SUDBURY AREA RISK ASSESSMENT

VOLUME 1
EXECUTIVE SUMMARY

This report is Volume I of the Sudbury Soils Study and Risk Assessment. It provides an introduction to and overview of the work carried out since 2001. Volumes II and III of the study are the Human Health Risk Assessment (HHRA) and the Ecological Risk Assessment (ERA), respectively. The three volumes together document existing conditions provide the basis for future decisions on the management of potential risks identified in the Sudbury study area.

The study is overseen by a collaborative Technical Committee (TC) in place since 2001 and comprised of Vale Inco[1], Xstrata Nickel, the Ontario Ministry of the Environment (MOE), the Sudbury & District Health Unit (SDHU), the City of Greater Sudbury and the First Nations and Inuit Health Branch of Health Canada. Funding is provided at arm's length by Vale Inco and Xstrata Nickel to ensure the study is conducted in a transparent manner. Broad consultation with local communities and stakeholder groups, as well as scientific peer review of the results, were integral features of the approach to this study.

Chapter 1. Introduction

Chapter 1 provides the background to the study and a description of the study area.

In 2001, the Ontario Ministry of the Environment (MOE) published the results of soil monitoring studies carried out between 1971 and 2000. Elevated levels of three metals (cobalt, copper and nickel) and arsenic were identified in soils near the historic smelting and refining centers of Copper Cliff, Coniston and Falconbridge. The 2001 MOE report recommended that a more detailed soil study be undertaken to fill in data gaps and that an HHRA and an ERA be done. An extensive soil survey was undertaken in 2001 by the MOE and the two mining companies. That study and an overview of the results are described in Chapters 7, 9 and 10 of this report. The Sudbury Area Risk Assessment (SARA) Group was selected in 2003 to undertake the risk assessments. The SARA Group is an affiliation of several Ontario-based

[1] Ownership of the two mining companies that funded this study changed since the study began. Inco Ltd. became CVRD Inco in 2006 and then had a name change to Vale Inco late in 2007. The company Falconbridge Ltd. became Xstrata Nickel in 2006. The current names of the companies are used in this report when referring to present day activities. However, the original company names are used when referring to historical activities, or actions undertaken by the companies prior to the name change. This is especially true for chapters 2 through 5 in this volume.

consulting firms specializing in the different scientific disciplines required to carry out a study of this broad scope.

An "Area-Wide Risk Assessment" (AWRA) approach was adopted for this work. An AWRA takes into account a wide range of technical or scientific, regulatory and social considerations. Although the impetus for the study was soil quality, all potential exposure pathways are considered for both the HHRA and ERA. At the time of this report no AWRA of this scope has been completed in Canada.

The study area for the work is an area approximately 200 km by 200 km in size that encompasses the City of Greater Sudbury. The boundaries of the City capture a diverse natural environment including over 300 inland lakes, wetlands and many different types of natural habitat and vegetation communities. For detailed evaluation in the HHRA, five specific Communities of Interest (COI) were identified:

- Copper Cliff
- Coniston
- Falconbridge
- Sudbury centre
- Hanmer

Chapter 2. History and Development of Mining and Smelting in Sudbury

Sudbury is a resource-based city that has defied the odds. From rail town to international mining centre, the city is transforming itself into a model of self-sustainability. The Sudbury of today is a city of lakes and tight-knit communities, full of hard-working, hard-playing people as down to earth as the rock on which they have built. The mining legacy of heady successes and economic downturns has made Sudbury what it is today: tenacious, innovative, and incredibly resilient.

Sudbury's legacy of mining and smelting activities is also the story of environmental degradation, and more recently, environmental restoration and rehabilitation. As the hills of the Sudbury region turn green once more it is important to consider the whole story, from roast yards to emission controls, and from environmental degradation to ecological restoration and rehabilitation so Sudbury and its people can move decisively into the future.

The Sudbury Area Risk Assessment is a logical step in the overall process of Sudbury's ongoing self-sustainability initiatives. The study will identify potential human health and ecological risks resulting from Sudbury's historic industrial development to provide a basis for managing those risks in the future.

