
Quinoline group[f]	-[e]	-[e]	-[e]	-[e]
VOLATILES				
Carbon tetrachloride	0.005	0.005	0.005	0.005
Chloroform	0.1	0.1	0.1	0.1
Ethylbenzene	0.0024[g]	0.7	0.0024	0.0024[g]
Methylene chloride	0.05	0.005	0.05	0.005
Toluene	0.024[g]	1	-[e]	0.024[g]
m-+p-xylenes	0.3[g]	10	0.3	0.3[g]
o-xylene	0.3[g]	10	0.3	0.3[g]
PHENOLIC COMPOUNDS				
Phenol	-[e]	-[e]	-[e]	-[e]
2,4-Dimethylphenol	-[e]	-[e]	-[e]	-[e]
m-cresol	-[e]	-[e]	-[e]	-[e]
NAPHTHENIC ACIDS				
Naphthenic acids	-[e]	-[e]	-[e]	-[e]

Table XIII-6 Human Health Screening Level Criteria for Consumption of Drinking Water

Chemicals	HWC[a] Drinking Water Criteria (mg/L)	U.S. EPA[b] Drinking Water Criteria (mg/L)	BC MOE[c] Drinking Water Criteria (mg/L)	Screening Level[d] Criteria (mg/L)
INORGANICS				
Aluminum	-[e]	0.2[g]	0.2	0.2[g]
Ammonia	-[e]	-[e]	-[e]	-[e]
Antimony	-[e]	0.006	-[e]	0.006
Arsenic	0.025	0.05	0.025	0.025
Barium	1	2	1	1
Beryllium	-[e]	0.004	-[e]	0.004
Boron	5	-[e]	5	5
Cadmium	0.005	0.005	0.005	0.005
Calcium	-[e]	-[e]	-[e]	-[e]
Chloride	250[g]	250[g]	250[g]	250[g]
Chromium	0.05	0.1	0.05	0.05
Cobalt	-[e]	-[e]	-[e]	-[e]
Copper	1[g]	1.3	1	1
Cyanide	0.2	0.2	0.2	0.2
Iron	0.3[g]	0.3[g]	0.3[g]	0.3[g]
Lead	0.01	0.015	0.01	0.01
Lithium	-[e]	-[e]	-[e]	-[e]
Magnesium	-[e]	-[e]	-[e]	-[e]
Manganese	0.05[g]	0.05[g]	0.05[g]	0.05[g]
Mercury	0.001	0.002	0.001	0.001
Molybdenum	-[e]	-[e]	0.25	0.25
Nickel	-[e]	0.14	0.2	0.14
Phosphorus	-[e]	-[e]	-[e]	-[e]
Potassium	-[e]	-[e]	-[e]	-[e]
Selenium	0.01	0.05	0.01	0.01
Silicon	-[e]	-[e]	-[e]	-[e]
Silver	-[e]	0.1[g]	-[e]	0.1[g]
Sodium	200[g]	-[e]	200[g]	200[g]
Strontium	-[e]	-[e]	-[e]	-[e]

Table XIII-6 Human Health Screening Level Criteria for Consumption of Drinking Water

Chemicals	HWC[a] Drinking Water Criteria (mg/L)	U.S. EPA[b] Drinking Water Criteria (mg/L)	BC MOE[c] Drinking Water Criteria (mg/L)	Screening Level[d] Criteria (mg/L)
Sulphate	500[g]	500[g]	500[g]	500[g]
Tin	_[e]	_[e]	_[e]	_[e]
Titanium	_[e]	_[e]	_[e]	_[e]
Uranium	_[e]	0.02	_[e]	0.02
Vanadium	_[e]	_[e]	_[e]	_[e]
Zinc	5[g]	5[g]	5[g]	5[g]
Zirconium	_[e]	_[e]	_[e]	_[e]

(a) Health Canada Maximum Acceptable Concentrations (MAC) (HealthCanada 1996).

(b) U.S. Environmental Protection Agency Maximum Contaminants Level for drinking water for human health (U.S. EPA 1996).

(c) British Columbia Ministry of the Environment water standards for drinking water (BCE Contaminated Sites Regulation 1997).

(d) Screening Level Criteria were based the lowest available criteria.

(e) No criterion.

(f) For information on grouping of chemicals and the use of surrogate chemicals, please refer to Table X-1.

(g) Based on an aesthetic objective for drinking water.

Table XIII-7 Comparison of Muskeg River Concentrations for Cumulative Effects Assessment to Background Concentrations and Human Health Screening Level Criteria for Water

Chemical	Muskeg River Concentrations for CEA				Screening Level Criteria[b]	Background Muskeg River[c]	Comments
	2007 (max)[a] (mg/L)	2020 (max)[a] (mg/L)	2030 (max)[a] (mg/L)	Equilibrium (max)[a] (mg/L)	(mg/L)	(median) (mg/L)	
PAHs AND SUBSTITUTED PAHs							
Benzo(a)anthracene group[d]	0	0	1.80E-05	3.70E-05	0.0001	-[e]	Does not exceed.
Benzo(a)pyrene group[d]	0	0	3.80E-06	4.40E-06	0.00001	-[e]	Does not exceed.
NAPHTHENIC ACIDS							
Naphthenic acids	3.4	3.8	3.5	4.2	-[e]	4	No criterion; EXCEEDS BACKGROUND
INORGANICS							
Aluminum	0.12	0.07	0.25	0.12	0.2	0.05	EXCEEDS
Ammonia	0.18	0.09	0.11	0.14	-[e]	0.05	No criterion; EXCEEDS BACKGROUND[g]
Antimony	0.000076	0.000023	0.00013	0.000015	0.006	-[e]	Does not exceed.
Arsenic	0.005	0.004	0.004	0.003	0.025	0.0029	Does not exceed.
Barium	0.05	0.03	0.05	0.03	1	0.03	Does not exceed.
Beryllium	0.00015	0.000047	0.00052	0.00014	0.004	-[e]	Does not exceed.
Boron	0.04	0.04	0.36	0.16	5	0.05	Does not exceed.
Cadmium	0.0002	0.0002	0.0008	0.0004	0.005	0.0002	Does not exceed.
Calcium	48.6	41.6	50.2	40.9	-[e]	38.4	No criterion; EXCEEDS BACKGROUND[g]
Chloride	2.7	3	7.7	4.3	250[f]	3.1	Does not exceed.
Chromium	0.0038	0.0015	0.0032	0.0007	0.05	0	Does not exceed.
Copper	0.002	0.001	0.003	0.001	1	0.001	Does not exceed.
Iron	1.6	1	1.2	0.9	0.3[f]	0.79	EXCEEDS[g]
Lead	0.0006	0.0005	0.0018	0.0006	0.01	0.0004	Does not exceed.
Lithium	0.006	0.006	0.024	0.014	-[e]	-[e]	No criterion
Magnesium	10.1	9.7	11.3	10.4	-[e]	9.6	No criterion; EXCEEDS BACKGROUND[g]
Manganese	0.15	0.07	0.1	0.05	-[e]	0.04	No criterion; EXCEEDS BACKGROUND[g]
Mercury	0.000085	0.000095	0.00009	0.000095	0.05	0.0001	Does not exceed.
Molybdenum	0.00062	0.00033	0.087	0.013	0.001	0.0002	EXCEEDS
Nickel	0.0003	0.0004	0.0022	0.0006	0.25	0.0004	Does not exceed.
Selenium	0.0018	0.0006	0.0008	0.000038	0.01	-[e]	Does not exceed.
Silver	0	0	0.0001	0.000016	-[e]	-[e]	No criterion
Sodium	9.7	10.2	55.8	41.2	200[f]	10.4	Does not exceed.
Strontium	0.08	0.06	0.2	0.09	-[e]	0.06	No criterion; EXCEEDS BACKGROUND
Sulphate	4.3	4.5	83.1	23.7	500[f]	4.52	Does not exceed.
Vanadium	0.001	0.001	0.011	0.002	-[e]	0.0004	No criterion; EXCEEDS BACKGROUND
Zinc	0.04	0.02	0.03	0.01	5	0.011	Does not exceed.

[a] Maximum predicted cumulative concentration for years specified (cumulative effects scenario; Section F12).
[b] Screening level criteria were based on the lowest water quality criteria for human drinking water.
[c] Median concentrations in Muskeg River in 1997.
[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X, Table X-1.
[e] No data or criterion.
[f] Based on an aesthetic objective for drinking water.
[g] These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

Table XIII-8 Comparison of Muskeg River Concentrations for Cumulative Effects Assessment to Risk Based Criteria for Human Health

Chemical	Muskeg River Concentrations for CEA				RBC for Water Ingestion (RBC)[b]	Comments
	2007 (max)[a]	2020 (max)[a]	2030 (max)[a]	Equilibrium (max)[a]		
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHs AND SUBSTITUTED PAHs						
Benzo(a)anthracene group[d]	0	0	1.80E-05	3.70E-05	0.00001	EXCEEDS
Benzo(a)pyrene group[d]	0	0	3.80E-06	4.40E-06	0.000001	EXCEEDS
NAPHTHENIC ACIDS						
Naphthenic acids	3.4	3.8	3.5	4.2	-[c]	No criterion
INORGANICS						
Aluminum	0.12	0.07	0.25	0.12	1.37	Does not exceed.
Antimony	0.000076	0.000023	0.00013	0.000015	0.0006	Does not exceed.
Arsenic	0.005	0.004	0.004	0.003	0.000045	EXCEEDS
Barium	0.05	0.03	0.05	0.03	0.096	Does not exceed.
Beryllium	0.00015	0.000047	0.00052	0.00014	0.000016	EXCEEDS
Boron	0.04	0.04	0.36	0.16	0.12	EXCEEDS
Cadmium	0.0002	0.0002	0.0008	0.0004	0.0007	EXCEEDS
Chromium	0.0038	0.0015	0.0032	0.0007	1.37	Does not exceed.
Copper	0.002	0.001	0.003	0.001	0.056	Does not exceed.
Lead	0.0006	0.0005	0.0018	0.0006	0.0006	EXCEEDS
Lithium	0.006	0.006	0.024	0.014	0.027	Does not exceed.
Manganese	0.15	0.07	0.1	0.05	0.03	EXCEEDS[e]
Mercury	0.000085	0.000095	0.00009	0.000095	0.004	Does not exceed.
Molybdenum	0.00062	0.00033	0.087	0.013	0.01	EXCEEDS
Nickel	0.0003	0.0004	0.0022	0.0006	0.03	Does not exceed.
Selenium	0.0018	0.0006	0.0008	0.000038	0.007	Does not exceed.
Silver	0	0	0.0001	0.000016	0.19	Does not exceed.
Strontium	0.08	0.06	0.2	0.09	0.81	Does not exceed.
Vanadium	0.001	0.001	0.011	0.002	0.004	EXCEEDS
Zinc	0.04	0.02	0.03	0.01	0.41	Does not exceed.

[a] Maximum predicted cumulative concentration for years specified (cumulative effects scenario; Section F12).

[b] Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1 x 10^{-6} (carcinogens).

[c] No data or criterion.

[d] For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X, Table X-1.

[e] Manganese was not evaluated in the risk assessment since it is a required nutrient.

Table XIII-9 Comparison of Cumulative Regional Development Muskeg River Concentrations to Background Concentrations and Human Health Screening Level Criteria for Water

Chemical	Muskeg River Concentrations for RDR				Screening Level Criteria[b]	Background Muskeg River[c]	Comments
	2007 (max)[a]	2020 (max)[a]	2030 (max)[a]	Equilibrium (max)[a]		(median)	
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHs AND SUBSTITUTED PAHs							
Benzo(a)anthracene group[d]	0	0	1.80E-05	4.20E-05	0.0001	-[e]	Does not exceed.
Benzo(a)pyrene group[d]	0	0	3.90E-06	4.80E-06	0.00001	-[e]	Does not exceed.
NAPHTHENIC ACIDS							
Naphthenic acids	3.4	3.7	3.4	4.1	-[e]	4	No criterion; EXCEEDS BACKGROUND
INORGANICS							
Aluminum	0.13	0.08	0.26	0.13	0.2	0.05	EXCEEDS
Ammonia	0.2	0.1	0.1	0.1	-[e]	0.05	No criterion; EXCEEDS BACKGROUND[g]
Antimony	0.00008	0.000032	0.00015	0.000015	0.006	-[e]	Does not exceed.
Arsenic	0.006	0.004	0.004	0.003	0.025	0.0029	Does not exceed.
Barium	0.05	0.04	0.05	0.03	1	0.03	Does not exceed.
Beryllium	0.00016	0.000065	0.00055	0.00016	0.004	-[e]	Does not exceed.
Boron	0.04	0.04	0.37	0.17	5	0.05	Does not exceed.
Cadmium	0.0002	0.0002	0.0008	0.0005	0.005	0.0002	Does not exceed.
Calcium	49.2	42.8	52	41.3	-[e]	38.4	No criterion; EXCEEDS BACKGROUND[g]
Chloride	2.6	2.9	7.8	4.4	250[f]	3.1	Does not exceed.
Chromium	0.004	0.0019	0.0037	0.0008	0.05	0	Does not exceed.
Copper	0.002	0.001	0.003	0.001	1	0.001	Does not exceed.
Iron	1.6	1.1	1.4	0.9	0.3[f]	0.79	EXCEEDS[7]
Lead	0.0006	0.0005	0.0019	0.0006	0.01	0.0004	Does not exceed.
Lithium	0.006	0.006	0.025	0.015	-[e]	-[e]	No criterion
Magnesium	10.1	9.8	11.5	10.6	-[e]	9.6	No criterion; EXCEEDS BACKGROUND[g]
Manganese	0.16	0.09	0.12	0.06	-[e]	0.04	No criterion; EXCEEDS BACKGROUND[g]
Mercury	0.000084	0.000094	0.000088	0.000094	0.05	0.0001	Does not exceed.
Molybdenum	0.00065	0.00038	0.091	0.013	0.001	0.0002	EXCEEDS
Nickel	0.0003	0.0004	0.0022	0.0006	0.25	0.0004	Does not exceed.
Selenium	0.0019	0.0008	0.0011	0.000041	0.01	-[e]	Does not exceed.
Silver	0	0	0.0001	0.000017	-[e]	-[e]	No criterion
Sodium	9.6	10.1	57.4	45.2	200[f]	10.4	Does not exceed.
Strontium	0.08	0.07	0.21	0.09	-[e]	0.06	No criterion; EXCEEDS BACKGROUND
Sulphate	4.3	4.4	86.1	25.3	500[f]	4.52	Does not exceed.
Vanadium	0.001	0.001	0.012	0.002	-[e]	0.0004	No criterion; EXCEEDS BACKGROUND
Zinc	0.04	0.02	0.03	0.01	5	0.011	Does not exceed.

(a) Maximum predicted cumulative concentration for years specified (regional development review scenario; Section G12).

(b) Screening level criteria were based on the lowest water quality criteria for human drinking water.

(c) Median concentrations in Muskeg River in 1997.

(d) For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X, Table X-1.

(e) No data or criterion.

(f) Based on an aesthetic objective for drinking water.

(g) These chemicals were not evaluated in the risk assessment since they are nutrients and/or non-toxic.

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Table XIII-10 Comparison of Cumulative Regional Development Muskeg River Concentrations to Risk-Based Criteria for Human Health

Chemical	Muskeg River Concentrations for RDR				RBC for Water Ingestion (RBC)[b]	Comments
	2007 (max)[a]	2020 (max)[a]	2030 (max)[a]	Equilibrium (max)(a)		
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	
PAHs AND SUBSTITUTED PAHs						
Benzo(a)anthracene group[d]	0	0	1.80E-05	4.20E-05	0.00001	EXCEEDS
Benzo(a)pyrene group[d]	0	0	3.90E-06	4.80E-06	0.000001	EXCEEDS
NAPHTHENIC ACIDS						
Naphthenic acids	3.4	3.7	3.4	4.1	-[c]	No criterion
INORGANICS						
Aluminum	0.13	0.08	0.26	0.13	1.37	Does not exceed.
Antimony	0.00008	0.000032	0.00015	0.000015	0.0006	Does not exceed.
Arsenic	0.006	0.004	0.004	0.003	0.000045	EXCEEDS
Barium	0.05	0.04	0.05	0.03	0.096	Does not exceed.
Beryllium	0.00016	0.000065	0.00055	0.00016	0.000016	EXCEEDS
Boron	0.04	0.04	0.37	0.17	0.12	EXCEEDS
Cadmium	0.0002	0.0002	0.0008	0.0005	0.0007	EXCEEDS
Chromium	0.004	0.0019	0.0037	0.0008	1.37	Does not exceed.
Copper	0.002	0.001	0.003	0.001	0.056	Does not exceed.
Lead	0.0006	0.0005	0.0019	0.0006	0.0006	EXCEEDS
Lithium	0.006	0.006	0.025	0.015	0.027	Does not exceed.
Manganese	0.16	0.09	0.12	0.06	0.03	EXCEEDS[e]
Mercury	0.000084	0.000094	0.000088	0.000094	0.004	Does not exceed.
Molybdenum	0.00065	0.00038	0.091	0.013	0.01	EXCEEDS
Nickel	0.0003	0.0004	0.0022	0.0006	0.03	Does not exceed.
Selenium	0.0019	0.0008	0.0011	0.000041	0.007	Does not exceed.
Silver	0	0	0.0001	1.7E0-5	0.19	Does not exceed.
Strontium	0.08	0.07	0.21	0.09	0.81	Does not exceed.
Vanadium	0.001	0.001	0.012	0.002	0.004	EXCEEDS
Zinc	0.04	0.02	0.03	0.01	0.41	Does not exceed.

