

The Potential for Peatland Reclamation in the Smelter-Impacted Landscape of Sudbury, Ontario, Canada

Peter Beckett
Professor Emeritus

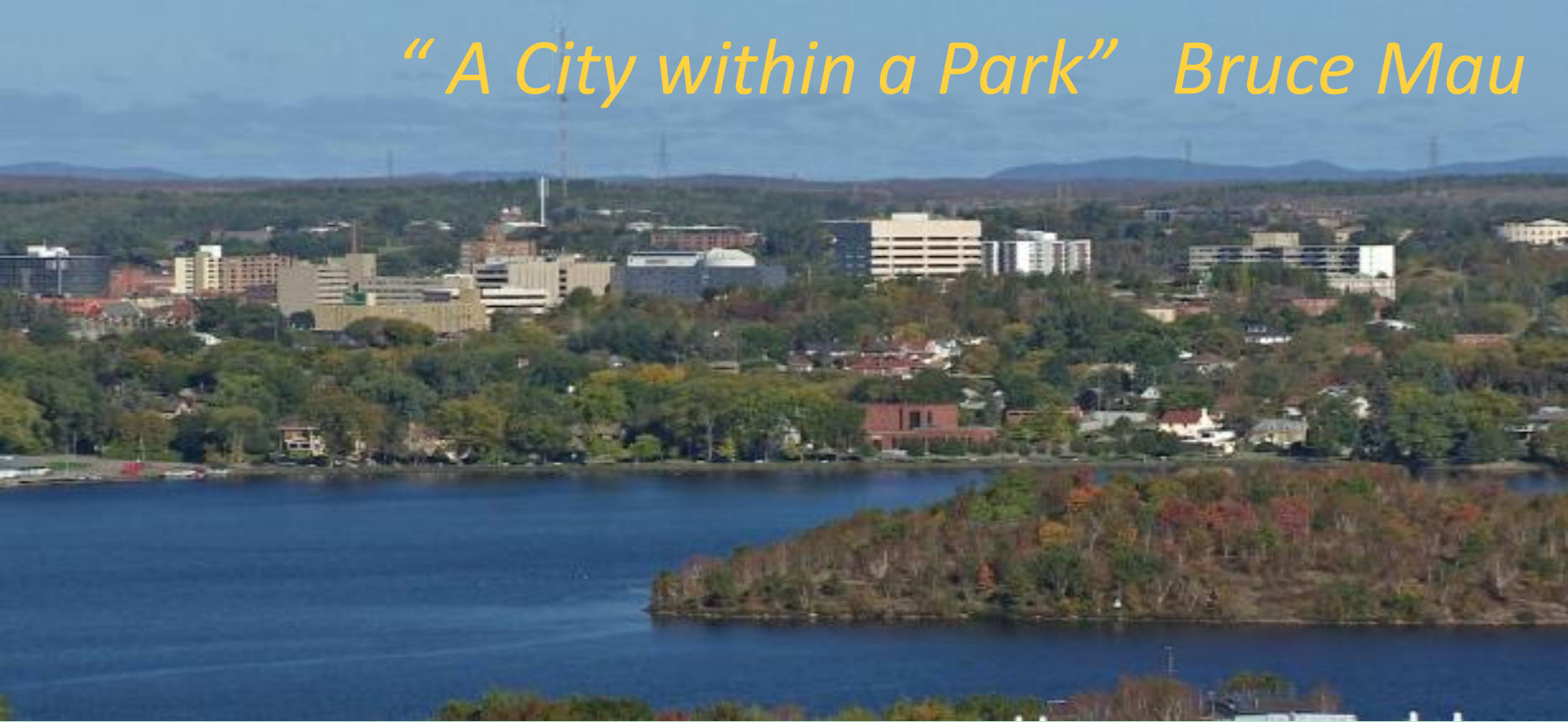


Laurentian University
Université Laurentienne

ASRS 42nd Annual Meeting, Butte, Montana

Sudbury, Canada today – 166,000 people

“A City within a Park” Bruce Mau



Land Acknowledgment

We would like to acknowledge the Robinson-Huron Treaty of 1850. We also recognize that activities occur on the traditional lands of the Atikameksheng Anishnawbek and that the City of Greater Sudbury, also includes the traditional lands of the Wahnapiitae First Nation. We extend our deepest respect to all Indigenous peoples - Miigwech.



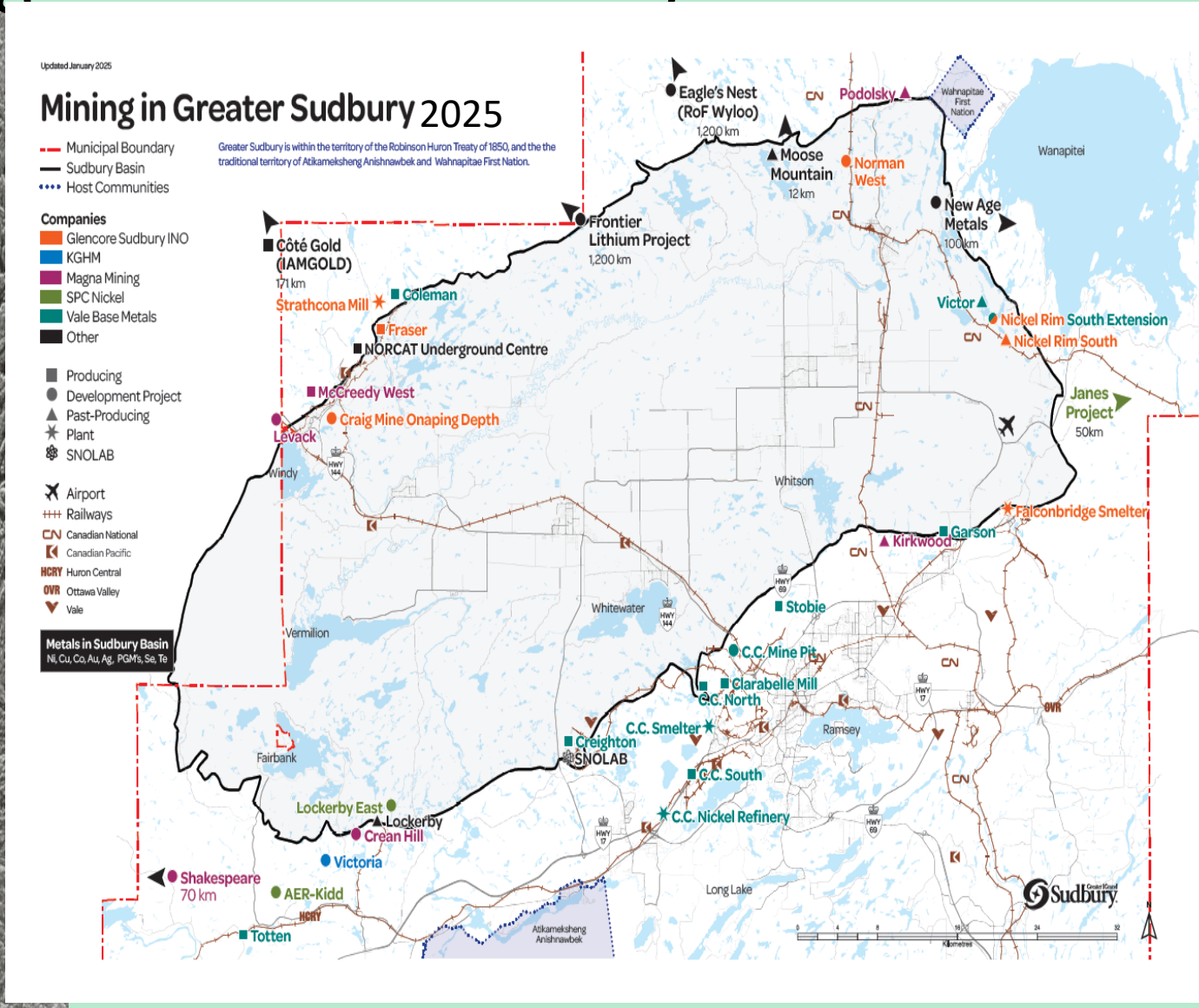
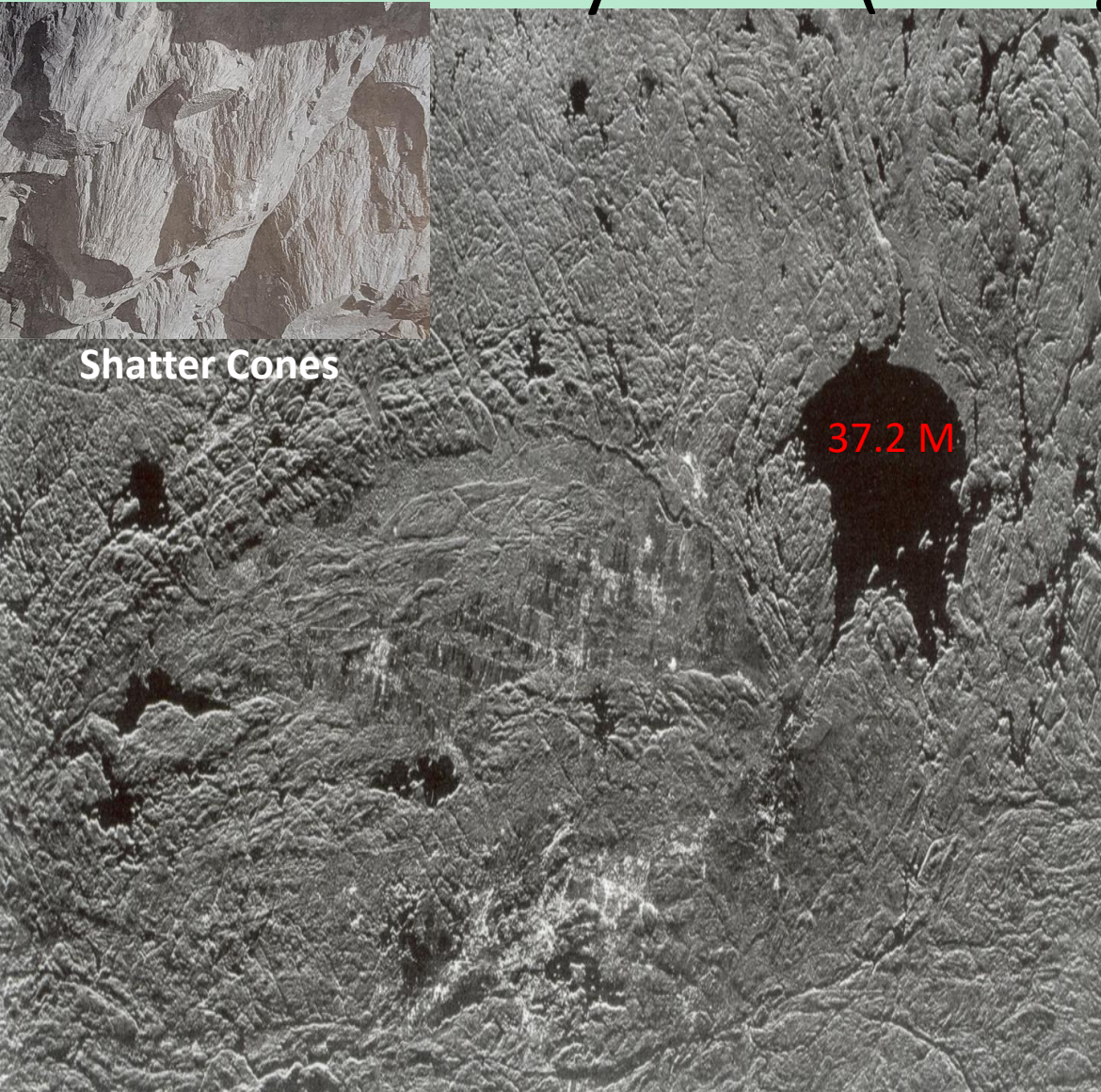
Atikameksheng
Anishnawbek





