SUDBURY AREA RISK ASSESSMENT

VOLUME III - CHAPTER 1.0
INTRODUCTION

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1.0 INTRODUCTION

The Sudbury Basin is an area rich in mineral deposits, particularly the nickel and copper ores that have drawn people to the region for the past 125 years. Recent studies identified areas in Sudbury with elevated metal and arsenic levels in the soil. These areas are generally close to the historic smelting sites of Coniston, Falconbridge and Copper Cliff. Although these metals do occur naturally in all soils, studies generally indicate higher levels in surface soil (the top 5 cm) as a result of dust and emissions from local mining, smelting and refining operations (see Volume I).

In 2001, the Ontario Ministry of the Environment (MOE) reported that concentrations of nickel, cobalt, copper and arsenic in the Sudbury area exceeded the generic MOE soil quality criteria[1] (MOEE, 1997). It must be noted that the MOE soil criteria published in the Guideline for Use at Contaminated Sites in Ontario (MOEE, 2001) are not "action levels." Therefore, exceeding the generic criteria does not automatically indicate that clean up is required (MOEE, 2001). However, soil contaminant concentrations in excess of the criteria listed in the guideline (MOEE, 1997) do indicate the need for further investigation and/or a risk assessment.

As a result of the recent findings at Sudbury, the MOE (2001) made two major recommendations:

- That a more detailed soil survey be undertaken to fill data gaps; and,
- That human health and ecological risk assessments be undertaken.

Both Vale Inco (formerly Inco Limited), and Xstrata Nickel (formerly Falconbridge Limited) voluntarily accepted the MOE recommendations and began working together to establish what is commonly referred to as "The Sudbury Soils Study". Volume I of the Sudbury Soils Study provides the background to the study including a more detailed description of the history of the Sudbury region, metal levels in soil and study organization and process. Some of that information is briefly reviewed in this introduction. Volume II of the study is the Human Health Risk Assessment. This report is Volume III (Ecological Risk Assessment or ERA) of the Sudbury Soils Study.

[1] In 2004, the MOE's Guideline for Use at Contaminated Sites was replaced by the new Records of Site Condition Regulation (O.Reg. 153/04) and associated guidance material. The soil quality criteria (Tables A to F) that had been used with the Guideline were reissued as Site Condition Standards (Tables 1 to 6). When they were first issued in 2004, the Site Condition Standards had the same values as the old criteria. The Guideline and associated criteria were non-regulatory in nature; however, where the Regulation applies, proponents now must either meet the Site Condition Standards, or conduct a risk assessment and develop risk-based objectives to the satisfaction of the MOE. The terminology in effect when the Sudbury Soils Study was initiated (i.e., the Guideline and Tables A to F) has been retained.

To oversee this complex study, the mining companies involved four other major stakeholders in Sudbury: the MOE, the Sudbury District Health Unit (SDHU), the City of Greater Sudbury, and Health Canada's First Nations and Inuit Health Branch. These stakeholders formed a Technical Committee (TC) to coordinate many facets of the program. A Public Advisory Committee (PAC) was also established to provide a link between the study and the public at large. The study organization is described in detail in Chapter 1 of Volume I of the Sudbury Soils Study.

Upon advice from the TC, Vale Inco and Xstrata Nickel retained the SARA Group (Sudbury Area Risk Assessment Group) early in 2003 to conduct the human health and ecological risk assessments for the City of Greater Sudbury and surrounding area. The SARA Group is a consortium of companies that came together to provide the TC with the necessary skills and experience to complete this complex project. Those companies include: Intrinsik Environmental Sciences Inc. (formerly Cantox Environmental Inc.), C. Wren & Associates (now part of AECOM Canada), Rowan Williams Davies & Irwin Inc., SGS Lakefield, Goss Gilroy Inc., Trevor Smith Diggins, Ms. Jan Lindquist, and other specialists as required.

1.1 Background to the Ecological Risk Assessment

The Sudbury region is in the transitional zone between the Great Lakes-Saint Lawrence Forest, and the Boreal Forest ecological regions. The southern margin of the Northern Temagami Forest Section is characterized by large stands of red pine and white pine, while the northern margin of the Southern Algonquin Section is comprised of white pine, eastern hemlock, sugar maple and red oak in the uplands. Numerous lowland areas are characterized by wetlands and black ash swamps. Vast expanses of the Sudbury region remain relatively undeveloped even today.