(a) Maximum predicted cumulative concentration for years specified (regional development review scenario; Section G12).

(b) Risk-Based Concentrations were conservatively recalculated from EPA Region III Risk-Based Concentrations (Smith 1997) based on child exposure and a target hazard quotient of 0.1 (non-carcinogens); child and adult exposure and an acceptable risk level of 1 x 10^{-6} (carcinogens).

(c) No data or criterion.

(d) For information on grouping of chemicals and the use of surrogate chemicals, please refer to Appendix X, Table X-1.

(e) Manganese was not evaluated in the risk assessment since it is a required nutrient.

Table XIII-11 Airborne Chemicals: Exposure Concentrations, Estimated Daily Intake Rates(Doses) and Risk Estimates for the CEA.

Maximum predicted concentrations from the indicated emission sources from existing, approved and Muskeg River Mine developments.
All exposure concentrations are expressed in (ug/m3).
Locations include: Overall Maximum (usually on the plant/mine/tailings site)
Fort McKay
Fort McMurray
Fort Chipeywan
Predictions do not include Suncor, Syncrude or community sources.

Source: Stationary Mine Point Sources (eg., Stacks)

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
CONVENTIONAL PARAMETERS												
NOx	1.30E+02	3.10E+01	2.30E+00	4.32E+01	5.36E+00	2.32E-01	1.54E+01	3.79E+00	1.44E-01	9.00E+00	6.90E-01	3.40E-02
NO2	6.60E+01	3.10E+01	2.30E+00	4.32E+01	5.36E+00	2.32E-01	1.54E+01	3.79E+00	1.44E-01	9.00E+00	6.90E-01	3.40E-02
CO	5.78E+01	1.38E+01	1.02E+00	1.92E+01	2.38E+00	1.03E-01	6.82E+00	1.68E+00	6.39E-02	4.00E+00	3.07E-01	1.51E-02
PM	1.87E+01	4.47E+00	3.31E-01	6.22E+00	7.72E-01	3.34E-02	2.21E+00	5.46E-01	2.07E-02	1.30E+00	9.94E-02	4.90E-03
THC	3.61E+00	8.60E-01	6.38E-02	1.20E+00	1.49E-01	6.44E-03	4.26E-01	1.05E-01	3.99E-03	2.50E-01	1.91E-02	9.43E-04
VOC	2.41E+00	5.74E-01	4.26E-02	8.00E-01	9.93E-02	4.30E-03	2.84E-01	7.02E-02	2.66E-03	1.67E-01	1.28E-02	6.30E-04

Source: Mine Fleet Exhaust Emissions

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
CONVENTIONAL PARAMETERS												
CO	5.71E+02	2.43E+02	5.61E+01	7.99E+02	8.43E+01	5.03E+00	3.38E+02	5.94E+01	1.50E+00	2.09E+02	1.17E+01	5.03E-01
NOx	1.59E+03	6.76E+02	1.56E+02	2.22E+03	2.35E+02	1.40E+01	9.41E+02	1.65E+02	4.18E+00	5.81E+02	3.26E+01	1.40E+00
SO2	1.07E+02	4.56E+01	1.05E+01	1.50E+02	1.58E+01	9.46E-01	6.36E+01	1.12E+01	2.82E-01	3.93E+01	2.20E+00	9.46E-02
CO2	1.05E+05	4.45E+04	1.03E+04	1.46E+05	1.54E+04	9.22E+02	6.20E+04	1.09E+04	2.75E+02	3.83E+04	2.14E+03	9.22E+01
PM10	8.10E+01	3.44E+01	7.95E+00	1.13E+02	1.19E+01	7.13E-01	4.79E+01	8.42E+00	2.13E-01	2.96E+01	1.66E+00	7.13E-02
PM2.5	5.15E+01	2.19E+01	5.05E+00	7.20E+01	7.59E+00	4.53E-01	3.05E+01	5.35E+00	1.35E-01	1.88E+01	1.05E+00	4.53E-02
ALIPHATICS												
ALKANES												
methane	1.10E+01	4.68E+00	1.08E+00	1.54E+01	1.62E+00	9.70E-02	6.52E+00	1.14E+00	2.89E-02	4.02E+00	2.25E-01	9.70E-03
ethane	6.31E+00	2.68E+00	6.20E-01	8.82E+00	9.31E-01	5.56E-02	3.74E+00	6.56E-01	1.66E-02	2.31E+00	1.29E-01	5.56E-03
propane	4.45E+00	1.89E+00	4.37E-01	6.22E+00	6.57E-01	3.92E-02	2.64E+00	4.63E-01	1.17E-02	1.63E+00	9.11E-02	3.92E-03
butane	6.57E+00	2.79E+00	6.45E-01	9.19E+00	9.70E-01	5.79E-02	3.89E+00	6.83E-01	1.73E-02	2.40E+00	1.35E-01	5.79E-03
pentane	4.28E+00	1.82E+00	4.20E-01	5.98E+00	6.31E-01	3.77E-02	2.53E+00	4.45E-01	1.12E-02	1.56E+00	8.76E-02	3.77E-03
hexane	8.16E+00	3.47E+00	8.02E-01	1.14E+01	1.20E+00	7.19E-02	4.83E+00	8.49E-01	2.14E-02	2.98E+00	1.67E-01	7.19E-03
heptane	5.49E+00	2.33E+00	5.39E-01	7.67E+00	8.09E-01	4.83E-02	3.25E+00	5.70E-01	1.44E-02	2.01E+00	1.12E-01	4.83E-03
octane	2.15E+00	9.12E-01	2.11E-01	3.00E+00	3.16E-01	1.89E-02	1.27E+00	2.23E-01	5.64E-03	7.84E-01	4.39E-02	1.89E-03
nonane	1.42E+00	6.05E-01	1.40E-01	1.99E+00	2.10E-01	1.25E-02	8.43E-01	1.48E-01	3.74E-03	5.20E-01	2.92E-02	1.25E-03
decane	6.68E+00	2.84E+00	6.56E-01	9.34E+00	9.86E-01	5.89E-02	3.96E+00	6.95E-01	1.76E-02	2.44E+00	1.37E-01	5.89E-03
undecane	6.80E+00	2.89E+00	6.67E-01	9.50E+00	1.00E+00	5.99E-02	4.02E+00	7.07E-01	1.79E-02	2.48E+00	1.39E-01	5.99E-03
dodecane	4.18E+00	1.77E+00	4.10E-01	5.84E+00	6.16E-01	3.68E-02	2.47E+00	4.34E-01	1.10E-02	1.53E+00	8.55E-02	3.68E-03
ALKANES TOTAL CONC.	6.75E+01	2.87E+01	6.63E+00	9.44E+01	9.96E+00	5.94E-01	4.00E+01	7.02E+00	1.77E-01	2.47E+01	1.38E+00	5.94E-02
ALKENES												
ethylene	3.16E+01	1.34E+01	3.10E+00	4.41E+01	4.65E+00	2.78E-01	1.87E+01	3.28E+00	8.29E-02	1.15E+01	6.46E-01	2.78E-02
propylene	5.44E+00	2.31E+00	5.34E-01	7.61E+00	8.03E-01	4.79E-02	3.22E+00	5.66E-01	1.43E-02	1.99E+00	1.11E-01	4.79E-03
butene	1.17E+00	4.99E-01	1.15E-01	1.64E+00	1.73E-01	1.03E-02	6.95E-01	1.22E-01	3.08E-03	4.29E-01	2.40E-02	1.03E-03
pentene	2.04E-01	8.65E-02	2.00E-02	2.85E-01	3.00E-02	1.79E-03	1.21E-01	2.12E-02	5.35E-04	7.44E-02	4.17E-03	1.79E-04
ALKENES TOTAL CONC.	3.84E+01	1.63E+01	3.77E+00	5.36E+01	5.66E+00	3.38E-01	2.27E+01	3.99E+00	1.01E-01	1.40E+01	7.86E-01	3.38E-02
SUM:ALIPHATICS CONC.	1.06E+02	4.50E+01	1.04E+01	1.48E+02	1.56E+01	9.32E-01	6.27E+01	1.10E+01	2.78E-01	3.87E+01	2.17E+00	9.32E-02
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				6.51E+01	6.87E+00	4.10E-01	2.76E+01	4.84E+00	1.22E-01	1.70E+01	9.54E-01	4.10E-02
ALIPHATICS ER CHILD (using RfC)				6.51E-01	6.87E-02	9.32E-04	2.76E-01	4.84E-02	2.78E-04	1.70E-01	9.54E-03	9.32E-05
ADULT INHALED DOSE ug/(kg*d)						1.31E+00			1.17E+00			1.13E+00
ALIPHATICS ER ADULT (using RfC)						4.09E-03			3.65E-03			3.53E-03
AROMATICS												
Ethylbenzene	8.16E-01	3.47E-01	8.02E-02	1.14E+00	1.20E-01	7.19E-03	4.83E-01	8.49E-02	2.14E-03	2.98E-01	1.67E-02	7.19E-04
Toluene	1.38E-01	5.84E-02	1.35E-02	1.92E-01	2.03E-02	1.21E-03	8.14E-02	1.43E-02	3.61E-04	5.03E-02	2.82E-03	1.21E-04
Xylene	2.21E-01	9.38E-02	2.17E-02	3.09E-01	3.26E-02	1.94E-03	1.31E-01	2.30E-02	5.80E-04	8.07E-02	4.52E-03	1.94E-04
AROMATICS TOTAL (excl. benzene)	1.17E+00	4.99E-01	1.15E-01	1.64E+00	1.73E-01	1.03E-02	6.95E-01	1.22E-01	3.09E-03	4.29E-01	2.41E-02	1.03E-03
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*					7.62E-02	4.55E-03	3.06E-01	5.37E-02	1.36E-03	1.89E-01	1.06E-02	4.55E-04
AROMATICS ER CHILD (using RfC)					3.81E-04	2.59E-05	1.53E-03	2.69E-04	7.71E-06	9.45E-04	5.29E-05	2.59E-06
*ADULT INHALED DOSE ug/(kg*d)*						1.45E-02			1.30E-02			1.25E-02
AROMATICS ER ADULT (using RfC)						1.13E-04			1.01E-04			9.78E-05
ALDEHYDES												
Acrolein (RfC=2.0E-02 mg/m^3)	1.23E+00	5.21E-01	1.20E-01	1.72E+00	1.81E-01	1.08E-02	7.26E-01	1.28E-01	3.22E-03	4.48E-01	2.51E-02	1.08E-03
Methacrolein	4.08E-01	1.73E-01	4.01E-02	5.71E-01	6.02E-02	3.59E-03	2.42E-01	4.24E-02	1.07E-03	1.49E-01	8.36E-03	3.59E-04
n-Butanal	5.12E-01	2.18E-01	5.03E-02	7.16E-01	7.55E-02	4.51E-03	3.03E-01	5.32E-02	1.35E-03	1.87E-01	1.05E-02	4.51E-04
3-Methylbutanal	7.05E-02	3.00E-02	6.92E-03	9.86E-02	1.04E-02	6.21E-04	4.17E-02	7.33E-03	1.85E-04	2.58E-02	1.44E-03	6.21E-05
TOTAL AS Acrolein/Methacrolein	2.22E+00	9.42E-01	2.18E-01	3.10E+00	3.27E-01	1.95E-02	1.31E+00	2.31E-01	5.83E-03	8.11E-01	4.54E-02	1.95E-03
RfC (Acrolein & Methacrolein)	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02
ER-Child Aldehydes (Based on RfC)						9.77E-01			2.91E-01			9.77E-02
ER-Adult Aldehydes (Based on RfC)						4.28E+00			3.82E+00			3.69E+00
KETONES												
*Acetone (RfD=1.0E-01 mg/(kg*d))*	2.23E+00	9.46E-01	2.19E-01	3.11E+00	3.28E-01	1.96E-02	1.32E+00	2.31E-01	5.85E-03	8.14E-01	4.56E-02	1.96E-03
Methyl Ethyl Ketone	4.75E-01	2.02E-01	4.66E-02	6.64E-01	7.01E-02	4.18E-03	2.81E-01	4.94E-02	1.25E-03	1.74E-01	9.73E-03	4.18E-04
3-Buten-2-one	8.91E-01	3.78E-01	8.74E-02	1.25E+00	1.31E-01	7.84E-03	5.27E-01	9.26E-02	2.34E-03	3.25E-01	1.82E-02	7.84E-04
TOTAL AS Acetone	3.59E+00	1.53E+00	3.53E-01	5.02E+00	5.30E-01	3.16E-02	2.13E+00	3.73E-01	9.43E-03	1.31E+00	7.35E-02	3.16E-03
*Inhhaled Child Dose (ug/(kg*d)*				2.21E+00	2.33E-01	1.39E-02	9.36E-01	1.64E-01	4.15E-03	5.78E-01	3.24E-02	1.39E-03
ER CHILD Ketones (RfD from IRIS)						1.39E-04			4.15E-05			1.39E-05
Inhaled Adult Dose ug/(kg*d)						4.44E-02			3.96E-02			3.83E-02
ER ADULT Ketones (RfD from IRIS)						4.44E-04			3.96E-04			3.83E-04
PAHs												
*Naphthalene (RfD=4.0E-02 mg/(kg*d))*	8.25E-02	3.51E-02	8.10E-03	1.15E-01	1.22E-02	7.27E-04	4.88E-02	8.58E-03	2.17E-04	3.02E-02	1.69E-03	7.27E-05
Acenapthylene	5.86E-03	2.49E-03	5.75E-04	8.19E-03	8.64E-04	5.16E-05	3.47E-03	6.09E-04	1.54E-05	2.14E-03	1.20E-04	5.16E-06
Acenaphthene	1.48E-02	6.30E-03	1.46E-03	4.15E-03	4.38E-04	2.61E-05	1.76E-03	3.08E-04	7.79E-06	1.08E-03	6.08E-05	2.61E-06
SUM:NAPHTHA	1.03E-01	4.39E-02	1.01E-02	1.28E-01	1.35E-02	8.04E-04	5.41E-02	9.50E-03	2.40E-04	3.34E-02	1.87E-03	8.04E-05
*Inhhaled Child Dose (ug/(kg*d)*				5.62E-02	5.93E-03	3.54E-04	2.38E-02	4.18E-03	1.06E-04	1.47E-02	8.23E-04	3.54E-05
NAPHTHALENE ER-Child (using RfC)						8.85E-06			2.64E-06			8.85E-07

