# Alberta Acid Deposition Management Framework

JULY 2020

Alberta

Ministry of Environment and Parks, Government of Alberta
Date of publication: TBD
Alberta Acid Deposition Management Framework
ISBN: 978-1-4601-4808-2



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# Acronyms and Abbreviations

| | |
|---|---|
| ADAG | Acid Deposition Assessment Group |
| ADMF | Acid Deposition Management Framework |
| ADMZ | Acid Deposition Management Zone |
| ADZMP | Acid Deposition Zone Management Plan |
| AENV | Alberta Environment |
| AEP | Alberta Environment and Parks |
| AER | Alberta Energy Regulator |
| AESRD | Alberta Environment and Sustainable Resource Development |
| CASA | Clean Air Strategic Alliance |
| $CL_{max}S$ | Critical Load Maximum Sulphur |
| $CL_{max}N$ | Critical Load Maximum Nitrogen |
| $CL_{min}N$ | Critical Load Minimum Nitrogen |
| CLF | Critical Load Function |
| CLRTAP | Convention on Long-range Transboundary Air Pollution |
| CMAQ | Community Multi-scale Air Quality |
| EIA | Environmental Impact Assessments |
| Energy Resource Enactment | (j) “energy resource enactment” means<br>(i) the Coal Conservation Act,<br>(ii) the Gas Resources Preservation Act,<br>(iii) the Oil and Gas Conservation Act,<br>(iv) the Oil Sands Conservation Act,<br>(v) the Pipeline Act,<br>(vi) the Turner Valley Unit Operations Act,<br>(vii) a regulation or rule under an enhancement referred to in sub subclauses (i) to (vi), or<br>(viii) any enactment prescribed by the regulations;<br>(source: http://www.qp.alberta.ca/documents/Acts/r17p3.pdf) |
| EPEA | Environmental Protection and Enhancement Act (RSA 2000, cE-12, as amended) |

| | |
|---|---|
| Facilities | A facility that operates under an approval or code of practice as required by Environmental Protection and Enhancement Act and/or the Energy Resource Enactments |
| $N_{dep}$ | Nitrogen deposition |
| RELAD | REgional Lagrangian Acid Deposition |
| Regulator | Means a decision maker who is vested with a power, duty or function under the Environmental Protection and Enhancement Act and includes, without limiting the generality of the foregoing: (i) a designated Director or other official, (ii) the responsible Government of Alberta department, as designated under the Environmental Protection and Enhancement Act, and (iii) the Alberta Energy Regulator, as designated under the Responsible Energy Development Act |
| $S_{dep}$ | Sulphur deposition |
| SSMB | Steady State Mass Balance |

# 1.0 Introduction

Many industrial and non-industrial activities result in air emissions of compounds containing sulphur (S) and nitrogen (N) which, when deposited to terrestrial and aquatic systems, may result in acidification of the recipient systems. Long-term and permanent changes in the chemical properties of the soil and water occur when acid deposition exceeds the buffering capacity of the receiving system. These effects can interfere with important ecosystem functions and services, such as forest diversity and productivity, water quality and healthy fisheries. Regardless of changes being subtle or dramatic within an affected area, they must be considered in the context of the long-term equilibrium of the ecosystem.

Management of acidic deposition requires an integrated approach that includes measurement; estimation of emissions and deposition; and evaluation of the effects of deposition on recipient ecosystems. The critical load approach has been developed to address these assessment issues. In 1999, Alberta developed its first framework for managing acidifying emissions (i.e., air emissions containing sulphur and nitrogen compounds) and acid deposition with the goal to prevent an acidification problem from developing due to acidifying emissions (CASA, 1999). Alberta Environment adopted the framework developed by the Clean Air Strategic Alliance (CASA) for management of acid deposition effects in Alberta (AENV, 1999). The Acid Deposition Management Framework (ADMF) is periodically reviewed and revised as necessary to take into consideration advances in knowledge and science. The 1999 ADMF was reviewed and revised by the department in 2008. The Acid Deposition Assessment Group (ADAG), a multi-stakeholder group lead by the department, started its review of the 2008 ADMF after the 2011 provincial acid deposition assessment was completed in 2014. In the 2008 ADMF review process, possible ADMF changes were identified and evaluated and recommended changes are described in Appendix A.

**Buffering Capacity**

The relative ability of a substance to resist change to its pH despite the addition of an acid or base.

This document replaces the “Alberta Acid Deposition Management Framework (2008).”

# 2.0 Alberta Acid Deposition Management Framework

Controlling acid deposition falls under the *Environmental Protection and Enhancement Act* (EPEA). One of the purposes of the EPEA is to provide government leadership in areas of environmental research, technology and protection standards. Section 14 under EPEA provides the authority for development of a provincial ADMF. The ADMF may be referenced in the Terms of Reference for projects that are required to conduct an Environmental Impact Assessment (EIA) and in project approval application requirements or projects subject to approval requirements as specified directly under EPEA or energy resource enactments.