Landscape with big changes 1: Meteorite impact 1.85 B years ago

Sudbury Basin (3rd largest crater on earth)



Landscape Big Change 2: Green Landscape and Soil formation

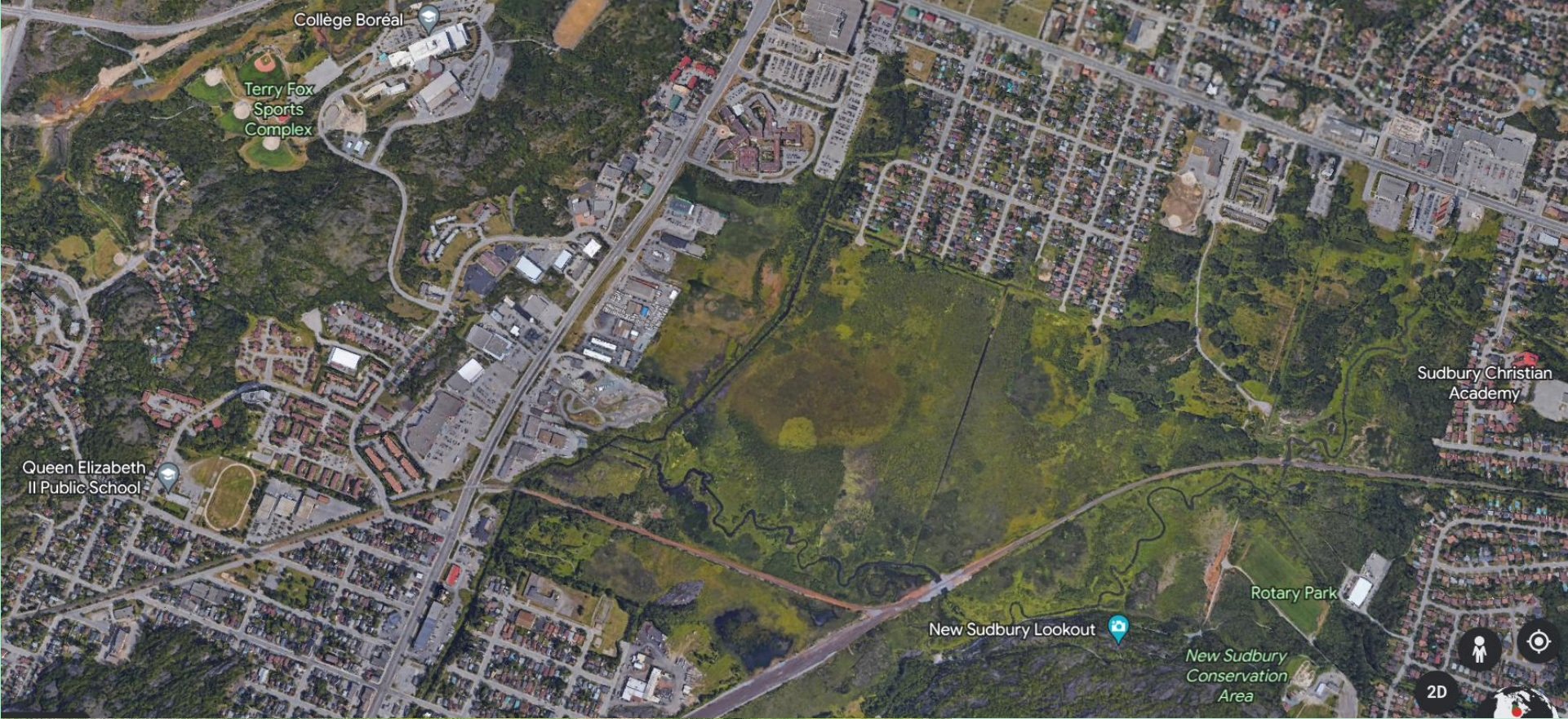


330 lakes – creeks – wetlands – hills - forests



soil





Ponderosa Wetland on
Junction Creek

Provincially Significant
Wetland

Landscape Change 3: Destruction



Late 19th Century
- Commercial forestry



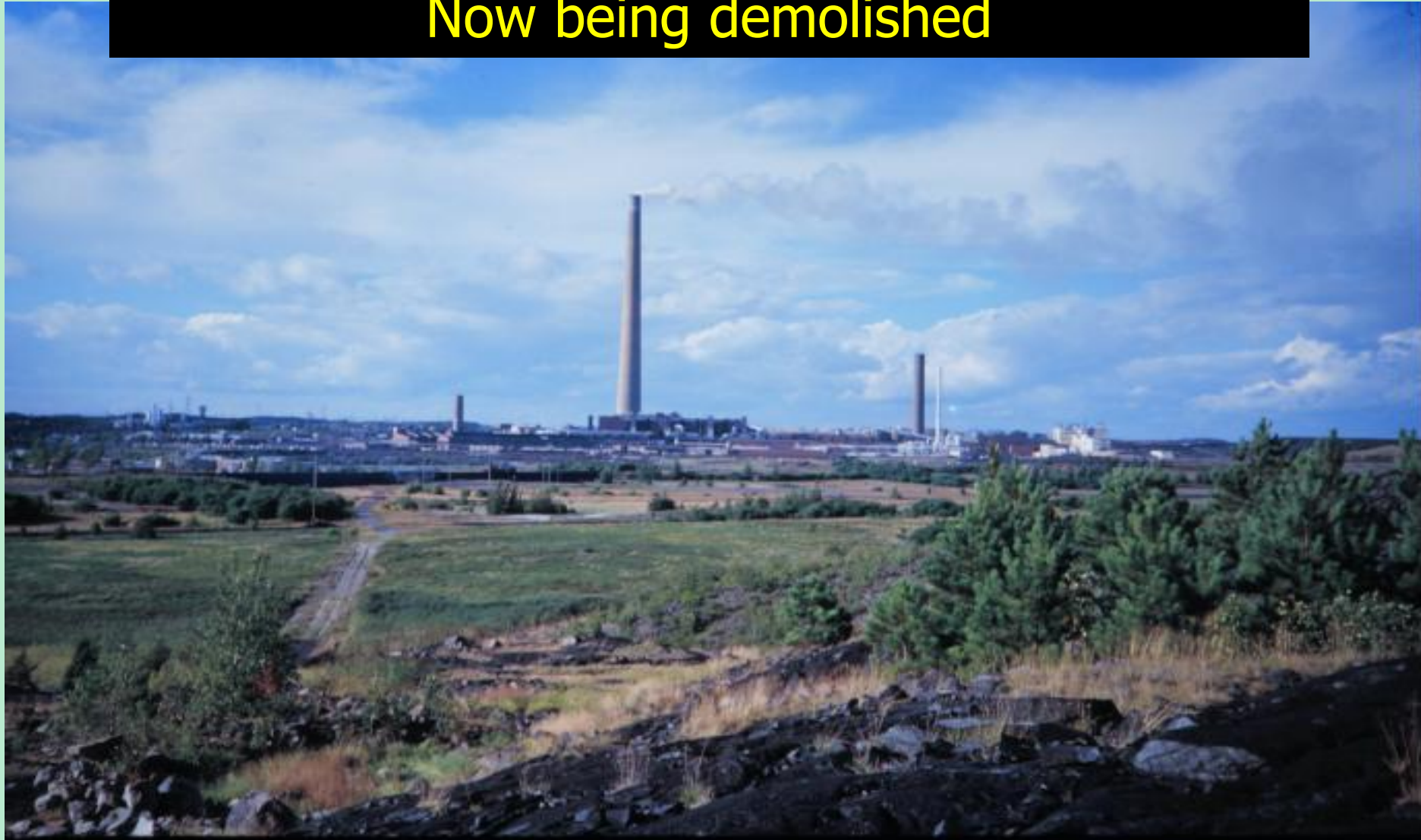
1886-1928
- open air roasting
13 roastyards – sulphur dioxide

Mining,
Smelting for
Cu, Ni

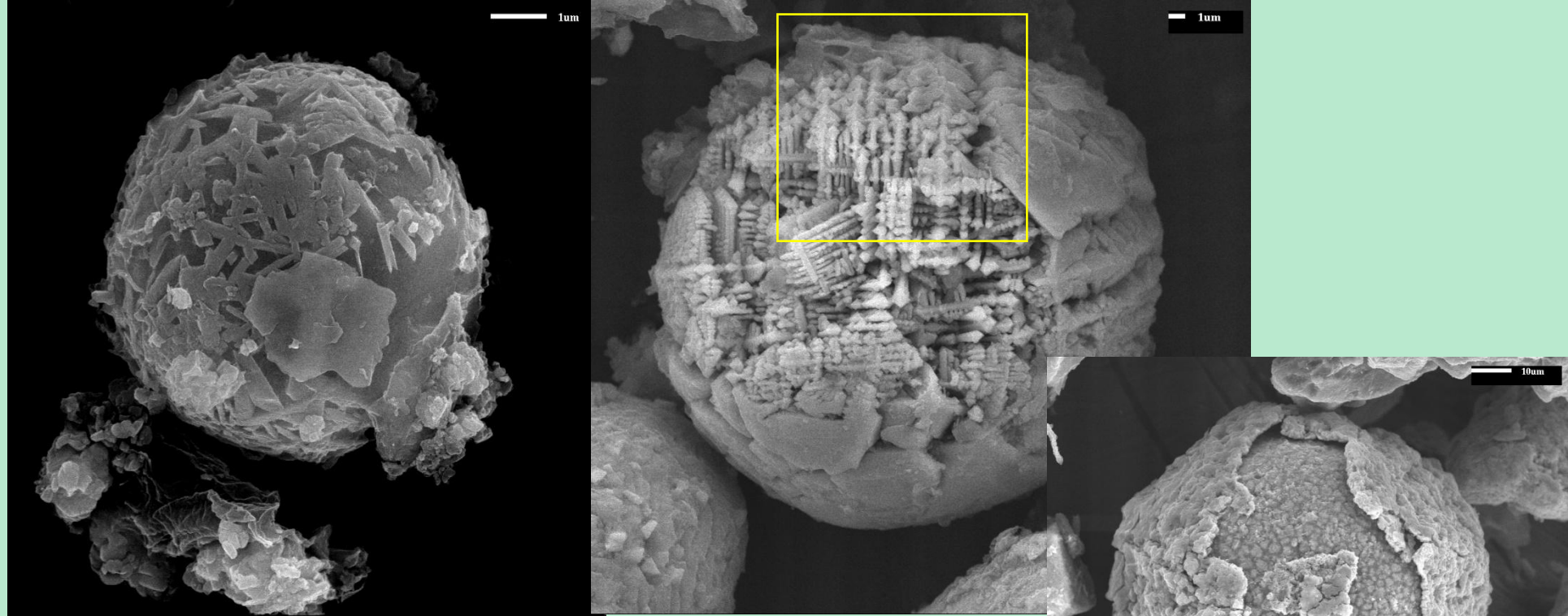
Major 3 smelters
from 1928 to 1972
2 smelters 1972 to
present