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
*Inhhaled Adult Dose (ug/(kg*d)*						1.25E-03			1.13E-03			1.10E-03
NAPHTHALENE ER-Adult (using RfC)						3.13E-05			2.62E-05			2.75E-05
Fluorene (RfD=4.0E-02 mg/(kg*d))	8.12E-03	3.45E-03	7.97E-04	1.14E-02	1.20E-03	7.15E-05	4.81E-03	8.44E-04	2.13E-05	2.97E-03	1.66E-04	7.15E-06
2-Methylfluorene	1.78E-05	7.57E-06	1.75E-06	2.49E-05	2.63E-06	1.57E-07	1.05E-05	1.85E-06	4.68E-08	6.51E-06	3.65E-07	1.57E-08
SUM:FLOURENE	8.14E-03	3.46E-03	7.99E-04	1.14E-02	1.20E-03	7.17E-05	4.82E-03	8.46E-04	2.14E-05	2.97E-03	1.67E-04	7.17E-06
*Inhhaled Child Dose (ug/(kg*d)*				5.01E-03	5.28E-04	3.15E-05	2.12E-03	3.72E-04	9.40E-06	1.31E-03	7.33E-05	3.15E-06
FLUORENE ER-Child (using RfC)						7.98E-07			2.35E-07			7.85E-08
*Inhhaled Adult Dose (ug/(kg*d)*						1.01E-04			8.98E-05			8.68E-05
FLUORENE ER-Adult (using RfC)						2.51E-06			2.24E-06			2.17E-06
Fluoranthene (RfD=4.0E-02 mg/(kg*d))	2.12E-03	8.99E-04	2.08E-04	2.96E-03	3.12E-04	1.86E-05	1.25E-03	2.20E-04	5.56E-06	7.73E-04	4.33E-05	1.86E-06
Anthracene	8.84E-04	3.76E-04	8.68E-05	1.24E-03	1.30E-04	7.78E-06	5.23E-04	9.19E-05	2.32E-06	3.23E-04	1.81E-05	7.78E-07
Phenanthrene	2.39E-02	1.01E-02	2.34E-03	3.34E-02	3.52E-03	2.10E-04	1.41E-02	2.48E-03	6.27E-05	8.72E-03	4.89E-04	2.10E-05
3-Methylphenanthrene	9.28E-03	3.94E-03	9.11E-04	1.30E-02	1.37E-03	8.17E-05	5.49E-03	9.64E-04	2.44E-05	3.39E-03	1.90E-04	8.17E-06
2-Methylanthracene	1.06E-02	4.51E-03	1.04E-03	1.48E-02	1.57E-03	9.35E-05	6.28E-03	1.10E-03	2.79E-05	3.88E-03	2.17E-04	9.35E-06
4-+9-Methylphenanthrene	1.14E-02	4.86E-03	1.12E-03	1.60E-02	1.69E-03	1.01E-04	6.77E-03	1.19E-03	3.00E-05	4.18E-03	2.34E-04	1.01E-05
1-Methylphenanthrene	9.50E-03	4.04E-03	9.33E-04	1.33E-02	1.40E-03	8.37E-05	5.62E-03	9.88E-04	2.50E-05	3.47E-03	1.95E-04	8.37E-06
SUM:FLUOANTHENE	6.77E-02	2.88E-02	6.65E-03	9.46E-02	9.98E-03	5.96E-04	4.01E-02	7.04E-03	1.78E-04	2.47E-02	1.39E-03	5.96E-05
*Inhhaled Child Dose (ug/(kg*d)*				4.16E-02	4.39E-03	2.62E-04	1.76E-02	3.10E-03	7.82E-05	1.09E-02	6.10E-04	2.62E-05
FLUORANTHENE ER-Child (using RfC)						6.56E-06			1.96E-06			6.55E-07
*Inhhaled Adult Dose (ug/(kg*d)*						8.36E-04			7.47E-04			7.22E-04
FLUORANTHENE ER-Adult (using RfC)						2.09E-05			1.87E-05			1.80E-05
Pyrene (RfD=3.0E-02 mg/(kg*d))	1.67E-03	7.08E-04	1.64E-04	2.33E-03	2.46E-04	1.47E-05	9.87E-04	1.73E-04	4.38E-06	6.09E-04	3.41E-05	1.47E-06
2-Methylpyrene	7.90E-04	3.36E-04	7.76E-05	2.21E-04	2.33E-05	1.39E-06	9.36E-05	1.64E-05	4.15E-07	5.78E-05	3.24E-06	1.39E-07
SUM:PYRENE	2.46E-03	1.04E-03	2.41E-04	2.55E-03	2.69E-04	1.61E-05	1.08E-03	1.90E-04	4.79E-06	6.67E-04	3.74E-05	1.61E-06
*Inhhaled Child Dose (ug/(kg*d)*				1.12E-03	1.18E-04	7.07E-06	4.75E-04	8.35E-05	2.11E-06	2.93E-04	1.64E-05	7.07E-07
PYRENE ER-Child (using RfC)						2.36E-07			7.03E-08			2.36E-08
*Inhhaled Adult Dose (ug/(kg*d)*						2.92E-05			2.68E-05			2.61E-05
PYRENE ER-Adult (using RfC)						9.72E-07			8.92E-07			8.69E-07
PAH-CHILD HAZARD INDEX						1.64E-05			4.90E-06			1.64E-06
PAH-ADULT HAZARD INDEX						5.57E-05			5.01E-05			4.85E-05
OTHER PAH SUBSTANCES												
Benzo(g,h,I)perylene	1.82E-04	7.72E-05	1.78E-05	2.54E-04	2.68E-05	1.60E-06	1.08E-04	1.89E-05	4.77E-07	6.64E-05	3.72E-06	1.60E-07
Benzo[a]fluorene	1.91E-04	8.14E-05	1.88E-05	2.68E-04	2.82E-05	1.69E-06	1.13E-04	1.99E-05	5.03E-07	7.00E-05	3.92E-06	1.69E-07
Benzo[ghi]fluoranthene	1.11E-04	4.73E-05	1.09E-05	1.56E-04	1.64E-05	9.80E-07	6.59E-05	1.16E-05	2.92E-07	4.07E-05	2.28E-06	9.80E-08
Cyclopenta[cd]pyrene	1.34E-05	5.68E-06	1.31E-06	1.87E-05	1.97E-06	1.18E-07	7.91E-06	1.39E-06	3.51E-08	4.88E-06	2.74E-07	1.18E-08
Benzo[e]pyrene	1.19E-05	5.05E-06	1.17E-06	1.66E-05	1.75E-06	1.05E-07	7.03E-06	1.23E-06	3.12E-08	4.34E-06	2.43E-07	1.05E-08
Perylene	1.48E-06	6.31E-07	1.46E-07	2.08E-06	2.19E-07	1.31E-08	8.79E-07	1.54E-07	3.90E-09	5.42E-07	3.04E-08	1.31E-09
Indeno[1,2,3-cd]fluoranthene	7.42E-06	3.15E-06	7.29E-07	1.04E-05	1.09E-06	6.54E-08	4.39E-06	7.72E-07	1.95E-08	2.71E-06	1.52E-07	6.54E-09
Picene	1.48E-06	6.31E-07	1.46E-07	2.08E-06	2.19E-07	1.31E-08	8.79E-07	1.54E-07	3.90E-09	5.42E-07	3.04E-08	1.31E-09
Benzo[ghi]perylene	1.04E-05	4.41E-06	1.02E-06	1.45E-05	1.53E-06	9.15E-08	6.15E-06	1.08E-06	2.73E-08	3.80E-06	2.13E-07	9.15E-09
Coronene	1.48E-06	6.31E-07	1.46E-07	2.08E-06	2.19E-07	1.31E-08	8.79E-07	1.54E-07	3.90E-09	5.42E-07	3.04E-08	1.31E-09
1-Nitropyrene	1.19E-04	5.05E-05	1.17E-05	1.66E-04	1.75E-05	1.05E-06	7.03E-05	1.23E-05	3.12E-07	4.34E-05	2.43E-06	1.05E-07
Dibenzothiophene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-Methyldibenzothiophene	1.26E-05	5.36E-06	1.24E-06	1.76E-05	1.86E-06	1.11E-07	7.47E-06	1.31E-06	3.31E-08	4.61E-06	2.58E-07	1.11E-08
3-Methyldibenzothiophene	2.08E-05	8.83E-06	2.04E-06	2.91E-05	3.07E-06	1.83E-07	1.23E-05	2.16E-06	5.46E-08	7.59E-06	4.25E-07	1.83E-08
SUM: (AS PYRENE UNITS)			6.72E-05			6.02E-06			1.80E-06			6.02E-07
*Inhhaled Child Dose (as pyrene units, ug/(kg*d)*						2.65E-06			7.91E-07			2.65E-07
ER-Child (as pyrene units, using RfC)						8.84E-08			2.64E-08			8.84E-09
*Inhhaled Adult Dose (as pyrene units, ug/(kg*d)*						8.45E-06			7.55E-06			7.29E-06
ER-Adult (as pyrene units, using RfC)						2.82E-07			2.52E-07			2.43E-07
CARCINOGENS (Fleet Emissions)	(Note: Inhalation dose assumes lifetime exposure (70yrs), with ages 20-70 involving 8hrs worker on site & 16hrs at residence.) (Note: See footnote for explanation of carcinogen dose equation.)											
Formaldehyde	2.67E+01	1.14E+01	2.63E+00	3.74E+01	3.95E+00	2.36E-01	1.58E+01	2.78E+00	7.03E-02	9.78E+00	5.48E-01	2.36E-02
Exposure Ratio based on RsC						**2.94E-01**			**8.78E-02**			**2.94E-02**
*Lifetime Residential Composite Dose (ug/(kg*d)*						8.01E-02			2.39E-02			8.01E-03
FORMALDEHYDE RESIDENTIAL LCR						**3.17E-06**			**9.46E-07**			**3.17E-07**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						2.68E-01			2.24E-01			2.12E-01
FORMALDEHYDE WORKER + RESID'L LCR						1.06E-05			8.87E-06			9.38E-06
	(Note: Formaldehyde slope factor = 3.96E-02mg/(kg*d) per IRIS inhalation unit risk of 1.3 E-05)											
Acetaldehyde	8.52E+00	3.62E+00	8.37E-01	1.19E+01	1.26E+00	7.50E-02	5.04E+00	8.86E-01	2.24E-02	3.11E+00	1.74E-01	7.50E-03
*Lifetime Residential Composite Dose (ug/(kg*d)*						2.55E-02			7.61E-03			2.55E-03
ACETALDEHYDE RESIDENTIAL LCR						**1.71E-07**			5.80E-08			1.96E-08
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						8.53E-02			7.14E-02			6.74E-02
ACETALDEHYDE WORKER + RESID'L LCR						5.71E-07			5.50E-07			5.19E-07
	(Note: Acetaldehyde slope factor = 8.7E-03mg/(kg*d) per IRIS inhalation unit risk of 2.2 E-06)											
Benzene	8.03E-01	3.41E-01	7.89E-02	1.12E+00	1.18E-01	7.07E-03	4.75E-01	8.35E-02	2.11E-03	2.94E-01	1.64E-02	7.07E-04
*Lifetime Residential Composite Dose (ug/(kg*d)*			2.68E-02			2.40E-03			7.17E-04			2.40E-04
BENZENE RESID'L LIFETIME CANCER RISK						**6.97E-08**			**2.08E-08**			**6.97E-09**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						8.04E-03			6.73E-03			6.36E-03
BENZENE WORKER + RESID'L LCR						2.33E-07			1.95E-07			1.84E-07
	(Note: Benzene slope factor = 2.9E-02mg/(kg*d) per TPHCWG, 1997)											
CARCINOGENIC PAHs (GROUPED, BaP-TEFs)												
Benz(a)anthracene * (.1)	2.15E-04	9.11E-05	2.11E-05	3.00E-04	3.16E-05	1.89E-06	1.27E-04	2.23E-05	5.63E-07	7.84E-05	4.39E-06	1.89E-07
Chrysene*(.01)	5.90E-04	2.51E-04	5.79E-05	8.24E-04	8.70E-05	5.19E-06	3.49E-04	6.13E-05	1.55E-06	2.15E-04	1.21E-05	5.19E-07
Benzo(b)fluoranthene*(.1)	7.04E-04	2.99E-04	6.91E-05	9.84E-04	1.04E-04	6.20E-06	4.17E-04	7.32E-05	1.85E-06	2.57E-04	1.44E-05	6.20E-07
Benzo(k)fluoranthene*(.1)	7.99E-05	3.40E-05	7.85E-06	1.12E-04	1.18E-05	7.04E-07	4.73E-05	8.31E-06	2.10E-07	2.92E-05	1.64E-06	7.04E-08
Benzo(a)pyrene*(1.0)	8.38E-05	3.56E-05	8.23E-06	1.17E-04	1.24E-05	7.38E-07	4.96E-05	8.71E-06	2.20E-07	3.06E-05	1.72E-06	7.38E-08
Indeno(1,2,3-W)pyrene*(.01)	1.33E-04	5.66E-05	1.31E-05	1.86E-04	1.97E-05	1.17E-06	7.89E-05	1.39E-05	3.50E-07	4.87E-05	2.73E-06	1.17E-07
Dibenz(a,h)anthracene*(1.0)	2.20E-04	9.35E-05	2.16E-05	3.07E-04	3.24E-05	1.94E-06	1.30E-04	2.29E-05	5.78E-07	8.04E-05	4.50E-06	1.94E-07
SUMCANCER CONCs as BAP TEQs	4.11E-04	1.75E-04	4.03E-05	5.74E-04	6.06E-05	**3.62E-06**	2.43E-04	4.27E-05	**1.08E-06**	1.50E-04	8.41E-06	**3.62E-07**
*Lifetime Residential Composite Dose (ug/(kg*d)*						1.23E-06			3.67E-07			1.23E-07
PAH RESID'L LIFETIME CANCER RISK						**8.98E-09**			**2.68E-09**			**8.98E-10**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						4.11E-06			3.44E-06			3.25E-06
PAH WORKER + RESID'L LCR						3.00E-08			2.51E-08			2.37E-08
	(Note: Benzo(a)pyrene slope factor = 7.3mg/(kg*d), per TPHCWG, 1997)											
TOTAL PAH RESIDENTIAL LCR						**3.42E-06**			**1.03E-06**			**3.45E-07**
TOTAL PAH WORKER + RESID'L LCR						1.14E-05			9.64E-06			9.11E-06

Source: Mine Surface Emissions

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALIPHATICS												
C1 to C3	2.71E+02	1.15E+02	2.62E+01	3.78E+02	3.97E+01	2.39E+00	1.60E+02	2.80E+01	7.07E-01	9.86E+01	5.48E+00	2.30E-01
i-BUTANE	6.26E+00	2.65E+00	6.05E-01	8.71E+00	9.14E-01	5.50E-02	3.68E+00	6.46E-01	1.63E-02	2.27E+00	1.26E-01	5.31E-03
n-BUTANE	1.09E+01	4.64E+00	1.06E+00	1.52E+01	1.60E+00	9.62E-02	6.44E+00	1.13E+00	2.85E-02	3.98E+00	2.21E-01	9.29E-03
i-PENTANE	4.69E+00	1.99E+00	4.54E-01	6.53E+00	6.86E-01	4.12E-02	2.76E+00	4.84E-01	1.22E-02	1.70E+00	9.48E-02	3.98E-03

