



# Environmental Legacy of Historical Gold Mining Activities in Nova Scotia



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Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



# Motivation for Study

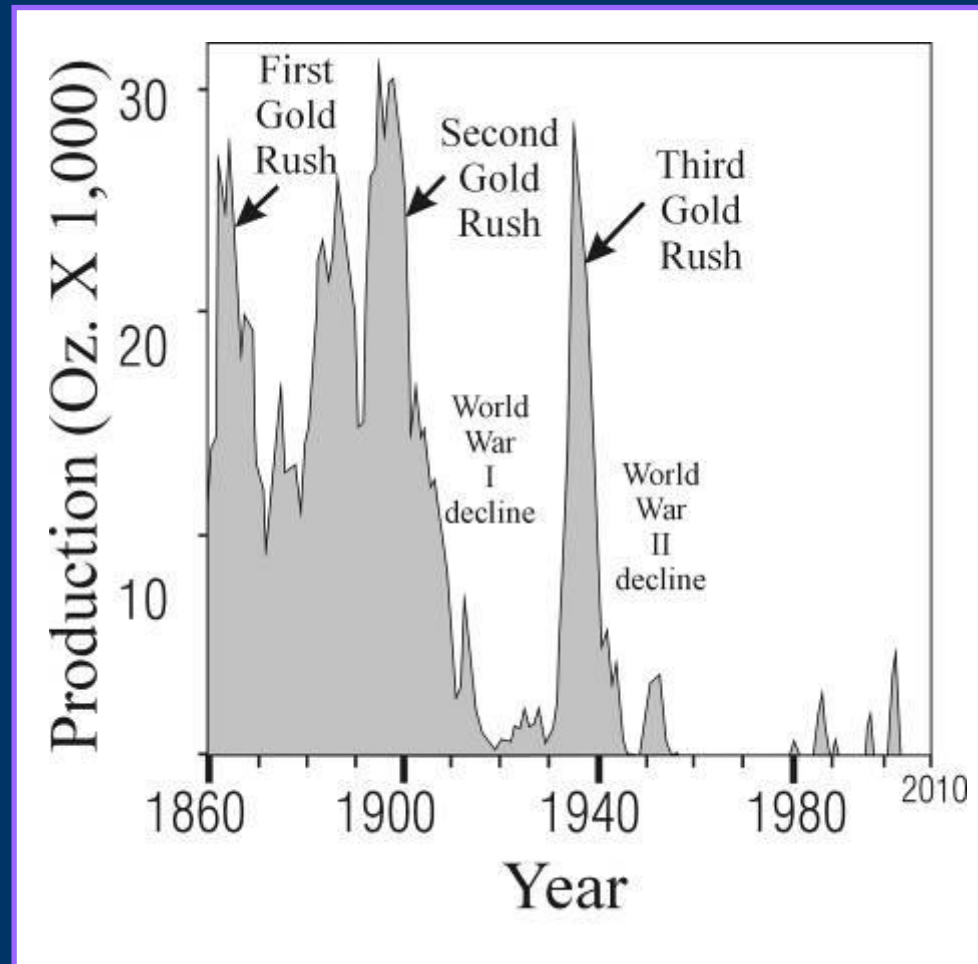


- Between the 1860s and 1940s, most gold mines in Canada used mercury amalgamation to recover gold from the ore. On average, 10–25% of this Hg was lost to tailings, or through retorting & spillage.
- Other potentially toxic elements (esp. As) occur naturally in the ore, and may be present at high concentrations in the mine wastes.
- Since the mid-1970s, several studies of gold districts in Nova Scotia have shown elevated metal(loid) concentrations in tailings, waters, sediments, and biota downstream from these mine sites.
- Expanding residential developments (e.g. Montague, Waverley) and recreational activities (e.g. ATVs, Goldenville 4X4 Rally) are increasing the likelihood of human exposure to these mine wastes.
- Rising gold prices (currently ~ \$560US / oz.) are generating renewed interest in re-processing historical mine tailings.



# History of Nova Scotia Gold Mining

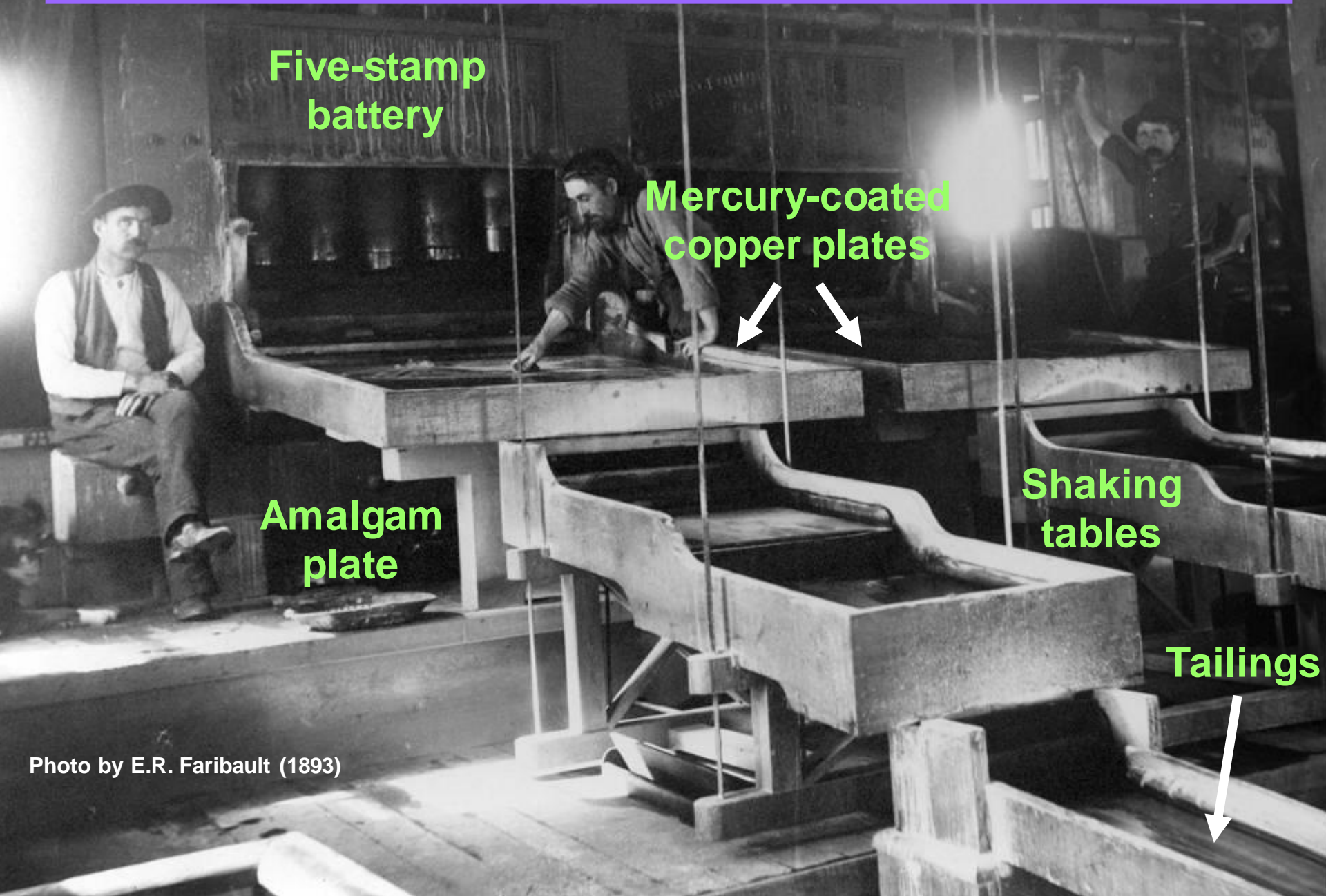
- Nova Scotia Gold Rushes
  - » 1<sup>st</sup> 1860-1870
  - » 2<sup>nd</sup> 1896-1903
  - » 3<sup>rd</sup> 1932-1942
- From 1861 to the mid-1940s, Au was produced from 64 mining districts, yielding ~1.2 million oz.
- Both Hg amalgamation and cyanidation (post-1880s) were used to extract Au from the crushed ore



Nova Scotia gold production, 1862-2005



# Cleaning up the 20-Stamp Mill, Dufferin Gold Mine, 1893



Five-stamp  
battery

Mercury-coated  
copper plates

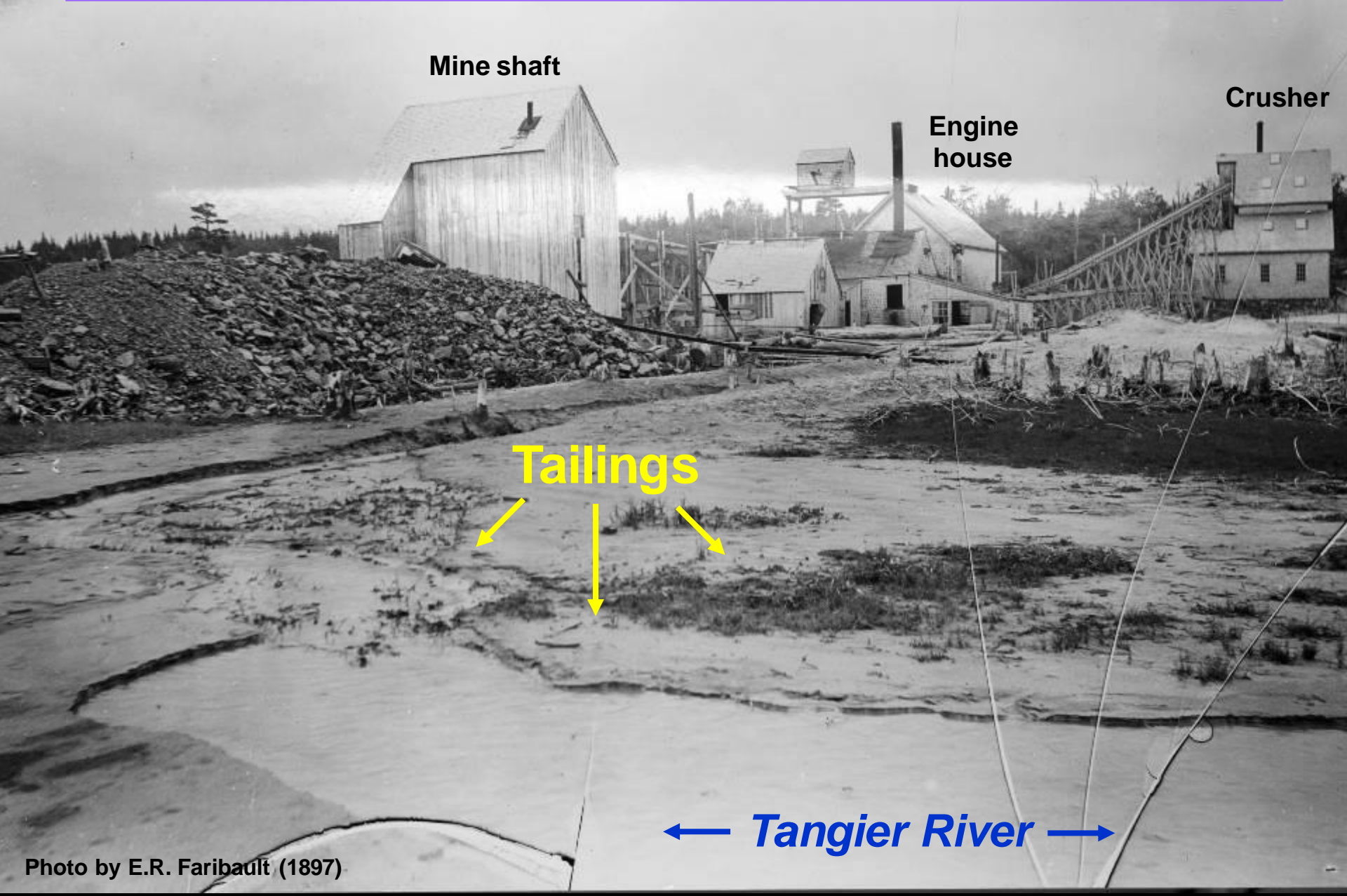
Amalgam  
plate

Shaking  
tables

Tailings

Photo by E.R. Faribault (1893)