**The Sudbury Icon– The superstack 1972-2024
Now being demolished**



Source of Metal Enrichment: Fugitive Aerosol Particles from Smelters



Graeme Spiers

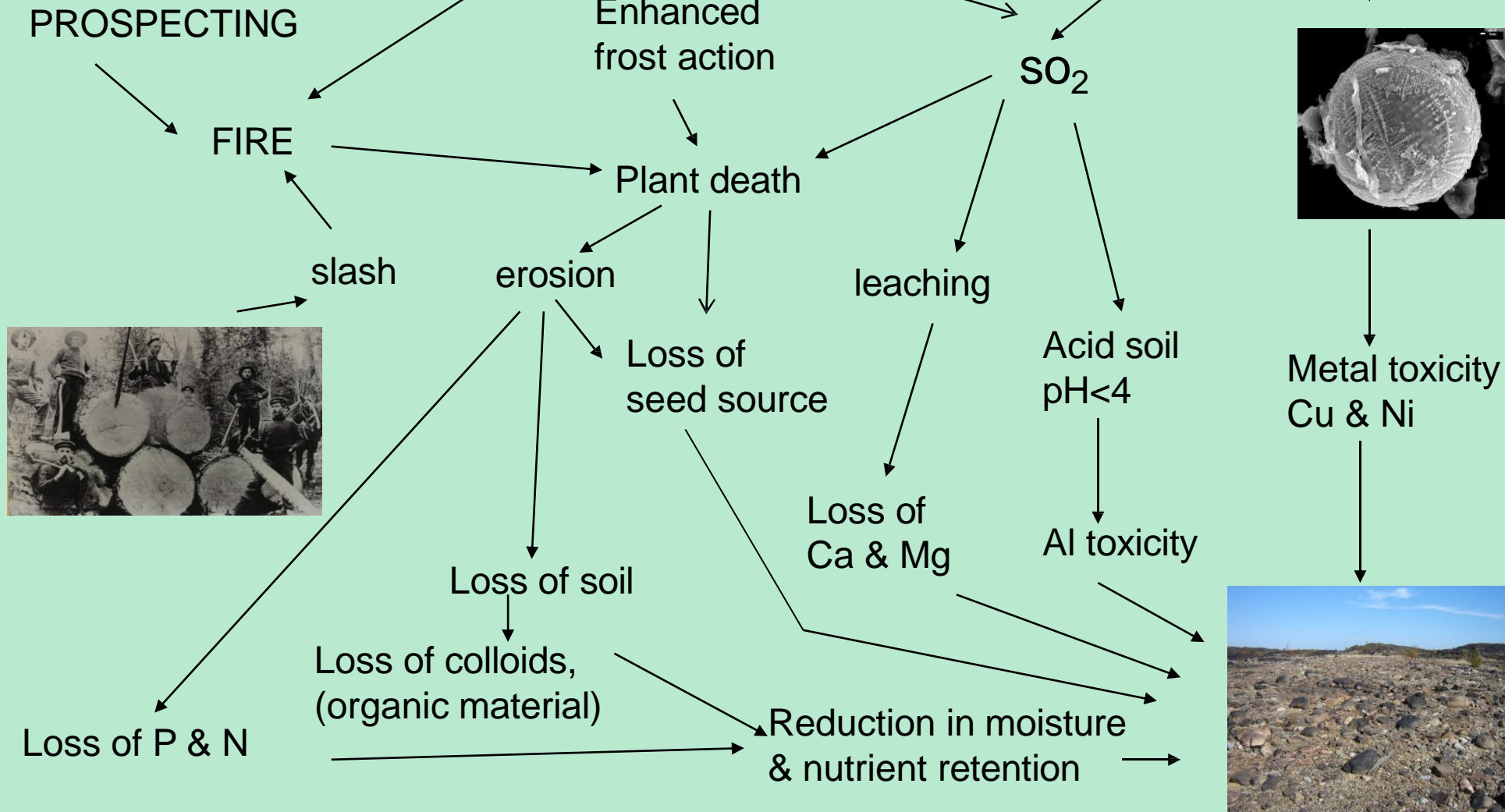
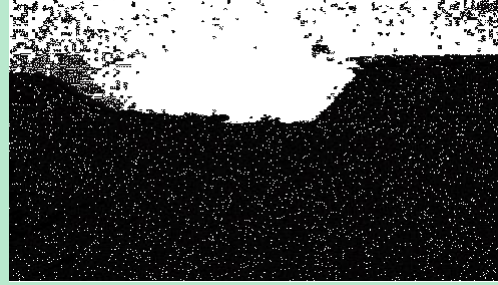
Slow dissolution by soil acids

Effects on Sudbury soils

Soil Layers	As	Cr	Cu	Ni	Pb	Se	Zn
0 to 5cm	60	95	4550	2560	417	24	188
5 to 10cm	17	42	105	40	12	1	32
10 to 20cm	7	82	13	62	12	1	117
20 to 50cm	4	66	14	32	6	nd	46
80+ cm	7	55	17	23	8	1	37

pH < 3.5

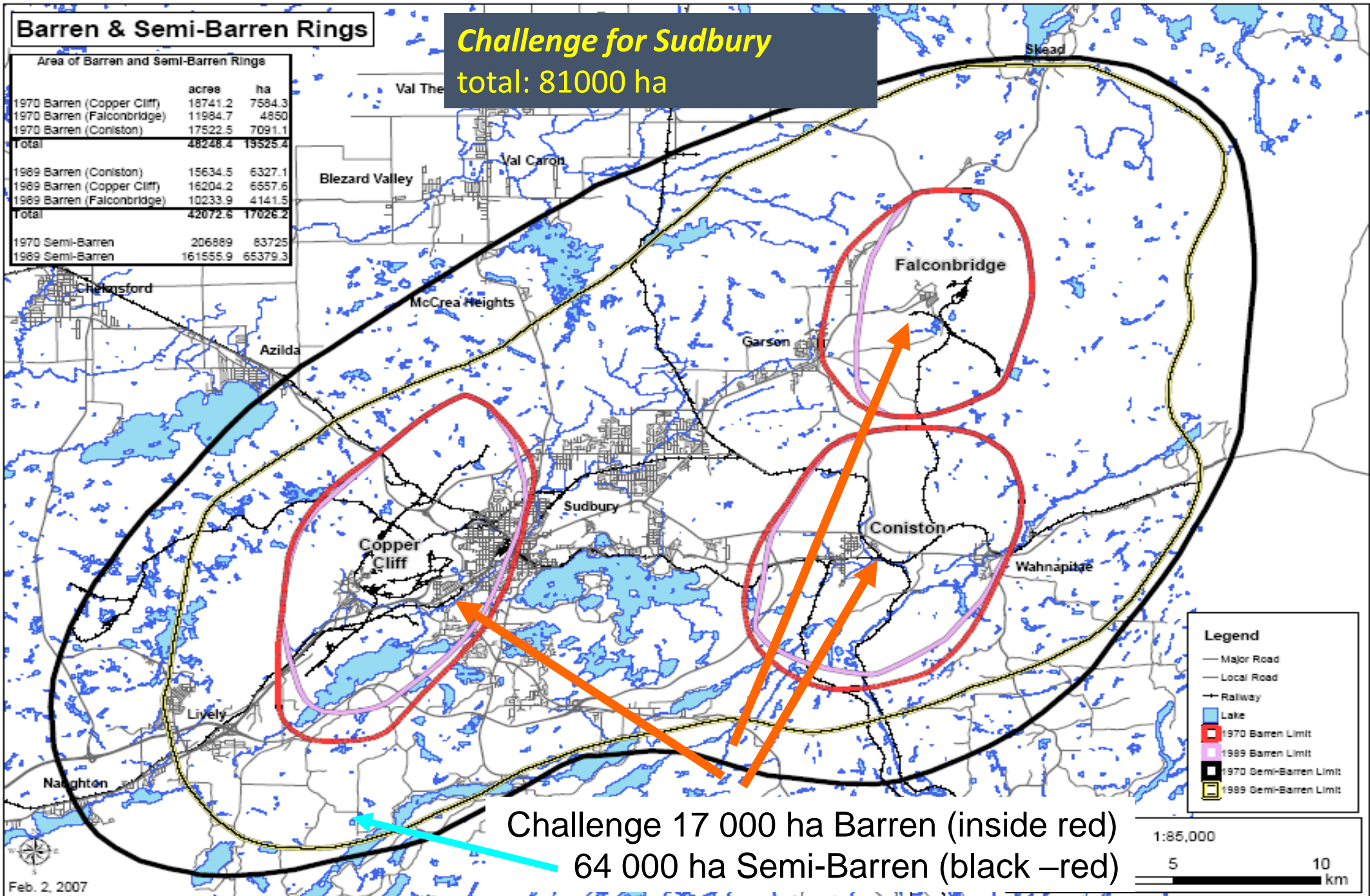
Synopsis of Ecological Effects



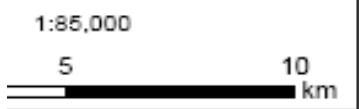
Barren & Semi-Barren Rings

**Challenge for Sudbury
total: 81000 ha**

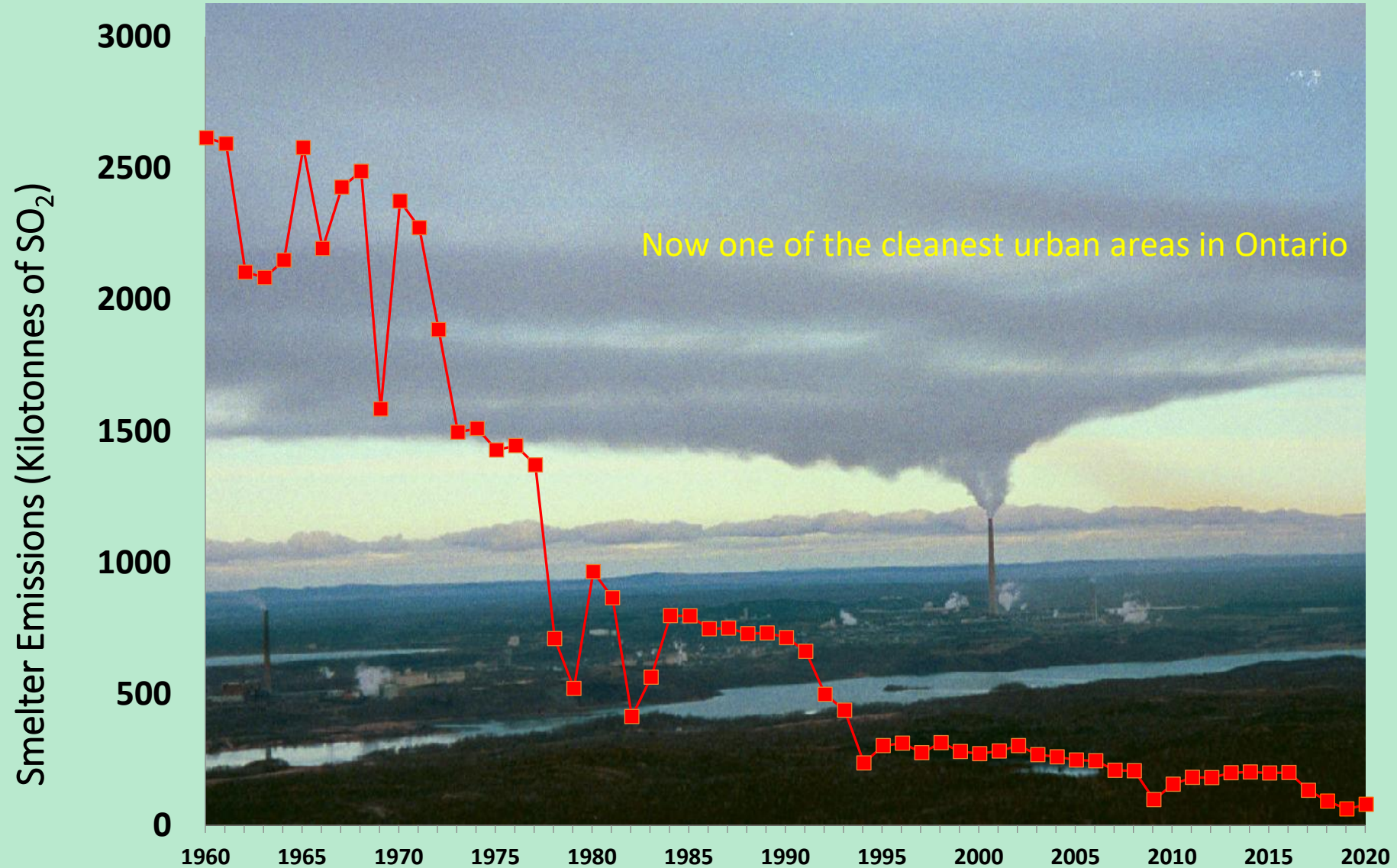
Area of Barren and Semi-Barren Rings		
	acree	ha
1970 Barren (Copper Cliff)	18741.2	7584.3
1970 Barren (Falconbridge)	11984.7	4850
1970 Barren (Coniston)	17522.5	7091.1
Total	48248.4	19525.4
1989 Barren (Coniston)	15634.5	6327.1
1989 Barren (Copper Cliff)	16204.2	6557.6
1989 Barren (Falconbridge)	10233.9	4141.5
Total	42072.6	17026.2
1970 Semi-Barren	206889	83725
1989 Semi-Barren	161555.9	65379.3