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
CYCLOPENTANE	9.38E+00	3.98E+00	9.08E-01	1.31E+01	1.37E+00	8.25E-02	5.52E+00	9.69E-01	2.45E-02	3.41E+00	1.90E-01	7.97E-03
3-ME-PENTANE	3.13E+00	1.33E+00	3.03E-01	4.35E+00	4.57E-01	2.75E-02	1.84E+00	3.23E-01	8.15E-03	1.14E+00	6.32E-02	2.66E-03
METHYLCYCLOPENTANE	3.13E+00	1.33E+00	3.03E-01	4.35E+00	4.57E-01	2.75E-02	1.84E+00	3.23E-01	8.15E-03	1.14E+00	6.32E-02	2.66E-03
CYCLOHEXANE	3.13E+00	1.33E+00	3.03E-01	4.35E+00	4.57E-01	2.75E-02	1.84E+00	3.23E-01	8.15E-03	1.14E+00	6.32E-02	2.66E-03
2,3-DIMETHYLPENTANE	3.13E+00	1.33E+00	3.03E-01	4.35E+00	4.57E-01	2.75E-02	1.84E+00	3.23E-01	8.15E-03	1.14E+00	6.32E-02	2.66E-03
3-METHYLHEXANE	7.82E+00	3.32E+00	7.56E-01	1.09E+01	1.14E+00	6.87E-02	4.60E+00	8.07E-01	2.04E-02	2.84E+00	1.58E-01	6.64E-03
N-HEPTANE	1.56E+00	6.64E-01	1.51E-01	2.18E+00	2.29E-01	1.37E-02	9.19E-01	1.61E-01	4.08E-03	5.68E-01	3.16E-02	1.33E-03
ME-CYCLOHEXANE	6.26E+00	2.65E+00	6.05E-01	8.71E+00	9.14E-01	5.50E-02	3.68E+00	6.46E-01	1.63E-02	2.27E+00	1.26E-01	5.31E-03
3-METHYLHEPTANE	1.02E+01	4.31E+00	9.83E-01	1.41E+01	1.49E+00	8.94E-02	5.98E+00	1.05E+00	2.65E-02	3.69E+00	2.05E-01	8.63E-03
2,3,4-TRIMETHYLHEXANE	2.35E+00	9.95E-01	2.27E-01	3.26E+00	3.43E-01	2.06E-02	1.38E+00	2.42E-01	6.12E-03	8.52E-01	4.74E-02	1.99E-03
N-OCTANE	8.60E+00	3.65E+00	8.32E-01	1.20E+01	1.26E+00	7.56E-02	5.06E+00	8.88E-01	2.24E-02	3.12E+00	1.74E-01	7.30E-03
BRANCHED NONANE	7.82E+00	3.32E+00	7.56E-01	1.09E+01	1.14E+00	6.87E-02	4.60E+00	8.07E-01	2.04E-02	2.84E+00	1.58E-01	6.64E-03
n-NONANE	1.17E+01	4.98E+00	1.13E+00	1.63E+01	1.71E+00	1.03E-01	6.89E+00	1.21E+00	3.06E-02	4.26E+00	2.37E-01	9.96E-03
n-DECANE	1.25E+01	5.31E+00	1.21E+00	1.74E+01	1.83E+00	1.10E-01	7.35E+00	1.29E+00	3.26E-02	4.54E+00	2.53E-01	1.06E-02
(ALIPHATICS TOTAL C5-C10)	1.76E+02	7.46E+01	1.70E+01	2.45E+02	2.57E+01	1.55E+00	1.03E+02	1.82E+01	4.59E-01	6.39E+01	3.55E+00	1.49E-01
ALIPHATICS TOTAL C1-C10	4.65E+02	1.97E+02	**4.50E+01**	6.48E+02	6.80E+01	4.09E+00	2.74E+02	4.80E+01	1.21E+00	1.69E+02	9.40E+00	3.95E-01
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				2.85E+02	2.99E+01	1.80E+00	1.20E+02	2.11E+01	5.34E-01	7.44E+01	4.14E+00	1.74E-01
ALIPHATICS ER CHILD (using RfC)				2.85E+00	2.99E-01	4.09E-03	1.20E+00	2.11E-01	1.21E-03	7.44E-01	4.14E-02	3.95E-04
ADULT INHALED DOSE ug/(kg*d)						5.67E+00			5.06E+00			4.88E+00
ALIPHATICS ER ADULT (RfD from TPHCWG, 1997)						1.77E-02			1.58E-02			1.53E-02
AROMATICS												
Carbon Range C5-C8												
TOLUENE	3.91E+00	1.66E+00	3.78E-01	5.44E+00	5.71E-01	3.44E-02	2.30E+00	4.04E-01	1.02E-02	1.42E+00	7.90E-02	3.32E-03
ET-BENZENE	3.13E+00	1.33E+00	3.03E-01	4.35E+00	4.57E-01	2.75E-02	1.84E+00	3.23E-01	8.15E-03	1.14E+00	6.32E-02	2.66E-03
M,P-XYLENE	1.56E+00	6.64E-01	1.51E-01	2.18E+00	2.29E-01	1.37E-02	9.19E-01	1.61E-01	4.08E-03	5.68E-01	3.16E-02	1.33E-03
O-XYLENE	7.82E+00	3.32E+00	7.56E-01	1.09E+01	1.14E+00	6.87E-02	4.60E+00	8.07E-01	2.04E-02	2.84E+00	1.58E-01	6.64E-03
TOTAL AROMATICS C5-C8 CONC.	1.64E+01	6.97E+00	**1.59E+00**	2.29E+01	2.40E+00	**1.44E-01**	9.65E+00	1.70E+00	**4.28E-02**	5.96E+00	3.32E-01	**1.39E-02**
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				1.01E+01	1.06E+00	6.35E-02	4.25E+00	7.46E-01	1.88E-02	2.62E+00	1.46E-01	6.13E-03
AROMATICS ER CHILD (RfD from TPHCWG, 1997)				5.03E-02	5.28E-03	3.61E-04	2.12E-02	3.73E-03	1.07E-04	1.31E-02	7.30E-04	3.49E-05
*ADULT INHALED DOSE ug/(kg*d)*						2.00E-01			1.79E-01			1.72E-01
AROMATICS ER ADULT (using RfC)						1.56E-03			1.39E-03			1.35E-03
Carbon Range C9-C18												
Cumene	7.82E+00	3.32E+00	7.56E-01	1.09E+01	1.14E+00	6.87E-02	4.60E+00	8.07E-01	2.04E-02	2.84E+00	1.58E-01	6.64E-03
TOTAL AROMATICS C9-C18 CONC.	7.82E+00	3.32E+00	7.56E-01	1.09E+01	1.14E+00	6.87E-02	4.60E+00	8.07E-01	2.04E-02	2.84E+00	1.58E-01	6.64E-03
TPHWG (1997) RfC (ug/m3)	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				4.79E+00	5.03E-01	3.02E-02	2.02E+00	3.55E-01	8.97E-03	1.25E+00	6.95E-02	2.92E-03
AROMATICS (C9-C18) ER CHILD (using RfC)				1.20E-01	1.26E-02	3.44E-04	5.06E-02	8.88E-03	1.02E-04	3.12E-02	1.74E-03	3.32E-05
*ADULT INHAL DOSE (ug/kg*day)*						9.53E-02			8.50E-02			8.21E-02
AROMATICS (C9-C18) ER ADULT (using RfC)						1.49E-03			1.33E-03			1.28E-03
AROMATICS ER CHILD (using RfC)						7.05E-04			2.09E-04			6.80E-05
AROMATICS ER ADULT (RfD from TPHCWG, 1997)						3.05E-03			2.72E-03			2.63E-03

Source: Tailings Pond

SUBSTANCE	Overall On Site Max.			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALIPHATICS												
C1 to C3	3.36E+02	1.88E+02	7.04E+01	2.47E+02	3.77E+01	4.47E+00	8.03E+01	1.47E+01	3.80E-01	4.46E+01	2.19E+00	9.28E-02
Isobutane	6.18E+00	3.45E+00	1.30E+00	4.55E+00	6.94E-01	8.23E-02	1.48E+00	2.70E-01	7.00E-03	8.21E-01	4.04E-02	1.71E-03
Isopentane	1.55E+00	8.63E-01	3.24E-01	1.14E+00	1.73E-01	2.06E-02	3.70E-01	6.75E-02	1.75E-03	2.05E-01	1.01E-02	4.27E-04
n-Pentane	2.32E+00	1.29E+00	4.86E-01	1.70E+00	2.60E-01	3.09E-02	5.55E-01	1.01E-01	2.62E-03	3.08E-01	1.51E-02	6.41E-04
Cyclopentane	3.86E-01	2.16E-01	8.10E-02	2.84E-01	4.33E-02	5.14E-03	9.24E-02	1.69E-02	4.37E-04	5.13E-02	2.52E-03	1.07E-04
2,3-Dimethylbutane	1.31E+01	7.34E+00	2.75E+00	9.66E+00	1.47E+00	1.75E-01	3.14E+00	5.74E-01	1.49E-02	1.74E+00	8.58E-02	3.63E-03
n-Hexane	1.08E+01	6.04E+00	2.27E+00	7.96E+00	1.21E+00	1.44E-01	2.59E+00	4.73E-01	1.22E-02	1.44E+00	7.07E-02	2.99E-03
2,4-Dimethylpentane	2.16E+01	1.21E+01	4.54E+00	1.59E+01	2.43E+00	2.88E-01	5.18E+00	9.45E-01	2.45E-02	2.87E+00	1.41E-01	5.98E-03
Cyclohexane	3.94E+01	2.20E+01	8.26E+00	2.90E+01	4.42E+00	5.25E-01	9.43E+00	1.72E+00	4.46E-02	5.23E+00	2.57E-01	1.09E-02
2,3-Dimethylpentane	5.02E+00	2.81E+00	1.05E+00	3.69E+00	5.63E-01	6.69E-02	1.20E+00	2.19E-01	5.69E-03	6.67E-01	3.28E-02	1.39E-03
3-Methylhexane	1.62E+01	9.06E+00	3.40E+00	1.19E+01	1.82E+00	2.16E-01	3.88E+00	7.09E-01	1.84E-02	2.15E+00	1.06E-01	4.49E-03
2,2,4-Trimethylpentane	3.63E+01	2.03E+01	7.61E+00	2.67E+01	4.07E+00	4.83E-01	8.69E+00	1.59E+00	4.11E-02	4.82E+00	2.37E-01	1.00E-02
n-Heptane	2.01E+01	1.12E+01	4.21E+00	1.48E+01	2.25E+00	2.67E-01	4.81E+00	8.78E-01	2.27E-02	2.67E+00	1.31E-01	5.56E-03
3-Methylheptane	1.31E+01	7.34E+00	2.75E+00	9.66E+00	1.47E+00	1.75E-01	3.14E+00	5.74E-01	1.49E-02	1.74E+00	8.58E-02	3.63E-03
2,2,5-Trimethylhexane	3.90E+01	2.18E+01	8.18E+00	2.87E+01	4.38E+00	5.19E-01	9.34E+00	1.70E+00	4.42E-02	5.18E+00	2.55E-01	1.08E-02
n-Octane	3.82E+01	2.14E+01	8.02E+00	2.81E+01	4.29E+00	5.09E-01	9.15E+00	1.67E+00	4.33E-02	5.08E+00	2.50E-01	1.06E-02
n-Nonane	2.09E+01	1.17E+01	4.37E+00	1.53E+01	2.34E+00	2.78E-01	4.99E+00	9.12E-01	2.36E-02	2.77E+00	1.36E-01	5.77E-03
ALIPHATICS TOTAL C5-C10	8.67E+02	4.84E+02	1.82E+02	6.38E+02	9.73E+01	1.15E+01	2.07E+02	3.79E+01	9.82E-01	1.15E+02	5.66E+00	2.40E-01
ALIPHATICS TOTAL C1-C10	1.21E+03	6.76E+02	**2.54E+02**	8.90E+02	1.36E+02	1.61E+01	2.89E+02	5.29E+01	1.37E+00	1.61E+02	7.90E+00	3.35E-01
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				3.91E+02	5.97E+01	7.08E+00	1.27E+02	2.33E+01	6.03E-01	7.06E+01	3.48E+00	1.47E-01
ALIPHATICS ER CHILD (using RfC)				3.91E+00	5.97E-01	1.61E-02	1.27E+00	2.33E-01	1.37E-03	7.06E-01	3.48E-02	3.35E-04
ADULT INHALED DOSE ug/(kg*d)						3.05E+01			2.73E+01			2.71E+01
ALIPHATICS ER ADULT (using RfC)						9.53E-02			8.54E-02			8.48E-02
AROMATICS												
Carbon Range C5-C8												
Toluene	3.32E+01	1.86E+01	6.97E+00	2.44E+01	3.73E+00	4.42E-01	7.95E+00	1.45E+00	3.76E-02	4.41E+00	2.17E-01	9.19E-03
Ethylbenzene	9.12E+01	5.09E+01	1.91E+01	6.71E+01	1.02E+01	1.21E+00	2.18E+01	3.98E+00	1.03E-01	1.21E+01	5.96E-01	2.52E-02
(p+m)-Xylene	9.12E+01	5.09E+01	1.91E+01	6.71E+01	1.02E+01	1.21E+00	2.18E+01	3.98E+00	1.03E-01	1.21E+01	5.96E-01	2.52E-02
o-Xylene	2.86E+01	1.60E+01	5.99E+00	2.10E+01	3.21E+00	3.81E-01	6.84E+00	1.25E+00	3.24E-02	3.79E+00	1.87E-01	7.91E-03
TOTAL AROMATICS C5-C8 CONC.	2.44E+02	1.36E+02	5.12E+01	1.80E+02	2.74E+01	3.25E+00	5.84E+01	1.07E+01	2.76E-01	3.24E+01	1.59E+00	6.75E-02
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				1.38E+00	2.10E-01	2.49E-02	4.47E-01	8.17E-02	2.12E-03	2.48E-01	1.22E-02	5.17E-04
AROMATICS (C5-C8) ER CHILD (using RfC)				6.88E-03	1.05E-03	8.13E-03	2.24E-03	4.09E-04	6.91E-04	1.24E-03	6.11E-05	1.69E-04
*ADULT INHAL DOSE (ug/kg*day)*						6.15E+00			5.52E+00			5.48E+00
AROMATICS (C5-C8) ER ADULT (using RfC)						4.81E-02			4.31E-02			4.28E-02
Carbon Range C9-C18												
1,2,3-TMB+p-Cymene	3.09E+01	1.73E+01	6.48E+00	2.27E+01	3.47E+00	4.11E-01	7.40E+00	1.35E+00	3.50E-02	4.10E+00	2.02E-01	8.55E-03
1,2,4-TMB+n-Decane	2.16E+01	1.21E+01	4.54E+00	1.59E+01	2.43E+00	2.88E-01	5.18E+00	9.45E-01	2.45E-02	2.87E+00	1.41E-01	5.98E-03
1,3,5-Trimethylbenzene	4.25E+00	2.37E+00	8.91E-01	3.13E+00	4.77E-01	5.66E-02	1.02E+00	1.86E-01	4.81E-03	5.64E-01	2.78E-02	1.18E-03
Cumene	1.47E+01	8.20E+00	3.08E+00	1.08E+01	1.65E+00	1.95E-01	3.51E+00	6.41E-01	1.66E-02	1.95E+00	9.59E-02	4.06E-03
TOTAL AROMATICS C9-C18 CONC.	7.15E+01	3.99E+01	1.50E+01	5.26E+01	8.02E+00	9.51E-01	1.71E+01	3.12E+00	8.09E-02	9.49E+00	4.67E-01	1.98E-02
TPHWG (1997) RfC (ug/m3)	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				2.31E+01	3.53E+00	4.19E-01	7.52E+00	1.37E+00	3.56E-02	4.17E+00	2.05E-01	8.70E-03
AROMATICS (C9-C18) ER CHILD (using RfC)				5.78E-01	8.82E-02	4.76E-03	1.88E-01	3.44E-02	4.05E-04	1.04E-01	5.14E-03	9.88E-05
*ADULT INHAL DOSE (ug/kg*day)*						1.80E+00			1.62E+00			1.60E+00
AROMATICS (C9-C18) ER ADULT (using RfC)						2.81E-02			2.52E-02			2.50E-02
AROMATICS ER CHILD (using RfC)				5.85E-01	8.93E-02	1.29E-02	1.90E-01	3.48E-02	1.10E-03	1.06E-01	5.20E-03	2.68E-04
AROMATICS ER ADULT (RfD from TPHCWG, 1997)						7.62E-02			6.84E-02			6.78E-02

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual

CHEMICAL/RECEPTOR	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALDEHYDES ER-Child (Based on RfC)	not applicable					9.77E-01	not apllicable		2.91E-01	not apllicable		9.77E-02
ALDEHYDES ER-Adult (Based on RfC)	not applicable					4.28E+00	not apllicable		3.82E+00	not apllicable		3.69E+00
KETONES ER-Child (using RfC)	not apllicable					1.39E-04	not apllicable		4.15E-05	not apllicable		1.39E-05
KETONES ER-Adult (using RfC)	not apllicable					4.44E-04	not apllicable		3.96E-04	not apllicable		3.83E-04
ALIPHATICS HI-Child	not apllicable					2.11E-02	not apllicable		2.86E-03	not apllicable		8.23E-04
ALIPHATICS HI-Adult	not apllicable					1.17E-01	not apllicable		1.05E-01	not apllicable		1.04E-01
AROMATICS HI-Child	not apllicable					1.36E-02	not apllicable		1.31E-03	not apllicable		3.38E-04
AROMATICS HI-Adult	not apllicable					7.94E-02	not apllicable		7.12E-02	not apllicable		7.05E-02
PAH-CHILD HAZARD INDEX	not apllicable					1.65E-05	not apllicable		4.93E-06	not apllicable		1.65E-06
PAH-ADULT HAZARD INDEX	not apllicable					5.60E-05	not apllicable		5.04E-05	not apllicable		4.88E-05
TOTAL RESIDENTIAL LCR	not apllicable					3.42E-06	not apllicable		1.03E-06	not apllicable		3.45E-07
TOTAL RESIDENTIAL CARCINOGEN ER	not apllicable					3.42E-01	not apllicable		1.03E-01	not apllicable		3.45E-02
TOTAL WORKER + RESID'L LCR	not apllicable					1.14E-05	not apllicable		9.64E-06	not apllicable		9.11E-06
TOTAL WORKER + RESID'L CARCINOGEN ER	not apllicable					1.14E+00	not apllicable		9.64E-01	not apllicable		9.11E-01

Notes:

1. Exposure concentrations may be slightly higher (i.e., conservative measure) than reported from air dispersion modelling (Section E2) due to rounding.
2. Fluoranthene used as model PAH instead of anthracene.
3. Additional PAHs modelled as pyrene units.
4. Slope factors for formaldehyde and acetaldehyde recalculated from unit risk using 23 m^3/d.
5. Composite receptor inhalation factor averaged over 70 years is 0.34 m^3/kg*d, based on Health Canada (CEPA).
6. Maximum inhalation factor is 0.44 m^3/kg*d, occurs for a child 5-11 years (per Health Canada, CEPA).
7. Adult exposure concentration based on 8 of 24 hrs workplace ambient air and 16 of 24 hrs at residence ambient air.
8. Adult carcinogenic inhalation factor in dose calculations is the time-weighted-average from ages 0 to 20 yrs for residential exposure, and 20 to 70yrs involving both residential and workplace exposure, per Health Canada (CEPA).

