WOOD BUFFALO ENVIRONMENTAL ASSOCIATION

WBEA TEEM Forest Health Monitoring Program

SOCIETY OF ENVIRONMENTAL TOXICOLOGY AND CHEMISTRY

NOVEMBER 5, 2019

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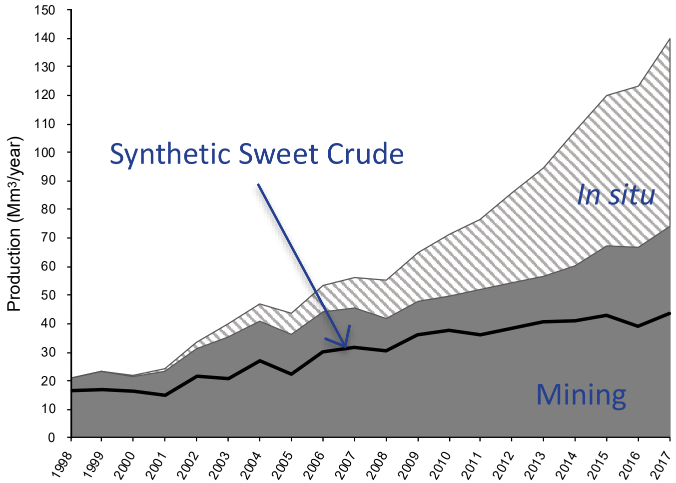
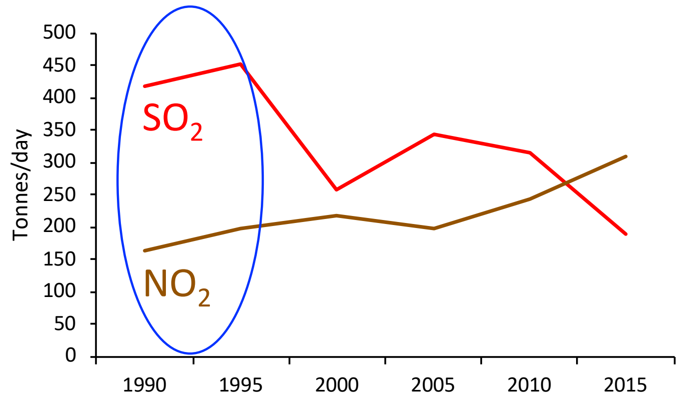
OIL SANDS MONITORING PROGRAM

Genesis of the Forest Health Monitoring Program

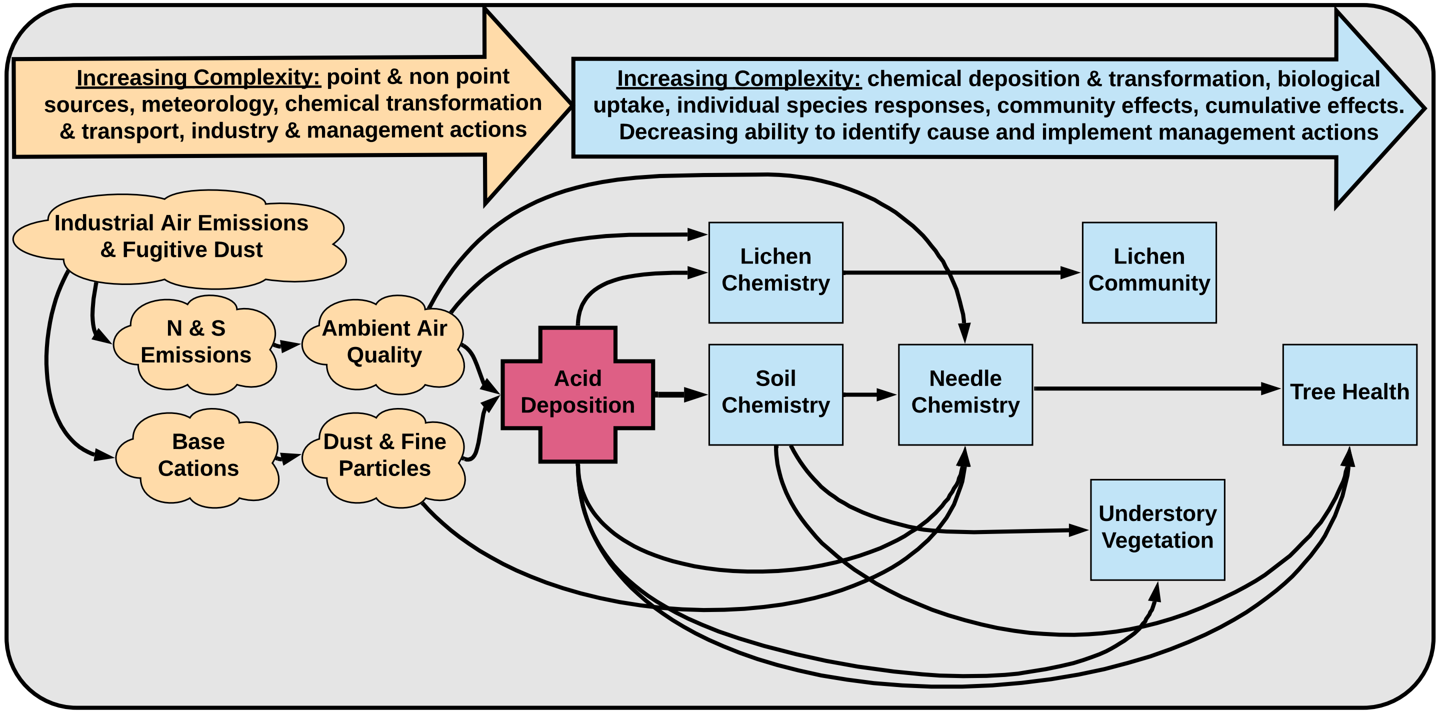
Applications for new & expanding oil sands operations beginning in the early 1990's lead to the creation of the WBEA TEEM multi-stakeholder committee





To develop and operate a long-term program to detect and characterize the effects of oil sands emissions on terrestrial and aquatic ecosystems, and on traditional resources and hence on traditional resource users (1996)

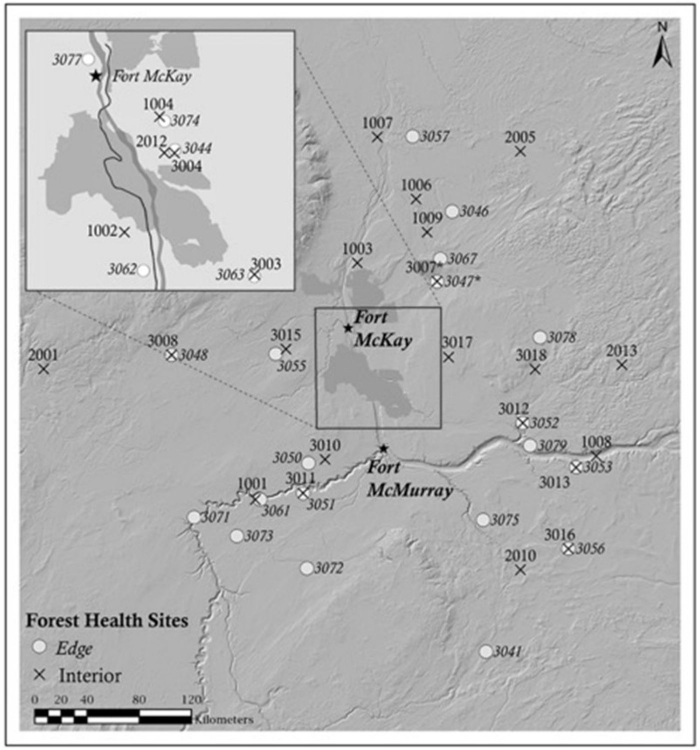
Acid Deposition Effects Monitoring Conceptual Model

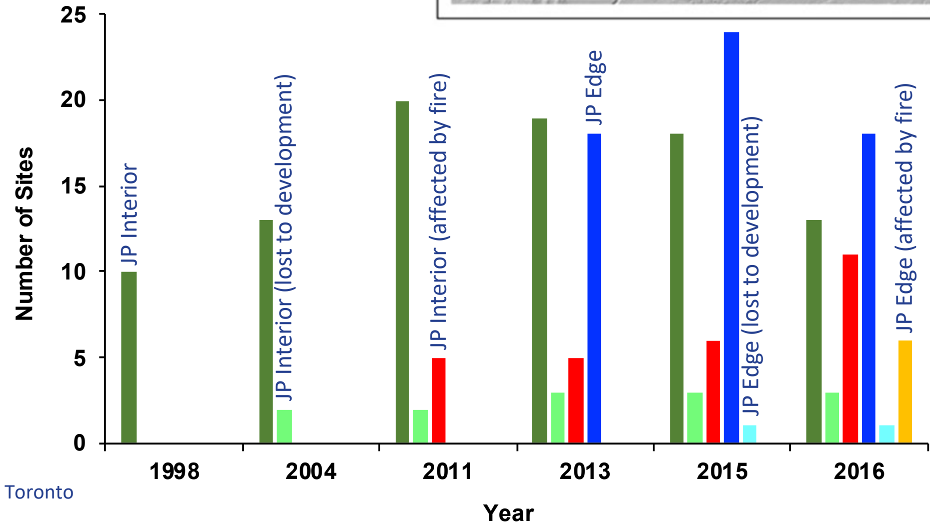


Although environmental acidification progresses from left (stressors) to right (effects), TEEM elected to initiate effects monitoring and to work from right to left. This created an ecological monitoring program prior to the anticipated expansion of the industry

