Recommendations for the Acid Deposition Management Framework for the Oil Sands Region of North-Eastern Alberta[1]

1.0 Management Framework Overview

The NO_x-SO_2 Management Working Group (NSMWG) of the Cumulative Environmental Management Association (CEMA) was formed with the objective of developing and recommending a management plan (framework) for oxides of nitrogen (NO_X) and sulphur dioxide (SO_2) emissions as they relate to acid deposition, and subsequently eutrophication and ground level ozone. This document details the recommended management framework for acid deposition. Section 0 and Appendix 1 provide summaries of the management framework. Illustrative flowcharts are included as Appendix 2.

The framework will provide a system for managing emissions of oxides of nitrogen (NO_x) and sulphur dioxide (SO_2). The goal of the framework is to maintain the chemical characteristics of soils and lakes to avoid adverse effects on ecosystems, plants, or animals in the management area. Acidification management objectives, in support of this goal, are defined for soils and lakes in terms of limits in change to monitored and model-predicted soil and water chemistry. The purpose of the management objectives is to limit changes in soil and water chemistry to provide protection to biological systems.

The framework is based on the following conceptual acidifying emissions management approaches:

- reasonable, cost effective measures in the design and operation of projects to minimize acidifying emissions. This will include the evaluation of Best Available Demonstrated Technology[2] (BADT) in new project design, existing project expansions, and equipment replacement;
- monitoring and predictive modeling to verify that acidification beyond limits (management objectives) identified in the management framework is not occurring and has a low risk of occurring;
- emissions management to prevent further increase in emissions, or reduce existing emissions, if management objectives regarding acidification effects are not achieved; and

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[1] Final document as accepted byCEMA Members Feb. 25, 2994. Addendum I has been added as agreed to at the February 25, 2004 CEMA General Meeting.

[2] Best Available Demonstrated Technology has been defined as "emission control technology based on the maximum degree of emission reduction that has been shown to be practicably and economically achievable for a given source and type" in *Sulphur dioxide management in Alberta. The report of the SO2 management project team,* CASA 1997, p.19. See also Appendix 3.

- ongoing monitoring and research to validate or improve the ecological assumptions and data underlying the assessment of acidification risk.

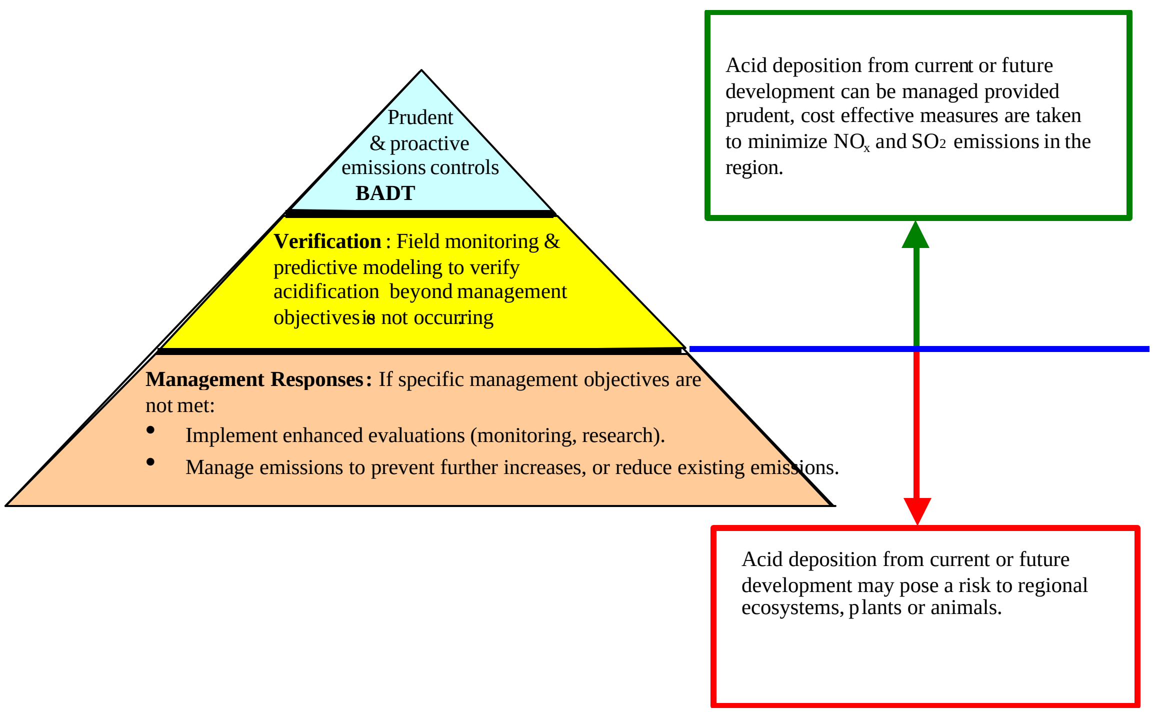
The management framework will be implemented in three stages, with immediate implementation of an initial framework. This initial framework will be revised after approximately two years to incorporate the results of short-term research projects, which will be completed at that time. These projects are focused on improving the reliability of acidification effects predictions by the models used for this purpose in the initial implementation of the framework. The framework will be further revised after approximately six years, when the results of several long-term research projects will be available. These projects focus on selection of better predictive models and collection of regional data inputs required by these models.

The emissions management responses to *acidification effects monitoring results* are consistent through all three stages. Management responses to *acidification effects predictions* change to reflect increased confidence in these predictions as model assumptions are validated, as better models are adopted, and as the input data base to the models improves.

The framework is intended, both to provide a basis for regulatory decisions on individual project approval applications, and to provide for periodic assessment of regional acidification risks. It is consistent with and complementary to the provincial framework for acid deposition management.

Figure 1 provides an overview of the conceptual approach of the management framework.

Figure 1: Conceptual Overview of Acid Deposition Management Framework



2.0 Existing Federal and Provincial Context

Federal and Provincial policies are in place to address acidifying emissions. These include the Canada-Wide Acid Rain Strategy and Alberta's framework for managing acid deposition. The CEMA Acid Deposition Management Framework is complementary and consistent with these existing policies.

The Canada-Wide Acid Rain Strategy (1998) is designed to prevent an acidification problem from developing in areas already identified as clean. This is embodied in the nationally adopted principle of "keeping clean areas clean". This principle supports use of best available technology to minimize acidifying emissions in regions where acidification problems do not currently exist. Canada has committed to a national sulphur dioxide (SO_2) emissions cap of 3.2 Mt/yr, thus, emissions from the oil sands region have some significance in Canada's international commitments.

Alberta's framework for addressing acidification is set out in, "Application of Critical, Target, and Monitoring Loads for the Evaluation and Management of Acid Deposition" (1999). This framework provides for assessment of acid deposition in relation to receptor sensitivity every five years. It uses the most recent historical emissions inventory and receptor sensitivity information available.

Key elements of the provincial system include:

- A management unit, or cell, of 1° latitude x 1° longitude with a 95-percentile level of protection applied within each cell.
- Three broad sensitivity categories based on surface- and sub-soil properties: sensitive, moderately sensitive, and not sensitive with critical loads of 0.25, 0.50, and 1.00 keq/ha/yr, respectively, based on studies with roughly similar soils in Europe.
- Monitoring, target, and critical loads, as follows,
    - Monitoring load - If average deposition within any cell exceeds a monitoring load, approximately 70% the critical load, a program is mandated to better define receptor sensitivity, confirm model-based estimates of deposition, and assess trends in emissions and deposition.
    - Target load - If average deposition within any cell exceeds the target load, approximately 90% of the critical load, the development of a regional emissions management plan for emissions reduction is required.
    - Critical load - If average deposition within any cell exceeds the critical load, then accelerated development of a regional emissions management plan for emissions reduction is required.

A regional acid deposition management framework is being recommended for the Athabasca oil sands area for the following reasons:

- The provincial framework is explicit in indicating that the target load may be applied as a benchmark but not as a regulatory objective in the context of assessing single or multiple projects.
- The provincial framework assesses average deposition within 1° latitude x 1° longitude cells using a broad-scale deposition model (RELAD) for western Canada. The Environmental Impact Assessments (EIAs) that serve as the basis for regulatory approval decisions in the region use a local/regional model (CALPUFF) that provides much greater spatial resolution regarding acid deposition.
- The provincial framework is based on sparse data regarding receptor sensitivity and has a low level of spatial resolution. There are only three broad sensitivity categories and lake sensitivity is accounted for by subsoil sensitivity. In contrast, soils in the oil sands region have been classified down to the level of soil series, with about 50 series in the region, and data are available to estimate series-specific critical loads. Lake-specific critical loads have been determined for 470 lakes in the oil sands region. Consequently, regional receptor sensitivity can be assessed with a much higher level of spatial resolution than used for the provincial framework.
- The provincial assessments use historical emissions inventories that may be five years or more out of date. The risk of exceeding target or critical loads may be low in the province generally, using this approach, due to the slow projected rate of increase in acidifying emissions. However, the risk is higher in the oil sands region with the rapid pace of development occurring at present and anticipated in the near future. Hence, there is greater need to estimate future acid deposition and cumulative environmental effects in making project approval decisions.

In response to the foregoing concerns, regional stakeholders, comprised of industry, regulators, ENGOs and Aboriginal organizations, agreed in 1998 to develop an acid deposition management framework for the oil sands region. The initiative was adopted by CEMA in 1999.

It is recognized that a five-year review of the provincial system is being conducted by Alberta Environment (AENV) with input from the Acid Deposition Advisory Group (ADAG). One aspect of this review is to make recommendations on the application of the provincial Acidifying Emissions system at the regional level. The development of the CEMA acidification framework is a specific response to the interests and issues associated with the Athabasca Oilsands region. Accordingly, direct application of this framework to other regions of the province may not be appropriate, although others may benefit from the learning's gained through development of the framework. Furthermore, the framework may benefit from recommendations and decisions arising from the provincial review and thus should incorporate such improvements where applicable.

3.0 Acid Deposition Management Framework for the Oil Sands Region of Northeastern Alberta

3.1 Goal of the Management Framework

Goal: Acid deposition from industrial activity will be managed to maintain the chemical characteristics of soils and lakes to avoid adverse effects on ecosystems, plants, or animals in the management area.