Chapter 3. Air Emissions Review

Chapter 3 reviews the sources and types of air emissions contributing to the elevated levels of metals in Sudbury soils. It also provides a history of smelting procedures.

Historically, the facilities at Copper Cliff, Coniston and Falconbridge produced emissions that resulted in local barren areas largely devoid of vegetation. In 1972, three major factors led to a dramatic improvement in air quality in the region: first, the construction of Inco's 381 metre "superstack"; second, the closure of the Coniston smelter; and third, the closure of Falconbridge's pyrrhotite (iron ore sintering) plant. Ground-level concentrations of sulphur dioxide dropped by 50% immediately, and Sudbury began to register lower pollution rates than Hamilton or Toronto.

Stringent provincial air quality guidelines also began to be imposed in the mid 1970s. Since the mid-1960s, sulphur dioxide emissions have been reduced by over 90% in the Sudbury area. Similarly, the emissions of particulate matter have also declined significantly.

Chapter 4. Regreening and the Changing Landscape

The term "regreening" has been used to describe the reclamation activities working toward re-establishing forest and vegetation cover in the Sudbury area. These activities began as a community-based initiative to repair the visible damage to the Sudbury landscape. The original causes of vegetation loss and damage to the regional vegetation include logging, forest fires and sulphur dioxide and metal emissions from the roast yards and later from the smelters. The removal and loss of vegetation and continued exposure to fumigations from the smelters exacerbated soil conditions and prevented natural growth up to the mid-1970s.

Natural recovery was also impeded due to physical loss of soil from erosion, loss of soil nutrients, elevated metal concentrations in soil, reduced soil pH as a result of sulphur deposition, needle ice formation that creates soil instability and severe micro-climate conditions of extreme temperatures.

The initial reclamation activities in the 1970s and early 1980s focused on removal of unsightly debris and tree planting along the major highways in and around Sudbury to improve the aesthetics of the region's "viewshed." The program has since greatly expanded with a systematic approach that is described in detail in this chapter.

The City of Sudbury Land Reclamation Program records indicate that by 2005, nearly 3,400 ha of barren grounds were treated and over 8.5 million tree seedlings were planted via this program alone. The program has successfully met the original mandate of the Land Reclamation Program in 1978, which was to create conditions that change the image of Sudbury from an undesirable place to live to a community and industry driven environmental success story. The regreening program, vegetation communities and social and environmental benefits are described in detail in this chapter.

Chapter 5. Analysis of Vegetation Change by Remote Sensing

This chapter assesses the success of the regreening program described in the previous chapter. In the context of this study, remote sensing is the analysis of satellite-based images over a broad geographic area to examine changes in vegetation patterns. This approach differs from traditional aerial photographs in that it provides images calibrated at discrete wavelengths or bands. A relationship can be developed to relate particular spectral bands to land cover types such as water, bedrock, deciduous and coniferous vegetation cover.

The primary objectives of this remote sensing study were as follows:

- Provide a generalized land cover description as a reference for future vegetation analysis,
- Quantify vegetation cover within selected regions of interest both temporally and spatially,
- Compare naturally occurring vegetation recovery and assisted vegetation recovery, and
- Provide information that can be integrated with the Ecological Risk Assessment

Two sets of remote sensing were obtained for this study covering the 30-year period from 1976 to 2003.

Mapping information was obtained from the City of Greater Sudbury that identified the spatial areas that have been treated for reclamation purposes. The "entire recovery area" is approximately 18,175 ha in size where liming, grassing or tree planting has occurred. Within that area, approximately 2,692 ha have undergone both liming and tree planting and are referred to in this study as the "concentrated recovery area".

Barren areas were identified around each of the historic smelting centres with estimated sizes at Coniston of 6,813 ha; Copper Cliff, 7,405 ha; and Falconbridge, 4,843 ha. A natural area outside the semi-barren area was used as a benchmark to examine changes in vegetation patterns from 1988 to 2003.

