COMMUNITY-BASED RISK ASSESSMENT

INTEGRATION REPORT

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Executive Summary

An extensive Community Based Risk Assessment (CBRA) has been carried out to determine the potential risk associated with elevated levels of nickel, copper, cobalt and arsenic (the chemicals of concerns, CoCs) in soil to human health, agricultural crops and the natural environment within the City of Port Colborne. This Integration Report concludes the CBRA (Phase 1) and provides guidance on how the findings of the CBRA (including possible remediation {Phase II}) will be applied on a site by site basis. A site refers to land that has a title, has clear boundaries and has an owner. Sites include properties used for city residences, rural residences, farming, having woodlots, and being undeveloped land and/or combinations of these typical uses. The CBRA derived safe soil concentrations for the CoCs for a worst case land use and the most sensitive receptor. The CBRA is, therefore, applicable to all sites within Port Colborne and site-specific information from each site will be used in applying the CBRA findings.

The CBRA serves two important purposes. First, it can be used to help identify whether any remediation or preventive measures should be taken by Vale Inco to address its responsibilities (including its potential liability under Ontario's environmental laws concerning remedial/preventive measures orders) and, if so, what those measures should be. Second, the CBRA can be used by property owners to facilitate any sale, development, financing or other valuation of their property. For example, together with site-specific information, the CBRA can be used to facilitate municipal development approvals or the obtaining of a Record of Site Condition under *O. Reg. 153/04*. Together with site-specific information, the CBRA can also be used to satisfy prospective purchasers or persons undertaking a valuation of a property that there are no concerns with the environmental condition of that property that would affect its use or value.

Human Health

Results of the Human Health Risk Assessment (HHRA) have determined that there exist no health risks from the CoCs for humans of any age living or working in Port Colborne, regardless of land use and/or soil type considerations. The intervention number (the maximum

safe level for a CoC) derived by the HHRA includes the protection of small children, which are the most sensitive human receptors. Based on the intervention numbers and the known soil CoC levels, no soil remediation is necessary to protect human health because no soils routinely used by humans are above the Port Colborne-specific “safe” CoC limits derived in the HHRA.

Agricultural Crops

Studies on crops included greenhouse studies and field trials that established Predicted No-Effects Concentrations (PNECs) for each soil type that are protective of a representative sensitive crop, oats. Nickel toxicity to sensitive crops, such as oats, is the most severe outcome of any of the CoCs and nickel content in soils is very well correlated with the contents of other CoCs. Accordingly, nickel concentration in soil is the parameter that influences decision-making on farmland remediation. In view of these conditions, Ni PNECs for oats will be used to determine whether farm soils in Port Colborne need remediation in Phase II. It should be noted that, since the Ni PNEC (oats) is lower than the Ni PNEC (earthworms), use of the Ni PNEC (oats) will also be protective of earthworms in farming fields.

Because sampling of soils across farmland has been limited, more intensive selective sampling will be done in order to accurately know what portions of certain farm sites are above the PNEC (oats). The program for farm sampling will be carried out for those farm sites that have any portion of land exceeding the 95% lower confidence level (LCL) of $PNEC_{Ni}$ (oats), as obtained using currently available computer-modeled nickel soil concentrations. The sampling criterion for soils greater than 95% LCL of PNEC (oats) was selected to make sure that no farm site close to having PNEC levels would fail to be sampled. The sampling of each site will be carried out on a grid pattern with a 30 meter spacing, which will be able to determine contours of nickel concentrations with adequate precision for making decisions about remediation for each farm property.

Residential Vegetable Gardens

According to the findings for agricultural crops, there may be some effect on certain vegetables grown on residential sites. These effects concern the growth and yield of vegetables; there are negligible risks to humans from eating home-grown vegetables. In order to protect home-grown vegetables, remediation of existing gardens (as Vale Inco is notified by property owners of such) will be carried out based on their garden soils being in excess of the PNEC (oats) for till soil. Since residential soil sampling in some areas may not be sufficient, existing vegetable garden sampling will be carried out. Vegetable gardens that are moved or expanded, or gardens that are established at some future time (upon notification to Vale Inco by property owners) will be sampled and remediated under the same criteria as is set forth herein for existing vegetable gardens.

Natural Environment

The technical risk assessment on a wide variety of Valued Ecosystem Components (VECs) determined that earthworms in woodlots in close proximity to the Vale Inco refinery may be impacted by nickel in soil and Ni PNECs (earthworms) were derived for woodlot soils. Woodlot remediation will be considered for a woodlot exceeding the relevant Ni PNEC (earthworm). Due to limited existing sampling, a woodlot sampling campaign will be conducted based on whether the woodlot is within a 2.5 km distance from the former Vale Inco stack in the north-east quadrant

Remediation Options

Removal and replacement of soil in agricultural settings and woodlots is not a practical remediation option. In the former setting, excessive topsoil would be lost; in the latter setting, excessive damage to vegetation would occur. The most practical and effective remediation for these lands is to make soil amendments to reduce CoC bioavailability. Chemical agents most commonly used for this kind of treatment contain carbonate or phosphate. An alternative to reduction of bioavailability is to use nickel hyper-accumulating plants that thrive on extracting nickel from soil into their biomass, which can be harvested and processed for nickel recovery.

For residential vegetable gardens, either removal/replacement or soil amendment are viable remediation options.

Remediation Actions And Certification

Detailed decision-making flowcharts are presented in the report. These flowcharts will assist landowners in understanding whether their site will be included in Phase II. The flowcharts detail decision-making steps for dealing with impacts to agricultural soils, residential vegetable gardens and woodlots. Remedial actions for a specific property will be agreed upon by the property owner and Vale Inco with the Ministry of the Environment playing an advisory role. After carrying out the remediation action for a site, verification of remediation will be done and a suitable certification of the remediation will be given to the property owner.

1.0 INTRODUCTION

A major Community-Based Risk Assessment (CBRA) has been completed for Port Colborne soils which contain levels of nickel, copper, cobalt and arsenic (the Chemicals of Concern, CoCs) above Ontario's generic soil criteria. The CBRA consisted of separate risk assessments that were carried out on the four CoCs for receptors in the natural environment, for sensitive crops and for humans. The details of each assessment are contained in three technical reports accompanying the present CBRA Integration Report.

1.1 Objectives Of This Report

Details of the individual risk assessments will not be repeated here and the reader should refer to the technical reports as necessary. This Integration Report has the following objectives:

- To summarize the findings (Port Colborne-specific intervention levels) of the risk assessments in terms of soil types and land uses;
- To describe the process by which Vale Inco intends to translate information in the risk assessments into information for any specific site within the Study Area;
- To discuss general approaches for risk reduction, where needed, as a function of soil type and land use; and
- To describe the process Vale Inco will use to determine which properties may need additional sampling.

1.2 Distinction Between Risk Assessment And Risk Management (Remediation)

There are two distinct phases related to assessing and managing risks from metals in Port Colborne soils:

- Phase I: Risk Assessment
- Phase II: Risk Management (for example, soil remediation)

Many organizations involved in Phase I will finish their work in Phase I and not be involved in Phase II. One of these, Jacques Whitford Limited, which performed the quantitative risk assessment, may or may not be involved in Phase II. The Public Liaison Committee (PLC), which provided input on matters relating to Phase I, will likely not be involved in Phase II. It is not clear if there is a need for public involvement in Phase II, but if the current stakeholders advise Vale Inco that the public should be involved in some manner, and recommend to Vale Inco a mechanism for such involvement, then Vale Inco would convene such a group and would define its terms of reference.

This Integration Report completes the CBRA (Phase I) and identifies a process for implementing remediation where it is needed (Phase II).

2.0 THE PORT COLBORNE SETTING

2.1 General Setting

The City of Port Colborne is situated on the north shore of Lake Erie at the Welland Canal. Geographically the land falls within the Limestone Plain of the Niagara Region. This Plain is characterized by shallow bedrock, which is usually covered with a relatively thin layer of silt (mixed between clay-like and stone-like) and glaciolacustrine sediments.

Port Colborne is in the Mixed Wood Plains Ecozone, which is located at the northern limit of the Carolinian Forest Region and near the southern portion of the Great Lakes-St. Lawrence Forest Region, and the ecosystem variety is mixed between representative species for each Region. As a consequence, certain species typical of each Region may be absent from the area.

The area is significantly altered due to forest clearing associated with settlement over the past two centuries. Few undisturbed areas exist and, when they do, they are small and isolated. Some secondary growth woodlots exist in fragments across the region.

2.2 History

With the completion of the Welland Canal in 1833, the small settlement located at its Lake Erie terminus was named Port Colborne to honour John Colborne, one of the major proponents of the Canal project. The settlement was incorporated in 1833 with slightly more than 1000 inhabitants. In 1918 the Town of Port Colborne was established with a population of 2,837. The City was established in 1966 and currently has a population of about 18,000 people.

2.3 Industry

The presence of the Welland Canal and local natural gas deposits attracted industries to the area. In addition to the obvious need for businesses related to shipping services, a number of medium- to heavy-industries were sited in Port Colborne. One of these was Inco (now Vale Inco), which commissioned its refinery in 1918. Already established in 1913 nearby the Inco site was the steelmaking operation of Canada Furnace (later Algoma Steel). Also near the Inco facility on the east side of the Canal was a Canadian National Railway yard, which had started operation in the 1860s and was associated with a coal storage yard and grain and fuel oil storage. Other industrial facilities on the east side of the Canal included a metal scrap depot, a forging operation, machine shops, gasoline stations and automotive repair shops.

2.4 Soils

Soil textures range from heavy clay soils (fine texture) to sandy soils (coarse texture). The clay soils have poor drainage and are spotted with wet depressions (marshes) of irregular sizes and shapes. Four soil types have been identified in the area as heavy clay, till clay, organic soils and sandy soils (Kingston and Presant, 1989; Jacques Whitford 2004). Draining agricultural areas has been managed by the use of drainage tiles, ditching and municipal drains. Major drains in the area are the Wignell Drain (draining a watershed of about 1200 hectares) and the Beaverdam Drain (draining a watershed of about 1400 hectares). Both of these drains are located east of the Welland Canal and drain water from north to south, emptying into Lake Erie.

3.0 CONTEXT OF THE CBRA

3.1 Vale Inco's Operations In Port Colborne

Vale Inco's presence in the city of Port Colborne began in 1916 with the purchase of a large tract of land on the eastern side of the Welland Canal adjacent to the shore of Lake Erie. A nickel refinery was built on the western edge of the property and was commissioned in 1918.

The Port Colborne area does not have a nickel mine. The refinery was sited in Port Colborne to take advantage of the transportation infrastructure present in the area so that nickel, as a strategic metal, could be easily supplied to North American and European World War I allies.

The Port Colborne nickel refinery used concentrated nickel-copper intermediates from other Vale Inco operations as feed material. The refinery was designed and constructed according to the best engineering and metallurgical standards of the day and has undergone numerous changes in process and equipment design, as well as in waste process gas treatments. In the earliest decades of its operation, however, loss of metal values occurred through process stack particulate and fugitive (through doors, windows, vents, etc.) dust emissions. These emissions were dispersed by the wind and particles of varying compositions fell onto the ground.

The prevailing wind direction for the area is SW to NE and so it would be expected that, over time, a higher concentration of dust deposition would have occurred to the NE of the refinery's buildings and chimneys. Because emissions would have consisted of particles covering a wide size distribution, a variation in the rates of settling in air would have existed with larger (heavier) particles settling rapidly (*i.e.*, closer to the refinery) and smaller (lighter) particles settling more slowly (*i.e*, farther from the refinery).

Scientific documentation of metal distribution in soils in the Port Colborne area started with soil sampling in the 1970s, culminating with a summary report issued in July 2000 by the Ontario Ministry of the Environment (MOE, 2000). The MOE findings indicated that a significant area existed where surface soils contained concentrations of nickel (Ni), copper (Cu) and cobalt (Co) higher than the generic criteria, which were derived for the prevention of toxicity to sensitive plants. In accordance with the MOE's *Guideline for Use at Contaminated Sites in Ontario* (MOE, 1997), elemental concentrations that exceed the generic criteria generally indicate that further study is required. Therefore, a more detailed risk assessment of nickel, copper, and cobalt present in specific soil types occurring in the Port Colborne area was undertaken. Early in the risk assessment it was concluded that arsenic (As) was also a chemical of concern.

Vale Inco's plant property was not included in the current CBRA. Clean-up decisions for Vale Inco's property are not required until the facility is decommissioned and the land is readied for other uses. This property is regulated under the *Mines Act*, which requires Vale Inco to formulate, and have approved, a closure plan for the facility site. Vale Inco has fulfilled these requirements for its Port Colborne facility and will continue to interface with the appropriate governmental authorities regulating its closure and any activities related thereto.

3.2 Provincial Guidelines and Regulations for Soils

3.2.1 The Guideline of 1996

When the MOE report on soil sampling in Port Colborne was issued in 2000, the relevant risk management guidance for Ontario was contained in the MOE's *Guideline* (issued in 1996; revised in 1997). Intended primarily to apply to individual contaminated industrial sites, the *Guideline* was interpreted by Vale Inco to also give guidance to non-industrial sites that had been affected by emissions from a nearby industrial operation. By this interpretation, residential lots, parkland, woodlots, schools and schoolyards, as well as fallow and active agricultural lands that had been affected by windblown emissions from Vale Inco, could receive guidance on risk management from the MOE *Guideline*.

3.2.2 *Ontario Regulation 153/04* (2004)

The *Guideline* was replaced by *Ontario Regulation 153/04* ("Records of Site Condition – Part XV.1 of the Act") on October 1, 2004. *O. Reg. 153/04* arose out of the *Brownfields Statute Law Amendment Act* of 2001. Although Site-Specific Risk Assessments (SSRAs) are now simply referred to as "Risk Assessments" under *O. Reg. 153/04*, the technical issues surrounding the use of risk assessment under *O. Reg. 153/04* are similar to those under the old *Guideline* and, for the CoCs in the Port Colborne CBRA, the generic criteria from the *Guideline* are identical (with a few exceptions) to the "Tables of Site Condition Standards" in *O. Reg. 153/04*. These similarities between the *Guideline* and *O. Reg. 153/04* indicate that the suggested use of risk assessment is largely unchanged. The overarching principle of the *Environmental Protection Act,* unaltered by *O. Reg. 153/04,* remains that of protection against "adverse effect", as it was under the *Guideline*. Therefore, the use of risk assessment also remains the same as under the *Guideline*, with acceptable risk being determined as a level at which no adverse effect is expected.