# Tailings disposal at the Mooseland Gold District, 1897







# Objectives of Study



- Determine the concentrations, distribution, and speciation of metal(loid)s in tailings, soils, till, rocks, sediment, water, and vegetation near these mine sites
  - » Establish local background levels for elements of concern (As, Hg)
- Identify and characterize chemical and physical processes that control the release of elements from the tailings
- Assess the bioavailability and biological impacts of metal(loid)s, and potential routes for human exposure
  - » Recommendations for mitigation of human & ecosystem health risks
  - » Communicate results to clients, both in Nova Scotia and across Canada



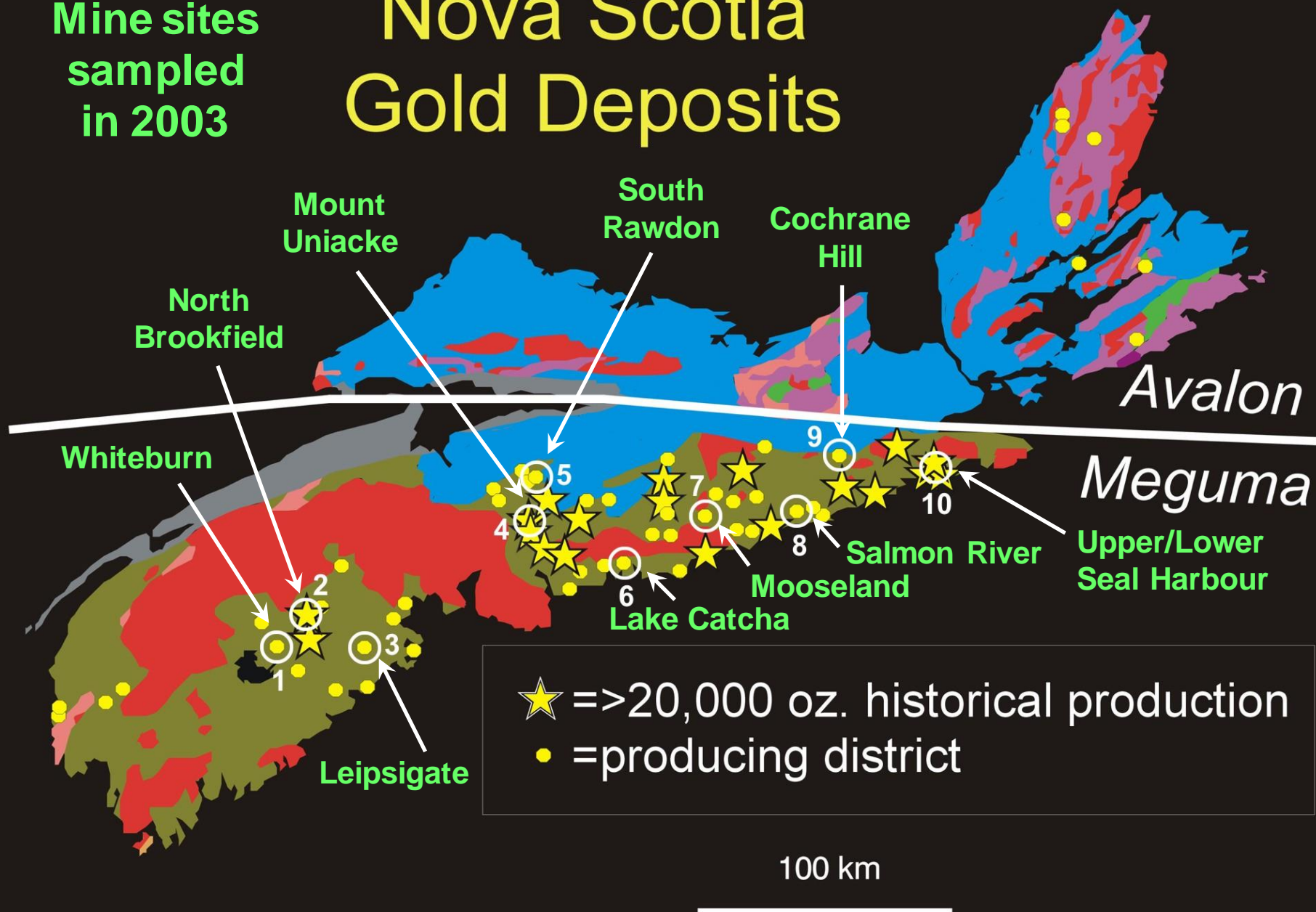


# Reconnaissance-level surveys in 2003

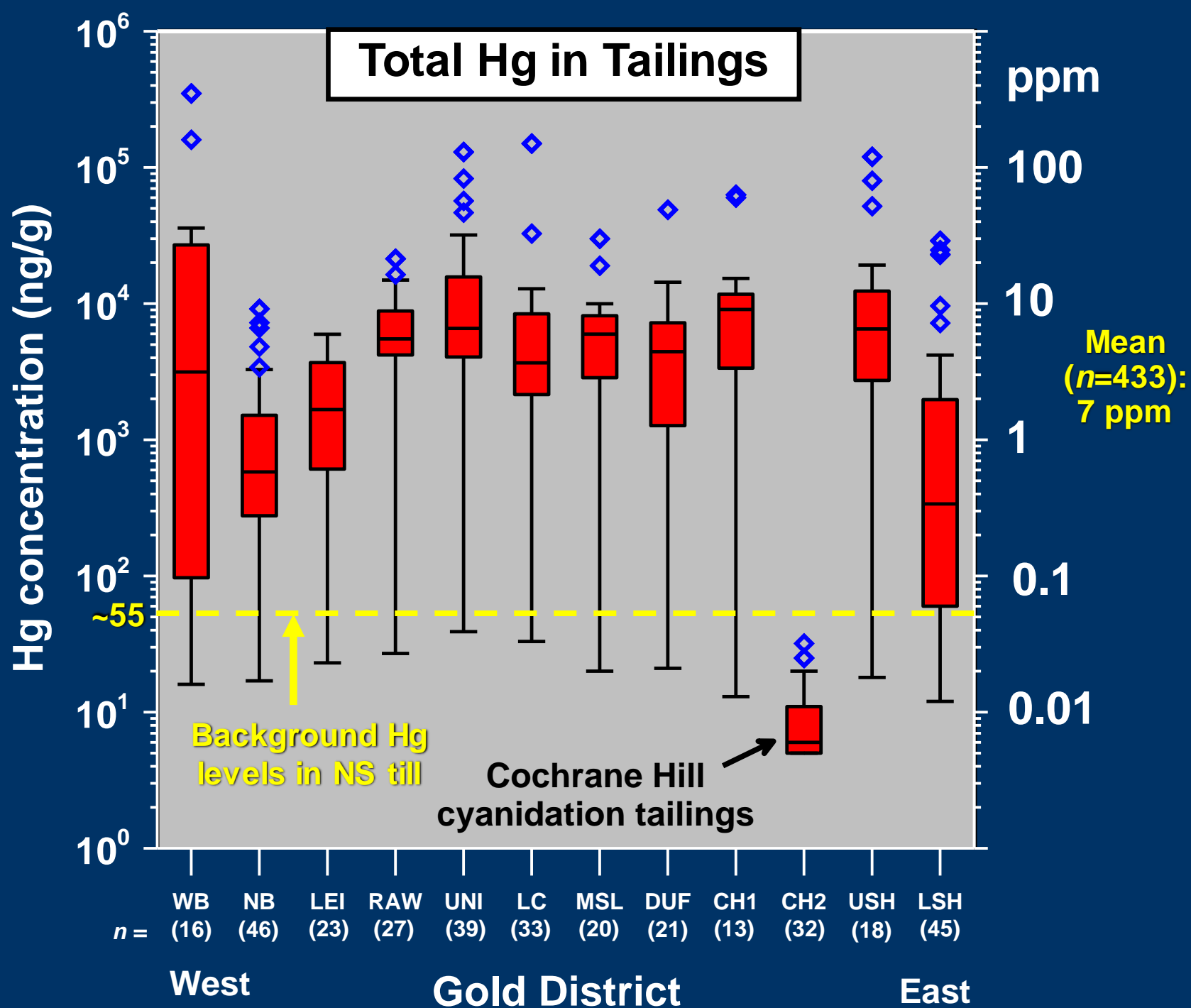


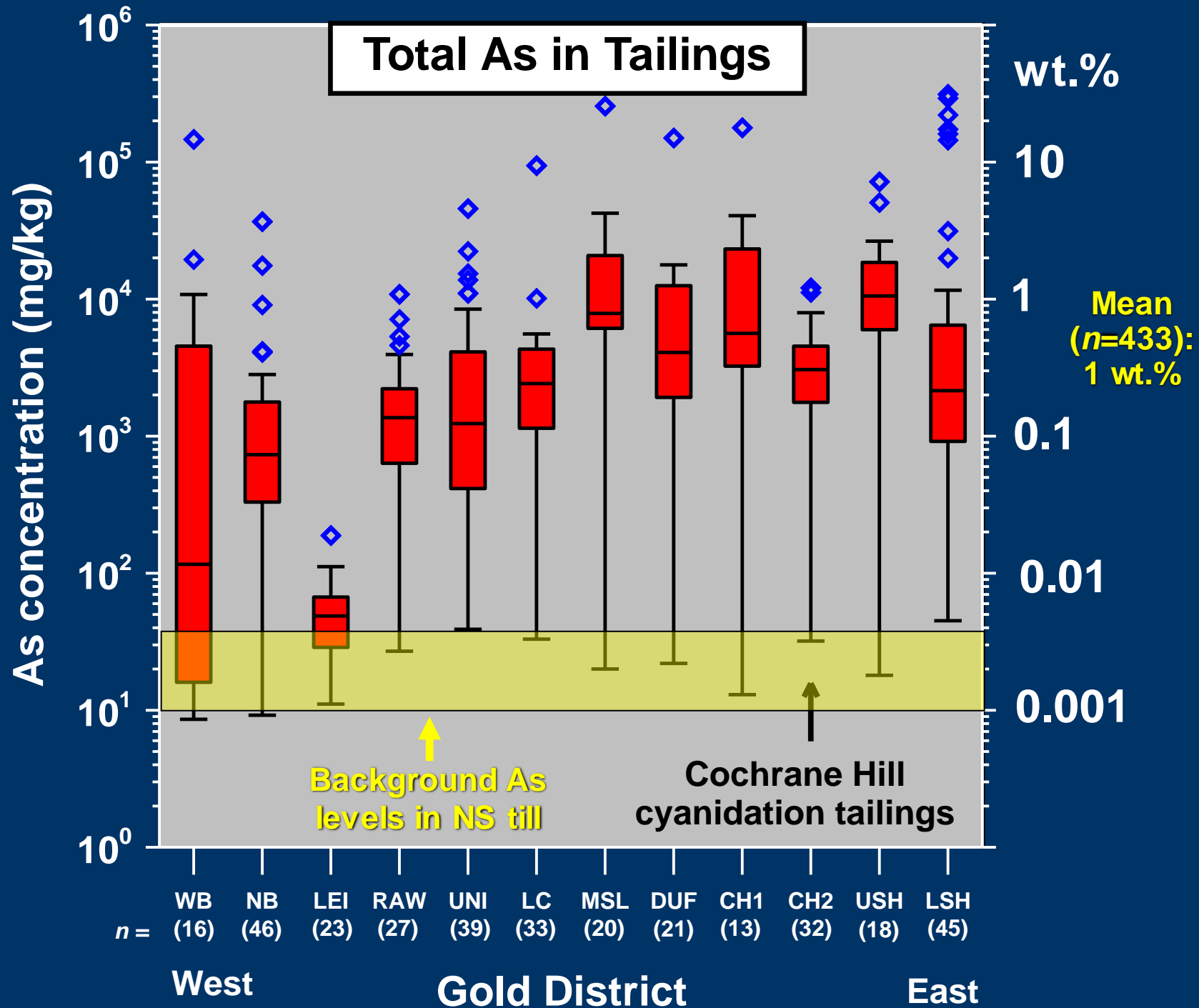
Mine sites  
sampled  
in 2003

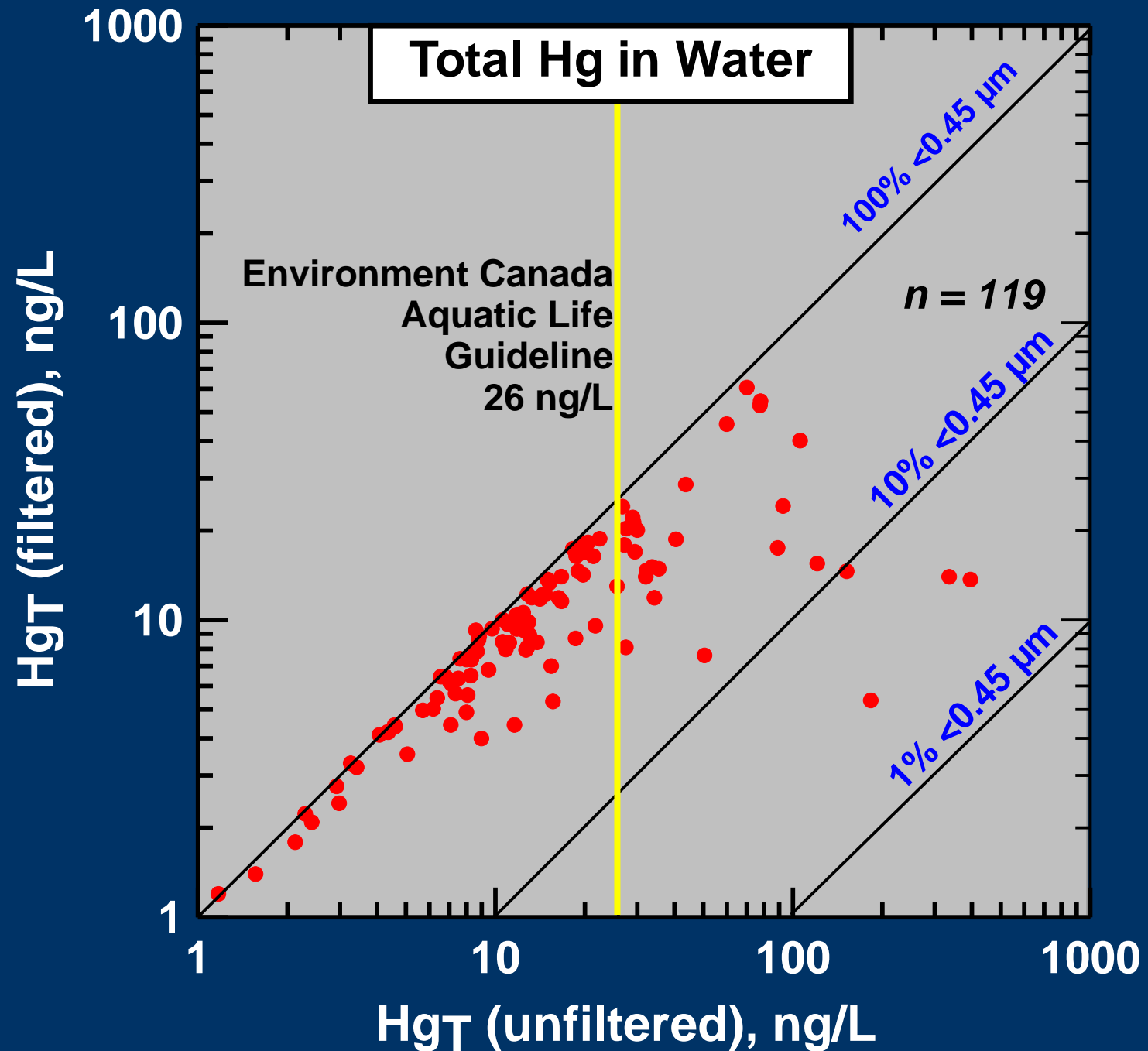
# Nova Scotia Gold Deposits



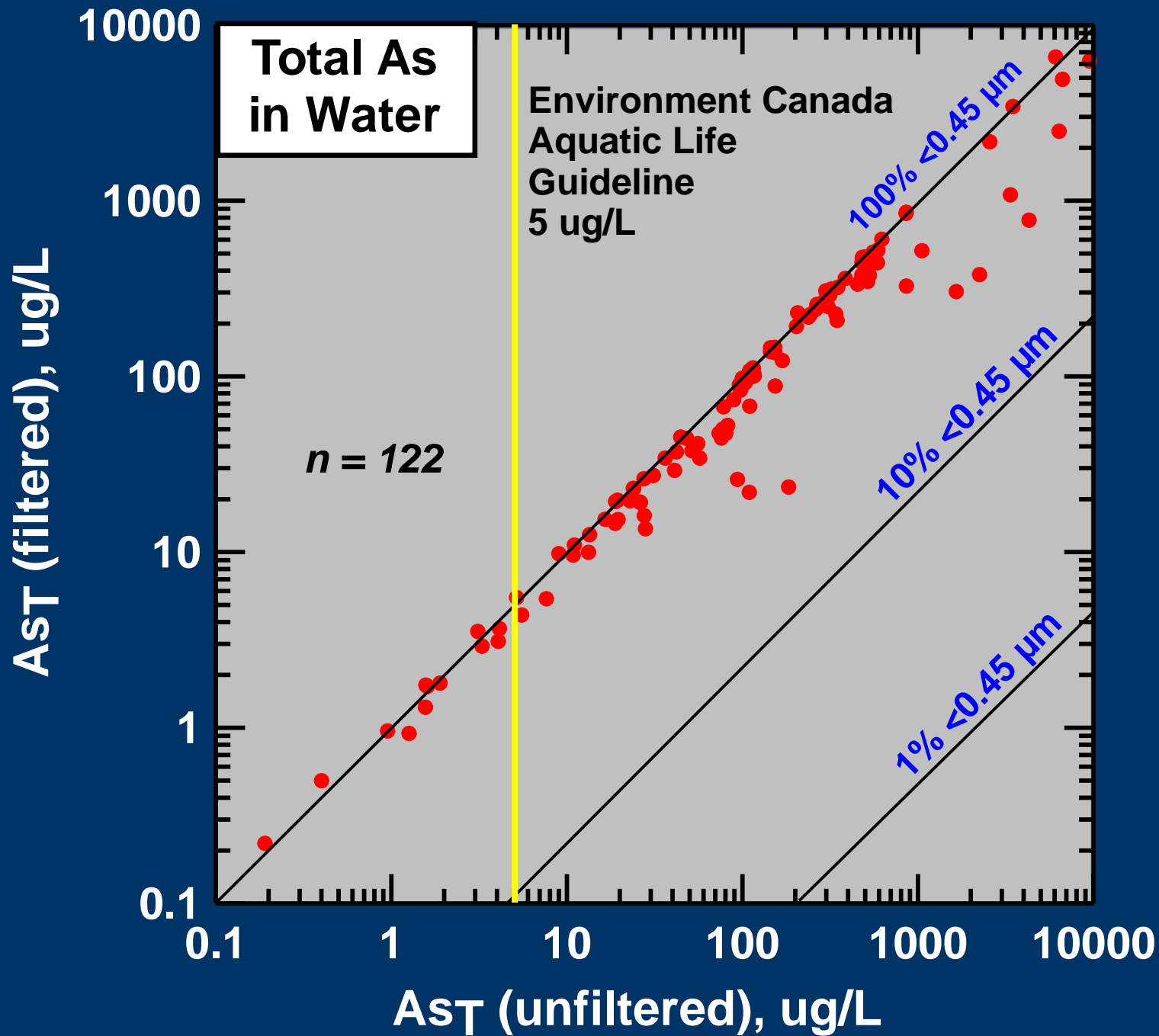














# Multi-disciplinary fieldwork in 2004 & 2005



# Project Partners

**Peter White, Catherine Champagne, Ridah Touzi (CCRS)**

- Hyperspectral and polarized radar imagery of Upper & Lower Seal Harbour

**Heather Jamieson, Madeleine Corriveau, Catherine Daniels (Queen's)**

- Speciation of metal(loid)s in dusts from gold mine sites using XAFS, PIXE, etc.