The first anthropogenic impact to the region was selective harvesting of the red and white pine, which began about 1870 and continued into the 1920s. Mining and smelting activities began in the mid 1880s, and widespread clear cutting began in earnest at this time to provide fuel to roast the ore containing nickel and copper. The original roasting yards were replaced by more modern smelting facilities in the late 1920s and early 1930s. However, the relatively low smokestacks, and lack of pollution control technology associated with these early smelters resulted in large emissions of particulate matter, sulphur dioxide gases and metals that were deposited in a relatively localized area. These high volume emissions and localized deposition continued into the 1970s when more effective emission controls were implemented, higher smoke stacks were constructed and the smelter at Coniston was closed. The smelting facilities and historical emissions are documented in detail in Chapter 3 of Volume I.

Environmental degradation was apparent in the early 1900s, and by the early 1940s, government representatives were already meeting with local industry to discuss the smelter emissions and damage to the forests and local agriculture. The most dramatic impacts to the vegetation were centred on the three historic smelting centres at Copper Cliff, Falconbridge and Coniston. The most severely impacted area was largely devoid of trees and soil pH was commonly < 4.0. This was referred to as the "Barrens", which covered approximately 20,000 ha by 1970. A further 80,000 ha, located slightly more distant to the smelters, were considered "Semi-Barrens" and supported a savannah-like cover of grasses with clusters of stunted white birch and red maple.

Beginning in the mid-1970s, several stakeholders in the Sudbury region began restoration activities aimed at "regreening" the Sudbury landscape. This included soil liming to raise soil pH, seeding with grass/legume mixtures, fertilizing and planting trees. The natural Sudbury vegetation and the regreening activities are described in detail in Chapter 4 of Volume I, and are re-visited in Chapter 6 of this Volume.

There is little doubt that a combination of smelter emissions and other activities (primarily logging and forest fires) historically caused widespread loss of the original forest cover in the area. Subsequent events have resulted in a large area (i.e., the barrens and semi-barrens) with either bare exposed bedrock that provides little growth medium for plants, or impacted soils that prevent natural recovery of a self-sustaining diverse ecosystem. Figure 1-1 provides a conceptual model illustrating linkages between some of the known ecological stressors, and impacts on the plant community and wildlife inhabiting the area.

The ERA recognizes three fundamental aspects of the terrestrial ecosystem around Sudbury: (1) past activities have severely impacted the vegetation; (2) restoration and regreening activities have been, and continue to be, very successful over broad areas; and, (3) not all areas have received regreening treatments, and in many areas recovery has been inhibited.