Forest Health Monitoring Program Design

- Acid-sensitive jack pine forest
- Initially 10 sites (1998; forest interior) increasing to 49 sites (interior & edge)
    - Canadian *Acid Rain Network Early Warning System* protocols
    - 6-year intensive sampling cycle, more frequent targeted sampling
    - Fire-affected sites continue to be monitored





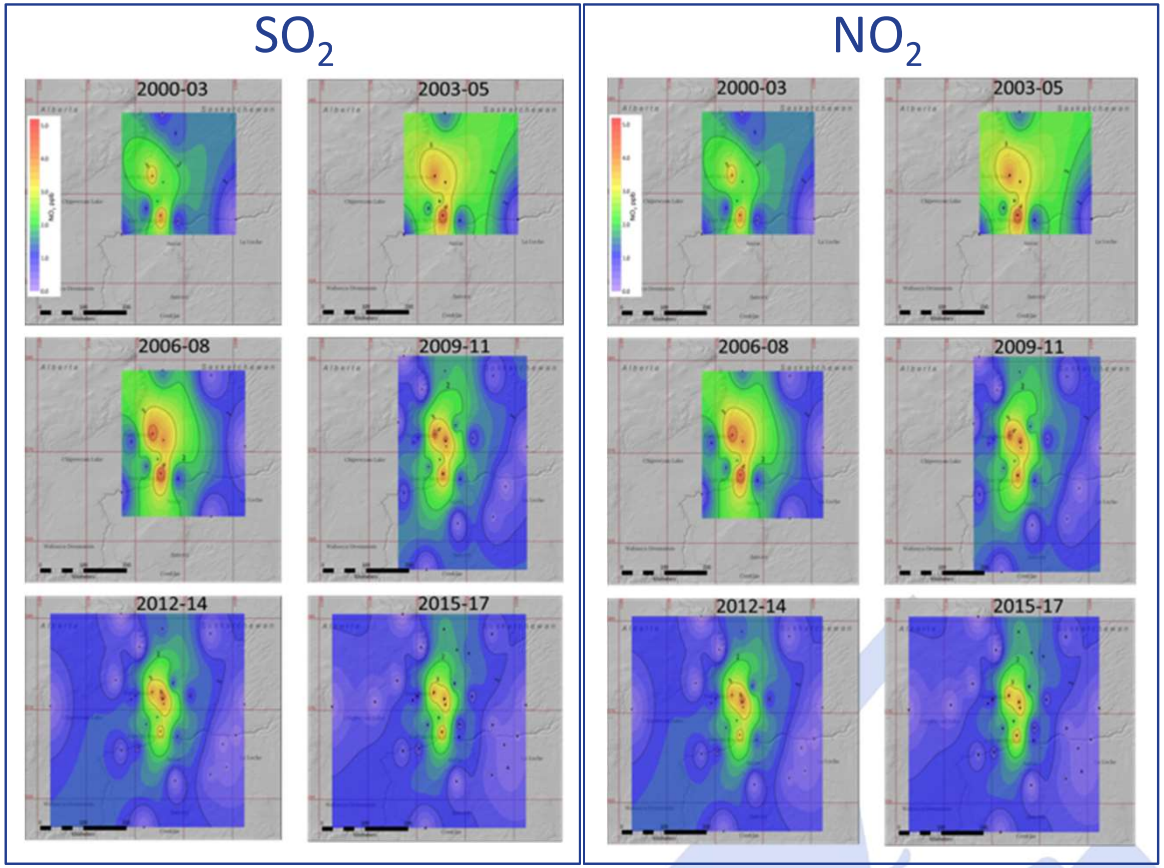
Forest Health Monitoring Program
Air Quality and Deposition Monitoring

- Passive SO_2, NO_2 and O_3 monitoring initiated in 1999; NH_3 and HNO_3 in 2005
- WBEA's AMS network (initiated 1999) provides continuous and intermittent air quality data
- Ion-exchange resin (acid, base) deposition monitoring initiated in 2007
- Cultural, traditional foods study in early 2000's, and since 2010, a Fort McKay First Nation – WBEA berry study
- Source apportionment studies (initiated 2007) to characterize source types and their relative contributions to air quality and deposition

Fort Chipewyan

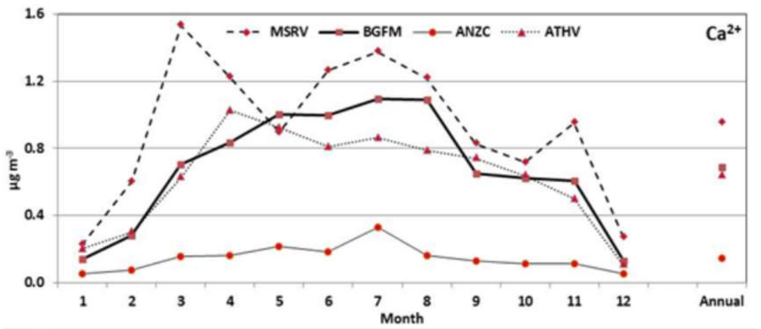
Ambient Air Quality

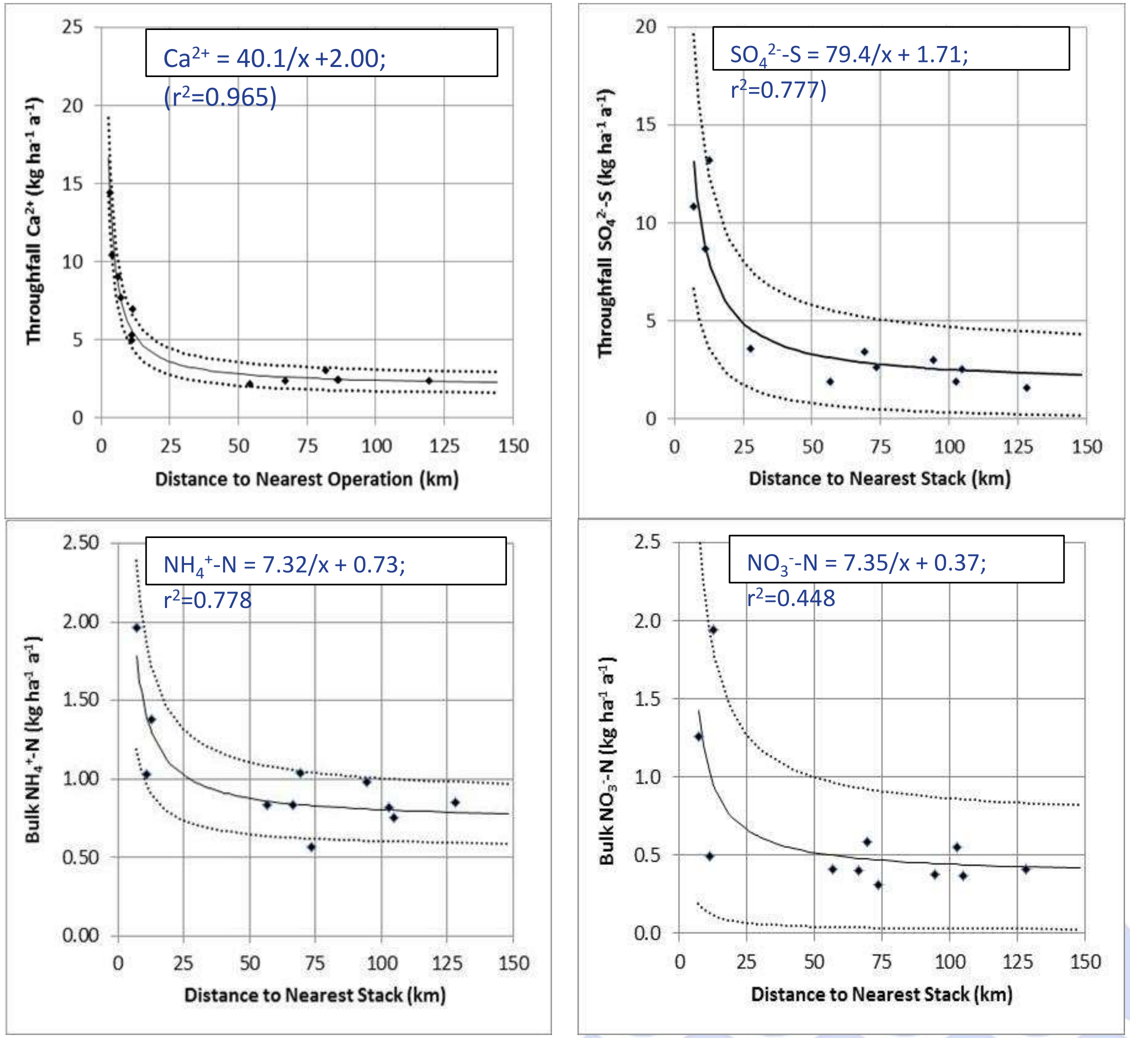
- SO_2: strong (5-10x) gradients across the region, decreased ~40% since 2000
- NO_2: strong (5-10x) gradients across the region, increased from 2000 to 2008, then plateaued or declined slightly
- Weak (2x) gradients for HNO_3, NH_3 & $PM_{2.5}$, but not enough data to determine trends
- Wildfires contribute significant amounts of NH_3