3.2 Management Objectives

3.2.1 Soil - Monitored

Objective: Limit the changes in soil chemistry as a result of anthropogenic activity in order to conserve the soil base cation pool.

- It is possible that some change in soil chemistry will occur from anthropogenic emissions. Any such change will be limited so that it is consistent with the management framework goal.
- Change in soil chemistry is defined as a statistically significant change in soil properties such as the base saturation or base cation: aluminum ratio for acid sensitive mineral soils (Mildred, Marguerite, and Firebag soil series) in near source monitored sites relative to distant reference monitored sites.
- If a possible trend is identified through regional monitoring, regulators will determine through an open and transparent scientific advisory process whether the trend is statistically significant or whether the monitoring program requires enhancement.
- If a need is identified, then a program of enhanced monitoring may be implemented.
- If a statistically significant trend is confirmed, then a further assessment of the ecological implications and significance of this change will be conducted by AENV, informed by science and involving stakeholders, to determine whether a red condition (Section 5.4) should be established.

3.2.2 Lakes – Monitored

Objective: Avoid change in water chemistry that will result in change to ecological receptors either in the short term or through a long-term trend.

- It is possible that some change in water chemistry will occur from anthropogenic emissions. Any such change will be limited so that it is consistent with the management framework goal.
- Change in water chemistry is defined as a statistically significant change in Acid Neutralizing Capacity (ANC) due to anthropogenic emissions.

- If a possible trend in chemistry, for example sulphate, nitrate, or ANC, is identified through regional monitoring, regulators will determine through an open and transparent scientific advisory process whether the trend is statistically significant or whether the monitoring program requires enhancement.
- If a need is identified, then a program of enhanced monitoring may be implemented.
- If a statistically significant trend is confirmed, then a further assessment of the ecological implications and significance of this change will be conducted by AENV, informed by science and involving stakeholders, to determine whether a red condition (Section 5.4) should be established.

3.2.3 Soils - Modeled

Objective: Limit model-predicted change in either base saturation or the ratio of base cations to aluminum (BC:Al) in mineral horizons of acid sensitive mineral soils located outside the full footprint of the surface oil sands mines to less than 50% of the difference between pre-industrial values and fixed effects levels (i.e. mid-case).

- Pre-industrial values are deemed to be values largely measured during the 1970's with some more recent supplementary measurements.
- Fixed effects levels are 10% for base saturation and a ratio of 2 for BC:Al.
- This model-based objective is less stringent than the monitoring-based objective because it is assumed that current models over-estimate acidification effects due to various conservative assumptions. As conservatism in the models is reduced, the model-based management objective may be revised to more closely reflect the monitoring management objective.

3.2.4 Lakes - Modeled

Objective: Maintain model-predicted acid deposition affecting regional lakes below critical loads.

- Initially, modeled critical loads will be based on the steady-state Henriksen model and will be determined based on ANC_{lim} = 75 µeq/l.
- A dynamic model may be used in the future to assess critical loads.

4.0 Management Area, Level of Protection and Management Unit

4.1 Management Area

The acid deposition management framework will be applied within a "management area" defined as the Regional Municipality of Wood Buffalo

(RMWB) with a focus on areas where predicted acid deposition is greater than the Provincial monitoring load for sensitive soils (0.17 keq H^+/ha-year)[3].

- The management area should be re-evaluated when the management system is periodically reviewed to consider changes to the boundaries (i.e. if the 0.17 keq H^+/ha-year deposition isopleth extends beyond the RMWB).

4.2 Level of Protection and Management Units

The Alberta acid deposition management framework uses a 1° longitude by 1° latitude grid of management units with a 95% level of protection. The NSMWG is endorsing the incorporation of "level of protection" into the management framework for application to model-predicted exceedances of management objectives. The level of protection concept defines the portion of the landscape on which exceedance of the acid deposition objectives is accepted. This does not imply that adverse biotic effects will occur.

The level of protection is chosen to reflect a balance between the potential risks to receptors from air emissions and the value of the related economic development. Management units have been typically established as uniform grids with a specified level of protection. While the NSMWG found resolving different views on appropriate management units and levels of protection challenging, there was broad consensus that ecosystems, plants and animals in important lakes and large land areas should not be put at risk from acid deposition.

The level of protection, described below, is proposed as an initial approach to the management framework. These criteria for levels of protection will be used in regulatory decisions regarding significant new acidifying emission sources (i.e. new projects or expansion of existing projects). The approach uses model-based predicted exceedances of management objectives. Key components of the approach are:

- An area exceeding a management objective of less than 100 km^2 within any 4 x 4 township floating[4] block in the management zone (RMWB) would not trigger emissions management beyond BADT under this framework.
- An area exceeding a management objective greater than the level of protection specified in the provincial framework within any floating management unit[5] would constrain future emissions. The proponent of the

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[3] The NSMWG evaluation is based on the Opti-Nexen Long Lake Project cumulative effects assessment (2001) case. The NSMWG expects that this cumulative effects case will be updated as needed to account for new scientific knowledge and new/revised information on industrial development in the region.

[4] A floating 4 x 4 township block is defined a block positioned anywhere along existing township lines within the management zone.

[5] A floating 1° x 1° block may be positioned anywhere along 10" subdivisions of latitude/longitude lines

new emission source will be required to find appropriate[6] regional offsets. The level of protection in the provincial framework is currently 95% of a 1° latitude by 1° longitude block. The provincial level of protection may be revised in a review of the provincial framework, scheduled for completion in 2004.

The NSMWG was not able to resolve how to manage between the limits noted above. The following process is one option for regulators to consider to address the situation:

- If the area exceeding a management objective is greater than 100 km^2 within a 4 x 4 township floating block in the management zone, but less than 5% of the provincial management unit, regulators will render a decision on the appropriate management response to be taken. Development of this decision is to be through an open and transparent process and could include convening an expert panel. The expert panel would advise regulators on the probable effect of the exceedance on receptors, ecological frameworks, and resources in the area of exceedance. AENV will consider the panel's advice when rendering a decision on appropriate management responses.

Revision of this approach for Stage 2 will be done under the guidance of AENV. A goal of the revision will be the selection of a single level of protection and associated management unit size.

NSMWG recommends that soil and lake areas of exceedance be integrated. If the critical load for a lake is exceeded, the geographic area of exceedance will be the watershed of the lake. Thus, a given area of land may be in exceedance either as a result of a lake-based or a soil-based exceedance. The total area of exceedance within a management unit will include both lake and soil-based exceedances.

NSMWG discussed but did not have time to resolve whether there is a need to provide a greater level of protection to small lakes. If there is a need to provide a greater level of protection for small lakes in Stage 2 this could be achieved by:

- weighting the aerial extent of small lakes and their watersheds by a factor of two or three, or
- establishing a list of selected lakes as independent "triggers", distinct from soil area exceedances.

[6] An appropriate offset is an offset that reduces the area of exceedance to less than the level of protection specified in the provincial framework.

5.0 Time to Effect Considerations

The NSMWG views the urgency and certainty of action to control acid deposition should reflect the time when adverse impacts may occur. That is, the "time-to-effect" should be incorporated into how management objectives are applied.

Major industrial acid deposition sources in the oil sands region of northeastern Alberta will have a finite lifespan. Accordingly, it is inappropriate to strictly compare acid deposition attributable to sources with finite, relatively short life spans with long-term or steady state receptor critical loads. The application of the management objectives should consider the time within which the criteria might be exceeded. The NSMWG proposes three response levels for implementing the objectives. The response levels have been given colour designations to simplify further discussions.

Green

- No exceedance of management objectives is indicated within 30 years of present by model[7] predictions.
- Monitoring results do not indicate any current exceedance of management objectives.

Yellow

- Modeling predicts exceedance of management objectives within 15-30 years of present.
- Monitoring results do not lead to a yellow condition.

Red

- Model predictions exceed management objectives within 15 years of present.
- Monitoring results confirm management objectives are being exceeded.

5.1 Management Response

The management response in the case of a yellow or red condition is intended to ensure there are no exceedances of management objectives beyond the level of protection area.

5.2 "*Green*" Condition

If there is no risk of current exceedance of the management objective indicated by monitoring, and no model-based prediction of exceedance within 30 years of the present, prudent development need not be constrained. Acidifying emissions should be minimized by practical, reasonable measures

- New projects and expansions should include BADT to limit acidifying emissions. BADT should be adopted throughout the life of such projects in evaluating options for capital equipment replacement and for project debottlenecking and expansions.

[7] Modeling incorporates historic emissions from 1970 on. Soil properties are initialized in 1970 at pre-industrial values as defined earlier. Predicted changes 15 and 30 years from present (2017 and 2032, respectively) are, in fact modelled changes over 47 years (1970 to 2017) and 62 years (1970 to 2034), respectively.

- Operators of existing projects should optimize facility performance towards continuous improvement in emissions controls.

5.3 "*Yellow*" Condition

5.3.1 Model Results

If model-based predictions indicate that management objectives will be exceeded within 15 to 30 years of present then greater prudence in managing emissions is needed. Management actions differ among Stages 1 to 3 due to an expectation of increased reliability in model-based estimates due to the research and monitoring actions that are prescribed. Management actions should include:

In Stage 1 (Section 6.2.1) the yellow response is same as green response:

- New projects and expansions should include BADT to limit acidifying emissions. BADT should be adopted throughout the life of such projects in evaluating options for capital equipment replacement and for project debottlenecking and expansions.
- Operators of existing projects should optimize facility performance towards continuous improvement in emissions controls.

In Stage 2 and Stage 3 (Sections 6.2.2 and 6.2.3) if a yellow condition is identified, the intent of the following is to have a no-net increase in acid deposition relevant to the affected area. Emissions will be managed to control increases in acid deposition in the affected area by:

- Emissions reduction from new sources through increased focus on use of enhanced emissions control technologies or other strategies (e.g. fuel switching), and
- Emissions reduction from existing sources when feasible (e.g. adopt BADT when expanding or for equipment replacements).

Should the above not be sufficient in controlling increases in deposition for the affected area, then proponents of new development, operators of existing facilities, and regulators would develop an action plan to manage increases in acidifying emissions consistent with the approach described in Section 5.4.