**Terry Goodwin (NSDNR)**

- Distribution of Hg and other elements in humus / soil / till

**Jeanne Percival (GSC)**

- Mineralogy of rocks, soils, tailings, sediments
- XAFS analysis of Hg
- Spectral reflectance studies

**Paul Smith (NSDNR)**

- Chemistry and mineralogy of rocks and tailings

**Gwendy Hall (GSC)**

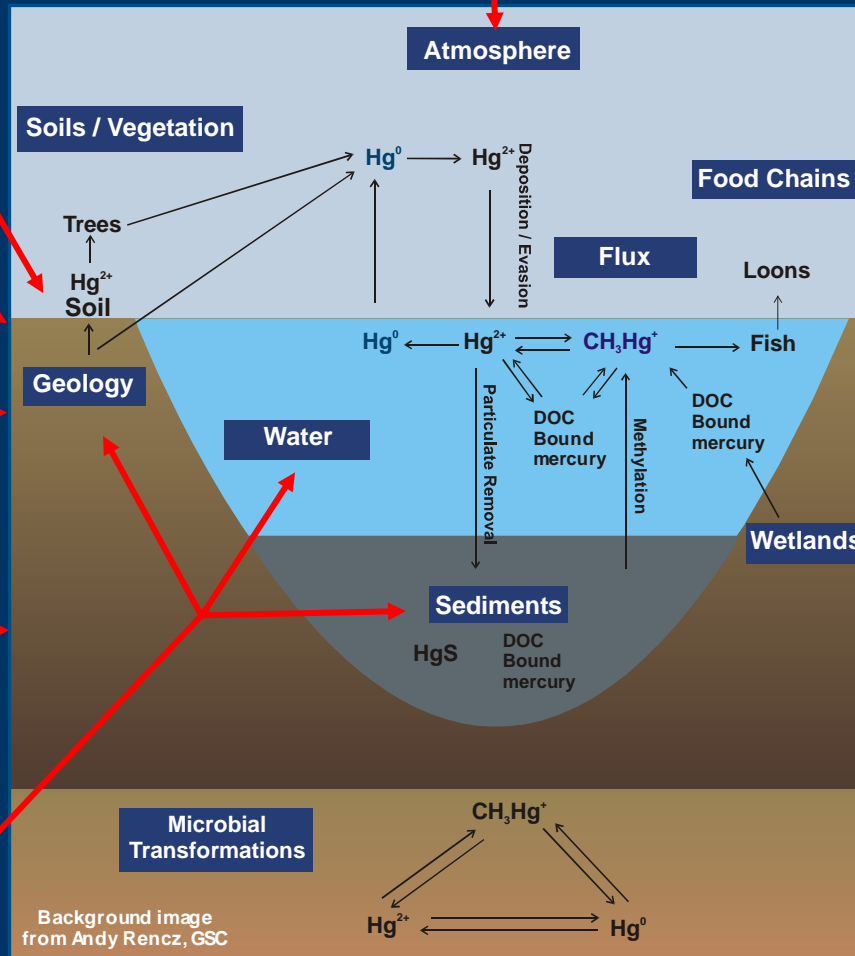
- Analytical method development (water, tailings, sediments)
- Sequential extractions

**Michael Parsons (GSC)**

- Project coordination
- Chemistry of tailings, water, sediments
- XAFS analysis of Hg

**Rob Tordon (EC) & John Dalziel (DFO)**

- Gaseous Hg fluxes



Background image from Andy Rencz, GSC

**André Gauthier, Ken Doe, Kok-Leng Tay, Rita Mroz (EC)**

- Sediment/water toxicity
- Bioaccumulation of Hg in frogs, clams, invertebrates

**Iris Koch, Ken Reimer, Jared Saunders (RMC)**

- As speciation / transfer in short food chains (e.g. soil – plants – mice)
- Gastric fluid extractions / health risk assessment

**Vince Palace (DFO)**

- Effects of As exposure on fish etc. (including HPLC / histology studies)
- Pore water geochemistry

**Al Sangster (GSC)**

- Hg-DOC interactions, biogeochemical Hg cycling
- Background levels of metal(loid)s in waters near mining districts

**Andrea Mosher, Megan Little (Dal)**

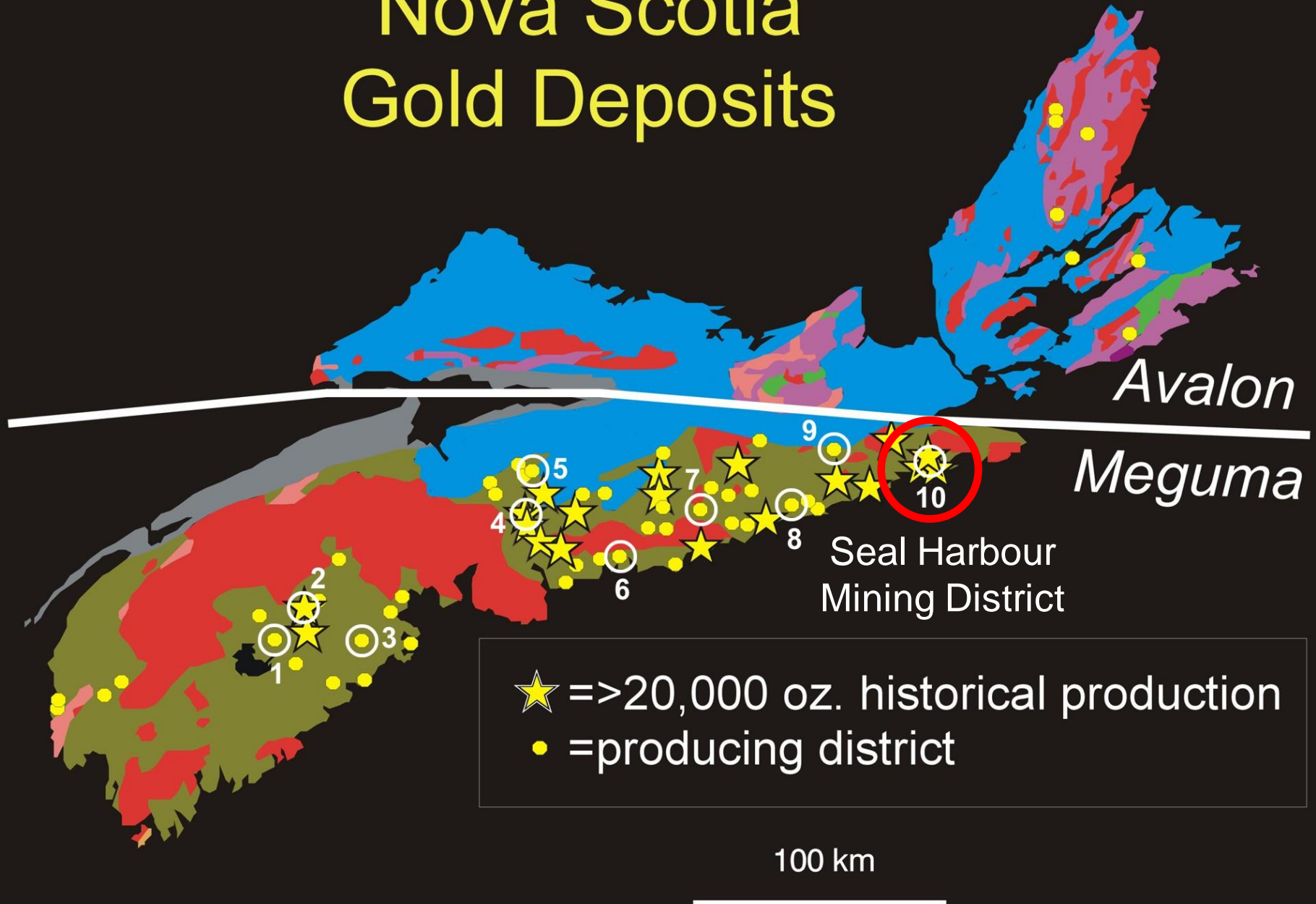
- B.Sc. theses on tailings at Cochrane Hill & Wine Harbour

