Rio Tinto Alcan

KMP SO_2 EEM Program – Technical Memo S01

Steady-State Soil Modelling

Revised Modelling and Mapping of Terrestrial Critical Loads

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1 Overview

To support the Key Performance Indicator 'critical load exceedance risk' under the Environmental Effects Monitoring (EEM) program, critical loads of acidity for (upland) forest soils will be revised during 2017.

Revised modelling and mapping of terrestrial critical loads will incorporate additional (new) observational data, improved regionalisation methods and updated model parameters as recommended under the STAR (ESSA et al., 2013) or following the Kitimat Airshed Emissions Effect Assessment (KAEEA; ESSA et al., 2014).

2 Critical Loads: 2017 Updates

The mapping and modelling of critical loads during 2017 under the EEM will following the methodology described in the STAR (ESSA et al., 2013) incorporating seven principal revisions (labelled A to G).

A. Soil data. Under the STAR, 51 soil plots were sampled and analysed for bulk density, organic matter content, particle size distribution and total element content. These data were used to estimate soil base cation weather rates, which were subsequently regionalised across the study domain.

Since 2013, additional soil sampling has been carried out in the STAR study domain (see Figure 1) under several external projects (KAEEA [n = 8], BC Ministry of Forest Experimental Plots [EP0712; n = 3] and the LNG Canada Project [URL: lngcanada.ca; n = 22]). Further, as recommended in the STAR, supplemental soil sampling will be carried out during the EEM Program to address critical uncertainties and data gaps in the regionalisation of soil base cation weathering rates (see Technical Memo: Supplemental Soil Sampling, March 2015).

Task A. All new soil data will be captured and incorporated into the STAR soils database. Base cation weathering rates will be estimated for all additional soil sampling plots with total element content data following the methodology used in the STAR.

B. Soil mapping. Under the STAR, the regionalisation of soil weathering rates was carried out by allocating the statistical summaries from 4–6 sampling plots to mapped bedrock classes across the region. The approach did not accommodate the variability in weathering rates within each class and provided limited or no integration of surficial geology.

The KAEEA used a regression-kriging approach (Hengl et al. 2004), which is a well-established geostatistical mapping technique (McBrantley et al., 2003), to regionalisation of soil parameters, e.g., weathering rates. The approach provided a better representation of the spatial variability in weathering rates, removing the dependency on bedrock classes.

Task B. Spatial prediction or regionalisation of soil input parameters for the determination of critical loads, e.g., weathering rates and soil organic matter will be carried out using regression-kriging. The approach will incorporate all available soil data in the study area (see revision A).

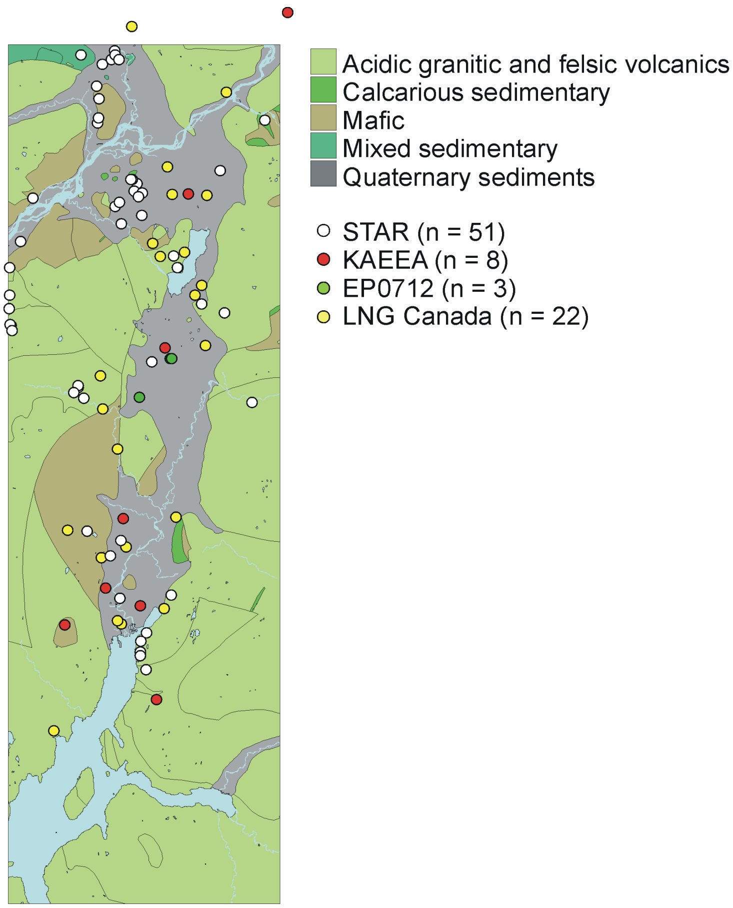

Figure 1. Location of soil sampling sites with total element analysis within (and outside) the STAR (ESSA et al., 2013) study domain. In addition to the 51 soil plots sampled under the STAR, soil plots have been sampled under the Kitimat Airshed Emissions Effect Assessment (KAEEA; n = 8), the BC Ministry of Forestry experimental growth plots (EP0712, n =3) and the LNG Canada Project (n = 22). The map depicts major bedrock and surficial (glaciofluvial material indicated as 'quaternary sediments') geology in the study area.

C. Base cation deposition. Under the STAR, the determination of critical load did not include base cation deposition. This was recognised as a critical uncertainty.

The National Atmospheric Deposition Program (NADP) precipitation chemistry stations at Haul Road and at Lakelse Lake provide data to evaluate regional base cation deposition. In additional, data may be supplemented with observations from other precipitation stations in western North American, and regional maps of rainfall volume.