Challenge 17 000 ha Barren (inside red)
64 000 ha Semi-Barren (black – red)



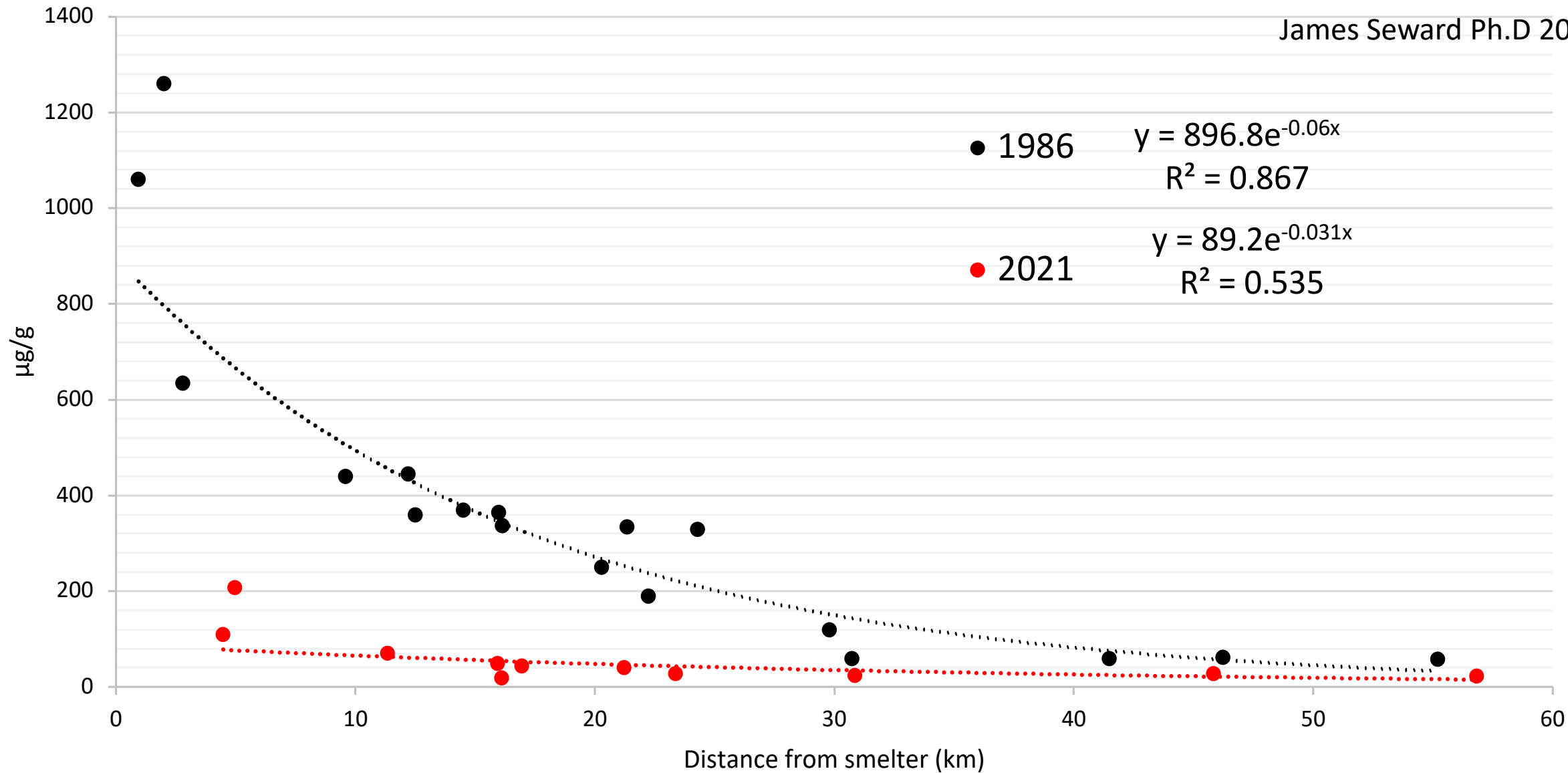
Sudbury Industrial Solution: SO₂ emission reduction 1970's – 2022 : >95% reduction



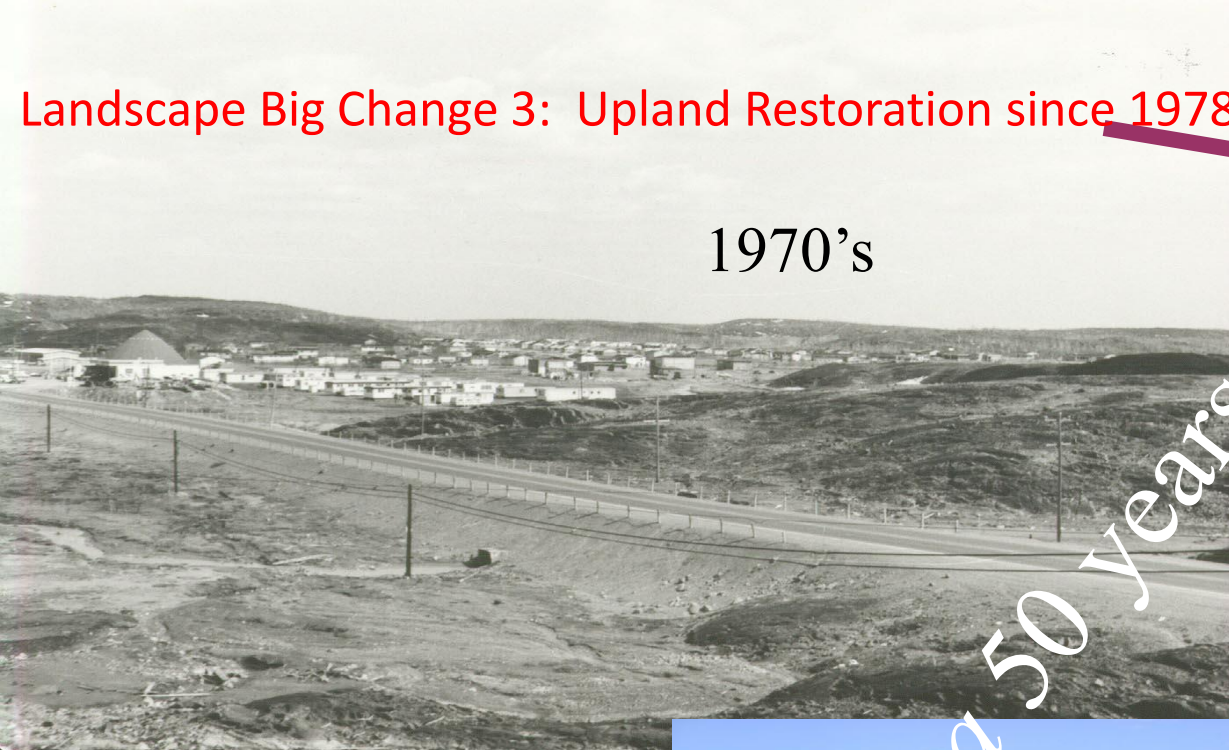
Decreases in SO₂ emissions allow vegetation recovery and growth

Total Cu (Dried Peat) vs Peatland-Smelter Proximity in 1986 & 2021

James Seward Ph.D 2023



Landscape Big Change 3: Upland Restoration since 1978



Wahnapiatae

A story of landscape change
through community action



Sustainability: community, industry, First Nations, academia and government working together since 1973 – >50 y



Advisory Committee/Panel February 2024



Land Restoration

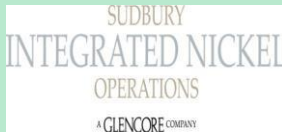


School Regreening

First Nations Industry



government



academia

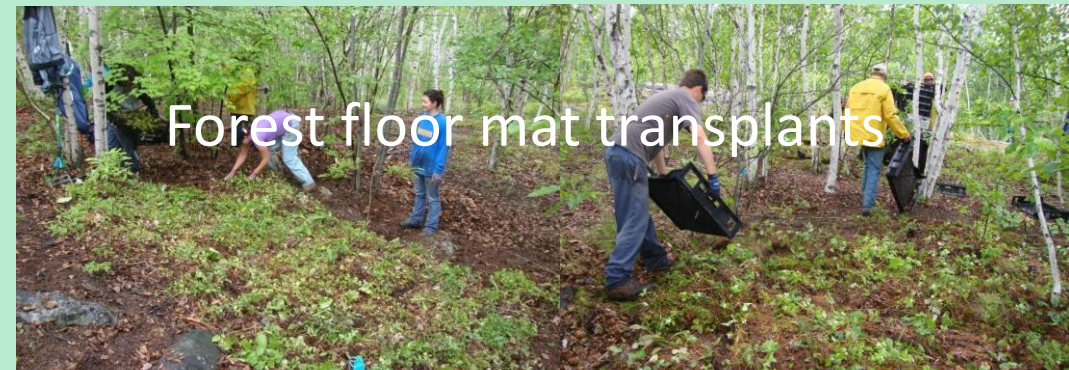


citizens, community groups



Aiming for Biodiversity: Sudbury Recipe

- Crushed limestone (dolomitic) – 10 t/ha (to counter acidity)
- Fertilizer (6-20-20) - 200 or 400 kg/ha (for nutrients)
- Initial seed mixture (mostly native grasses)
- Over 85 native tree and shrub species used (for habitat, structure, food and general diversity)
- Forest Floor mat and other transplants (increasing diversity)





Limestone

10 tonnes/ha

dolostone, dolomite

(Ca:Mg 55:45)

