Volume II

Appendices of the Independent Expert Review Panel Meeting Report for the Sudbury Area Ecological Risk Assessment

March 6-7, 2007
Collège Boréal
Sudbury, Ontario

Peer Review Organized by
Toxicology Excellence for Risk Assessment
(http://www.tera.org/peer/)

June 11, 2007

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Appendix A – List of Observers

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Sudbury Soils Study ERA Independent Expert Review
List of Attendees
March 6-7, 2007

Dr. Peter Beckett
Laurentian University

Mr. Marc Butler
Xstrata Nickel
Sudbury Smelter

Mr. Karl Bresee
Cantox Environmental, Inc.

Mr. Brian Cameron
Ontario Ministry of the Environment

Dr. Bruce Conard
CVRD Inco Limited

Mr. Dick DeStefano
Sudbury Soils Study

Mr. Murray Dixon
Ontario Ministry of the Environment

Dr. Mike Dutton
CVRD Inco Limited

Mr. Bruce Fortin
Sudbury & District Health Unit

Ms. Mary-Kate Gilbertson

Mr. John C. Hogenbirk
Public Advisory Committee

Mr. Gary Hrytsak
The People of Greater Sudbury

Mrs. Ruth Hull
Cantox Environmental

Ms. Maureen Kershaw

Ms. Aino Laamanen

Mr. Bill Lautenbach
City of Greater Sudbury

Mr. Marius Marsh
Ontario Ministry of the Environment

Dr. Stephen Monet
City of Greater Sudbury

Ms. Patricia Nance
Toxicology Excellence for Risk Assessment
(*TERA*)

Dr. Evert Nieboer
McMaster University

Ms. Jacqueline Patterson
Toxicology Excellence for Risk Assessment
(*TERA*)

Mrs. Julie Sabourin
PAC/TC

Mr. Graeme A. Spiers
Laurentian University, MIRARCO

Dr. Mark St. John
Laurentian University

Ms. Devon Stanbury
Gartner Lee Limited

Dr. Gladys Stephenson
Stantec

Mr. Ido Vettoretti
Sudbury & District Heath Unit

Mr. Glen Watson
CVRD Inco Limited

Dr. Paul Welsh
Ontario Ministry of the Environment

Dr. Christopher Wren
SARA Group
Gartner Lee Limited

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Appendix B – Meeting Materials

Agenda, Panel Charge, Overview, Panelist Biographical Sketches and Conflict of Interest/Bias Disclosures, Presenter Biographical Sketches, and Observer Guidelines

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Sudbury Soils Study ERA Independent Expert Review
Agenda
March 5-7, 2007

Monday, March 5, 2007

7:30 PM **Public Briefing**
Welcome
Overview of ERA
Description of Peer Review Process
Introduction of IERP members

Tuesday, March 6, 2007

7:30 AM **Registration and Continental Breakfast**

8:00 **Meeting Convenes**[1]
Welcome, Ms. Jacqueline Patterson, *TERA*
Panel Introductions and Conflict of Interest/Bias Disclosures, Panel
Meeting Process and Ground Rules, Dr. Charles Pittinger, Chair

8:30 **Human Health Risk Assessment IERP Conclusions and Recommendations**
Dr. Joyce Tsuji

8:45 **Problem Formulation and Volume 1**
SARA Group Presentation on Problem Formulation and Volume 1, Dr. Christopher Wren and Ms. Ruth Hull
Panel Discussion

10:00 **Objective #1**
SARA Group Presentation on Objective #1, Ms. Mary Kate Gilbertson and Ms. Devon Stanbury
Panel Discussion

12:00 PM **Lunch and Tour for Panel**

2:00 **Objective #1**
Continue Panel Discussion on Objective #1

5:30` **Conclusions from Day 1**

6:00 **Meeting Adjourns for the Day**

7:30 **Panel Dinner**

[1] [1] The Chair will call a break mid-morning and mid-afternoon at convenient breaking times in the agenda.

Wednesday, March 7, 2007

7:45 AM **Continental Breakfast**

8:15 **Meeting Reconvenes**[2]
Chair's summary of Day 1 and plan for Day 2

8:30 **Objective #2 and #3**
SARA Group presentation on Objective #2 and #3, Ms. Ruth Hull and Mr. Karl Bresee
Panel discussion

12:00 PM **Lunch**

1:00 **Conclusions (Chapter 6)**
SARA Group presentation on Conclusions, Dr. Christopher Wren
Panel discussion

3:00 **Conclusions and Recommendations**
Panel drafts bulleted list of its conclusions and recommendations

5:00 **Meeting Adjourns**

[2] The Chair will call a break mid-morning and mid-afternoon at convenient breaking times in the agenda.

Sudbury Soils Study ERA Independent Expert Review
Charge to Peer Reviewers
March 6-7, 2007

Background

The purpose of the Independent Expert Review Panel (IERP) is to provide expert review and evaluation of the Sudbury Soils Study Ecological Risk Assessment (ERA). The panel members will review the provided documentation and will objectively discuss the materials and charge questions at a panel meeting on March 6 and 7, 2007. The panel will attempt to reach consensus opinions on the assessment's conclusions. *TERA* will compile the panel discussions into a meeting report that will summarize the key points from the discussions, with a focus on the conclusions regarding the charge questions.

Sudbury is a nickel mining community in Northern Ontario. The soils are contaminated with nickel, arsenic, lead and some other chemicals. In 2001, the Ontario Ministry of the Environment (MOE) published the results of soil monitoring studies conducted in the Sudbury area and identified elevated levels of several elements in soils near the three historic smelting and refining centers of Copper Cliff, Coniston, and Falconbridge. The MOE recommended a more detailed soil study be conducted to fill data gaps and that human health and ecological risk assessments be conducted. The Sudbury Soils Study was then initiated, with the underlying objective to answer the question: "Do Sudbury soils containing metal and arsenic levels above the generic guidelines pose an unacceptable ecological or human health risk?"

The Study is overseen by a Technical Committee (TC), comprised of Inco (CVRD) and Falconbridge Ltd. (Xstrata), the Ontario Ministry of the Environment (MOE), the Sudbury & District Health Unit, the City of Greater Sudbury, and the First Nations and Inuit Health Branch of Health Canada. The assessments were prepared by the SARA Group, a group of environmental consulting firms and consultants. The Study has included broad consultation with local communities and stakeholder groups. The two mining companies are providing funding for the study and this peer review. More information can be found at www.sudburysoilsstudy.com.

The package of materials for this review includes Volume I– Background, Study Organization and 2001 Soils Survey and Volume III – Ecological Risk Assessment. Some appendices, along with additional reference materials and data are provided on compact discs.

Background Information from Volume III, Executive Summary is extracted below (from pages ES-1 to ES-3):

> "The main goal of the ERA, as stated below, not only recognizes the importance of evaluating ecological risks, but also the significance of evaluating ecological recovery:
>
> *To characterize the current and future risks of Chemicals of Concern (COC) to terrestrial and aquatic ecosystem components from particulate emissions from Sudbury smelters. To provide information to support activities related to the recovery of regionally representative, self-sustaining ecosystems in areas of Sudbury affected by the COC.*

Four specific objectives were identified to assist in meeting the main ERA goal:

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

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

Objective 3: Evaluate risks to individuals of threatened of endangered terrestrial species due to COC; and,

Objective 4: Conduct a comprehensive problem formulation for the aquatic and wetland environments in the Sudbury areas to facilitate more detailed risk assessment in the aquatic/wetland ecosystems.

The overall Management Objective of the ERA was to -- *evaluate levels of COC in various soil types to determine COC levels in soil which do not result in unacceptable risks to Valued Ecosystem Components*. These objectives and goals were developed during the course of this study in consultation with members of the Technical Committee.

The current study is considered an area-wide, or community-based risk assessment (CBRA), because it evaluates a very large geographical area. While many elements of an area-wide risk assessment are based on the requirements for a site-specific risk assessments (SSRA), it is important to note there is no specific regulatory guidance available governing the application of risk assessment on this scale in Canada….

The initial study area for the Sudbury Soils Study was defined as the area from which soil samples were collected during the 2001 Sudbury Regional Soils Project. The study area encompasses approximately 40,000 km^2 (200 km x 200 km) of the Sudbury basin….The primary source of COC to the terrestrial environment included in this assessment is aerial deposition of particulate-associated metals and metalloids from smelter emissions. The selection of COC for the risk assessment was based on metal concentrations in Sudbury soils measured during the 2001 soil survey."

The ERA will provide information to support Sudbury ecosystem recovery efforts. The SARA Group and Technical Committee will consider the IERP recommendations and revise the ERA as needed. The final assessment will be released to the public.

Charge for Sudbury Soils Study Ecological Risk Assessment Independent Expert Review Panel

Problem Formulation [Chapter 2 and Volume I]

1. How effective was the process used to identify Valued Ecosystem Components (VECs) in identifying plant and animal species, populations, and communities of ecological importance in the region? of socio-economic importance? Did the authors identify an appropriate set of Valued Ecosystem Components (VECs)?

2. Have the appropriate Chemicals of Concern (COCs) and other stressors been identified and included in the risk assessment?

3. How well does the conceptual model convey the principle linkages among COCs, and terrestrial plant and wildlife VECs?

4. Recognizing that not all of the sampling sites were systematically chosen in an *a priori* manner for the ERA, how well did the breadth of the study area defined by the sites capture the spatial scale of ecological impact?

Objective 1 – Evaluate the extent to which COC are preventing the recovery of regionally representative, self-sustaining terrestrial plan communities. [Chapter 3]

To evaluate the extent to which COCs are preventing the recovery of regionally representative, self-sustaining terrestrial plant communities, the authors used multiple assessment approaches and then integrated the diverse data to reach conclusions. Data from 22 study sites were collected to produce four distinct "lines of evidence" (LOEs), which were evaluated independently at the 22 sites. Interactions between the LOEs were evaluated using statistical techniques and then the LOEs were integrated using a weight-of-evidence approach to determine whether the concentrations of metals in the soil were impeding recover of a self-sustaining forest ecosystem.

5. Discuss the strengths and weaknesses of the lines of evidence approach.

6. For each of the four LOEs, discuss whether the methods used were appropriate, whether the assessment approaches were effective, and the usefulness and reliability of the results of the studies.

7. Were the weightings of the LOE appropriate?

8. How well did the LOEs, singly and collectively, characterize the existing plant community and key stressors that are impeding recovery?

9. Are there additional important issues, concerns, or limitations regarding Objective 1?

Objective 2 – Evaluate risks to terrestrial wildlife populations and communities due to COCs. [Chapter 4]

10. Was the wildlife exposure modeling approach sound, and was it conducted appropriately? Was the selection of model inputs appropriate? Discuss the relative absorption fractions, concentrations of COCs in the environmental media and diets, and input distributions for the parameters.

11. Were the approaches to describe population densities across the study area sound? How well are the conclusions supported by the data?

12. Are the estimates of COC exposures to wildlife defensible? Are there additional data or different approaches that could be considered to improve these exposure estimates?

13. Are direct effects of COCs correctly distinguished from indirect effects of poor soil conditions and/or habitat constraints (e.g., lack of cover from predators, lack of food sources and nesting sites)?

14. Toxicity Reference Values (TRVs) were derived for each VEC and COC. Were the TRVs selected defensible? Are there alternatives? Was the approach used scientifically sound and consistent with established practice of regulatory bodies?.

15. Was the approach used to calculate Exposure Ratios consistent with accepted risk assessment methods and were they calculated correctly?

16. Are the predicted risk estimates for each Zone and Community of Interest scientifically defensible? Are the conclusions for each COC valid, and are they supported by the risk assessment?

17. Discuss the analysis of uncertainty and variability. Are the key sources of uncertainty and variability well characterized, and are they weighed in the interpretation of the results and the strength of the conclusions that can be drawn?

18. Do you have additional important issues, concerns, or limitations regarding Objective 2?

Objective 3 – Evaluate risks to individuals of threatened or endangered terrestrial species due to the COC. [Chapters 2 and 4]

19. Was the selection of the peregrine falcon as the only threatened/endangered species of concern appropriate? Is the conclusion regarding its status in the study area reasonable?

20. Do you have additional important issues, concerns, or limitations regarding Objective 3?

Conclusions and Recommendations

21. To what extent did the ERA achieve its two major goals: 1. To characterize the current and future risks of COCs to terrestrial and aquatic ecosystem components; and 2. To provide information to support activities related to the recovery of regionally-representative, self-sustaining ecosystems in areas affected by the COCs? To what extent did the ERA achieve Objectives 1-3?

22. Were the approaches used for this ecological risk assessment consistent with commonly accepted methods and sound scientific procedures?

23. Overall, how clear and transparent are the assumptions, methods, results, and conclusions described in the ERA? Have the important uncertainties been identified and have the uncertainties' significance and impact on the characterization of risk and overall conclusions been identified and fully discussed?

24. Were the non-COC stressors to terrestrial plant communities cited in the ERA (i.e., low pH, low nutrient levels, erosion, and lack of organic matter) appropriately identified and interpreted?

25. Discuss the recommendations found in Chapter 6. Are they supported by the data and are they scientifically defensible?

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Sudbury Soils Study ERA Independent Expert Review
Overview of the Independent Expert Review Panel (IERP) Process
Panel Biographical Sketches and Conflict of Interest/Bias Discussion
March 6-7, 2007

Background

This peer review meeting has been organized by Toxicology Excellence for Risk Assessment (*TERA)*. *TERA* is an independent non-profit organization with a mission to protect public health through the best use of toxicity and exposure information in the development of risk assessments. *TERA* has organized and conducted peer review and consultation meetings for private and public sponsors since 1996 (see www.tera.org/peer for information about the program and reports from meetings).

The purpose of this peer review is to have a panel of experts carefully evaluate the science and conclusions of the ecological risk assessment. The Sudbury Soils Study and human health and ecological risk assessments have been undertaken to determine if there are unacceptable human health or ecological risks associated with metal and arsenic levels present in the Sudbury area. Based on the available information for Sudbury, the study will provide a measure of the risk from metals and arsenic in soils and provide information to support activities related to the recovery of regionally representative, self-sustaining ecosystems.

The human health and ecological risk assessments were prepared by the SARA Group, which consists of scientists from Cantox Environmental Inc., Gartner Lee Limited, SGS Lakefield, Goss Gilroy Inc., RWDI, 4DM, Frontline Communications, and Lesbia Smith, MD. The Study is overseen by a Technical Committee, comprised of Inco Ltd. (CRVD) and Falconbridge Ltd. (Xstrata), the Ontario Ministry of the Environment, the Sudbury & District Health Unit, the City of Greater Sudbury, and the First Nations and Inuit Health Branch of Health Canada. Inco Ltd. and Falconbridge Ltd. have paid for the risk assessment and this peer review.