Deposition Gradients for Key Components of PAI

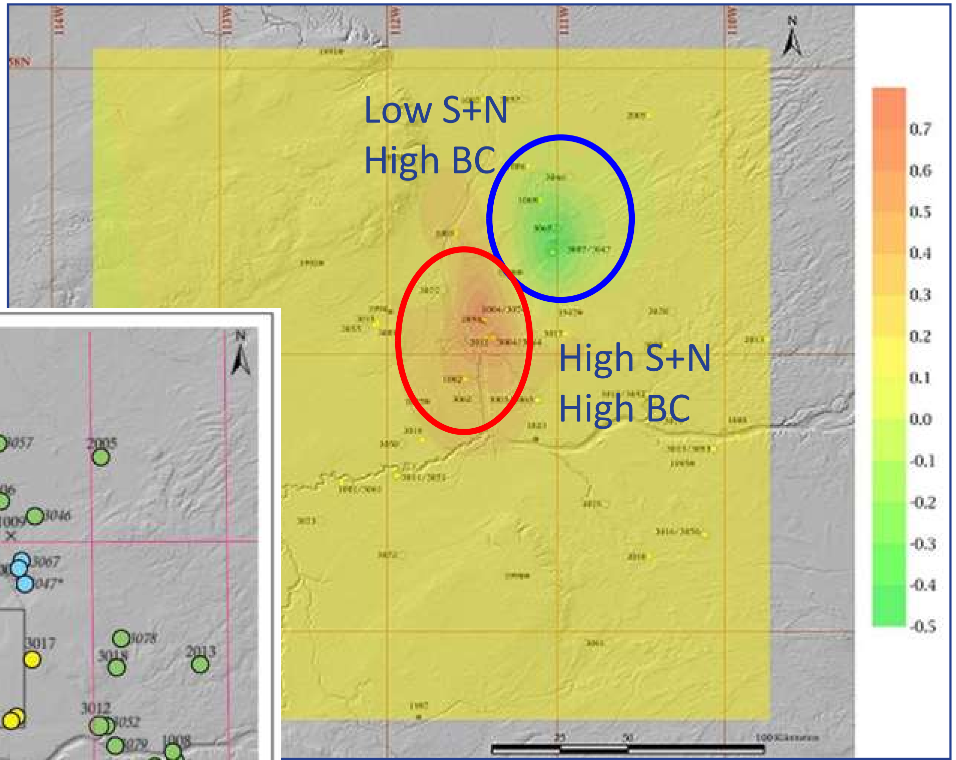
- Deposition of S, N, and base cations (BC) show strong gradients, reaching near background levels 10 to 50 km from nearest sources
- PM_{10} deposition data limited to community/industrial sites, but indicate high alkalinity, strong spatial gradients and high seasonality

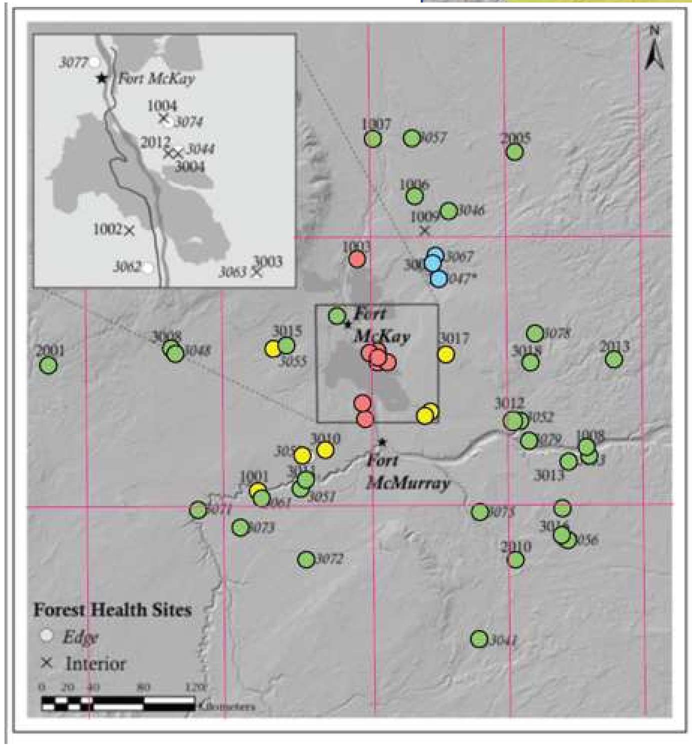




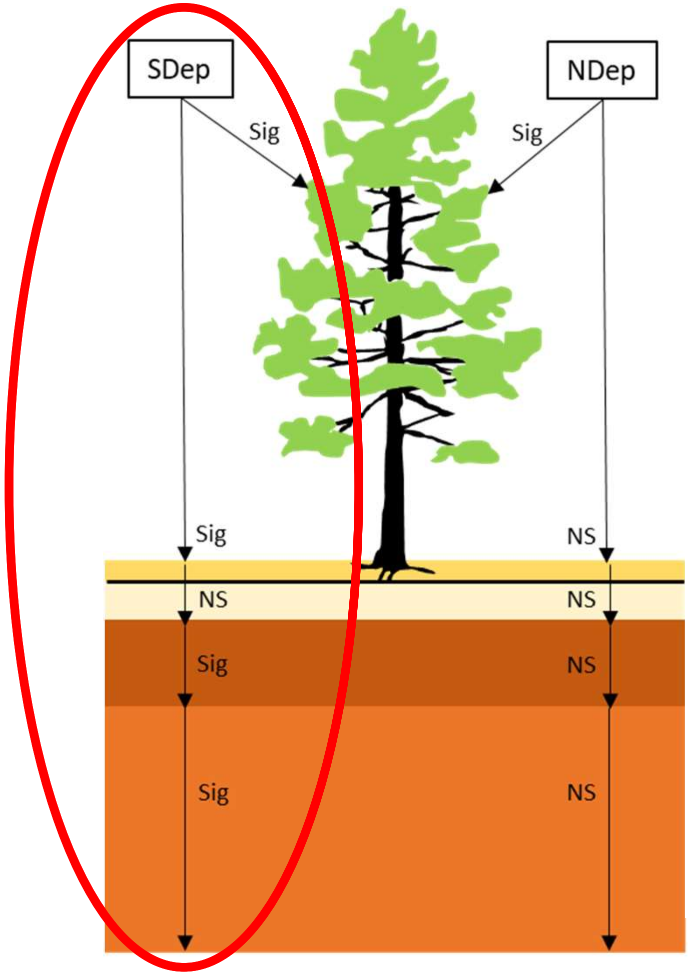
Estimated PAI at TEEM FHM Sites (2011-2012)

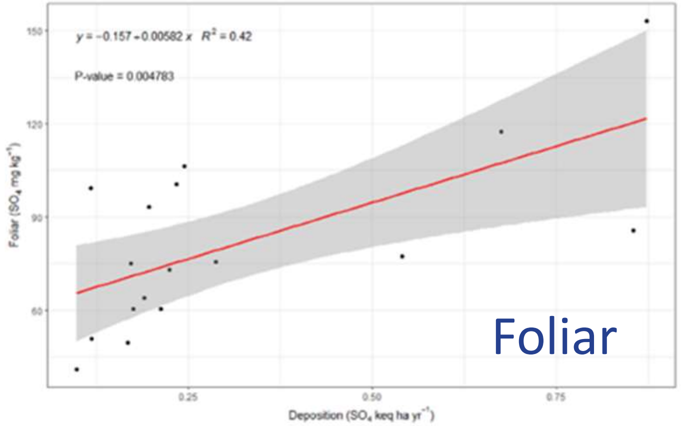
- Potential Acid Input (PAI) <0.2 keq H^+/ha/yr at most sites, ranging from -0.6 keq H^+/ha/yr (alkaline) to 0.8 keq H^+/ha/yr (acidic)
  - >0.25 keq H^+/ha/yr
  - >0.17 and <0.25 H^+ keq/ha/yr
  - <0.17 and >0.00 H^+ keq/ha/yr
  - <0.00 keq H^+/ha/yr (alkaline)