## 2.1 Alberta's Critical Load Maps

The critical load is based on the soil properties of the ecosystems within each grid cell on the maps. Sensitivity in each grid cell is indicated by the magnitude of the critical loads – the lower the critical load, the greater the sensitivity of the grid cell. The Steady State Mass Balance (SSMB; CLRTAP, 2015, 2016) method was used to calculate the critical loads of acidity for terrestrial ecosystems in Alberta. The use of the SSMB method required the generation of three critical loads maps ($CL_{max}S$, $CL_{max}N$ and $CL_{min}N$) using 2.5 km x 2.5 km grid cells (Appendix A1 & AEP, 2020). The decision to use a 36 km x 36 km grid in the framework as the management unit size, required that these 2.5 km x 2.5 km grid cells be aggregated to the 36 km x 36 km grid and associated critical load maps generated (Figure 1). Detailed information of the data and methods used are described in the document "Using steady-state mass balance model to determine Critical Loads of Acidity for Terrestrial Ecosystems in Alberta" (AEP, 2020). When the critical load is exceeded, a management plan must be developed and implemented to reduce all point and non-point sources that are significantly contributing to acid deposition in the grid cell(s) that are above their critical load.

### Critical Load

A quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge (Nilsson & Grennfelt, 1988).

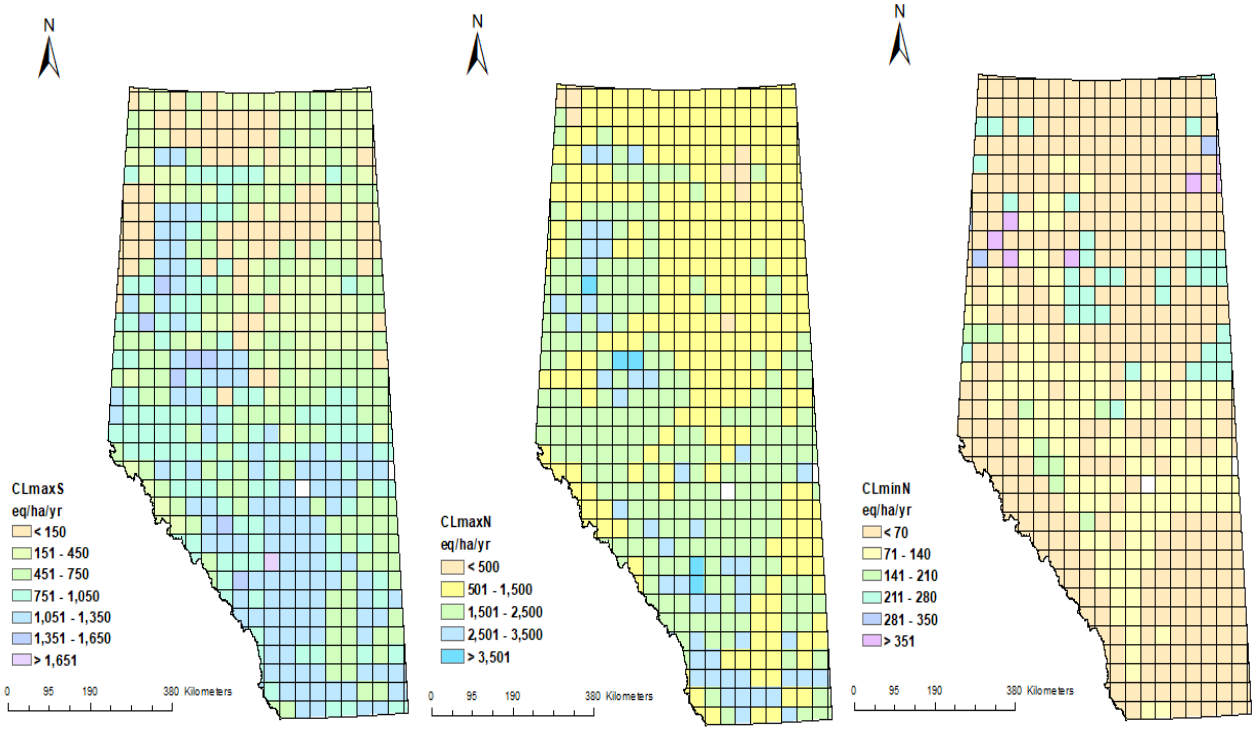


**Figure 1** **Maps for three quantities of critical load in Alberta with 36km by 36km resolution: (a) $CL_{max}(S)$, $CL_{max}(N)$ and $CL_{min}(N)$.**

## 2.2 Acid Deposition Management Levels

A tiered monitoring, target and critical load acid deposition management approach was used in the 2008 ADMF. It is being replaced with a new management approach that will provide an early warning of potential areas “at risk” to long-term acidification. The new approach also provides guidance to manage and reduce, where necessary, acidifying emissions adversely affecting the identified areas.

Figure 2 shows the risk management levels that have been selected to guide responses to the SSMB critical load predictions. The framework consists of three separate critical load based management levels. Of the three levels, Level 1 is the lowest and Level 3 is the highest. Each management level is colour-coded, and associated with a suite of acid deposition management actions that are progressively more rigorous. The greater than 50% above critical loads Level 3 designation is based on uncertainties and limitations associated with the SSMB mathematical calculations and data inputs, the conservatism of the model, and some of the key model input parameters. With this management approach, the critical load becomes the environmental outcome.