This meeting and the process is not open to the general public and the assessment results are not yet final; therefore, the panel and observers are asked to keep the assessment and panel discussions confidential and not discuss them with others, including the media.

Independent Expert Review Panel

The independent peer review panel includes six scientists who have expertise in the key disciplines and areas of concern. Each panelist is a well-respected scientist in his or her field. The panel members have expertise in ecological risk assessment; terrestrial and aquatic ecotoxicology; toxicology of metals and arsenic; bioavailability of metals in soils and water; biogeochemistry; environmental fate of metals; effects of metals on flora and fauna, including forest ecosystems; ecological processes; ecological modeling; landscape ecology, probabilistic risk assessment; and remote sensing. *TERA* was solely responsible for the selection of the panel members.

Each panel member has disclosed information regarding potential conflicts of interest and biases related to the Sudbury Soils Study and its sponsors. *TERA* carefully evaluated these disclosures

when selecting panel members. Short biographical sketches and disclosure statements for panel members are provided.

Review Package and Charge to Peer Reviewers

The panel received the review package approximately seven weeks prior to the meeting to ensure adequate time to carefully review the document and prepare for the meeting discussions. Materials sent included Volume I– Background, Study Organization and 2001 Soils Survey and Volume III – Ecological Risk Assessment. Review materials also included compact discs, including data and reports from the soil surveys and appendices. *TERA* developed a "charge to peer reviewers" document that outlined the key questions and scientific issues that need to be discussed by the panel in order to evaluate the quality and completeness of the risk assessment.

Meeting Procedures

The meeting will be organized to make the best use of the time available to hear and discuss the opinions of the panelists regarding the charge questions and the ecological risk assessment. The meeting will begin with brief panel introductions and a discussion of conflict of interest and bias issues. The discussion will then address the four broad areas of the assessment: data collection and site characterization, exposure assessment, hazard assessment, and risk characterization. To start each discussion section, the authors of the assessment document will make a short presentation. These presentations will highlight the salient points and focus on important issues. There will be a brief period for panel member clarifying questions and then the panel will discuss the relevant charge questions. At the end of the second day, the panel members will compile their major recommendations and conclusions into a bulleted list that will be included in the meeting report.

Observers

Members of the Technical Committee and Public Advisory Committee have been invited to observe the panel meeting process. As the purpose of the IERP meeting is to have the expert panel discuss the assessment and reach conclusions on the science and the quality, the discussions will be limited to the panel members. To insure the panel's independence, observers are asked to refrain from discussing the assessment or related issues with the panel members. Please refer to the Observer Handout for more information.

Meeting Report

TERA will draft a meeting report that briefly summarizes the panel's discussions and recommendations. The meeting report will serve as a record of the peer review and will assist the authors in making revisions to the assessment. The report will be reviewed by the panel members for accuracy before it is finalized.

Conflict of Interest

TERA was selected by the Technical Committee to independently organize and conduct this expert panel review. The Working Group of the Technical Committee has directed *TERA*'s work to organize the expert review. Inco and Falconbridge are paying for the expenses related to this review. *TERA* has not participated in the development or preparation of the human health and ecological risk assessments that are the subject of these reviews. *TERA* is not contracted to do any other work for Inco/CVRD or Falconbridge/Xstrata, nor for the SARA Group and its member companies. *TERA* has past experience in risk assessment and toxicity of metals. This work has been done for a variety of public and private sponsors, but none of it is related to the Sudbury assessments.

TERA has conducted reviews and worked on projects involving some of the contaminants considered at the Sudbury site, including arsenic, nickel, copper, lead, cadmium, and selenium for a variety of sponsors. These projects were sponsored by the U.S. EPA, Health Canada, the Metal Finishing Association of Southern California, the International Copper Association, the U.S. Bureau of Land Management, Elf AtoChem North America Inc., the U.S. National Institutes of Occupational Safety and Health, and a metal refiner in South Africa. Dr. Lynne Haber of *TERA* served as a peer reviewer for the Ontario MOE on the Rodney Street risk assessment and has been asked by MOE to be a peer reviewer for a community risk assessment currently being prepared. Dr. Pittinger, the panel chair, is a Visiting Scientist with *TERA.* He has worked on projects related to human health and environmental toxicity of mineral products and metal substances and he and his employer, ARCADIS BBL, provide consulting services to many types of public and private clients, including mining companies and consortia. None of Dr. Pittinger's projects has been with Inco or Falconbridge and to best of his knowledge his employer has not worked directly with these companies.

TERA follows the U.S. National Academy of Sciences (NAS) guidance on selection of panel members to create panels that have a balance of scientific viewpoints on the issues to be discussed. As a result, the expert panels have a broad and diverse range of knowledge, experience, and perspective, including diversity of scientific expertise and affiliation. Panel members serve as *individuals*, representing their own personal scientific opinions. They do not serve as representatives of their companies, agencies, funding organizations, or other entities with which they are associated. Their opinions should not be construed to represent the opinions of their employers or those with whom they are affiliated.

An essential part of panel selection is the identification and disclosure of conflicts of interest and biases. Prior to selecting the panelists, each candidate completes a questionnaire to determine whether their activities, financial holdings, or affiliations could pose a real or perceived conflict of interest or bias. The completed questionnaires were reviewed by *TERA* staff and discussed further with panel candidates as needed. (See www.tera.org/peer/COI.html for *TERA's* conflict of interest and bias policy and procedures for panelist selection).

TERA has determined that each panel member has no conflicts of interest and is able to objectively participate in this peer review. None of the panel members has a financial or other interest that would interfere with his or her abilities to carry out the duties in an objective fashion. None of the panel members is employed by Inco/CVRD, Falconbridge/Xstrata, the

other companies or agencies represented on the Sudbury Soils Study Technical Committee, or the companies comprising the SARA Group. Nor do the panel members have financial interests in the two mining companies. None of the panel members was involved in the preparation of the Sudbury human health or ecological risk assessments.

A brief biographical sketch of each panel member is provided below. To promote transparency, as appropriate, a short disclosure statement describing potential conflict of interest or bias issues that were disclosed and evaluated is also included.

Biographical Sketches and Disclosures of Panel Members

Mr. Joseph W. Gorsuch

Mr. Gorsuch is President and owner of Gorsuch Environmental Management Services, Inc (G.E.M.S., Inc). Prior to developing G.E.M.S., Inc., he worked 30 years for the Eastman Kodak Company before retiring in 2004. Mr. Gorsuch has a B.S. in Wildlife Biology and an M.S. in Environmental Sciences, with both degrees from Purdue University. Through his work at Purdue University and Kodak, and with professional societies and trade group committees, Joe has over 35 years of experience with soils toxicity testing. He has served on numerous professional, government and trade group committees, task groups, and review panels regarding plant testing and toxicology, environmental effects and fate of silver, ecological risk assessment, and metals in soils. He was a presenter and co-facilitator at several U.S. EPA Workshops on Environmental and Plant Toxicology, and Genetic Engineered Plant Topics, and a peer reviewer of extensive EPA plant studies in 2006, including native vegetation. In 1993, as a plant toxicity expert, he was an invited participant in the Environment Canada CAPP Workshop "Tests to Evaluate Natural Gas Well Remediation Sites" in Calgary, Alberta. Since 2000, he has been a member of the Environment Canada Science Advisory Group for Plant Tests. In 2005, he was an invited participant of the Natural Resources Canada International Workshop "Metals in Soils: Science Gaps and Regulatory Needs" in Ottawa, Ontario. Mr. Gorsuch's continuous dedication and involvement with the Society of Environmental Toxicology & Chemistry (SETAC) since 1980, led him to be the recipient of the "Herb Ward Exceptional Service Award" in 2003. He has been a member of the American Society of Testing and Materials (ASTM), Committee E47 Environmental Effects and Fate, since 1980, receiving two awards, including the ASTM Committee E47's highest award. Mr. Gorsuch serves on four scientific journal editorial boards, has authored and co-authored approximately 40 scientific peer-reviewed publications, has helped organize and facilitate over 10 symposia on plant and soil testing, and has served as editor on six books (three on using plants in toxicity tests) and five special journal publications (including risk assessment of metals in soil).

Mr. Gorsuch was selected for the ERA panel for his experience and expertise with soils, earthworm and plant toxicity testing; effects of metals on flora and fauna; ecological risk assessment; and, remote sensing.

Disclosure: Mr. Gorsuch is semi-retired and provides consulting services to a number of companies, including some international businesses involved in metals, but not the metals of concern nor the companies involved in the Sudbury Soils Study. In an unpaid capacity, Mr. Gorsuch provided scientific publications on effects and fate of silver in the environment and suggested study designs using silver compounds in soils to the Ontario Ministry of the Environment during 2006. *TERA* does not consider Mr. Gorsuch's unpaid work for MOE to constitute a conflict of interest or create the potential for bias, because the work was unpaid and was not relevant to the Sudbury risk assessment.

Dr. Samuel N. Luoma

Dr. Luoma is a Senior Research Hydrologist with the US Geological Survey (USGS). He has been with USGS since 1975. Dr. Luoma served as the first Lead Scientist for the CALFED Bay-Delta program between August 2000 and November 2003. He received his Ph.D. in Zoology from the University of Hawaii. His research interests are in the fate and effects of contaminants, primarily metals and metalloids, in aquatic ecosystems. He has worked on contaminant bioavailability to invertebrates from diet and water, biomonitoring, sediment contamination, processes affecting metal fate and form, and both organism-level and community-level effects of metals. He has additional interests the linkages between science and policy, and communication of environmental risks, especially in the arena of water management. He has advised and contributed in a number of different forums on the implications of various advances in metals science to managing those contaminants in the environment. Advisory functions have included the Canadian NRC Committee on Biologically Available Metals in Sediments (1988); the Ad Hoc, 4 person committee that designed USGS National Water Quality Assessment; National Science & Engineering Research Council, Canada, Strategic Grant Selection Panel for Environmental Quality; U.S. EPA Science Advisory Board Subcommittees on Sediment Quality Criteria; and, the U.S. EPA SAB panel reviewing the Metal Framework. He chaired the Science Advisory Group for the Interagency Ecological Program, San Francisco Bay/Delta and was Chair of the Science Advisory Committee, for Water Resources Division USGS Senior Staff. He was on the Science Advisory Committee for the U.S. EPA Center of Excellence (Center for Environmental Health Research), UC Davis. He participated in a series of four Society of Environmental Toxicology and Chemistry (SETAC) and U.S. EPA Workshops on Re-evaluation of the State the Science for Water Quality Criteria development and hazard assessment for metals. In 2002-03 he was on the National Academy of Sciences, NRC committee on Bioavailability of Contaminants from Soils and Sediments. Dr. Luoma has received several awards and commendations, including the Distinguished Government Service Award from SETAC and in 2004 he was named a Fulbright Distinguished Scholar and served in London at the Natural History Museum. He is currently working on a book on managing metal contamination in aquatic environments as a follow-up to that appointment. Sources of funding include City of Palo Alto for San Francisco Bay monitoring, State of California (CALFED Bay-Delta Program) for work with selenium and mercury, US EPA Superfund Program for work monitoring the Clark Fork River in Montana, US EPA Region 9 for work on evaluating alternative site-specific criteria for selenium in California, and the US Department of Defense to study ecosystem recovery after *in situ* remediation of PCB sediment contamination. Dr. Luoma has published approximately 140 peer-reviewed articles, authored a dozen book chapters, and co-authored two books.

Dr. Luoma was selected for the ERA expert panel for his expertise and experience in ecological risk assessment, bioavailability of trace metals in soils, environmental fate of metals, effects of metals on fauna and ecological processes.

Disclosure: Dr. Luoma recently married an executive of Rio Tinto ltd., a mining company. He does not think this creates a conflict of interest or source of bias, given his long history of independent, non-biased science and advisory work. *TERA* agrees and does not believe this would interfere with Dr. Luoma's ability to provide objective opinions.

Dr. Charles A. Pittinger

Dr. Pittinger is a Senior Toxicologist with ARCADIS BBL in their Global Product Stewardship Practice. He is also a Visiting Scientist with Toxicology Excellence for Risk Assessment (*TERA*). He worked for seventeen years as Principal Scientist for The Procter & Gamble Company, during which he conducted basic and applied research and risk assessments of consumer product ingredients, and developed regulatory submissions for federal and international authorities. Dr. Pittinger has over twenty-five years of experience in toxicology, environmental risk assessment methodologies, and aquatic and terrestrial ecotoxicology. He received his Master's in Aquatic Ecology from The University of Tennessee, and his Ph.D. in Environmental Toxicology from Virginia Tech. His experience ranges from environmental and human health risk assessment and management of consumer product ingredients and industrial emissions; physicochemical property estimation by quantitative structure-activity relationships; environmental fate and transport modeling; technical external relations; environmental chemistry; toxicology; and sediment contamination.

Dr. Pittinger served two terms on the U.S. EPA's Science Advisory Board, Ecological Processes, and Effects Committee (EPEC). He participated as a panelist in numerous other peer reviews and technical advisories, including the EPA's Southeastern Ecological Framework and the Index of Watershed Indicators. He also helped to champion the establishment of SETAC's (Society of Environmental Toxicology and Chemistry) Peer Review Program and led the first SETAC peer review of the American Chemical Council's Long-Range Research Initiative. He also chaired the American Industrial Health Council's Ecological Risk Assessment Committee for five years, and he served on the OECD's Risk Assessment Advisory Board, the American Chemistry Council's Ecological Risk Assessment Steering Team, and ASTM Subcommittee E-47. Dr. Pittinger has published more than forty technical articles, book chapters, and editorials. He has convened and chaired numerous technical steering committees and peer reviews for the public and private sectors.

Dr. Pittinger was selected by *TERA* to be the Chair of the ERA IERP based on his experience and knowledge of ecological risk assessment and experience in chairing scientific workshops and panels. His expertise includes ecological risk assessment, and bioavailability, toxicity and environmental fate of metals.

Disclosure: Dr. Pittinger works for ARCADIS BBL, which provides consulting services to many types of public and private clients, including mining companies and consortia (e.g., Rio Tinto, the Nickel Producers Environmental Research Association, the International Tungsten Industry Association). None of Dr. Pittinger's projects has been with Inco or Falconbridge and to best of his knowledge his employer has not worked directly with these companies. This information is being disclosed to promote transparency. *TERA* does not consider Dr. Pittinger's work on projects for mining companies to constitute a conflict of interest or create the potential for bias, because the work has not involved the Sudbury risk assessment or the companies in Sudbury.