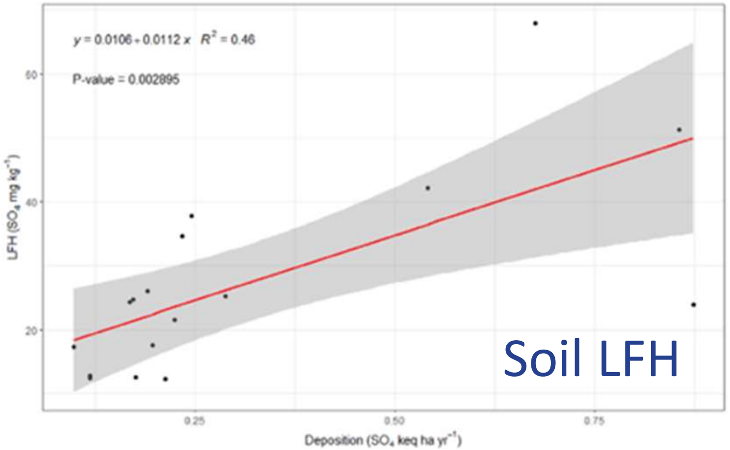


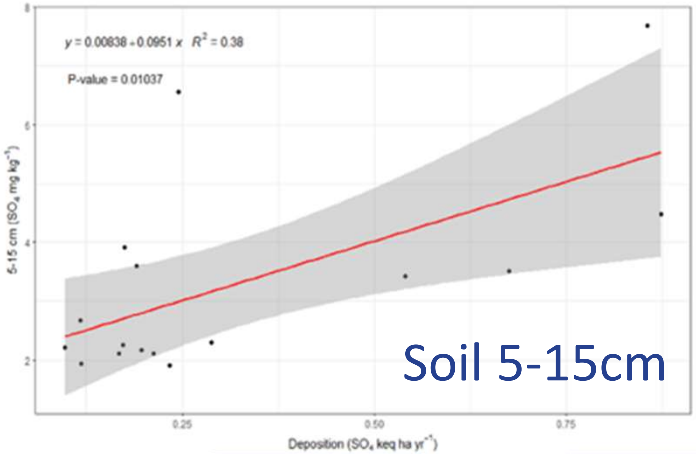


Sulphur in Tree Needles and Soil

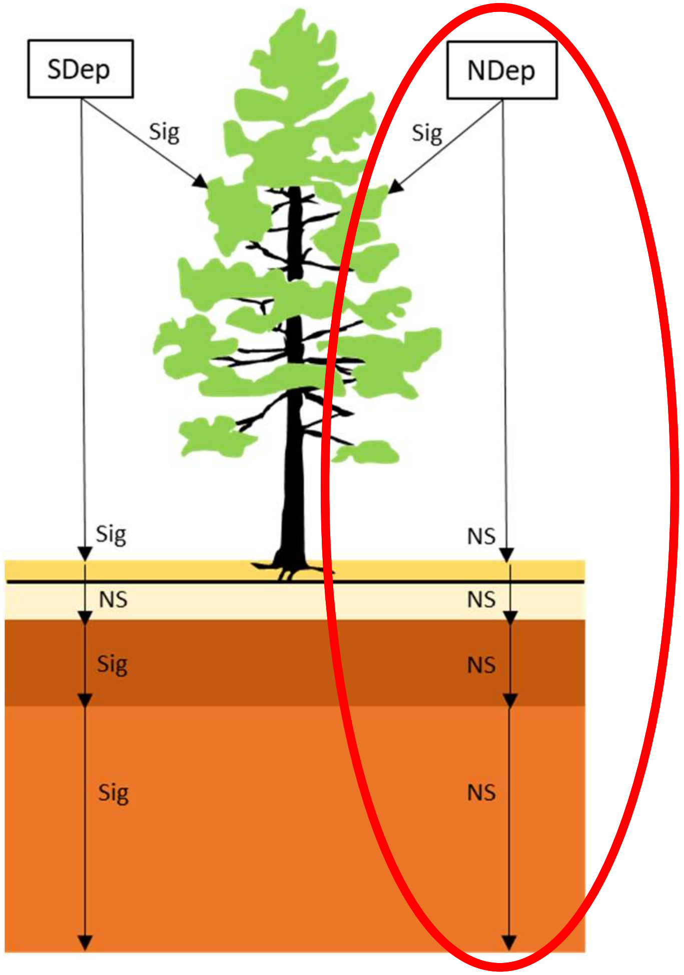


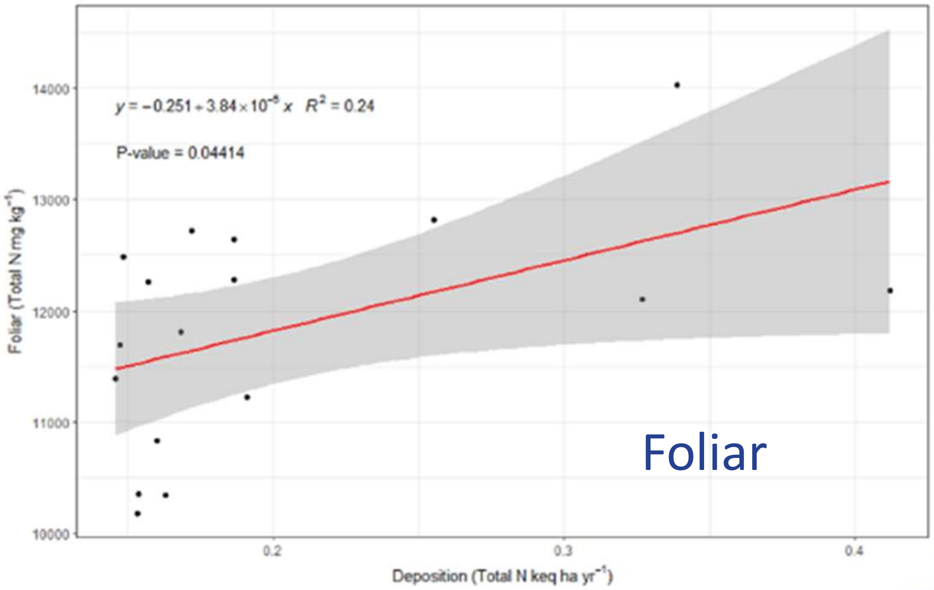






Nitrogen in Tree Needles and Soil





Evaluation of Atmospheric Deposition on Tree Growth and Understory Vegetation

Jack Pine Trees

BAI **increased** with N, S and BC deposition

BAI **higher** in pre-mining era compared with current period & natural gradients appear to be present

Understory Vegetation

Vascular plant cover, richness, and diversity **increased** in relation to N and S deposition

- Atmospheric deposition was **not detrimental** to tree growth or understory vegetation
- **Possible fertilization effect** due to enhanced atmospheric deposition of nitrogen compounds

Key Findings
20 Years of Forest Health Monitoring in the Athabasca Oil Sands

- There is alignment among air, deposition, soil, needle and lichen monitoring showing that deposition, increased elemental concentrations, and ecological responses are detectable within 50 km of the nearest oil sands emission sources, beyond which deposition occurs at near-background levels
- An area within the core of mining and upgrading operations is receiving deposition at levels that may exceed the critical load (acidification) for sensitive ecosystems. High, local base cation deposition levels was an unexpected finding
- No negative effects of deposition on jack pine tree growth have been observed, however, nitrogen deposition may be functioning as a fertilizer that is resulting in community composition changes (understory)

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W B E A

Thank You

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OIL SANDS MONITORING PROGRAM

Acknowledgements
TEEM Committee members past & present, Sanjay Prasad, Dianne McIsaac, Cody David, Yu-Mei Hsu, Kelly Munkittrick, Shanti Berryman, Martin Hansen, Emily White & numerous specialists and contractors

https://www.sciencedirect.com/journal/science-of-the-total-environment/special-issue/10LW6CG6CPT

Estimation of Potential Acid Input (PAI) to WBEA Forest Health Monitoring (FHM) Sites

Eric S. Edgerton

LICA ADMPEC Virtual Meeting

December 2, 2021

Ambient Concentrations and Total Deposition of Inorganic Sulfur, Inorganic Nitrogen and Base Cations in the AOSR

Eric S. Edgerton, Yu-Mei Hsu, Emily M. White, Matthew S. Landis, Mark E. Fenn

PAI Defined

- $PAI_i = S_{dep} + N_{dep} - BC_{dep}$

  $= (S_{wet} + N_{wet} - BC_{wet}) + (S_{dry} + N_{dry} - BC_{dry})$

  Where, i is i^{th} land use, BC = base cations (Ca^{2+}, K^+, Mg^{2+}, Na^+), and units are kequiv/ha.