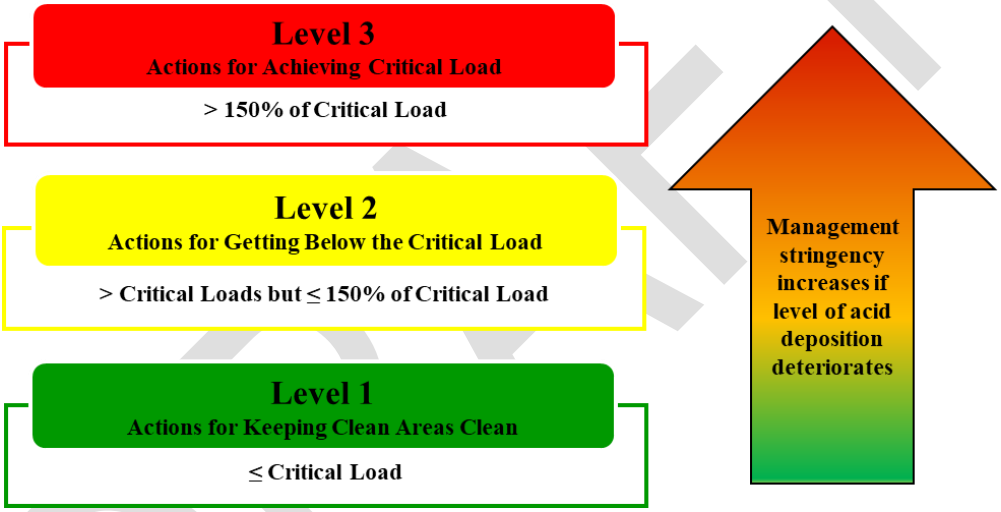


**Figure 2 Action levels for Alberta's Acid Deposition Management Framework.**

# 3.0 Acid Deposition Assessment for Alberta

The assessment of acidifying emissions and subsequent deposition relative to the critical load will be conducted to reflect Alberta's air quality management system principle of continuous improvement (AENV, 2009) over time. Assessment frequency is currently estimated to be a 5-

year cycle based on the pace of scientific understanding and knowledge advancement in this discipline.

## Acid Deposition Assessment

A process in which a clear understanding of baseline conditions and ensuing changes to ecosystems are monitored and documented over time with the goal of establishing long-term environmental outcomes. The assessment is integrated and can capture the full range of processes and responses from emissions to atmospheric transport to deposition to ecological impacts. The end-goal of the assessment is to have evaluated how well current emission control efforts work in reducing environmental impacts, and to determine the potential need for further actions.

The department will conduct the assessment as deemed necessary, to answer the following questions:

- what is the current provincial situation regarding acid deposition?
- are large areas at risk due to deposition of acidifying substances?
- are there likely to be changes in acid deposition patterns over the long term that may result in harmful effects in some areas in the foreseeable future?
- are activities and associated acidifying emissions in Alberta potentially negatively impacting the environment in neighboring jurisdictions?

The flowchart in Figure 3 outlines the general process for conducting an acid deposition assessment. The following sections describe key process components in detail.