5.3.2 Monitoring Results

A monitored exceedance of the management objective for soils or lakes will be considered a 'red' condition, with the appropriate management response implemented as discussed under the red response. If no exceedance is identified, the management response would be implemented as discussed under the green response. Monitoring results do not lead to a yellow condition.

5.4 "*Red*" Condition

If monitoring observations demonstrate acidification management objectives have been exceeded in Stages 1, 2, and 3, or if model-based predictions in Stages 2 and 3 indicate that the management objectives will be exceeded within 15 years of present, then a reduction in emissions contributing significantly to the exceedance will be initiated.

- Significant contributing emitters would be defined as those sources individually contributing more than 10% and those regional sources cumulatively contributing at least 80% of the acid deposition in the affected area.
- An action plan would be developed within two years and implemented to reduce deposition to acceptable levels within an appropriate time period (e.g. 10 years) considering both the scale and urgency of reductions required, economic implications, and constraints to implementation of control technologies (e.g. engineering, procurement, capital turnover).
- The action plan would be developed in two phases:
    - Phase One of the plan would recommend acceptable deposition reduction and the timeline for implementation. Participants would include AENV, the Energy and Utilities Board (EUB), operators of major source contributors to the acidification problem, other regulatory bodies, as well as other interested stakeholders including ENGOs and Aboriginal organizations. An economic assessment of the potential management alternatives will be conducted to provide an indication of the impact of the proposed management options on industrial development in the Athabasca oil sands region.
    - Phase Two of the plan would determine the specific roles for each company in implementing the plan (including emission reductions, cost apportionment, timeframes to implement, etc.). Participants would include AENV, EUB and operators of major source contributors to the acidification problem.
    - A protocol for enabling entry of new or expanded industrial sources would need to be developed. Until such time as a protocol can be developed, proposed new industrial development with significant acidifying emissions would likely need to arrange for actions that will reduce emissions affecting deposition in the management unit.
- Regulators will select an acceptable deposition reduction in the event that stakeholders cannot reach agreement and will impose management actions in the event that emitters are unable to arrive at a timely solution (within two years) to achieve acceptable deposition reduction.

6.0 Implementation

Implementation of the acid deposition management framework will be staged over approximately the next six years. Implementation of successive stages will depend on a monitoring and research program, the results of which will provide increasing confidence regarding our ability to detect and predict changes caused by acidic deposition.

6.1 Monitoring and Research

The members of NSMWG, in preparing a management framework based on “predicted time to effect”, acknowledge that improvements are required both within the deposition models and within the models that predict chemical change in soils and lakes in response to acid deposition. Consequently, the management framework includes both a research component to improve the reliability of predicted responses and an enhanced monitoring program to ensure protection of receptors during the research development phase of the plan.

The monitoring and research program consists of:

- Continuation and enhancement of current Regional Aquatics Monitoring Program (RAMP) and Terrestrial Environmental Effects Monitoring (TEEM) monitoring programs to assess the field status of receptors with respect to acid inputs and to support the management framework.
- Continuation of Wood Buffalo Environmental Association (WBEA) and AENV wet and dry deposition monitoring programs. These data will be used to evaluate the deposition response to changes in regional emissions and to validate deposition calculations by models such as CALPUFF.
- Short term research projects to test, and revise as necessary, the assumptions and data inputs of the soil and water acidification models used in Stages 1 and 2 of the management framework. These models will be used to assess compliance with management objectives. Completion of these projects is required to move to Stage 2 of the management framework.
- Long-term research projects to select, calibrate, and support the implementation of dynamic models for predicting long-term acidification effects. These models will be used to assess compliance with management objectives in Stage 3 and beyond. Completion of these projects is required to move to Stage 3 of the management framework

Monitoring programs will consist of:

- *Acid deposition monitoring:* WBEA operates a regional air quality monitoring system that includes continuous and passive monitoring of SO_2 and NO_2 ambient air concentrations. The Fort McKay monitoring station is located in an area of highest regional acidic deposition but away from the immediate vicinity of urban and industrial sources of acidifying emission.

The Fort Chipewyan station is distant from industrial emission sources and provides regional background concentrations. These are supplemented with 14 passive SO_2 and NO_2 monitoring stations located across the regional acid deposition gradient. Precipitation chemistry is monitored at the Fort McKay station. This program will be maintained, and enhanced as required, in order to monitor temporal trends in regional acidic deposition.

- *Soil acidification monitoring:* The TEEM program which monitors acid deposition effects on sensitive mineral soils in exposed (near source) and distant (reference) sites will continue and will be modified as appropriate to assess compliance with the acid deposition management monitoring objectives. The monitoring program will be extended to include limited monitoring of organic soils and enhanced analysis of mineral soil samples to facilitate calibration and validation of soil models.
- *Lake acidification monitoring:* The RAMP program monitoring exposed (near source) lakes and distant (reference) lakes will continue and will be modified as required to assess compliance with acid deposition management monitoring objectives, to facilitate calibration and validation of aquatic models, and to understand long term natural variability in lake ANC. It may include monitoring of nitrate and sulphate concentrations in order to help determine whether changes in ANC are emissions-induced.

Short-term research projects to be implemented in 2003-2005 include:

- *Inflow to lakes*: Accurate information on annual water inflow to lakes is critical to reliable estimation of lake critical loads with the Henriksen model used in Stage 1 of the management framework. Stable isotope analysis will be used to determine annual inflow of both ground and surface water. The project will focus on acid sensitive lakes.
- *Organic buffering of lakes:* Organic buffering may contribute substantially to acid neutralizing capacity for a number of naturally low ANC (soft water) regional lakes. This project will examine the mechanism of organic buffering and enable a more reliable assessment of the response of such lakes to acid input than is presently possible.
- *Seasonal variability in lake ANC:* An accurate measurement of lake ANC is critically important to reliable estimation of lake critical loads with the Henriksen and other models. This project will examine seasonal changes in lake ANC to determine whether a single measurement in fall reliably represents year-round ANC.
- *Historical changes in lake chemistry:* Assessment of historical changes in lake biota and associated chemistry will be determined by examination of changes in diatom species assemblages in lake sediment cores.
- *Soil acidification and vegetation response:* A literature review will be conducted to assess the response of vegetation to the changes in soil pH, base saturation, and BC:Al associated with soil acidification. This

information will contribute to future review, and possible revision, of management objectives.

Long-term research projects to be implemented during 2004 – 2009 include:

- *dynamic acidification prediction models for soils and lakes:* Integrated assessment models that predict acidification effects for both soils and lakes will be evaluated to determine which, if any, is suitable for this region. The information on watershed properties (i.e. physical and chemical attributes) required as inputs to the model will be determined and a field program implemented to obtain the information. It is anticipated that obtaining the information will require the instrumentation and monitoring over several years of one or more small watersheds and their associated sensitive soils. In the event that an integrated model cannot be used separate models for lakes and soils will be selected:
  - *aquatic acidification prediction model:* The Henriksen model used in Stage 1 and 2 is a steady state model and does not support the time-to-effect concept chosen as the acidification management approach for the region. The available dynamic models will be assessed and the most suitable for this region selected. The information on watershed properties required as inputs to the model will be determined and a field program implemented to obtain the required information.
  - *soil acidification prediction model:* The available dynamic models, along with the Alberta Research Council model being used at present, will be assessed and the most suitable for this region selected. The information on soil properties required as inputs to the model will be determined and a field program implemented to obtain the required information.
- *soil acid response validation:* Field experimental programs involving application of nitrogen and sulphur to simulate various levels of potential acid input will be implemented. Soil response will be assessed and results used to calibrate and validate the selected model.

6.2 Staged Implementation of Management Framework

It is recommended that the management framework be implemented in stages as key research milestones are completed.

6.2.1 Stage 1 – Initial Framework

It is recommended that Stage 1 be implemented immediately and remain in place for approximately two years (projected 2003 – 2005). At that time it is anticipated that completion of the following studies (literature reviews and/or field studies) that will provide greater confidence in the reliability of model predictions of acidification effects:

- Determination of appropriate assumptions in models related to:

  - Inflow to lakes
  - Organic buffering of lakes
  - Seasonal changes in lake chemistry
  - Nitrogen and sulphur fate in terrestrial and aquatic ecosystems
  - Nitrogen deposition near emission sources
  - Deposition of base cations from local sources
  - Effective soil depth.
- Historical changes in lake chemistry.
- Soil acidification and vegetation response.

During Stage 1:

- Proponents of new projects or expansions of existing industrial operations may be required to assess the impacts of related acidifying emission increases on management units in the area relative to the NSMWG baseline case, if information on emissions sources has not been previously considered.
- Predicted exceedance of management objectives within 15 years of present (a "red" condition) would result in actions to minimize emission increases (i.e. yellow response):
  - New or expanded acidifying emissions sources would be required to adopt BADT. Proponents should be expected to demonstrate that they have assessed commercial control technologies to demonstrate that their approach achieves the highest performance levels practicable.
  - Accelerated completion of Stage 1 studies (see above) and implementation of Stage 2. Actions to reduce existing emissions would not be required until Stage 2 is implemented.
- Predicted exceedance of management objectives within 15 to 30 years of present (a "yellow" condition in subsequent stages) would result in a green response. Proponents of new or expanded projects would be required to achieve BADT standards as a minimum and operators of existing projects would be expected to optimize facility performance towards continuous improvement in emissions.

6.2.2 Stage 2 – Final Framework

It is recommended that the acid deposition management framework be fully implemented by 2006. Incorporating results of literature reviews or short-term studies completed in Stage 1, NSMWG will reassess compliance with management objectives in the management area based on an assessment of "baseline" (existing plus approved projects) acidifying emission sources in the region.

Milestones to be completed during Stage 2 before moving to Stage 3 include:

- Selection, refinement, and calibration of dynamic acidification prediction models for soils and lakes.
- Soil acid response validation.

Elements of the final framework would include:

- NSMWG or AENV evaluation of the "baseline" case status of management units in the region.
- Proponents of new projects or expansions of existing industrial operations may be required to assess the impacts of related acidifying emission increases on management units in the area relative to the NSMWG baseline case as part of EIA preparation.
- The management objectives, management units and management response actions as defined in Sections 3.0, 4.0, and 5.0 above would be fully implemented on the basis of both field monitoring and modeling results.