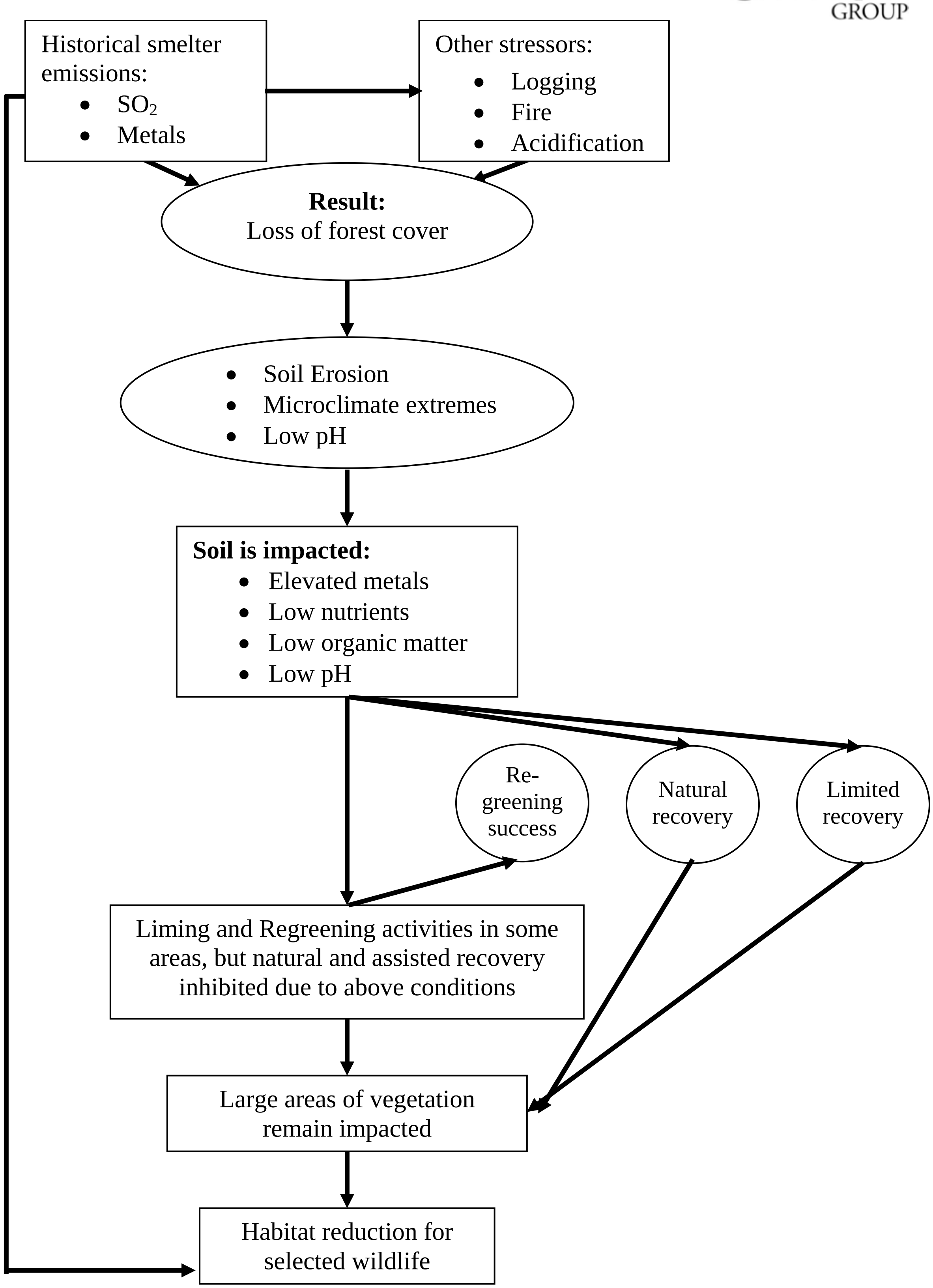

Figure 1-1 Conceptual Linkages of Past Impacts, COC and Wildlife Habitat with VECs

1.2 Ecological Risk Assessment Goal

Against a backdrop of significantly reduced smelter emissions and considerable regreening activities, one of the first tasks for this study was to achieve clear agreement on, and understanding of, the goals and objectives for the ERA. The original Request for Proposal (RFP; August 13, 2002) provided by the Technical Committee included a Scope of Work, which contained 10 objectives. Some of the original objectives were interpreted and incorporated as study tasks in the ERA approach; however, the original 10 study objectives remain embodied in the spirit of the ERA approach.

The SARA Group provided a Draft ERA Methodology and Preliminary Problem Formulation to the TC (ERA Document 1.0, April, 2003). A meeting was subsequently convened on September 11, 2003, to better define these issues. The following Goals and Objectives are based on the outcome of this meeting, and additional input from the TC and Scientific Advisor (Dr. Stella Swanson, formerly with Golder Associates).

The main **Ecological Risk Assessment Goal** for the Sudbury Soils Study recognizes the importance of evaluating ecological risks, and ecological recovery:

To characterize the current and future risks to terrestrial and aquatic ecosystem components due to Chemicals of Concern (COC) from the particulate emissions of Sudbury smelters; and to provide information that will support activities related to the recovery of regionally-representative, self-sustaining ecosystems in areas of Sudbury affected by the COC.

1.3 ERA Objectives

To achieve the ERA Goal, four **ERA Objectives** were identified:

Objective 1: Evaluate the extent to which the COC are preventing the recovery of regionally representative, self-sustaining terrestrial plant communities.

Objective 2: Evaluate risks to terrestrial wildlife populations and communities due to the COC.

Objective 3: Evaluate risks to individuals of threatened or endangered terrestrial species due to the COC.

Objective 4: Conduct a comprehensive Problem Formulation for the aquatic and wetland environments in the Sudbury area to facilitate more detailed risk assessment in the aquatic/wetland ecosystems.

The results from the first three objectives were used to address a **Management Objective** for the terrestrial environment (i.e., an overall terrestrial ERA objective):

Evaluate levels of COC in various Sudbury soil types to determine COC levels in soil that do not result in unacceptable risks to Valued Ecosystem Components (VECs).