**Susan Winch, Nicolette Stanley, David Lean, Danielle Fortin (Univ. of Ottawa)**

- Controls on mercury methylation in tailings & surface waters



# Nova Scotia Gold Deposits



# Upper & Lower Seal Harbour

Upper  
Seal  
Harbour

Outlet of  
West Brook

SEAL  
HARBOUR

Goldboro  
Gas Plant

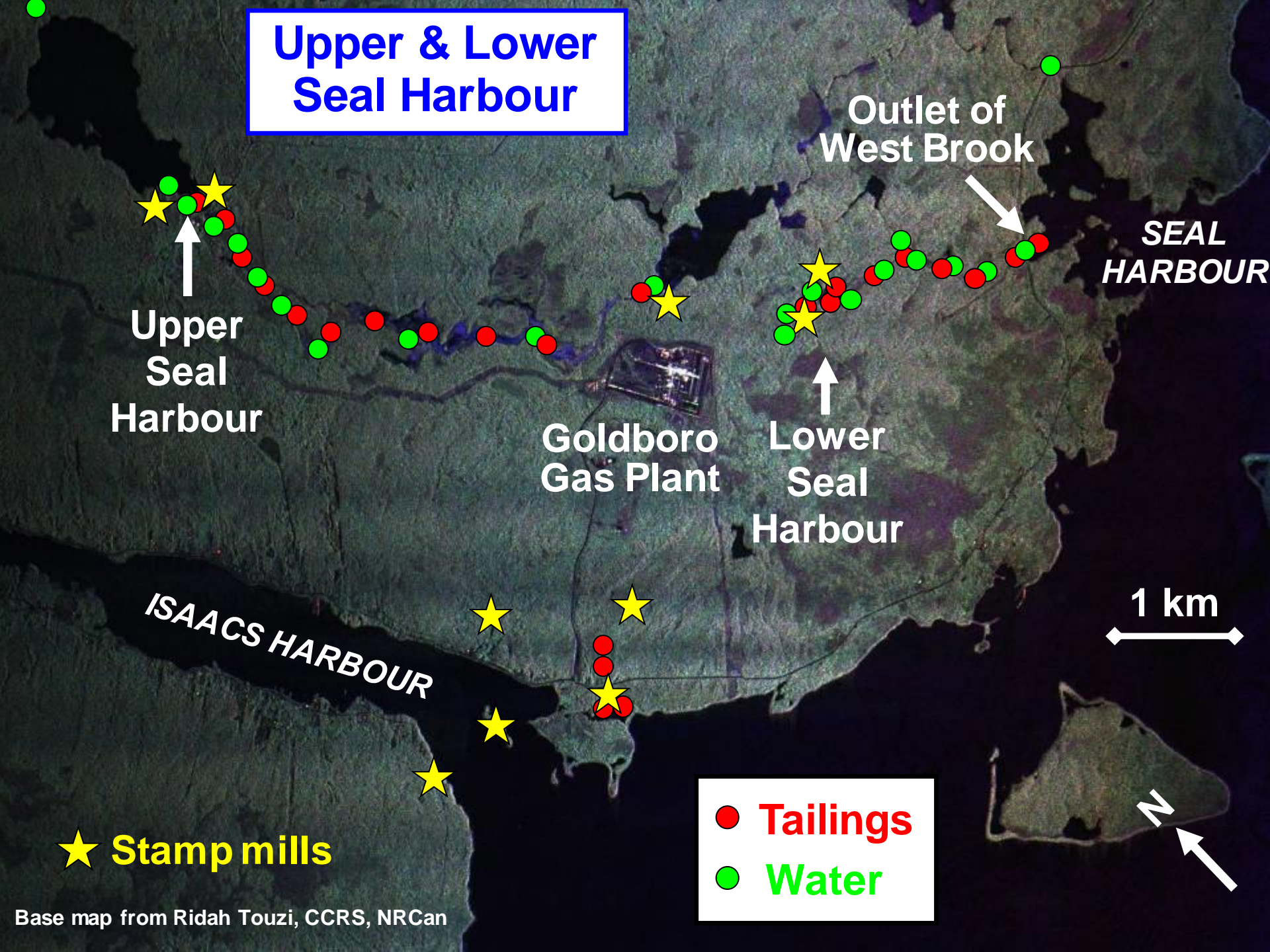
Lower  
Seal  
Harbour

ISAACS HARBOUR

1 km

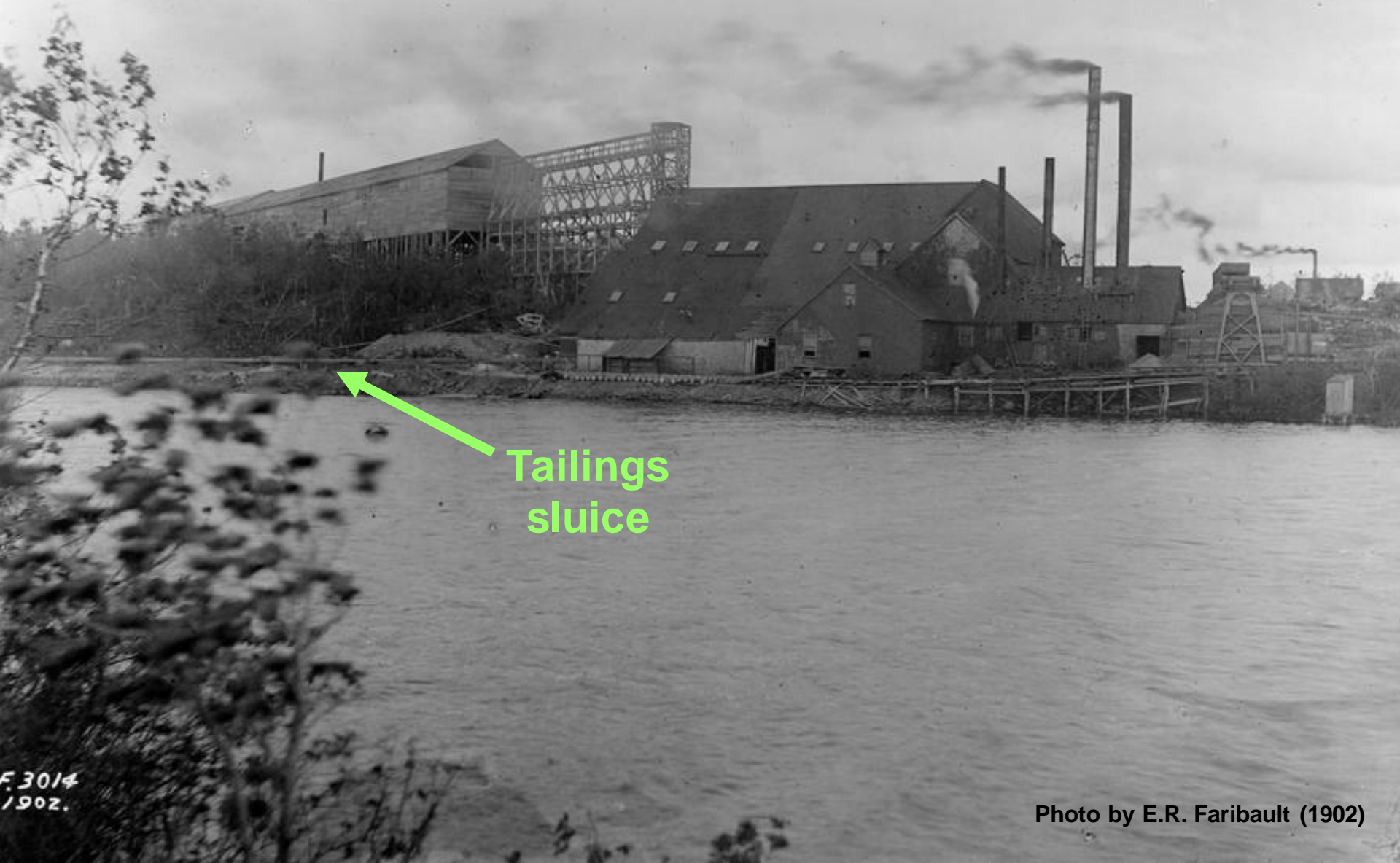
★ Stamp mills

● Tailings  
● Water





**60-stamp mill, Richardson Gold Mine, Upper Seal Harbour (1902)**



F 3014  
1902.

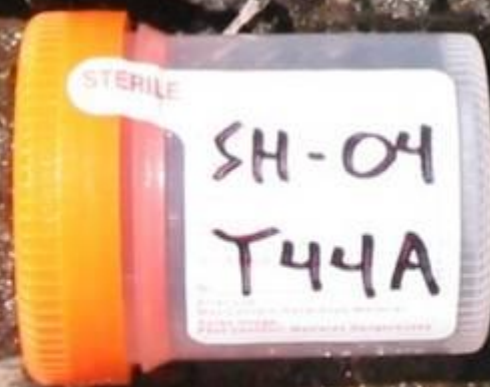
Photo by E.R. Faribault (1902)



# Upper Seal Harbour



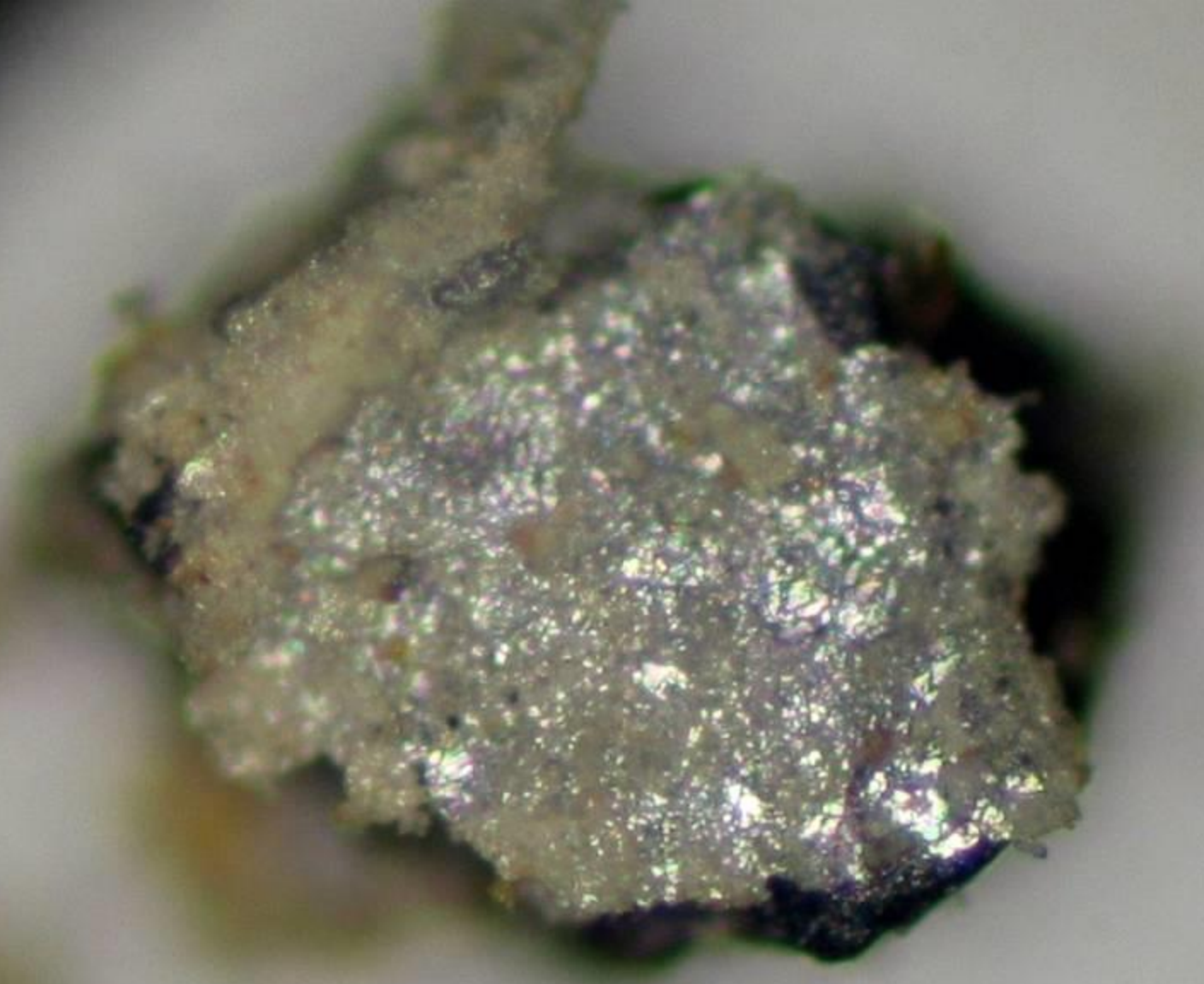




SH-04

T44A





**Amalgam / elemental Hg on sulfide grain from tailings**



**B-R  
Headframe**



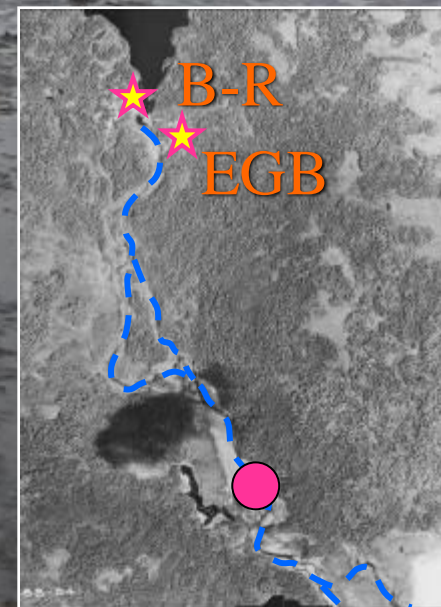
**Tailings on Gold  
Brook floodplain,  
1 km downstream  
of Richardson mill**





**Seal Harbour Run (~2.5 km downstream of Boston-Richardson Mill)**  
**Tailings deposit >1 km long & ~300 m wide**

B-R  
Headframe



**Shaft house, mine buildings, crusher, and ore conveyor leading to cyanide plant, Lower Seal Harbour Mine (ca. 1937)**





# Lower Seal Harbour









# Tailings delta / clam flats in Seal Harbour



**Hwy 316**

**Mouth of  
West Brook**

**Tailings**

**Tailings**



# Seasonal water sampling

Dissolved As concentrations (ppb)