  Ca^{2+} is the dominant base cation

  N_{dry} is estimated from ambient concentrations of NO_2, HNO_3, NH_3 and site-specific deposition velocity (V_d)

WBEA Approach

- $PAI_{JP} \sim N_{bulk} + N_{dry} + S_{throughfall} - adjBC_{throughfall}$

  Where, JP are jack pine sites, bulk refers to open IER deposition and throughfall refers to throughfall IER deposition

4 Key Measurements Used to Estimate PAI to Jack Pine Sites

- Bulk deposition of NH_4^+ and NO_3^-
- Active and passive concentrations of NO_2, HNO_3 and NH_3
- Throughfall deposition of SO_4^{2-}
- Throughfall deposition of base cations

Note: particulate NH_4^+ and NO_3^- are assumed to be minor components of deposition, and can be inferred from measurements at other sites

Canopy Interactions (What does jack pine add/subtract from incoming deposition?)

Subtractions

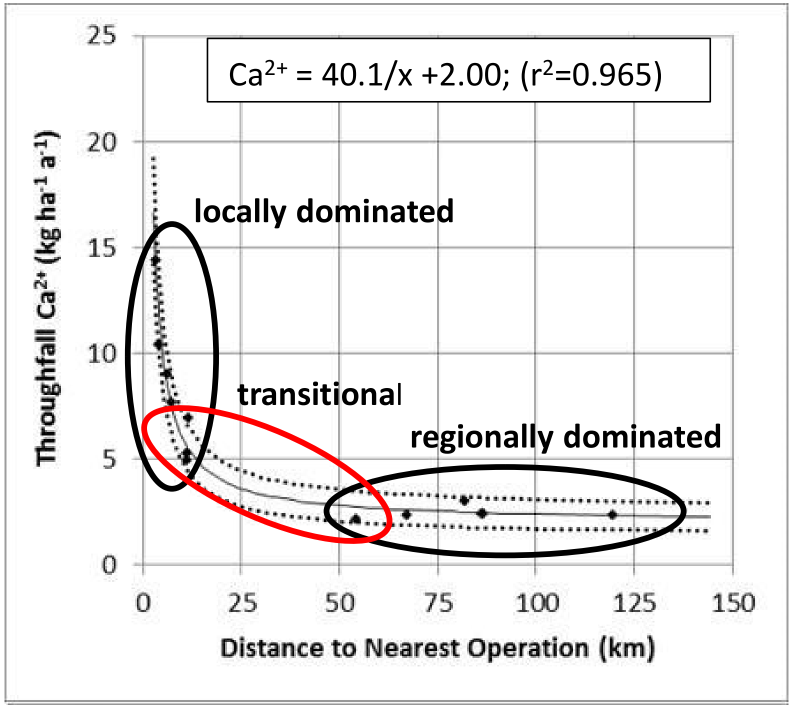
NH_4^+ ~ 50%
NO_3^- ~ 50%
SO_4^{2-} 0-20%?

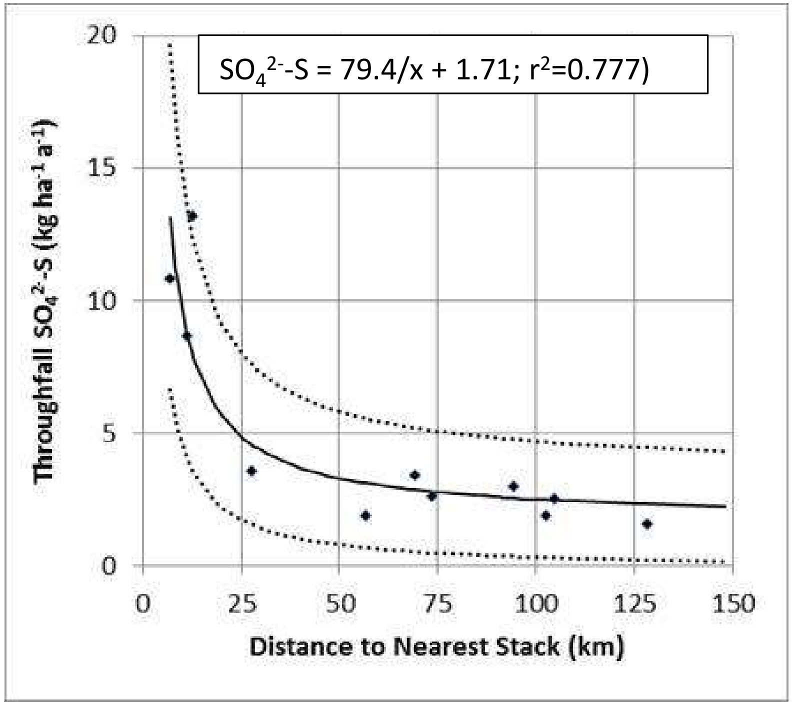
Additions

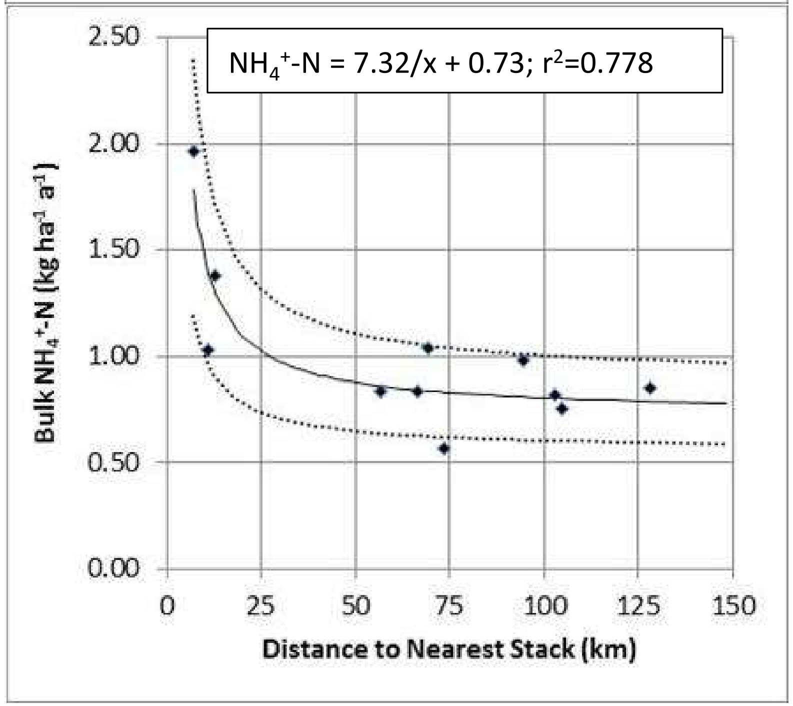
K^+ ~100%
Mg^{2+} ~40%
Ca^{2+} ~0-10%
Na^+ 0*