Dr. William A. Stubblefield

Dr. Stubblefield is a senior environmental toxicologist with Parametrix, Inc., and serves as a courtesy faculty member at Oregon State University, Department of Molecular and Environmental Toxicology. He has more than 20 years of experience in environmental toxicology, ecological risk assessment, water quality criteria derivation, and aquatic and wildlife toxicology studies. Dr. Stubblefield received his Ph.D. in Aquatic Toxicology from the University of Wyoming and his M.S. in Toxicology/Toxicodynamics from the University of Kentucky. Dr. Stubblefield served as President of the Society of Environmental Toxicology and Chemistry (SETAC) and chaired several SETAC committees. He has served on numerous committees and panels for the U.S. EPA, including the Science Advisory Board's Framework for Inorganic Metals Risk Assessment Review Panel; and the Multimedia, Multipathway, and Multireceptor Risk Assessment Model System Panel. He recently chaired an independent-review panel that looked at issues associated with liquid waste management in the Capital Regional District (Victoria, BC). Dr. Stubblefield has authored more than 100 peer-reviewed publications and technical presentations in aquatic and wildlife toxicology and environmental risk assessment. He is a co-editor of a recently published book, *Re-evaluation of the State of the Science for Water Quality Criteria*, which examines the issues and approaches to be used in the evaluation of environmental impacts associated with contaminants.

Dr. Stubblefield was selected for the ERA panel for his expertise in bioavailability of trace metals in soils, environmental fate of metals, effects of metals on flora and fauna, and ecological risk assessment.

Disclosure: As an employee of Parametrix and previously with ENSR, Dr. Stubblefield has worked on a variety of projects for mining companies and consortia (e.g., NIPERA) including studies used in the development of water quality criteria/standards and models used to predict toxicity of metals. To the best of his knowledge, neither Dr. Stubblefield nor his employer (Parametrix) has worked directly with any of the individual companies involved with the Sudbury Soils Study. This information is being disclosed to promote transparency. *TERA* does not consider Dr. Stubblefield's work on projects for mining companies to constitute a conflict of interest or create the potential for bias, because the work has not involved the Sudbury risk assessment.

Dr. Joyce S. Tsuji

Dr. Tsuji is a Principal in Exponent's Health Sciences practice and is located in the firm's Bellevue, Washington office. Dr. Tsuji received a B.S. in biological sciences from Stanford University with honors and distinction, Phi Beta Kappa, and a Ph.D. focused in physiology and ecology from the Department of Zoology, University of Washington. She is a Diplomate of the American Board of Toxicology and has 19 years of experience in toxicology and risk assessment on projects in the United States, Canada, South America, Africa, Australia, and Asia for industry, as well as for the U.S. EPA, the U.S. Department of Justice, the Australian EPA, and state and local municipalities and agencies. Particular areas of interest include exposure assessment and toxicology of a variety of chemicals including those from industrial releases and in consumer products and nanomaterials. Dr. Tsuji has specialized experience with mining and smelting sites and the toxicology, bioavailability, and exposure to metals such as arsenic, lead, cadmium, mercury, manganese, chromium, and zinc. She has conducted and reviewed human health and ecological risk assessments of mining and smelting sites, and has designed and directed exposure studies involving health education, environmental sampling, and biomonitoring of populations potentially exposed to metals in soil, water, and the food chain. Dr. Tsuji has served on expert committees for the National Research Council, including serving as a peer reviewer for the report on the Coeur d'Alene Basin mining site and risk assessment. She has also served on committees for the U.S. EPA, U.S. Army, and the State of Washington (including the Area Wide Soil Contamination group of experts convened by the State of Washington to evaluate arsenic and lead in soil). Dr. Tsuji has served as an expert witness on several legal cases involving metals and mines and has published a number of papers on risk assessment issues, including arsenic and lead in soils.

In addition to human health studies, Dr. Tsuji has also directed and conducted studies assessing the ecological effects of chemicals in the environment, many involving mining and smelting sites. These studies have evaluated the ecological effects of metals and other chemicals in soil, water, and sediments as well as their bioavailability and transfer via the food web. As noted above, she has a strong background from her doctoral studies in ecology and physiology and her published research involved fieldwork in Washington, California, Colorado, and Costa Rica.

Dr. Tsuji served on the HHRA IERP and has been selected for the ERA panel to provide scientific linkage between the panels, as there are a number of scientific issues that overlap. Dr. Tsuji is the best-qualified member of the HHRA panel to serve on the ERA due to her background in ecology and ecological risk assessment.

Disclosure: Dr. Tsuji has performed work for a number of mining companies, but not Inco or Falconbridge, nor on any project related to Sudbury. However, she did work on a project for Noranda Mining (merged with Falconbridge in 2005) in the late 1990s/early 2000s commenting on an EPA risk assessment of Noranda's Blackbird Mine site in Idaho. She also was asked to discuss soil action levels for temporary worker housing on site with EPA in late December 2004 to early January 2005. As the Record of Decision has been issued for this site, she has no expectation of any future work on it.

Other professionals in her company have been involved in the past in litigation cases with multiple defendants (e.g., 30+) in which Falconbridge and Inco were defendants. Exponent was not hired by Falconbridge or Inco except in one case in which all defendants were noted as beneficial parties. Exponent has also consulted to Health Canada in the past. Dr. Tsuji did not

participate in any of these cases herself, nor does she work regularly with the individuals on these projects. None of these past cases or projects appears to be currently active and she does not think any of this work related to Sudbury. Since the HHRA IERP meeting, Dr. Tsuji's employer, Exponent hired Dr. Charles Menzie to lead their Ecosciences Division. Previously, Exponent was not involved in any work for Inco or Falconbridge; however, Dr. Menzie brought with him several current projects with Inco on sites in Connecticut and outside of the U.S. Dr. Tsuji is not aware of any plans for her to work on these projects. She works in the Health Sciences Division, which is a separate division and profit center than the Ecosciences Division and the two divisions report to different managers. Dr. Tsuji has not discussed these projects with Dr. Menzie and only became aware of the projects when she conducted a conflict of interest search to update her information from the HHRA panel tenure.

These activities are being disclosed to promote transparency. *TERA* does not consider these activities to be conflicts of interest because they do not involve the Sudbury risk assessment, nor has Dr. Tsuji been directly involved in any Exponent work that involved Inco or Falconbridge. Dr. Tsuji is not involved in these recently acquired projects of her employer for Inco and is far removed from the division and individuals doing the work. In addition, the projects do not involve the Sudbury Soils Study or the Inco facility in Sudbury either directly or indirectly. Dr. Tsuji provided knowledgeable and unbiased scientific opinions as a participant of the HHRA IERP and would do so again. *TERA* thinks that Dr. Tsuji can participate in an unbiased manner and provide the IERP with objective scientific opinions that are not influenced by the Exponent projects.

Dr. Shaun A. Watmough

Dr. Watmough is an Assistant Professor in the Environmental Resource Science Program of Trent University. His research focuses on ecosystems and environmental stress, and his research interests include forest ecology, plant stress, biogeochemistry, forestry, air pollution, climate change, trace metals, eutrophication, and environmental modeling. Dr. Watmough received his Ph.D. in Plant Stress Physiology from Liverpool John Moores University (UK) and his B.Sc. in Applied Biology from Liverpool Polytechnic (UK). His Ph.D. research assessed the impacts of metals to long-lived plant species. Dr. Watmough has received research support from Trent University and a number of government and other sources, including the Canada Foundation for Innovation, National Sciences and Engineering Research Council of Canada, Canadian Wildlife Service, Canada Foundation for Innovation, Ontario Ministry of the Environment (MOE), Canadian Council Ministers on Environment, Cumulative Environmental Management Association, Environment Canada, Ontario Power Generation, Metals in the Environment (MITE) Research Network, North Eastern Research Cooperative, and the Canadian Forest Service. His funding from MITE has been used in the past to study metal biogeochemistry in forested ecosystems. The MITE Research Network is a collaboration of academia, government, and industry; funding is administered through Guelph University. He has over 50 peer-reviewed publications, including more than 15 that study metal cycling and impacts in the natural environment. He serves as a manuscript referee for numerous journals.

Dr. Watmough was selected for the ERA expert panel for his expertise in the impacts of metals on soils and vegetation, vegetation response to metals, ecology and ecological modeling, and metal biogeochemistry.

Disclosure: Dr. Watmough is currently funded by the Ontario MOE to assess the impacts of air pollution (nitrogen and ozone) and acidification on Ontario's hardwood forest. Dr. Watmough does not receive support from Inco or Falconbridge and none of his research has been used directly for the ecological assessment for Sudbury. This information is being disclosed to promote transparency. *TERA* does not consider Dr. Watmough's work for the MOE to constitute a conflict of interest, create the potential for bias, because the work was not related to the Sudbury risk assessment.

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Sudbury Soils Study ERA Independent Expert Review
SARA Group Biographical Sketches
March 6-7, 2007

Dr. Christopher D. Wren
Dr. Wren is a Senior Environmental Scientist with Gartner Lee Limited, in Guelph, Ontario. Prior to joining Gartner Lee early in 2006 he managed his own environmental consulting practice.

Chris completed his Ph.D. in Aquatic Science in 1983 at the University of Guelph. He subsequently completed postdoctoral research at the University of Toronto where he examined metal accumulation in piscivorous wildlife (mink, otter) across Ontario including Sudbury. He also conducted experiments to examine interactions of methylmercury and PCBs on mink reproduction. He then conducted further studies on wildlife toxicology at the University of Trondheim, Norway. He has published over 40 scientific papers in peer-reviewed journals and frequently lectures on risk assessment and environmental toxicology at the University of Guelph, Queens University and University of Waterloo and other scientific forums.
During the past 20 years as an environmental consultant in Ontario Dr. Wren has continued to focus on the fate, behaviour and effects of metals in the environment. For the past decade much of his work has been directed at the mining sector. He routinely acts as a senior advisor to industry and various levels of government, and has peer reviewed many human and ecological risk assessment reports for various clients. Dr. Wren was intricately involved in revising the metal mining effluent regulations for the mining sector and development of guidance for environmental monitoring methods. He has also been involved with development of many environmental quality guidelines (water, soil) for both the Ontario Ministry of the Environment and Environment Canada. In particular he directed revision of Provincial Water Quality Objectives for zinc, copper, nickel, lead and arsenic to name a few substances.

Dr. Wren has also been involved with international mining projects including a review role in the Natural Resources Damage Assessment (NRDA) for the Anaconda smelter in Montana; investigation of a fish kill near a smelter in the Dominican Republic, and overseeing baseline environmental monitoring programs in Brazil and Indonesia. In 2001, Dr. Wren was selected by the World Bank (Washington) to participate in an investigation and assessment of a mercury spill from a gold mine in Peru, that resulted in mercury exposure and poisoning to several hundred country people.

Ms. Mary-Kate Gilbertson
Mary-Kate holds a BSc. in Environmental Science from Plymouth University (UK), a HND in Environmental Science from Coventry University (UK), and a MSc. in Toxicology from the Great Lakes Institute for Environmental Research, University of Windsor. She has experience in toxicology, toxicity test method development, risk assessment, contaminated site assessments, remediation, herpetology and wildlife biology.

During the past 6 years as an environmental consultant, Mary-Kate has worked on terrestrial toxicity test development and application to contaminated sites, pipeline environmental assessments, pipeline spill remediation and clean-up, and site-specific and community-based risk

assessments. She has designed, managed and implemented a variety of field programs. She is currently overseeing collection, interpretation and integration of data for aspects of Ecological Risk Assessment and Human Health Risk Assessment in Sudbury, Ontario.

As part of the Sudbury ERA the possible risk from airborne particulate emissions from the chemicals of concern (COC) which are nickel, cadmium, copper, cobalt, arsenic, lead and selenium to vegetation communities was evaluated. Field and laboratory studies were conducted to determine whether the concentrations of the COCs present in the Sudbury soils pose an unacceptable risk to plants, invertebrates or microbial activity and are inhibiting the recovery of a self-sustaining forest ecosystem. This risk was determined using multiple lines of evidence (LOEs) including: a battery of single species terrestrial toxicity tests; field-based ecological measurements; in situ litter bags; and, soil chemistry. A weight of evidence approach was applied to determine whether the concentrations of metals in the soil were inhibiting the recovery of a self-sustaining forest system.

Ms. Ruth N. Hull

Ms. Hull obtained her M.Sc. in ecotoxicology from Concordia University in Montreal and her B.Sc. in biology with a chemistry minor from University of Waterloo in Waterloo, Ontario. She has 15 years of experience in the fields of ecotoxicology and ecological risk assessment. She has managed and conducted complex risk assessments at sites across Canada and the U.S. and abroad. For example, Ms. Hull is currently involved as Cantox Environmental's technical manager for the wide-area ecological risk assessment of Teck Cominco's lead/zinc smelter in Trail, British Columbia, and she is assisting Teck Cominco with the wide-area remediation planning. She also is leading the wildlife and aquatic portions of the ecological risk assessment related to smelter emissions in the City of Greater Sudbury and surrounding area in Ontario. Recent projects include: a review of nickel chloride fate and ecological effects in the marine environment for Sherritt International; a review of terrestrial ecological effects associated with lead for U.S. EPA; a human and ecological risk assessment associated with industrial airborne emissions in Egypt; a detailed ERA for a secondary lead smelter in Indiana (RCRA site).

Ms. Hull regularly provides expert advice to the Ontario Ministry of the Environment (OMOE) and other government agencies on ecological risk assessment and other related environmental issues. Prior to her years in environmental consulting, Ms. Hull was part of the ecological risk assessment team at Oak Ridge National Laboratory in Tennessee, and was responsible for ecological risk assessments at U.S. Department of Energy facilities in Tennessee, Ohio and Kentucky. Prior to her work at ORNL, Ms. Hull provided human health and ecological risk assessment oversight for the State of Minnesota Superfund Program. She has been responsible for all technical aspects of risk assessment projects, including: project management; project scoping; data interpretation; exposure analysis; development of ecotoxicological benchmarks; effects assessment; characterization of ecological risks; and communication of results to regulators and the public.

She is an active member of the Society of Environmental Toxicology and Chemistry (since 1990), has authored several papers on the topic of ecological risk assessment, and co-edited a Special Technical Publication on environmental toxicology and risk assessment for the American Society for Testing and Materials (2000).