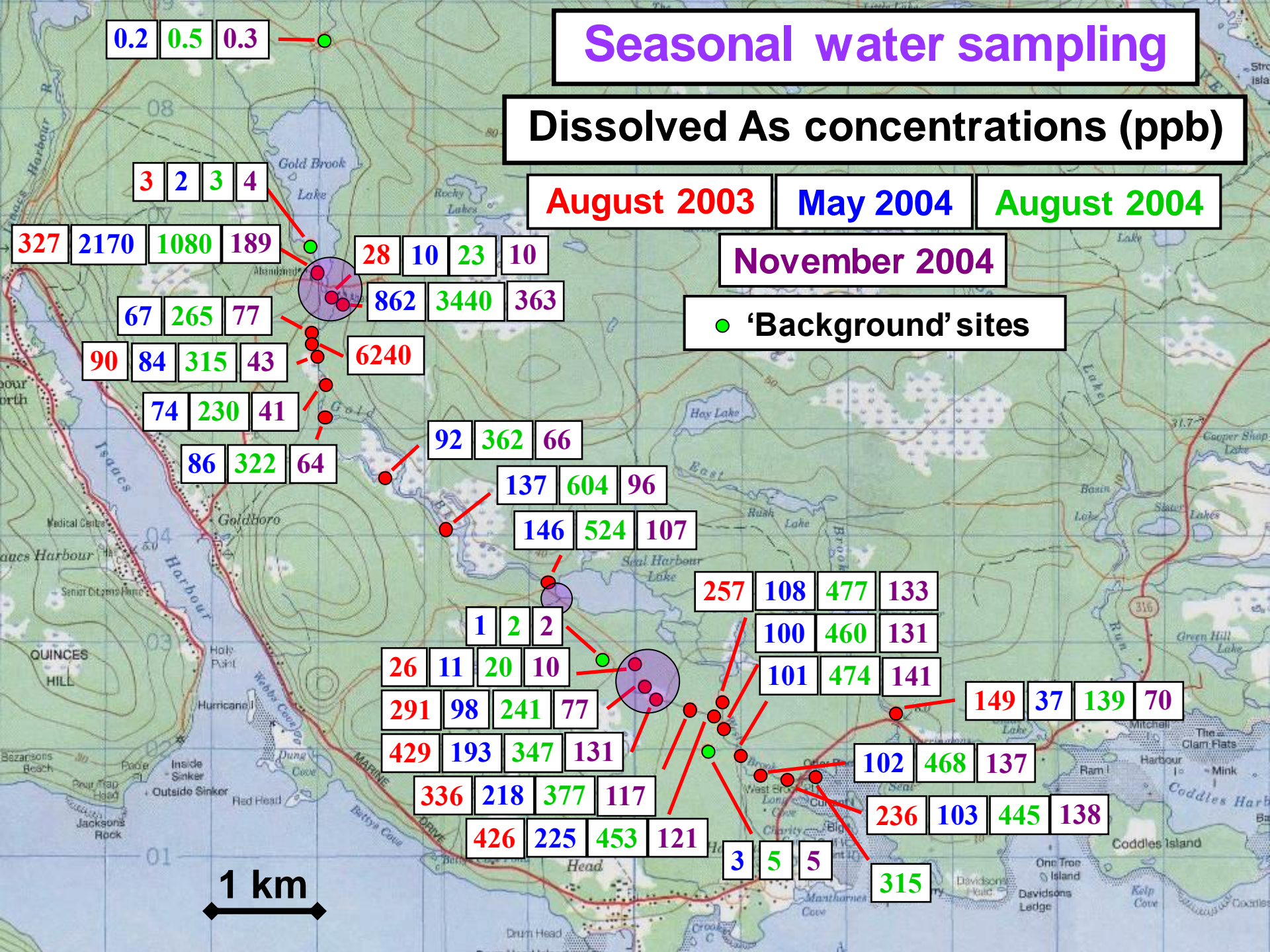
August 2003

May 2004

August 2004

November 2004

● 'Background' sites



# Fieldwork in 2004-2005: Terrestrial

- Analyses of metal(loid) speciation in tailings, sediments & waters
  - » As(III)/As(V) analyses in surface / pore waters
  - » Methylmercury studies
  - » Sequential extractions / mineralogy
  - » X-ray Absorption Fine Structure (XAFS) spectroscopy





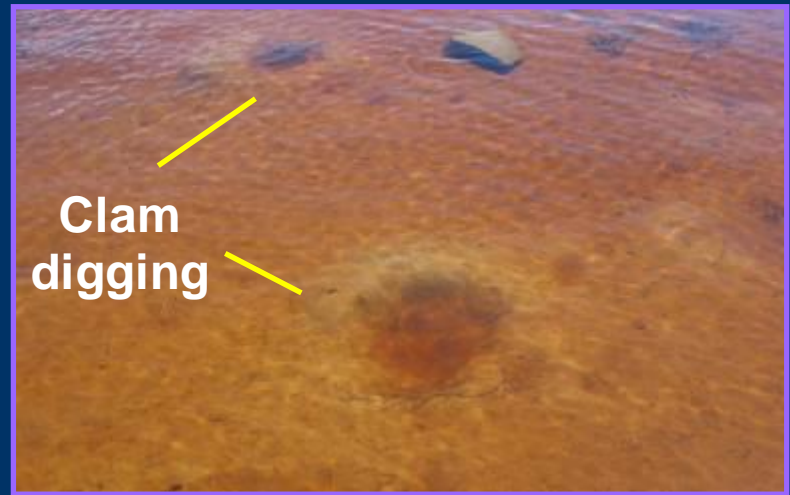
# Fieldwork in 2004-2005: Terrestrial / Intertidal

- Studies of sediment / water toxicity & bioaccumulation of metals in fish, frogs, clams, mice, and plants

Electrofishing

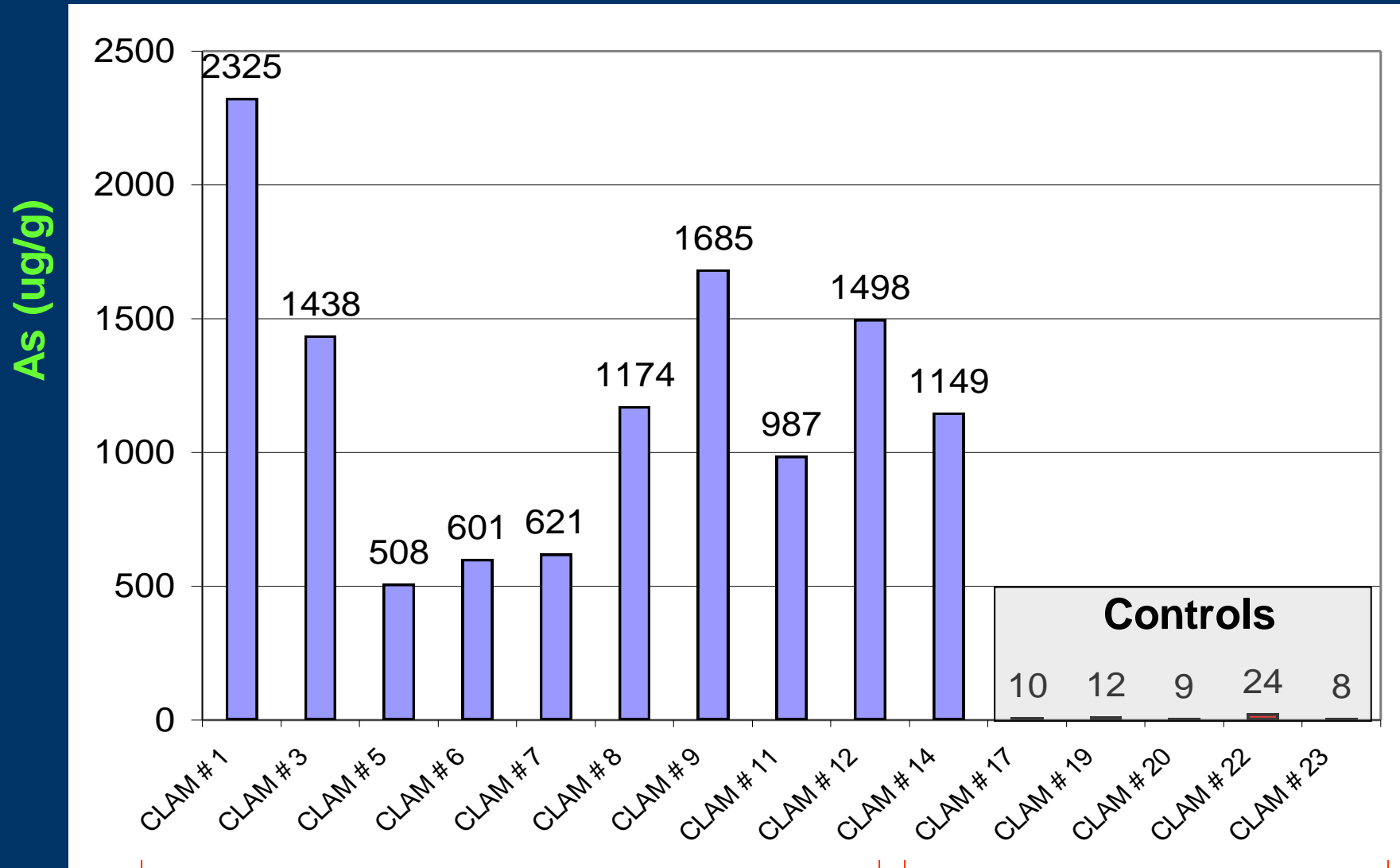


Clam digging





# Arsenic Concentrations in Clam Tissue (ug/g dry weight)



Clams from Seal Harbour (1-14)

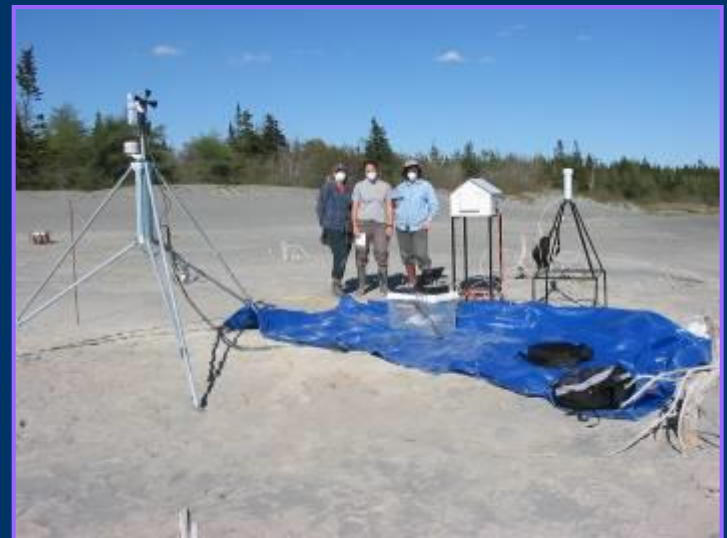
Control samples (17-23)

Health Canada guideline for As in clam tissues is currently being developed

Data from Ken Doe, Environment Canada (March 21, 2005)

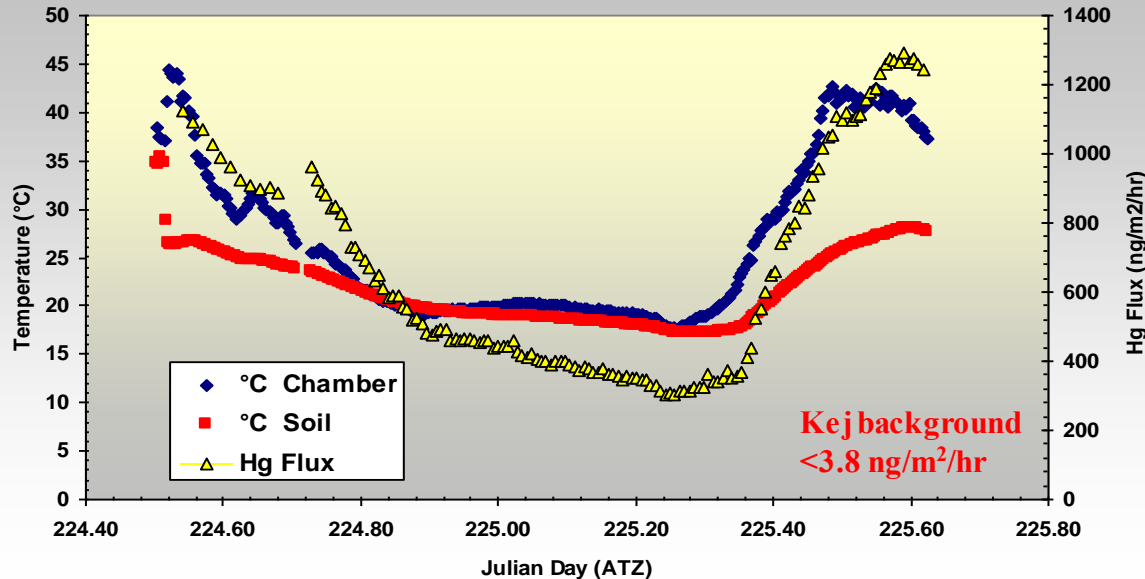
# Fieldwork in 2004-2005: Terrestrial

- Short food chain transfer studies (tailings-plants-mice); measurement of gaseous Hg fluxes & analyses of airborne particulates