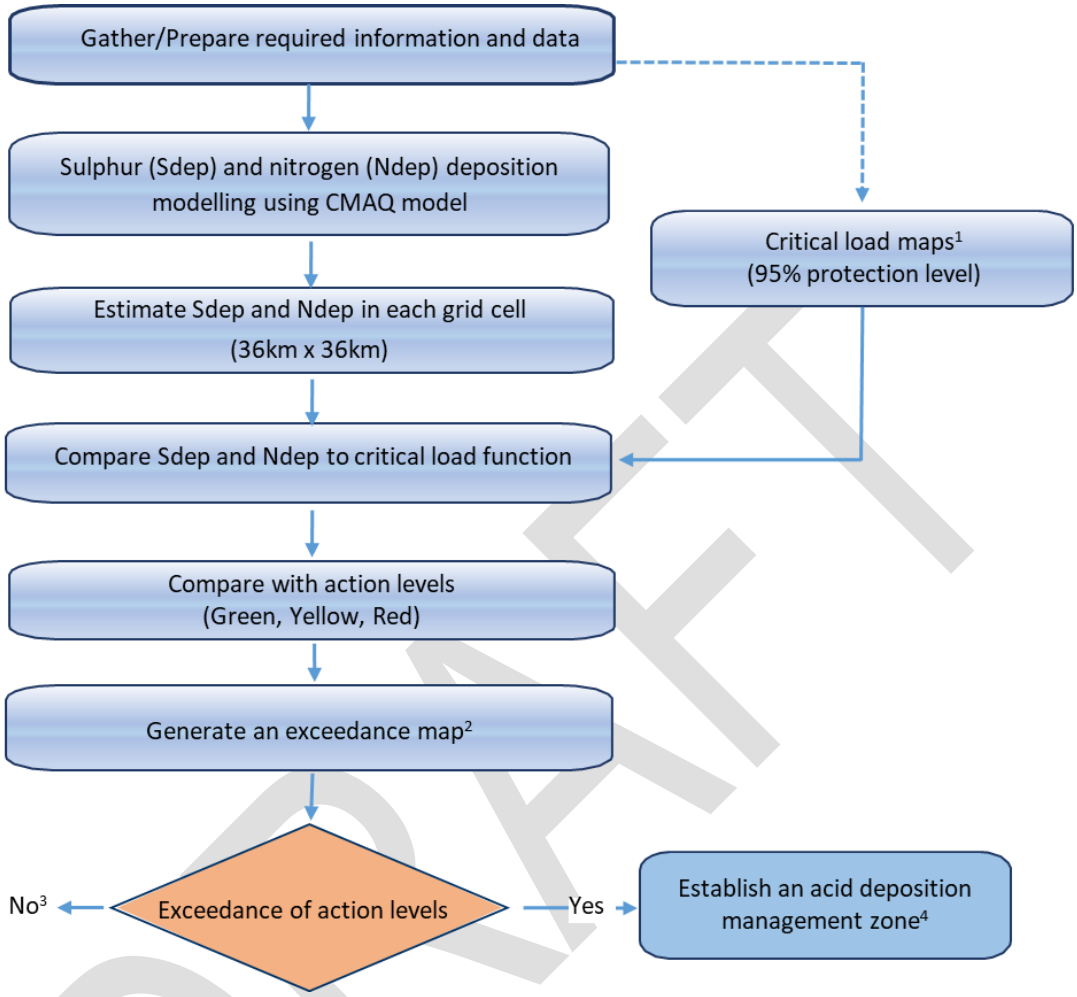


**Figure 3 The general process for conducting the provincial acid deposition assessment.**

Note: [1]When new data and information is available, critical load maps will be updated by the department through the assessment process. [2]Exceedance is calculated using (Exceedance = Deposition – Critical Load). [3]When the % of critical load is less than 100%, this finding will be documented and no further assessment required. [4]When an acid deposition management zone is established, actions are to be taken as outlined in Chapter 4.

## 3.1 Estimating Atmospheric Deposition of Sulphur and Nitrogen

Based upon the most recently available and appropriate emissions inventories and a representative meteorological data set, an estimation of wet and dry S and N deposition in each grid cell will be made. Deposition estimates will be made for the entire province with the Community Multi-scale Air Quality (CMAQ) model (U.S. Environmental Protection Agency ((U.S. EPA), 2017) using a 36 km x 36 km grid.

## 3.2 Level of Protection and Management Unit

An essential component in application of critical loads is the level of protection that is to be applied. A 95% protection level (i.e., 5th percentile) was chosen for Alberta's first framework (CASA, 1999), and during the review of the 2008 framework ADAG agreed that 95% remains an acceptable level of protection. The 95% protection level means that 95% of the most sensitive soils will be protected at the critical load within each 36 km x 36 km grid cell.

## 3.3 Evaluation of Model Predictions

Any deposition monitoring data that has become available since the previous provincial assessment will be compared to model predictions. The purpose of this comparison is to evaluate how reasonably the model predicts the spatial variability and general deposition magnitudes for a representative Alberta meteorology. Evaluation of air quality modelling elements integral to the framework will be conducted in two ways. These are:

(1) determine the acceptability of the input modelled meteorology used in the framework for precision and accuracy. This will be undertaken using the currently accepted U.S. EPA guidance for evaluation of meteorological models (U.S. EPA, 2013).

(2) examine the general spatial and temporal agreement between available monitoring data and model predictions. Given that the meteorological year of choice may not coincide with the available monitoring data (which may span several years), a direct evaluation of the model performance may not be possible. Therefore, a "weight of evidence" comparison of modelling predictions to the average of the available monitoring data at each station weighted by the quality of data at each monitoring station will be undertaken. This comparison can be done using both paired and unpaired statistics between the two data sets using professional judgment to determine whether the agreement is acceptable and whether or not the model predictions are reasonable and representative of deposition in the province.

## 3.4 Comparing Modelled Deposition to Critical Loads

The modelled total deposition (wet and dry) estimates are used when calculating critical load exceedances. Positive values reflect the extent to which current pollution loading exceeds the critical load. An exceedance map will provide a magnitude of the exceedance in grid cells (e.g., No Exceedance, 1-1.5 times Exceedance, >1.5 times Exceedance).

## 3.5 Review of Science Gaps and Recommendations

Consistent with Alberta's initiatives for continuous improvement and keeping clean areas clean, the status of the science gaps identified and recommendations put forth in the previous provincial assessment will be reviewed. Recommendations may be provided to fill science gaps or to improve the assessment method.

## 3.6 A Report Describing the Results of the Provincial Assessment

The assessment report will be public and available online through the department's website. The report will include:

- a summary of the emissions inventory used and assumptions for projected emissions.
- a brief description of the model used to predict nitrogen and sulphur deposition.
- a discussion of sulphur and nitrogen deposition in Alberta and neighboring jurisdictions.
- a summary of critical loads updates when new data and information are available (note: data obtained between assessments may lead to a revision of the critical load for individual grid cells, should the data indicate that the critical load is different from that assigned in the previous assessment).
- the results of comparing modelled deposition to the critical loads.
- a review of the status of science gap(s) from the previous report and newly identified science gap(s) and recommendation(s).