Table XIII-12 Airborne Chemicals: Exposure Concentrations, Estimated Daily Intake Rates(Doses) and Risk Estimates for the RDR.

Maximum predicted concentrations from the indicated emission sources from existing, approved, planned and Muskeg River Mine Developments.
All exposure concentrations are expressed in (ug/m3).
Locations include: Overall Maximum (usually on the plant/mine/tailings site)
Fort McKay
Fort McMurray
Fort Chipeywan
Predictions do not include Suncor, Syncrude or community sources.

Source: Stationary Mine Point Sources (eg., Stacks)

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
CONVENTIONAL PARAMETERS												
NOx	1.30E+02	3.10E+01	2.30E+00	4.32E+01	5.36E+00	2.32E-01	1.54E+01	3.79E+00	1.44E-01	9.00E+00	6.90E-01	3.40E-02
NO2	6.60E+01	3.10E+01	2.30E+00	4.32E+01	5.36E+00	2.32E-01	1.54E+01	3.79E+00	1.44E-01	9.00E+00	6.90E-01	3.40E-02
CO	5.78E+01	1.38E+01	1.02E+00	1.92E+01	2.38E+00	1.03E-01	6.82E+00	1.68E+00	6.39E-02	4.00E+00	3.07E-01	1.51E-02
PM	1.87E+01	4.47E+00	3.31E-01	6.22E+00	7.72E-01	3.34E-02	2.21E+00	5.46E-01	2.07E-02	1.30E+00	9.94E-02	4.90E-03
THC	3.61E+00	8.60E-01	6.38E-02	1.20E+00	1.49E-01	6.44E-03	4.26E-01	1.05E-01	3.99E-03	2.50E-01	1.91E-02	9.43E-04
VOC	2.41E+00	5.74E-01	4.26E-02	8.00E-01	9.93E-02	4.30E-03	2.84E-01	7.02E-02	2.66E-03	1.67E-01	1.28E-02	6.30E-04

Source: Mine Fleet Exhaust Emissions

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
CONVENTIONAL PARAMETERS												
CO	5.71E+02	2.43E+02	5.61E+01	1.28E+03	1.35E+02	8.05E+00	5.41E+02	9.51E+01	2.40E+00	3.34E+02	1.87E+01	8.05E-01
NOx	1.59E+03	6.76E+02	1.56E+02	3.56E+03	3.75E+02	2.24E+01	1.51E+03	2.64E+02	6.68E+00	9.30E+02	5.21E+01	2.24E+00
SO2	1.07E+02	4.56E+01	1.05E+01	2.40E+02	2.54E+01	1.51E+00	1.02E+02	1.79E+01	4.51E-01	6.28E+01	3.52E+00	1.51E-01
CO2	1.05E+05	4.45E+04	1.03E+04	2.34E+05	2.47E+04	1.48E+03	9.92E+04	1.74E+04	4.40E+02	6.12E+04	3.43E+03	1.48E+02
PM10	8.10E+01	3.44E+01	7.95E+00	1.81E+02	1.91E+01	1.14E+00	7.67E+01	1.35E+01	3.40E-01	4.74E+01	2.65E+00	1.14E-01
PM2.5	5.15E+01	2.19E+01	5.05E+00	1.15E+02	1.21E+01	7.25E-01	4.87E+01	8.56E+00	2.16E-01	3.01E+01	1.69E+00	7.25E-02
ALIPHATICS												
ALKANES												
methane	1.10E+01	4.68E+00	1.08E+00	2.46E+01	2.60E+00	1.55E-01	1.04E+01	1.83E+00	4.63E-02	6.44E+00	3.61E-01	1.55E-02
ethane	6.31E+00	2.68E+00	6.20E-01	1.41E+01	1.49E+00	8.89E-02	5.98E+00	1.05E+00	2.65E-02	3.69E+00	2.07E-01	8.89E-03
propane	4.45E+00	1.89E+00	4.37E-01	9.96E+00	1.05E+00	6.27E-02	4.22E+00	7.40E-01	1.87E-02	2.60E+00	1.46E-01	6.27E-03
butane	6.57E+00	2.79E+00	6.45E-01	1.47E+01	1.55E+00	9.26E-02	6.23E+00	1.09E+00	2.76E-02	3.84E+00	2.15E-01	9.26E-03
pentane	4.28E+00	1.82E+00	4.20E-01	9.57E+00	1.01E+00	6.03E-02	4.05E+00	7.11E-01	1.80E-02	2.50E+00	1.40E-01	6.03E-03
hexane	8.16E+00	3.47E+00	8.02E-01	1.83E+01	1.93E+00	1.15E-01	7.73E+00	1.36E+00	3.43E-02	4.77E+00	2.67E-01	1.15E-02
heptane	5.49E+00	2.33E+00	5.39E-01	1.23E+01	1.30E+00	7.73E-02	5.20E+00	9.13E-01	2.31E-02	3.21E+00	1.80E-01	7.73E-03
octane	2.15E+00	9.12E-01	2.11E-01	4.80E+00	5.06E-01	3.02E-02	2.03E+00	3.57E-01	9.02E-03	1.25E+00	7.03E-02	3.02E-03
nonane	1.42E+00	6.05E-01	1.40E-01	3.19E+00	3.36E-01	2.01E-02	1.35E+00	2.37E-01	5.98E-03	8.33E-01	4.67E-02	2.01E-03
decane	6.68E+00	2.84E+00	6.56E-01	1.50E+01	1.58E+00	9.42E-02	6.33E+00	1.11E+00	2.81E-02	3.91E+00	2.19E-01	9.42E-03
undecane	6.80E+00	2.89E+00	6.67E-01	1.52E+01	1.60E+00	9.58E-02	6.44E+00	1.13E+00	2.86E-02	3.97E+00	2.23E-01	9.58E-03
dodecane	4.18E+00	1.77E+00	4.10E-01	9.34E+00	9.86E-01	5.89E-02	3.96E+00	6.95E-01	1.76E-02	2.44E+00	1.37E-01	5.89E-03
ALKANES TOTAL CONC.	6.75E+01	2.87E+01	6.63E+00	1.51E+02	1.59E+01	9.51E-01	6.39E+01	1.12E+01	2.84E-01	3.95E+01	2.21E+00	9.51E-02
ALKENES												
ethylene	3.16E+01	1.34E+01	3.10E+00	7.06E+01	7.45E+00	4.45E-01	2.99E+01	5.25E+00	1.33E-01	1.84E+01	1.03E+00	4.45E-02
propylene	5.44E+00	2.31E+00	5.34E-01	1.22E+01	1.28E+00	7.67E-02	5.15E+00	9.05E-01	2.29E-02	3.18E+00	1.78E-01	7.67E-03
butene	1.17E+00	4.99E-01	1.15E-01	2.63E+00	2.77E-01	1.65E-02	1.11E+00	1.95E-01	4.93E-03	6.86E-01	3.85E-02	1.65E-03
pentene	2.04E-01	8.65E-02	2.00E-02	4.56E-01	4.81E-02	2.87E-03	1.93E-01	3.39E-02	8.56E-04	1.19E-01	6.67E-03	2.87E-04
ALKENES TOTAL CONC.	3.84E+01	1.63E+01	3.77E+00	8.58E+01	9.06E+00	5.41E-01	3.63E+01	6.38E+00	1.61E-01	2.24E+01	1.26E+00	5.41E-02
SUM:ALIPHATICS CONC.	1.06E+02	4.50E+01	1.04E+01	2.37E+02	2.50E+01	1.49E+00	1.00E+02	1.76E+01	4.45E-01	6.19E+01	3.47E+00	1.49E-01
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				1.04E+02	1.10E+01	6.56E-01	4.41E+01	7.75E+00	1.96E-01	2.72E+01	1.53E+00	6.56E-02
ALIPHATICS ER CHILD (using RfC)				1.04E+00	1.10E-01	1.49E-03	4.41E-01	7.75E-02	4.45E-04	2.72E-01	1.53E-02	1.49E-04
ADULT INHALED DOSE ug/(kg*d)						1.43E+00			1.20E+00			1.14E+00
ALIPHATICS ER ADULT (using RfC)						4.46E-03			3.76E-03			3.56E-03
AROMATICS												
Ethylbenzene	8.16E-01	3.47E-01	8.02E-02	1.83E+00	1.93E-01	1.15E-02	7.73E-01	1.36E-01	3.43E-03	4.77E-01	2.67E-02	1.15E-03
Toluene	1.38E-01	5.84E-02	1.35E-02	3.08E-01	3.25E-02	1.94E-03	1.30E-01	2.29E-02	5.78E-04	8.04E-02	4.51E-03	1.94E-04
Xylene	2.21E-01	9.38E-02	2.17E-02	4.94E-01	5.21E-02	3.11E-03	2.09E-01	3.67E-02	9.28E-04	1.29E-01	7.23E-03	3.11E-04
AROMATICS TOTAL (excl. benzene)	1.17E+00	4.99E-01	1.15E-01	2.63E+00	2.77E-01	1.66E-02	1.11E+00	1.95E-01	4.94E-03	6.87E-01	3.85E-02	1.66E-03
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*					1.22E-01	7.28E-03	4.90E-01	8.60E-02	2.17E-03	3.02E-01	1.69E-02	7.28E-04
AROMATICS ER CHILD (using RfC)					6.10E-04	4.14E-05	2.45E-03	4.30E-04	1.23E-05	1.51E-03	8.47E-05	4.14E-06
*ADULT INHALED DOSE ug/(kg*d)*						1.58E-02			1.34E-02			1.27E-02
AROMATICS ER ADULT (using RfC)						1.24E-04			1.04E-04			9.89E-05
ALDEHYDES												
Acrolein (RfC=2.0E-02 mg/m^3)	1.23E+00	5.21E-01	1.20E-01	2.74E+00	2.90E-01	1.73E-02	1.16E+00	2.04E-01	5.16E-03	7.18E-01	4.02E-02	1.73E-03
Methacrolein	4.08E-01	1.73E-01	4.01E-02	9.13E-01	9.63E-02	5.75E-03	3.87E-01	6.79E-02	1.72E-03	2.39E-01	1.34E-02	5.75E-04
n-Butanal	5.12E-01	2.18E-01	5.03E-02	1.15E+00	1.21E-01	7.22E-03	4.85E-01	8.52E-02	2.15E-03	2.99E-01	1.68E-02	7.22E-04
3-Methylbutanal	7.05E-02	3.00E-02	6.92E-03	1.58E-01	1.66E-02	9.93E-04	6.68E-02	1.17E-02	2.96E-04	4.12E-02	2.31E-03	9.93E-05
TOTAL AS Acrolein/Methacrolein	2.22E+00	9.42E-01	2.18E-01	4.96E+00	5.23E-01	3.12E-02	2.10E+00	3.69E-01	9.32E-03	1.30E+00	7.27E-02	3.12E-03
RfC (Acrolein & Methacrolein)	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02	2.00E-02
ER-Child Aldehydes (Based on RfC)						1.56E+00			4.66E-01			1.56E-01
ER-Adult Aldehydes (Based on RfC)						4.67E+00			3.94E+00			3.73E+00
KETONES												
*Acetone (RfD=1.0E-01 mg/(kg*d))*	2.23E+00	9.46E-01	2.19E-01	4.98E+00	5.25E-01	3.14E-02	2.11E+00	3.70E-01	9.36E-03	1.30E+00	7.29E-02	3.14E-03
Methyl Ethyl Ketone	4.75E-01	2.02E-01	4.66E-02	1.06E+00	1.12E-01	6.69E-03	4.50E-01	7.90E-02	2.00E-03	2.78E-01	1.56E-02	6.69E-04
3-Buten-2-one	8.91E-01	3.78E-01	8.74E-02	1.99E+00	2.10E-01	1.25E-02	8.44E-01	1.48E-01	3.74E-03	5.21E-01	2.92E-02	1.25E-03
TOTAL AS Acetone	3.59E+00	1.53E+00	3.53E-01	8.03E+00	8.48E-01	5.06E-02	3.40E+00	5.97E-01	1.51E-02	2.10E+00	1.18E-01	5.06E-03
*Inhhaled Child Dose (ug/(kg*d)*				3.54E+00	3.73E-01	2.23E-02	1.50E+00	2.63E-01	6.64E-03	9.24E-01	5.18E-02	2.23E-03
ER CHILD Ketones (RfD from IRIS)						2.23E-04			6.64E-05			2.23E-05
Inhaled Adult Dose ug/(kg*d)						4.84E-02			4.08E-02			3.87E-02
ER ADULT Ketones (RfD from IRIS)						4.84E-04			4.08E-04			3.87E-04
PAHs												
*Naphthalene (RfD=4.0E-02 mg/(kg*d))*	8.25E-02	3.51E-02	8.10E-03	1.85E-01	1.95E-02	1.16E-03	7.82E-02	1.37E-02	3.47E-04	4.83E-02	2.70E-03	1.16E-04
Acenapthylene	5.86E-03	2.49E-03	5.75E-04	1.31E-02	1.38E-03	8.26E-05	5.55E-03	9.75E-04	2.46E-05	3.43E-03	1.92E-04	8.26E-06
Acenaphthene	2.97E-03	1.26E-03	2.91E-04	6.64E-03	7.00E-04	4.18E-05	2.81E-03	4.94E-04	1.25E-05	1.74E-03	9.72E-05	4.18E-06
SUM:NAPHTHA	9.13E-02	3.88E-02	8.97E-03	2.04E-01	2.16E-02	1.29E-03	8.65E-02	1.52E-02	3.84E-04	5.34E-02	2.99E-03	1.29E-04
*Inhhaled Child Dose (ug/(kg*d)*				8.99E-02	9.49E-03	5.66E-04	3.81E-02	6.69E-03	1.69E-04	2.35E-02	1.32E-03	5.66E-05
NAPHTHALENE ER-Child (using RfC)						1.42E-05			4.22E-06			1.42E-06
*Inhhaled Adult Dose (ug/(kg*d)*						1.23E-03			1.04E-03			9.84E-04