3.3 Land Use Changes

O. Reg. 153/04 was promulgated to assist lands being changed from old uses to more sensitive new uses. It applies to a property that is changing from either industrial, commercial or community use to residential, institutional, parkland or agricultural use. As most subject properties are likely to be old industrial sites, the regulation is often referred to as the Brownfields Legislation. It generally applies to any land use change that involves more sensitive and intimate use of the land.

O. Reg. 153/04, together with the Provincial Policy Statement (Ministry of Municipal Affairs and Housing, 2005), gives direction by providing comprehensive, integrated and long term approaches which recognize the inter-relationship among environmental, economic, and social factors in land use planning.

The Port Colborne Official Plan proposed in 2006 complements the provincial initiatives. For example, the document states:

> *"Where it is determined that there is a proposed change in land use to a more sensitive use on a property…identified through the City's planning application…process as 'potentially contaminated', the City…will require written verification from a Qualified Person that the property in question is suitable or has been made suitable for the proposed use in accordance with O. Reg. 153/04"* [p 2.10]

As part of the process of land use change, a Record of Site Condition is required to be filed by the owner of the land. This is an electronic document that provides interested parties with a summary of the environmental conditions of a property. It is filed on the Environmental Site Registry and is acknowledged by the relevant MOE Regional Director. A Certificate of Requirement may be invoked by the Director that requires the Record of Site Condition to be registered with the title to the land. Also, a Certificate of Property Use may be issued by the Director to prevent, eliminate or ameliorate an adverse effect from occurring on the property or to prohibit the property from being used in a particular manner.

3.3.1 The CBRA and *O. Reg 153/04*

It can be seen from the discussion above that *O.Reg. 153/04* seeks to establish soils that are protective when the land use is changed from a less sensitive use to a more sensitive use. Most of the lands being assessed under the CBRA are, however, not now ear-marked for land use change. Accordingly, risk management strategies that come out of the CBRA will be applied mainly for protecting current land uses and their receptors.

Information gathered by the CBRA, however, may also be useful in considering cases where land use changes are proposed at a future time and to which *O. Reg. 153/04* will apply. In the case where a land use change is contemplated in the future, the property owner would be the person responsible for meeting all regulatory obligations. Assessing the risks posed by CoCs in the soil would be the responsibility of the land owner (there could be more CoCs on the land than were present in the CBRA). The CBRA results would obviously be an important source of exposure and risk estimates for Ni, Cu, Co and As. If remediation of the land were necessary to protect receptors for the new land use, then Vale Inco, in agreement with the property owner, would conduct appropriate remediation for Ni, Cu, Co and As. Other parties might be responsible for other contaminants. Following successful verification of remediation, the property owner would then file the Record of Site Condition in accordance with *O.Reg. 153/04*.

It should be emphasized that only land use changes that aim for a more sensitive use would fall under *O.Reg. 153/04*. If, for example, agricultural land were to be proposed for parkland or residential land, then *O.Reg. 153/04* would not apply to nickel in soil because parkland and residential use is less sensitive than agricultural use for nickel in soil. Each candidate land use change would have to be considered on a case by case basis by each property owner, but it is clear that Vale Inco would remain the party responsible for managing risks posed by Ni, Cu, Co and As.

3.3.2 Changes in Vegetable Garden Locations

If someone owning a residential property in Port Colborne wishes to establish or to move a vegetable garden on the property, no change in land use is invoked because the main purpose of using the property is unchanged. However, in order to protect vegetables being grown, specific conditions will be instituted for risk management for such cases.

The risk management strategy for vegetable gardens is laid out in Section 6.6 in this Report. Any new or newly moved garden will be treated in the same manner as an existing garden, that is, sampling of the newly moved or newly installed garden will be undertaken by Vale Inco according to the procedures given in Section 7 and will be remediated by Vale Inco (provided agreement with the property owner is obtained) in the same way as the procedures laid out herein for existing gardens. It is therefore incumbent on the property owner to install a vegetable garden in a desired location, and to notify Vale Inco of such placement, prior to Vale Inco assuming responsibility for sampling the soil of the garden and remediating it, if necessary.

3.4 Negligible Risk ("Safe") Generic Criteria

The MOE generic criteria were established as conservative soil concentrations that are low enough that they are not expected to cause adverse effects to either humans or ecological receptors at any location in Ontario. Concentrations of chemicals that exceed the criteria do not immediately indicate risk. Rather, they indicate that further investigation is warranted. For a site with concentrations of a chemical above the generic criteria, there are three options for risk management. First, the proponent (site owner) could remediate the site to background levels. Second, remediation could be done to achieve levels below the applicable generic criteria, in which case the site would be considered as safe for human uses and as being unlikely to result in adverse effects towards ecological receptors. Third, the proponent could use risk assessment to determine scientifically defensible site-specific risk-based criteria for site clean up.

The MOE allows a potential variety of clean-up levels for different sites across the Province because it is scientifically inappropriate to set one "safe" concentration for chemically variable, complex, and heterogeneous materials like soils. The generic criteria/standards are used to indicate levels below which no action is required by a site owner. If the generic values are exceeded, it does not automatically mean that a remedy is required.

With respect to metals, toxicity can occur with high variability in concentrations in soils. For example, two different soils can have the same total Ni concentration and yet have vastly different toxicities from the Ni. This can occur if the nickel in one soil is present in a highly soluble form that is quickly and easily able to exert toxicity towards plants or animals, while the nickel in the other soil is present as a less soluble species or is bound to organic material that makes the nickel less available for biological uptake and, therefore, less toxic.

Thus, soils within Ontario will exhibit different nickel toxicities because of the presence of different nickel compounds present and the soils' capacities to bind more or less nickel. Recognition of this fact was built into the *Guidelines* and into *O. Reg. 153/04*. The generic criteria or standards are designed to be protective across all soils found in Ontario (*e.g.*, relatively higher nickel-sensitive soils may be found in northern Ontario where soil acidity may be high and the amount of organic matter is low). For most soils in southern Ontario, however, concentrations of nickel higher than the generic level could be present, and yet still be fully protective of human and ecological organisms as mandated by the generic criteria.

For nickel, the generic criterion is 200 mg/kg (ppm), which is the concentration of free divalent nickel ions known to cause toxicity in a sensitive plant, oats. For certain sandy or acidic soils a total nickel concentration of 200 ppm in the soil could, depending on the form of nickel present, give rise to 200 ppm free nickel ions that are able to cause toxicity in oats. In another soil having naturally occurring minerals, such as iron and manganese oxides, and solid organic matter arising from decomposing vegetation, a total concentration of nickel of perhaps 1000 ppm may yield 200 ppm as free nickel ions. The difference in toxicity between total concentrations of 1000 ppm Ni and 200 ppm Ni is due to the capacity of the soil to strongly bind nickel within the soil, making it unavailable to plants' roots. Yet another soil, depending on the nickel species and the chemical/physical characteristics of the soil, may require 5000 ppm nickel before a level of 200 ppm free nickel ion exists.

An SSRA of a specific chemical in a particular soil is able to examine the precise characteristics of a site's soil and the result of exposure to the chemicals in it. An SSRA is able to determine toxicity under site-specific conditions. Such an SSRA is, therefore, able to derive a site-specific concentration that is protective for that site to the same extent that the generic criterion/standard protects sites that have a highly bioavailable form of the contaminant (MOE, 2004).

In the case of Port Colborne soils, Vale Inco, as the proponent of risk management, opted to conduct a risk assessment to derive Port Colborne-specific soil clean-up criteria. It is to be expected that these Port Colborne criteria will be different than the generic criteria, yet will provide the same level of protection for the Port Colborne area as would be provided by the generic criteria for the most sensitive soils in Ontario.

3.5 The Difference Between The CBRA And Many SSRAs

Because of the nature of transportation and deposition of windblown dusts, there are a large number of sites potentially affected by Vale Inco's historical operation in Port Colborne. Each site within Port Colborne could have had its own SSRA. However, the lack of efficiency in doing this, and the extended time it would take, seemed prohibitive and impractical. In addition, depending on when risk assessments were conducted, scientific information could be different and this might cause different clean-up criteria to be deemed necessary for sites with identical levels of contamination. In view of these challenges, Vale Inco suggested that a larger area risk assessment, one that could encompass all soil types, all toxic pathways and endpoints, and all receptors, was a more reasonable approach. This became the CBRA. It was intended that the CBRA would conduct its scientific work in precisely the same way such work is conducted within the SSRA framework. The CBRA differs from an SSRA only in its scope. All sites within the CBRA are considered within one massive assessment, which takes into account all soil types, soil conditions and land uses present in Port Colborne.

3.6 CBRA → SSRA

The need for soil remediation in the Port Colborne area will be decided on a site-by-site basis. “Site” refers to land (or a portion thereof) that has a title associated with it. A site has definite described boundaries and has an owner. The site is stated to have a particular land use as may be specified by municipal zoning by-laws.

Since the CBRA applies to a large area and remediation applies to specific sites within this area, a process is needed for taking the results of the CBRA and determining how they apply on a site-by-site basis.

Within the normal risk assessment framework, sites are usually small enough so that there exists a relatively uniform soil type and soil chemistry having one type of land use. Often an SSRA can be carried out in such cases to determine a specific clean-up criterion of a CoC for that site. Accordingly, if an SSRA were to be performed on a site within the Study Area of Port Colborne, then a single set of CoC clean-up levels would be produced. There may exist an erroneous expectation by some people that the CBRA would also give one clean-up criterion for each CoC. This is not the case. The reason why the CBRA will have multiple criteria for each CoC is that the CBRA deals with a large area, an area in which land uses, soil types and soil chemistries vary widely. In order for the CBRA to be able to specify risks across such a varied area, the CBRA will have multiple clean-up criteria for each CoC.

Multiple clean-up or “intervention” criteria across Port Colborne, then, arise because there exists a variety of key receptors and soil types in the area. These receptors and soil types are composed of all the receptors and soil types found in the wide area, which is composed of all the individual properties (sites). The CBRA considers all the receptors and soil types because the CBRA must be able to determine risks for each property (site) within the Study Area. The CBRA is better suited to doing this than would be the case if hundreds of SSRAs were to be carried out. In many cases, the CBRA is able to combine sites that have the same soil type and/or the same land use (the same receptors) and derive clean-up criteria for the CoCs specific for those sites.

The question may be asked: why not apply the lowest clean-up level across all of Port Colborne? While such an application would appear to simplify decision-making, it goes counter to the very reason for carrying out the comprehensive and careful risk assessments as a function of different receptors and soil types. That is, applying one clean-up level for each CoC would result in a large number of irrelevant and probably foolish decisions. This can best be seen by an example.

It is well known that certain plants suffer a toxic reaction when too much soluble nickel is available to their roots. Such plants turn out to be the most sensitive organism to systemic nickel uptake. This does not mean that toxicologists are more worried about these plants than they are about our children. Rather, it means that extensive studies on both children and plants show that children suffer no adverse health effects from a certain CoC soil level, but plants clearly do suffer an adverse effect at that soil level. In other words, sensitive plants are more sensitive than young children to many CoCs in soil. Thus, for sites where such plants are expected to be a primary receptor, the clean-up level must be low enough to protect the plants. For a site where children are the primary receptors (e.g. residential areas, schoolyards, etc.), the clean-up level must be low enough to protect the children. But there is no reason to apply the plant-specific clean-up to areas where the sensitive plants are not now, nor ever expected to be, grown.

Thus, there exist multiple clean-up criteria for each CoC and this is consistent with the SSRA framework, and is appropriate for use in the CBRA. The proposed process for translating the CBRA findings to specific sites is presented within this Integration Report.

4.0 THE CBRA

The CBRA serves two important purposes. First, it can be used to help identify whether any remediation or preventive measures should be taken by Vale Inco to address its responsibilities (including its potential liability under Ontario's environmental laws concerning remedial/preventive measures orders) and, if so, what those measures should be. Second, the CBRA can be used by property owners to facilitate any sale, development, financing or other valuation of their property. For example, together with site-specific information, the CBRA can be used to facilitate municipal development approvals or the obtaining of a Record of Site Condition under *O. Regulation 153/04*. Together with site-specific information, the CBRA can also be used to satisfy prospective purchasers or persons undertaking a valuation of a property that there are no concerns with the environmental condition of that property that would affect its use or value.

The acceptance of the CBRA process as the means to assess risks to environmental, agricultural and human receptors in Port Colborne occurred in April 2000 when, supported by the MOE, the Port Colborne City Council appointed a Public Liaison Committee (PLC), consisting of seven citizens, to interface and work with Vale Inco and its consultants. The Council requested, and Vale Inco agreed, that Vale Inco pay for an independent technical consultant to assist the PLC members and City personnel in understanding the science of risk assessment in general and understanding the specific toxicological information of the four chemicals of concern (CoCs). The consultant chosen to provide this service was Beak International (purchased by Stantec, from which Watters Environmental Group evolved).

Vale Inco's consultant performing the technical work of the CBRA is Jacques Whitford Environment Limited (now Jacques Whitford Limited).

In the early stages it was recognized that detailed technical discussions were going to be needed on an on-going basis between technical experts. Accordingly, a technical sub-committee (TSC) of the PLC was constituted, consisting of technical representatives of the stakeholders (the City, the Niagara Regional Health Unit, the MOE, Vale Inco, Jacques Whitford and Watters Environment Group). Decisions about the technical work were made by consensus of TSC.