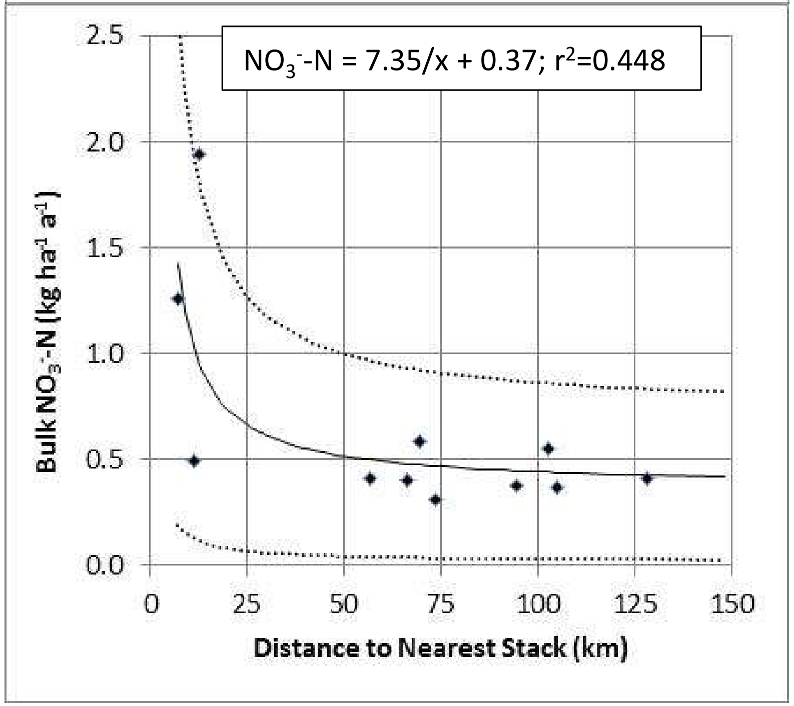
* assumed conservative

Deposition Gradients for Key Components of PAI

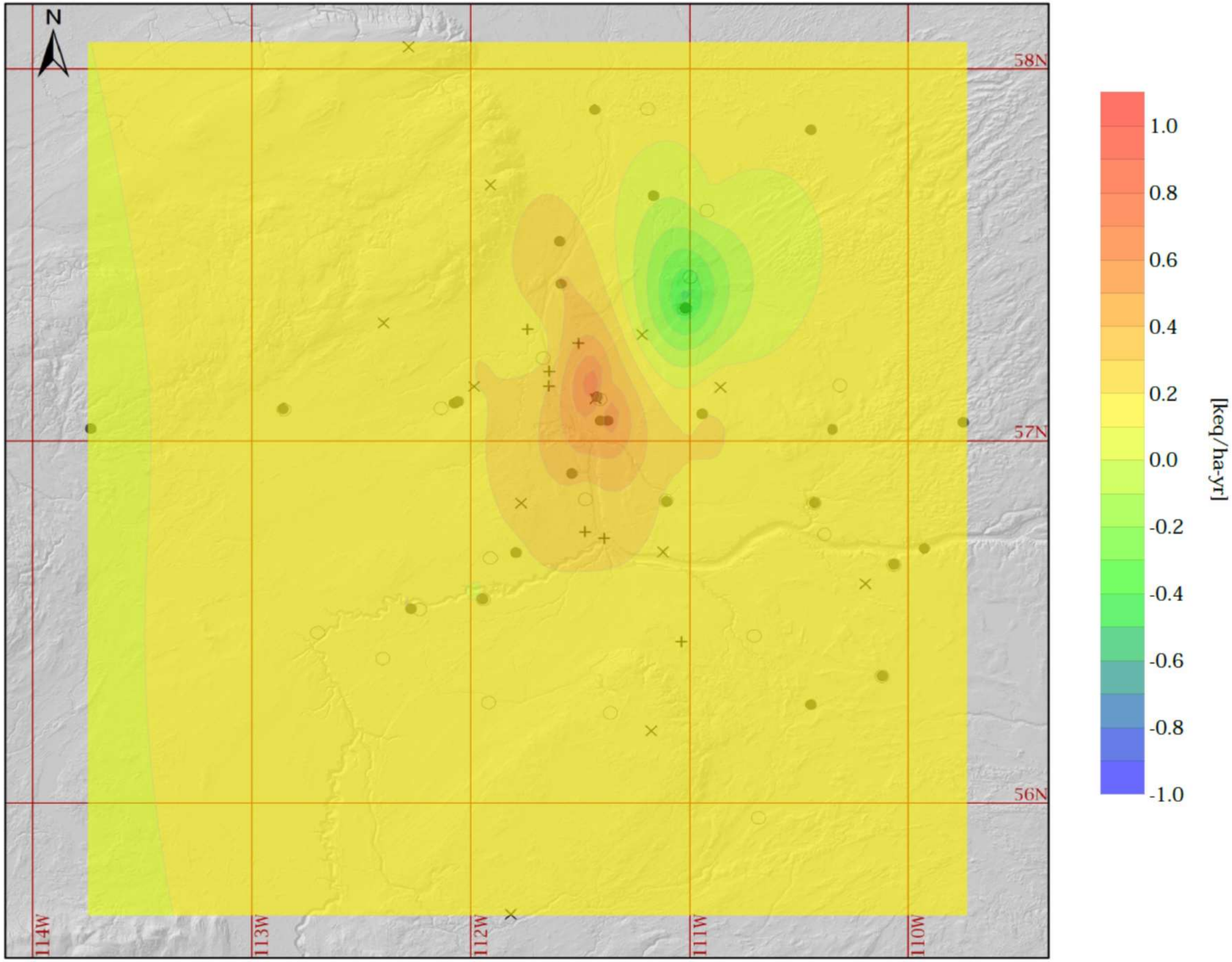








Estimated Potential Acid Input (2011-12)



PAI Defined

- $PAI_i = S_{dep} + N_{dep} – BC_{dep}$

  $= (S_{wet} + N_{wet} – BC_{wet}) + (S_{dry} + N_{dry} – BC_{dry})$

  Where, i is i^{th} land use, BC = base cations (Ca^{2+}, K^+, Mg^{2+}, Na^+), and units are kequiv/ha.

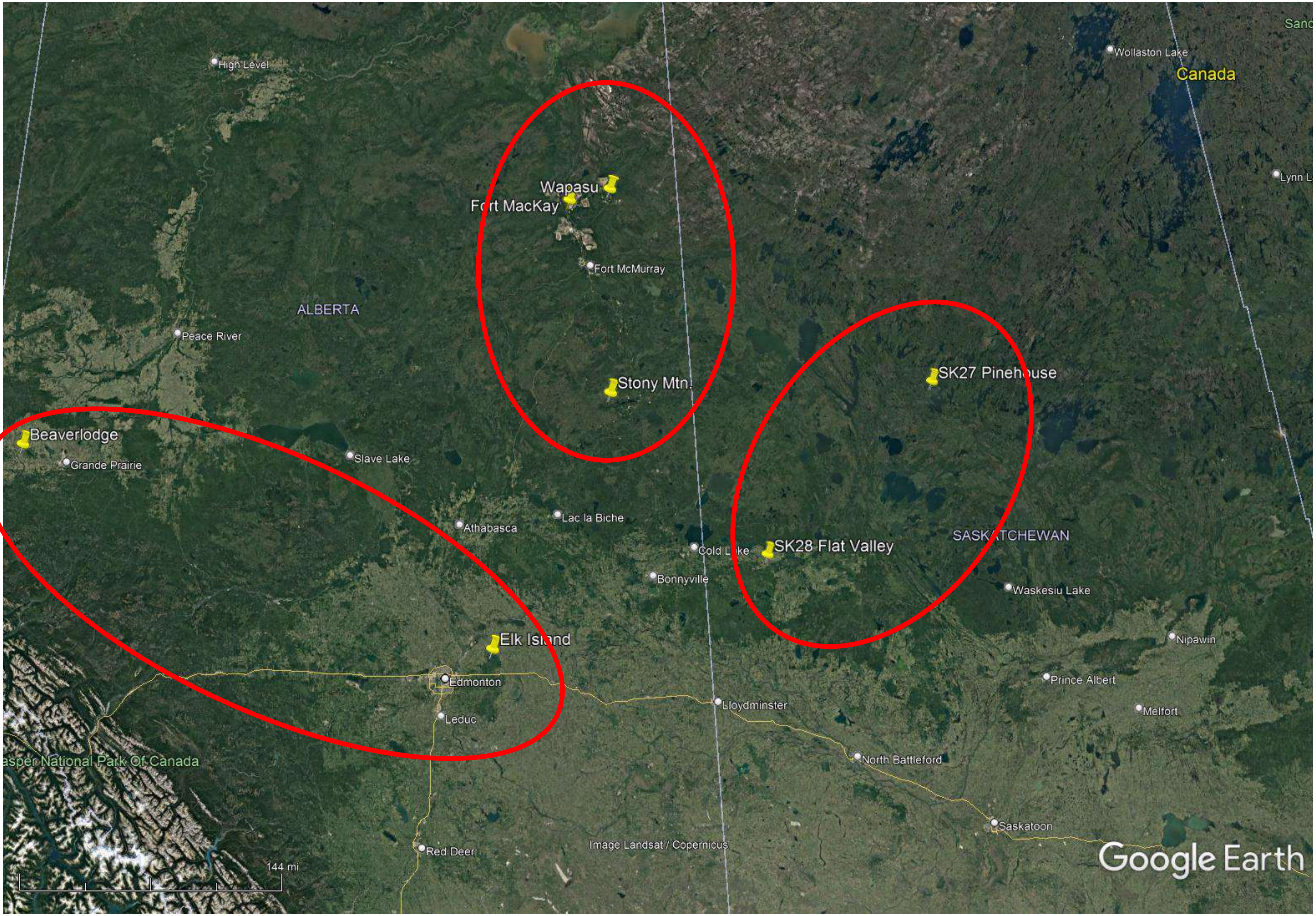
  Ca^{2+} is the dominant base cation

  N_{dry} is estimated from ambient concentrations of NO_2, HNO_3, NH_3 and site-specific deposition velocity (V_d)