Ms. Devon-Anne Stanbury

Ms. Stanbury has over four years of experience in environmental work, including more than three years in human health and ecological risk assessment (HHERA). Ms. Stanbury has worked on both site-specific and community-based risk assessments and has also been involved in terrestrial toxicity test development and its applications to ecological risk assessment. Ms. Stanbury holds a Master's Degree Environment Soil Chemistry and specializes in the design, management, and implementation of field sampling programs in support of HHERAs. For the past two years, Ms. Stanbury has worked outside the risk assessment field in the interior of British Columbia, implementing a wildlife rehabilitation program for orphaned Grizzly Bears. Prior to that Ms. Stanbury worked on the Sudbury Area Risk Assessment (SARA), where she was responsible for helping to design and conduct an ecological risk assessment to determine whether the concentrations of metals in the soil are inhibiting the recovery of self-sustaining forest systems. This portion of the risk assessment involved the collection of multiple lines of evidence, including plant community assessment; toxicological investigations; decomposition study; and, comprehensive physical and chemical soil characterization. Presently Ms. Stanbury has returned to the risk assessment field and her work with the SARA project and is helping to complete the Sudbury ERA. Most recently, Ms. Stanbury shared some of the findings of the Sudbury ERA at SETAC North America where she gave a talk on the application of a weight of evidence approach from the mining-impacted region of Sudbury, Ontario (November 2006).

Ms. Maureen Kershaw

Maureen Kershaw is a graduate of the University of Waterloo's Environmental Studies program specializing in resource management and ecology. Early in her career she focused on fisheries management but soon switched to applied forest based ecology. She then completed a MSc. in Plant Ecology at the University of Alberta analyzing plant community development on an alluvial fan in Nahanni National Park, NWT. After working for the Alberta Ecological Survey, the Canadian Wildlife Service in Alberta and NWT, and the Museum of Natural History in Edmonton Maureen served as a District Land Use Planner for the Ontario Ministry of Natural Resources in Wawa, followed by an 10 year career as Regional Soils Specialist and Regional Forest Ecologist for the NE Region operating out of Sudbury Ontario. Following this Maureen completed her Registered Professional Forester certification and established an environmental and forestry consulting firm that has operated for the past 17 years carrying life and earth science surveys, environmental assessments for proposed developments including mining, roads, snowmobile trails. She has completed research in ecosystem based tourism, ecosystem based community development, best practices for forest management to protect site productivity, soils and water and guidelines for protecting earth science features, and summaries of the silvics of both commercial and non-commercial forest species. Maureen is currently a PhD candidate at Lakehead University in the Forest and the Environment program. She is also the Chair of the Forestry Futures Trust Committee which administers a $20 million fund for forest remediation, research and forest inventory.

Dr. Mark St. John

Mark St. John has a doctorate in Ecology from Colorado State University. He specializes in soil ecology, studying the biodiversity of soil organisms, and their roles in decomposition and nutrient cycling. Mark publishes original research on both restoration and basic ecological theory using a variety of multivariate-statistical and modelling approaches. He recently co-authored a paper submitted to Proceedings of the Naitonal Academy of Sciences reporting on the first-ever study to determine the role of soil invertebrates on decomposition processes at the global scale. Mark is currently teaching at Laurentian and Nipissing Universities, and working as an independent consultant. He is also an active member of the Vegetation Enhancement Technical Advisory Committee, which coordinates restoration efforts in the Sudbury, Ontario region."

Dr. Peter Beckett

Peter Beckett received his B.Sc degree from King's College London (1969) and his Ph.D in peatland ecology from the same university in 1972. In 1976 he moved to Laurentian University and is now an Associate Professor of Plant Ecology. In Sudbury he has been involved with the successful reclamation of the acid-metal denuded landscape. Peter and students in his laboratory investigate reclamation and wetland projects in Sudbury, Elliot Lake and Hudson Bay Lowlands, including tailings reclamation, biosolids, ecological evaluations of mining activities on the landscape. Peter is a Director of Canadian Land Reclamation Association, Chair of the Sudbury Vegetation Enhancement Technical Advisory Committee (VETAC). He is a recipient of the CLRA Noranda Award for 'outstanding efforts in reclamation'. He is an active member of the Junction Creek Stewardship Committee. For his community efforts to the environment in Sudbury Peter received a Sudbury Community Enhancement Award in 2005.

Dr. Graeme Spiers

Dr. Graeme Spiers is the Chair of Environmental Monitoring, Laurentian University. Graeme is cross appointed in the Departments of Chemistry - Biochemistry, Earth Sciences and Biology, and Director of the Centre for Environmental Monitoring with MIRARCO. A retired dairy farmer from New Zealand, he has nearly 25 years of research and facilities management experience in academic, government and commercial laboratory environments. This experience is coupled with extensive field experience in vegetation, soil and surficial geological mapping. Involved in the training of over 40 graduate students in recent years, Graeme's academic research initially focused on pedological processes in catenary systems and on effects of acidification and extreme metal insult on pedologic processes, particularly as these relate to seasonal metal fluxes to industrially-impacted water bodies. Dr. Spiers current research program is focused on developing an understanding of metal speciation, bioaccessibility and bioavailability of metals and metalloids in diverse environmental media such as aerosols, soils, sediments and vegetation.

Over 100 publications in diverse areas ranging from pedology and clay mineralogy to analytical chemistry (35 journal papers) have contributed to the understanding of metal translocation in soil-plant systems, and have included pioneering work in development of specialized analytical methodologies for elemental quantification in diverse mineral and biological materials.

Dr. Gladys L. Stephenson

Gladys L. Stephenson has developed a battery of terrestrial toxicity tests for soil quality evaluations and to support ecological risk assessments of contaminated lands. The battery of species and methods are used as tools in a toxicity assessment framework developed at Stantec for site-specific risk assessments of contaminated lands. The toxicity assessment framework recently was endorsed by the CCME Sub-group for use in developing site-specific Tier 2 or Tier 3 standards for the eco-contact exposure pathway (ERAs). The approach generates site-specific toxicity data in support of ERAs (e.g., Swanhills-SSRA, Port Colborne-CBRA, Murdochville-CBRA; Sudbury-ARA), for the derivation of site-specific remedial targets and to support decisions regarding the management of contaminated lands. To date, ecotoxicity assessments have been completed with soils contaminated with petroleum hydrocarbon products and mixtures, mixtures of amine and glycol compounds, aged and weather uranium, a mixture of metals, PHCs with barite (barium sulphate) as a co-contaminant, PHCs with arsenic as a co-contaminant, and lead-contaminated bog material. These data were used to either derive site-specific remedial targets or to assess risk associated with these contaminated lands for the soil contact exposure pathway. Gladys' understanding of the fate and effects of contaminants (pesticides, metals, organic compounds) in both aquatic and terrestrial systems is germane to the interpretation of toxicological results in the context of risk assessment at any scale. Directing or conducting ERAs for oil spills, land application of biotreated soils, and for contaminated urban lands (REG 153) have resulted in improved management decisions and cost savings for clients.

Mr. Karl Bresee

Mr. Karl Bresee holds a Minor in Geology, a B.Sc. in Biology and a Post Bachelor's Diploma in Ecotoxicology. Mr. Bresee specializes in human and ecological risk assessment with extensive experience in exposure modelling. Mr. Bresee has over 8 years of experience in human, aquatic and wildlife toxicology, fate and transport modeling and exposure modelling. Recent projects include the development of probabilistic models for the wide-area ecological risk assessment of Teck Cominco's lead/zinc smelter in Trail, British Columbia, and the ecological risk assessment related to smelter emissions in the City of Greater Sudbury and surrounding area in Ontario. He also has managed many environmental impact assessments in Alberta, such as Devon's Jackfish and Jackfish 2 SAGDs, Shell's Scotford expansion project, both the Deer Creek SAGD and North Mine projects, Shell's Carmon Creek, Petro Canada's McKay River II SAGD, the North West Upgrader project, the BA Energy Hearthland Upgrader and Terminal, MEG Energy's SAGD, JACOS's Hangingstone SAGD, Imperial Oil's Cold Lake oil sands operations, Koch Oils's True North oil sands, Husky's Sunrise and Tucker SAGD projects, and Petro Canada's Lewis SAGD. He's also been involved with large industrial coal fired power generation projects in Alberta - EPCOR Genessee, TransAlta Centennial, and the proposed Luscar Brooks Power Plant. Mr. Bresee's role in these projects was project management, multiple pathway exposure assessment, chemical toxicity assessment, risk characterization and public/stakeholder consultation.

He has conducted deterministic and probabilistic risk assessments in Canada and the U.S.A. for both industry, private and government clients. He has conducted human and wildlife risk assessments for the metal smelting and oil sands industries and environmental impact assessments for agriculture, petroleum and the mining industry. In addition, he has experience with performing and communicating over 25 human and ecological risks assessments for contaminated sites in Canada.

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Sudbury Soils Study ERA Independent Expert Review
Observer Guidelines
March 6-7, 2007

Welcome Observers!

Welcome members of the Technical Committee and the Public Advisory Committee to this expert panel review of the Sudbury Ecological Risk Assessment! We are pleased that you have chosen to attend this meeting and observe the peer review process.

As you know, the purpose of the IERP meeting is to have the expert panel discuss the assessment and reach conclusions on the science and the quality. The discussions at the meeting will be limited to the panel members. The SARA Group authors will be making short presentations and will answer the experts' questions. SARA Group authors may also ask clarifying questions of the panel members so that they understand the recommendations and the basis for them.

It is important that all participants remember that the panel members must remain independent and not be influenced by any party regarding the assessment and conclusions. Therefore, we ask the observers to refrain from discussing the assessment or related issues with the panel members before, during, or after the meeting. We ask observers to refrain from discussing the risk assessment or related topics with panel members during the breaks. Other topics (the weather, ice fishing, sports, etc.) are all fine.

We know it can be difficult to observe such a meeting and not participate. Please realize the panel has a very limited amount of time and needs to discuss many complex scientific issues. The discussions will move quickly, and the Chair will do his best to summarize the conclusions and recommendations as they go through the charge questions. If you find that you have an important question that comes up during the meeting, please write it on a note card (available at the registration desk) and give it to a person from *TERA* at a break. We will review the questions and as appropriate answer it either privately or when the meeting reconvenes after the break. Note that the IERP meeting is not designed to educate or teach you about risk assessment, nor is this to be used as an opportunity for observers to provide technical comments or voice opinions or positions.

This meeting and the process is not open to the general public and the assessment results are not yet final; therefore, we remind observers that the panel discussions are confidential and should not be discussed with others, including the media. Please understand that the panel will attempt to reach a common consensus opinion about the most important issues. The final meeting report will be the official record of the peer review and will be made public with the final assessment document next year. The meeting report will not be a transcript; rather it will be a summary of the important conclusions and recommendations. The individual panel members' comments will not be identified by name in the meeting report; it is the consensus opinion that is the important result.

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Appendix C – Public Briefing Materials

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Public Briefing on the

Independent Expert Review Panel (IERP) for the Ecological Risk Assessment Sudbury Soils Study

March 5, 2007
7:30-8:30 PM
Collège Boréal

AGENDA

I. Welcome
Dr. Stephen Monet, Sudbury Soils Study Technical Committee

II. Background and Overview of the Ecological Risk Assessment
Dr. Christopher Wren, SARA Group

III. Overview of the Independent Expert Review Panel (IERP) Process
Ms. Jacqueline Patterson, *TERA*

IV. Introduction of the IERP

V. Audience Questions on the IERP process

After this session, members of the Technical Committee will be available to answer questions on the Soils Study.

Toxicology Excellence for Risk Assessment (*TERA*)
www.tera.org

Contact: Jacqueline Patterson 513-521-7426, Patterson@tera.org

The Independent Expert Review Panel (IERP) Process

This Independent Expert Review Panel (IERP) and meeting have been organized by Toxicology Excellence for Risk Assessment (*TERA)*. *TERA* is an independent non-profit organization with a mission to protect public health through the best use of toxicity and exposure information in the development of human health risk assessments. *TERA* has organized and conducted peer review and consultation meetings for private and public parties since 1996 (see http://www.tera.org/peer for information about the program and reports from meetings).

TERA scientists are well-experienced in toxicology, risk assessment, and conducting peer reviews. *TERA* was selected by the Technical Committee to independently organize and conduct this expert panel review. *TERA* has experience in risk assessment and toxicity of metals and has performed this work for a variety of public and private clients. None of *TERA*'s previous work related to the Sudbury Soils Study, nor has *TERA* worked for Inco or Falconbridge.

TERA has conducted reviews and worked on projects involving some of the contaminants considered at the Sudbury site, including arsenic, nickel, copper, lead, cadmium, and selenium, for a variety of clients. These projects were supported by the U.S. EPA, Health Canada, the Metal Finishing Association of Southern California, the International Copper Association, the U.S. Bureau of Land Management, Elf AtoChem North America Inc., the U.S. National Institutes of Occupational Safety and Health, and a metal refiner in South Africa. For the Ontario MOE, Dr. Lynne Haber of *TERA* peer reviewed the Rodney Street risk assessment and has been asked by MOE to be a peer reviewer for a community risk assessment currently being prepared. Dr. Pittinger, the panel chair, is a Visiting Scientist with *TERA.* He has worked on projects related to human health and environmental toxicity of mineral products and metal substances and he and his employer, ARCADIS BBL, provide consulting services to many types of public and private clients, including mining companies and consortia. None of Dr. Pittinger's projects has been with Inco or Falconbridge and to best of his knowledge his employer has not worked directly with these companies.

Independent Expert Review Panel

Peer review is commonly used in the sciences to judge the scientific merit of a manuscript or document. The intent of a peer review is to have a group of external experts evaluate a document's conclusions and the scientific basis for those conclusions. The purpose of this peer review is to have a panel of experts carefully evaluate the science and conclusions of the ecological risk assessment. The Sudbury Soils Study and human health and ecological risk assessments have been undertaken to determine what human health or ecological risks are associated with metal and arsenic levels present in the Sudbury area, and if there are unacceptable risks. Based on the available information for Sudbury, the study will provide a measure of the risk level from metals and arsenic in soils, and may determine site-specific soil guidelines for the Sudbury area.

TERA staff, with the assistance of Dr. Charles Pittinger, was solely responsible for the selection of the IERP. *TERA* followed the U.S. National Academy of Sciences (NAS) guidance on selection of panel members to create a panel with a broad and diverse range of knowledge, experience, and perspective, including diversity of scientific expertise and affiliation. *TERA* reviewed dozens of scientist's credentials and selected these panel members for their extensive knowledge and experience in their fields. *TERA* believes this group of experts is well equipped to conduct a thorough review of the materials and provide expert advice. The panel members serve as *individuals*, representing their own personal scientific opinions. They do not serve as representatives of their companies, agencies, funding organizations, or other entities with which they are associated. Their opinions should not be construed to represent the opinions of their employers or those with whom they are affiliated.