## Site 2 - Goldboro



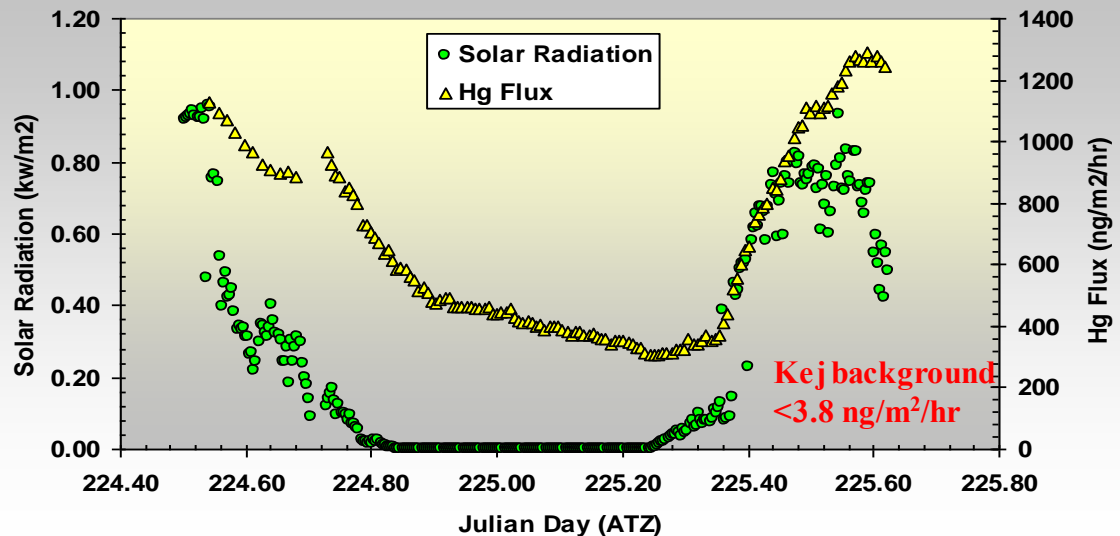
## Gaseous Hg flux measurements on high-Hg tailings at Lower Seal Harbour

Meteorological data versus Hg Flux

- Mid-day Hg flux > 1200 ng m<sup>-2</sup> hr<sup>-1</sup>
- Declining to 300 ng m<sup>-2</sup> hr<sup>-1</sup> during the evening and throughout the night
- Daily mean was 652 ng m<sup>-2</sup> hr<sup>-1</sup> - max of 1292 ng m<sup>-2</sup> hr<sup>-1</sup>

Data from Rob Tordon & John Dalziel, Environment Canada (March 21, 2005)

## Site 2 - Hg Flux vs Solar Radiation





# Human exposure to gold mine tailings



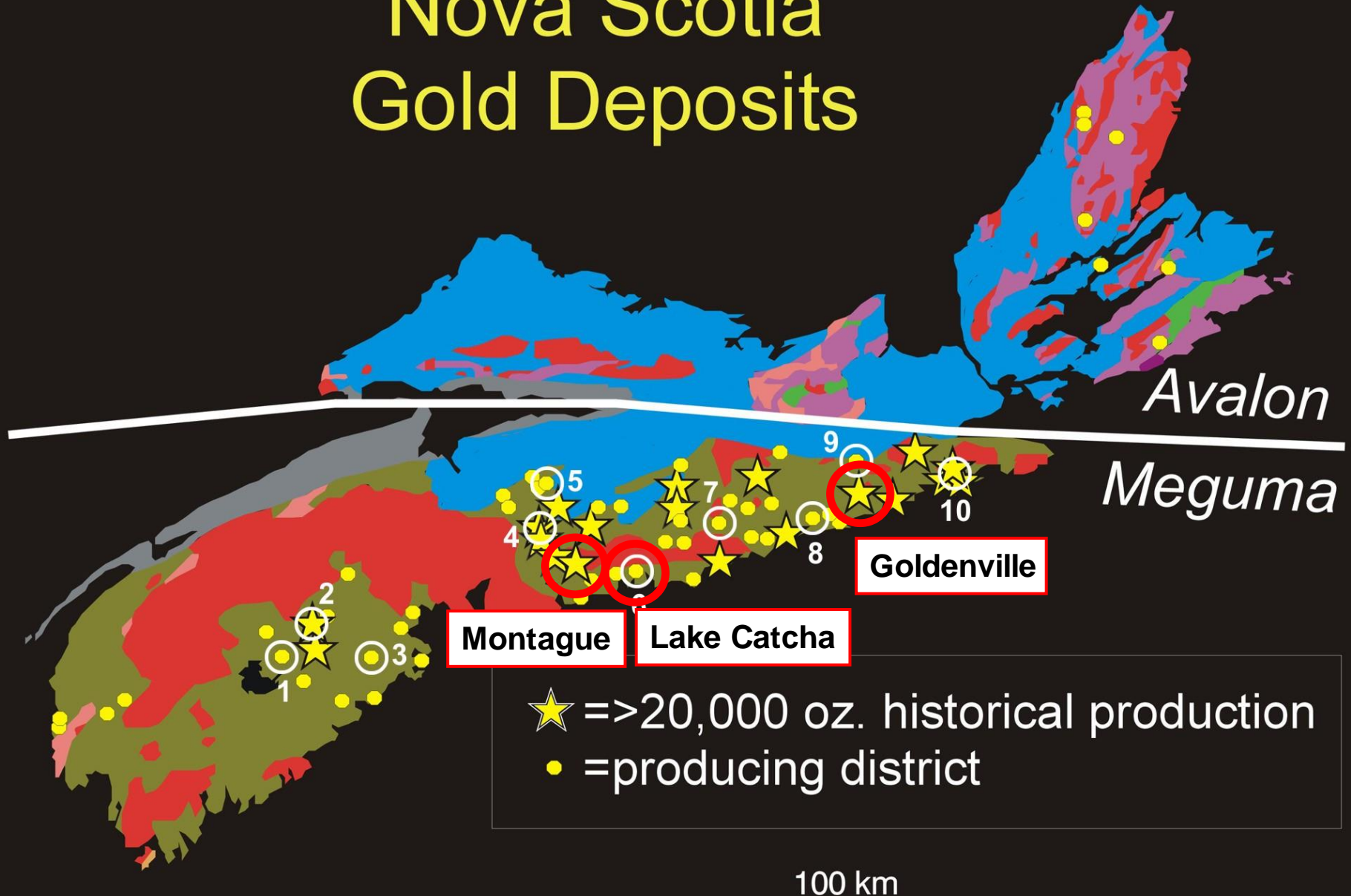
Natural Resources  
Canada

Ressources naturelles  
Canada

Canada



# Nova Scotia Gold Deposits

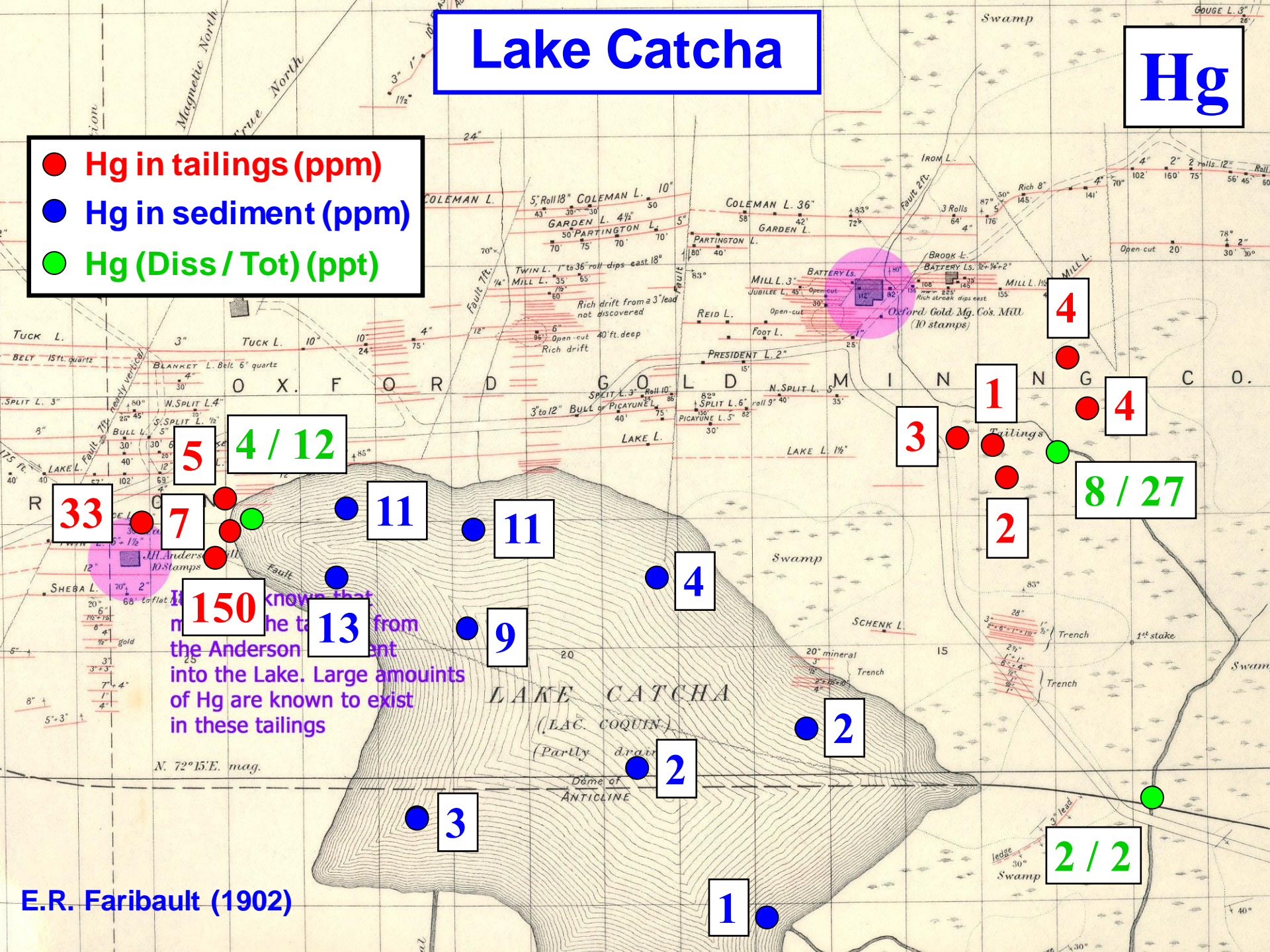




## Lake Catcha

**Hg**

- Hg in tailings (ppm)
- Hg in sediment (ppm)
- Hg (Diss / Tot) (ppt)



## E.R. Faribault (1902)



FOR SALE

Century

WATERFRONT

A.B.C. Realty Ltd.