## 3.7 Response to Acid Deposition Assessment

Should the assessment indicate that deposition in one or more grid cells exceeds Level 3 or Level 2 (i.e., as the result of two sequential acid deposition assessments), an Acid Deposition Management Zone (ADMZ) will be established by the Department. The ADMZ will include the exceedance cell(s) and all grid cells with acidifying emission sources that substantially contribute to acidifying deposition in the exceedance cell(s). There may be some cells that do not have acidifying emission sources that contribute to the exceedance, but are located between cells that do, and that if development were to occur within those cells they may become acidifying contributors to the exceedance cell(s). These cells would then also be included in the ADMZ.

The framework recommends a suite of management response options for each level (Chapter 4). These actions include a range of potential measures and tools with varying degrees of rigour and flexibility. When mitigative management actions are required, the department will collaborate with stakeholders to identify and implement the appropriate management action. This will include identifying the public, stakeholders and different levels of government that need to be involved in the plan. The department, as accountable for the framework, provides leadership and guidance and will work with stakeholders to identify appropriate parties who will be required to deliver a flexible management response.

Stakeholders share ownership of the concepts, management approach and intent of the framework and in this way demonstrate their partnership commitment to take appropriate action that will maintain and improve acidification issues in Alberta.

This framework will be updated from time to time, to reflect changing standards and objectives, demonstrating continuous improvement over time based on best available knowledge and investigation findings.

### 3.7.1 Development of an Acid Deposition Management Zone Plan

As structured in Figure 2, the framework maximizes the potential for management on the basis of measurement (monitoring and receptor measurement), and minimizes the reliance on model prediction. Following the collaboration process with relevant stakeholders, details on the chosen management actions and an implementation plan will be provided in the Acid Deposition Zone Management Plan (ADZMP).

The ADZMP includes (but is not limited to):

- a program to evaluate the overall emissions reductions necessary to reduce acid deposition and to establish related long-term emissions management objectives for the ADMZ (this will involve an evaluation of required emission reductions and derivation of an emissions reduction schedule).
- a process to allocate acidifying emission reduction targets to acidifying emission sources regulated under EPEA and/or the Energy resource enactments (section 1(1) (j)) in the ADMZ identified above.
- a process to inform the approval of new acidifying emission sources in the ADMZ in a manner that will not compromise the ability to meet the ADMZ acidifying emission reduction targets and schedules.
- development of an acidifying emissions inventory and acid deposition monitoring programs to verify progress in achieving management plan objectives (the program will include processes for adjusting acidifying emissions reduction targets based on actual performance of the management system).
- measures to reduce point and non-point source emissions where these emissions contribute substantially to the exceedance cell(s).

# 4.0 Alberta Acid Deposition Management Actions

The framework uses the assessment of the receptor sensitivity by applying the levels in the following tables (Tables 1 to 3) to help select management actions that can be taken to reduce the likelihood of reaching the critical loads. Management actions associated with the lower levels are intended to provide options to address acidification issues and avoid reaching the higher levels. Once it is determined that management actions are necessary, the department will:

- help to ensure that necessary regulatory or management changes are undertaken.
- work with stakeholders to identify the appropriate parties to be involved in the development and implementation of management actions. There will be shared responsibility amongst there parties to make sure the actions are taken.

The following sections outline the key actions that should be followed in initiating and carrying out the management planning process.

## 4.1 Level 1 – Keeping Clean Areas Clean

**Objective:** Ensuring clean areas remain clean.

The primary action at this level is ongoing monitoring of acid deposition. No additional/new monitoring or management activities are required.

**Table 1 Management actions for Level 1**

| Action | Description | Primary Responsibility |
|---|---|---|
| Acid Deposition Monitoring | Baseline monitoring and data gathering. | The department, with assistance from provincial science and technical experts as needed and available. |

## 4.2 Level 2 – Actions for Getting Below the Critical Load

**Objective:** Get below the critical load by reducing acid deposition through taking investigative and education actions. The focus of this level is to better understand and quantify the acid deposition risk in Level 2 grid cells. When deposition is predicted to occur that is in excess of Level 2 (i.e., this action level has been exceeded) actions are to be taken as outlined in Table 2.

If, as the result of two sequential provincial acid deposition assessments or an observed (monitoring result) deposition is predicted to occur that is in excess of Level 2, then an ADZMP may be required to be developed within two years after ADMZ establishment. The department will determine the need for development of ADZMP as specified in Table 3.