An essential part of panel selection is the identification and disclosure of conflicts of interest and biases. Prior to selecting the panelists, each candidate completed a questionnaire to identify activities, financial holdings, or affiliations that may pose a real or perceived conflict of interest or bias. The completed questionnaires were reviewed by *TERA* staff and discussed further with panel candidates as needed. (See http://www.tera.org/peer/COI.html for *TERA's* conflict of interest and bias policy and procedures for panelist selection).

TERA has determined that each panel member has no conflicts of interest and is able to objectively participate in this peer review. None of the panel members has a financial or other interest that would interfere with his or her abilities to carry out the duties in an objective fashion. None of the panel members is employed by Inco/CVRD, Falconbridge/Xstrata, the other companies or agencies represented on the Sudbury Soils Study Technical Committee, or the companies comprising the SARA Group. Nor do the panel members have financial interests in the two mining companies. None of the panel members was involved in the preparation of the Sudbury human health or ecological risk assessments.

The independent peer review panel includes six scientists who have expertise in the key disciplines and areas of concern. Each panelist is a well-respected scientist in his or her field. The panel members have expertise in ecological risk assessment; terrestrial and aquatic ecotoxicology; toxicology of metals and arsenic; bioavailability of metals in soils and water; biogeochemistry; environmental fate of metals; effects of metals on flora and fauna, including forest ecosystems; ecological processes; ecological modeling; landscape ecology, probabilistic risk assessment; and remote sensing.

Sudbury Ecological Risk Assessment Expert Panel

Joseph W. Gorsuch, M.S.
President
Gorsuch Environmental Management Services, Inc.
Webster, New York, USA

Samuel N. Luoma, Ph.D.
Senior Research Hydrologist
U.S. Geological Survey
Menlo Park, California, USA
Scientific Associate
The Natural History Museum
London, UK

Charles A. Pittinger, Ph.D.
Senior Toxicologist
ARCADIS/BBL
Cincinnati, Ohio, USA

William A. Stubblefield, Ph.D.
Senior Environmental Toxicologist
Parametrix, Inc.
Oregon State University (Courtesy Faculty)
Albany, Oregon, USA

Joyce S. Tsuji, Ph.D., DABT
Principal
Exponent
Bellevue, Washington, USA

Shaun Watmough, Ph.D.
Assistant Professor
Environmental Resource Science Program
Trent University
Peterborough, Ontario, Canada

Review Package and Charge to Peer Reviewers

The panel received the review package approximately seven weeks prior to the meeting to ensure adequate time to carefully review the documents and prepare for the meeting discussions. Materials sent included Volume I– Background, Study Organization and 2001 Soils Survey and Volume III – Ecological Risk Assessment. Review materials also included compact discs, including data and reports from the soil surveys, and appendices with key data and information. *TERA* developed a "charge to peer reviewers" document that outlined the key questions and scientific issues that need to be discussed by the panel in order to evaluate the quality and completeness of the risk assessment. The charge covers a number of comprehensive questions about quality

and scientific defensibility. In addition, there are several dozen more detailed questions that the panel will use to help guide their discussions and conclusions (see www.tera.org/peer/sudbury/sudburywelcome.htm for complete list of charge questions).

Questions for the Sudbury Soils Study
Ecological Risk Assessment Expert Panel

1. To what extent did the ERA achieve its two major goals:
   - to characterize the current and future risks of COCs to terrestrial and aquatic ecosystem components; and
   - to provide information to support activities related to the recovery of regionally-representative, self-sustaining ecosystems in areas affected by the COCs?
2. Have the key ecological objectives of the Sudbury Soils Study been addressed by this assessment?
3. Were the approaches used for this ecological risk assessment consistent with commonly accepted methods and sound scientific procedures?
4. Is the Ecological Risk Assessment presented clearly and completely?
5. Are the conclusions and recommendations supported by the available data?
6. Have the important uncertainties been identified and their impact on the characterization of risk and overall conclusions been fully discussed?
7. Are there additional important issues that should have been addressed?

Meeting Procedures

The meeting will be organized to make the best use of the time available to hear and discuss the opinions of the panelists regarding the charge questions and the ecological risk assessment. The meeting will begin with brief panel introductions and a discussion of any conflict of interest and bias issues. The discussion will then address the problem formulation, the work done for the three main objectives of the ERA, and the conclusions and recommendations. Before each discussion section, the authors of the assessment document will make a short presentation. These presentations will highlight the salient points and focus on important issues. There will be a brief time for panel member clarifying questions and then the panel will discuss the relevant charge questions. The panel recommendations and conclusions will be summarized in a meeting report.

Meeting Report

TERA will draft a meeting report that briefly summarizes the panel's discussions and recommendations. The meeting report will serve as a record of the peer review and will assist the authors in making revisions to the ecological risk assessment. The report will be reviewed by the panel members for accuracy before it is finalized.

Biographical Sketches of the Sudbury Soils Study Ecological Risk Assessment Independent Expert Review Panel (IERP)

Joseph W. Gorsuch

Mr. Gorsuch is President and owner of Gorsuch Environmental Management Services, Inc (G.E.M.S., Inc). Prior to developing G.E.M.S., Inc., he worked 30 years for the Eastman Kodak Company before retiring in 2004. Mr. Gorsuch has a B.S. in Wildlife Biology and an M.S. in Environmental Sciences, with both degrees from Purdue University. Through his work at Purdue University and Kodak, and with professional societies and trade group committees, Joe has over 35 years of experience with soils toxicity testing. He has served on numerous professional, government and trade group committees, task groups, and review panels regarding plant testing and toxicology, environmental effects and fate of silver, ecological risk assessment, and metals in soils. He was a presenter and co-facilitator at several U.S. EPA Workshops on Environmental and Plant Toxicology, and Genetic Engineered Plant Topics, and a peer reviewer of extensive EPA plant studies in 2006, including native vegetation. In 1993, as a plant toxicity expert, he was an invited participant in the Environment Canada CAPP Workshop "Tests to Evaluate Natural Gas Well Remediation Sites" in Calgary, Alberta. Since 2000, he has been a member of the Environment Canada Science Advisory Group for Plant Tests. In 2005, he was an invited participant of the Natural Resources Canada International Workshop "Metals in Soils: Science Gaps and Regulatory Needs" in Ottawa, Ontario. Mr. Gorsuch's continuous dedication and involvement with the Society of Environmental Toxicology & Chemistry (SETAC) since 1980, led him to be the recipient of the "Herb Ward Exceptional Service Award" in 2003. He has been a member of the American Society of Testing and Materials (ASTM), Committee E47 Environmental Effects and Fate, since 1980, receiving two awards, including the ASTM Committee E47's highest award. Mr. Gorsuch serves on four scientific journal editorial boards, has authored and co-authored approximately 40 scientific peer-reviewed publications, has helped organize and facilitate over 10 symposia on plant and soil testing, and has served as editor on six books (three on using plants in toxicity tests) and five special journal publications (including risk assessment of metals in soil).

Mr. Gorsuch was selected for the ERA panel for his experience and expertise with soils, earthworm and plant toxicity testing; effects of metals on flora and fauna; ecological risk assessment; and, remote sensing.

Dr. Samuel N. Luoma

Dr. Luoma is a Senior Research Hydrologist with the US Geological Survey (USGS). He has been with USGS since 1975. Dr. Luoma served as the first Lead Scientist for the CALFED Bay-Delta program between August 2000 and November 2003. He received his Ph.D. in Zoology from the University of Hawaii. His research interests are in the fate and effects of contaminants, primarily metals and metalloids, in aquatic ecosystems. He has worked on contaminant bioavailability to invertebrates from diet and water, biomonitoring, sediment contamination, processes affecting metal fate and form, and both organism-level and community-level effects of metals. He has additional interests the linkages between science and policy, and communication of environmental risks, especially in the arena of water management. He has advised and contributed in a number of different forums on the implications of various advances in metals science to managing those contaminants in the environment. Advisory functions have included the Canadian NRC Committee on Biologically Available Metals in Sediments (1988); the Ad Hoc, 4 person committee that designed USGS National Water Quality Assessment; National Science & Engineering Research Council, Canada, Strategic Grant Selection Panel for Environmental Quality; U.S. EPA Science Advisory Board Subcommittees on Sediment Quality Criteria; and, the U.S. EPA SAB panel reviewing the Metal Framework. He chaired the Science Advisory Group for the Interagency Ecological Program, San Francisco Bay/Delta and was Chair of the Science Advisory Committee, for Water Resources Division USGS Senior Staff. He was on the Science Advisory Committee for the U.S. EPA Center of Excellence (Center for Environmental Health Research), UC Davis. He participated in a series of four Society of Environmental Toxicology and Chemistry (SETAC) and U.S. EPA Workshops on Re-evaluation of the State the Science for Water Quality Criteria development and hazard assessment for metals. In 2002-03 he was on the National Academy of Sciences, NRC committee on Bioavailability of Contaminants from Soils and Sediments. Dr. Luoma has received several awards and commendations, including the Distinguished Government Service Award from SETAC and in 2004 he was named a Fulbright Distinguished Scholar and served in London at the Natural History Museum. He is currently working on a book on managing metal contamination in aquatic environments as a follow-up to that appointment. Sources of funding include City of Palo Alto for San Francisco Bay monitoring, State of California (CALFED Bay-Delta Program) for work with selenium and mercury, US EPA Superfund Program for work monitoring the Clark Fork River in Montana, US EPA Region 9 for work on evaluating alternative site-specific criteria for selenium in California, and the US Department of Defense to study ecosystem recovery after *in situ* remediation of PCB sediment contamination. Dr. Luoma has published approximately 140 peer-reviewed articles, authored a dozen book chapters, and co-authored two books.

Dr. Luoma was selected for the ERA expert panel for his expertise and experience in ecological risk assessment, bioavailability of trace metals in soils, environmental fate of metals, effects of metals on fauna and ecological processes.

Dr. Charles A. Pittinger

Dr. Pittinger is a Senior Toxicologist with ARCADIS BBL in their Global Product Stewardship Practice. He is also a Visiting Scientist with Toxicology Excellence for Risk Assessment (*TERA*). He worked for seventeen years as Principal Scientist for The Procter & Gamble Company, during which he conducted basic and applied research and risk assessments of consumer product ingredients, and developed regulatory submissions for federal and international authorities. Dr. Pittinger has over twenty-five years of experience in toxicology, environmental risk assessment methodologies, and aquatic and terrestrial ecotoxicology. He received his Master's in Aquatic Ecology from The University of Tennessee, and his Ph.D. in Environmental Toxicology from Virginia Tech. His experience ranges from environmental and human health risk assessment and management of consumer product ingredients and industrial emissions; physicochemical property estimation by quantitative structure-activity relationships; environmental fate and transport modeling; technical external relations; environmental chemistry; toxicology; and sediment contamination.

Dr. Pittinger served two terms on the U.S. EPA's Science Advisory Board, Ecological Processes, and Effects Committee (EPEC). He participated as a panelist in numerous other peer reviews and technical advisories, including the EPA's Southeastern Ecological Framework and the Index of Watershed Indicators. He also helped to champion the establishment of SETAC's (Society of Environmental Toxicology and Chemistry) Peer Review Program and led the first SETAC peer review of the American Chemical Council's Long-Range Research Initiative. He also chaired the American Industrial Health Council's Ecological Risk Assessment Committee for five years, and he served on the OECD's Risk Assessment Advisory Board, the American Chemistry Council's Ecological Risk Assessment Steering Team, and ASTM Subcommittee E-47. Dr. Pittinger has published more than forty technical articles, book chapters, and editorials. He has convened and chaired numerous technical steering committees and peer reviews for the public and private sectors.

Dr. Pittinger was selected by *TERA* to be the Chair of the ERA IERP based on his experience and knowledge of ecological risk assessment and experience in chairing scientific workshops and panels. His expertise includes ecological risk assessment, and bioavailability, toxicity and environmental fate of metals.

Dr. William A. Stubblefield

Dr. Stubblefield is a senior environmental toxicologist with Parametrix, Inc., and serves as a courtesy faculty member at Oregon State University, Department of Molecular and Environmental Toxicology. He has more than 20 years of experience in environmental toxicology, ecological risk assessment, water quality criteria derivation, and aquatic and wildlife toxicology studies. Dr. Stubblefield received his Ph.D. in Aquatic Toxicology from the University of Wyoming and his M.S. in Toxicology/Toxicodynamics from the University of Kentucky. Dr. Stubblefield served as President of the Society of Environmental Toxicology and Chemistry (SETAC) and chaired several SETAC committees. He has served on numerous committees and panels for the U.S. EPA, including the Science Advisory Board's Framework for Inorganic Metals Risk Assessment Review Panel; and the Multimedia, Multipathway, and Multireceptor Risk Assessment Model System Panel. He recently chaired an independent-review panel that looked at issues associated with liquid waste management in the Capital Regional District (Victoria, BC). Dr. Stubblefield has authored more than 100 peer-reviewed publications and technical presentations in aquatic and wildlife toxicology and environmental risk assessment. He is a co-editor of a recently published book, *Re-evaluation of the State of the Science for Water Quality Criteria*, which examines the issues and approaches to be used in the evaluation of environmental impacts associated with contaminants.

Dr. Stubblefield was selected for the ERA panel for his expertise in bioavailability of trace metals in soils, environmental fate of metals, effects of metals on flora and fauna, and ecological risk assessment.

Dr. Joyce S. Tsuji

Dr. Tsuji is a Principal in Exponent's Health Sciences practice and is located in the firm's Bellevue, Washington office. Dr. Tsuji received a B.S. in biological sciences from Stanford University with honors and distinction, Phi Beta Kappa, and a Ph.D. focused in physiology and ecology from the Department of Zoology, University of Washington. She is a Diplomate of the American Board of Toxicology and has 19 years of experience in toxicology and risk assessment on projects in the United States, Canada, South America, Africa, Australia, and Asia for industry, as well as for the U.S. EPA, the U.S. Department of Justice, the Australian EPA, and state and local municipalities and agencies. Particular areas of interest include exposure assessment and toxicology of a variety of chemicals including those from industrial releases and in consumer products and nanomaterials. Dr. Tsuji has specialized experience with mining and smelting sites and the toxicology, bioavailability, and exposure to metals such as arsenic, lead, cadmium, mercury, manganese, chromium, and zinc. She has conducted and reviewed human health and ecological risk assessments of mining and smelting sites, and has designed and directed exposure studies involving health education, environmental sampling, and biomonitoring of populations potentially exposed to metals in soil, water, and the food chain. Dr. Tsuji has served on expert committees for the National Research Council, including serving as a peer reviewer for the report on the Coeur d'Alene Basin mining site and risk assessment. She has also served on committees for the U.S. EPA, U.S. Army, and the State of Washington (including the Area Wide Soil Contamination group of experts convened by the State of Washington to evaluate arsenic and lead in soil). Dr. Tsuji has served as an expert witness on several legal cases involving metals and mines and has published a number of papers on risk assessment issues, including arsenic and lead in soils.