6.2.3 Stage 3 – First Framework Revision

It is recommended that the framework would be reviewed and revised periodically. The first review and revision would be conducted during 2009 to 2011. Elements of the review and revision process would include:

- Updating of models and assessment tools, incorporating relevant research and monitoring results.
- Review of management framework objectives and other elements for consistency with new information and development of appropriate revisions.
- Alberta Environment or regional multi-stakeholder group assessment of the status of management units in the region based on then existing plus approved sources.

6.3 Economic Assessment

Selection of BADT for a specific project involves an economic assessment (Appendix 3). If emissions restrictions or reductions are indicated, the economic implications will be assessed on a case-specific basis (Sections 5.3 and 5.4).

7.0 Appendices

Appendices 1 (Management Framework Summary) and 2 (Emissions Management Flowchart) provide a table and a flowchart to assist the reader in understanding the key features of the management framework recommendations. The information is simplified for clarity. If there are any omissions or inconsistencies with the text of Sections 1-6, the text should be considered authoritative.

Appendix 3 is a description of Best Available Demonstrated Technology (BADT).

Appendix 4 is Glossary of Terminology.

Addendum 1 provides background information on air emissions, environmental monitoring, receptor indicators, and deposition.

Appendix 1: Management Framework Summary[8]

Stage 1 (2003-2005)

Research during Stage 1 – results needed to implement Stage 2

- Determine appropriate model assumptions related to inflow to lakes, organic buffering of lakes, & seasonal variability of lake chemistry.
- Determine historical changes in chemistry of sensitive lakes and vegetation response to soil acidification.

Status	Soils Criteria		Lakes Criteria		Management Action[9]
	Monitoring	Modeling	Monitoring	Modeling	
Green	No statistically and environmentally significant trends related to industry emissions in base saturation or BC:Al	Predicted change in base saturation and BC:Al within 30 years is within management objective limits[10]	No statistically and environmentally significant trends related to industry emissions in ANC	No critical load exceedances	BADT for emission controls on new sources and expansions. Continuous improvement of existing sources
Yellow	No yellow condition	Predicted change greater than management objective within 15-30 years	No yellow condition	No yellow condition	BADT for emission controls on new sources and expansions. Continuous improvement of existing sources.

8 This summary has been simplified for clarity, for a complete description of the management framework see Section 5.

9 Soil and Lake areas of exceedance will be summed within each floating management unit (except where they overlap). Management actions apply when the summed exceedance area is greater than the selected level of protection. For details regarding level of protection is text in the main body of the document.

10 The management objective limit is a reduction of 50% of the difference between pre-industrial values and fixed effects levels.

Stage 1 (2003-2005)					
Research during Stage 1 – results needed to implement Stage 2 • Determine appropriate model assumptions related to inflow to lakes, organic buffering of lakes, & seasonal variability of lake chemistry. • Determine historical changes in chemistry of sensitive lakes and vegetation response to soil acidification.					
Status	**Soils Criteria**		**Lakes Criteria**		**Management Action[9]**
	Monitoring	**Modeling**	**Monitoring**	**Modeling**	
Red	Statistically and environmentally significant trends related to industry emissions in base saturation or BC:Al	No red condition due to model limitations and low short term acidification risk	Critical load exceedance	No red condition due to model limitations and low short term acidification risk	Emissions reduction according to plan developed by stakeholders, if possible, or by regulators within 10 years.

Stage 2 (2006-2009)					
Research during Stages 1 and 2 – results needed to implement Stage 3 • Selection, refinement, & calibration of dynamic soil and lake models • Field programs to validate soil acid response					
Status	**Soils Criteria**		**Lakes Criteria**		**Management Action[11]**
	Monitoring	**Modeling**	**Monitoring**	**Modeling**	

[11] Soil and Lake areas of exceedance will be summed within each floating management unit (except where they overlap). Management actions apply when the summed exceedance area is greater than the selected level of protection. For details regarding level of protection is text in the main body of the document.

Stage 2 (2006-2009)

Research during Stages 1 and 2 – results needed to implement Stage 3

- Selection, refinement, & calibration of dynamic soil and lake models
- Field programs to validate soil acid response

Status	Soils Criteria		Lakes Criteria		Management Action[11]
	Monitoring	Modeling	Monitoring	Modeling	
Green	No statistically and environmentally significant trends, related to industry emissions, in base saturation or BC:Al	Predicted change in base saturation and BC:Al within 30 years is within management objective limits[12]	No statistically and environmentally significant trends related to industry emissions in ANC	No critical load exceedances	BADT for emission controls on new sources and expansions. Continuous improvement of existing sources.
Yellow	No yellow condition	Predicted change greater then management objective limits within 15-30 years	No yellow condition	No yellow condition	Action plan to control emissions increase. Intent is no-net increase in deposition for affected area.
Red	Statistically and environmentally significant trends, related to industry emissions, in base saturation or BC:Al	Predicted change greater then management objective limits within 15 years	Statistically and environmentally significant trends, related to industry emissions, in ANC	Critical Load Exceedance	Emissions reduction according to plan developed by stakeholders, if possible, or by regulators within 10 years

[12] The management objective limit is a reduction of 50% of the difference between pre-industrial values and fixed effect levels.

Stage 3 (2009-2011)					
Status	**Soils Criteria**		**Lakes Criteria**		**Management Action**[13]
	Monitoring	**Modeling**	**Monitoring**	**Modeling**	
Green	No statistically and environmentally significant trends, related to industry emissions, in base saturation or BC:Al	Predicted change in base saturation and BC:Al within 30 years is within management objective limits[14]	No statistically and environmentally significant trends, related to industry emissions, in ANC	Predicted change in ANC within 30 years is within management objective limits	BADT for emission controls on new sources or expansions. Continuous improvement of existing sources.
Yellow	No yellow condition	Predicted change greater then management objective limits within 15-30 years	No yellow condition	Predicted change in ANC within 15 to 30 years is greater than management objective limits	Action plan to control emissions increase. Intent is no-net increase in deposition for affected area.
Red	Statistically and environmentally significant trends, related to industry emissions, in base saturation or BC:Al	Predicted change greater then management objective limits within 15 years	Statistically and environmentally significant trends, related to industry emissions, in ANC	Predicted change in ANC within 15 years is greater than management objective limits	Emissions reduction according to plan developed by stakeholders, if possible, or by regulators within 10 years

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[13] Soil and Lake areas of exceedance will be summed within each floating management unit (except where they overlap). Management actions apply when the summed exceedance area is greater than the selected level of protection. For details regarding level of protection see text in the main body of the document.

[14] The management objective limit is a reduction of 50% of the difference between pre-industrial values and fixed effects levels (fixed effects levels are 10% for base saturation and a ration of 2 for BC:Al).

Appendix 2: Emissions Management Flowcharts

Chart 1: Stage 1 through 3 management responses to soil and water monitoring results