Need to raise pH > 4.85

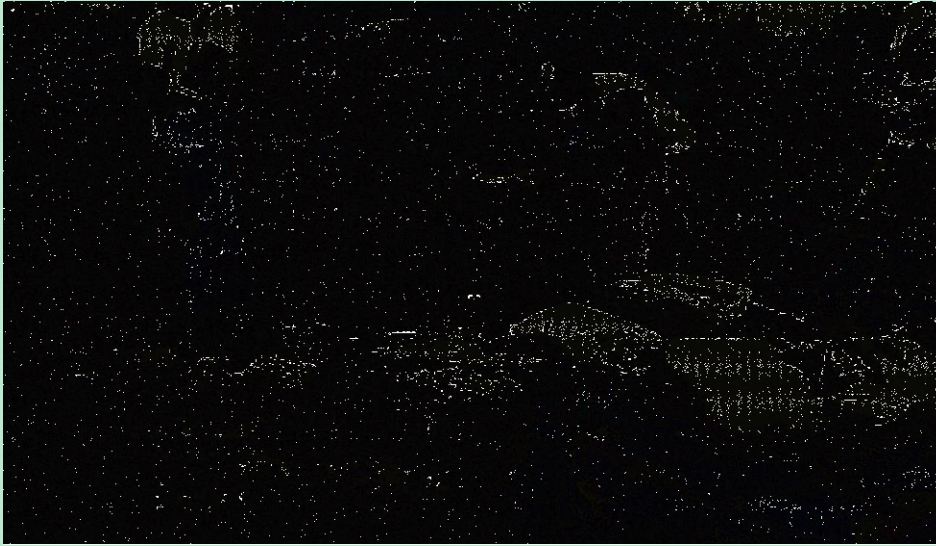


placing



spreading

Fertilizing – épandre l'engrais



- 400 kg /ha
- 6-20-20

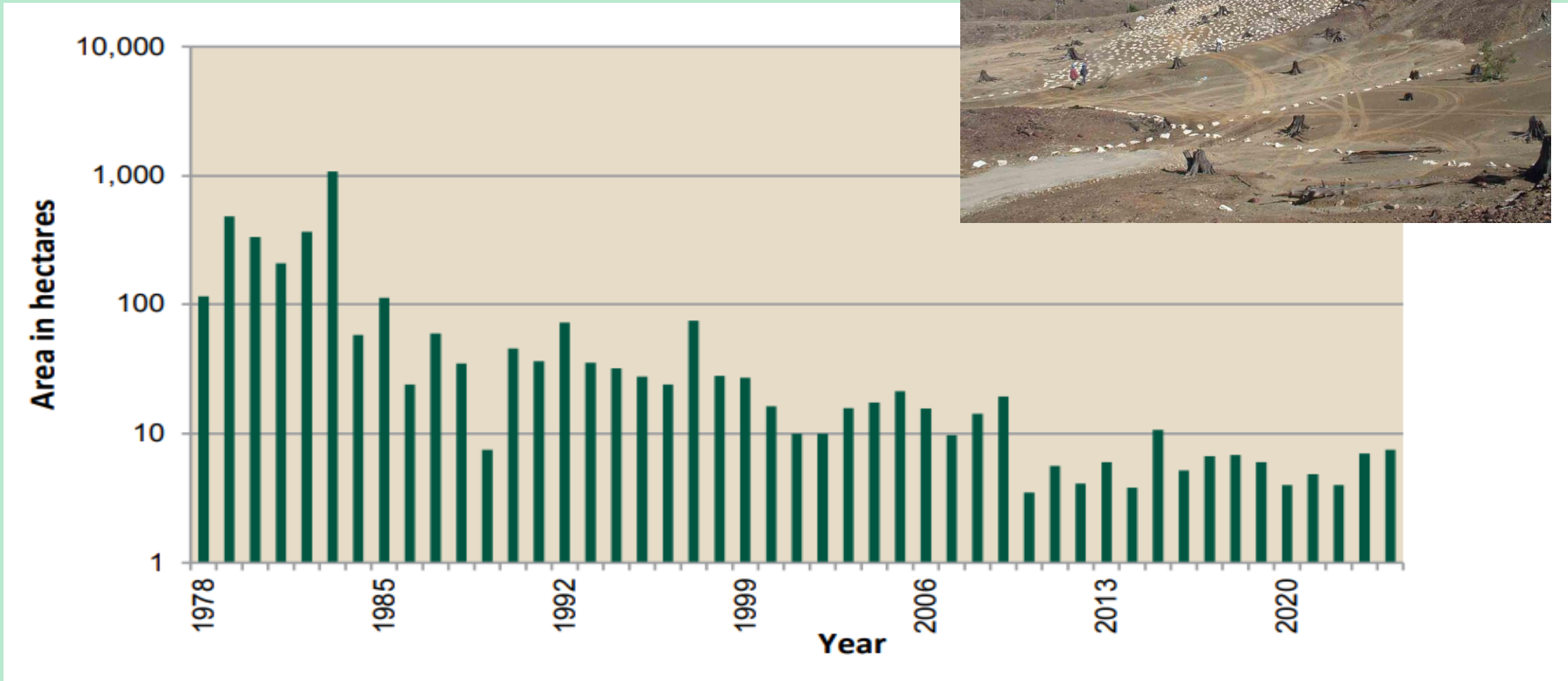


Seeding - semence

- 40 kg/ ha
- grass-legume mix

Hectares receiving limestone 1978-2024

Grand Total: 3,512 ha



[total area to treat is ca 7000 ha]

Aerial Application of limestone pellets, fertilizer, seed
Through co-operation with Vale >1000 ha
Now using helicopters.





Regreening crew

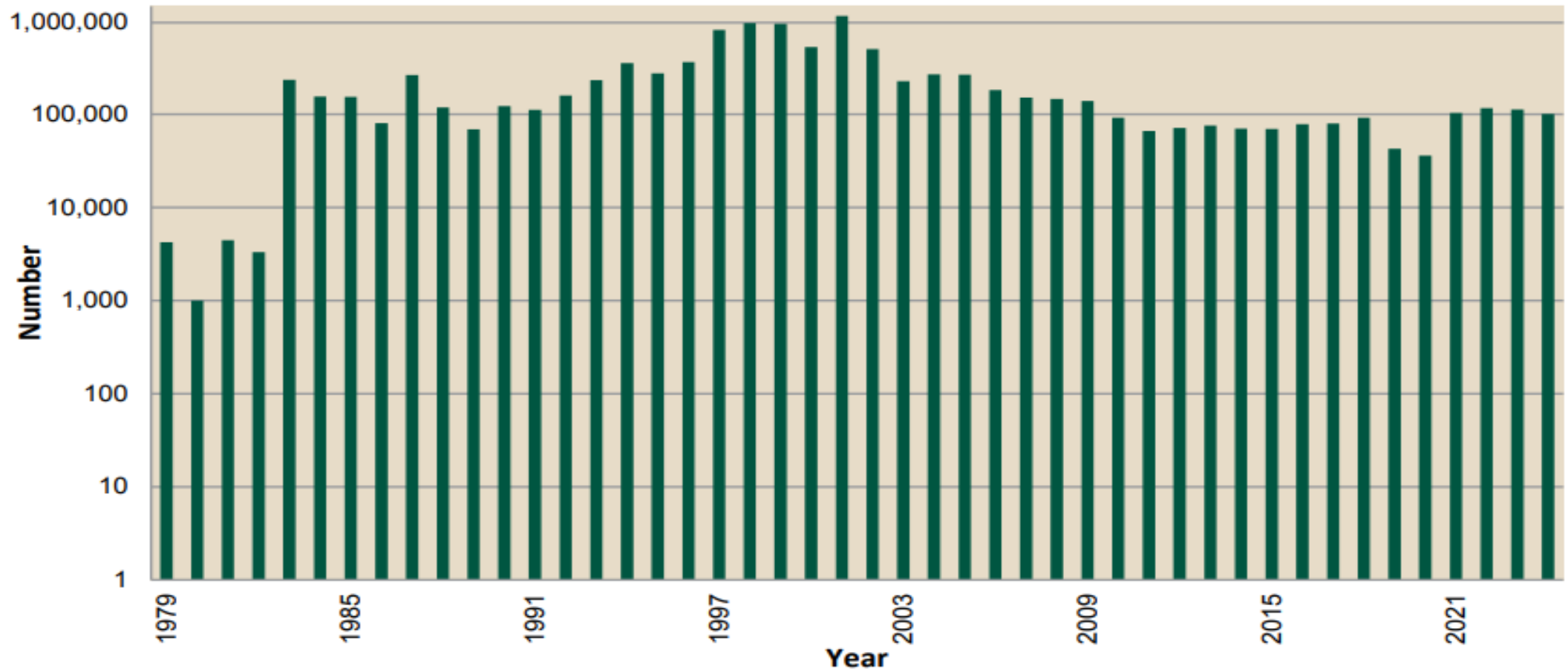
TREE & SHRUB INTRODUCTION



community volunteers
(schools, service clubs,
citizens etc)

2006 7 6

Number of Trees Planted 1979 to 2024 – 10,323,560
(trees and shrubs – 10,923,550)