In addition to human health studies, Dr. Tsuji has also directed and conducted studies assessing the ecological effects of chemicals in the environment, many involving mining and smelting sites. These studies have evaluated the ecological effects of metals and other chemicals in soil, water, and sediments as well as their bioavailability and transfer via the food web. As noted above, she has a strong background from her doctoral studies in ecology and physiology and her published research involved fieldwork in Washington, California, Colorado, and Costa Rica. Dr. Tsuji served on the HHRA IERP and has been selected for the ERA panel to provide scientific linkage between the panels, as there are a number of scientific issues that overlap.

Dr. Shaun A. Watmough

Dr. Watmough is an Assistant Professor in the Environmental Resource Science Program of Trent University. His research focuses on ecosystems and environmental stress, and his research interests include forest ecology, plant stress, biogeochemistry, forestry, air pollution, climate change, trace metals, eutrophication, and environmental modeling. Dr. Watmough received his Ph.D. in Plant Stress Physiology from Liverpool John Moores University (UK) and his B.Sc. in Applied Biology from Liverpool Polytechnic (UK). His Ph.D. research assessed the impacts of metals to long-lived plant species. Dr. Watmough has received research support from Trent University and a number of government and other sources, including the Canada Foundation for Innovation, National Sciences and Engineering Research Council of Canada, Canadian Wildlife Service, Canada Foundation for Innovation, Ontario Ministry of the Environment (MOE), Canadian Council Ministers on Environment, Cumulative Environmental Management Association, Environment Canada, Ontario Power Generation, Metals in the Environment (MITE) Research Network, North Eastern Research Cooperative, and the Canadian Forest Service. His funding from MITE has been used in the past to study metal biogeochemistry in forested ecosystems. The MITE Research Network is a collaboration of academia, government, and industry; funding is administered through Guelph University. He has over 50 peer-reviewed publications, including more than 15 that study metal cycling and impacts in the natural environment. He serves as a manuscript referee for numerous journals.

Dr. Watmough was selected for the ERA expert panel for his expertise in the impacts of metals on soils and vegetation, vegetation response to metals, ecology and ecological modeling, and metal biogeochemistry.

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Appendix D – Presentation Slides

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Independent Expert Review Panel for the Sudbury Soils Study

Human Health Risk Assessment Conclusions and Recommendations

ERA IERP Meeting
March 6, 2007

Sudbury HHRA Charge to Peer Reviewers

- Was the approach used for this community assessment consistent with commonly accepted methods and procedures by government agencies (such as Environment Canada, Health Canada, the Canadian Council of Ministers of the Environment, and the United States Environmental Protection Agency [U.S. EPA])?
- Is the Human Health Risk Assessment presented clearly and completely?
- Are the input data and assumptions valid and appropriate for the Sudbury community?

2

Charge, continued

- Are the conclusions for each chemical of concern valid and defensible, and are they supported by the risk assessment?
- Have the important uncertainties been identified and their impact on the characterization of risk and overall conclusions been discussed?
- Have the key objectives of the Sudbury Soils Study been addressed by this assessment?
- Are there additional important issues that should have been addressed?

3

Independent Expert Review Panel

Dr. Gary L. Diamond, Syracuse Research Corporation

Dr. Michael L. Dourson, Toxicology Excellence for Risk Assessment (*TERA*), Panel Chair

Dr. Andrew P. Gilman, University of Ottawa, Population Health Institute and Sustainable Solutions International

Dr. Susan Griffin, U.S. EPA - Denver

Dr. Heather E. Jamieson, Department of Geological Sciences and Geological Engineering, Queen's University

Dr. Rosalind A. Schoof, Integral Consulting, Inc.

Dr. Joyce S. Tsuji, Exponent

4

Overall Panel Conclusions

NOTE- the HHRA has not been finalized or released to the public. Do not cite or quote these conclusions, nor share the meeting report.

- The panel found the HHRA to be a very comprehensive assessment. They were especially pleased to see the extent of sampling done in the community – for example: soil, air, dust, market basket and local foods.
- The overall approach used for the Sudbury HHRA was generally consistent with common practice, drew upon the best and most appropriate procedures from various jurisdictions, and focused on current and future risk to the Sudbury population.

5

Conclusions, continued

- The panel thought that the assessment appropriately considered all potentially highly exposed and sensitive groups of the population and the possible ways that people in Sudbury might be exposed.
- The panel provided specific technical recommendations for revisions to improve the scientific soundness of the results.

6

Conclusions, continued

- The panel thought that overall the calculations of exposure and risk associated with metals from sources of concern (i.e., smelting and mining) are health protective. Given the approach taken and assumptions, the estimates more likely overestimate risk than underestimat.
- In communicating the results to the public, the panel thought it very important that the authors clearly explain how much exposure and resulting risk is from the mining and smelting activities, and how much is from background sources, such as market foods, common to all Ontario residents.

7

Key Recommendations

- Identify objective criteria used to screen data and select chemicals of concern.
- Questioned if selenium should have been a COC.
- Expand discussion on other possible metals that might be enriched in area from local geology or mining/smelting to provide assurance to reader that suite of metals examined was adequate.
- Mercury, manganese, uranium (chemical) and cadmium should also be evaluated against the objective criteria.

8

Key Recommendations, continued

- Address attic dust and outdoor surface dust as potential sources of exposure
- Clarify how background exposures were determined and used.
- More description of distribution of soil data within the communities of interest and the likelihood of small areas having higher exposures point concentrations.

9

Bioavailability and Bioaccessibility

- Oral bioavailability of some metals can be lower in soil than water or food, but panel less confident in relying on *in vitro* bioaccessibility assay for deriving the adjustment factors for metals, other than lead.
- Panel recommended stomach phase extraction data for lead.

10

Sudbury Ecological Risk Assessment

Introduction and Problem Formulation

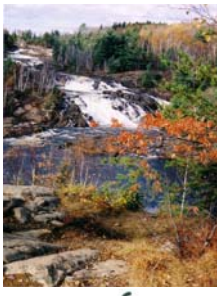
Christopher Wren and Ruth Hull
March 6, 2007

Presentation Overview

Introduction to the ERA team
Goals and Objectives
- Report organization

Problem Formulation
- Study area
- COCs
- VECs

Summary



SARA Team Presenters

- Christopher Wren, Ph.D.
- Ruth Hull, M.Sc.
- Mary Kate Gilbertson, M.Sc.
- Devon Stanbury, M.Sc.
- Karl Bresee, B.Sc., PBD Ecotoxicology

Members of the SARA Team

- **Soil Chemistry LOE**
  - Dr. Graeme Spiers
- **Plant Community Assessment**
  - Dr. Peter Beckett
  - Maureen Kershaw, M.Sc.
- **Toxicity Testing LOE**
  - Dr. Gladys Stephenson
- **Litter Decomposition LOE**
  - Dr. Mark St. John

Sudbury Soils Study Report Organization

- Volume I- Background and Study Organization
- Volume II – Human Health Risk Assessment
- Volume III – Ecological Risk Assessment

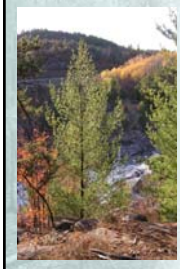
Volume III - ERA

1. Introduction
2. Problem Formulation
3. Objective #1
4. Objective #2 and 3
5. Aquatic Problem Formulation
6. Conclusion and Recommendations

Ecological Risk Assessment Goals:

- To characterize risks of COCs from smelter emissions to terrestrial plants and wildlife
- To provide information to **support** activities related to the recovery of regionally representative, self-sustaining ecosystems in areas of Sudbury affected by the COCs

ERA Objectives



- **Objective #1**: Evaluate the extent to which COCs are preventing the recovery of regionally representative, self-sustaining terrestrial plant communities
- **Objective #2**: Evaluate risks to terrestrial wildlife populations and communities due to COCs
- **Objective #3**: Evaluate risks to individuals of threatened or endangered species due to COCs
- **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

Why only a Problem formulation for aquatic ecosystems?

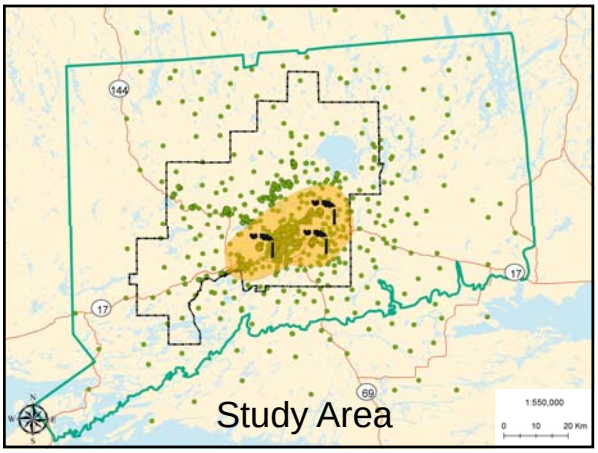
- Impetus for this study was metal levels in soil exceeding Ontario soil guidelines
- Risk management not expected for aquatic environment

Original Risk Management Objective

Evaluate levels of COCs in various soil types to determine COC levels in soil which do not result in unacceptable risks to Valued Ecosystem Components

Scope of an ERA

- Answers specific questions, and contributes to risk management planning
- Does not identify risk management or future monitoring studies
- Is not a research project
- Requires sufficient data to have confidence in the conclusions, and to contribute to risk management decision making



Time frame

- Succession of vegetation not assessed
- 30 years since emissions reduced, and start of regreening initiatives
- 30 years is not long enough to enable natural recovery
- Recovery is a work in progress
- Many large areas will not recover without intervention
- Intervention will be required for several generations

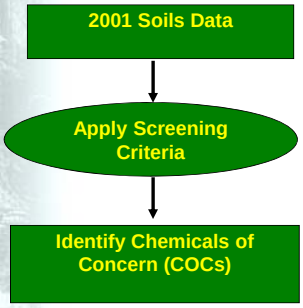
2001 Soil Sampling Program

- Almost 8,500 soil samples were collected and analyzed for 20 inorganic parameters

As, Al, Sb, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Pb, Mg, Mn, Mo, Ni, Se, Sr, V, Zn

These data formed the basis for this study.

Selection of Chemicals of Concern



Chemicals of Concern

- **Arsenic (As)**
- **Cobalt (Co)**
- **Cadmium (Cd)**
- **Copper (Cu)**
- **Lead (Pb)**
- **Nickel (Ni)**
- **Selenium (Se)**

Summary of Metal Concentrations (mg/kg) at ERA sites for Objective #1

	Test	Reference	MOE Guidelines Table A (F)
As	2.0 – 117	2.6 – 5.8	20 (17)
Cd	0.1 – 1.3	0.2 – 0.3	12 (1)
Co	4.8 – 48.0	5.4 – 11.5	40 (21)
Cu	76 – 1,000	19 – 42	225 (85)
Pb	5 – 162	19 – 33	200 (120)
Ni	77 – 1,100	39 – 46	150 (43)
Se	0.3 – 10.5	0.5 – 1.0	10 (1.9)

COCs In Combination

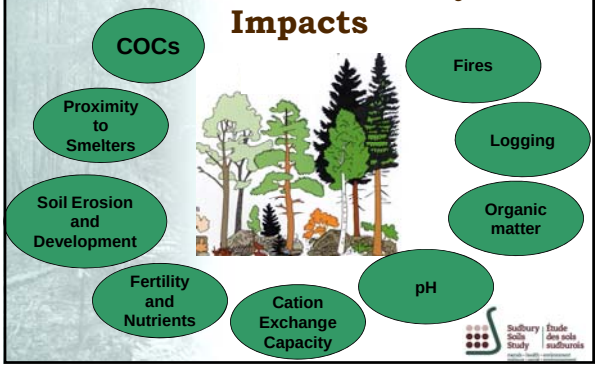
COCs in combination were taken into account for assessment of the plant community:

- Field vegetation surveys
- Laboratory toxicity tests

COCs were not considered in combination for modeling assessment of wildlife VECs:

- Requires same target organ and mechanism of action

Many Factors Contributing to Plant Community Impacts



Valued Ecosystem Components

Several criteria were used (Section 2.4.2)

- VTE (sensitive)
- Ecological significance
- High potential for exposure
- Resident or reproduces in Sudbury area (therefore exposure during sensitive life stage)
- Identified by stakeholders as being important
- Socio-economic importance
- Representative of major feeding guild/trophic level
- Toxicity data available for related species
- Information exists on local populations

**not all criteria must be met*

List of Terrestrial VECs

- Self-Sustaining Terrestrial Plant Community
- Northern Short-tailed Shrew
- Meadow Vole
- Moose
- White-tailed Deer
- Red Fox
- Beaver
- American Robin
- Ruffed Grouse
- Peregrine Falcon

VEC Selection: Aquatic

Wildlife with link to aquatic environment were included in the Aquatic Problem Formulation (Appendix H)

- Common loon
- Mallard
- Mink
- Amphibians

VECs Excluded

Willow tree to ptarmigan pathway was not assessed.

- Ptarmigan are not found within the study area (their range is MUCH further north)
- This pathway is assessed for mine sites; the focus of this study is smelter emissions.

VECs Excluded

Reptiles were not assessed (see Section 2.4.3)

- Lack of toxicity data for metals
- No standard toxicity tests for reptiles in Ontario
- Generally only assess in ERA if Vulnerable, Threatened or Endangered (VTE)

VEC Selection: Processes

Ecological processes were not considered VECs:

- They were, however, considered important in the assessment of the Plant Community VEC (see Chapter 3, Figure on page 3-70)
  - litter decomposition
  - downed woody debris
  - productivity, etc.