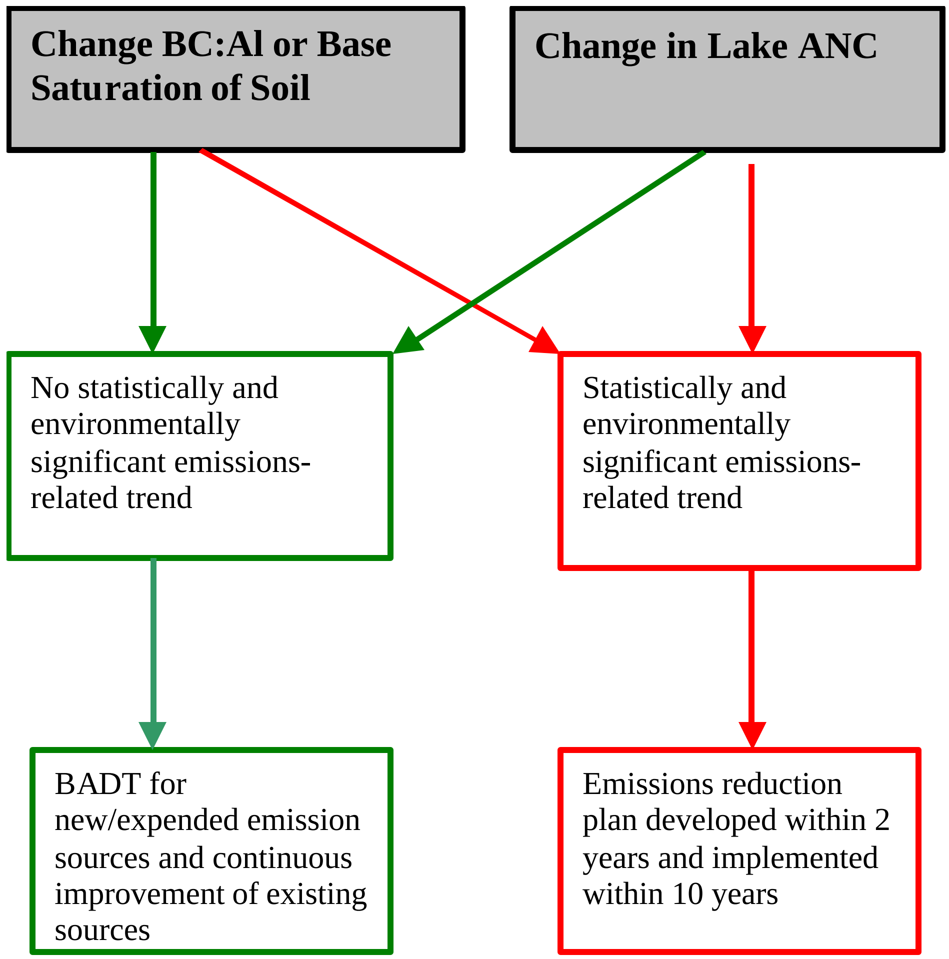
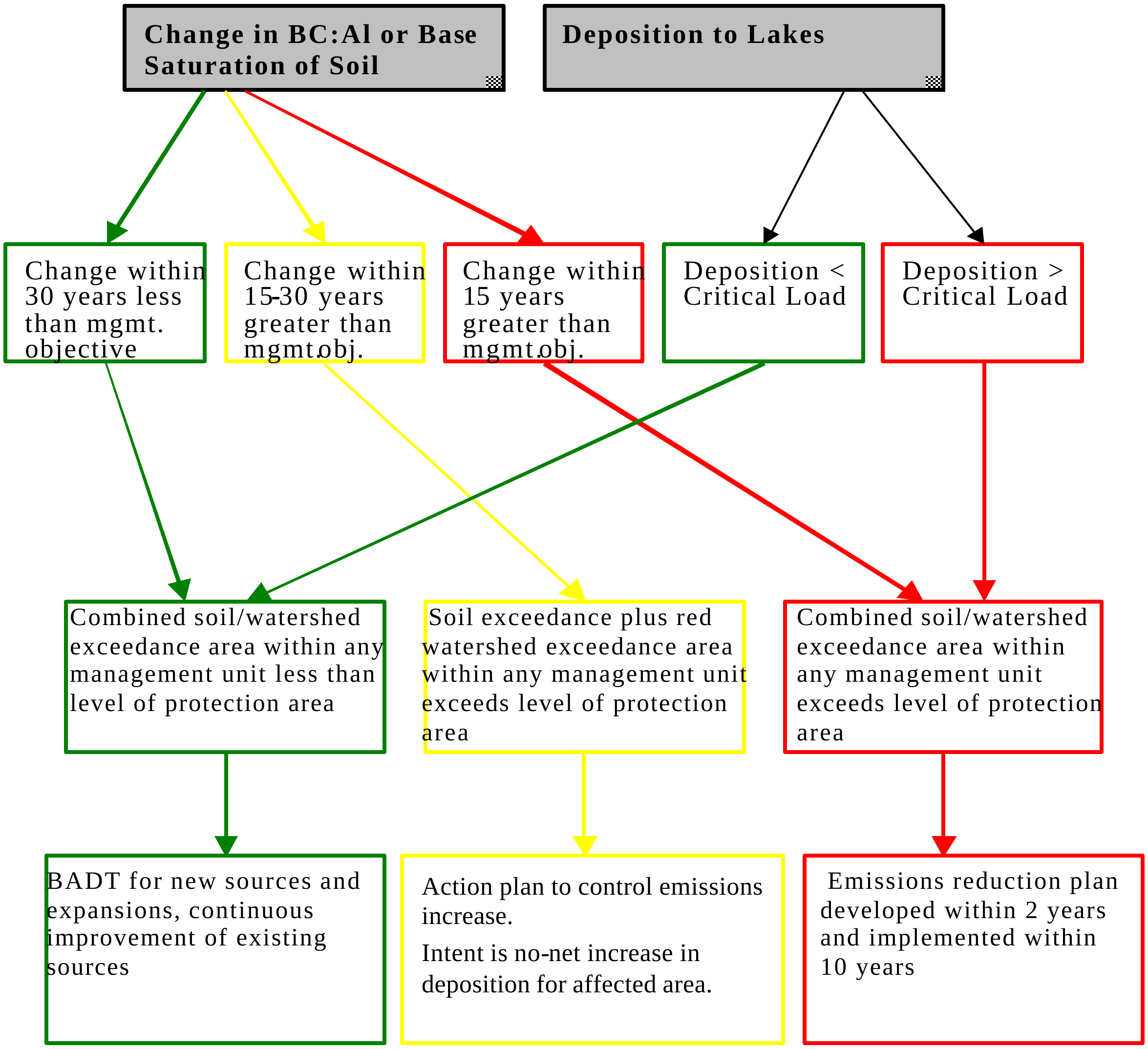


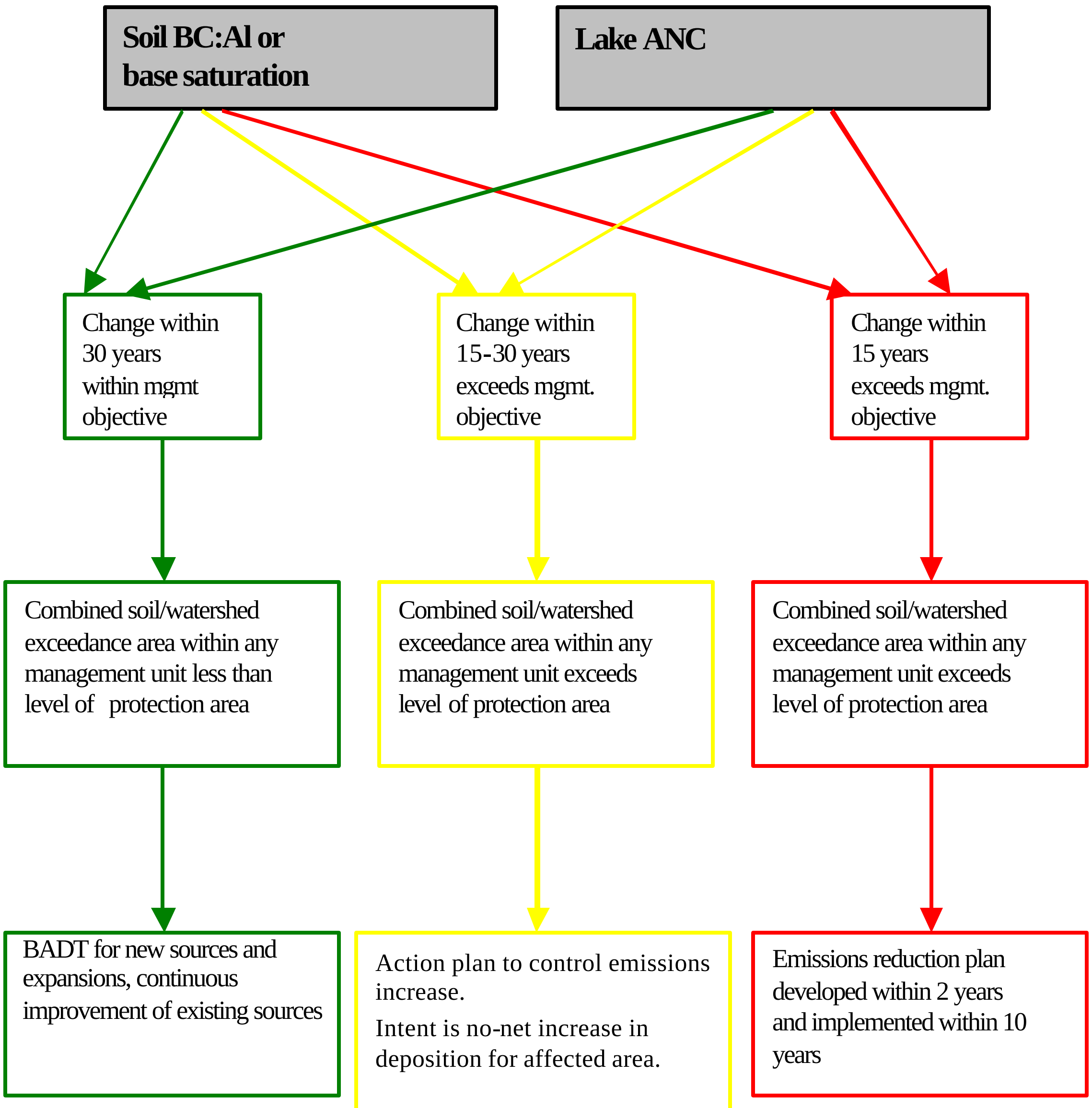
Chart 2: Stage 2 emissions management responses to model predictions (during Stage 1 there are no emissions management responses to model predictions)



Note 1: The management limit for soil BC:Al and base saturation is 50% of the difference between pre-industrial values and BC:Al =2 and base saturation = 10%.

Note 2: If a lake is in exceedance, the exceedance is extrapolated to the watershed. Overlapping soil-based and watershed-based exceedances are only counted once in summing of soil/watershed exceedance area.

Chart 3: Stage 3 emissions management responses to model predictions



Note 1: The management limit for soil BC:Al and base saturation is 50% of the difference between pre-industrial values and BC:Al =2 and base saturation = 10%.

Note 2: If a lake is in exceedance, the exceedance is extrapolated to the watershed. Overlapping soil-based and watershed-based exceedances are only counted once in summing of soil/watershed exceedance area.

Appendix 3: Best Available Demonstrated Technology (BADT)

Ongoing technological innovation and enhancement results in a continually evolving understanding of BADT. Three sources of information provide a starting point for consideration of minimum standards of emission control technology for oil sand operations:

- Source emission standards outlined in Alberta's Air Toxics Management Program
- Canadian Council of Ministers of the Environment (CCME) Guidelines and Codes of Practice
- The EUB sulphur recovery guidelines that set the percent of sulphur expected to be recovered from various facilities. The technology to be used for sulphur recovery is not specified.

In addition, Guidelines and Codes of Practice from other jurisdictions can be considered.

Source Emission Standards (Air Toxics Management Program in Alberta, 1998, p. 3, 4)

Alberta has a number of key policies that guide the management of industrial air toxics. These are as follows:

- Industrial facilities must be designed and operated in accordance with the pollution prevention principle;
- Emissions from each industrial source must be controlled using:
  - the best available control technology for carcinogens; and
  - best available demonstrated technology that is economically achievable for other air toxics.

To ensure that the quality of the ambient air is maintained within ambient guidelines, emissions of various air contaminants must be restricted. This is done through regulating these emissions by legislation and management using an approval system. Under the approval system, regulated industries and facilities are allowed to emit limited amounts of various air contaminants. These emissions limits or source emission standards are specified in approvals issued to specific facilities.

The determination of air toxics source emission standards for any given facility requesting or applying for an approval is dependent on:

- The existing air quality;
- Ambient air quality guidelines or prescribed ambient levels;
- Source emission standards based on the:
  - Nature of the air contaminant, that is, carcinogenic or not,
  - Nature of the process industry,
  - Air pollution technology that is determined to be the best available demonstrated, or best available

- The results of air dispersion modeling which takes into account the
  - Local meteorology and terrain, and surrounding emission sources.