4.1 CBRA Scope Of Work

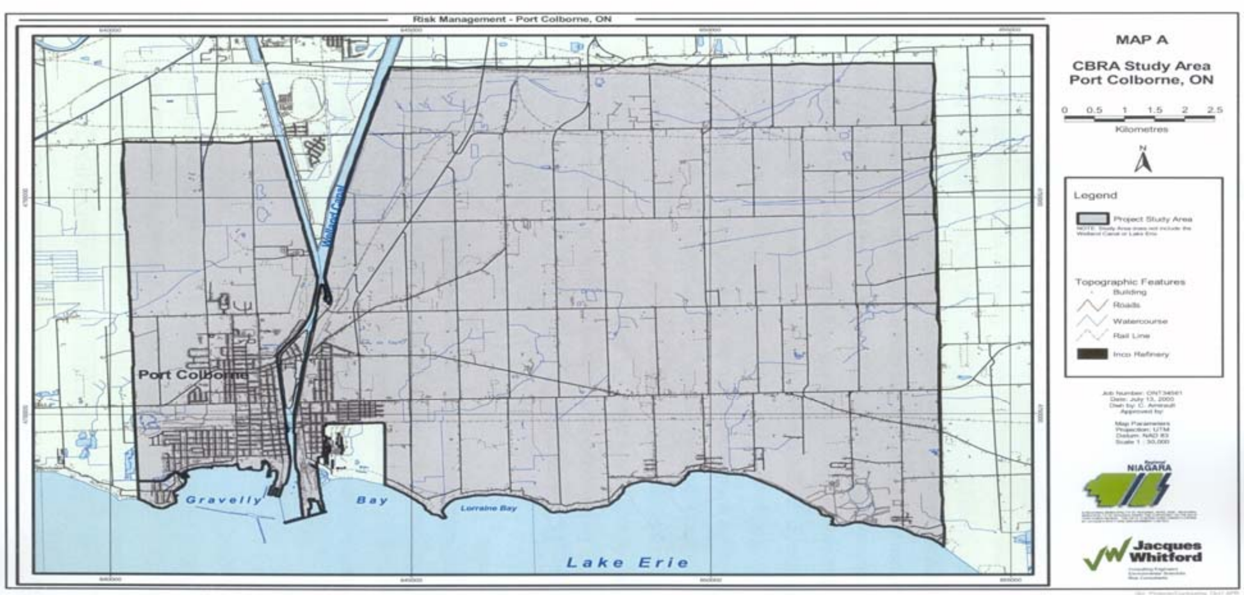
The scope of work for the CBRA went through several drafts, finally being agreed upon in November 2000. Work was split into several main tasks:

- Identification of the CoCs;
- Risk Assessment for the natural environment;
- Risk Assessment for agricultural crops; and
- Risk Assessment for humans.

Each of these tasks resulted in a major technical report, each of which was reviewed by all stakeholders. Public input was sought through PLC meetings, open houses and written documents. Each major report also underwent external peer review:

- Rowan Williams Davies Irwin (RWDI) reviewed the Re-evaluation of Lead as a CoC;
- CH2MHill reviewed the Natural Environment Risk Assessment;
- Professor M. McBride of Cornell University reviewed the Crops Risk Assessment; and
- CH2MHill reviewed the Human Health Risk Assessment.

The risk assessments cover a Study Area, shown in Map A, with approximate dimensions of 13km x 7km covering about 90 km^2. This area includes all of the 27km^2 where soil concentrations of Ni, Cu, Co and As were generally above the MOE generic criteria.



Map A: CBRA Study Area is shaded

The Study Area also included lands designated as the Core Natural Heritage System by the Niagara Region. Examples of these areas are the Wainfleet Bog at the northwest corner of the Study Area and the Humberstone Marsh in the northeast corner.

The CBRA did not include the Vale Inco plant property, which is regulated under the *Mines Act*, which requires Vale Inco to formulate (and have approved) a closure plan for the facility site. Vale Inco has fulfilled these requirements for its Port Colborne facility and will continue to interface with the appropriate government authorities regulating its closure and any activities related thereto. The Nickel Beach Woodlot, most of which is located on Vale Inco's plant site, is part of the Core Natural Heritage System.

The CBRA also did not include aquatic receptors within the near shore freshwater environment of Lake Erie to the immediate south of Vale Inco's plant property because this part of Lake Erie is part of Vale Inco's facility and is covered under the Vale Inco site closure plan.

All non-industrial properties owned by Vale Inco (*e.g.*, past and current agricultural lands and certain residential properties) were included in the CBRA.

The CBRA scope excluded the liquid and gaseous substances that may have been emitted by Vale Inco's operation. The CBRA focuses on the risks posed by soils.

Natural Environment

In assessing environmental risks, fourteen valued ecosystem components (VECs) were selected (with input from the PLC) as adequately representing the common or important organisms in the natural environment of the Port Colborne area. By conducting detailed risk assessments on all the VECs, the risks to all organisms in the Study Area are likely to be adequately considered. For some considerations, such as for woodlot health and leaf litter, relevant parameters were identified and measurements performed to assess risks.

Agricultural Crops

Due to the significant area of land in the Study Area that is devoted to commercial agricultural activities, greenhouse and field experiments were conducted on sensitive crop species. Since oat is one of the most sensitive crops for nickel-induced toxicity, it was used as the reference crop for establishing the MOE's generic nickel guideline for soil. Since nickel in soil has by far the highest concentration of the four CoCs, oat phytotoxicity to nickel was used to determine intervention levels that would be reasonably protective for all crops, whether currently grown in Port Colborne or not. The contention in the risk assessment for crops is that nickel is the driver of crop toxicity and, therefore, ensuring the elimination of nickel toxicity would also eliminate potential toxicity of the other CoCs.

Human Health

The human health risk assessment had the objective of determining what risks exist at the present time for reasonable maximum exposures to CoCs from all sources. A life span of 70 years was assumed for human exposures to the CoCs. This lifetime was split into five sub-categories (infant, toddler, child, teen, adult) to take into account varying exposure scenarios as a function of age; each age group was assessed individually. All pathways for exposure (inhalation, ingestion, dermal) were considered and background diet and water consumptions were included. Both carcinogenic and non-carcinogenic health effects were considered.

5.0 RESULTS OF THE RISK ASSESSMENTS

Detailed risk assessments for the natural environment, agricultural crops, and human health are provided in separate technical reports. The purpose of this section of the Integration Report is to summarize the conclusions of these assessments and to discuss their level of certainty.

5.1 Human Health

The Human Health Risk Assessment (HHRA) was conducted according to well-established scientific principles for such work. Both cancer and non-cancer endpoints were evaluated by the CBRA and reasonable maximum exposures were applied for all human age groups to ensure a protective assessment for each age group as well as a lifetime.

For Non-cancer Effects

For non-cancer endpoints, a reference dose (RfD) of 20 micrograms of nickel per kilogram of body weight per day was used. This reference dose was selected by the US EPA after their thorough review of relevant literature and was confirmed by the most recent animal study carried out by Springborn Laboratories (Springborn, 2000) . A reference dose is generally considered to be a very safe dose for humans because the animal no-observed effect dose is usually adjusted by a factor of 100-1000 times to take into account differences that could exist between animals and humans and to take into account the variation of susceptibility among individuals in the population. While the reference dose is the dose that could be received daily over an entire lifetime without any adverse health effects, the HHRA also assumed that the reference dose could be applied in a conservative manner to any of the five life stages making up the human lifetime. The stages of a human life are conventionally separated by toxicologists into five periods: the infant from 0 to <0.5 years, the young child from 0.5 to <5years, the child from 5 to < 12 years, the teen from 12 to < 20 years and the adult for ages 20 and over. These stages are important because body weight changes as a function of age and toxicity usually vary with body weight.

For chemicals in soil, the young child is the most sensitive stage because of the low body weight and the relatively high non-food incidental ingestion from extensive hand-to-mouth activity. In assessing human risks, the CBRA has applied the lifetime reference dose to the 4.5 years a person spends at the sensitive young child stage, and this results in an extra margin of safety for children.

Another example of the conservative protectiveness of the CBRA is the inclusion of backyard garden vegetables in regular Port Colborne diets. This results in over-protection because of the very small fraction of households in the Port Colborne area that have backyard gardens. Including such vegetables, which have a somewhat higher content of CoCs than vegetables obtained from supermarkets, results is an over-estimation of the total intake of CoCs by most residents.

Yet another example of conservatism is that soil ingestion, particularly for young children, is assumed to occur at a relatively high rate every single day when snow cover is absent. This assumption provides a reasonable maximum dose of CoCs from inadvertent soil ingestion. An important parameter for soil ingestion is the proportion of each CoC that is bioaccessible. Instead of relying only on laboratory scale simulated gastric leaching of soils, the HHRA conducted experiments on living mammals to determine what fractions of CoCs from actual Port Colborne soils were able to cross the gastro-intestinal tract membranes and enter the bloodstream. Spending this extra time, effort and money on CoC *in-vivo* bioavailability measurements resulted in key knowledge about Port Colborne soils and improved the accuracy of the HHRA considerably.

Cancer Endpoints

In the case of cancer endpoints, certain nickel- and arsenic-containing substances merited particular attention in the HHRA. In the case of nickel-containing materials, the only cancer endpoint reported in the scientific literature is respiratory cancer. The HHRA placed air samplers around the community to collect airborne dusts. The dusts collected contained predominantly oxidic compounds of nickel. No nickel sulfides were seen in any of these samples.

The toxicological literature about excess risk of respiratory cancer and nickel exposures has resulted from occupational studies of certain nickel-producing calcining and sintering facilities. These operations prior to the 1960s were known to produce very high concentrations of dusts in workroom air. It was estimated that about equal proportions of nickel monoxide (NiO) and nickel subsulfide (Ni_3S_2) were present in workroom aerosols in these facilities, and toxicologists considered both of these nickel compounds to be carcinogenic.

Unlike an occupational setting where mixtures of chemicals are present, more recent studies on individual nickel compounds have been conducted using animals. The animal results have clearly shown a marked difference in the carcinogenic potency via inhalation of nickel compounds. Nickel subsulfide was found to be about 10 times more potent than nickel monoxide. This finding has had significant implications for human risk assessment by means of inhalation.

If, for example, one is trying to evaluate the risk to workers exposed to lower and lower levels (with improvements of dust controls) of a 50:50 mixture of NiO and Ni_3S_2, then it is reasonable to use the information obtained from the old workplaces in which this mixture was present. If, on the other hand, one is assessing the risk to the general population from exposure to ambient air, the question one must answer first is: Is the ambient air expected to be the same as the workplace air in sintering operations? If the answer is yes, then it is appropriate to use the workplace results to assess risks among the general population. If, however, the answer is no, because the ambient air is known to be quite different than the workplace air, then judgements of risks for inhaling ambient air must be based on other information. In Port Colborne, forms of oxidic nickel are seen to be present in ambient air, but forms of sulfidic nickel are absent. Thus, the risks seen in sintering and calcining plants are not valid for estimating respiratory cancer risks for the general population of Port Colborne.

The HHRA then asked the question: is there risk information about the individual nickel compounds that can be gained from the animal experiments? The answer was yes. The animal data for nickel monoxide were used to derive risk information that could be used for Port

Colborne's ambient air. The approach taken was to select a very sensitive unit risk by applying the 95% confidence levels. Therefore, even though having some degree of uncertainty, the derivation provides a significant level of protection.

In the case of arsenic-containing inhaled substances, the HHRA found no perceptible difference between the background risk (without soil exposure) and an "exposed" risk. This finding is corroborated by similar findings in risk assessments conducted by others at other sites in Ontario (Cantox, 1999; Goss Gilroy, 2001).

Intervention Limit For Residential Soils

In the final analysis, the young child was found to have the highest potential exposure. Assuming the lifetime daily dose to be applicable to a young child, a maximum level of each CoC in residential soil was calculated. For nickel, this concentration for residences located on organic soils, is 20,000 parts per million. This intervention limit is a safe soil concentration for the worst case soil use (residential) and the most sensitive receptor (small children). Any other soil type or use or receptor would have a much higher safe level.

All of the sampling conducted by the Ministry of the Environment and by the CBRA show a maximum nickel concentration in residential soil of 11,000 parts per million (0-5 cm depth)[ℵ]. This is considerably below the intervention limit of 20,000 ppm. The only areas where soils may exceed the intervention limit are in selected woodlots and Vale Inco's plant site. Since young children would not be expected to be able to receive a significant daily dose from these soils, such soils are considered to be of negligible importance in the protection of human health. The copper and cobalt concentrations in Port Colborne's soils are also well below intervention limits calculated from the risk assessment models. Exposure to arsenic in Port Colborne was found to be indistinguishable from background exposures and, for this reason, no intervention limit for arsenic was derived.

[ℵ] At a depth of 5-10 centimetres, the MOE reported a maximum value of 17, 000 ppm Ni and a duplicate sample of 8, 800ppm Ni, and at 10-20 reported a maximum value of 14,000 ppm Ni and a duplicate of 11,000.

As a consequence of the above information and analysis, no human health risk is deemed to be present from CoCs in residential soils. No further testing of residential soils is necessary because the sampling that exists is sufficient to clearly show that no residential soils come anywhere close to this intervention limit.

5.2 Natural Environment

Potential risks to valued ecological components (VECs), were based on CoC exposures within the entire Study Area using site-specific data. For this risk assessment, 14 VECs were identified and included species such as the White-tailed Deer, Meadow Vole, Red-tailed Hawk and American Robin, earthworms, and amphibians such as the Fowler's Toad. VECs chosen for this ERA also included leaf litter to represent decomposition processes and woodlots that represented forest health and species composition. The ERA conducted in Port Colborne was extremely comprehensive and utilized large site-specific data sets producing three lines of evidence (toxicity tests, assessment of risk using hazard quotients, and field surveys) that were used to assess if VECs were exposed to a potential risk from CoCs in the natural environment.

Large mammals were found to have negligible risks from the CoCs. Based on extrapolation from findings for mammals such as deer, the assessment indicates that farm animal stock would be protected. In part this is because such stock would be expected to consume foods lower in CoC content relative to deer, which would likely receive much of their food from woodlots and fields within the Study Area.

Small mammals, such as the vole and racoon, were found to have negligible risks. It should be noted that, although household pets were not specifically assessed, risks to pets from CoC exposures were included by assessing the risks to wild small mammals. Since household pets would be expected to have lower exposures than small wild animals, pets are protected because small mammals had negligible risk.