However, early in the ERA it was recognized that in a large scale, complex ecological system such as the Sudbury area, risk cannot be related to single metal concentrations in soil. This is because there are multiple metals in the soils, and other confounding soil properties, environmental factors and stressors that affect ecological receptors. Rather, we have identified ecosystem areas that remain impacted by the multiple stressors, and describe the impacts using ecological characteristics of the areas. Chapters 3 and 6 of this volume identify characteristics of impacted and non-impacted vegetation communities and associated soil properties.

1.4 Underlying Principals

Several **Underlying Principles** were followed while conducting the ERA:

- Evaluation of aspects of the ecosystem with a direct or indirect link to human health is desirable.
- Coordination of efforts between the ecological risk assessment and the human health risk assessment is essential, so that required and relevant data are obtained for both assessments.
- Identification and synthesis of the large amount of relevant scientific information, related to COC for the Sudbury area, should provide a resource document that will guide subsequent scientific research and remediation efforts.

- Accounting for modifying factors such as pH and sulphur dioxide emissions is necessary, but an assessment of direct effects resulting from emissions of SO_x or other acidifying substances was not a component of this ERA.

1.5 Overview of the Study Process and Tasks

The formal Sudbury ERA began in early 2003 when the SARA Group was retained by Vale Inco and Xstrata Nickel. A good part of 2003 was devoted to gathering background information, understanding the data gaps and limitations, and formulating clear study objectives and goals (as discussed above). A wildlife dietary field survey was undertaken in 2003 to obtain information on metal levels in wildlife dietary items (vegetation, terrestrial invertebrates and co-located soil samples). Figure 1-2 provides a conceptual chronology of the major events and undertakings that were completed as part of the ERA.

Selection of the chemicals of concern (COC) for both the ERA and HHRA began in 2003 and continued for some time. The original COC nominated by the Technical Committee included As, Cu, Co and Ni. During the latter part of 2003 and into 2004, the SARA Group also identified Pb and Se as candidate COC for the risk assessments. Later in 2005, Cd was included as a COC for the purpose of the ERA only.

The selection of COC for the purpose of the Sudbury Soils Study was primarily directed by selection criteria provided in the study Terms of Reference from the TC. The COC were based on the concentrations of metals and other elements in soil samples from the 2001 Sudbury soil survey. These approaches are described in more detail in the COC screening section of Volume I, and also described in Chapter 2 (Problem Formulation) of this report.

Sources of COC to the terrestrial environment include: aerial deposition of particulate-associated COC from the smelters, historical emissions of COC from roast beds, and fugitive dust from tailings, slag pile areas and associated operations. They do not include direct liquid effluent discharges, waste rock piles or tailings areas themselves.

The selection of Valued Ecosystem Components (VECs) for the ERA primarily took place during 2004. Lists of candidate VECs and supporting rationale were provided to the TC during the spring and summer of 2004, and a special meeting of the TC was convened November 9 and 10, 2004, to fully discuss VEC selection and to finalize the list of VECs to be considered in the ERA.

Exposure modeling to calculate risk to the terrestrial VECs (Objectives 2 and 3) began in earnest after this time, and a Draft ERA report addressing Objectives 2 and 3 was submitted to the TC for review in December, 2005. Discussions with the TC took place throughout 2006 regarding Objectives 2 and 3 (Chapter 4 of this report) and as a result a number of changes were incorporated into the modeling approach.

Concurrent to the above activities, study tasks were being undertaken to address Objective #1. The selection of test and reference sites for the necessary field surveys took place during the spring of 2004, with collection of soil for toxicity testing, and detailed measurement of ecosystem variables taking place throughout the summer. To assess organic matter decomposition, litter bags were placed in the field in the fall of 2004, and retrieved for analysis over the next 12 months. Laboratory toxicity testing of the field-collected soils took place during the period of fall 2004 to summer of 2005 (Figure 1-2). Various technical sessions and discussions were held to finalize the toxicity testing approach, species to be used and test protocols leading up to and during this period. Lastly, the extensive data that were collected as part of the plant community assessment was transferred from field notes and synthesized during the fall of 2004 and winter of 2005. Also during this time extensive effort was devoted to examining methodologies to integrate the various lines of evidence (LOE) for Objective #1, and the Weight of Evidence approach evolved.