CCME Guidelines and Codes of Practice

Examples of current CCME guidelines that would apply are as follows:

- Use of low NO_x technology for turbines and boilers having regard for the Canadian Council of Ministers of the Environment (CCME) *National Emissions Guidelines for Stationary Combustion Turbines* and CCME *National Emissions Guideline for Commercial/Industrial Boilers and Heaters*;
- Fugitive emissions control program to detect, measure and control emissions and odours from equipment leaks having regard for the CCME *Code of Practice for Measurement and Control of Fugitive VOC Emissions*;
- Use of technology to meet or do better than CCME *Environmental Guidelines for Controlling Emissions of Volatile Organic Compounds from Aboveground Storage Tanks* and Alberta Environment *Guidelines for Secondary Containment for Aboveground Storage Tanks*

EUB Sulphur Recovery Guidelines

The sulphur recovery guidelines for new sour gas plants set out in *IL 88-13: Sulphur Recovery Guidelines—Gas Processing Operations* and as described in Table 1 have been adopted as the basis for sulphur recovery and emissions reduction from sour gas processing plants, sour gas emissions at other types of upstream petroleum industry operations, and acid gas streams produced in downstream petroleum industry facilities, including refineries and heavy oil upgraders.

Table 1. Alberta Sulphur Recovery Guidelines

	% of sulphur inlet that must be recovered	
Sulphur inlet rate (tonnes/day)	**Design sulphur recovery criteria**	**Calendar quarter-year sulphur recovery guidelines**
1-5	70	69.7
> 5-10	90	89.7
> 10-50	96.2	95.9
> 50-2000	98.5 - 98.8[15]	98.2 – 98.5[16]
> 2000	99.8	99.5

[15] Recovery = $98.18185 + 0.187259\log_{10}$(sulphur inlet rate).

[16] Calendar quarter-year recovery = $97.88185 + 0.187259\log_{10}$(sulphur inlet rate).

Appendix 4: Glossary

Acid deposition	The process by which emissions (of SO_2 and NO_x) are transformed in the air into acid compounds which are then deposited to the earth (i.e. to soils, plants & surface waters) in either wet (i.e. acid rain) or dry forms.
Acidification	The process by which a receptor (soil, water) becomes more acidic, through deposition of acidic compounds, or through the loss of substances, which are able to act as buffers.
Acid Neutralizing Capacity	A measure of an aquatic system's ability to neutralize acid (ANC)input. This measurement includes inorganic, organic, and metal buffering processes, and is a more integrated measure of buffering capacity than measurement of calcium carbonate concentration alone.
Base Cation (BC)	A substance that is able to substitute for a hydrogen ion (acid), thus reducing the acidity of the soil or water body. Calcium, magnesium, potassium and sodium are the predominant base cations. Greater concentrations of base cations in soil or water increase the buffering capacity of the soil or water, making the receptor less sensitive to chemical change due to acid deposition.
Base Saturation	The proportion of the cation exchange complex occupied by base cations, as opposed to hydrogen and aluminum ions.
BC:Al	The ratio of base cations to aluminum.
Best Available Demonstrated Technology	BADT implies an emission control technology based on the maximum degree of emission reduction that has been shown to be practicably and economically achievable for a given source and type.
Buffering Capacity	The ability for water to neutralize acidity due to the concentration of basic anions in water.
Cation	A positively charge ion such as calcium (Ca^{2+}) and sodium (Na^{+})
Continuous Improvement	Remedial and preventative actions by existing facilities to reduce acidifying emissions to the extent practicable through ongoing operational enhancements and the evaluation of BADT during upgrades carried out in the course of normal capital stock turnover.
Critical Load	The highest load of acid deposition that will not cause chemical changes leading to long-term, harmful effects on the most sensitive ecological systems (as defined in the provincial framework).

Emissions Inventory	A database containing the emissions of the substances of interest from the area of interest. Emissions inventories may also contain information regarding the source of the emissions (urban, industrial, etc.), the height at which the emissions enter the atmosphere (e.g. a ground-level, or from the top of a tall stack), or other information.
Environmental Management Objective	Refers to the maximum ambient levels of emission substances that are negotiated by stakeholders, incorporating social, economic, and environmental considerations with the long-term goal of achieving environmental capacity guidelines. A level below which acid deposition (or concentrations in the case of an ambient air quality objective) is to be maintained. Should deposition occur outside of the limits defined by the Environmental Management Objectives, management actions are taken to reduce acidifying emissions.
Equivalent eq [includes kiloequivalent (keq) and milliequivalent (meq)]	A term that expresses the amount of a substance in terms of equivalencey to another. For acidification, amounts are expressed in terms of their equivalency to hydrogen (H+), which is an expression of their potential to cause acidification. For alkalinity, amounts may be expressed in terms of their equivalency to calcium carbonate, an expression of their ability to neutralize acidity. “Kilo” is the SI unit for 1000, “milli” the SI unit for one-thousandth.
Eutrophic (eutrophication)	A system rich in nutrients. Eutrophication is the process of making a system richer in nutrients, often beyond the ability of the system to assimilate and utilize the added nutrient load.
Exceedance	A term used to describe the deposition (or concentration) above a defined value. In the case of acid deposition management, exceedances of management objectives are defined, with actions specified when deposition exceeds each of these values.
Henriksen Model	A model for calculating critical loads based on steady state water chemistry.
Mineral Soil	A soil system derived from mineral origins. Gravel, sand, silt, and clay are the primary components of a mineral soil. Organic material forms a smaller (less than 30%) proportion of the soil.

Monitoring Load	A level of acidic atmospheric deposition assigned to a grid cell that leads to the initiations of studies of receptor sensitivity and monitoring of acid deposition to confirm or adjust the critical load applied to that grid cell, and to assess the accuracy of deposition model predictions (as defined in the provincial framework).
NOx	A class of compounds composed of nitrogen and oxygen (e.g. NO, NO2, N2O) generally referred to as oxides of nitrogen.
Organic Soil	A soil derived primarily from vegetation debris (litter, deadand decaying plant material). Generally associated with wetlands, where a thick layer of organic material provides the substrate for plant growth, and generally governs the chemical and physical properties of the soil. Organic soils contain 30% or higher organic matter content.
pH	A measure of the activity of hydrogen ions in a solution,which determines the acidity or alkalinity of that solution. A difference of one unit in pH (e.g. 6.0 and 7.0) represents a 10-fold difference in activity.
Potential Acid Input (PAI)	The difference between deposited nitrogen/sulphur and base cations, expressed in H^+ equivalents.
Receptor	Any biological or physical component of the ecosystem that receives acid deposition. Receptors include soils, vegetation, and aquatic systems.
RELAD	The Regional Lagrangian Acid Deposition model. A mathematical model that estimates the amount of acid deposition based upon inputs containing meteorological data, emissions inventory data, and estimates of atmospheric chemical reactions.
Saturation	The concentration at which a substance can no longer (a) dissolve into the solution, or (b) be assimilated by a system. An example of (a) is base saturation, where 100% base saturation indicates that the maximum amount of base cations is present in the soil. An example of (b) is nitrogen-saturation, where additional inputs of nitrogen (from the air) can not be assimilated by vegetation, leading to increased nitrogen content in the soil, and in the streams and rivers leaving the watershed.
SO_2 (Sulphur Dioxide)	SO_2 is a gas formed in the combustion of hydrocarbons. SO_2 is involved in the formation of acid gases in the air and can also be directly deposited as elemental sulphur.

Target Load	The maximum level of acidic atmospheric deposition that affords long-term protection from adverse ecological consequences, and that is practically and politically achievable (as defined in the provincial framework).
Time to Effect	The time to effect concept is the time it would take the combined acidifying emissions in the region to potentially change the chemistry of the soils or waterbodies and reduce their buffering capacity to that reflected in the environmental management objectives.

Addendum I

CEMA Acid Deposition Management Framework Recommendations for the Oil Sands Region of North-eastern Alberta

CEMA adopted the NO_x/SO_2 Management Working Group's (NSMWG) recommended framework for acid deposition management for the oil sands region of north-eastern Alberta on February 25, 2004. In response to a request by CEMA stakeholders, the NSMWG has prepared this addendum that provides background information on air emissions, environmental monitoring, receptor indicators, and deposition.

The framework recommended by CEMA focuses on providing a structure for managing acidification issues related to emissions of oxides of nitrogen (NO_x) and sulphur dioxide (SO_2) emissions. This framework needs to be viewed as contributing one piece to a much larger environmental management picture that is under development by CEMA and other organizations operating in the oil sands region of north-eastern Alberta.

The framework proposed by CEMA includes three time dependant stages, each described in the management framework recommendation package. During each of these stages further research and monitoring work will occur in order to allow refinement and enhancement of the framework.

The focus of the goal and objectives of the framework is to manage acid deposition from industrial activity to maintain the chemical characteristics of soils and lakes to avoid adverse effects on ecosystems, plants or animals in the management area. The NSMWG included in the framework a research program that will further improve the understanding of acidification risks to ecological receptors. This information will be incorporated when available and where appropriate in Stages 2 and 3.

The current management framework does not address or identify specific biological receptors that would provide an indication of environmental effects; rather the framework seeks to protect the chemical characteristics of soil and water, which provide an early and proactive warning for biological receptors. The framework does not address the potential effects of air contaminants on the potential acidification of the flowing waters (i.e. streams and rivers) of the oil sands region because these are not considered to be at risk.

As described in section 4.2 of the framework document, elements of the "level of protection" and "management unit" recommendations were not fully resolved by the NSMWG. A process for resolution has been recommended to the implementing regulatory agency, should the need arise.

Emissions

The acid deposition management framework deals with NO_x and SO_2 emissions; it does not address other air contaminants in the Athabasca oil sands region. Other air contaminants in the region include ozone, particulate matter, total reduced sulphur and hydrogen sulphide (TRS), carbon monoxide, volatile organic compounds (VOC), and greenhouse gas emissions (carbon dioxide and methane). Table 1 provides a summary of air emissions based on the OPTI-Nexen Long Lake Project[17] environmental impact assessment.