Selected species of birds having various diets and feeding behaviours were evaluated and negligible risk was concluded. The health of woodlots in the Study Area, including those closest to the Vale Inco plant and having the highest CoC concentrations in soils, were compared with the health of woodlots in non-affected areas (reference woodlots). Woodlot health was examined using twelve forest health criteria (for example, species diversity and tree size) and concluded that no significant differences existed between the woodlots in the Study Area and the reference sites.

Regarding amphibian health, two approaches were used. The first approach used the "hazard quotient method[1]" to assess potential risks for frogs and toads. Two toxicity reference values (TRVs) were identified as potentially relevant. The TRV specific to Fowler's Toad showed an HQ<1 and negligible risk. The second TRV was from a species (the Narrow-mouthed Toad) not occurring in the Study Area and this resulted in an HQ>1, indicating a potential risk to frogs and toads. As is recommended by widely accepted risk assessment principles, a second line of evidence was used when HQ>1, namely, field surveys were used to determine frog and toad population density and species diversity. The result of these surveys was that all species expected to occur in the Study Area were found, including the nationally- and provincially-threatened Fowler's Toad. This assessment, which showed a good population of frogs, is a better indicator of negligible risk than that derived by the hazard quotient method. This is because the lowest reference concentration found in the literature is likely overprotective for the site-specific species of frogs present in this area, and the concentrations of CoCs (particularly for nickel) in wet areas used for breeding purposes of frogs are not seen to be causing an amphibian reproductive problem.

Potential risks to earthworms from exposure to the CoCs in soils were evaluated using three approaches: first, assessing potential risk using the quotient method wherein relevant TRVs were taken from literature; second, toxicity tests using Port Colborne soils; third, field surveys of naturally-occurring earthworm populations in fallow fields and woodlots of the Study Area. The third approach was found to be the most helpful because it was based on what was actually observed in the area being studied. The field surveys showed earthworm species richness with good abundance and biomass and indicated that earthworm populations in the Study Area have

[1] HQ is the Hazard Quotient, which is defined as the ratio of the estimated dose to the toxicity reference value (TRV). A ratio of < 1 indicates negligible risk.

not been unduly affected by the presence of the CoCs except for a small woodlot area just to the east of Reuter Road having very high CoC soil concentrations. To address this, a specific survey was conducted in this woodlot. It was determined that organic soil nickel concentrations up to 3500 mg/kg maintain an earthworm population that is typical of the region. For clay soil, 3000 mg Ni/kg was determined to be the concentration at which no adverse effects are present for earthworms. Thus, these values will be the respective Predicted No Effect Concentration (PNEC) values for earthworms. Since there were no fallow fields identified to have mean concentrations exceeding this value, the earthworm PNEC values only apply to woodlot soils. Additional information that is collected as the result of new sampling to be conducted for certain agricultural lands (see below) will be used to improve soil Ni contours across the Study Area. This information will be used to determine if any fallow fields are > PNEC (earthworms).

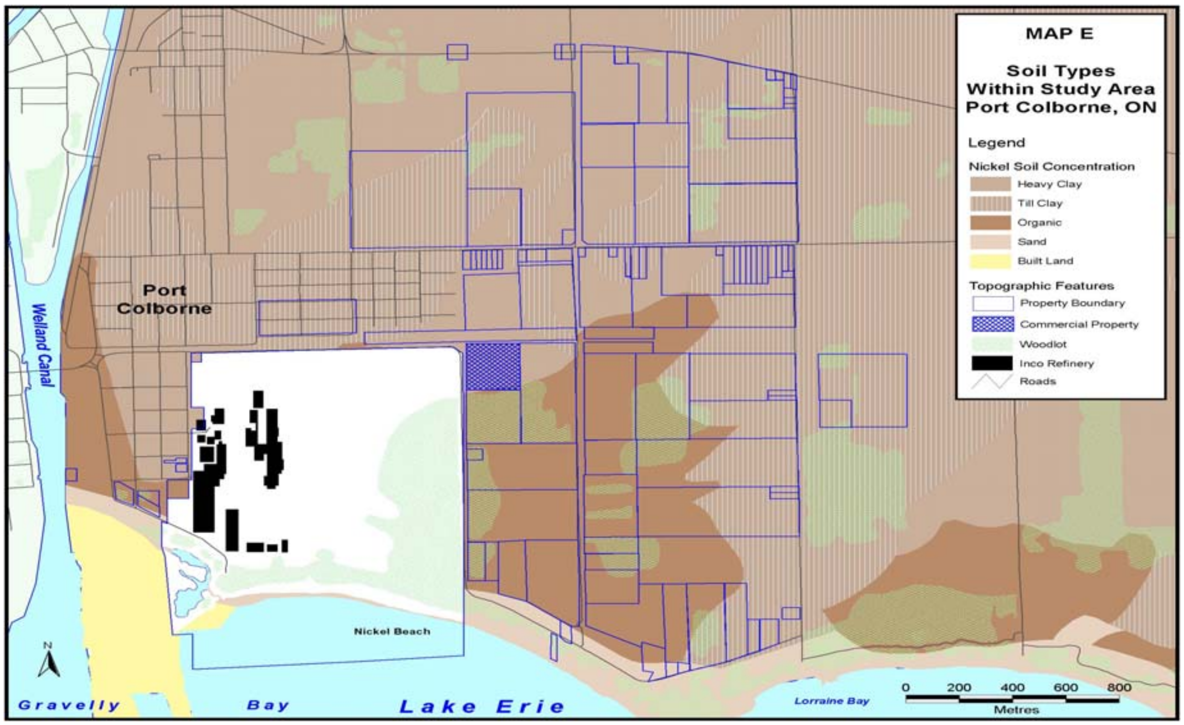
5.3 Agricultural Crops

The risk assessment on agricultural crops had the objective of determining CoC concentrations that would present no risk to any agricultural crops being grown or reasonably expected to be grown within the Study Area. The assessment considered each of the CoCs, but ultimately it was concluded that nickel in soil represented the most severe risks to sensitive crops and that there were no areas having risks from copper, cobalt or arsenic that would not also have more significant risks to nickel. Therefore, nickel in soil was the sentinel CoC for evaluating risks to crops.

It was impractical to assess risks to all crops that could possibly be grown in the Port Colborne area. The strategy employed was to assess the risk for a well-recognized very sensitive crop, oat, with the expectation that protection of oat would result in protection of any crop of interest. The choice of oats as the sentinel crop was supported by the fact that the MOE's generic clean-up criterion of 200 ppm Ni in soil is based on the effects of soluble nickel on oats.

Over a two-year period, the four soil types existing in the Study Area were examined in greenhouse experiments, while heavy clay soils were examined by field experiments. While real field experiments are preferred in assessing crop performance because of the actual conditions being experienced by the subject crop, the lack of experimental control and lack of knowledge of precise nickel levels across fields meant that field experiments could not provide a strong enough link between toxicity and nickel in soil.

In order to obtain reliable dose-response information for determining the threshold soil nickel concentrations for toxicity to oats, carefully controlled greenhouse experiments were conducted using blended Port Colborne soils of each soil type to give a satisfactory range of nickel concentrations for experimentation. The resulting dose-response information was then used to estimate Predicted No-Effect Concentrations (PNECs) of nickel for oat plants grown in each soil type. Map E shows the locations of various soil types in the Port Colborne area.



Map E: Soil types within the Port Colborne area are shaded according to the legend.

Vale Inco could have used Effective Concentration for 25% effect (EC_{25}) values because the MOE criteria state that remedial actions for SSRAs can be based on greenhouse EC_{25} values[Ψ]. Vale Inco chose not to use greenhouse EC_{25} values, but instead to use the more conservative PNECs so that an additional margin of safety existed in these values. This additional protection takes into account the amount of greenhouse experimental variability and also accounts for certain crops that may be slightly more sensitive to nickel than oats. On balance, the use of PNEC for agricultural soil intervention limits is a conservative approach for protecting crops.

The nickel PNECs derived are given in Table 1.

TABLE 1: OAT PNECS FOR PORT COLBORNE SOIL TYPES

Soil type	PNEC, mg Ni/kg soil
Organic	2350
Heavy Clay	1650
Till Clay	1400
Sand	750

[Ψ] One of the chief reasons why the MOE specified greenhouse EC_{25} levels as appropriate clean-up levels was that greenhouse studies are well known to give more severe toxic responses than the same situation in the field. The reasons for this result are various, one of which has to do with the limited root volume in greenhouse pots (i.e. the roots become pot-bound) and the uniformity of contaminated soil in pots, as contrasted with the usual gradient of contaminants in the field (i.e. the roots of plants in the field can go deeper into the field soil to find areas of lower contaminant concentrations). Another factor is that greenhouse studies control temperature and relative humidity, whereas plants grown in fields are more likely to be subject to ambient environmental stressors, which can reduce growth and enhance hardiness, both of which can result in plants being less sensitive to pollutants in soils.

6.0 SITE-BY-SITE REMEDIATION DECISION MAKING

This chapter considers which Port Colborne soils need remediation to reduce risks posed by CoCs. The need for remediation must be considered in terms of the land use and receptors present. For example, human health risks are due to exposures primarily associated with where people live and spend the majority of their time. Human health risks are therefore associated with residential areas where clusters of houses occur on city streets. Human health risks are not associated with toxicity for agricultural crops. Therefore, residential soils will be remediated on the basis of human health risk, not on the basis of productivity loss for sensitive crops being grown on farms. For convenience, a concordance table is located in Appendix 1, which provides a linkage to where specific conclusions were made in the HHRA, ERA-NE, and Crop Studies. Below we discuss the receptors being protected for each soil use.

6.1 Residential Soils

Human Lifetime Risks

The CBRA determined that negligible risks exist for humans living in either residential or rural areas (including houses on farms) of Port Colborne. These negligible risks were for any CoC exposure by ingestion or inhalation (both inside and outside air) and took into account recreational uses by residents of other land types in the area (*e.g.*, beaches, nature trails). No residential soils have been found to contain in excess of the human health intervention level of 20,000 ppm Ni in soil.

Young Children

Because of differences in possible exposures for different human life stages, young children were specifically assessed due to their increased ingestion of indoor dust and outside soil. While higher exposures for all CoCs existed for young children on a per kilogram weight basis than existed for teens or adults in the same residential setting, all risks still remained negligible for young children.

Children In school

Negligible risks exist for children present in school classrooms and in schoolyards during recesses.

Workers In Port Colborne

Non-Vale Inco workplaces in Port Colborne are not expected to have higher exposures to the CoCs than people who reside in Port Colborne. In cases where workers spend time working in soil, the frequency and exposure duration of such episodes is considered to be small relative to a lifetime and therefore no risk reduction measures are necessary to protect such workers.

Certain Vale Inco workers could be expected to have higher overall exposures resulting from their jobs. Vale Inco maintains a comprehensive industrial hygiene program, which includes routine workroom monitoring and periodic personal exposure measurements. These data are necessary to comply with standards put in place by the Ministry of Labour. In addition, Vale Inco conducts intensive epidemiological studies on its workers to determine if excessive disease is occurring in particular areas of the plant. These studies have pointed to certain risks having existed for employees in the Port Colborne refinery's Leaching, Calcining and Sintering Department (process was discontinued about 50 years ago). No other risks associated with the CoCs have been identified for Vale Inco's Port Colborne workers; these studies are on-going.

Household Pets

Pets such as dogs, cats, rabbits and rodents are expected to have less exposure to CoCs than wild animals. Since wild mammals have been shown to have negligible risks, it is concluded that household mammalian pets would have negligible risks as well. Pets such as birds and reptiles would be expected to have significantly lower exposure to soil CoCs than birds and reptiles in the environment. Since negligible risks have been found for such environmental receptors, it is concluded that negligible risks exist for bird and reptile pets.

Livestock

Since negligible risks exist for large wild mammals such as deer, it is concluded that negligible risks exist for horses, cattle, hogs, etc. No risks were found for humans ingesting meat from Port Colborne livestock, wild animals such as deer, rabbits and perch fish or from consuming milk and eggs from livestock/poultry.

Overall

The highest soil nickel concentration for residential property was found in the Rodney St. area by the MOE during their sampling campaign in which virtually all residential properties (over 180) were sampled. Twenty-four residential properties having soil nickel > 8000 ppm in this area were remediated in compliance with an MOE order. Also in compliance with the MOE order, additional samplings of all properties between Louis St. and Durham on the east side of the canal were carried out by Vale Inco and all properties in this area were significantly below 8000 ppm Ni.

Based on all the sampling to date and the remediation already performed, the probability that any residential property is close to 20000 ppm Ni is exceedingly small. As a consequence, no additional soil sampling in residential areas is required and no further remediation of residential properties is envisioned.

6.2 Vegetable Garden Soils

For the purposes of decision-making, vegetable gardens are defined as an area of a site, generally a relatively small portion of the total site, devoted to growing vegetables for individual or family consumption and for providing, in a non-commercial manner, friends and relatives with produce when the garden's productivity exceeds the needs of the individual or family.

There exist no unacceptable human health risks from ingesting vegetable garden produce containing reasonable maximum levels of CoCs. Remediation of vegetable gardens may be necessary at certain sites to yield optimum productivity of metal-sensitive vegetables, which could experience stunted growth when vegetable garden soil CoC concentrations exceed the soil-type-specific PNEC given for agricultural crops. The agricultural PNEC for till clay soils (1400 ppm Ni) will be used as the vegetable garden PNEC for remediation decisions, but such remediation decisions pertain only to the vegetable garden areas on residential sites. It is unreasonable to expect remediation of an entire residential property simply because a vegetable garden site is not necessarily permanent. The issue is to protect potential vegetable plants where they are being grown, not to protect an entire property in case they are grown somewhere at some future time. If the property owner notifies Vale Inco that a vegetable garden exists on his/her residential site, then it will be investigated for the level of CoCs and remediation decisions, if necessary, will be agreed upon by the property owner and Vale Inco.