The second draft of the ERA was submitted to the Technical Committee for review in December, 2006. This draft was also circulated to an Independent Expert Review Panel (IERP) for external peer review. The IERP consisted of experts in the area of ecological risk assessment. The panel members met with SARA Group in March 2007 to discuss the draft ERA. This Final Draft of the ERA takes into consideration comments provided to the SARA Group from both the IERP and TC.

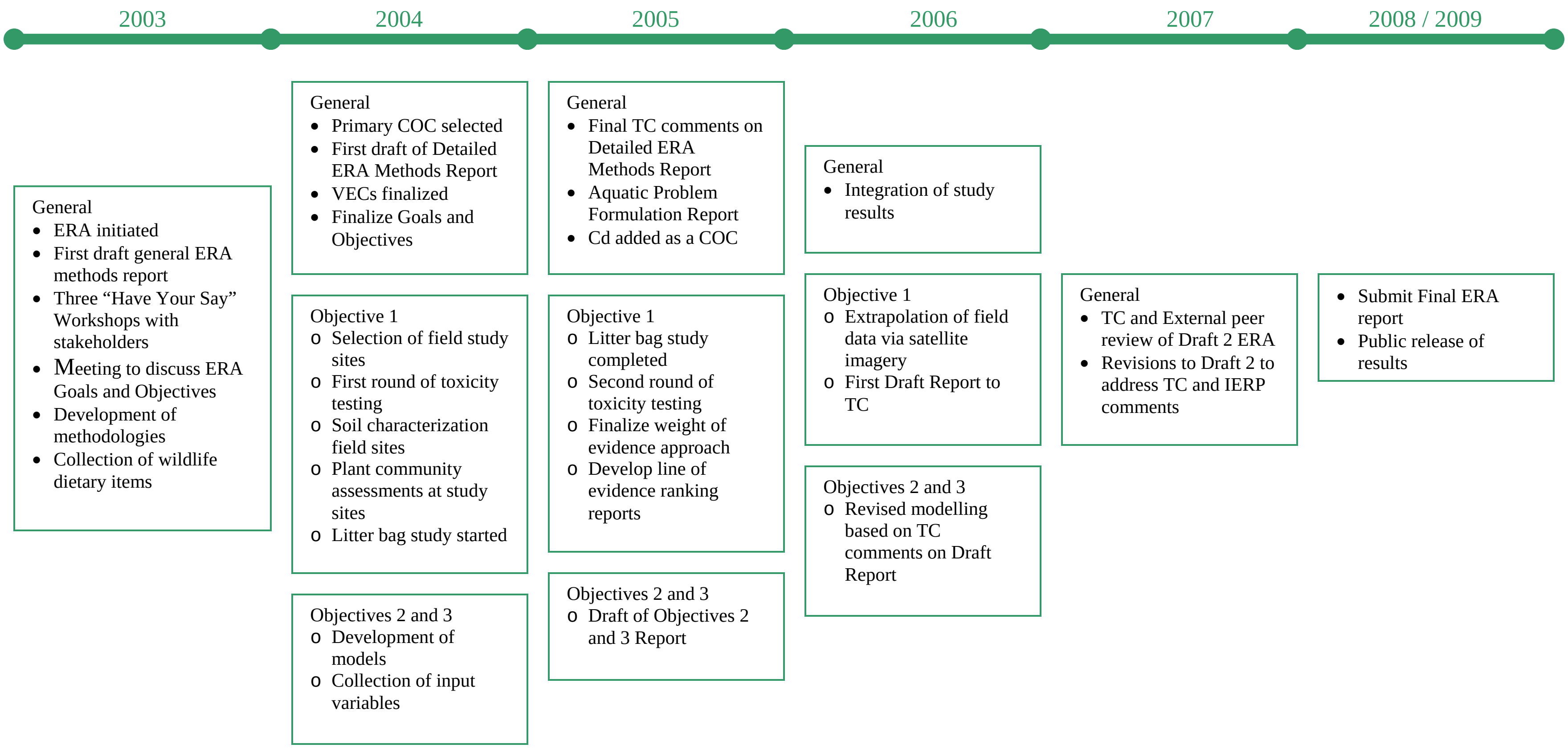

Figure 1-2 Timeline of ERA Activities

1.6 Scope of the Aquatic ERA

The Sudbury Soils Study was based on concerns that the concentrations of several metals and metalloids in soil exceeded the Ontario Ministry of the Environment soil quality criteria. While it is recognized that the terrestrial and aquatic environments are linked, and that there have been impacts to aquatic environments in the Sudbury area due to smelter emissions, the assessment of aquatic ecological risks is not directly linked to the soil quality criteria. In addition, it was not expected that remediation or restoration of the aquatic systems would be proposed at this time. Therefore, a detailed ecological risk assessment of the aquatic environment was considered to be outside the scope of this ERA.