Tree density 100 – 500 trees ha⁻¹

Landscape change: *ca* 1978



Landscape change: 1987



- Landscape change: 1994



Landscape change: 2004



Landscape change: 2011

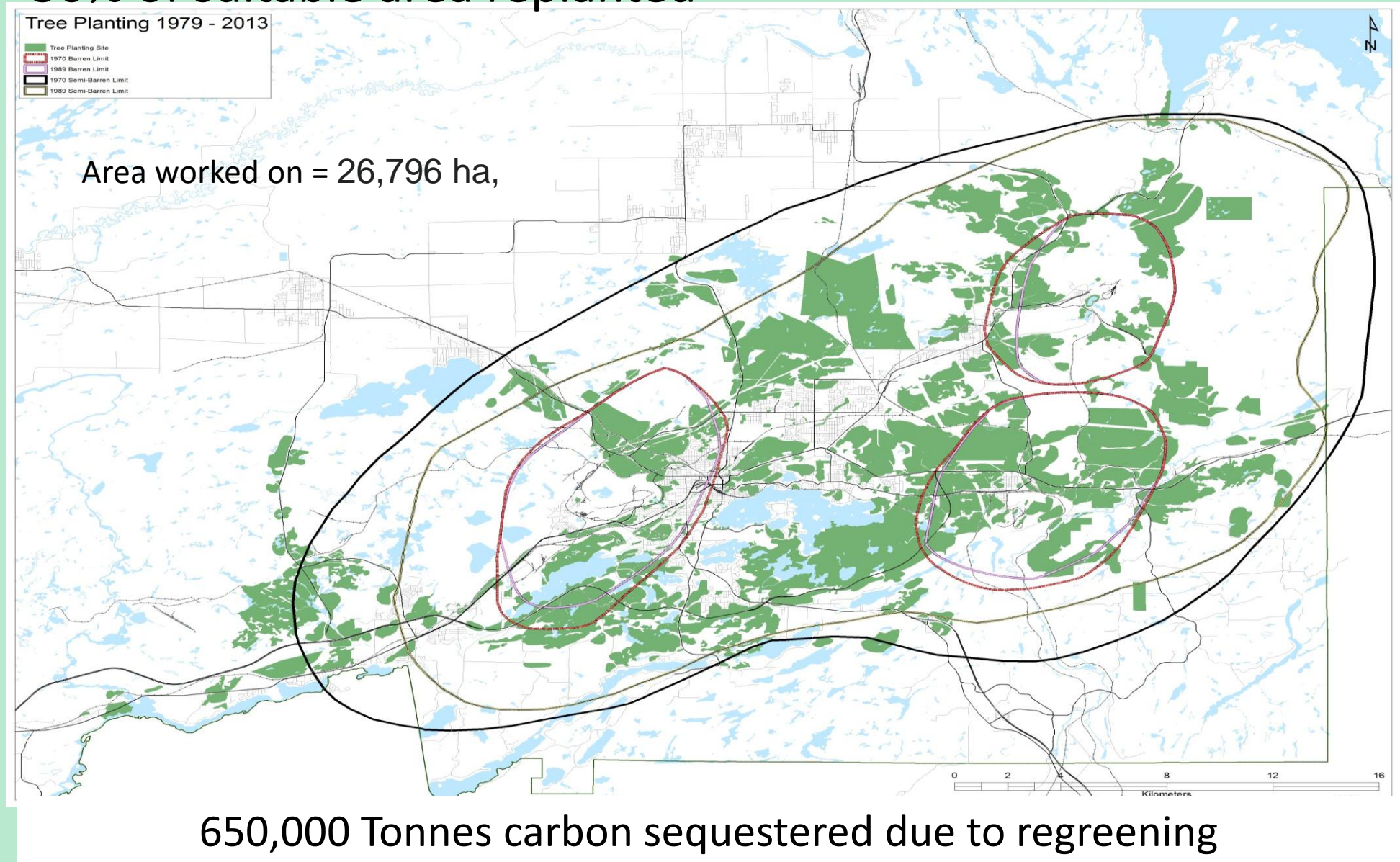


- Landscape change: **2024** (45+ years) upland forest

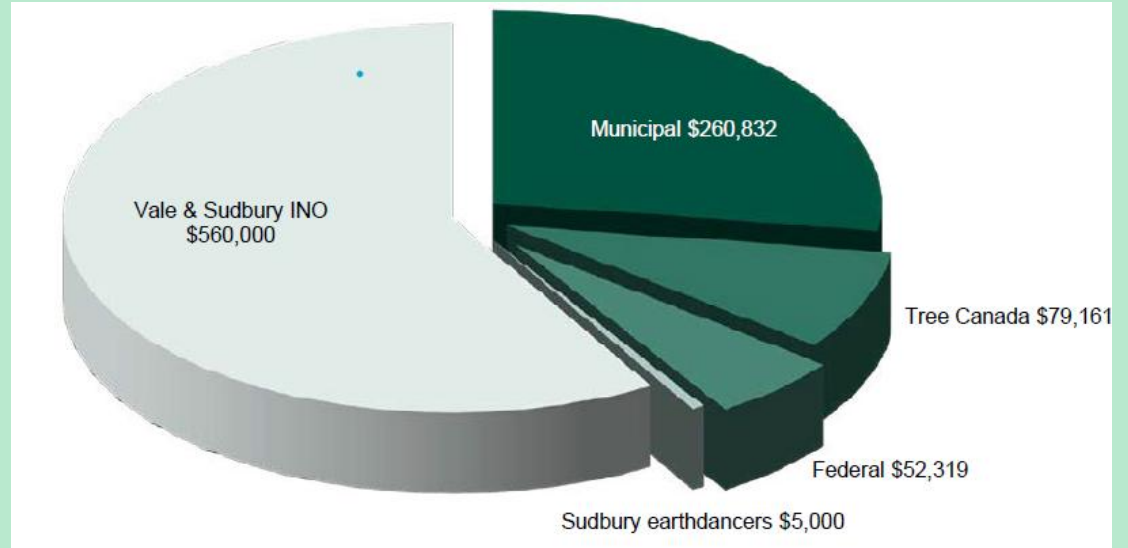
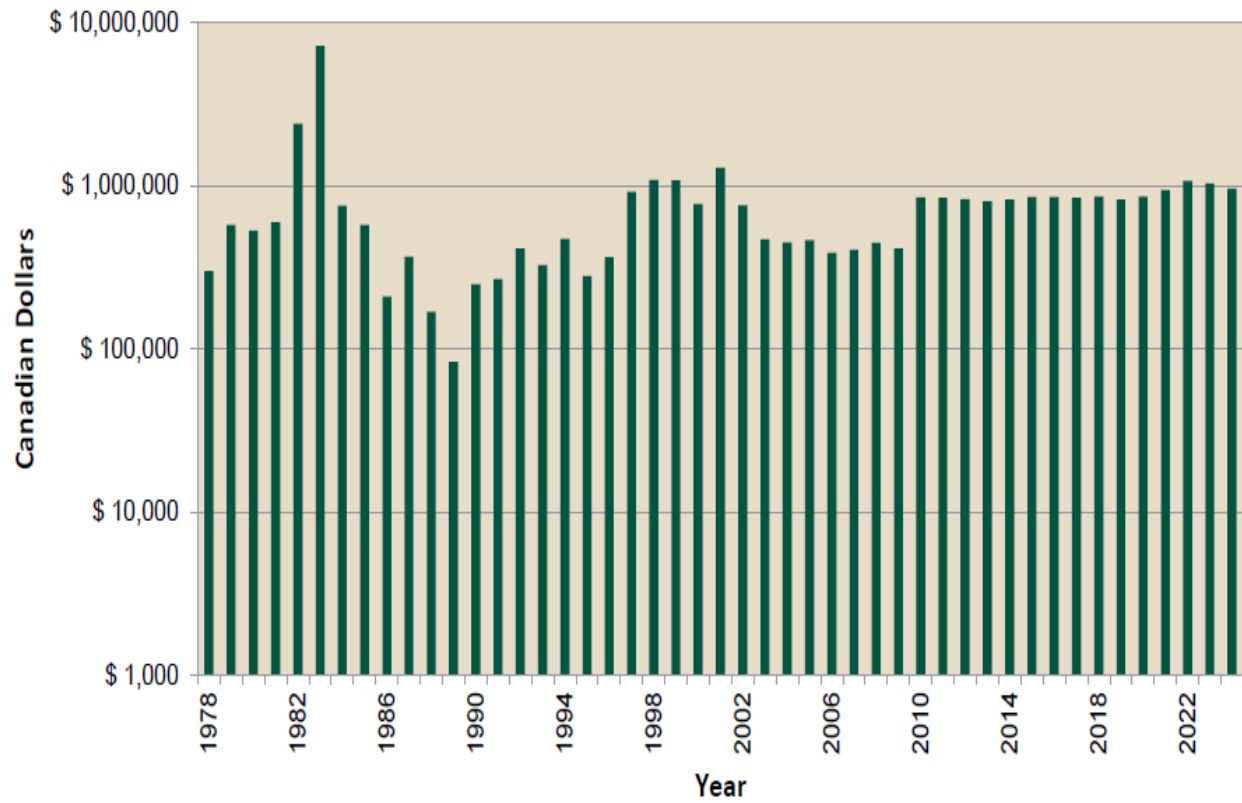


Inner Zone Restoration

50% of suitable area replanted



Total costs 1978 – 2024: \$38,400,825



2024

Helping Climate Change

How much carbon from regreening?

■ Assuming: 3,500 ha with the full Sudbury recipe of liming, fertilize, seeding and tree planting 16,500 ha tree only

Estimate: **650,000 Mg carbon** sequestered due to regreening

■ Including natural regeneration:

Estimate: > **1,000,000 Mg carbon** have been sequestered so far over 45 years

Helping Sudbury be carbon neutral by 2050

Annual C sequestration = C emissions of 20% of Sudbury population

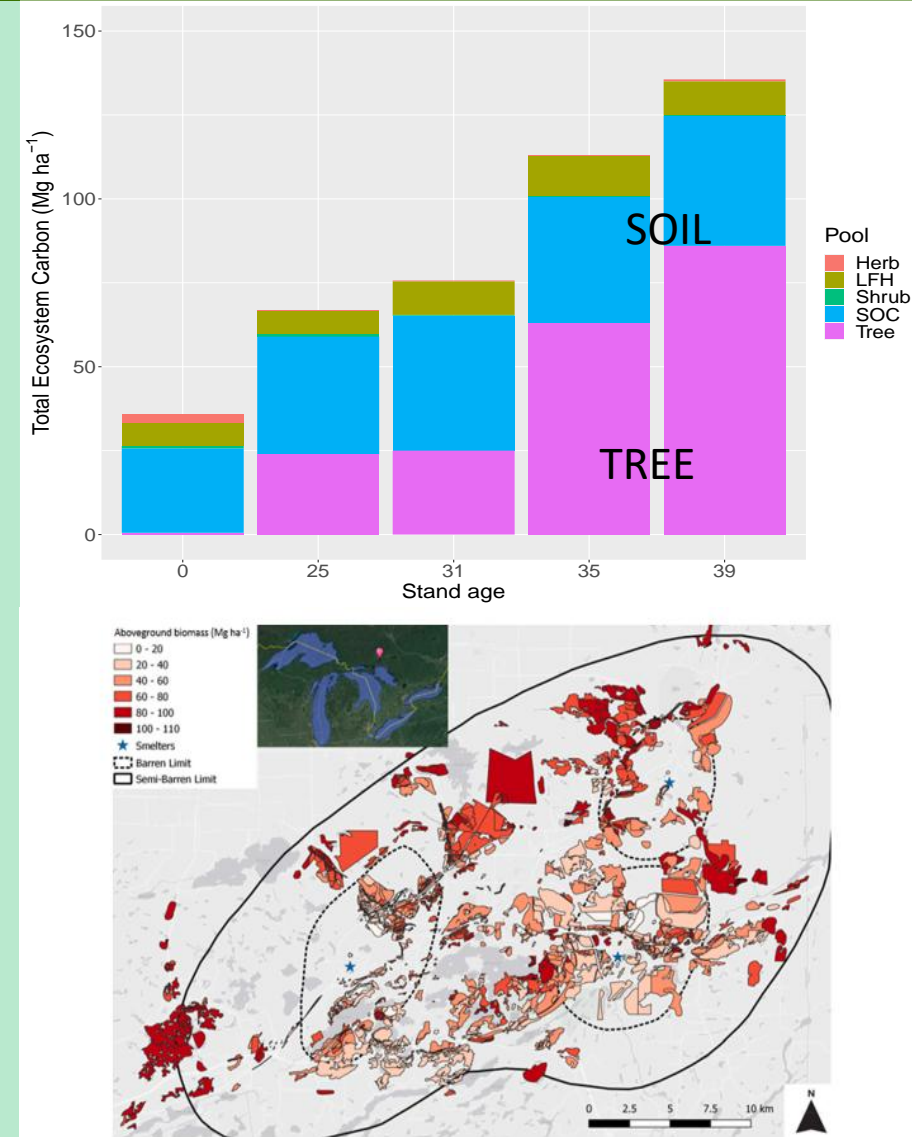


Fig. 6. Aboveground biomass for red pine and jack pine planting sites across the City of Greater Sudbury, Ontario, Canada. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Northern Ontario Peatland



Landscape Change 4:
Sudbury's Peatlands

James
Seward

8000 ha within city





Garson Bog, Sudbury – 4 km from smelter

The effect of smelting operations on peatlands near Sudbury, Ontario, Canada

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AND

PETER J. BECKETT

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Received June 3, 1985

“in close proximity to a smelter, the expanses of flat, black, barren peat are a dramatic testimony to pollutant stresses.”