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
NAPHTHALENE ER-Adult (using RfC)						3.08E-05			2.60E-05			2.46E-05
Fluorene (RfD=4.0E-02 mg/(kg*d))	8.12E-03	3.45E-03	7.97E-04	1.82E-02	1.92E-03	1.14E-04	7.69E-03	1.35E-03	3.41E-05	4.75E-03	2.66E-04	1.14E-05
2-Methylfluorene	1.78E-05	7.57E-06	1.75E-06	3.98E-05	4.20E-06	2.51E-07	1.69E-05	2.96E-06	7.49E-08	1.04E-05	5.84E-07	2.51E-08
SUM:FLOURENE	8.14E-03	3.46E-03	7.99E-04	1.82E-02	1.92E-03	1.15E-04	7.71E-03	1.35E-03	3.42E-05	4.76E-03	2.67E-04	1.15E-05
*Inhhaled Child Dose (ug/(kg*d)*				8.01E-03	8.45E-04	5.04E-05	3.39E-03	5.96E-04	1.50E-05	2.09E-03	1.17E-04	5.04E-06
FLUORENE ER-Child (using RfC)						1.26E-06			3.76E-07			1.26E-07
*Inhhaled Adult Dose (ug/(kg*d)*						1.10E-04			9.25E-05			8.77E-05
FLUORENE ER-Adult (using RfC)						2.74E-06			2.31E-06			2.19E-06
Fluoranthene (RfD=4.0E-02 mg/(kg*d))	2.12E-03	8.99E-04	2.08E-04	4.73E-03	4.99E-04	2.98E-05	2.00E-03	3.52E-04	8.89E-06	1.24E-03	6.93E-05	2.98E-06
Anthracene	8.84E-04	3.76E-04	8.68E-05	1.98E-03	2.09E-04	1.25E-05	8.37E-04	1.47E-04	3.71E-06	5.17E-04	2.90E-05	1.25E-06
Phenanthrene	2.39E-02	1.01E-02	2.34E-03	5.34E-02	5.63E-03	3.36E-04	2.26E-02	3.97E-03	1.00E-04	1.40E-02	7.82E-04	3.36E-05
3-Methylphenanthrene	9.28E-03	3.94E-03	9.11E-04	2.08E-02	2.19E-03	1.31E-04	8.79E-03	1.54E-03	3.90E-05	5.42E-03	3.04E-04	1.31E-05
2-Methylanthracene	1.06E-02	4.51E-03	1.04E-03	2.37E-02	2.50E-03	1.50E-04	1.01E-02	1.77E-03	4.46E-05	6.21E-03	3.48E-04	1.50E-05
4-+9-Methylphenanthrene	1.14E-02	4.86E-03	1.12E-03	2.56E-02	2.70E-03	1.61E-04	1.08E-02	1.90E-03	4.80E-05	6.68E-03	3.74E-04	1.61E-05
1-Methylphenanthrene	9.50E-03	4.04E-03	9.33E-04	2.12E-02	2.24E-03	1.34E-04	9.00E-03	1.58E-03	3.99E-05	5.55E-03	3.11E-04	1.34E-05
SUM:FLUOANTHENE	6.77E-02	2.88E-02	6.65E-03	1.51E-01	1.60E-02	9.54E-04	6.41E-02	1.13E-02	2.84E-04	3.96E-02	2.22E-03	9.54E-05
*Inhhaled Child Dose (ug/(kg*d)*				6.66E-02	7.03E-03	4.20E-04	2.82E-02	4.95E-03	1.25E-04	1.74E-02	9.76E-04	4.20E-05
FLUORANTHENE ER-Child (using RfC)						1.05E-05			3.13E-06			1.05E-06
*Inhhaled Adult Dose (ug/(kg*d)*						9.12E-04			7.70E-04			7.29E-04
FLUORANTHENE ER-Adult (using RfC)						2.28E-05			1.92E-05			1.82E-05
Pyrene (RfD=3.0E-02 mg/(kg*d))	1.67E-03	7.08E-04	1.64E-04	3.73E-03	3.93E-04	2.35E-05	1.58E-03	2.77E-04	7.01E-06	9.75E-04	5.46E-05	2.35E-06
2-Methylpyrene	1.58E-04	6.72E-05	1.55E-05	3.54E-04	3.73E-05	2.23E-06	1.50E-04	2.63E-05	6.64E-07	9.24E-05	5.18E-06	2.23E-07
SUM:PYRENE	1.83E-03	7.76E-04	1.79E-04	4.08E-03	4.31E-04	2.57E-05	1.73E-03	3.04E-04	7.67E-06	1.07E-03	5.98E-05	2.57E-06
*Inhhaled Child Dose (ug/(kg*d)*				1.80E-03	1.90E-04	1.13E-05	7.61E-04	1.34E-04	3.37E-06	4.70E-04	2.63E-05	1.13E-06
PYRENE ER-Child (using RfC)						3.77E-07			1.12E-07			3.77E-06
*Inhhaled Adult Dose (ug/(kg*d)*						2.46E-05			2.08E-05			1.97E-05
PYRENE ER-Adult (using RfC)						8.20E-07			6.92E-07			6.55E-07
PAH-CHILD HAZARD INDEX						2.63E-05			7.84E-06			2.63E-06
PAH-ADULT HAZARD INDEX						5.72E-05			4.82E-05			4.57E-05
OTHER PAH SUBSTANCES												
Benzo(g,h,l)perylene	1.82E-04	7.72E-05	1.78E-05	4.06E-04	4.29E-05	2.56E-06	1.72E-04	3.02E-05	7.63E-07	1.06E-04	5.95E-06	2.56E-07
Benzo[a]fluorene	1.91E-04	8.14E-05	1.88E-05	4.28E-04	4.52E-05	2.70E-06	1.81E-04	3.18E-05	8.05E-07	1.12E-04	6.27E-06	2.70E-07
Benzo[ghi]fluoranthene	1.11E-04	4.73E-05	1.09E-05	2.49E-04	2.63E-05	1.57E-06	1.05E-04	1.85E-05	4.68E-07	6.51E-05	3.65E-06	1.57E-07
Cyclopenta[cd]pyrene	1.34E-05	5.68E-06	1.31E-06	2.99E-05	3.15E-06	1.88E-07	1.27E-05	2.22E-06	5.61E-08	7.81E-06	4.38E-07	1.88E-08
Benzo[e]pyrene	1.19E-05	5.05E-06	1.17E-06	2.66E-05	2.80E-06	1.67E-07	1.12E-05	1.98E-06	4.99E-08	6.94E-06	3.89E-07	1.67E-08
Perylene	1.48E-06	6.31E-07	1.46E-07	3.32E-06	3.50E-07	2.09E-08	1.41E-06	2.47E-07	6.24E-09	8.68E-07	4.86E-08	2.09E-09
Indeno[1,2,3-cd]fluoranthene	7.42E-06	3.15E-06	7.29E-07	1.66E-05	1.75E-06	1.05E-07	7.03E-06	1.23E-06	3.12E-08	4.34E-06	2.43E-07	1.05E-08
Picene	1.48E-06	6.31E-07	1.46E-07	3.32E-06	3.50E-07	2.09E-08	1.41E-06	2.47E-07	6.24E-09	8.68E-07	4.86E-08	2.09E-09
Benzo[ghi]perylene	1.04E-05	4.41E-06	1.02E-06	2.32E-05	2.45E-06	1.46E-07	9.84E-06	1.73E-06	4.37E-08	6.08E-06	3.40E-07	1.46E-08
Coronene	1.48E-06	6.31E-07	1.46E-07	3.32E-06	3.50E-07	2.09E-08	1.41E-06	2.47E-07	6.24E-09	8.68E-07	4.86E-08	2.09E-09
1-Nitropyrene	1.19E-04	5.05E-05	1.17E-05	2.66E-04	2.80E-05	1.67E-06	1.12E-04	1.98E-05	4.99E-07	6.94E-05	3.89E-06	1.67E-07
Dibenzothiophene	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
4-Methyldibenzothiophene	1.26E-05	5.36E-06	1.24E-06	2.82E-05	2.98E-06	1.78E-07	1.19E-05	2.10E-06	5.30E-08	7.38E-06	4.13E-07	1.78E-08
3-Methyldibenzothiophene	2.08E-05	8.83E-06	2.04E-06	4.65E-05	4.90E-06	2.93E-07	1.97E-05	3.46E-06	8.73E-08	1.22E-05	6.81E-07	2.93E-08
SUM: (AS PYRENE UNITS)			6.72E-05			9.64E-06			2.87E-06			9.64E-07
*Inhhaled Child Dose (as pyrene units, ug/(kg*d)*						4.24E-06			1.26E-06			4.24E-07
ER-Child (as pyrene units, using RfC)						1.41E-07			4.22E-08			1.41E-06
*Inhhaled Adult Dose (as pyrene units, ug/(kg*d)*						9.22E-06			7.78E-06			7.37E-06
ER-Adult (as pyrene units, using RfC)						3.07E-07			2.59E-07			2.46E-07
CARCINOGENS (Fleet Emissions)	(Note: Inhalation dose assumes lifetime exposure (70yrs), with ages 20-70 involving 8hrs worker on site & 16hrs at residence.) (Note: See footnote for explanation of carcinogen dose equation.)											
Formaldehyde	2.67E+01	1.14E+01	2.63E+00	5.98E+01	6.31E+00	3.77E-01	2.53E+01	4.45E+00	1.12E-01	1.56E+01	8.76E-01	3.77E-02
Exposure Ratio based on RsC						**4.71E-01**			**1.41E-01**			**4.71E-02**
*Lifetime Residential Composite Dose (ug/(kg*d)*						1.28E-01			3.82E-02			1.28E-02
FORMALDEHYDE RESIDENTIAL LCR						**5.07E-06**			**1.51E-06**			**5.07E-07**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						3.05E-01			2.35E-01			2.15E-01
FORMALDEHYDE WORKER + RESID'L LCR						1.21E-05			9.31E-06			8.53E-06
	(Note: Formaldehyde slope factor = 3.86E-02mg/(kg*d) per IRIS inhalation unit risk of 1.3 E-05)											
Acetaldehyde	8.52E+00	3.62E+00	8.37E-01	1.91E+01	2.01E+00	1.20E-01	8.07E+00	1.42E+00	3.58E-02	4.98E+00	2.79E-01	1.20E-02
*Lifetime Residential Composite Dose (ug/(kg*d)*						4.08E-02			1.22E-02			4.08E-03
ACETALDEHYDE RESIDENTIAL LCR						**2.74E-07**			8.39E-08			3.14E-08
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						9.72E-02			7.49E-02			6.86E-02
ACETALDEHYDE WORKER + RESID'L LCR						6.51E-07			5.77E-07			5.28E-07
	(Note: Acetaldehyde slope factor = 8.7E-03mg/(kg*d) per IRIS inhalation unit risk of 2.2 E-06)											
Benzene	8.03E-01	3.41E-01	7.89E-02	1.80E+00	1.90E-01	1.13E-02	7.61E-01	1.34E-01	3.38E-03	4.70E-01	2.63E-02	1.13E-03
*Lifetime Residential Composite Dose (ug/(kg*d)*			2.68E-02			3.85E-03			1.15E-03			3.85E-04
BENZENE RESID'L LIFETIME CANCER RISK						**1.12E-07**			**3.33E-08**			**1.12E-08**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						9.16E-03			7.06E-03			6.47E-03
BENZENE WORKER + RESID'L LCR						2.65E-07			2.05E-07			1.88E-07
	(Note: Benzene slope factor = 2.9E-02mg/(kg*d) per TPHCWG, 1997)											
CARCINOGENIC PAHs (GROUPED, BaP-TEFs)												
Benz(a)anthracene * (.1)	2.15E-04	9.11E-05	2.11E-05	4.80E-04	5.06E-05	3.02E-06	2.03E-04	3.57E-05	9.01E-07	1.25E-04	7.03E-06	3.02E-07
Chrysene*(.01)	5.90E-04	2.51E-04	5.79E-05	1.32E-03	1.39E-04	8.31E-06	5.58E-04	9.81E-05	2.48E-06	3.45E-04	1.93E-05	8.31E-07
Benzo(b)fluoranthene*(.1)	7.04E-04	2.99E-04	6.91E-05	1.58E-03	1.66E-04	9.92E-06	6.67E-04	1.17E-04	2.96E-06	4.12E-04	2.31E-05	9.92E-07
Benzo(k)fluoranthene*(.1)	7.99E-05	3.40E-05	7.85E-06	1.79E-04	1.89E-05	1.13E-06	7.57E-05	1.33E-05	3.36E-07	4.67E-05	2.62E-06	1.13E-07
Benzo(a)pyrene*(1.0)	8.38E-05	3.56E-05	8.23E-06	1.87E-04	1.98E-05	1.18E-06	7.94E-05	1.39E-05	3.52E-07	4.90E-05	2.74E-06	1.18E-07
Indeno(1,2,3-W)pyrene*(.01)	1.33E-04	5.66E-05	1.31E-05	2.98E-04	3.14E-05	1.88E-06	1.26E-04	2.22E-05	5.60E-07	7.79E-05	4.36E-06	1.88E-07
Dibenz(a,h)anthracene*(1.0)	2.20E-04	9.35E-05	2.16E-05	4.92E-04	5.19E-05	3.10E-06	2.08E-04	3.66E-05	9.24E-07	1.29E-04	7.21E-06	3.10E-07
SUMCANCER CONCs as BAP TEQs	4.11E-04	1.75E-04	**4.03E-05**	9.19E-04	9.70E-05	**5.79E-06**	3.89E-04	6.83E-05	**1.73E-06**	2.40E-04	1.35E-05	**5.79E-07**
*Lifetime Residential Composite Dose (ug/(kg*d)*						1.97E-06			5.87E-07			1.97E-07
PAH RESID'L LIFETIME CANCER RISK						**1.44E-08**			**4.29E-09**			**1.44E-09**
*Lifetime Worker/Residential Comosite Dose (ug/(kg*d)*						4.69E-06			3.61E-06			3.31E-06
PAH WORKER + RESID'L LCR						3.42E-08			2.64E-08			2.42E-08
	(Note: Benzo(a)pyrene slope factor = 7.3mg/(kg*d), per TPHCWG, 1997)											
TOTAL PAH RESIDENTIAL LCR						**5.47E-06**			**1.64E-06**			**5.51E-07**
TOTAL PAH WORKER + RESID'L LCR						1.30E-05			1.01E-05			9.27E-06

Source: Mine Surface Emissions

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALIPHATICS												
C1 to C3	2.71E+02	1.15E+02	2.62E+01	6.04E+02	6.35E+01	3.82E+00	2.55E+02	4.48E+01	1.13E+00	1.58E+02	8.77E+00	3.69E-01
i-BUTANE	6.26E+00	2.65E+00	6.05E-01	1.39E+01	1.46E+00	8.80E-02	5.88E+00	1.03E+00	2.61E-02	3.64E+00	2.02E-01	8.50E-03
n-BUTANE	1.09E+01	4.64E+00	1.06E+00	2.44E+01	2.56E+00	1.54E-01	1.03E+01	1.81E+00	4.57E-02	6.36E+00	3.54E-01	1.49E-02
i-PENTANE	4.69E+00	1.99E+00	4.54E-01	1.04E+01	1.10E+00	6.60E-02	4.41E+00	7.75E-01	1.96E-02	2.73E+00	1.52E-01	6.37E-03
CYCLOPENTANE	9.38E+00	3.98E+00	9.08E-01	2.09E+01	2.19E+00	1.32E-01	8.83E+00	1.55E+00	3.91E-02	5.45E+00	3.03E-01	1.27E-02