As a result, it was proposed that the SARA Group complete a comprehensive Problem Formulation for the aquatic environment. The Problem Formulation would summarize the relevant existing data (e.g., toxicity, population or other effects data published on Sudbury aquatic environments), identify COC in the aquatic environment, identify a preliminary list of Valued Ecosystem Components (VECs), and use qualitative and quantitative approaches to identify issues that require further evaluation. Any further evaluation would occur outside of the Sudbury Soils Study. This allows the Sudbury Soils Study to focus on the terrestrial environment.

Government, industry and university researchers have undertaken numerous studies to examine the state of aquatic ecosystems in the Sudbury area during the past four decades. This ERA identifies and documents many of the studies undertaken, synthesizes the information as much as possible, and utilizes relevant data within the context of the comprehensive Problem Formulation. This allows the identification of data gaps and lays the foundation for future studies and monitoring.

The Aquatic Problem Formulation is provided in Chapter 5 of this report.

1.7 What is not Expected of the ERA?

Part of the clarification of the scope of the ERA was the identification of questions or issues that were not expected to be assessed or resolved by the assessment. It was not expected that the ERA would:

- Review and understand all information and ecological studies conducted in and related to Sudbury;
- Understand, in detail, the extent or dynamics of past impacts;
- Address all questions related to revegetation;
- Quantify habitat suitability for wildlife;

- Design a program to restore the natural environment; or,
- Conduct risk analyses for the aquatic environment beyond a Problem Formulation.

1.8 Structure of the Report

The ERA contained in this volume addresses the Goals and Objectives within the limitations outlined above. It is comprised of six main chapters and a glossary. Objectives #2 and #3 are addressed together in Chapter 4, due to the commonality of methods used to assess risks to wildlife, whether or not the species is threatened or endangered.

Chapter 1	Introduction, goals and objectives
Chapter 2	Problem Formulation including definition of the study area, selection of COC and VECs for the terrestrial ERA, assessment endpoints.
Chapter 3	Objective #1 Evaluation of the extent to which COC are preventing the recovery of regionally-representative, self-sustaining terrestrial plant communities
Chapter 4	Objective #2 Evaluation of risks to terrestrial wildlife populations due to COC and Objective #3 Evaluation of risks to individuals of threatened or endangered terrestrial species due to COC
Chapter 5	Objective #4 Problem formulation for the aquatic and wetland environments
Chapter 6	Data integration, summary and recommendations.
Acronyms/Glossary	Definitions and clarification of the terms used in the report.
Appendices	Supporting information and data collected as part of the field or laboratory studies are provided in appendices. The line of evidence ranking reports are provided in hardcopy in the main body of the report, while all other appendices are provided in electronic format on the accompanying CDs.

1.9 Sudbury ERA Team

In order to address the many technical aspects involved in addressing the objectives of the ERA, a large team consisting of consultants and academics was assembled. This allowed the SARA Group to draw upon a broad range of expertise, including risk assessors, local researchers, and ecologists with extensive experience with the Sudbury environment. The primary individuals involved in the Sudbury ERA study team are listed in Table 1.1 below, including a brief description of affiliation, background and role in the study.