Problem Formulation Summary

- Study Goals and objectives determined
- Study area was defined and divided into zones for detailed assessment
- Chemicals of Concern were identified
- Valued Ecosystem Components chosen

Sudbury Ecological Risk Assessment

Objective 1

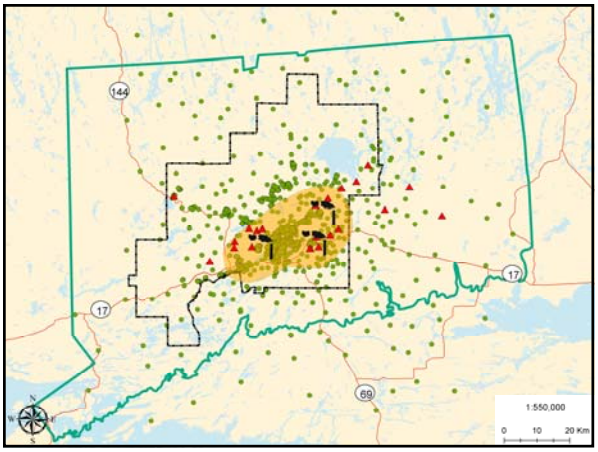
Mary-Kate Gilbertson
and Devon Stanbury
March 6, 2007

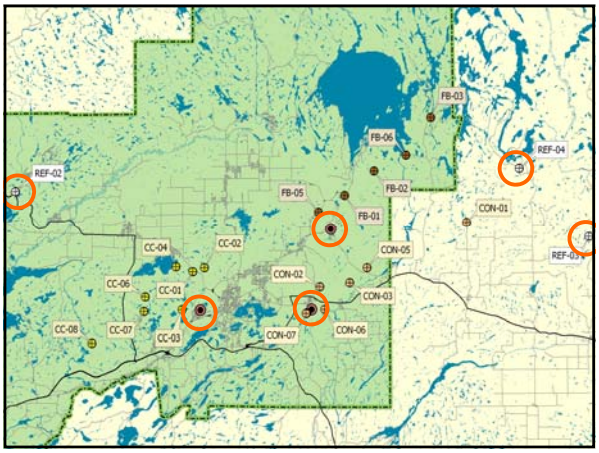
Outline of Presentation

- Site selection and study design
- Four lines of evidence
- Evaluation approach
- Addressing comments
- Conclusions

Ecological Risk Assessment Objective # 1

- Evaluate the extent to which COCs are preventing the recovery of regionally representative, self-sustaining terrestrial plant communities

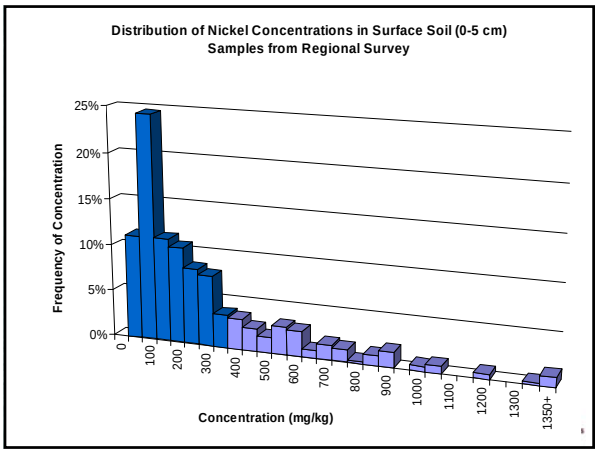


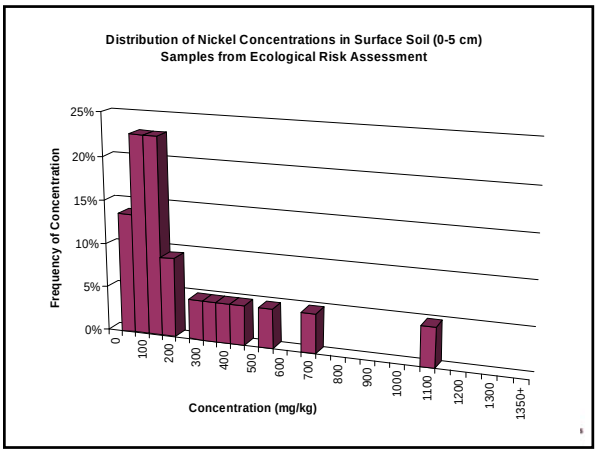


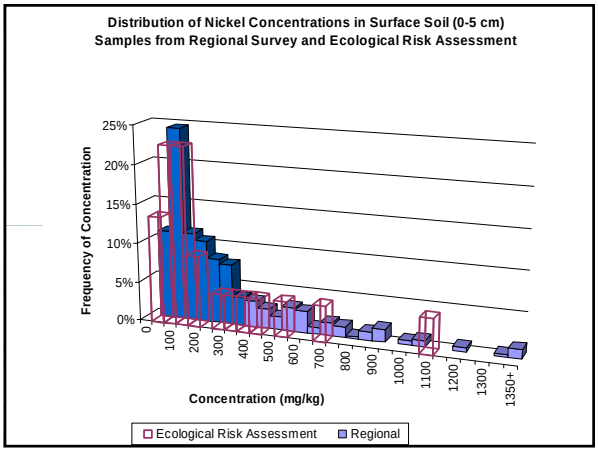
How Representative are these Sites of the Overall Study Area?

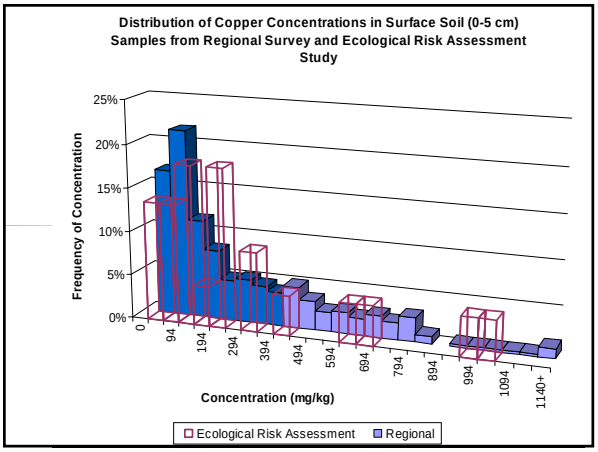
- Regional Survey Cu and Ni concentration range (µg/g):
  - Cu 6.10 – 3850
  - Ni 14 – 2900
- Objective # 1 sites (µg/g):
  - Cu 18.7 - 1000
  - Ni 40 – 1100

Were the Objective # 1 samples representative of the study area?





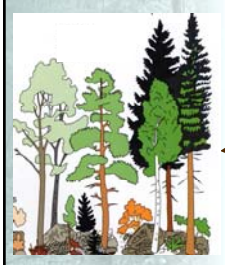


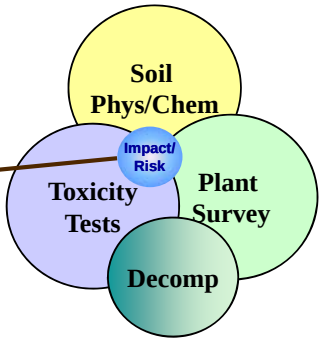


Number of Sites: When is Enough Ever Enough?

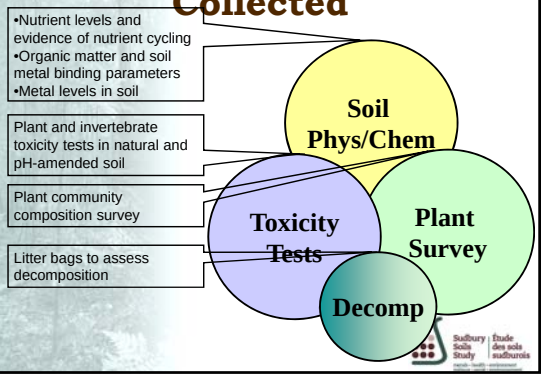
- The objective was NOT to fully characterize the plant community of the Sudbury region
- Information was collected at test sites to identify whether metals were inhibiting recovery of plant communities
- Chosen sites were representative of typical areas around Sudbury

Collect Multiple Lines of Evidence and Apply a Weight of Evidence Approach





Lines of Evidence Collected



Toxicity Testing Endpoints

- **Invertebrates**
  - Survival
  - Number of juveniles
  - Mass of juveniles
  - Avoidance (earthworm)
- **Plants**
  - Emergence
  - Root length
  - Root mass
  - Shoot length
  - Shoot mass

Litter Bags

Plant Community Survey

- Broad plant survey
- Detailed plant list of herbaceous and tree species
- Percentage cover
- Coarse and down woody debris
- Photographs of transects and plots

Soil Collection: Phys/Chem

- Soil core (0-5 cm, 5-10 cm, 10-20 cm)
  - Original, duplicates and blinds
  - Collected during initial site characterization – max 50 m from stake
  - Composite of 50 cores

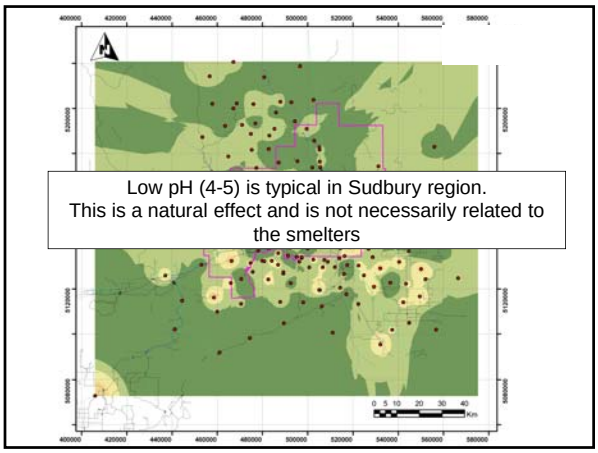
Evaluation Steps

For each LOE the results from the test site compared to the three reference sites or to a mean of the three reference sites

Step 1: Evaluate of LOEs Separately Irrespective of the Metal Levels

Step 2: Evaluate Interactions Between LOEs

Step 3: Evaluate Whether Metals are Impacting Site Recovery



pH as a Modifying Factor

- The role of metals cannot be differentiated from that of pH
- When the soil was limed plant growth increased – but was this because of increased nutrients, metals bound up or pH effect?
- All sites had soil pH levels that could be limiting for plant growth yet the plant community was considered healthy at the reference sites

Investigating pH

- Aim: To establish whether plant growth or earthworm reproduction occurred differently in the test and reference sites
- Concurrent testing with both natural and pH amended soil
- Additional amendments (OM, nutrient) may be interesting as part of the risk management of the area but were not considered as part of the risk assessment
- A large quantity of homogenized soil from each site has been archived for future use in risk management

Why Concentrate on Unlimed Areas?

- Although >3000 hectares have been limed and regreened, the majority of the Sudbury region has not been amended
- The RA needed to focus attention on whether recovery was occurring in these natural areas.
- Without the addition of soil amendments would these sites eventually recover?
- Study design incorporated a limed site adjacent to a test site for comparative purposes

CON-07 and CON-08

Metal Analysis from Decomposition Testing

- All leaves were collected from same trees at same site and homogenized. **The metal concentration in the leaves at start was identical**
- Test is looking at the **function** of the microbial community in same initial media.

Causality

- We cannot state that metals **ALONE** are the sole cause of impact at these test sites
- A variety of factors contribute to the lack of recovery of which metals are often one factor
- Given the long history, complexity and nature of the damage to the Sudbury landscape it is impossible to determine any one causative factor

Conclusions

1. Risk can not be ruled out at any of our test sites
2. The reference sites can be considered mature, healthy forests typical of NE Ontario
3. Some of the test sites may be starting to recover but stressors exist at the sites (metals, nutrients, lack of soil etc) which may be impeding recovery

Sudbury Ecological Risk Assessment

Wildlife Risks (Chapter 4)

Ruth Hull and Karl Bresee
SARA Group
March 7, 2007

Objectives 2 and 3

Objective #2:
Evaluate risks to terrestrial wildlife populations and communities due to COCs.

Objective #3:
Evaluate risks to individuals of threatened or endangered terrestrial species due to COCs.

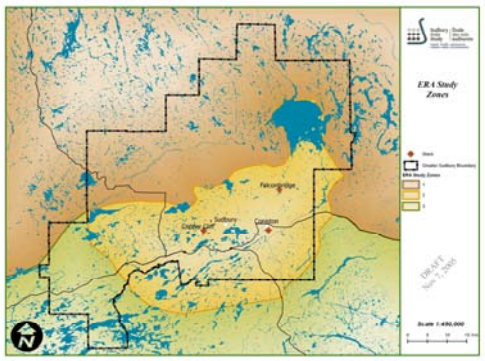
Overview

Overview of model data

Preliminary comments focused on several key issues:

- Use of HHRA bioaccessibility data
- Incidental soil/sediment ingestion
- Selection of plant dietary items
- Relative contribution of various exposure routes
- Habitat

7 Areas, 9 VECs, 7 COCs



Media Input Variables

Sediment (site-specific distribution)
- Uptake into Benthos (literature regression or BSAF)

Surface water (site-specific distribution)
- Uptake into Aquatic Plants (literature BCF)

Fish Tissue (site-specific distribution)

Soil (site-specific distribution)
- Uptake into small mammals (literature models)
- Uptake into plant shoots, plant roots, invertebrates and worms (site-specific regression or uptake factor)

Receptor Characteristic Variables

A range of values was used for:

- Food ingestion rate
- Soil/sediment ingestion rate
- Water ingestion rate
- Proportion of each dietary item
- Body weight

Modelling Methods

External doses are estimated and compared to Toxicity Reference Values (TRVs) to estimate risks (standard ERA method)

- TRVs are not based on "accumulation", and do not address where the metal partitions/ accumulates in the body

Exposure Ratios (ERs) were estimated using probabilistic exposure and deterministic TRVs (SSDs not used)

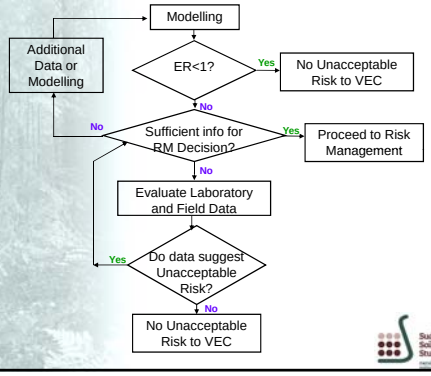
- Insufficient quantity of data to develop more sophisticated TRVs (Dwayne Moore)

ERA Approach

Wildlife modeling is generally intended to OVER-predict risks

- We want to be confident that we are correctly "ruling out" risk
- Field data then can be used to evaluate potential risks (the weight-of-evidence approach)

ERA Approach



Use of HHRA Bioaccessibility Data

Problems identified in HHRA for bioaccessibility of metals in DUST, and method to assess Pb - the ERA did not use these values

None of the other soil bioaccessibility values were called into question in the HHRA

The ERA can be updated using new soil values from HHRA (when available) but these are not expected to change significantly

Use of HHRA Bioaccessibility Data

- The ERA did not use the HHRA values for Cd or Pb (U.S. DOD recommended values used)
- The HHRA Co value was used, but even assuming 100% bioaccessibility will not result in unacceptable risks
- The HHRA Ni and Cu bioaccessibility values are greater than those from the literature
- No other value for Se is available

Incidental Soil/Sediment Ingestion

- Wildlife were assumed to incidentally ingestion soil or sediment while feeding, preening, etc.
- Exposure from food evaluated separately from exposure to incidental soil/sediment that may be attached to or within the food item
- Standard practice in ERA

Incidental Soil/Sediment Ingestion

- In few cases, non-depurated data were used (i.e., Cu and Se uptake into benthos).
- This uncertainty is discussed in Section 4.4.5.2.
- Relates to aquatic data; recommendations were made to analyze uptake directly into benthos (Appendix H).