When Vale Inco is notified by a property owner that a vegetable garden has been installed at some time in the future, each such garden will be sampled and remediated by Vale Inco, in agreement with the property owner, using the same criteria as those laid out above for existing gardens.

6.3 Natural Environment Soils (except woodlots)

All organisms assessed under the natural environment portion of the CBRA showed negligible risks to the CoCs in soils with the exception of earthworms in certain woodlots. The presence of earthworms in Port Colborne soils was verified and acceptable species diversity in all soil types was observed. Earthworm abundance is known to vary widely from site to site and from region to region and is known to have a negligible effect on the overall health of flora and fauna living on soils. For this reason, it is not considered mandatory to achieve certain population densities of earthworms in soils. Nevertheless, remediation of certain woodlots in Port Colborne should be considered so that earthworm populations are as healthy as possible (see below).

6.4 Agricultural Soils

It is clear that sensitive crops can suffer metal toxicity for certain soils and that the intervention level (mandatory remediation) is dependent on soil type. Agricultural land that is found to be above the intervention level for its particular soil type should be remediated so that sensitive crops are completely protected against metal toxicity. Such remediation is to be carried out on all agricultural soils independent of the specific crops currently grown or those that will potentially be grown in the coming years. The objective of remediation of such agricultural soils is to render them suitable for growing any crop desired and to protect the health of earthworms. Remediation is therefore required for any part of an agricultural site that is determined to contain nickel concentrations higher than the Predicted No Effect Concentration for oats ($PNEC_{oats}$) for its specific soil type. Since the Ni PNEC (oats) is lower than the Ni PNEC (earthworms), using the criterion of PNEC (oats) will also be protective of earthworms in agricultural soils.

In the case of land that has been used for agriculture in the past, but is no longer in agricultural service, remediation decisions will be made on a case-by-case basis. This will allow decisions to be made that optimize environmental sustainability. For example, some agricultural lands that were formerly cultivated have been fallow for several decades and are in a process of natural succession. If left uncultivated, these lands will eventually regenerate to forests that could benefit Port Colborne in many ways.

6.5 Woodlots

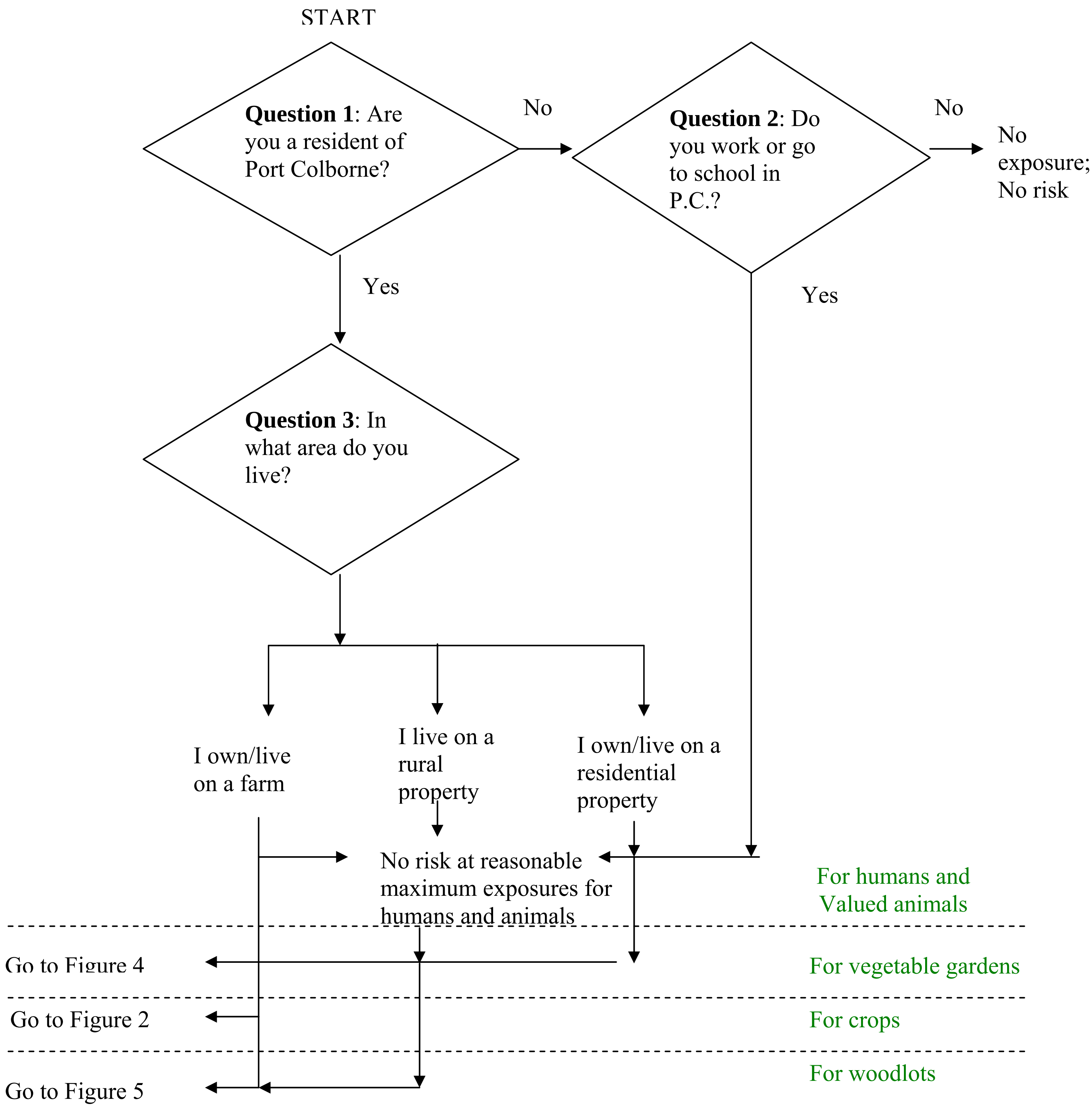
For the purposes of CBRA remediation decisions on a site-specific basis, a woodlot is defined as an area of at least 2 acres (0.8 hectares) in size having a density of not less than 400 trees of any size per acre. These criteria have been taken from "The Regional Niagara Tree Conservation By-law" (Region of Niagara, 1996) for the purpose of distinguishing a woodlot from other treed areas. Decisions for woodlots fitting this definition would be made in accordance with Section 6.6.

Decisions about remediation of woodlots will be made on the basis of the Ni PNEC (earthworms).

6.6 How To Determine Which Sites Need Remediation

To assist property owners in understanding whether their site needs remediation, a number of decision flowcharts have been constructed. The first such flowchart, which is applicable to all residents of Port Colborne, is where everyone should start. The pertinence of other decision flow sheets to a resident is dependent on the answers given in Figure 1.
The diamond-shaped boxes in Figure 1 indicate that a decision needs to be made. The decision is based on the YES/NO answer given to a question. The first question asks: are you a

FIGURE 1: CBRA→SSRA BASIC DECISION PROCESS



resident of Port Colborne? The purpose of this question is to separate residents of Port Colborne from those people who may work in Port Colborne yet still are concerned about health risks potentially affecting them due to exposure to soils. If the answer is NO to this question, then the non-residents follow the NO arrow to a box that asks a second question, namely, do you work or go to school in Port Colborne? If the answer is NO to this second question, then it is clear that the place of residence offers no exposure to Port Colborne soils and the property lies outside the CBRA Study Area. If the answer is YES, then another arrow is followed, leading to an explanation that negligible risks to human health exist at expected maximum exposures to Port Colborne soils.

If the answer to the question in the first diamond box is YES, then one follows an arrow that leads to a question about what type of land your residence is on. This question begins to take into account the specifics of different kinds of sites. Below Question 3 in Figure 1 there exist three areas where residents of Port Colborne live, namely, 1) in a residential section of the city where municipal services are supplied, 2) on a rural property without municipal water supply, or 3) on a farm without municipal water supply. Different decisions about remediation exist for each of these types of sites.

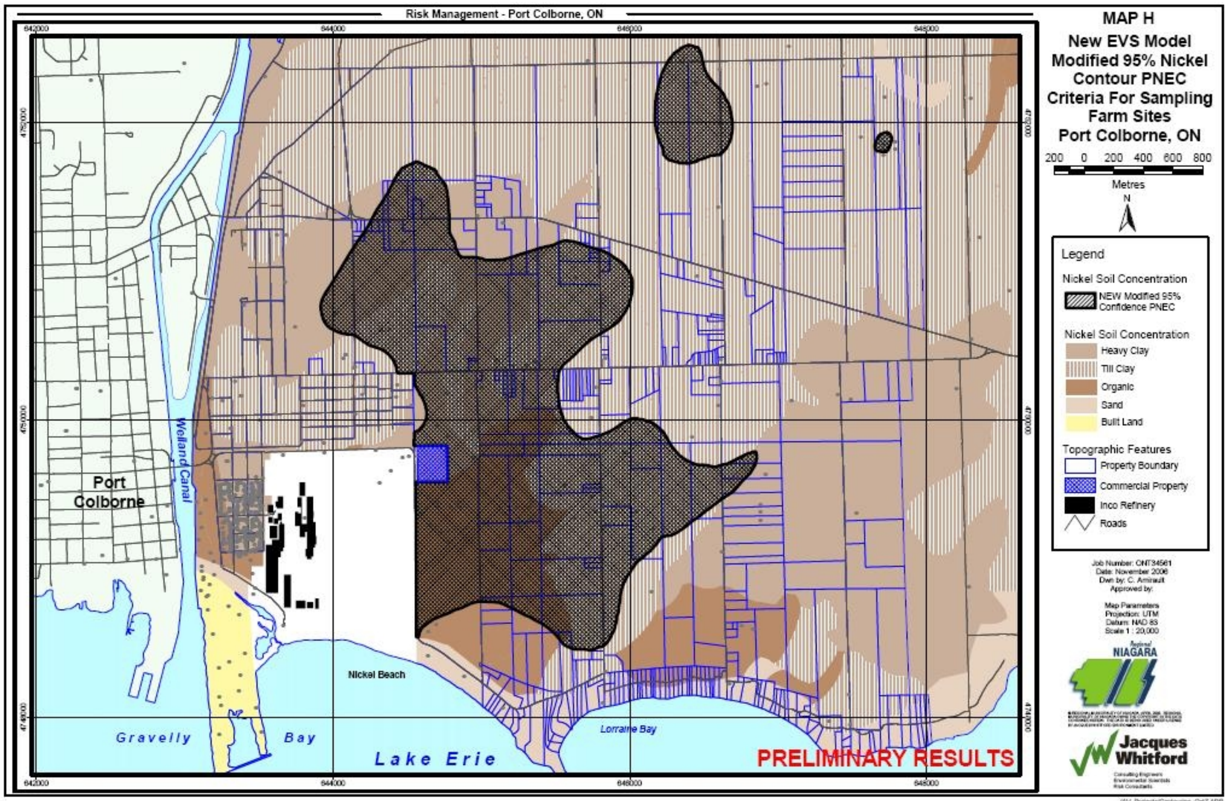
<u>Human Health decisions</u>

The decision regarding human health is straightforward. No matter where you live in Port Colborne, negligible risks exist for human health due to soil concentrations of CoCs arising from historical Vale Inco refinery emissions. Therefore, no remediation is necessary for any human health endpoint.

<u>Agricultural decisions</u>

Farms require site-specific attention because of the potential for crops to be affected by the CoCs in soils. In Figure 1 one can see that farm property owners are referred to Figure 2 to address a specific farm site. In Figure 2 the first question refers to Map A (see page 22) and asks whether the specific farm lies within the Study Area for the CBRA. If the farm site is outside the Study Area, no further decisions about remediation are necessary because the site is deemed to be unaffected by the CoCs. If the farm is within the Study Area, then Question 2 refers to Map

H (see below), which shows the soil Ni concentration contour at the 95% lower confidence level of the Predicted No Effect Concentrations (PNEC)[Ψ]. Vale Inco believes that having a sampling criterion at the 95% LCL of the PNEC will provide a suitable buffer zone to accommodate uncertainty that exists in the general Ni contours obtained by larger area sampling, and that this criterion will ensure that no farm will fail to be sampled that would have soil levels at the PNEC or above.



Map H: Sampling Criterion: The shaded area includes all agricultural soils that are in excess of 95% of the lower confidence level of the Ni PNEC for oats. Any farm having any portion of it within the shaded area is a candidate for additional intensive sampling. See Appendix 3 for more detail on how this map was derived.

Since some additional intensive sampling of certain agricultural lands in areas of high interest will be necessary, these new soil Ni data will be used to improve the accuracy of Ni contours. Improvements to Map H over time will result in a series of maps labelled "revised Map Hx as of (date)", where x is a number starting at 1 and increasing by 1 for each subsequent new Map H.

[Ψ] Map H: Ni concentration contours have been drawn using all available surface soil samples collected by Jacques Whitford Limited and the Ministry of the Environment. See Appendix 3.

If a farm site has soils containing Ni levels at less than the 95% LCL of the Ni PNEC for oats on Map H or a revised Map Hx, then the site does not need to be sampled and the site can be deemed to be below the PNEC for crops and, accordingly, no remediation is necessary. If the site has a Ni concentration that is greater than the 95% LCL of the Ni PNEC for oats, then there exists a possibility that the site or a portion of the site could be above the PNEC. In order to determine with greater confidence how much Ni the soils contain, a site-specific soil sampling program for that farm will be carried out according to the procedures specified in Chapter 7. This additional sampling for a farm site will allow site-specific nickel concentration contours to be drawn for that farm with a high degree of confidence. These contours will be used to determine what portion of the farm site has soil nickel concentrations above the PNEC for sensitive crops for its specific soil type. The sampling of the farm would only be done with the owner's permission. Thus, Question 3 in Figure 2 asks whether the owner wants sampling to be conducted. If they do not want the sampling, then no remedial action is possible. If the sampling is desired, then Vale Inco's consultants would conduct the sampling (see Chapter 7) and draw Ni iso-concentration contours on a site map and would send the results (both the analyses and the contour map) to the farm's owner and the MOE.