Table 1: Summary of Emissions in the Oil Sands Region

(OPTI Canada 2000, pg. E4-11)

	Emission Rates (t/cd)					
	SO_2	**NO_x**	**CO**	**$PM_{2.5}$**	**VOC**	**TRS**
Baseline Case[18]	282.43	182.60	168.17	17.88	315.32	4.35
Cumulative Effects Assessment Case[19]	358.78	334.10	228.04	25.02	641.32	7.45

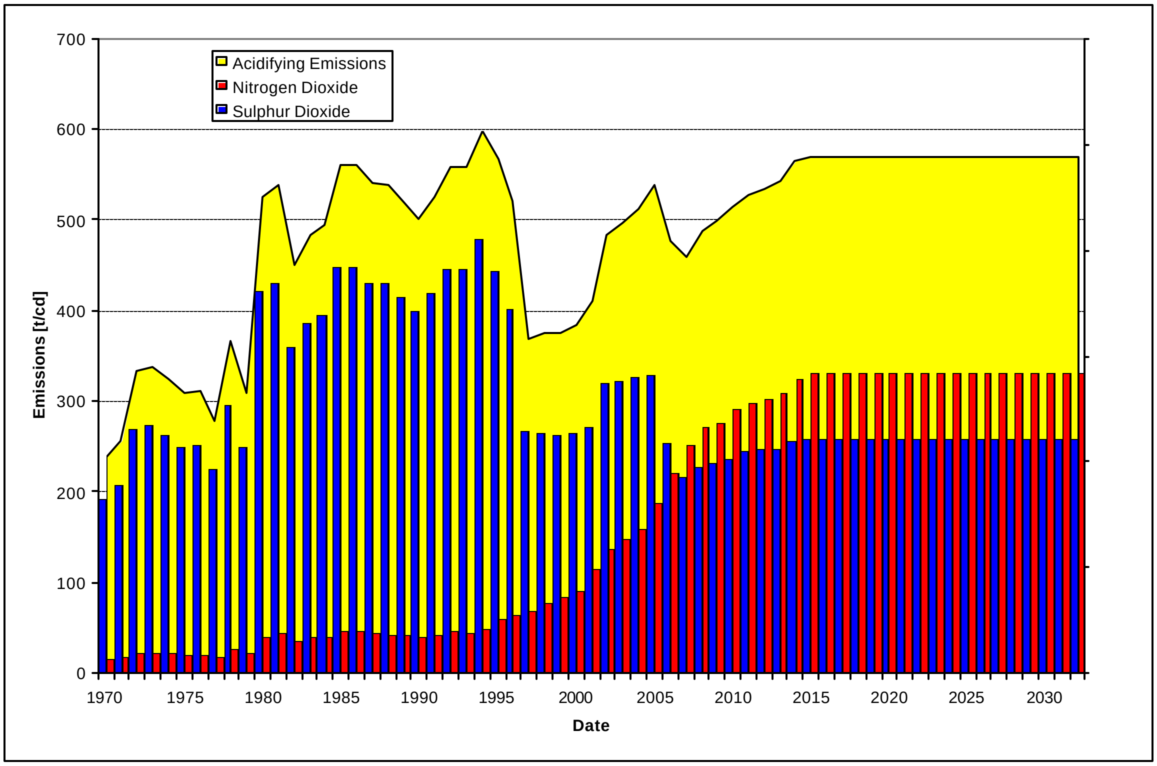
The NSMWG based its framework on extensive literature and research including an evaluation of historic, present, and future acidifying emissions. Figure 1 shows estimated emissions of sulphur dioxide, nitrogen dioxide, and acidifying emissions from 1970 to 2030. Figure 1 represents estimated annual emissions of sulphur dioxide, oxides of nitrogen and acidifying emissions from combined sources in the oil sands area. This figure does not take into account reductions in nitrogen dioxide emission that will occur with implementation of US EPA Tier IV standards for off-road diesel engines.

[17] The NSMWG evaluation for the management area of the framework is based on the OPTI-Nexen Long Lake Project cumulative effects assessment case.

[18] The baseline case includes emissions from existing and approved industrial emission sources.

[19] The CEA case includes existing, approved, and planned regional emission sources.

Figure 2: Annual trends of acidifying emissions in the oil sands region



(Golder 2003a, Report B, p. 21)

Environmental Monitoring Programs

Air Quality Monitoring

The Wood Buffalo Environmental Association (WBEA) conducts air monitoring. The WBEA network consists of thirteen air quality monitoring stations, which continuously monitor air emissions and parameters including:

- sulphur dioxide
- oxides of nitrogen
- hydrocarbons
- total reduced sulphur compounds
- ozone
- carbon monoxide
- particulates
- meteorology.

Stations are located in the communities of Fort McKay and Fort Chipewyan, in the City of Fort McMurray and on or near the plant sites of Syncrude Canada Ltd., Suncor Energy Inc. and Albian Sands Energy Inc. (Figure 3). Ten passive monitors collect average concentrations of sulphur dioxide, nitrogen dioxide and ozone at various locations in the region away from urban centers (Figure 2). Four operating approval-based passive stations are located at the Petro-Canada McKay River project site to measure average concentrations of sulphur dioxide, nitrogen dioxide, ozone and hydrogen sulphide.

WBEA has been operating for five years. The ambient air monitoring network collects data 24 hours/day, 365 days a year. WBEA's air monitoring results are available on the WBEA website and the CASA data website. Specific data reports can be generated for:

- average and maximum summary reports
- air quality index
- long-term air quality trends
- compliance and exceedance reports
- air quality maps
- hourly, daily, and monthly average data reports
- data availability and instrument operation reports
- submitted data files.

Annual summaries are also available from WBEA. Although air quality monitoring information can aid in the understanding of the acid deposition issue, the data does not provide direct information on the environmental effects of acid deposition. Terrestrial and aquatics monitoring programs are in place to determine effects of acid deposition. The NSMWG is not using odour as a human ecological indicator.

Figure 3: WBEA Passive Monitoring Stations (WBEA 2002, p. 57)

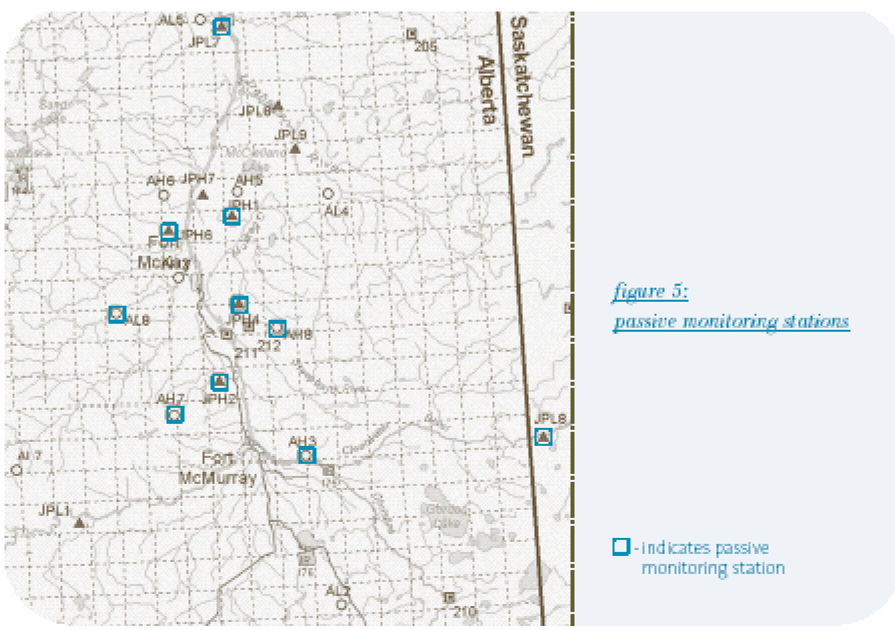


Figure 4: WBEA Air Monitoring Stations (WBEA 2002, p. 44)

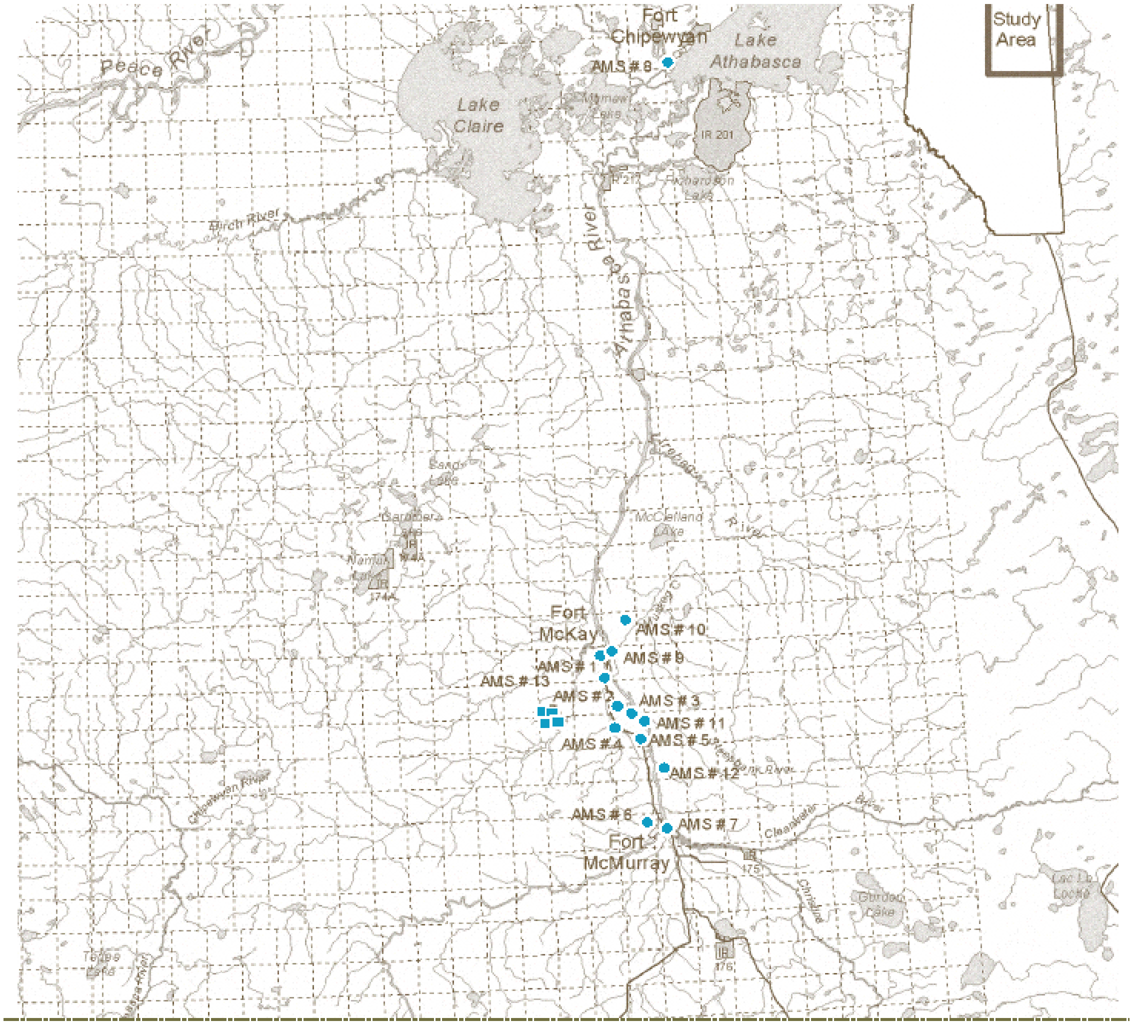


figure 1: regional distribution of wbea air monitoring stations in the wood buffalo regions