Remote sensing analysis revealed the following general results:

- Vegetation on the barren grounds is now dominated by deciduous trees and shrubs while coniferous vegetation is not a large component of the barrens. This contrasts with the natural vegetation communities outside the barren and semi-barren areas.

- Between the period 1988 to 2003, conifer cover in the "concentrated recovery area" was almost double that in the "general recovery area".

- Between 1988 to 2003 there was a positive increase in vegetation cover of barren areas for 59% of the area at Coniston, 54% at Copper Cliff and 46% at Falconbridge.

The remote sensing analysis has provided a synoptic and temporal view of vegetation patterns over the Sudbury area. Revegetation of the barren areas is occurring both through natural recovery and reclamation activities. The rate of recovery is spatially different, which may be due to a combination of factors.

Chapter 6. Public Consultation

Chapter 6 summarizes the activities and achievements of the public consultation component of the Area Wide Risk Assessment.

The Technical Committee (TC) has demonstrated a strong commitment to community involvement in the study. A Public Advisory Committee (PAC) of 10 to 12 community members is charged with reviewing and contributing to all study communications and consultation materials and initiatives. An Independent Process Observer has participated in TC and PAC meetings and issues quarterly reports to the community.

A communications and community involvement plan was developed and updated through the course of the study. The SARA Group solicited feedback through a number of vehicles, including meetings with the Communications Sub-committee (CSC), the TC, the PAC, various interest groups, First Nations, as well as three workshops and four community open house/information sessions. The local media has conducted over 50 interviews with team members and produced over 150 media stories on the work. The study website is regularly updated and over 450 people have used the toll-free phone number and email.

Issues that have received prominent status as a result of the communication and public consultation activities include addressing the health of children; surveys of vegetable gardens; biodiversity and ecosystem links; clear and professional communications; transparency of process and results; and increased opportunities for public consultation. Public consultation and communication is an on-going activity and will continue into 2008 with presentation of the final results to the public.

Chapter 7. The 2001 Soil Survey

Chapter 7 provides a brief overview of the 2001 soil survey. The results of the entire survey are provided in three separate reports, which are found on CD in the back of this volume.

The 2001 soil survey had several objectives:

- To determine the spatial extent of elevated metal levels in soil in the Sudbury region;
- To determine Sudbury specific "background" metal concentrations of metals; if possible,
- To examine the contribution of metals from atmospheric deposition; and
- To provide comprehensive baseline data for the human health risk assessment (HHRA) and ecological risk assessment (ERA).

Approximately 8,400 soil samples were collected from 1,190 sites in a 200 km by 200 km sampling area. Samples were collected from 10% of all residential properties in the smelter communities of Copper Cliff, Coniston and Falconbridge, and a representative number of residential properties in the remainder of the City of Greater Sudbury. Soil samples were collected from every school, park and daycare centre in the area.

Every soil sample was analyzed for the following 20 inorganic parameters: aluminium (Al), arsenic (As), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cr), iron (Fe), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), tin (Sb), selenium (Se), strontium (Sr), vanadium (V) and zinc (Zn). Summary statistics are provided in this chapter and further presentations of the data are found in subsequent chapters of this report.

Chapter 8. Selection of Chemicals of Concern (COC)

It is common practice in a risk assessment to limit the number of chemicals being evaluated in detail to those substances that represent the greatest concern to the area being studied. Based on a review of historical soil quality information, the Technical Committee identified four candidate COC in the study Terms of Reference. These were As, Co, Cu and Ni.

For this assessment, the source of information for identification of candidate COC was the 2001 soil survey database.

In the Terms of Reference for the risk assessment, the TC provided three criteria for the identification of COC:

1. Parameter must be above the Ontario Ministry of the Environment Table A or Table B criterion as published in the MOEE's *Guideline for Use at Contaminated Sites* (MOEE 1997). These criteria were developed to "protect against adverse effects to human health, ecological health and the natural environment" (MOEE, 1997).
2. Parameter must be present across the study area.
3. Parameter must scientifically show origin from the companies' operations.