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
3-ME-PENTANE	3.13E+00	1.33E+00	3.03E-01	6.96E+00	7.31E-01	4.40E-02	2.94E+00	5.17E-01	1.30E-02	1.82E+00	1.01E-01	4.25E-03
METHYLCYCLOPENTANE	3.13E+00	1.33E+00	3.03E-01	6.96E+00	7.31E-01	4.40E-02	2.94E+00	5.17E-01	1.30E-02	1.82E+00	1.01E-01	4.25E-03
CYCLOHEXANE	3.13E+00	1.33E+00	3.03E-01	6.96E+00	7.31E-01	4.40E-02	2.94E+00	5.17E-01	1.30E-02	1.82E+00	1.01E-01	4.25E-03
2,3-DIMETHYLPENTANE	3.13E+00	1.33E+00	3.03E-01	6.96E+00	7.31E-01	4.40E-02	2.94E+00	5.17E-01	1.30E-02	1.82E+00	1.01E-01	4.25E-03
3-METHYLHEXANE	7.82E+00	3.32E+00	7.56E-01	1.74E+01	1.83E+00	1.10E-01	7.35E+00	1.29E+00	3.26E-02	4.54E+00	2.53E-01	1.06E-02
N-HEPTANE	1.56E+00	6.64E-01	1.51E-01	3.48E+00	3.66E-01	2.20E-02	1.47E+00	2.58E-01	6.52E-03	9.09E-01	5.06E-02	2.12E-03
ME-CYCLOHEXANE	6.26E+00	2.65E+00	6.05E-01	1.39E+01	1.46E+00	8.80E-02	5.88E+00	1.03E+00	2.61E-02	3.64E+00	2.02E-01	8.50E-03
3-METHYLHEPTANE	1.02E+01	4.31E+00	9.83E-01	2.26E+01	2.38E+00	1.43E-01	9.56E+00	1.68E+00	4.24E-02	5.91E+00	3.29E-01	1.38E-02
2,3,4-TRIMETHYLHEXANE	2.35E+00	9.95E-01	2.27E-01	5.22E+00	5.49E-01	3.30E-02	2.21E+00	3.87E-01	9.79E-03	1.36E+00	7.58E-02	3.19E-03
N-OCTANE	8.60E+00	3.65E+00	8.32E-01	1.92E+01	2.01E+00	1.21E-01	8.09E+00	1.42E+00	3.59E-02	5.00E+00	2.78E-01	1.17E-02
BRANCHED NONANE	7.82E+00	3.32E+00	7.56E-01	1.74E+01	1.83E+00	1.10E-01	7.35E+00	1.29E+00	3.26E-02	4.54E+00	2.53E-01	1.06E-02
n-NONANE	1.17E+01	4.98E+00	1.13E+00	2.61E+01	2.74E+00	1.65E-01	1.10E+01	1.94E+00	4.89E-02	6.82E+00	3.79E-01	1.59E-02
n-DECANE	1.25E+01	5.31E+00	1.21E+00	2.79E+01	2.93E+00	1.76E-01	1.18E+01	2.07E+00	5.22E-02	7.27E+00	4.04E-01	1.70E-02
(ALIPHATICS TOTAL C5-C10)	1.76E+02	7.46E+01	1.70E+01	3.92E+02	4.11E+01	2.47E+00	1.65E+02	2.91E+01	7.34E-01	1.02E+02	5.69E+00	2.39E-01
ALIPHATICS TOTAL C1-C10	4.65E+02	1.97E+02	**4.50E+01**	1.04E+03	1.09E+02	6.54E+00	4.38E+02	7.68E+01	1.94E+00	2.70E+02	1.50E+01	6.32E-01
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				4.56E+02	4.79E+01	2.88E+00	1.93E+02	3.38E+01	8.54E-01	1.19E+02	6.62E+00	2.78E-01
ALIPHATICS ER CHILD (using RfC)				4.56E+00	4.79E-01	5.54E-03	1.93E+00	3.38E-01	1.94E-03	1.19E+00	6.62E-02	6.32E-04
ADULT INHALED DOSE ug/(kg*d)						6.20E+00			5.21E+00			4.93E+00
ALIPHATICS ER ADULT (RfD from TPHCWG, 1997)						1.94E-02			1.63E-02			1.54E-02
AROMATICS												
Carbon Range C5-C8												
TOLUENE	3.91E+00	1.66E+00	3.78E-01	8.71E+00	9.14E-01	5.50E-02	3.68E+00	6.46E-01	1.63E-02	2.27E+00	1.26E-01	5.31E-03
ET-BENZENE	3.13E+00	1.33E+00	3.03E-01	6.96E+00	7.31E-01	4.40E-02	2.94E+00	5.17E-01	1.30E-02	1.82E+00	1.01E-01	4.25E-03
M,P-XYLENE	1.56E+00	6.64E-01	1.51E-01	3.48E+00	3.66E-01	2.20E-02	1.47E+00	2.58E-01	6.52E-03	9.09E-01	5.06E-02	2.12E-03
O-XYLENE	7.82E+00	3.32E+00	7.56E-01	1.74E+01	1.83E+00	1.10E-01	7.35E+00	1.29E+00	3.26E-02	4.54E+00	2.53E-01	1.06E-02
TOTAL AROMATICS C5-C8 CONC.	1.64E+01	6.97E+00	**1.59E+00**	3.66E+01	3.84E+00	**2.31E-01**	1.54E+01	2.71E+00	**6.85E-02**	9.54E+00	5.31E-01	**2.23E-02**
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				1.61E+01	1.69E+00	1.02E-01	6.80E+00	1.19E+00	3.01E-02	4.20E+00	2.34E-01	9.81E-03
AROMATICS ER CHILD (RfD from TPHCWG, 1997)				8.04E-02	8.45E-03	5.77E-04	3.40E-02	5.97E-03	1.71E-04	2.10E-02	1.17E-03	5.58E-05
*ADULT INHALED DOSE ug/(kg*d)*						2.19E-01			1.84E-01			1.74E-01
AROMATICS ER ADULT (using RfC)						1.71E-03			1.44E-03			1.36E-03
Carbon Range C9-C18												
Cumene	7.82E+00	3.32E+00	7.56E-01	1.74E+01	1.83E+00	1.10E-01	7.35E+00	1.29E+00	3.26E-02	4.54E+00	2.53E-01	1.06E-02
TOTAL AROMATICS C9-C18 CONC.	7.82E+00	3.32E+00	7.56E-01	1.74E+01	1.83E+00	1.10E-01	7.35E+00	1.29E+00	3.26E-02	4.54E+00	2.53E-01	1.06E-02
TPHWG (1997) RfC (ug/m3)	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				7.66E+00	8.05E-01	4.84E-02	3.24E+00	5.68E-01	1.44E-02	2.00E+00	1.11E-01	4.67E-03
AROMATICS (C9-C18) ER CHILD (using RfC)				1.92E-01	2.01E-02	5.50E-04	8.09E-02	1.42E-02	1.63E-04	5.00E-02	2.78E-03	5.31E-05
*ADULT INHAL DOSE (ug/kg*day)*						1.04E-01			8.76E-02			8.29E-02
AROMATICS (C9-C18) ER ADULT (using RfC)						1.63E-03			1.37E-03			1.30E-03
AROMATICS ER CHILD (using RfC)						1.13E-03			3.34E-04			1.09E-04
AROMATICS ER ADULT (RfD from TPHCWG, 1997)						3.34E-03			2.81E-03			2.66E-03

Source: Tailings Pond

SUBSTANCE	Overall On Site Max.			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALIPHATICS												
C1 to C3	3.36E+02	1.88E+02	7.04E+01	3.95E+02	6.03E+01	7.15E+00	1.29E+02	2.35E+01	6.08E-01	7.13E+01	3.51E+00	1.49E-01
Isobutane	6.18E+00	3.45E+00	1.30E+00	7.27E+00	1.11E+00	1.32E-01	2.37E+00	4.32E-01	1.12E-02	1.31E+00	6.46E-02	2.74E-03
Isopentane	1.55E+00	8.63E-01	3.24E-01	1.82E+00	2.77E-01	3.29E-02	5.92E-01	1.08E-01	2.80E-03	3.28E-01	1.61E-02	6.84E-04
n-Pentane	2.32E+00	1.29E+00	4.86E-01	2.73E+00	4.16E-01	4.94E-02	8.87E-01	1.62E-01	4.20E-03	4.92E-01	2.42E-02	1.03E-03
Cyclopentane	3.86E-01	2.16E-01	8.10E-02	4.55E-01	6.94E-02	8.23E-03	1.48E-01	2.70E-02	7.00E-04	8.21E-02	4.04E-03	1.71E-04
2,3-Dimethylbutane	1.31E+01	7.34E+00	2.75E+00	1.55E+01	2.36E+00	2.80E-01	5.03E+00	9.18E-01	2.38E-02	2.79E+00	1.37E-01	5.81E-03
n-Hexane	1.08E+01	6.04E+00	2.27E+00	1.27E+01	1.94E+00	2.30E-01	4.14E+00	7.56E-01	1.96E-02	2.30E+00	1.13E-01	4.79E-03
2,4-Dimethylpentane	2.16E+01	1.21E+01	4.54E+00	2.55E+01	3.88E+00	4.61E-01	8.28E+00	1.51E+00	3.92E-02	4.59E+00	2.26E-01	9.57E-03
Cyclohexane	3.94E+01	2.20E+01	8.26E+00	4.64E+01	7.07E+00	8.39E-01	1.51E+01	2.75E+00	7.14E-02	8.37E+00	4.12E-01	1.74E-02
2,3-Dimethylpentane	5.02E+00	2.81E+00	1.05E+00	5.91E+00	9.02E-01	1.07E-01	1.92E+00	3.51E-01	9.10E-03	1.07E+00	5.25E-02	2.22E-03
3-Methylhexane	1.62E+01	9.06E+00	3.40E+00	1.91E+01	2.91E+00	3.46E-01	6.21E+00	1.13E+00	2.94E-02	3.45E+00	1.70E-01	7.18E-03
2,2,4-Trimethylpentane	3.63E+01	2.03E+01	7.61E+00	4.27E+01	6.52E+00	7.73E-01	1.39E+01	2.54E+00	6.58E-02	7.71E+00	3.80E-01	1.61E-02
n-Heptane	2.01E+01	1.12E+01	4.21E+00	2.36E+01	3.61E+00	4.28E-01	7.69E+00	1.40E+00	3.64E-02	4.27E+00	2.10E-01	8.89E-03
3-Methylheptane	1.31E+01	7.34E+00	2.75E+00	1.55E+01	2.36E+00	2.80E-01	5.03E+00	9.18E-01	2.38E-02	2.79E+00	1.37E-01	5.81E-03
2,2,5-Trimethylhexane	3.90E+01	2.18E+01	8.18E+00	4.59E+01	7.00E+00	8.31E-01	1.49E+01	2.73E+00	7.07E-02	8.29E+00	4.08E-01	1.73E-02
n-Octane	3.82E+01	2.14E+01	8.02E+00	4.50E+01	6.87E+00	8.15E-01	1.46E+01	2.67E+00	6.93E-02	8.12E+00	4.00E-01	1.69E-02
n-Nonane	2.09E+01	1.17E+01	4.37E+00	2.45E+01	3.74E+00	4.44E-01	7.99E+00	1.46E+00	3.78E-02	4.43E+00	2.18E-01	9.23E-03
ALIPHATICS TOTAL C5-C10	8.67E+02	4.84E+02	1.82E+02	1.02E+03	1.56E+02	1.85E+01	3.32E+02	6.06E+01	1.57E+00	1.84E+02	9.06E+00	3.84E-01
ALIPHATICS TOTAL C1-C10	1.21E+03	6.76E+02	**2.54E+02**	1.42E+03	2.17E+02	2.58E+01	4.63E+02	8.46E+01	2.19E+00	2.57E+02	1.26E+01	5.35E-01
TPHWG (1997) minimum RfC (ug/m3)	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03	1.00E+03
*CHILD INHAL DOSE (ug/kg*day)*				6.26E+02	9.55E+01	1.13E+01	2.04E+02	3.72E+01	9.64E-01	1.13E+02	5.56E+00	2.35E-01
ALIPHATICS ER CHILD (using RfC)				6.26E+00	9.55E-01	2.58E-02	2.04E+00	3.72E-01	2.19E-03	1.13E+00	5.56E-02	5.35E-04
ADULT INHALED DOSE ug/(kg*d)						3.25E+01			2.75E+01			2.72E+01
ALIPHATICS ER ADULT (using RfC)						1.02E-01			8.60E-02			8.49E-02
AROMATICS												
Carbon Range C5-C8												
Toluene	3.32E+01	1.86E+01	6.97E+00	3.91E+01	5.96E+00	7.08E-01	1.27E+01	2.32E+00	6.02E-02	7.06E+00	3.47E-01	1.47E-02
Ethylbenzene	9.12E+01	5.09E+01	1.91E+01	1.07E+02	1.64E+01	1.94E+00	3.49E+01	6.37E+00	1.65E-01	1.94E+01	9.53E-01	4.03E-02
(p+m)-Xylene	9.12E+01	5.09E+01	1.91E+01	1.07E+02	1.64E+01	1.94E+00	3.49E+01	6.37E+00	1.65E-01	1.94E+01	9.53E-01	4.03E-02
o-Xylene	2.86E+01	1.60E+01	5.99E+00	3.36E+01	5.13E+00	6.09E-01	1.09E+01	2.00E+00	5.18E-02	6.07E+00	2.99E-01	1.27E-02
TOTAL AROMATICS C6-C8 CONC.	2.44E+02	1.36E+02	5.12E+01	2.87E+02	4.38E+01	5.20E+00	9.35E+01	1.71E+01	4.42E-01	5.19E+01	2.55E+00	1.08E-01
TPHWG (1997) RfC (ug/m3)	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02	4.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				2.20E+00	3.36E-01	3.98E-02	7.16E-01	1.31E-01	3.39E-03	3.97E-01	1.95E-02	8.27E-04
AROMATICS (C5-C6) ER CHILD (using RfC)				1.10E-02	1.68E-03	1.30E-02	3.58E-03	6.54E-04	1.11E-03	1.99E-03	9.77E-05	2.70E-04
*ADULT INHAL DOSE (ug/kg*day)*						6.57E+00			5.56E+00			5.48E+00
AROMATICS (C5-C6) ER ADULT (using RfC)						5.13E-02			4.34E-02			4.28E-02
Carbon Range C9-C18												
1,2,3-TMB+p-Cymene	3.09E+01	1.73E+01	6.48E+00	3.64E+01	5.55E+00	6.58E-01	1.18E+01	2.16E+00	5.60E-02	6.56E+00	3.23E-01	1.37E-02
1,2,4-TMB+n-Decane	2.16E+01	1.21E+01	4.54E+00	2.55E+01	3.88E+00	4.61E-01	8.28E+00	1.51E+00	3.92E-02	4.59E+00	2.26E-01	9.57E-03
1,3,5-Trimethylbenzene	4.25E+00	2.37E+00	8.91E-01	5.00E+00	7.63E-01	9.05E-02	1.63E+00	2.97E-01	7.70E-03	9.03E-01	4.44E-02	1.88E-03
Cumene	1.47E+01	8.20E+00	3.08E+00	1.73E+01	2.64E+00	3.13E-01	5.62E+00	1.03E+00	2.66E-02	3.12E+00	1.53E-01	6.50E-03
TOTAL AROMATICS C9-C18 CONC.	7.15E+01	3.99E+01	1.50E+01	8.41E+01	1.28E+01	1.52E+00	2.74E+01	5.00E+00	1.29E-01	1.52E+01	7.47E-01	3.16E-02
TPHWG (1997) RfC (ug/m3)	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02	2.00E+02
*CHILD INHAL DOSE (ug/kg*day)*				3.70E+01	5.65E+00	6.70E-01	1.20E+01	2.20E+00	5.70E-02	6.68E+00	3.29E-01	1.39E-02
AROMATICS (C9-C18) ER CHILD (using RfC)				9.25E-01	1.41E-01	7.61E-03	3.01E-01	5.50E-02	6.47E-04	1.67E-01	8.22E-03	1.58E-04
*ADULT INHAL DOSE (ug/kg*day)*						1.92E+00			1.63E+00			1.61E+00
AROMATICS (C9-C18) ER ADULT (using RfC)						3.01E-02			2.54E-02			2.51E-02
AROMATICS ER CHILD (using RfC)				9.36E-01	1.43E-01	2.06E-02	3.05E-01	5.56E-02	1.75E-03	1.69E-01	8.31E-03	4.28E-04
AROMATICS ER ADULT (RfD from TPHCWG, 1997)						8.14E-02			6.88E-02			6.79E-02

SUBSTANCE	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
CHEMICAL/RECEPTOR	Overall Maximum Predicted			Fort McKay			Fort McMurray			Fort Chipeywan		
	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual	1 hour	1 day	annual
ALDEHYDES ER-Child (Based on RfC)	not applicable					1.56E+00	not apllicable		4.66E-01	not apllicable		1.56E-01
ALDEHYDES ER-Adult (Based on RfC)	not applicable					4.67E+00	not apllicable		3.94E+00	not apllicable		3.73E+00
KETONES ER-Child (using RfC)	not apllicable					2.23E-04	not apllicable		6.64E-05	not apllicable		2.23E-05
KETONES ER-Adult (using RfC)	not apllicable					4.84E-04	not apllicable		4.08E-04	not apllicable		3.97E-04
ALIPHATICS HI-Child	not apllicable					3.38E-02	not apllicable		4.58E-03	not apllicable		1.32E-03
ALIPHATICS HI-Adult	not apllicable					1.26E-01	not apllicable		1.06E-01	not apllicable		1.04E-01
AROMATICS HI-Child	not apllicable					2.18E-02	not apllicable		2.10E-03	not apllicable		5.41E-04
AROMATICS HI-Adult	not apllicable					8.48E-02	not apllicable		7.17E-02	not apllicable		7.07E-02
PAH-CHILD HAZARD INDEX	not apllicable					2.64E-05	not apllicable		7.88E-06	not apllicable		2.64E-06
PAH-ADULT HAZARD INDEX	not apllicable					5.75E-05	not apllicable		4.85E-05	not apllicable		4.59E-05
TOTAL RESIDENTIAL LCR	not apllicable					**5.47E-06**	not apllicable		**1.64E-06**	not apllicable		**5.51E-07**
TOTAL RESIDENTIAL CARCINOGEN ER	not apllicable					**5.47E-01**	not apllicable		**1.64E-01**	not apllicable		**5.51E-02**
TOTAL WORKER + RESID'L LCR	not apllicable					1.30E-05	not apllicable		1.01E-05	not apllicable		9.27E-06
TOTAL WORKER + RESID'L CARCINOGEN ER	not apllicable					1.30E+00	not apllicable		1.01E+00	not apllicable		9.27E-01

Notes:

1. Exposure concentrations may be slightly higher (i.e., conservative measure) than reported from air dispersion modelling (Section E2) due to rounding.
2. Fluoranthene used as model PAH instead of anthracene.
3. Additional PAHs modelled as pyrene units.
4. Slope factors for formaldehyde and acetaldehyde recalculated from unit risk using 23 m^3/d.
5. Composite receptor inhalation factor averaged over 70 years is 0.34 $m^3/kg*d$, based on Health Canada (CEPA).
6. Maximum inhalation factor is 0.44 $m^3/kg*d$, occurs for a child 5-11 years (per Health Canada, CEPA).
7. Adult exposure concentration based on 8 of 24 hrs workplace ambient air and 16 of 24 hrs at residence ambient air.
8. Adult carcinogenic inhalation factor in dose calculations is the time-weighted-average from ages 0 to 20 yrs for residential exposure, and 20 to 70yrs involving both residential and workplace exposure, per Health Canada (CEPA).