● AIR MONITORING STATIONS	■ MCKAY RIVER PASSIVES	DATE FEBRUARY 2003	ANALYST KP
CLIENT WOOD BUFFALO ENVIRONMENTAL ASSOCIATION		JOB NO. CE02631	
PROJECT TEEM MONITORING PROGRAMS		GIS FILE wood_buff_teem.apr	

20 0 20 40 60 80

WBEA ANNUAL REPORT 2002
44.

Terrestrial Monitoring

WBEA's Terrestrial Environmental Effects Monitoring (TEEM) acidification monitoring program[20] involves monitoring of permanent plots situated on sensitive mineral soils with Jack Pine forest communities, over a gradient of deposition and exposure ranging from high to low. These plots are monitored for soil properties that are known to change in response to excess acidic deposition. These properties include the ratio of base cations to aluminum, base saturation, and pH. Baseline conditions on these plots were established in 1998. At that time there were no differences between the high and low exposure plots, suggesting that there had been no changes to soil chemistry as a result of acid deposition. Near sites will be sampled every three years, distant sites are sampled at 6-year intervals. The next assessment of all sites will occur in 2004.

Dr. David Schindler conducted an analysis of acidification trends for Alberta lakes in 1996. These included several acid sensitive lakes in north-eastern Alberta. He concluded that "…long term records, current HCO3 to Ca + Mg ratios and one paleoecological study showed no evidence of anthropogenic acidification of lakes in Alberta"[21].

Water Monitoring

The Regional Aquatics Monitoring Program (RAMP) established a long-term acid sensitive lakes acidification monitoring network in 1999. The main objective of the network is to monitor the water chemistry of acid sensitive lakes in north-eastern Alberta, with changes in water chemistry serving as early warning indicators of potential effects caused by acidic deposition. Lakes in the network are monitored annually for field parameters, acidity-related parameters, carbon parameters, major ions, nutrients and productivity indicators (Golder 2003b). Forty-nine lakes were sampled in 2002. This included 39 lakes in the Oil Sands Region, five lakes in the Caribou Mountains and five lakes on the Canadian Shield. Acidity-related variables (pH, alkalinity) generally showed no indication of changes signaling acidification in 2002 compared to data from previous years (Golder 2003b).

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20 The full report on this program is "Monitoring the long-term effects of acid emission on soil and vegetation in jack pine and aspen forest of northeast Alberta: 1998 annual report". Submitted to the Wood Buffalo Environmental Association by AMEC Earth & Environmental. November 2000, 92 pp. + appendices.

21 This report is "Section 2. The response of aquatic ecosystems in Alberta to acidifying deposition. D.W. Schindler. IN Scientific Appendix to the Final Report of the Target Load Subgroup on Critical and Target Loading in Alberta. May 1996".

Ecological Indicators

Provincial Context

The Alberta Acidification provincial framework[22] is based on monitoring, target, and critical loads. Target and critical loads are tied to changes in chemical properties. If a critical load is exceed over the long-term this may lead to ecological effects. If deposition rates exceed the natural ability of soils and water to "take up" deposition, this may cause a change in chemical characteristics of sensitive water bodies or soils.

For example, from an aquatics perspective a pH of 6.0 is considered to be the ecological effects level for the most sensitive aquatic species. If a critical load is exceeded, a decrease in pH, changes in ion chemistry and decreased ANC and carbonate buffering of lakes will result. A large scientific literature base is available corroborating the pH 6 level as protective for most aquatic organisms. No provincial guidelines exist at the present time for the changes in ion chemistry expected from acid deposition. The NSMWG set the management objectives based on changes in chemical parameters through a thorough review of the literature and available data.

Link Between Chemical Indicators and Ecological Indicators

The relationship between lake water chemistry and diatom assemblages is an example of the link between the goal of the framework and use of chemistry to indicate change as described in management objectives. Because acidification occurs slowly, and response from damage occurs even more slowly, the framework uses early indications of chemical change in soil and lakes rather than waiting for ecological change to occur. The chemical indicators used are based on experience in other jurisdictions. The linkages between lake chemistry changes and biotic indicators are well known as consistent worldwide; relationships in soils are less well understood but are synonymous with changes in base cation depletion. For lakes an early indication of changing chemistry in response to acidification would be a shift in phytoplankton assemblages, which are primary drivers of lake productivity.

Chemical Loading and Deposition

Modelling was carried out to identify the extent of acid deposition in the oil sands region, as part of the development of the framework. The Potential Acid Input (PAI) loads for three time periods were modelled, showing the predicted area of acid deposition from 1970-2032 for the provincial monitoring load of 0.17 keq/ha/yr isopleth and the provincial critical load of 0.25 keq/ha/yr isopleth (Golder 2003a). Figure 4 shows the isopleths for 2003-2017.

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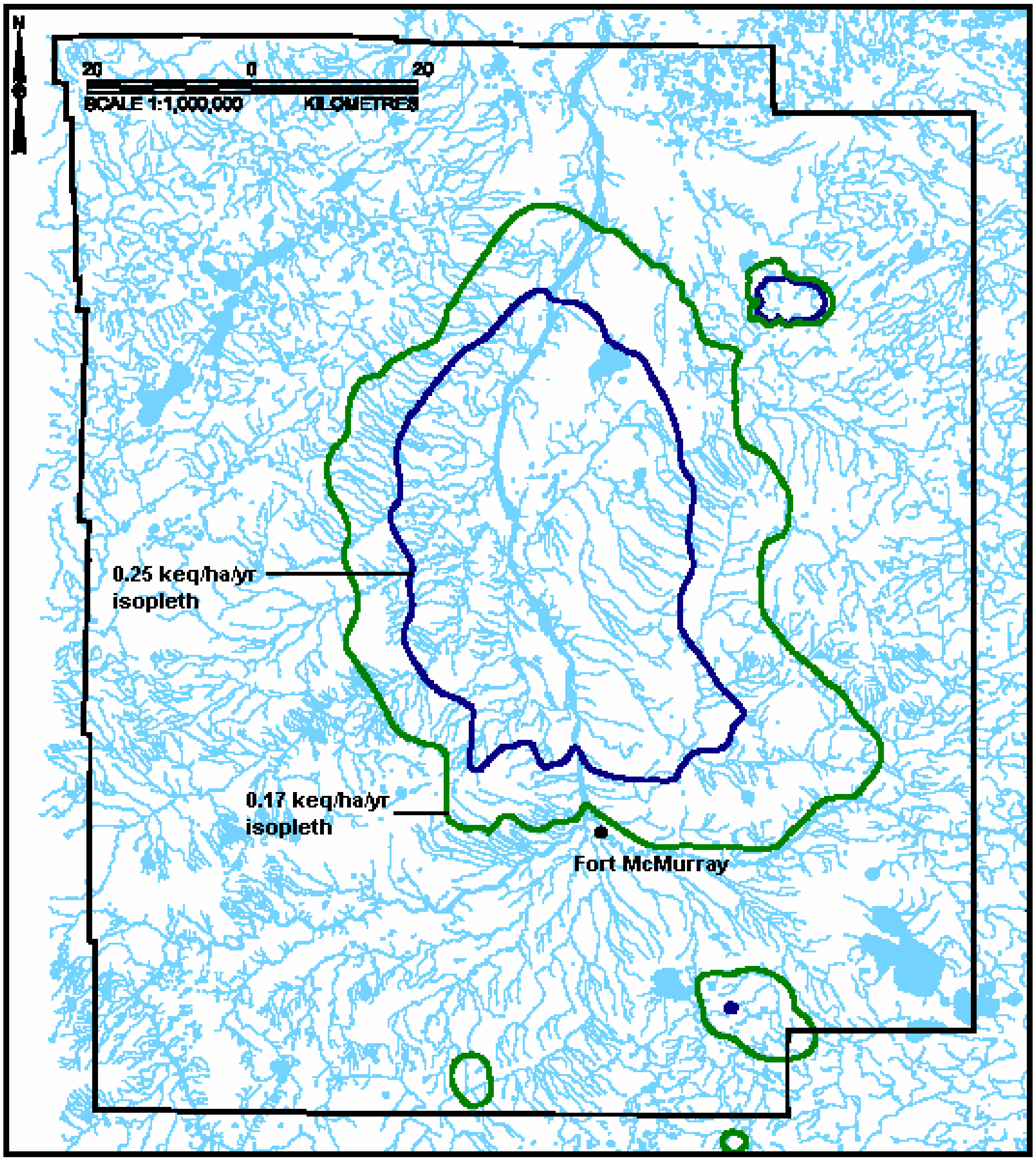
[22] CASA (Clean Air Strategic Alliance). 1999. Application of Critical, Target and Monitoring Loads for the Evaluation and Management of Acid Deposition. Prepared by the Target Loading Subgroup.

Figure 5: 2003-2017 PAI Isopleths (adapted from Golder 2003a, p. 25)



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