The decisions regarding a farm site that has been sampled are schematically shown in Figure 3. Any portion of a farm that is above the PNEC for the specific soil types present will be remediated. Remediation options are discussed in Chapter 8. If the entire farmland is above the PNEC, then the entire farming soil will be remediated. If a portion of a farm is above the PNEC, then only that portion will be remediated and remediation will extend to the sampling points on the farm that are below the PNEC. Verification of effective remediation will be conducted by the company doing the remediation and approved by the MOE. A letter certifying the remediation, issued by the company doing the remediation, will be sent to the owner and the MOE. A letter from the MOE to the property owner to confirm that remediation has been done is also being planned.

FIGURE 2: DECISION PROCESS FOR FARMS

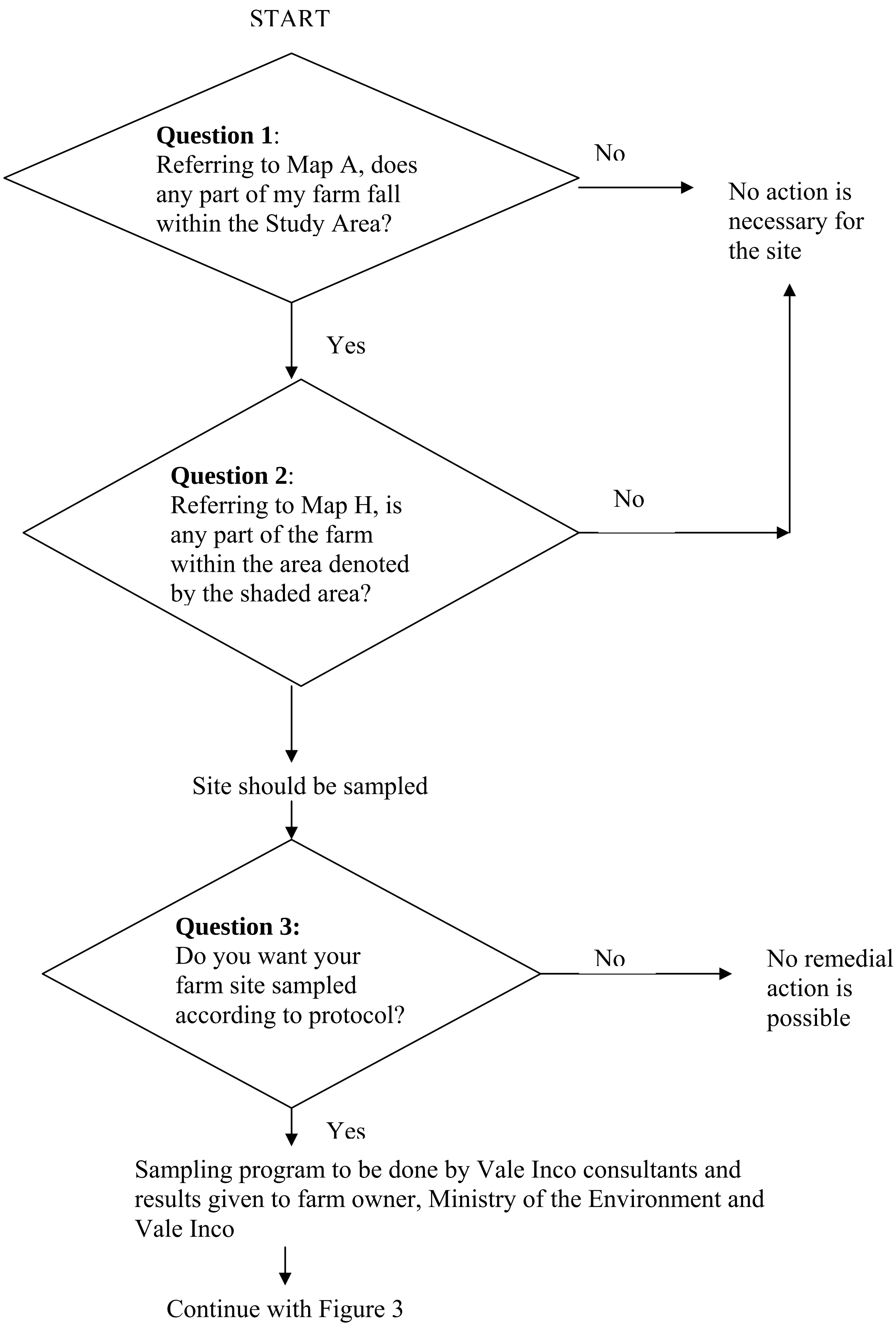
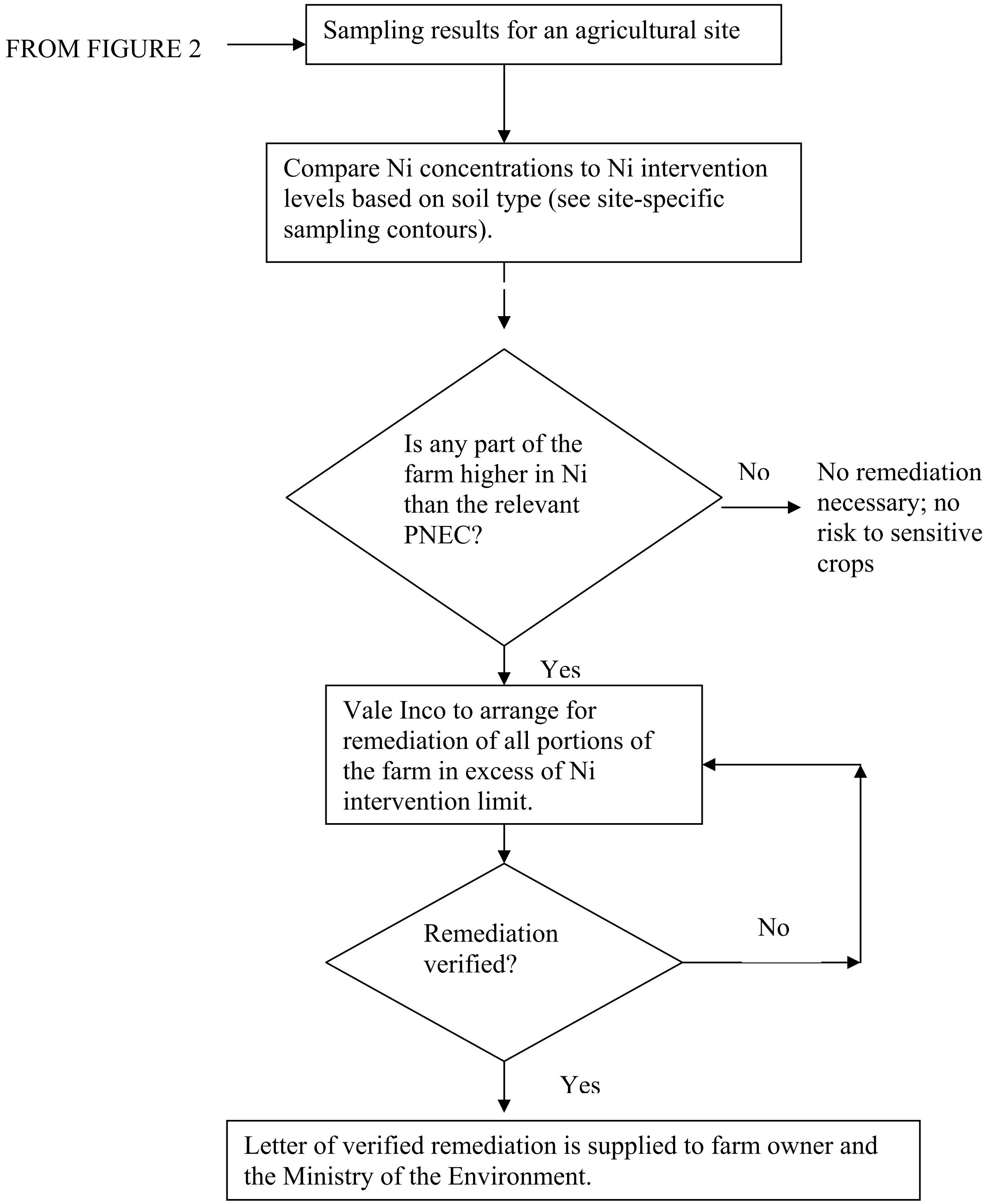
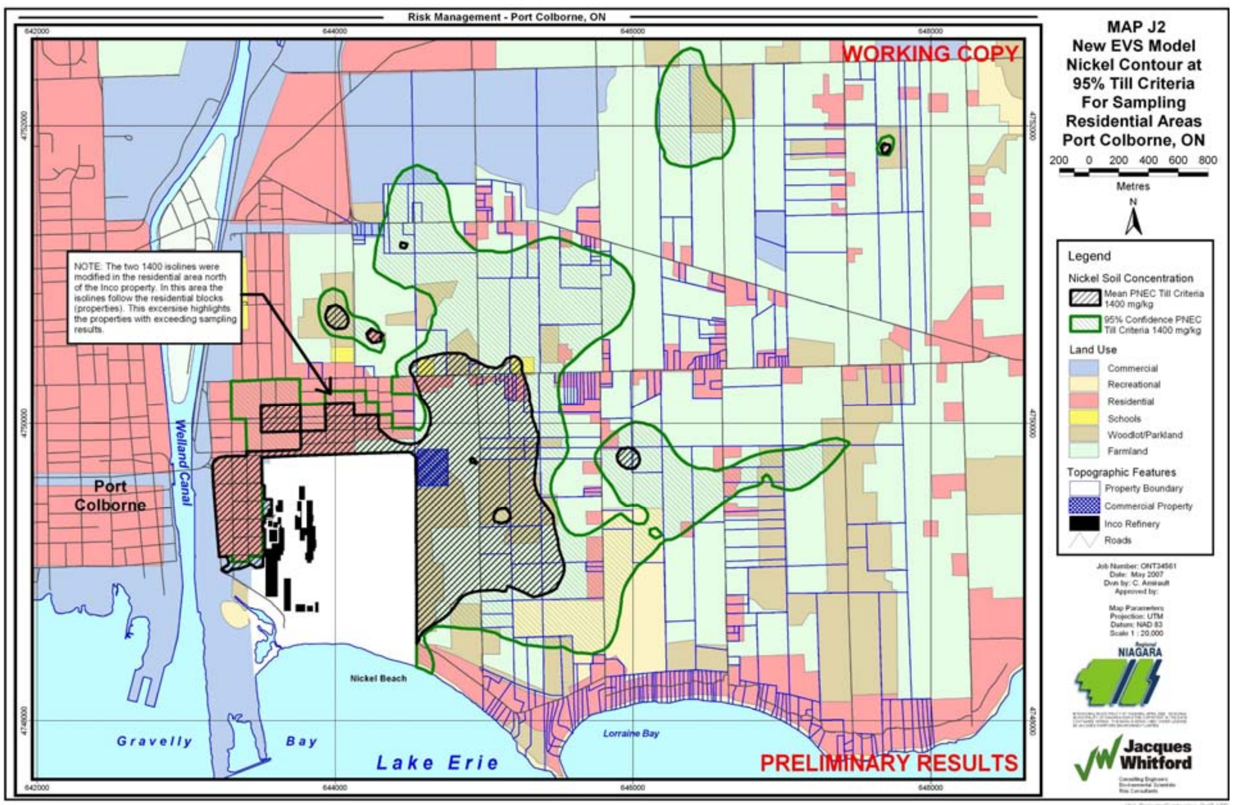


FIGURE 3: DECISION PROCESS FOR SAMPLED FARMS



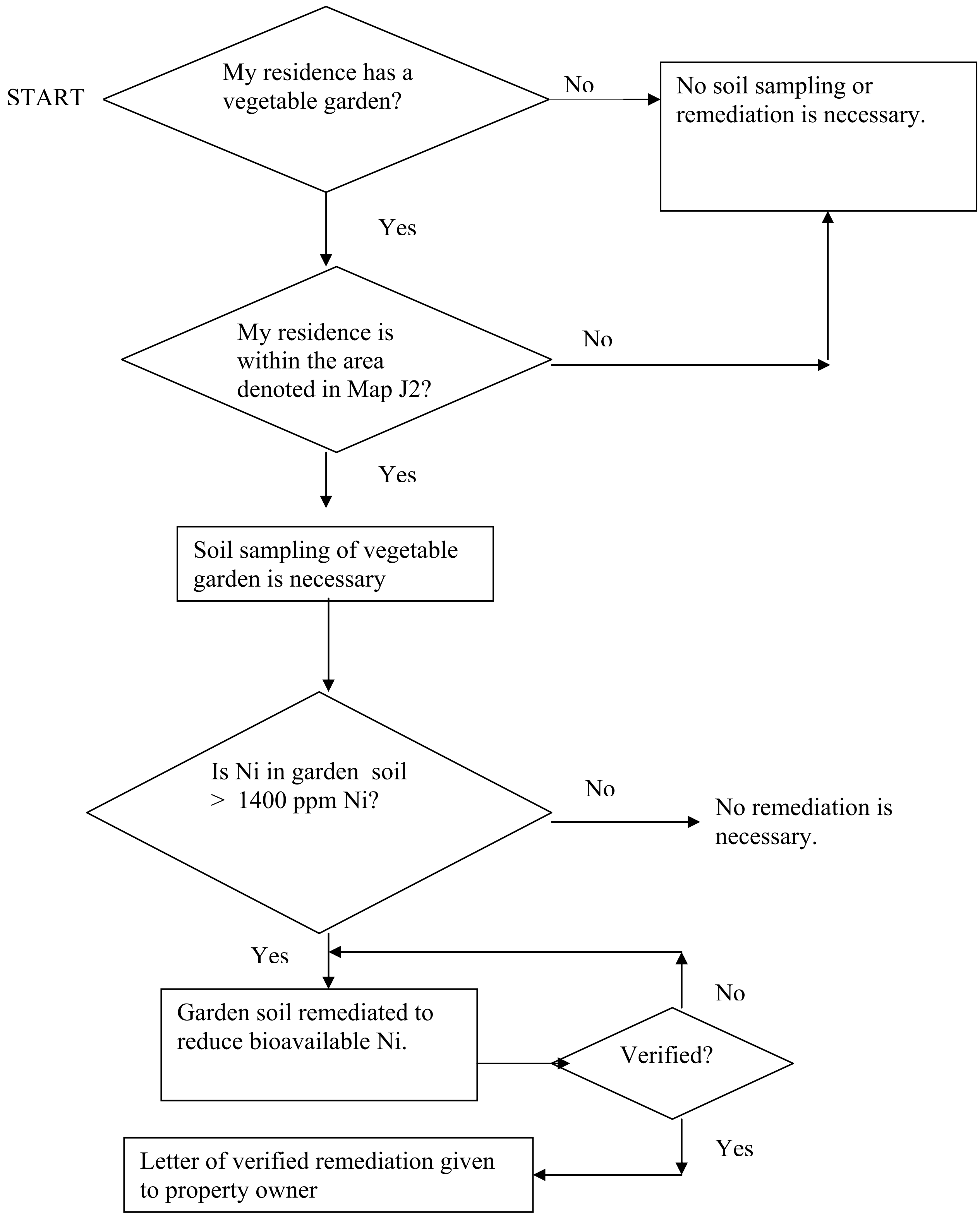
Vegetable garden decisions

Any type of residence may have a family vegetable garden on its property. The site-specific need for remediation of a vegetable garden is covered in a separate decision process given in Figure 4. If a site has a vegetable garden, and the site lies within the contour at the 95% lower confidence limit of the PNEC for oats on till clay soil, shown in Map J2, then the garden soil needs to be sampled according to the procedures specified in Chapter 7. Vegetable gardens will be sampled using a composite sample of several locations for each 12 m^2 of garden area. If the garden sampled has a nickel concentration above 1400 ppm Ni, which is the PNEC for oats on till clay, then the entire garden soil will be considered for remediation. The effectiveness of the remediation to achieve the target low bioavailability and, upon being verified, will result in a letter being supplied by the company doing the remediation to the owner stating that the remediation has been performed for the garden to prevent phytotoxicity.