463-100

**SOLD**  
ACREAGE

SHEILA LIVINGSTON 497-4442

September 2003





Beach area is  
composed  
entirely of  
mine tailings

September 2003



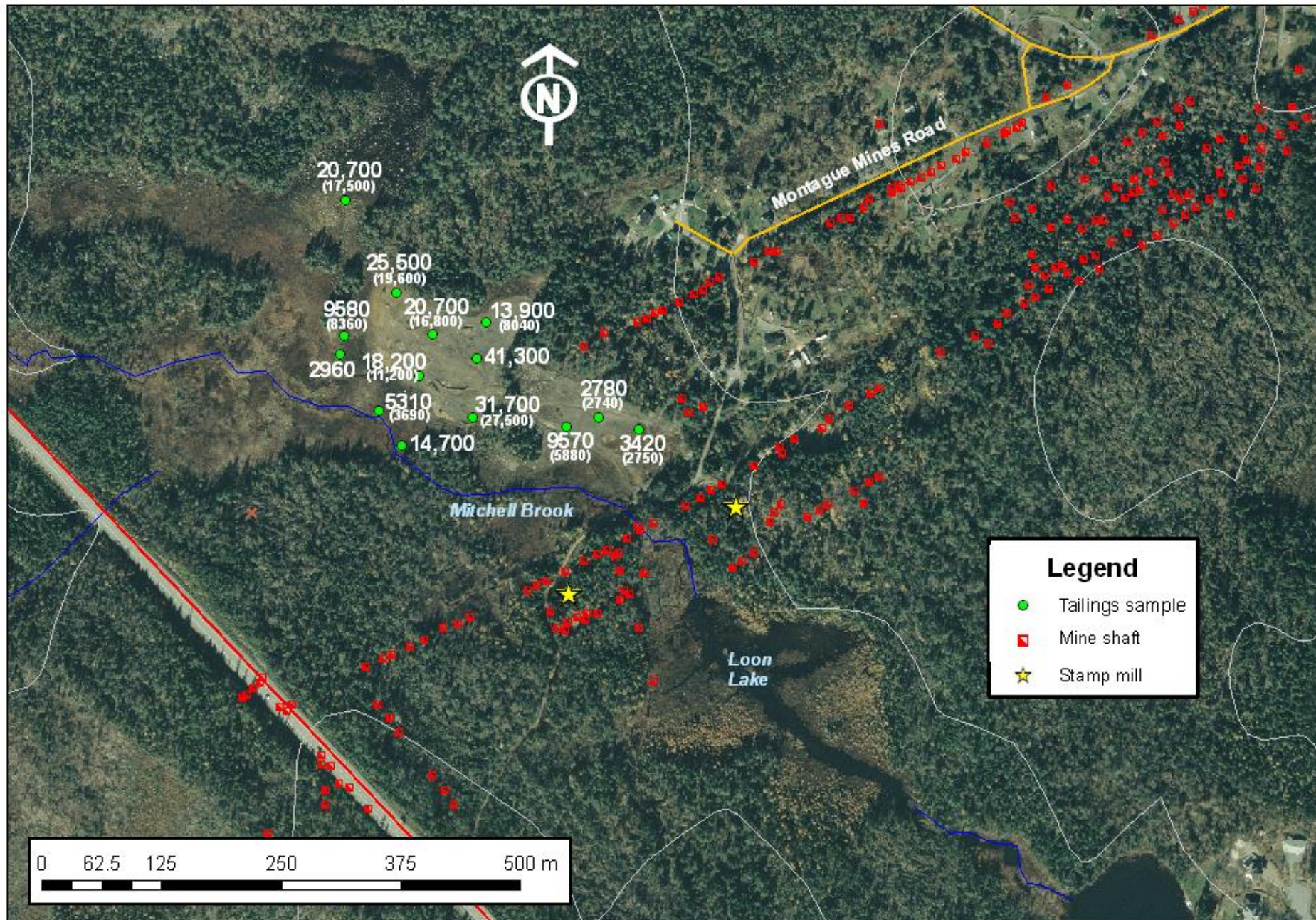


**December 2004**



# As concentrations (ppm) in Montague tailings

(maximum and (mean) concentrations in top 25 cm; <2 mm size fraction)







**Dirtbikes racing on gold mine tailings, Montague Gold Mines, NS**

# **GOLDENVILLE**

## **HOME OF THE ANNUAL**

### **4X4**

### **RALLY**



Signs  
By **T-MAC**  
AUTO GLASS & TRIM

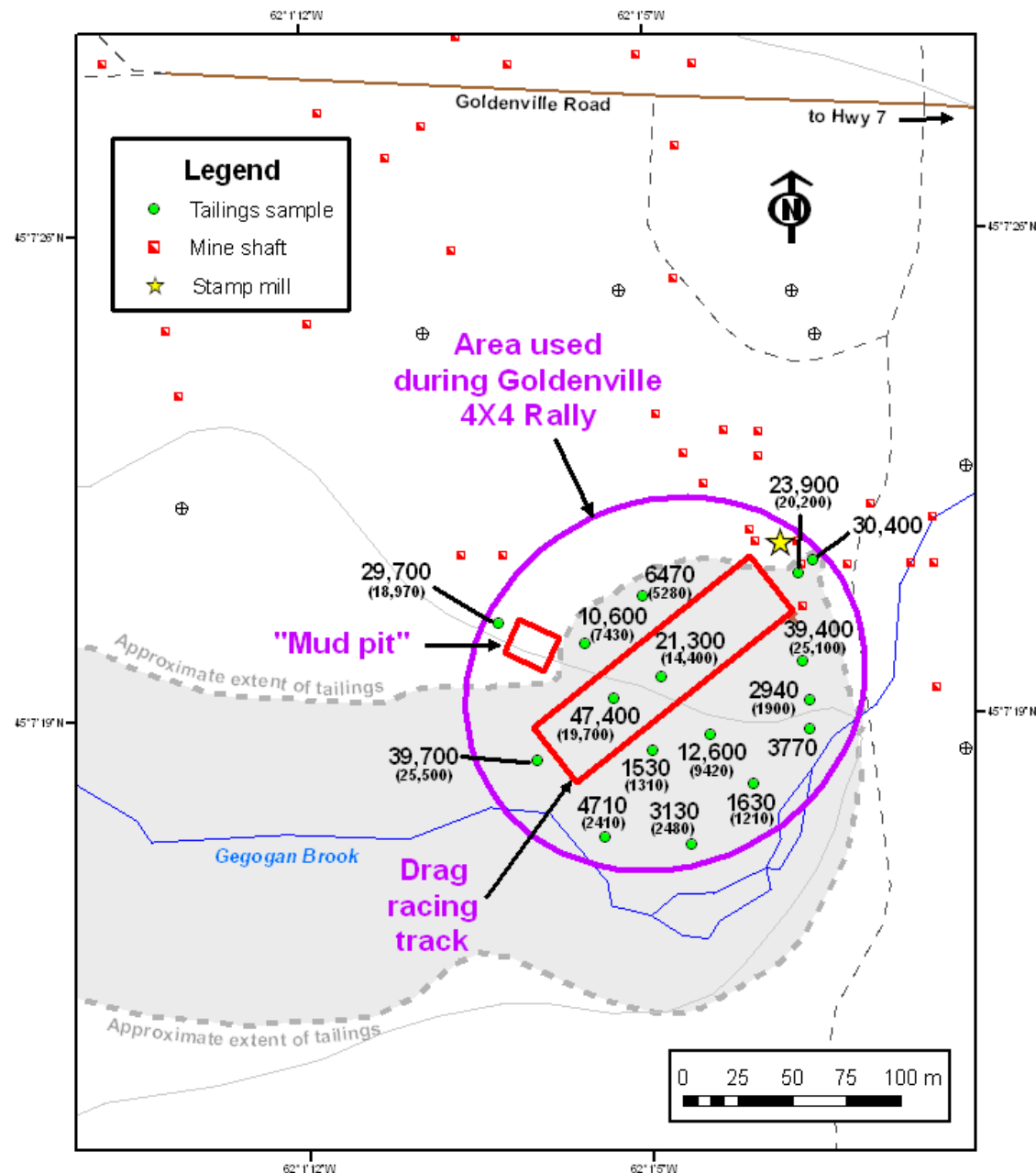


# As (ppm) in Goldenville tailings

Maximum and (mean)  
concentrations;  
<2 mm size fraction

CCME Soil Guideline:  
**12 ppm**

As concentrations (ppm) in Goldenville tailings  
(maximum and (mean) concentrations in top 25 cm; <2 mm size fraction)









**4X4 rally on gold mine  
tailings, Goldenville, NS**





**4X4 rally on gold mine  
tailings, Goldenville, NS**





# Summary of Key Findings



- Concentrations of mercury (Hg) and arsenic (As) in mine tailings and surrounding environments are significantly elevated above natural background levels (for Hg, up to 7000X; for As, up to 9500X).
- Mine wastes have been, and continue to be, transported over considerable distances (up to 6 kilometres), impacting terrestrial and aquatic ecosystems, and the marine environment.
- Very high concentrations of gaseous mercury measured in air immediately overlying tailings deposits.
- Numerous examples of human exposure to mine wastes; for example,
  - » Expanding development encroaching on abandoned mine lands
  - » Mine wastes frequented by the public for recreational purposes
- At one clam digging site, extremely high concentrations of As have been documented in clam tissues (from 500-2300 ppm, dry weight).



# Management Actions: May 2005 - present

## *Provincial Members*

NS Dept. of  
Environment &  
Labour (**Chair**)

NS Dept. of  
Natural  
Resources

NS Dept.  
of Health

NS Dept. of  
Agriculture &  
Fisheries

Service NS &  
Municipal  
Relations

**Nova Scotia Cabinet**

**Senior Provincial Managers**

**Historic Gold Mines  
Advisory Committee**

## **Working Groups**

- **Data Compilation**
- **Gold District Mapping**
- **Human Health Risk**
- **Marine / Shellfish**
- **Freshwater**

## *Federal Members*

Natural  
Resources  
Canada

Environment  
Canada

Health  
Canada

Canadian Food  
Inspection  
Agency

Fisheries &  
Oceans Canada





# Precautionary shellfish closure issued on May 6, 2005





# Summary of HGMAC activities



- Web site describing tailings, arsenic, and mercury:  
<http://www.gov.ns.ca/enla/contaminatedsites/goldmines.asp>
- Press releases on June 23 and December 16, 2005:  
“Nova Scotians advised to avoid gold tailings”  
<http://www.gov.ns.ca/news/details.asp?id=20050623004>  
“Medical Officer of Health advises to avoid gold tailings”  
<http://www.gov.ns.ca/news/details.asp?id=20051216001>
- Letter sent to organizers of Goldenville 4X4 Rally
- Data compilation & mapping ongoing, addition sampling of bivalve shellfish and freshwater fish completed in Summer / Fall 2005
- Detailed studies of As bioaccessibility and human health risks underway





# Acknowledgements

- Financial support from ESS MITE Program, and NSERC's Metals in the Human Environment - Research Network (MITHE-RN)
- Ongoing support from Andy Rencz, ESS MITE Program Manager

North Brookfield, NS