Sphagnum moss was not observed until roughly 12 km away from the smelter

- Gignac and Beckett, 1986

Assessing Sudbury's peatlands, 35 years later

Do Sudbury's peatlands reflect signs of recovery?
Has *Sphagnum* moss re-colonized?

Common Mosses of Sudbury

Sphagnum mosses occur all around the globe, and Sudbury is no different. A handful of different species can be observed in the region, including the ones on this poster. A number of environmental factors can aid in identification of these peat mosses by narrowing down the possibility of which species might be present, such as pH, nutrient source, hydrology and microclimate conditions.

Hummock species

Hummock are low mounds rising from the surface of the bog. They are very acidic, their pH range is typically between 2.7 - 3.1. The water table sits below the surface of the moss.



S. capillifolium
-burgundy
-very compact
-also in boreal forest



S. fuscum
-brown/green
-main hummock former

Lawn species

Lawns or carpets are a thick mat of moss that covers an area, normally just above the water table. Their pH exists between 3.1 - 3.3.



S. fallax
-green/brown-yellow
-form lawn around perimeter of hollows
-often fill in moose paths



S. magellanicum
-red/green

S. divinum



S. papillosum
-large structure & leaves
-brown/green



S. rubellum
-red
-compact

Hollow species

Hollows are also known as pools, due to them existing close to or even under the water table. The pH range of these areas are between 3.4 - 4.0.



S. girgensohnii
-large stem leaf with central fringe
-often occurs in shade



S. squarrosum
(Spiky Bog Moss)
-leaves grow at 45 degrees
-common in acidic hollows around Sudbury

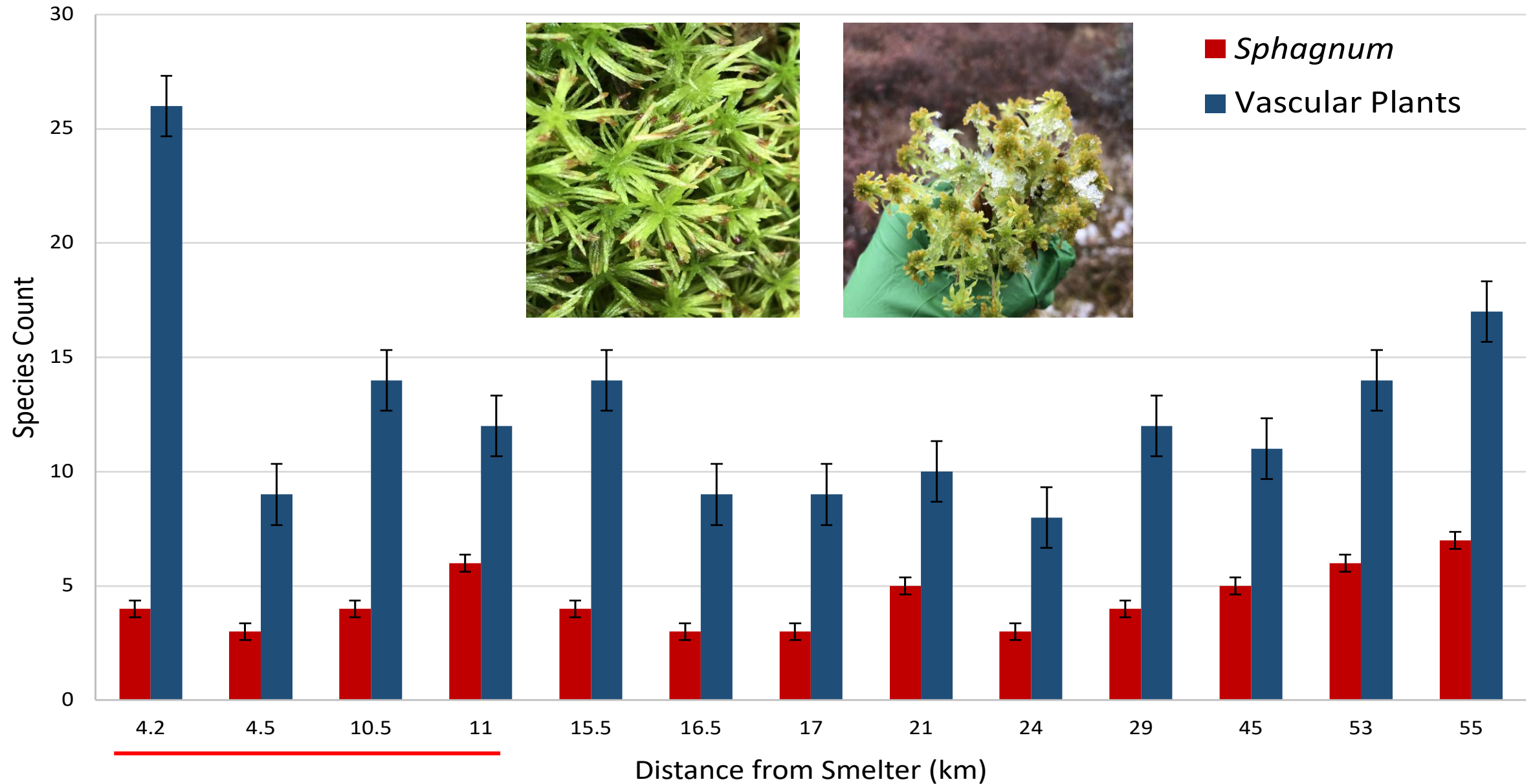


S. fimbriatum
-large number of red-brown sporophytes
-pioneer species
-acidifies area

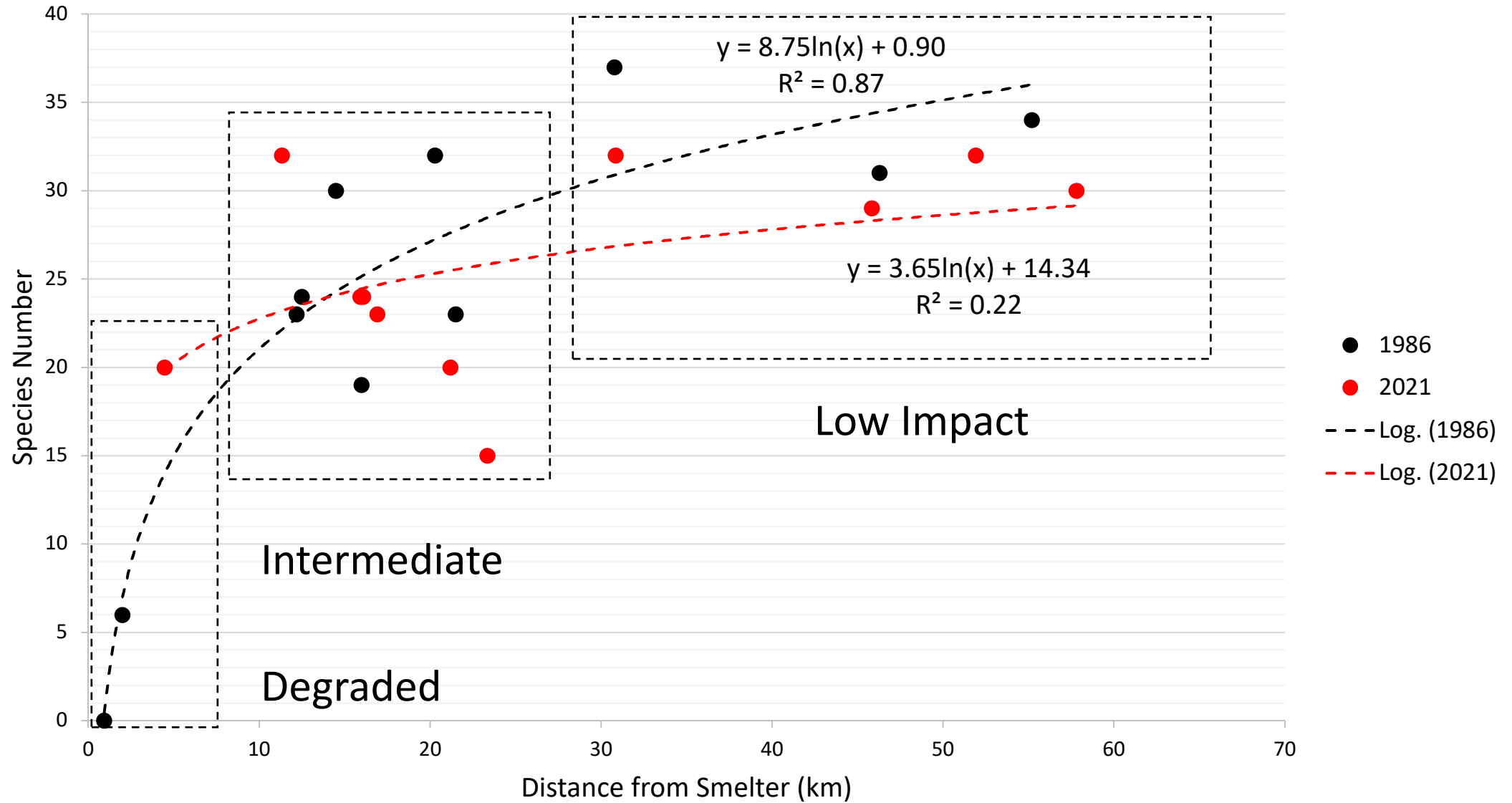


S. cuspidatum
-long leaves
-free floating
-shortened leaves on margin of pool

Sphagnum & Vascular Plant Count vs. Distance



Overall Poor Fen Vegetation Species





A *Sphagnum* Moss Transplant Experiment in a Metal Contaminated Peatland



S. fuscum

10 x 10 cm plug

Drastically grew in
surface area (now 25 x
30 cm by 2024

(May) 2020

2021

2024

Potential Peatland Carbon Sequestration

- Based on estimates from restored peatlands expect
10 000 – 20 000 t carbon over 8000 ha
- Compare with 50 000 t carbon for 30 000 ha upland forest

Building on Past Restoration Knowledge: Moss Layer Transfer Technique

- A bog restoration technique
 - Developed by Line Rochefort *et al.* (Universit e Laval, in Quebec City)
- Used globally to restore peatlands that have been extracted for horticultural peat extraction
- Process includes:
 - Prepare the fields
 - Level/remove internal drainage
 - Spread donor moss material
 - Spread straw mulch
 - Apply fertilizer
 - Block perimeter drainage ditches



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Restoration Trials (Started June 2024)

All treatments get:
Shrubs removed (1)