Another Approach for PAI for Multiple Land-Use Application

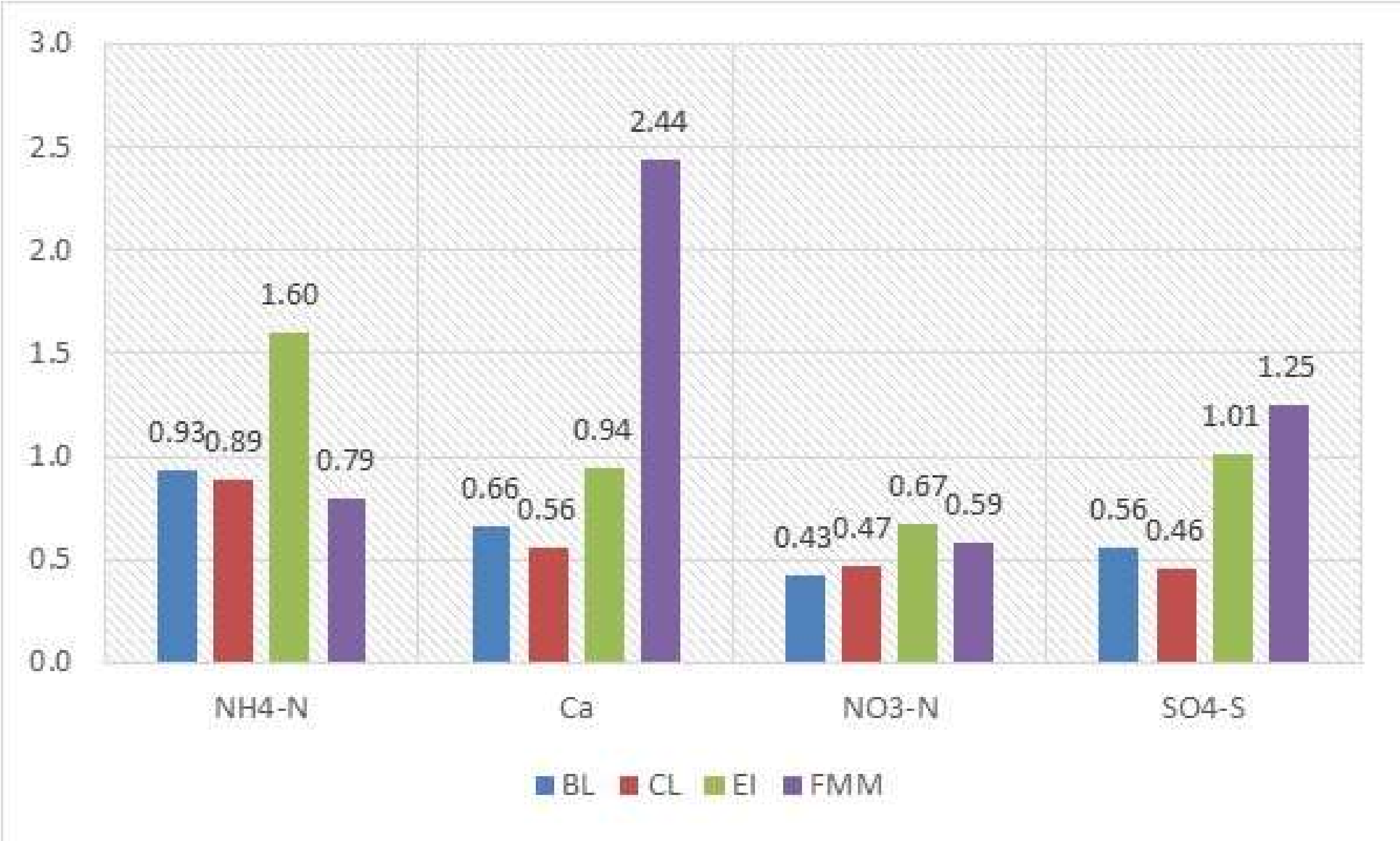
- Measure Wet Deposition (S,N,BC)
- Measure Ambient Gases and PM
  - Already measuring SO_2 and NO_2 via passives
  - Add HNO_3 and NH_3 using denuders
  - Add PM_{10} using partisol sampler
- Estimate Dry Components using Deposition Velocity Approach
  - Implement a dry deposition box model (MLM)
  - Use literature values for Vd
  - Use modelled values for Vd (GEM-MACH, CMAQ, etc.)

Wet Deposition Sites in Region of Interest



Multiple Networks with Current or Historical Data

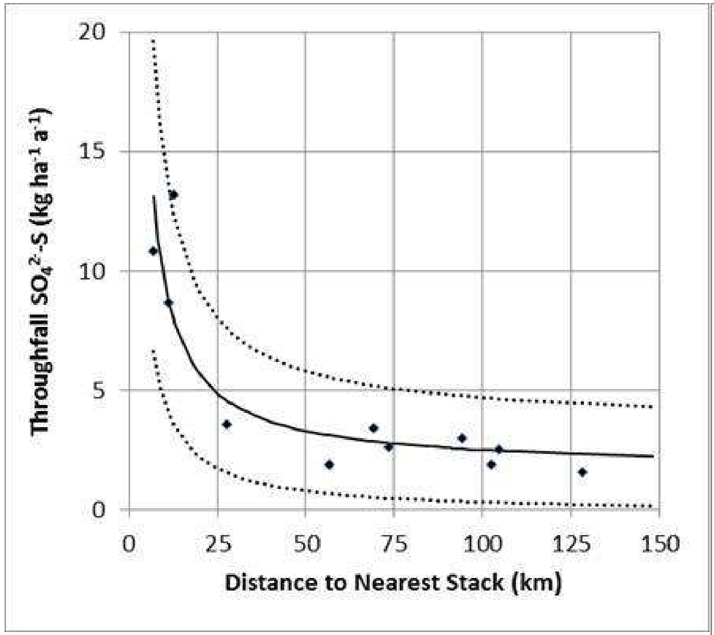
Wet Deposition at AB Sites 2014-16
(kg/ha)

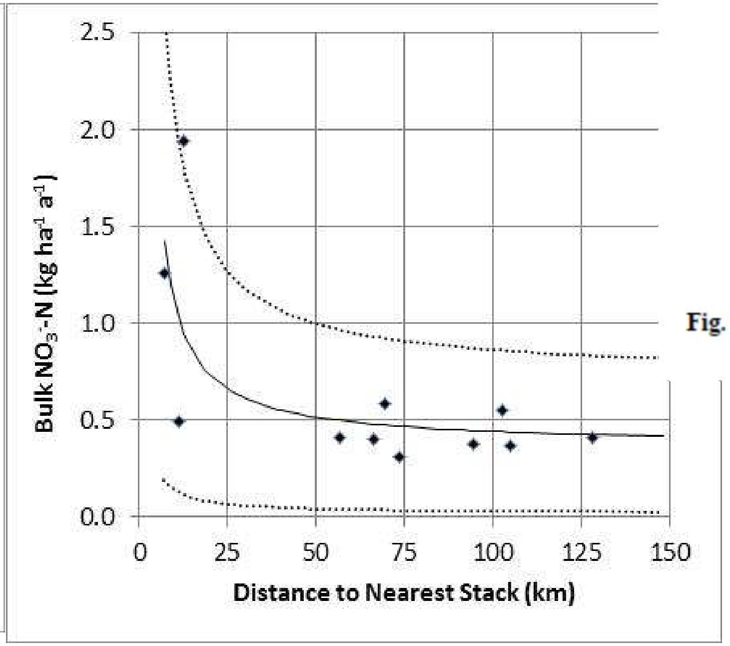


BL=Beaverlodge CL=Cold Lake EI=Elk Island FMM=Fort McMurray (AMS6)

What does 1 ppb of ambient concentration imply for dry deposition calculations?