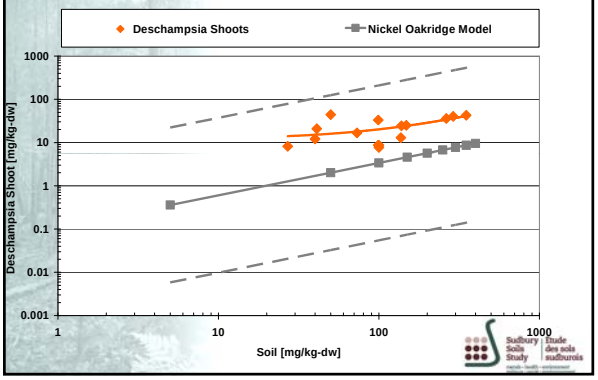
Selection of Plant Diet Items

- Sampling of *Deschampsia* was done since this plant is present across the study area, would be a common food source for many herbivores.
- We were limited in the number of food items we could sample, and to one sampling time
- Alternative is to use generic literature sources for uptake into "generic" plants (common practice in ERA; e.g., ORNL)

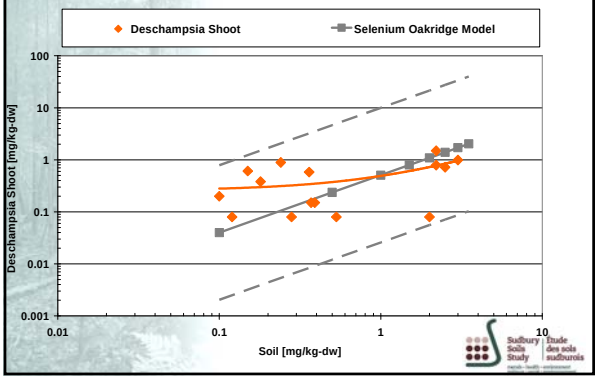
Selection of Plant Diet Items

- Site-specific data were considered preferable to literature data
- Other food items (plant parts) likely accumulate less (e.g., roots>leaves> fruit, buds, twigs, bark; Baes et al., 1984)
- A range of concentrations was used (to address uncertainties).
- Uptake into *Deschampsia* shoots was compared to results from standard models (ORNL)

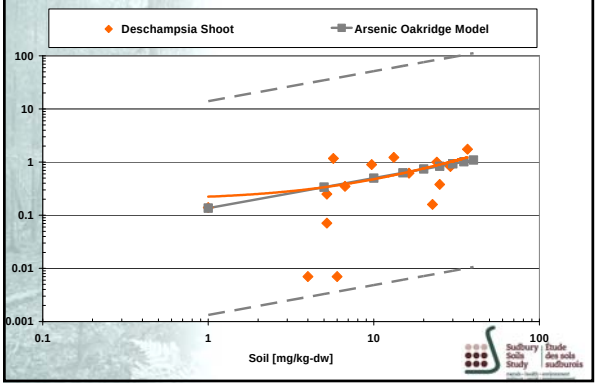
Sudbury/ORNL Comparison: Ni



Sudbury/ORNL Comparison: Se



Sudbury/ORNL Comparison: As



Relative Contribution of Exposure Routes

- At soil contaminated sites, the primary exposure routes are ingestion of food (all wildlife) and soil (those in close association with soil).
- Ingestion of water rarely contributes significantly to exposure
- Inhalation not assessed (see Section 2.6)

Relative Contribution of Exposure Routes

Predators are assumed to consume small mammals (whole body);

- only predators of large mammals are likely to be selective re: ingestion of organs
- when food is plentiful

Influence of Habitat on Wildlife VECs

Wildlife habitat suitability was not assessed

- it is recognized that habitats (plant communities) were severely impacted in the past, and the ERA shows that plant communities are still impacted
- direct toxicological risks to wildlife are low
- influence of habitat quality on wildlife may be significant (not quantified)

Objective #2 and 3 Conclusions

COCs in Sudbury are not impacting wildlife directly

- Individuals of T&E species
- Populations of wildlife
- Current conditions
- Future (assuming habitat suitability increases)

Sudbury Ecological Risk Assessment

Concluding Remarks and Recommendations

March 7, 2007

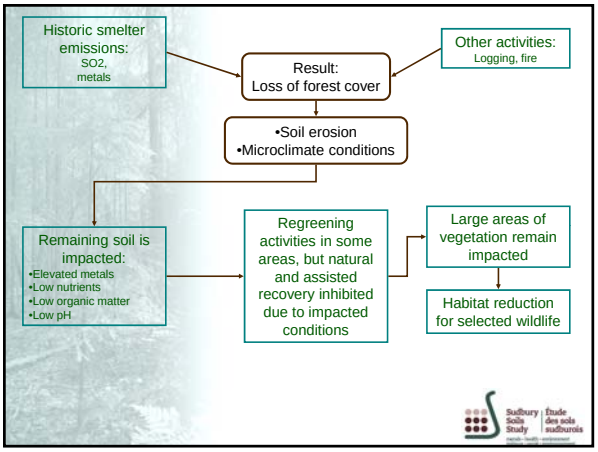
Christopher Wren, Ph.D.

Ecological Risk Assessment Goals:

- To characterize risks of COCs from smelter emissions to terrestrial plants and wildlife
- To provide information to **support** activities related to the recovery of regionally representative, self-sustaining ecosystems in areas of Sudbury affected by the COCs

The ERA recognizes three facts at Sudbury:

- Past activities have severely impacted the vegetation;
- Regreening activities have been successful; and
- Intervention is required to promote development of the vegetation.



What have we achieved?

- Developed a definition of a diverse, self-sustaining forest ecosystem for Sudbury
- Identified diagnostic characteristics of reference and impacted northern soils and vegetation communities

What have we achieved?

- Demonstrated that the COCs (and other factors) are continuing to limit vegetation growth and recovery in the study area
- Systematically evaluated risk of the metals to wildlife VECs in the area

What have we achieved?

- Provided a comprehensive problem formulation for aquatic ecosystems that can be used as a basis for future studies
- Provided mapping, data and integrated methodologies that can be used to support future regreening and forest recovery initiatives

Were the Study Goals Achieved?

YES

Recommendations

- Risk management objectives in the Sudbury area should be defined spatially using ecological endpoints, not just metal levels in soil for guidance or goal setting
- Future risk management activities should include consideration of wildlife habitat suitability

Recommendations

- The ground cover map that identifies areas at risk may be used as one possible tool to help guide future risk management activities;
- Ground truthing of the map is essential
- The 22 study sites used in the ERA should continue to be included in future studies or monitoring programs

Thank You

Appendix E – Summary of Observer Questions

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Summary of Observer Questions

Observers for the independent expert review meeting did not participate in the panel discussions. They were provided the opportunity to submit questions during the meeting. The observer questions were reviewed by the chair who read the collected questions to the panel members, who then offered individual responses. The following is a brief summary of observer questions and responses.

1. *Please comment on how natural confounding stressors can be distinguished from non-smelter anthropogenic stressors (e.g. logging) and how well the risk assessment framework addresses these natural and non-smelter stressors. Can these stressors realistically be addressed in risk assessment?*

   The panel replied that distinguishing natural confounding stressors is always a problem in these situations and very difficult. Fire around smelters is not followed by recovery, like a non-smelter site would, and recovery from logging is also impacted by the smelting. However, the impacts from the smelters are hard to distinguish from these other stressors.

2. *Current analysis of biological response variables conducted primarily by transects. Data could also be assessed as a gradient design (n=22) to capture full range of responses and increase power of statistical analysis (i.e., use all sites including reference sites). Would this type of analysis provide useful information to this risk assessment?*

   A panelist responded that in this case it would not matter. The covariance prevents separating the variables; even with a random design, there is a lot of covariance with physical- chemical parameters. The SARA group clarified each test site was analyzed on an individual basis. When they compared results in Step 1 to the mean or each reference site, this was not on a transect-by-transect basis.

3. *Relationship between soil properties (COC, nutrients, etc.) and biological response variables examined all lines of evidence and all response data. These relationships could also be evaluated for each line of evidence using a range of simple and complex models. Would this statistical analysis support interpretation and understanding of these relationships?*

   The panel suggested that additional statistical analysis might be done, but would not recommend doing all four separately

4. *Toxicity tests were conducted in natural soils and pH amended soils. Is it appropriate to use the results from the pH amended soils in the overall toxicity line of evidence rank?*

   Depending upon how the data are used, panel members thought that it could be appropriate to consider the pH-amended results, particularly to provide information about the mechanism and basis for any toxicity observed. However, these results would not be appropriate for an evaluation of the overall site conditions at this point in time and should not be used in an overall ranking.

5. *From a human nutritional perspective, fish are an appropriate source of selenium [which is an] essential element. Is it appropriate to assume that selenium is toxic for all fish consuming VECs? Similarly, is it valid to consider that all plant selenium is toxic? In some countries, soil is supplemented with Se when growing grains for human consumption.*

   Panel members made several comments regarding selenium. They noted that selenium is a controversial element, and is the least understood of the essential elements. It is an antioxidant for humans and one of the lesser of the toxic metals; it antagonizes arsenic toxicity. There are many selenium deficient regions of the world, and regulations for selenium vary extremely widely. On the ecological side, there is a narrow window between essentiality or beneficial aspects and levels that are toxic. It is a reproductive poison for predators that consume prey low on the food chain.

6. *Earthworms are not abundant in the Sudbury area due to the low pH of the soils (e.g. in non-urban areas). Are earthworms an appropriate surrogate for other vertebrates in the diet of wildlife VECs? Any additional implications for the wildlife model?*

   Panel members discussed use of the earthworm during discussions on Objective 2.

7. *Would it be useful to conduct a wildlife field survey at the 22 study sites? This would allow wildlife data to be integrated with the plant community assessment and provide a baseline for current conditions.*

   The panel discussed this issue under Objective 2.

Appendix F – Panel Suggestions for Revisions to Conceptual Model

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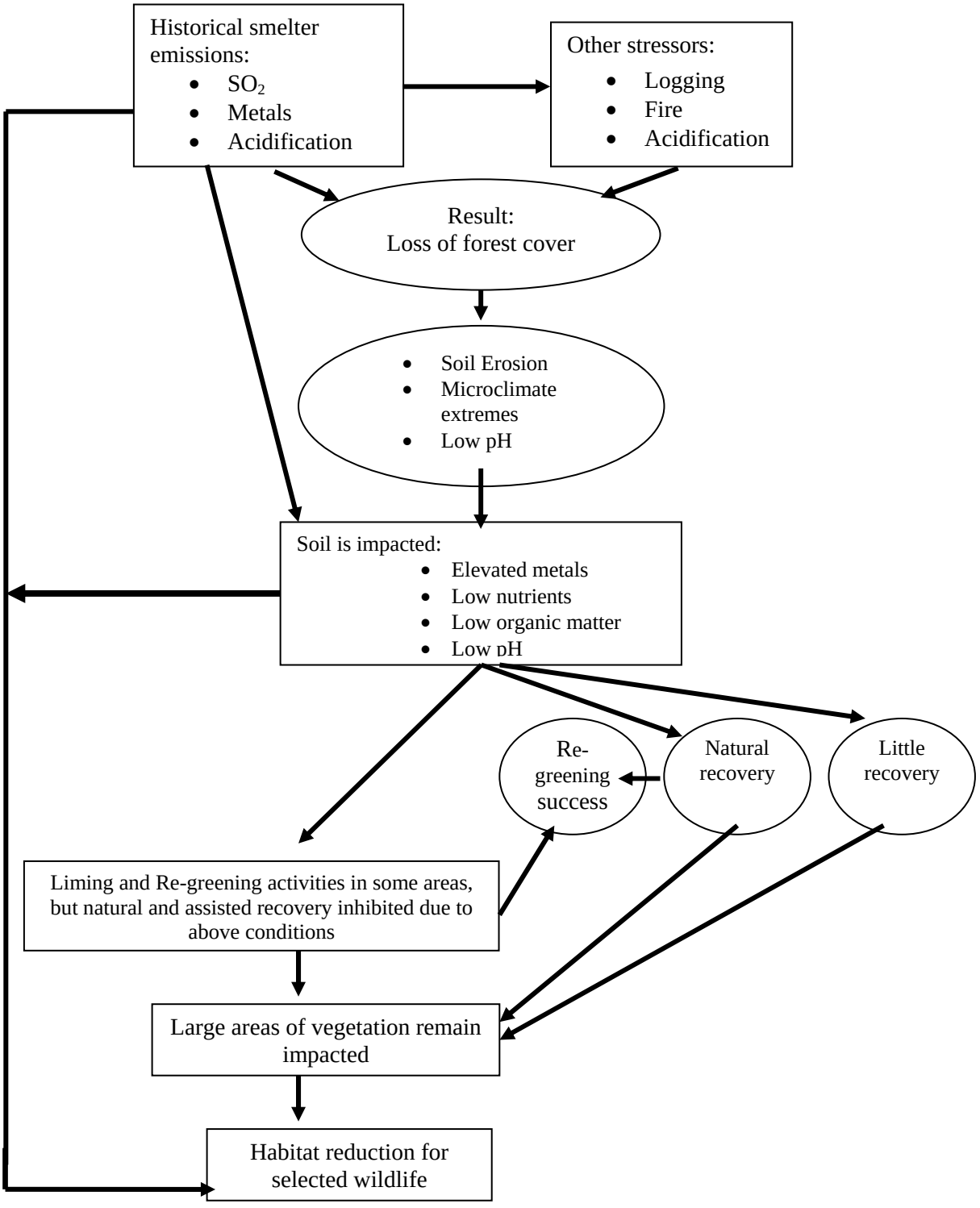

Revisions to Figure 1-1 Conceptual linkages of past impacts, COC and wildlife habitat with VECs