Table 1.1 Overview of Study Team for the Sudbury Ecological Risk Assessment

Name	Degree	Background	Study Role
Christopher Wren	Ph.D.	AECOM Canada. Senior Scientist, experience in behaviour and ecotoxicology of metals	Director, Sudbury Soils Study
Ruth Hull	M.Sc.	Intrinsik Environmental Sciences Inc.*, Senior Scientist, experience in ERA of smelter sites, ecotoxicology and ERA	Coordinator of ERA and responsible for Objectives #2 to #4
Mary Kate Gilbertson	M.Sc.	AECOM Canada. Ecotoxicology and ecological risk assessment.	Managed field studies and approach for Objective #1
Devon Stanbury	M.Sc.	Formerly with AECOM Canada. Environmental soil chemist and ecological risk assessment.	Conducted field studies and approach for Objective #1
Steve Gautreau	B.Sc.	Formerly with AECOM Canada. Database management, statistics and Geographical Information Systems.	Completed primary statistical analysis for Objective #1and provided mapping.
Dwayne Moore	Ph.D.	Intrinsik Environmental Sciences Inc., Senior Scientist, experience in probabilistic risk assessment of large, complex sites	Provided exposure input parameters (distributions) for the wildlife models (Objectives #2 and 3)
Karl Bresee	M.Sc.	Intrinsik Environmental Sciences Inc., Scientist, experience in ERA of smelter sites, ecotoxicology, risk modelling	Conducted probabilistic modelling for Objectives #2 and #3
Adam Safruk	M.E.S	Intrinsik Environmental Sciences Inc., Scientist, aquatic toxicology, fish and wildlife biology, risk modelling	Completed the Aquatic Problem Formulation (Objective #4)
Josephine Archbold	M.Sc.	Formerly with Intrinsik Environmental Sciences Inc., Scientist, multi-media ecological risk modelling, ERA	Completed literature review of studies of the terrestrial environment (Appendix C); assisted in assessment of Objectives #2 and #3.
Graeme Spiers	Ph.D.	Associate Professor, Centre for Environmental Monitoring, Laurentian University. Soil chemistry and analytical chemistry	Co-developed soil chemistry line of evidence for Objective 1. Designed and implemented the 2001 Regional Soil Survey
Peter Beckett	Ph.D.	Professor, Department of Biology, Laurentian University. Long history of experience studying impacts to Sudbury vegetation and involved with regreening programs for 30 years	Co-developed protocols for assessing plant community at test sties and data interpretation for Objective #1
Maureen Kershaw	M.Sc.	PhD candidate, Lakehead University, Forest and Environment. Over 17 years of experience in life and earth science surveys, and environmental assessments for proposed developments.	Co-developed protocols for assessing plant community at test sties and data interpretation for Objective #1
Mark St. John	Ph.D.	Associate Professor, Nippising University, Laurentian University. Specializes in soil ecology.	Completed statistical analysis of Decomposition LOE and Step 3 Ordination analysis.
Glenn Parker	Ph.D.	Professor, Dept. of Biology, Laurentian University. Interests in wildlife and metal accumulation in Sudbury ecosystem	Provided data on metal levels in deer and deer browse for ERA

Table 1.1 Overview of Study Team for the Sudbury Ecological Risk Assessment

Name	Degree	Background	Study Role
Bill Keller	B.Sc.	Aquatic Scientist, Freshwater Co-op unit, Laurentian University and Ministry of Natural Resources. 30 yr history studying Sudbury area lakes	Provided water chemistry and zoo plankton data for Sudbury lakes, and overview of aquatic ecosystem recovery for aquatic problem formulation (Objective #4)
George Morgan		Fisheries Scientist, Freshwater Co-op unit	Collected sport and forage fish from eight Sudbury urban lakes for metal analysis
Gladys Stephenson	Ph.D.	Stantec. Extensive experience in the development of soil toxicity testing methods and protocols.	Contributed to design of soil toxicity test battery and directed invertebrate soil toxicity tests.
Natalie Feisthauer	M.Sc.	Environmental toxicologist and supervisor of the Soil Ecotoxicity Laboratory at Stantec.	Contributed to design and implementation of soil toxicity test battery.
Mary Moody	B.Sc.	Research Scientist at Saskatchewan Research Council for over 20 years.	Design and implemented method development for tree species in the soil toxicity test battery.
Rick Scroggins	B.Sc.	Chief of Biological Methods Division at the Environmental Technology Centre, Environment Canada. Ottawa	Contributed to design of soil toxicity test battery and directed invertebrate soil toxicity tests.
Jan Lindquist	B.Sc.	NAR Environmental, Sudbury. Aquatic biology and ecology.	Co-ordinated field studies and data collection.

* Intrinsik Environmental Sciences Inc. formerly operated as Cantox Environmental Inc.

1.10 References

MOEE. 2001. Metals in Soil and Vegetation in the Sudbury Area (Survey 2000 and Additional Historic Data). Ecological Standards and Toxicology Section, Standards Development Branch, Ontario Ministry of the Environment, Toronto, Ontario. Report Number SDB-045-3511-2001.

MOEE. 1997. Guideline for Use at Contaminated Sites in Ontario. Ontario Ministry of Environment and Energy. ISBN-0-7778-4052-9.