**Table 2 Management actions for Level 2**

| Action | Description | Primary Responsibility |
|---|---|---|
| Acid Deposition Monitoring | Assess the adequacy of existing acid deposition monitoring (i.e., receptor).<br>○ Collect available data for evaluating/validating the SSMB critical load exceedance result. | The department and stakeholders, with assistance from provincial science and technical experts as needed and available. |

| | | |
|---|---|---|
| Modelling | Conduct additional modelling, as needed, to identify sources of acidifying emissions that contribute to deposition above the Level 2 in the grid cell.<br>○ Compile emissions inventory (current and historical where possible), derived from any available and appropriate emissions inventories and supplemented with location specific data as required. | The department and stakeholders, with assistance from provincial science and technical experts as needed and available. |
| Stakeholder Engagement and Education | Engage local stakeholders as appropriate based on local conditions. | The department, with assistance from the affected stakeholders and partners, as appropriate. |

## 4.3 Level 3 – Actions for Achieving Critical Load

**Objective:** Achieve ADMZ critical load through advanced ADMZ actions.

For each cell that is predicted (model result), or observed (monitoring result) to exceed Level 3, an ADMZ will be established. Establishment of this zone will be the responsibility of AEP and the boundaries of the ADMZ will be determined based on the acid deposition assessment result. The ADMZ will include the exceedance cell(s) and all grid cells which substantially contribute to acidifying deposition in the exceedance cell(s). There may be some cells that do not have acidifying emissions that contribute to the exceedance, but are located between cells that do. If development were to occur within those cells, they could become acidifying contributors to the exceedance cell(s) and would be included in the ADMZ. At the red level, an ADZMP must be developed within one and a half years after ADMZ establishment. Stakeholders will be engaged to a high degree. As part of the plan development, government and stakeholders should consider current and likely future acid deposition pressures and issues. If stakeholders do not agree to, and/or implement, the management plan within the required timeframe, the department may impose a plan. Associated Level 3 actions are outlined in Table 3.

**Table 3 Management actions for Level 3**

| Action | Description | Primary Responsibility |
|---|---|---|
| Acid Deposition Monitoring | Ensure the adequacy of existing acid deposition monitoring (i.e., receptor).<br>○ Collect available data for evaluating/validating the SSMB critical load exceedance result. | The department and stakeholders, with assistance from provincial science and technical experts as needed and available. |
| Modelling and Research | Conduct additional modelling to identify sources of acidifying emissions that contribute to deposition above the Level 3 in the grid cell.<br>○ Compile an ADMZ-specific emissions inventory (current and historical where possible), derived from the national emissions inventory and supplemented with location specific data as required.<br>Analyze the trends in acid deposition and acidifying pollutant emissions and evaluate/validate the SSMB critical load exceedance results. | The department and stakeholders, with assistance from provincial science and technical experts as needed and available. |

| | | |
|---|---|---|
| | Discuss the best approach for implementing any required monitoring/research studies and confirm resourcing of these studies. | |
| Stakeholder Engagement and Education | Engage local stakeholders with roles and deliverables identified.<br>Notify stakeholders, including the public, municipalities, all facilities or activities, of the establishment of the ADMZ that:<br>○ operate under an approval or code of practice as required by EPEA and/or AER authorization under the Energy resource enactments approvals for $SO_2$ and NOx emissions.<br>○ are regulated by the Regulator.<br>○ are the emitters that contribute to acid deposition in the affected area or their constituents. | The department, with assistance from the affected stakeholders and partners, as appropriate. |
| Implement Acid Deposition Management Plan | Implement the ADZMP, with clear roles and responsibilities for all participants, timelines, and a defined process for review and revision as necessary. | The department leads the implementation of ADZMP, all stakeholders responsible for the actions committed to the plan. |
| Progress Assessments | Assess progress in implementing management actions, track the implementation of the action plans, and demonstrate how the management actions are contributing to improved air quality and reduced deposition. Identify and fill in gaps in the information needed for management planning. | The department and stakeholders. |

## 4.4 Guidance for Approval of Facilities within an Acid Deposition Management Zone

There may be situations where a decision needs to be made by a Regulator on the approval for a facility (i.e., new, amended, renewal), where the facility will be located in an established ADMZ, but an ADZMP has yet to be developed. In such situations, the guiding principle for the Regulator will be to ensure that the approval of any acidifying emission(s) associated with the facility will not compromise the ability of the ADZMP to bring ADMZ below the critical load. If the approval of acidifying emission(s) are likely to compromise the efficacy of the ADZMP, the application of sufficiently stringent emissions control measures and/or tools (Table 4) to mitigate this risk is recommended.

The Regulator will notify, in writing, all facilities that contribute acidifying emissions to the ADMZ indicating that additional emissions management actions may be required in the future and these actions may be stipulated in a revised approval issued to the applicant. As a mandatory requirement, applicants will participate in the development of the ADZMP. The ADZMP, and other development and economic viability factors will guide the approval process of acidifying emission sources within an ADMZ.

Table 4 is a list of potential measures and tools that could be used to manage acidifying pollutants as part of the ADMF. The list is not exhaustive, but can be used as a guide.

The framework also recognizes that emission control technology and scientific understanding may change over time; and flexibility is needed to ensure that the desired environmental outcomes continue to be achieved.