Map J2: Sampling criteria for residential vegetable gardens. Residences lying within the green contour line will have their vegetable garden plots sampled. The green line is the 95% lower confidence limit of the PNEC(oats) for till clay. The shaded area is the area where the PNEC(oats) is exceeded for the soil sampling existing to date.

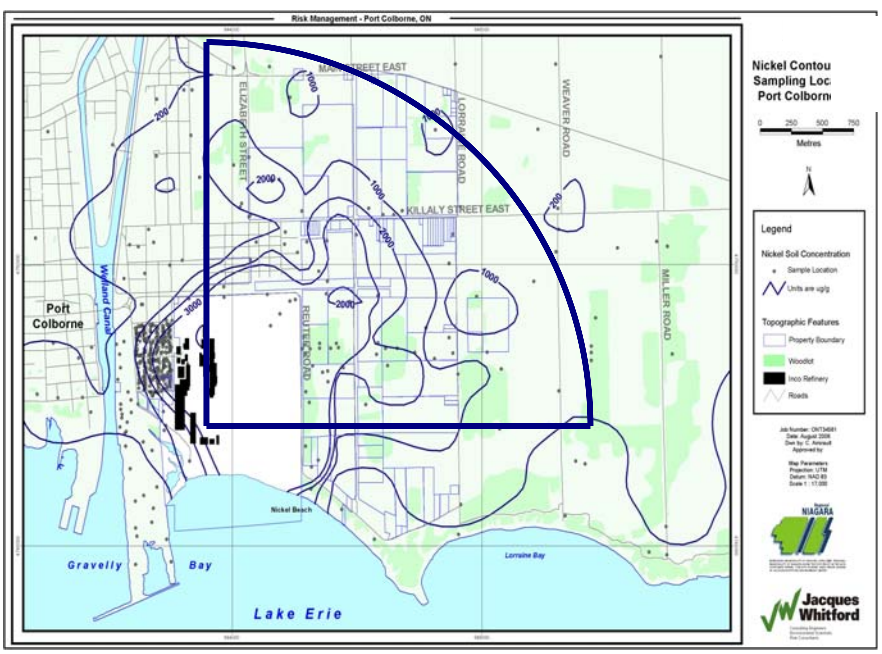
FIGURE 4: DECISION PROCESS FOR VEGETABLE GARDENS



<u>Woodlot decisions</u>

Since woodlots are by definition excluded from residential areas, questions about whether a site has a woodlot that needs remediation applies only to rural and farm residences and relevant questions for these sites are posed in Figure 5. The first question concerns the existence of a woodlot on a site. If there is no woodlot on the property, then obviously no action is necessary. The second question concerns whether the wooded area of the site meets the size criterion. If it does, then a decision about sampling the woodlot needs to be made.

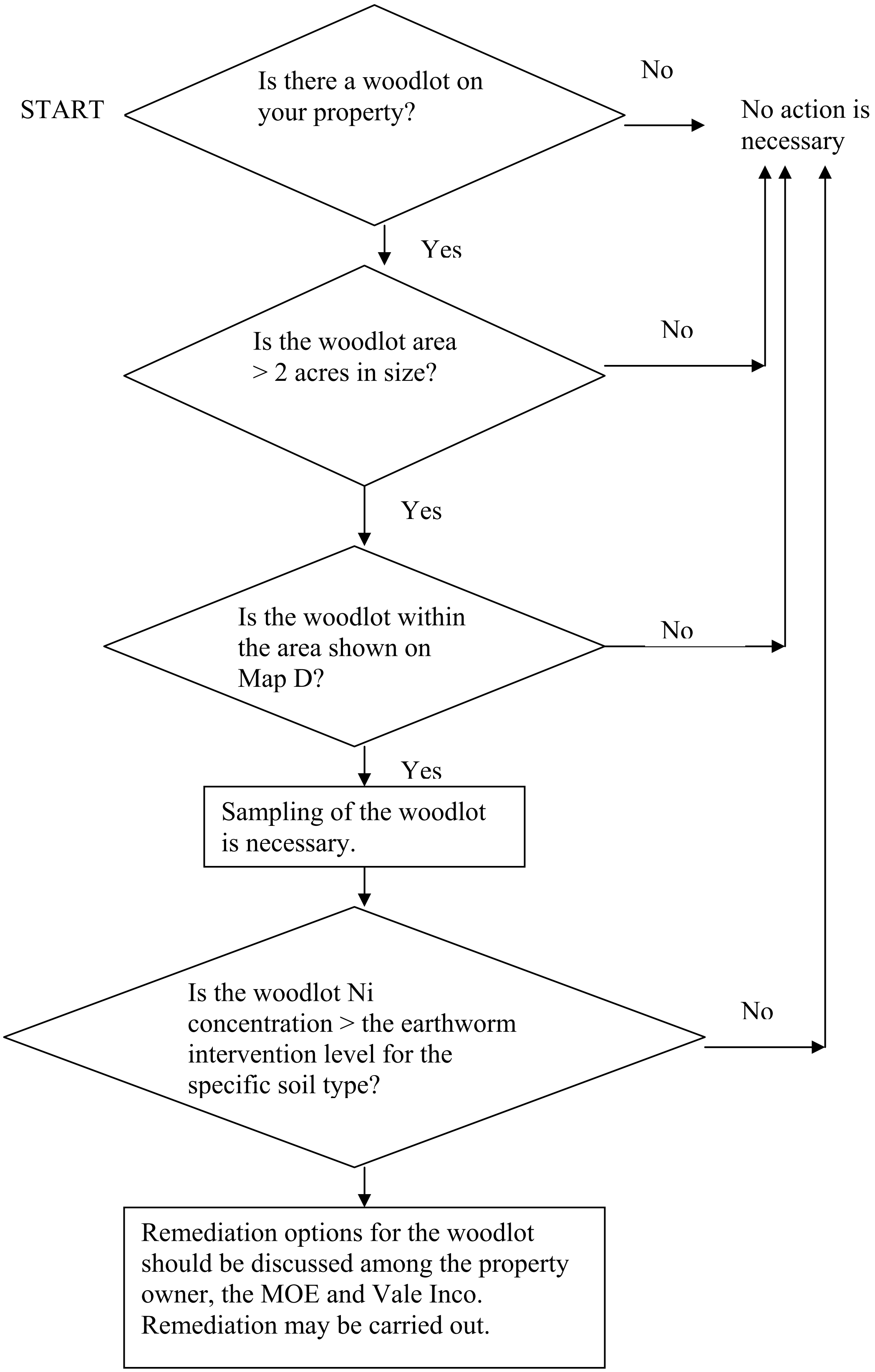
Because of the limited number of woodlot samples that currently exist, existing woodlot Ni contours have a high degree of imprecision. Even using open areas near woodlots to predict woodlot Ni levels would be highly variable because of different distances between the available open areas and the closest woodlot. Accordingly, based on the existing sampling results of open fields and woodlots, Vale Inco concludes that the current sampling data are insufficient to make decisions about woodlots except to say that woodlots greater than 2.5 km away from the position of the Vale Inco main stack need not be sampled. All other woodlots within 2.5 km radius between east and north directions, as shown in Map D, should be sampled. Such sampling would be carried out according to procedures specified in Chapter 7.



Map D: Woodlots within the area defined by the heavy blue line (northeast quadrant relative to the main stack of the Vale Inco plant) need to be sampled.

The results of a woodlot's sampling will be given to the site's owner and the MOE. Because of the likely difficulties in effective remediation of woodlots that are found to be above the earthworm PNEC, discussions between the site owner, the MOE and Vale Inco will take place. These discussions will review the results and examine the possible effectiveness of remedial options. Action on a site's woodlot will be taken from the consensus reached among the concerned parties as listed above. Any woodlot remediation would be accompanied by a letter reporting remediation (and verification) to the site owner and the MOE. As with the agricultural remediation described earlier, a letter from the MOE confirming the verified remediation is planned.

FIGURE 5: DECISION PROCESS FOR WOODLOTS



7.0 SITE-SPECIFIC SOIL SAMPLING PROCEDURES

Site-specific detailed soil sampling will be required on all farm sites that have any portion of land inside the 95% LCL of the PNEC (oats) contour shown on Map H, in woodlots that are within or partially inside the area shown on Map D, and in residential vegetable gardens located with the area of Map J2. Sites or portions of sites not within the respective areas shown on Map H, Map D and Map J2 will not be candidates for site-specific soil sampling. The following section discusses grid sampling, which is a systematic sampling methodology that will be employed for site-specific soil sampling on agricultural land and woodlots. Vegetable gardens will be sampled using a random sampling methodology described in this section.

7.1 Sampling Strategy Using A Systematic Approach

In the planning of a sampling program, a stage is always reached where decisions must be made about the number of samples to collect, and how the sampling points should be selected. These decisions are important. Too large a sample size wastes resources. Too small a sample size may not adequately characterize the concentrations and distributions of the CoCs on the site and compromises the usefulness of the results. The sampling program for site-specific sampling will follow the US EPA Guidance on Choosing a Sampling Design for Environmental Data Collection for Use in Developing a Quality Assurance Project Plan (EPA, 2002). The EPA describes a number of different sampling methodologies that satisfy different objectives for sampling programs. For example, simple random sampling is appropriate when contamination in an area is relatively uniform in distribution and the objective is to determine a mean soil concentration. Stratified sampling is used when prior information about soils can be used to determine groups (called strata) that are sampled independently so that better precision is obtained for pre-determined areas.

Soil CoC concentrations in Port Colborne can vary widely across the landscape and even across a site. Site-specific soil sampling for determining what sites require remediation has the objective of detailing CoC soil concentrations across an entire subject site. To achieve this objective, site-specific soil sampling on agricultural lands and in woodlots will utilize a systematic (also known as grid sampling) method that will provide uniform site coverage, thus enabling the spatial distribution of soil nickel across the site to be determined.

Systematic sampling or grid sampling is used to collect soil samples in a specified pattern. A systematic design (as opposed to a random sampling design) on a relatively large site is preferable, since the method ensures complete coverage so that soils across a site are fully represented in the set of samples collected. Systematic sampling of sites in Port Colborne will enable soil CoC concentrations to be mapped, so that CoC levels are identified spatially. A random sampling method would likely require more samples to be taken to achieve a similar objective (EPA, 2002). Systematic soil sampling for agricultural and woodlot sites in Port Colborne will provide a practical and efficient sampling method that will enable soil CoCs to be mapped on individual farm-specific sites. As well, the sampling procedure for residential vegetable gardens is described in this section.

Soil Sample Spacing

A grid design has the benefit of providing the maximum spatial coverage of an area for a given number of samples. Obtaining the right number of samples from each site is therefore an important consideration for systematic sampling so that uncertainty in the data is reasonably minimized. Uncertainty is measured by the population variance and standard deviation, two related measures that reflect the underlying variability in the measured parameter. In most environmental datasets, as the mean metal concentration rises, so does the population variance. As a consequence of this, the ability to define the confidence limits around the mean grows weaker. Put simply, where the metal concentrations are low, a high level of confidence in the mean value will be achieved based on a set number of samples. Where the metal concentrations are high, it is likely that confidence in the mean will decrease on the set number of samples. To account for this, site-specific sampling will apply a reasonable spacing that is consistent for all sites that will yield adequate sample sizes to predict areas of a site that should be considered for remediation. It is proposed that a sampling density be based on 30 meter spacing, which would result in 25 samples (16 area samples plus 9 edge samples) being collected on a one-hectare site.

It is recognized that the variance between samples can be significant in Port Colborne soils, even within relatively small areas. Due to this variance, it may be difficult to derive computer-generated contour lines that have a high degree of confidence for some sites. In the event that extreme variance in soil nickel concentrations is evident in the sampling results, then subsequent sampling can be implemented at more frequent intervals for such specific sites.

7.2 Setting Up The Sampling Grid

For each site, grid sampling will be based on the selection of an initial random sampling point to maintain a probability-based design. The random point will be selected using simple calculations outlined in Section 7.7 of the EPA guidance document (EPA, 2002).