The data screening process confirmed that As, Co, Cu and Ni met the above criteria. In addition, Pb and Se met the three criteria and were recommended as COC for the detailed risk assessment.

It was subsequently recognized that the Table A and B criteria only apply to soils with a pH between 5 and 9 for surface soils. Many of the soils in Sudbury are naturally below pH 5.0. Soil pH in many areas has been further depressed due to sulphur deposition. Further analysis of soils collected in 2001 revealed that soils in the urban areas were predominantly above pH 5.0, due to importing of soil and soil amendments. In contrast, soil pH in the rural and undisturbed areas was predominantly below pH 5.0. This meant that Table A and B could be applied to the urban soils, but not rural or regional soils. Thus, for the HHRA the candidate COC remained as As, Co, Cu, Ni, Pb and Se.

The regional soils data with pH below 5.0 were re-screened against typical Ontario background concentrations (Table F). This analysis revealed that Cd was elevated above background concentrations in rural Sudbury soils, although substantially below Table A. Therefore, Cd was also nominated as a COC for the purpose of the ERA only.

Overview of Levels of Chemicals of Concern in Sudbury Soils (0-20 cm depth) expressed as mg/kg (n=8,148)

Parameter	Minimum	Mean	Maximum	MOE Criterion
Arsenic	2.5	16	620	20 [1]
Cobalt	1.0	14	190	40 [1]
Copper	2.7	260	5600	225 [1]
Nickel	7.0	264	3700	150 [1]
Lead	1.0	35	790	200 [1]
Selenium	0.5	2	49	10 [1]
Cadmium (ERA only)	0.4	1	6.7	1.0 [2]

[1] Table A criteria for coarse textured soil (potable groundwater condition) with pH 5.0 > 9.0 for surface soil and pH 5.0 > 11.0 for subsurface soil; and, intended for residential/parkland uses
[2] Table F Ontario typical range soil concentrations (background)

Chapter 9. Regional Distribution of Chemicals of Concern in the Study Area.

The distribution of each of the COC in surface soils (0 to 5 cm) in the general study area was mapped by plotting each sample location and colour coding the site according to metal concentration. Metal concentrations tended to be elevated within 7 to 10 km of the historic smelting centres of Copper Cliff, Coniston and Falconbridge. However, in some instances metals levels were elevated up to 120 km distance from the smelters. Soil concentrations of Pb and Se tended to be elevated around Copper Cliff and not the other sites, while As was generally higher in soils around the Falconbridge smelter.

The vertical distribution of the metals was analyzed in numerous soil cores. This analysis revealed that metal concentrations were generally highest in the surface soils (0 to 5 cm layer) compared with deeper soils. This strongly suggests atmospheric deposition as the primary source of the elevated metal levels in the Sudbury soils.

Deep (> 80 cm) soil samples were collected from about 250 locations in the regional soil survey. These “parent material” samples were considered to represent natural or background soil metal concentrations for the Sudbury region. Although Sudbury is known as a highly mineralized area, the background metal concentrations as determined from these samples were not significantly higher or different than background metal levels in other Ontario locations.

Chapter 10. Distribution of COC in the Communities of Interest (COI)

Five primary COI were identified for detailed evaluation for the HHRA. This is necessary since the soil concentrations of the COC differ considerably throughout the study area. Thus, a person's exposure would also differ in each community. The five communities are Copper Cliff, Coniston, Falconbridge, Hanmer and Sudbury Centre.

This chapter provides summary statistics for each of the COC in each of the communities for each of the major soil layers (0 to 5 cm, 5 to 10 cm and 10 to 20 cm). Thirty maps are also presented that display the concentrations of each COC in surface soils in each of the communities of interest.

Lastly, a summary of soil metal concentrations is provided for each of the smelting communities of Copper Cliff, Coniston and Falconbridge by land use: residential, schools and daycares, and parks.