kg/ha-yr			
SO2-S	NH3-N	HNO3-N	NO2-N
2.2	0.9	3.6	0.5





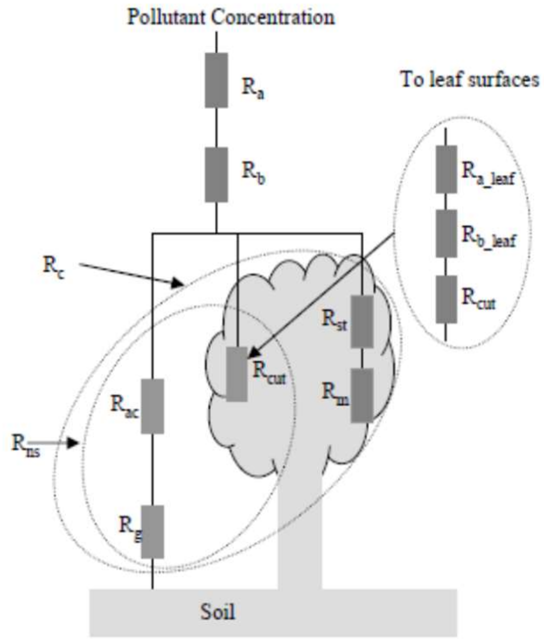
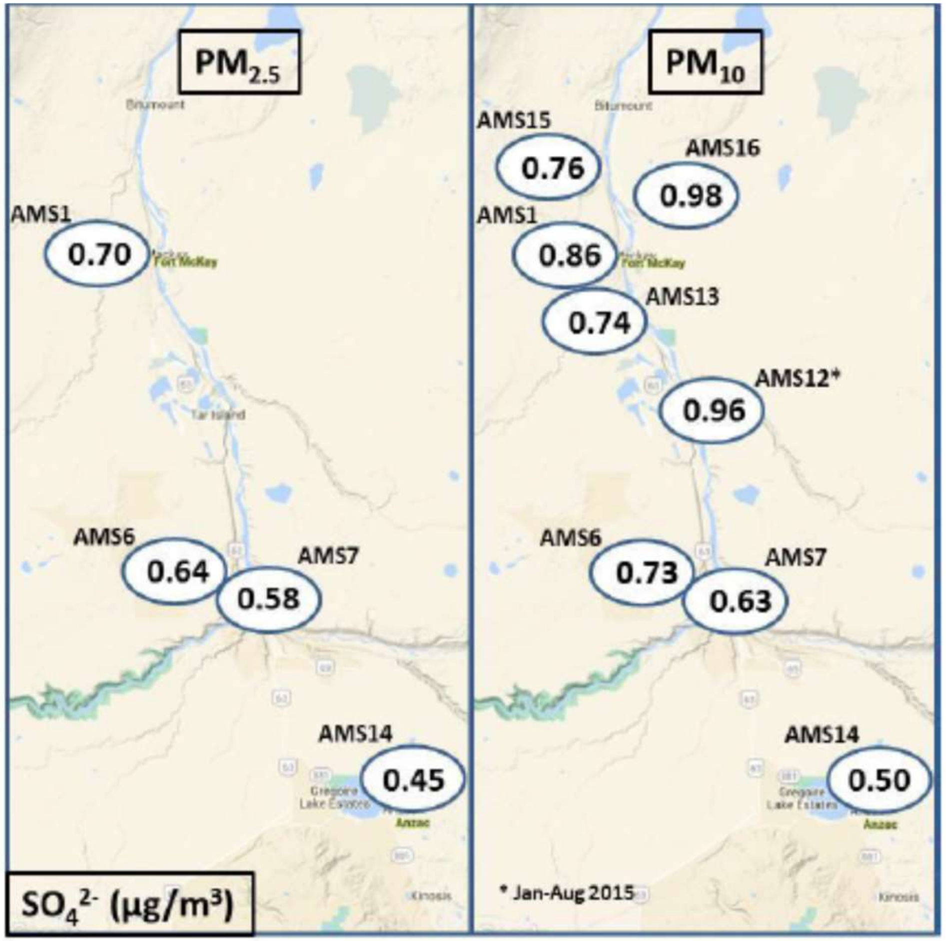


Fig. 1. Scheme of resistance analogy.

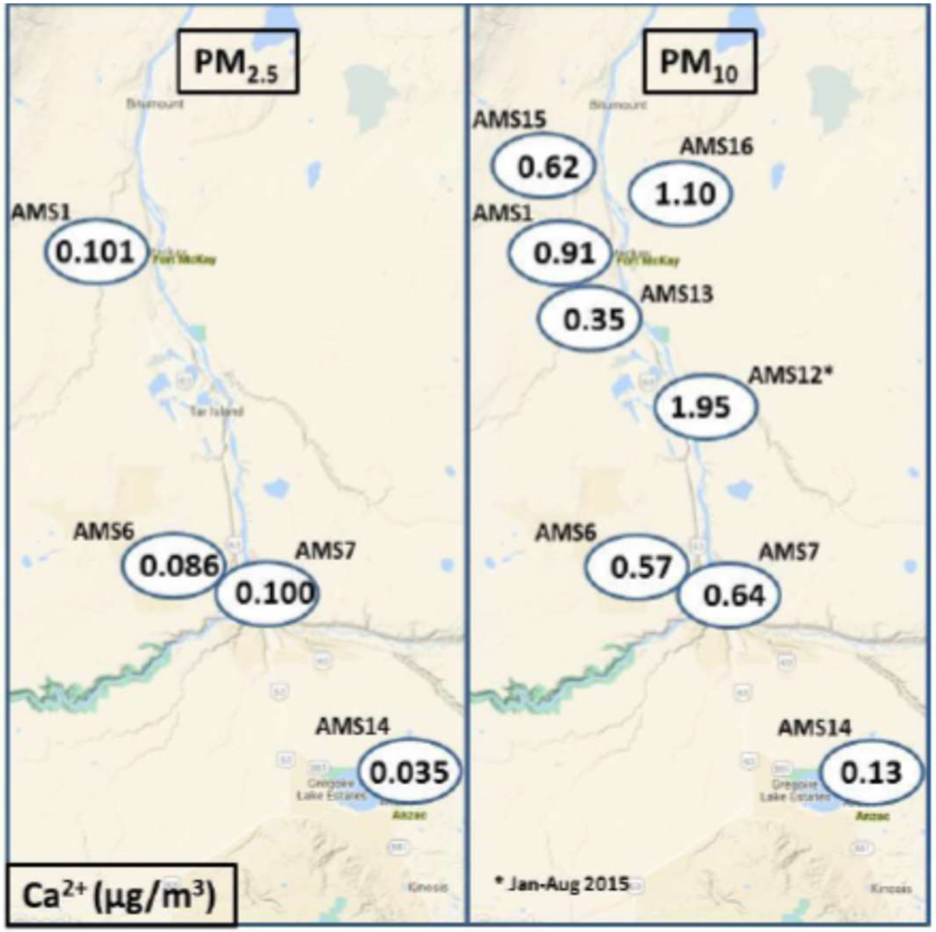
SO_4^{2-} and Ca^{2+} by Size Range

SO_4^{2-}



75-90% in $PM_{2.5}$

Ca^{2+}



75-90% >$PM_{2.5}$

Example Literature Values for Gas Phase Deposition Velocity

Table 2. Campaign-Average Dry Deposition Velocities[a]

	HNO_3	NO_3^-	NO_2	PAN	Other NO_y	NH_3	NH_4^+
FRS1	1.32	0.11	0.17	0.14	0.19	0.43	0.14
FRS2	1.38	0.20	0.27	0.21	0.26	0.43	0.16
EGB1	1.43	0.15	0.11	0.09	0.17	0.46	0.18
KEJ1	1.53	0.16	0.29	0.22	0.27	0.52	0.11
KEJ2	2.11	0.20	0.27	0.21	0.30	0.63	0.15
ALG1	1.06	0.09	0.09	0.07	0.12	0.35	0.09
ALG2	0.98	0.14	0.16	0.12	0.17	0.33	0.08
LED1	1.30	0.17	0.27	0.20	0.25	0.51	0.11
LED2	1.21	0.10	0.16	0.12	0.17	0.32	0.10
CHA1	0.61	0.09	0.06	0.05	0.09	0.12	0.10
CHA2	1.10	0.15	0.20	0.14	0.19	0.48	0.10
SPR1	1.09	0.16	0.22	0.17	0.21	0.44	0.10
SPR2	0.89	0.10	0.11	0.09	0.13	0.28	0.09
BRL1	1.02	0.14	0.07	0.05	0.13	0.32	0.15

[a]Unit is cm s^{-1}.

Dry deposition of individual nitrogen species at eight Canadian rural sites

L. Zhang,[1] R. Vet,[1] J. M. O'Brien,[1] C. Mihele,[1] Z. Liang,[1] and A. Wiebe[1]

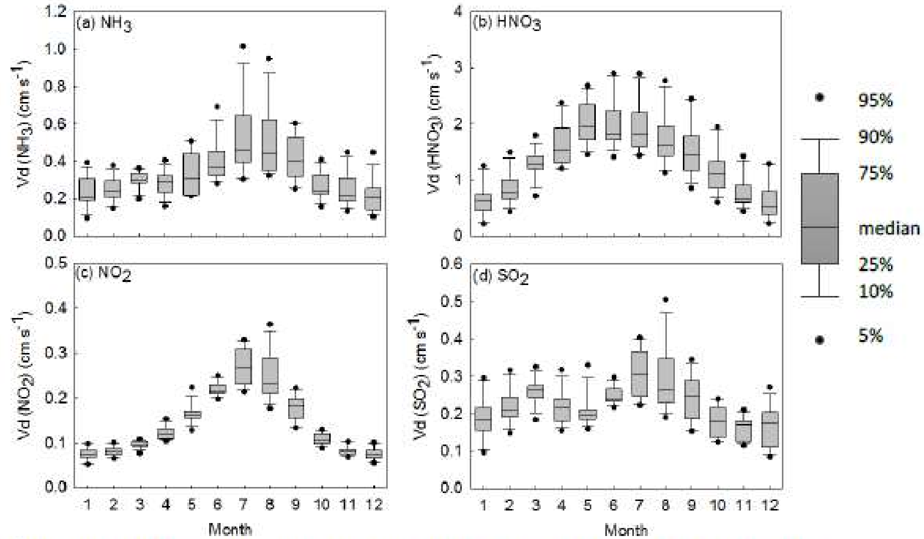


Figure 2. 15 Monthly deposition velocities of (a) NH_3, (b) HNO_3, (c) NO_2 and (d) SO_2 at AMS 1 (from 2000 to 2012) calculated by MLM.

2015 Forest Health Report

Thanks for your time.

Questions?