**Table 4 Potential measures and tools that can be used for acid deposition management**

- Emission reduction requirements to allow for new sources.
- Director-initiated approval amendments (in accordance with authority under EPEA).
- More rigorous performance standards.
- Restrictions on additional emission sources.
- Application of practicable control technology to prevent pollution, stringent control technology as needed to meet operational excellence
- Approval conditions or restrictions.
- Environmental Protection Order.

- Approval conditions to participate in the ADZMP.
- Additional acid deposition modelling assessment.

## 4.5 Acidifying Emissions Modelling Requirement and Protocol

In order to realistically capture the detailed deposition characteristics close to the emission sources when modelling acid deposition, CALPUFF, or any other deposition model recommended by the department, shall be used. This modelling shall be done in accordance with the current version of the Alberta Air Quality Model Guideline.

Facilities emitting $SO_2$, NOx or $NH_3$ and requiring an EIA must conduct an acid deposition modelling assessment. All other facilities (new approved, amending, renewing) contributing to the ADMZ should be required to complete acid deposition modelling assessment if:

- the facility's new approved/increased emissions of $SO_2$, NOx, and NH3 are greater than 0.175 t/d of H+ equivalent.

Acid deposition modelling would not normally be required if:

- the facility's new/increased emissions of $SO_2$, NOx, and $NH_3$ are less than 0.175 t/d of $H^+$ equivalent, and/or
- the facility's emissions have been included in an ADZMP modelling with acid deposition estimates.

If an ADZMP has been initiated, but not completed, the applicant must participate with other stakeholders within the associated ADMZ in completion and implementation of the ADZMP.

There may be situations where a facility is recently approved, but an ADMZ is declared afterwards, that will directly affect the facility. In this situation, the facility is required to fully participate in the development and implementation of the ADZMP. It is prudent for applicants to stay apprised of acid deposition assessments and consider the potential for establishment of ADMZ's when preparing an approval application.

Notwithstanding the foregoing, the Regulator may require an applicant of a project to conduct one or more air quality and/or deposition modelling exercises if there is some overriding concern that must be addressed.

Figure 4 illustrates the steps to follow to determine if acid deposition modelling is required for the proposed project.

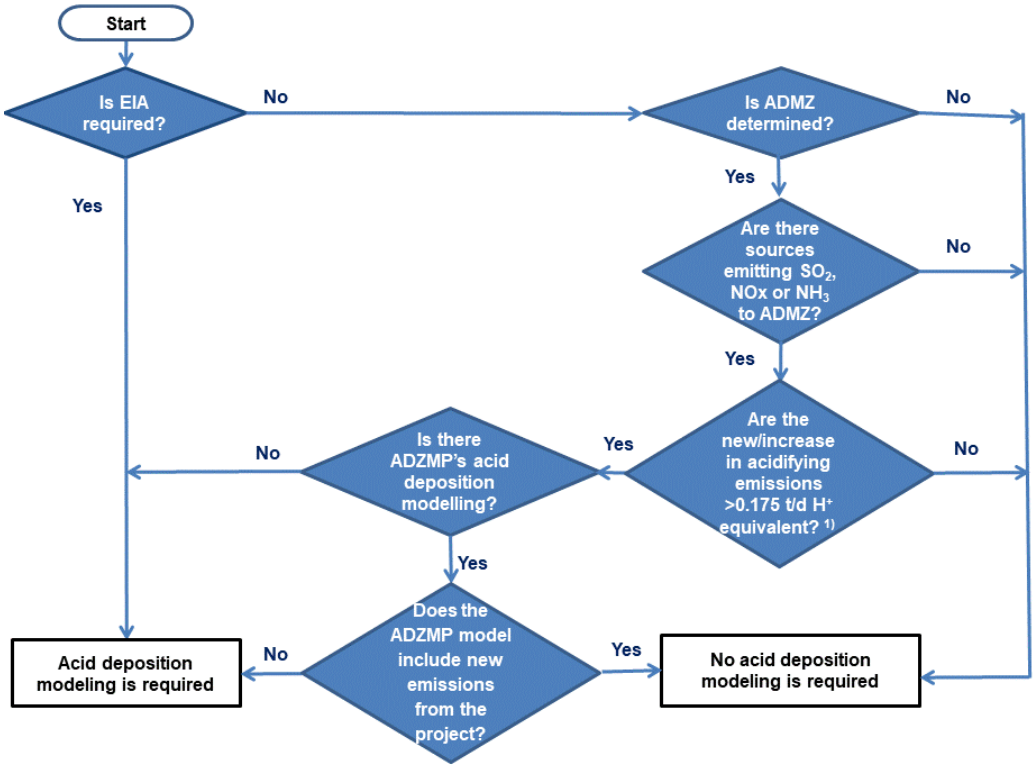


**Figure 4 Flowchart to determine when the applicant will be required to conduct acid deposition modelling as part of their approval application**

Note: Total acidifying emissions of H+ equivalent (t/d H+) = [2×($SO_2$ t/d)/(64)] + [1×(NOx t/d)/(46)] + [1×(NH3 t/d)/(17)].

The framework does not in any way alter the existing authority of agencies, departments and organizations to use regulatory mechanisms in the event that the environmental outcomes of the framework are not being achieved.