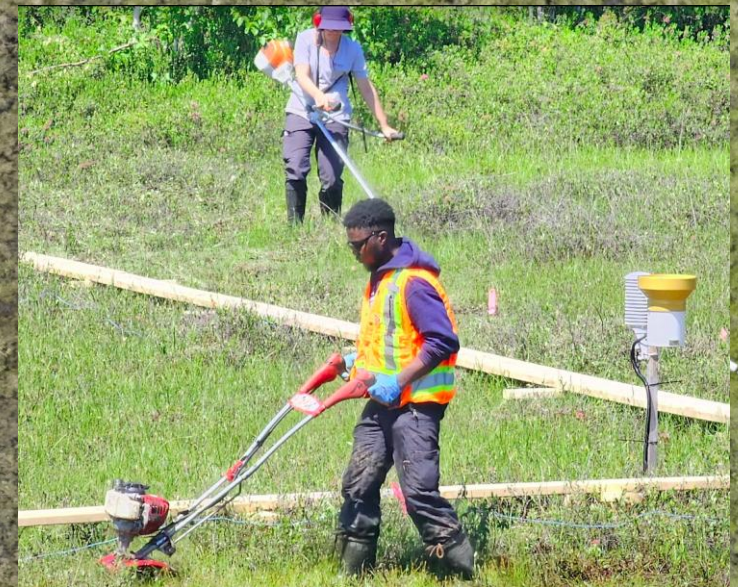
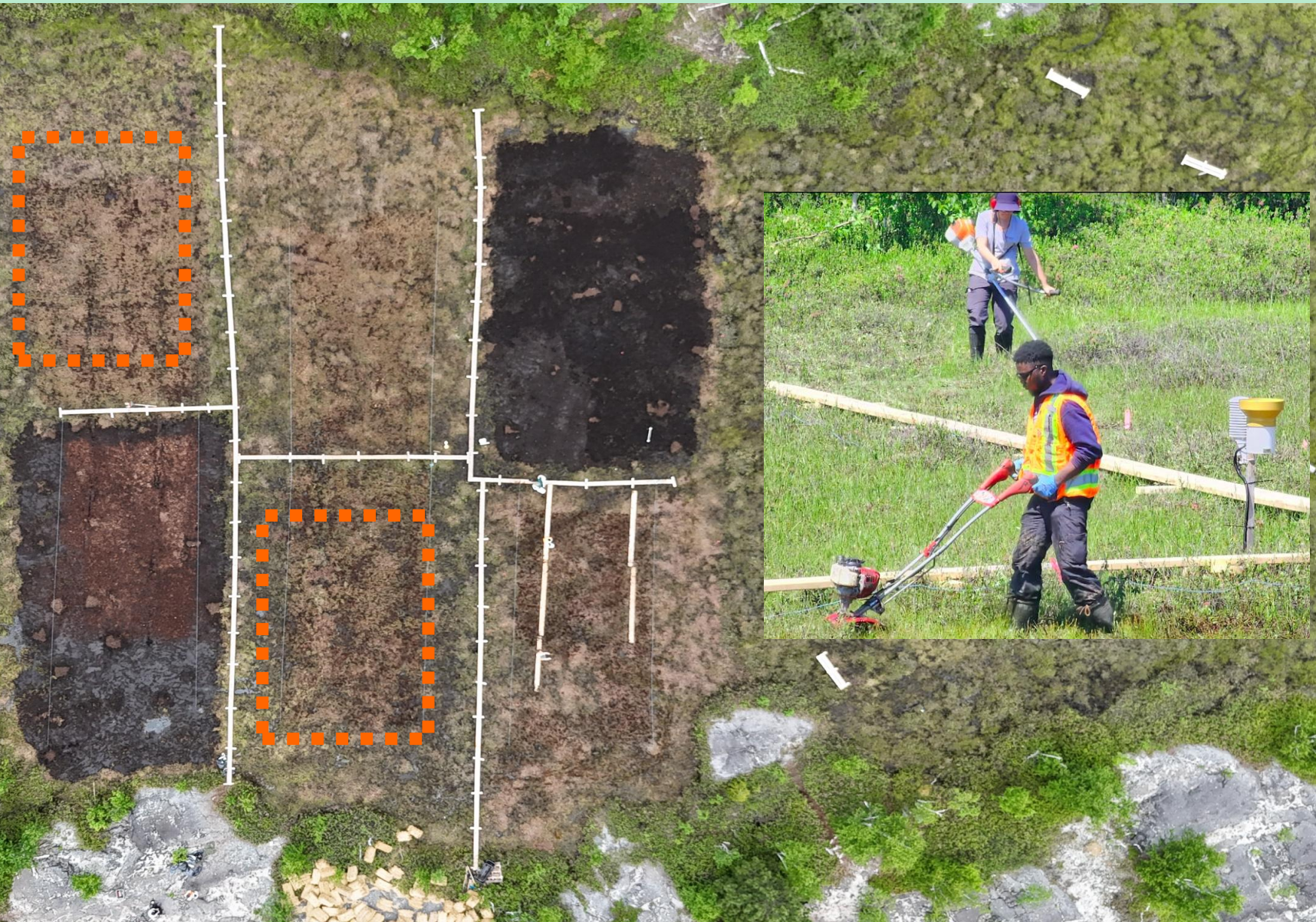
(treatments are ~8x15m)



Restoration Trials (Started June 2024)

All treatments get:
Shrubs removed (1)
+ Tilling (2)

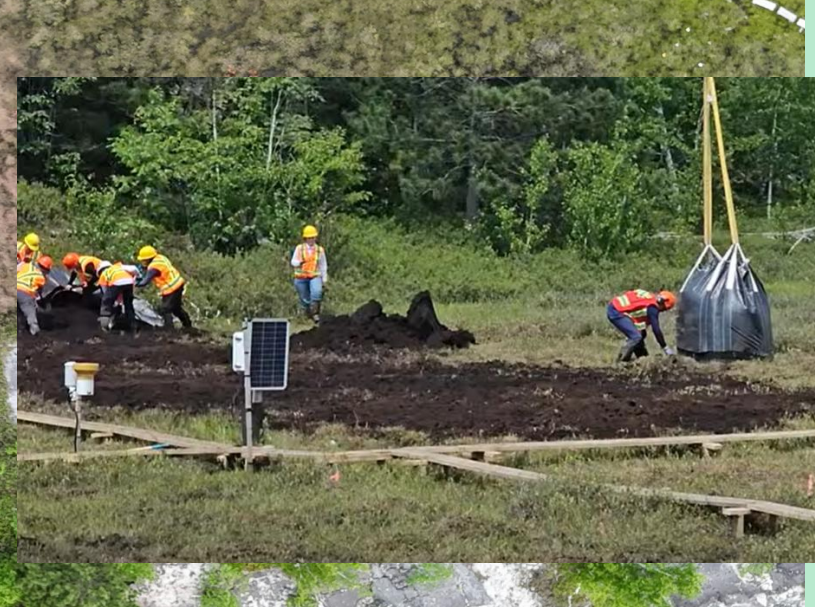
(treatments are ~8x15m)



Restoration Trials (Started June 2024)

All treatments get:
Shrubs removed (1)
+ Tilling (2)
+ Buffer peat (3)

(treatments are ~8x15m)



Restoration Trials (Started June 2024)

All treatments get:
Shrubs removed (1)
+ Tilling (2)
+ Buffer peat (3)

(treatments are ~8x15m)



Restoration Trials (Started June 2024)

All treatments get:
Shrubs removed (1)
+ Tilling (2)
+ Buffer peat (3)
Donor Material

(treatments are ~8x15m)



Restoration Trials (Started June 2024)

All treatments get:
Shrubs removed (1)
+ Tilling (2)
+ Buffer peat (3)
Donor Material
Surface Compaction

(treatments are ~8x15m)



Restoration Trials (Started June 2024)

All treatments get:
Shrubs removed (1)
+ Tilling (2)
+ Buffer peat (3)
Donor Material
Surface Compaction
Straw mulch
Rock Phosphorus

(treatments are ~8x15m)



Transplant Peatland: Alliance Restoration Field Trail 2024



Conclusions



- Presence of Sphagnum now as close as 4 km to smelter is evidence of natural vegetation recovery after decades of pollution control.
- Legacy concentrations of Ni(t) and Cu(t) smelting still measurable in peat, though significantly lower.
- Sudbury's peatlands need active restoration research trials – now in progress



Project: Integrative Peatland Restoration Science



Colin McCarter



Ellie Goud



Pete Whittington



Nate Basiliko



Peter Beckett, John Gunn,



Florin Pendea



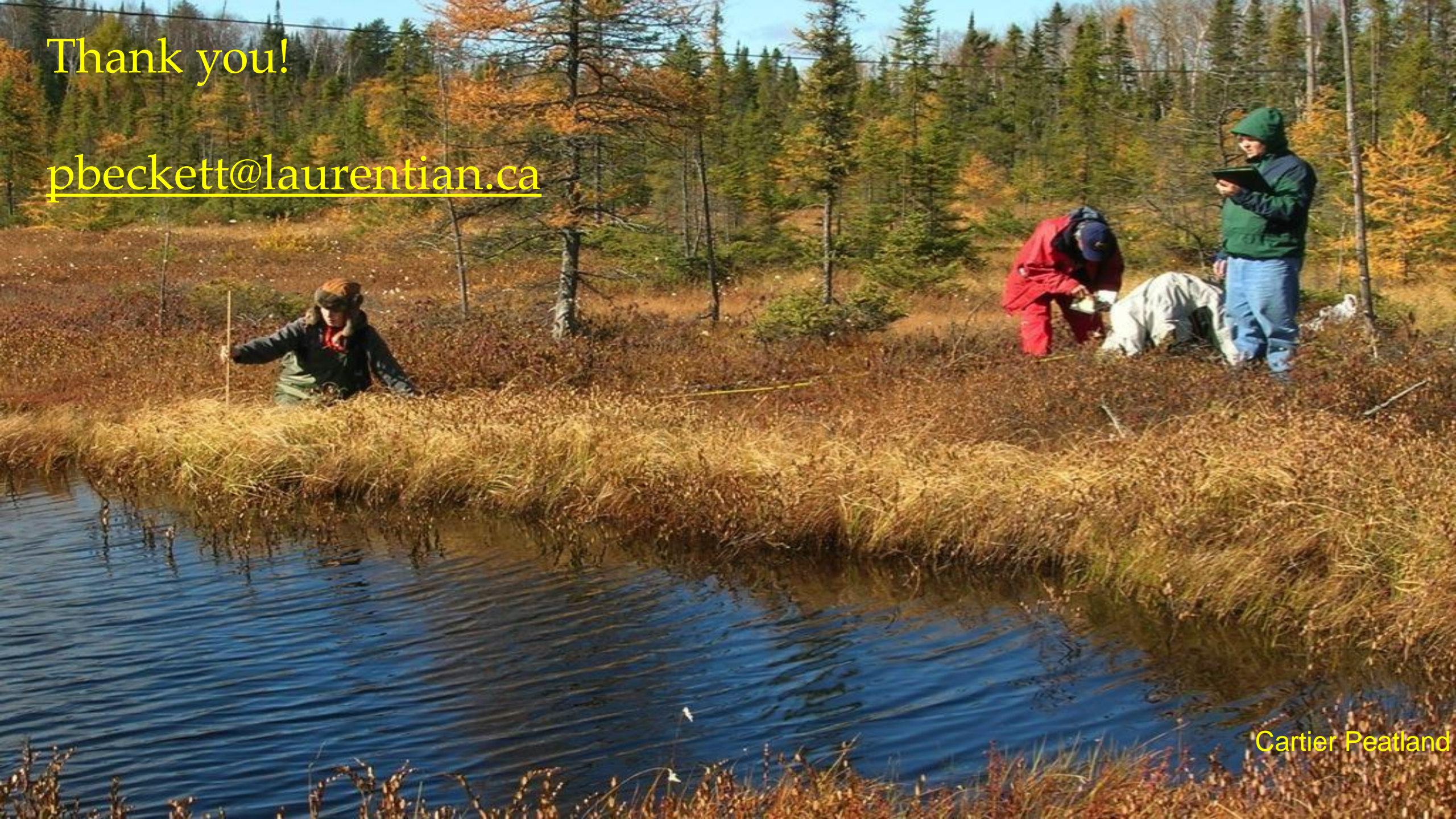
Project Goals:

1. Determine the **impacts** of industrial **contamination** and **liming** on peatland structure & function (C-storage)
2. Develop novel **restoration** techniques to address these impacts



Thank you!

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Cartier Peatland