Task C. Base cation deposition will be mapped across the study domain and incorporated into the determination of critical loads of acidity for (upland) forest soils.

D. Background sulphur and nitrogen deposition. Under the STAR, modelled sulphur and nitrogen deposition estimates did not include background deposition estimates. The modelled deposition represented the contribution of stationary and mobile emissions sources to total deposition, rather than total anthropogenic deposition to the study domain. Transboundary atmospheric sources can contribute a significant amount of anthropogenic sulphur and nitrogen deposition, as observed by monitoring stations in background regions.

The KAEEA (ESSA et al., 2014) incorporated a constant sulphur deposition of 10 meq m^{-2} yr^{-1} and nitrogen deposition of 5 meq m^{-2} yr^{-1} to represent background deposition. The selected values represented precautionary estimates of background deposition as actual background deposition will vary across a region.

Task D. Incorporation of background sulphur and nitrogen deposition in the determination of exceedance of critical loads following the KAEEA (ESSA et al., 2014).

E. Critical Bc:Al ratio. Under the STAR, a Bc:Al ratio equal to 1.0 was used as the critical chemical criterion or indicator of damage to receptor ecosystems, i.e., upland forest ecosystems on mineral soil. In contrast, the KAEEA (ESSA et al., 2014) incorporated broad vegetation-specific critical limits, i.e., Bc:Al = 1.0 for coniferous forests and Bc:Al = 6.0 for deciduous and mixed forests.

Following the KAEEA, the EEM will incorporate vegetation-specific Bc:Al limits into the revised critical loads of acidity. In collaboration with the BC MOE, regionally-relevant vegetation-specific Bc:Al ratios will be identified from available literature sources (e.g., Sverdrup and Warfvinge, 1993). A map overlay or decision tree approach will be used to delineate or map identified vegetation types from existing spatial databases (see Technical Memo: Vegetation Resource Inventory Metadata, December 2014).

Task E. Spatial delineation of unique vegetation types within the study domain and assignment of vegetation-specific Bc:Al ratios. Incorporation of vegetation-specific Bc:Al ratios into the determination of critical loads of acidity.

F. Multiple chemical criteria. Under the STAR, the exceedance of critical loads for acidity (and subsequent risk rating) was based on one chemical criterion, i.e., Bc:Al = 1.0 for forest ecosystems. In contrast, the KAEEA incorporated a multi-criteria approach to evaluate the influence of the chosen criterion on predicted exceedance. Four critical chemical criteria were selected (ESSA et al., 2014).

Following the KAEEA, the EEM will incorporate a sensitivity analysis on the influence of the chosen criterion on predicted exceedance. In consultation with the BC MOE, a range of critical chemical criteria will be identified from literature sources (e.g., UNECE 2004).

Task F. Determination of exceedance of critical load under multiple chemical criteria to assess the influence of the chosen criterion on predicted exceedance following the KAEEA (ESSA et al., 2014).

G. Effects domain. The Key Performance Indicator 'critical load exceedance risk' is estimated as the proportional areal exceedance of the receptor study domain. In the absence of provincially-established air zone boundaries, the STAR used a study domain along the Kitimat valley encompassing the modelled post-KMP 10 kg SO_4^{2-} ha^{-1} yr^{-1} deposition plume and potentially sensitive terrestrial and aquatic receptor ecosystems. This study domain was defined in agreement with BC MOE, and encompassed 1991 km^2 of forested ecosystems on mineral soil (69% of the study area). The proportional exceedance reported in the STAR was referenced to this domain area. Under the KAEEA (ESSA et al. 2014), the BC MOE favoured an 'effects domain' based on the area under the modelled 7.5 kg SO_4^{2-} ha^{-1} yr^{-1} deposition plume.

The EEM will evaluate exceedance under both domains.

Task G. Determination of proportional areal exceedance using the original domain and an effects domain defined by the area under the 7.5 kg SO_4^{2-} ha^{-1} yr^{-1} deposition plume.

3 Literature Cited

ESSA Technologies, J. Laurence, Limnotek, Risk Sciences International, Rio Tinto Alcan, Trent University, Trinity Consultants and University of Illinois. 2013. Sulphur Dioxide Technical Assessment Report in Support of the 2013 Application to Amend the P2-00001 Multimedia Permit for the Kitimat Modernization Project. Vol.2: Final Technical Report. Prepared for RTA, Kitimat, BC. 450 pp.

ESSA Technologies, J. Laurence, Risk Sciences International, Trent University, and Trinity Consultants. 2014. Kitimat Airshed Emissions Effects Assessment. Report prepared for BC Ministry of Environment, Smithers, BC. 205 pp. + appendices.

Hengl, T., G. Heuvelink and A. Stein. 2004. A generic framework for spatial prediction of soil variables based on regression-kriging. Geoderma 122 (1–2), 75–93.

McBratney, A.B., M.L. Mendonça Santos and B. Minasny. 2003. On digital soil mapping. Geoderma 117, 3–52.

Technical Memo: Vegetation Resource Inventory Metadata, December 2014. In, Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project, 2013 and 2014 Annual Reports. ESSA Technologies Ltd, Vancouver, Canada.

Technical Memo: Supplemental Soil Sampling, March 2015. In, Sulphur Dioxide Environmental Effects Monitoring for the Kitimat Modernization Project, 2013 and 2014 Annual Reports. ESSA Technologies Ltd, Vancouver, Canada.

UNECE. 2004. Manual on methodologies and criteria for modelling and mapping critical loads and levels and air pollution effects, risks and trends. Federal Environment Agency, Texte 52/04, Berlin, Germany [URL: www.icpmapping.org].