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# Appendix A Review of the 2008 Framework

Alberta's ADMF is periodically reviewed and as necessary revised to take into consideration new knowledge and science. The Acid Deposition Assessment Group (ADAG) started its review of the 2008 framework after the 2011 provincial acid deposition load assessment was completed in 2014. As part of the ADMF review process the following items were identified as a priority for review and possible revision:

- using a more open and supported model to predict sulphur and nitrogen deposition than the REgional Lagrangian Acid Deposition (RELAD) air quality model which is no longer supported.
- the size of the grid/cells used to assess and manage acid deposition.
- the need to examine and update the current critical, target and monitoring load values using less empirical and more transparent and standardized methods.
- updating the provincial critical load map.
- improving base cation deposition estimates.

**A1. Review of the Acid Deposition Model**

The RELAD model was used for previous assessments (AENV, 2006; AESRD, 2014) but as it is no longer supported, and has been replaced with newer, more comprehensive air quality models, it was decided to look at possible replacement models. The critical characteristics and elements of a replacement model were considered to be that the model should:

- have multi-layer representation of the atmosphere,
- use the resistance model to estimate deposition,
- be able to simulate temporal and spatial variability,
- be able to model at a spatial and temporal resolution that would meet the needs of the framework,
- have the ability to represent atmospheric chemistry as well as dispersion, and
- be publically available and approved by the U.S. EPA.

Given the above criteria, it was decided that the framework should use the U.S. EPA approved photochemical Community Multi-scale Air Quality (CMAQ) Modelling System to estimate acid deposition. As this model is actively updated by the air quality modelling community, the model version and chemistry will be chosen at the time of the framework review to best model acid deposition as judged on the basis of its performance with similar projects and by a literature review. The framework will be based on 36 km x 36 km grid cells to provide a reasonable resolution appropriate for acid deposition loading and potential impact screening purposes.

In regard to the meteorological data used, the 1980 MM5 data at 36 km x 36 km resolution used in the 2013 assessment will be retained for future framework assessments. In the case where there is evidence to suggest that modelled acid deposition using 1980 meteorology is no longer representative of average deposition related meteorology due to a climatological change in Alberta, a new meteorological data set will be created that allows CMAQ to representatively model long term typical acid deposition across the province. Also, if there are additional modelling or other technical demands suggesting an update of the meteorology is necessary a new meteorological data set will be created.

### A2. Method to Determine Critical Load Values

In its review of the 2008 ADMF, the ADAG assessed critical load determination options and agreed to use the Steady State Mass Balance (SSMB) model for determining long-term critical loads of sulphur and nitrogen in Alberta. The SSMB model is a widely accepted scientific approach for determining critical loads and is used by many jurisdictions such as Europe, the USA, and Asia (CLRTAP, 2016; Hettelingh et al., 1995; Duan et al., 2010; Williston et al., 2016). The SSMB model assumes a simplified, steady-state input-output description of the most important biogeochemical processes that affect soil acidification (CLRTAP, 2016).

The Critical Load Function (CLF) considers the combined inputs of S and N deposition when determining exceedances of their respective critical loads (CLRTAP, 2015; CLRTAP, 2016). The CLF is a three-node line on a graph defined by the maximum critical load of S (CLmaxS), the minimum critical load of N (CLminN), and the maximum critical load of N (CLmaxN). The CLF is divided into 5 regions. The grey depicts Region 0 which is the area “below” the CLF line where sulphur deposition (Sdep), and nitrogen deposition (Ndep) combined do not exceed the critical loads of acidity. Regions 1 to 4 are the areas “above” the CLF line where a conditional comparison of critical loads and Sdep and Ndep pairs indicate an exceedance. Table A.1 shows these region designation and how they may inform acid deposition management.

**Table A-1 $S_{dep}$ and $N_{dep}$ deposition regions and possible reduction strategies when the Critical Load Function is exceeded**

| Region | Deposition | Example | Exceedance | Optimal reduction* |
|---|---|---|---|---|
| 0 | $S_{dep}$ and $N_{dep}$ fall in Region 0 below the Critical Load Function | | No | N/A |
| 1 | $S_{dep}$ and $N_{dep}$ fall in Region 1 | $N_{dep1}$, $S_{dep1}$ | Yes | Reduction of $S_{dep}$ and $N_{dep}$ |

| | | | | |
|---|---|---|---|---|
| 2 | $S_{dep}$ and $N_{dep}$ fall in Region 2 | $N_{dep2}$, $S_{dep2}$ | Yes | Reduction of $S_{dep}$ and $N_{dep}$ |
| 3 | $S_{dep}$ and $N_{dep}$ fall in Region 3 | $N_{dep3}$, $S_{dep3}$ | Yes | Reduction of $S_{dep}$ and $N_{dep}$ |
| 4 | $S_{dep}$ and $N_{dep}$ fall in Region 4 | $N_{dep4}$, $S_{dep4}$ | Yes | Reduction of $S_{dep}$ |

*Optimal reduction - the deposition reduction needed for $S_{dep}$ and/or $N_{dep}$ to fall below the CLF.