Common Name	*Scientific Name*
VEGETATION	
awned hair cap	*Polytrichum piliferum*
balsam fir	*Abies balsamea*
balsam poplar	*Populus balsamifera*
beaked hazelnut	*Corylus cornuta*
bearberry	*Arctostaphylos uva-ursi*
bishop's cap	*Mitella nuda*
blueberry	*Vaccinium angustifolium var. myrtilloides*
bog cranberry	*Vaccinium vitis-idaea*
bracted honeysuckle	*Lonicera involucrata*
brown moss	*Drepanocladus spp.*
brown-foot cladonia	*Cladonia gracilis*
buck-bean	*Menyanthes trifoliata*
bulrush	*Scirpus spp.*
bunchberry	*Cornus canadensis*
Canada buffalo-berry	*Sheperdia canadensis*
cattail	*Typha latifolia*
choke cherry	*Prunus virginiana*
cloudberry	*Rubus chamaemorus*
common horsetail	*Equisetum arvense*
common pink wintergreen	*Pyrola asarifolia*
cotton grasses	*Eriophorum sp.*
cream-colored vetchling	*Lathyrus ochroleucus*
creeping spike-rush	*Eleocharis palustris*
currant	*Ribes spp.*
dewberry	*Rubus pubescens*
dogwood	*Cornus stolonifera*
dwarf birch	*Betula pumila*
dwarf scouring rush	*Equisetum scirpoides*
feathermoss	*Pleurozium spp.*
fireweed	*Epilobium angustifolium*
golden moss	*Tomenthypnum nitens*
green alder	*Alnus crispa*
hairy wild rye	*Elymus innovatus*
jack pine	*Pinus banksiana*
knight's plume moss	*Ptilium crista-castrensis*
Labrador tea	*Ledum groenlandicum*

Common Name	*Scientific Name*
lichens	*Cladonia sp., and Cladina sp*
low-bush cranberry	*Viburnum edule*
marsh cinquefoil	*Potentilla palustris*
marsh marigold	*Caltha palustris*
marsh reed grass	*Calamagrostis canadensis*
marsh skullcap	*Scutellaria galericulata*
meadow horsetail	*Equisetum pratense*
midway peat moss	*Sphagnum magellanicum*
northern reed grass	*Calamagrostis inexpansa*
northern willowherb	*Epilobium ciliatum*
oak fern	*Gymnocarpium dryopteris*
palmate-leaved coltsfoot	*Petasites palmatus*
peat moss	*Sphagnum spp.*
peat moss	*Sphagnum angustifolium*
peat moss	*Sphagnum fuscam*
pin cherry	*Prunus pensylvanica*
pitcher plants	*Sarracenia purpurea*
prickly rose	*Rosa acicularis*
ragged moss	*Brachythecium spp.*
reed grass	*Phalaris spp./Phragmites spp.*
reindeer lichen	*Cladina spp.*
river alder	*Alnus tenuifolia*
rushes	*Juncus sp., Luzula sp.*
sand heather	*Hudsonia tomentosa*
saskatoon	*Amelanchier alnifolia*
Schreber's moss	*Pleurozium schreberi*
scorpion feathermoss	*Scorpidium scorpioides*
sedges	*Carex spp.*
shield fern	*Dryopteris carthusiana*
shore-growing peat moss	*Sphagnum. riparium*
showy aster	*Aster conspicuus*
slender hair-cap moss	*Polytrichum strictum*
small bog cranberry	*Oxycoccus microcarpus*
snowberry	*Symphoricarpos albus*
stair-step moss	*Hylocomium splendens*
stiff club-moss	*Lycopodium annotinum*
sweet gale	*Myrica gale*

Common Name	*Scientific Name*
sweet-scented bedstraw	*Galium triflorum*
tall lungwort	*Mertensia paniculata*
tamarack	*Larix laricina*
three-leaved Solomon's seal	*Smilacina trifolia*
trembling aspen	*Populus tremuloides*
tufted moss	*Aulacomnium palustre*
twin-flower	*Linnaea borealis*
water smartweed	*Polygonum amphibium*
white birch	*Betula papyrifera*
white spruce	*Picea glauca*
wild lily-of-the-valley	*Maianthemum canadense*
wild mint	*Mentha arvensis*
wild red raspberry	*Rubus idaeus*
wild sarsaparilla	*Aralia nudicaulis*
wild strawberry	*Frageria virginiana*
willow	*Salix spp.*
woodland horsetail	*Equisetum sylvaticum*
algae	*Selenastrum capricornutum*
INVERTEBRATES	
chironomid midge larvae	*Chironomus tentans*
amphipod	*Hyallela azteca*
oligocaete worm	*Lumbriculus*
stoneflies	*Plecoptera*
mayflies	*Ephemeroptera*
dragonflies and daselflies	*Odonata*
caddishflies	*Trichoptera*
water flea	*Daphnia magna*
water flea	*Ceriodaphnia dubia*
luminescent bacteria	*Vibrio fischeri*
FISH	
arctic grayling	*Thymallus arcticus*
brook stickleback	*Culaea inconstans*
bull trout	*Salvelinus Confluentus*
burbot	*Lota Lota*
cisco	*Coregonus artedi*
emerald shiner	*Notropis atherinoides*
Fathead Minnow	*Pimephales promelas*

Common Name	*Scientific Name*
finescale Dace	*Platygobio gracilis*
goldeye	*Hiodon alosoides*
Iowa Darter	*Etheostoma exile*
lake Chub	*Couesius plumbeus*
lake whitefish	*Coregonus clupeaformis*
longnose Dace	*Rhinichthys cataractae*
longnose Sucker	*Catostomus catostomus*
mountain Whitefish	*Prosopium williamsoni*
ninespine Stickleback	*Pungitius pungitius*
northern Pike	*Esox lucius*
northern Redbelly Dace	*Phoxinus eos*
pearl Dace	*Semotilus margarita*
rainbow trout	*Oncorhynchus mykiss*
river Shiner	*Notropis blennius*
shiner Species	*Notropis sp.*
slimy Sculpin	*Cottus cognatus*
spoonhead Sculpin	*Cottus ricei*
spottail Shiner	*Notropis hudsonius*
trout Perch	*Percopsis omiscomaycus*
walleye	*Stizostedion vitreum*
white Sucker	*Catostomus commersoni*
yellow Perch	*Perca flavescens*
REPTILES AND AMPHIBIANS	
Canadian toad	*Bufo hemiophrys*
red-sided garter snake	*Thamnophis sirtalis*
stripped chorus frog	*Pseudacris triseriata*
wood frog	*Rana sylvatica*
BIRDS	
alder flycatcher	*Empidonax alnorum*
American bittern	*Botaurus lentiginosus*
American coot	*Fulica americana*
American crow	*Corvus brachyrhynchos*
American goldfinch	*Carduelis tristis*
American kestrel	*Falco sparverius*
American pipit	*Anthus rubescens*
American redstart	*Setophaga ruticilla*
American robin	*Turdus migratorius*

Common Name	***Scientific Name***
American tree sparrow	*Spizella arborea*
American white pelican	*Pelecanus erythrorhynchos*
American wigeon	*Anas americana*
bald eagle	*Haliaeetus leucocephalus*
bank swallow	*Riparia riparia*
barn swallow	*Hirundo rustica*
bay-breasted warbler	*Dendroica castanea*
belted kingfisher	*Ceryle alcyon*
black tern	*Chlidonias niger*
black-and-white warbler	*Mniotilta varia*
black-backed woodpecker	*Picoides arcticus*
black-billed magpie	*Pica pica*
black-capped chickadee	*Parus atricapillus*
black-throated green warbler	*Dendroica virens*
blackpoll warbler	*Dendroica striata*
blue jay	*Cyanocitta cristata*
blue-winged teal	*Anas discors*
bohemian waxwing	*Bombycilla garrulus*
Bonaparte's gull	*Larus philadelphia*
boreal chickadee	*Parus hudsonicus*
boreal owl	*Aegolius funereus*
Brewer's blackbird	*Euphagus cyanocephalus*
broad-winged hawk	*Buteo platypterus*
brown creeper	*Certhia americana*
brown-headed cowbird	*Molothrus ater*
bufflehead	*Bucephalus albeola*
California gull	*Larus californicus*
Canada goose	*Branta canadensis*
Canada warbler	*Wilsonia canadensis*
canvasback	*Aythya valisineria*
Cape May warbler	*Dendroica tigrina*
cedar waxwing	*Bombycilla cedrorum*
chipping sparrow	*Spizella passerina*
clay-colored sparrow	*Spizella pallida*
cliff swallow	*Hirundo pyrrhonota*
common goldeneye	*Bucephala clangula*
common grackle	*Quiscalus quiscula*

Common Name	*Scientific Name*
common loon	*Gavia immer*
common merganser	*Mergus merganser*
common nighthawk	*Chordeiles minor*
common raven	*Corvus corax*
common redpoll	*Carduelis flammea*
common snipe	*Gallinago gallinago*
common tern	*Sterna hirundo*
common yellowthroat	*Geothlypis trichas*
Connecticut warbler	*Oporonis agilis*
dark-eyed junco	*Junco hyemalis*
double-crested cormorant	*Phalacrocorax auritus*
downy woodpecker	*Picoides pubescens*
eastern kingbird	*Tyrannus tyrannus*
eastern phoebe	*Sayornis phoebe*
European starling	*Sturnus vulgaris*
evening grosbeak	*Coccothraustes vespertinus*
fox sparrow	*Passerella iliaca*
Franklin's gull	*Larus pipixcan*
gadwall	*Anas strepera*
golden eagle	*Aquila chrysaetos*
golden-crowned kinglet	*Regulus satrapa*
gray jay	*Perisoreus canadensis*
great blue heron	*Ardea herodias*
great gray owl	*Strix nebulosa*
great-crested flycatcher	*Myiarchus crinitus*
great-horned owl	*Bubo virginianus*
greater yellowlegs	*Tringa melanoleuca*
green-winged teal	*Anas crecca*
hairy woodpecker	*Picoides villosus*
hermit thrush	*Catharus guttatus*
herring gull	*Larus argentatus*
hooded merganser	*Lophodytes cucullatus*
horned grebe	*Podiceps auritus*
horned lark	*Eremophila alpestris*
house sparrow	*Passer domesticus*
killdeer	*Charadrius vociferus*
least flycatcher	*Empidonax minimus*

Common Name	Scientific Name
least sandpiper	*Calidris minutilla*
LeConte's sparrow	*Ammodramus leconteii*
lesser scaup	*Aythya affinis*
lesser yellowlegs	*Tringa flavipes*
Lincoln's sparrow	*Melospiza lincolnii*
magnolia warbler	*Dendroica magnolia*
mallard	*Anas platyrhynchos*
marbled godwit	*Limosa fedoa*
marsh wren	*Cistothorus palustris*
merlin	*Falco columbarius*
mew gull	*Larus canus*
mountain bluebird	*Sialia currucoides*
mourning warbler	*Oporornis philadelphia*
northern flicker	*Colaptes auratus*
northern goshawk	*Accipiter gentilis*
northern harrier	*Circus cyaneus*
northern hawk owl	*Surnia ulula*
northern pintail	*Anas acuta*
northern shoveler	*Anas clypeata*
northern waterthrush	*Seiurus noveboracensis*
olive-sided flycatcher	*Contopus borealis*
orange-crowned warbler	*Vermivora celeta*
osprey	*Pandion haliaetus*
ovenbird	*Seiurus aurocapillus*
palm warbler	*Dendroica palmarum*
peregrine falcon	*Falco peregrinus*
Philadelphia vireo	*Vireo philadelphicus*
pied-billed grebe	*Podilymbus podiceps*
pileated woodpecker	*Dryocopus pileatus*
pine siskin	*Carduelis pinus*
purple finch	*Carpodacus purpureus*
red crossbill	*Loxia curvivostra*
red-breasted merganser	*Mergus serrator*
red-breasted nuthatch	*Sitta canadensis*
red-eyed vireo	*Vireo olivaceus*
red-necked grebe	*Podiceps grisegena*
red-tailed hawk	*Buteo jamaicensis*

Common Name	*Scientific Name*
red-winged blackbird	*Agelaius phoeniceus*
redhead	*Aythya americana*
ring-billed gull	*Larus delawarensis*
ring-necked duck	*Aythya collaris*
rock dove	*Columba livia*
rose-breasted grosbeak	*Pheucticus ludovicianus*
ruby-crowned kinglet	*Regulus calendula*
ruddy duck	*Oxyura jamaicensis*
ruffed grouse	*Bonasa umbellus*
rusty blackbird	*Euphagus carolinus*
sandhill crane	*Grus canadensis*
savannah sparrow	*Passerculus sandwichensis*
Say's phoebe	*Sayornis saya*
semipalmated plover	*Charadrius semipalmatus*
sharp-shinned hawk	*Accipiter striatus*
sharp-tailed grouse	*Tympanuchus phasianellus*
sharp-tailed sparrow	*Ammodramus caudacutus*
short-billed dowitcher	*Limnodramus griseus*
solitary sandpiper	*Tringa solitaria*
solitary vireo	*Vireo solitarius*
song sparrow	*Melospiza melodia*
sora	*Porzana carolina*
spotted sandpiper	*Actitis macularia*
spruce grouse	*Dendragapus canadensis*
Swainson's thrush	*Catharus ustulatus*
swamp sparrow	*Melospiza georgiana*
Tennessee warbler	*Vermivora peregrina*
three-toed woodpecker	*Picoides tridactylus*
tree swallow	*Tachycineta bicolor*
vesper sparrow	*Pooecetes grammineus*
warbling vireo	*Vireo gilvus*
western tanager	*Piranga ludoviciana*
western wood-pewee	*Contopus sordidulus*
white-crowned sparrow	*Zonotrichia leucophrys*
white-throated sparrow	*Zonotrichia albicollis*
white-winged crossbill	*Loxia leucoptera*
Wilson's phalarope	*Phalaropus tricolor*

Common Name	*Scientific Name*
Wilson's warbler	*Wilsonia pusilla*
winter wren	*Troglodytes troglodytes*
yellow warbler	*Dendroica petechia*
yellow-bellied flycatcher	*Empidonax flaviventris*
yellow-bellied sapsucker	*Sphyrapicus varius*
yellow-headed blackbird	*Xanthocephalus xanthocephalus*
yellow-rumped warbler	*Dendroica coronata*
MAMMALS	
arctic shrew	*Sorex arcticus*
beaver	*Castor canadensis*
big brown bat	*Eptesicus fuscus*
black bear	*Ursus americanus*
Canada lynx	*Lynx canadensis*
caribou	*Rangifer tarandus*
coyote	*Canis latrans*
deer mouse	*Peromyscus maniculatus*
dusky shrew	*Sorex monticolus*
ermine	*Mustela erminea*
fisher	*Martes pennanti*
gray wolf	*Canis lupus*
heather vole	*Phenacomys intermedius*
hoary bat	*Lasiurus cinereus*
least chipmunk	*Tamias minimus*
least weasel	*Mustela nivalis*
little brown bat	*Myotis lucifugus*
marten	*Martes americana*
masked shrew	*Sorex cinereus*
meadow jumping mouse	*Zapus hudsonius*
meadow vole	*Microtus pennsylvanicus*
mink	*Mustela vison*
moose	*Alces alces*
mule deer	*Odocoileus hemionus*
muskrat	*Ondatra zibethicus*
northern bog lemming	*Synaptomys borealis*
northern flying squirrel	*Glaucomys sabrinus*
northern long-eared bat	*Myotis septentrionalis*
porcupine	*Erethizon dorsatum*

Common Name	*Scientific Name*
pygmy shrew	*Sorex hoyi*
red fox	*Vulpes vulpes*
red squirrel	*Tamiasciurus hudsonicus*
river otter	*Lutra canadensis*
silver-haired bat	*Lasionycteris noctivagans*
snowshoe hare	*Lepus americanus*
southern red-backed vole	*Clethrionomys gapperi*
striped skunk	*Mephitis mephitis*
water shrew	*Sorex palustris*
white-tailed deer	*Odocoileus virginianus*
wolverine	*Gulo gulo*
woodchuck	*Marmota monax*

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