Once the random sample is selected, the remaining sampling locations are then spaced and selected according to a grid pattern. A soil sample will be taken at every point where lines intersect on the grid. To set up the sampling grid, a coordinate axis will be drawn through the randomly selected point. Vertical and horizontal lines will then be drawn parallel to the axis and separated by a distance of 30 meters. For illustration purposes only, sampling intervals of 30 meters are shown in Figure 6 below. The rationale for sample spacing of 30 meters as well as determining how many samples are required on a given size of property is discussed in Appendix 2.

<u>Soil Sampling</u>

Once a random sample point has been selected for a site, and a grid pattern designed based on 30 meter spacing, and approval from the site owner has been received, soil sampling can commence. All soil samples will be collected using a stainless steel Oakfield soil corer (1.5 centimeter diameter). Soil samples will be taken to a depth of 20 centimetres. At each sampling point, 4 samples will be taken in N,E,W, and S directions within a one-meter diameter circle around the sampling point. These samples will be placed in a clean plastic sample bag and mixed from the outside of the bag. This process will break apart larger pieces of soil and enable a clean glass jar to be filled with representative soil, and labelled. Samples will be sent to a certified laboratory for determination of CoC concentrations. Sampling and analysis of all soil samples will be done as described in Appendix 1.1 of the HHRA. All sampling locations will be geographically referenced using a hand held GPS unit having a resolution of <10 m, so that soil analyses can be geographically referenced for purposes of data interpretation and mapping described below. In woodlots, where a grid sample falls in the location of a tree, the nearest point next to the tree will be selected.

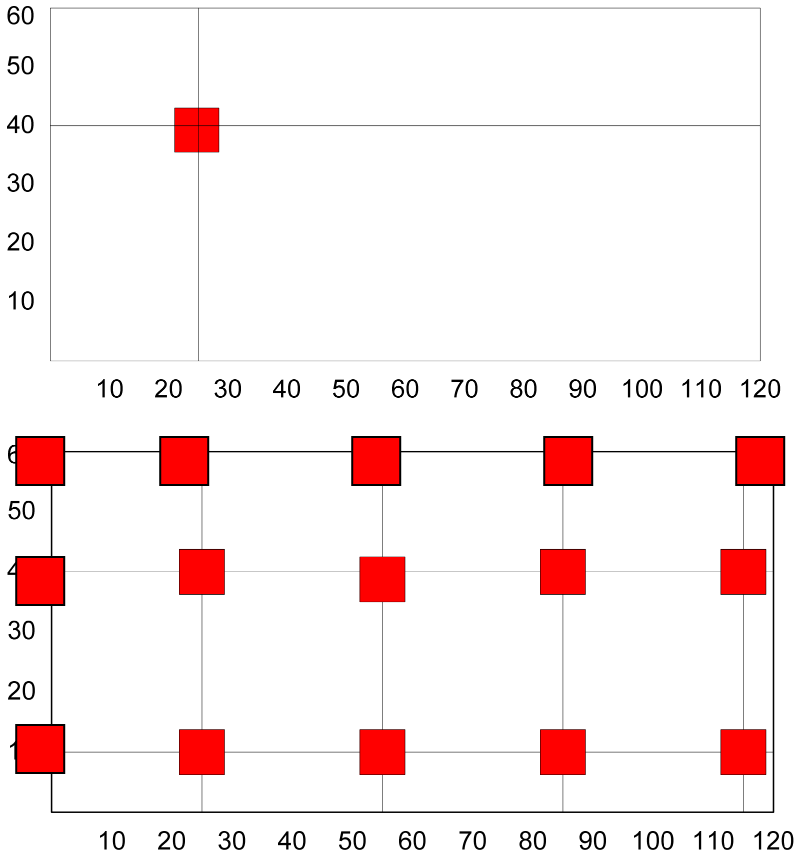


Figure 6: Designing grid sampling for a site (modified from EPA, 2002). A random point is selected on the property. Horizontal and vertical spacing is initiated from this point. Samples are taken every 30 meters on the property in a grid pattern. Spacing originates from the randomly chosen point. Edge samples are taken if the internal sampling point is more than 15 m (50% of the sample point spacing) from the edge of the site.

Interpretation and Mapping of Soil Nickel Concentrations

When site-specific soil sampling is complete and nickel values have been obtained for all samples taken on a site, interpretation of the data will commence. A map showing soil nickel concentrations will be created for each site. If all nickel values obtained from site-specific sampling on a site are below the PNEC value specific for that soil type, no further data interpretation will be required and the owner will receive a letter containing all the analyses. In a scenario where all soil nickel values on an agricultural site are above the PNEC value for that soil type, then remediation of the entire site will be carried out. If only a portion of a site is above the PNEC, then only that portion will be remediated. Detailed nickel contours for each farm site will be carried out using modelling software and techniques described in Appendix 3.

Figure 7 is an example of soil nickel contouring based upon hypothetical data that was derived from variance typical for agricultural fields in Port Colborne. In this example, soil nickel values are shown at a sample spacing of 30 meters in a grid pattern. This type of mapping will be generated for sites that exceed PNEC criteria.

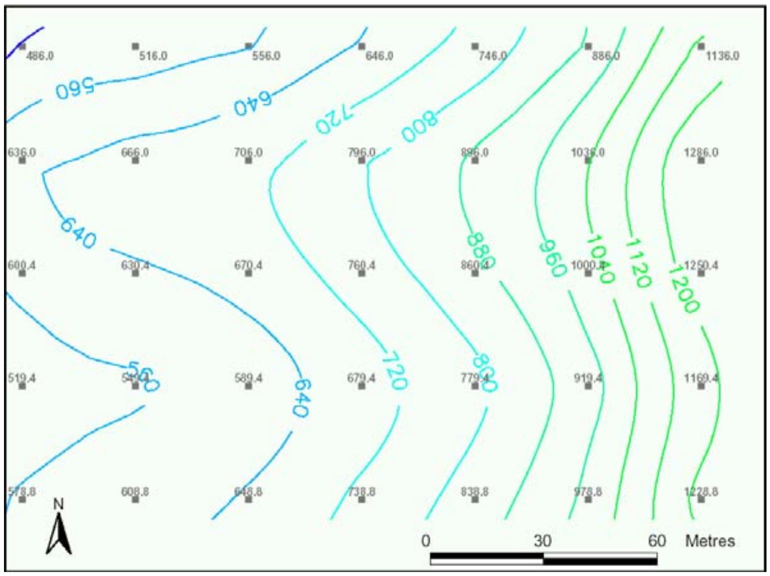


Figure 7: Hypothetical example of Ni concentration contour mapping. Techniques used to perform this mapping are described in Appendix 3.

7.3Random Sampling Of Vegetable Gardens

Vegetable gardens exceeding the 95%LCL of the Ni PNEC (oats) for till clay will be sampled with permission of the landowner. If the longest side of a vegetable garden is > 10m, then this longest side will be used to bisect the garden into two approximately equal areas, and each of these areas will be treated as single gardens for sampling and potential remediation. Vegetable gardens will be randomly sampled by selecting 12 sample points for each 12m^2 garden area. The 12 soil samples will be taken using a stainless steel Oakfield soil corer to a depth of 20 centimetres as described below. One composite soil sample will be obtained for each 12 m^2 area of the vegetable garden. The 12 individual soil core samples will be placed in a clean plastic bag and mixed to form one composite soil sample, which will be transferred to an appropriately labelled glass sample jar. Soil samples will be collected according to procedures described in Appendix 1.1 of the HHRA. These samples, with chain of custody documentation, will be sent to a certified laboratory for determination of CoC concentrations using the aqua regia digestion procedure as specified in Appendix 1.1 of the HHRA. If any composite soil sample collected for a garden is above 1400 ppm ($PNEC_{oats}$ for till clay), then the vegetable garden will be a candidate for remediation. If all composite soil samples from a garden are found to be below 1400 ppm Ni, the garden will not be remediated and the landowner will receive a letter with the analytical results.

8.0 OPTIONS FOR REMEDIAL ACTIONS

Potential soil remedial actions to either remove or stabilize soil CoCs on agricultural land and certain woodlots are described below. Feasibility of these options is based on effectiveness, environmental considerations, and cost. Consideration of these factors by Vale Inco, the MOE and the property owner will be carried out to arrive at an acceptable remedial plan for sites where remediation is warranted. Remedial options are described below in three sections that include three fundamentally different approaches to soil remediation: 1) removal of soil CoCs, 2) capping a site to block the exposure pathway and 3) reducing the bioavailability of CoCs.

8.1 Removal Of CoCs From Soil

This section outlines three methods that can be employed to remove CoCs or block their exposre pathway from a site. The first method is soil excavation where soil is removed from the site; leaching is a second remediation approach where CoCs are removed from soils using a leaching solution; phytoremediation is the third method where CoCs are removed from soils using plants.

Soil Excavation

Soil excavation is a process where soil in a subject area is removed to a desired depth using an excavator. The soil is hauled from the site and placed in a suitable landfill or other waste site. After soil excavation is complete, and sampling at the bottom and sides of the hole has confirmed acceptable CoC levels, new clean soil is transported to the site and put in place of the excavated soil, and levelled to the original grade.

Soil Excavation Applied To Agricultural Lands

Removing soil from a site to a secure landfill is often a quick method for dealing with contamination on a site. However, the practicality of trucking soils from a site quickly diminishes as the area and depth of soil to be removed increases. For this reason, soil excavation is most practical in situations where the volume of soil to be removed is localized and minimal. Another consideration for soil excavation is that once contaminated soil is removed, sufficient replacement of topsoil must be available.

To assess the feasibility of soil excavation in Port Colborne, it is necessary to consider the land area and depth that would potentially require remediation. Map H agricultural land where site sampling will be required. If soil in this area were to be removed to a depth of 25 cm (equivalent to plough depth), approximately 572,500 cubic meters (1,145, 000 tonnes) of soil would be excavated and removed. Additionally, an equal volume of uncontaminated fertile soil would be required to replace excavated soil.

There are several fundamental issues with excavating and removing agricultural soils from Port Colborne. Clay and organic soils in Port Colborne are well suited to farming due to their unique formation over thousands of years. Excavation of these soils would permanently remove and disrupt the soil structure and composition that has taken so many years to develop. Secondly, once removed from the site, Port Colborne soils would require a prohibitively large space at a waste facility. Thirdly, an equal volume of fertile soil would be required to replace Port Colborne excavated soils, and this would require another area to be identified and permission to be obtained to strip its topsoil, thereby altering and disrupting the soil ecology at that location.

Soil excavation is most often utilized at small urban locations such as industrial sites where the soil is not valued or desired for agricultural purposes. This is not the case for many Port Colborne agricultural soils, for which removal would not be preferred (due to cost, restricted landfill space for deposition, lack of equal fertility of replacement soil, the disruption and the presence of dust caused by removal activities). Vale Inco does not intend to remediate agricultural soils by means of removal/replacement.

<u>Soil Excavation Applied To Woodlots</u>

Woodlots shown on Map D (total of 55 hectares) are becoming an increasingly rare feature in southern Ontario due to agricultural and urban development. Removal of soils to any depth in these woodlots would require the removal of young trees, herbaceous plants, and vital rooting systems of the larger trees on the sites. Rooting depths of the trees on organic soils are shallow, due to moist conditions on site. It is not likely that trees would survive significant soil excavation since their roots would be irreversibly damaged. Vale Inco does not intend to remediate woodlots by removing/replacing soil.

Jeopardizing the current health of any woodlots, particularly the Provincially significant woodlots along Reuter Road, by soil excavation and subsequent soil replacement, is not an acceptable or necessary method for reducing risks to earthworms in woodlots.

Soil Leaching

Soil leaching is a process by which soils are injected with a solution to leach out contaminants from the soil. While soil leaching has been practiced for some time in removing petroleum contaminants from certain sites, Vale Inco knows of no leaching solutions that could be used effectively for the metals and metalloids in Port Colborne soils. It therefore appears that this remedial option for nickel is not feasible. The following two sections, however, discuss fundamental issues with using this method in Port Colborne for agricultural land and woodlots, even if a leaching solution for the CoCs could be identified.

Applying Soil Leaching To Agricultural Lands

There are several drawbacks that would make *in-situ* soil leaching prohibitive in Port Colborne. Soil leaching causes metals to become mobilized from within the soil matrix, creating the potential for contaminants to migrate from the site or sink lower in the soil. In Port Colborne, poorly drained soils such as the clay, and high water tables and clay content in organic soil areas within the Study Area would make it prohibitive to uniformly introduce leachate to the soils, control and collect all subsurface leachate flows (to protect the environment) and maintain the water table below the target zones to induce controlled downward gradients. Since metals in Port Colborne soils are already tightly bound to the soil matrix, as shown by extraction tests (see the Crop Studies report, 2004) and bioavailability studies (ERA-Natural Environment report, 2004), it would be counter-productive to alter the chemistry of the soils and risk having contaminants migrate laterally or vertically through the soil matrix and potentially leave the site.

A better alternative is to increase the stability of metals within the soil matrix, as described in Section 8.3. This would enhance the soils natural ability to retain metals in a form that are mostly inert and not bioavailable.

Applying Soil Leaching To Woodlots

Soil leaching in a forest environment would not be feasible for several reasons. Currently, metals in clay and organic soils are relatively stable (Crop Studies report, 2004) with very limited bioavailability. The process of mobilizing metals in the soil for any amount of time would cause severe toxicity, killing or severely injuring all of the microbial, plant and invertebrate life in the targeted woodlot. Another limitation would include limited access for setting up a leachate recovery system. Installing this equipment would require trees to be cleared and soils to be excavated, destroying a significant portion of the woodlot being protected.

Phytoextraction

Phytoextraction is a relatively new technology that is achieving increased success. The process of phytoextraction, also known as phytoremediation, uses special plants to extract selected metals from contaminated soils, transferring the metal into the plant biomass, which can then be harvested and treated for metal recovery elsewhere. Over several harvests, metal burdens in the soil can be reduced to a desirable level.

Applying Phytoextraction To Agricultural Lands

Small field trials in Port Colborne have shown that *Alyssum murale* is a potential candidate for phytoremediation of agricultural soils in Port Colborne. Plants were able to accumulate > 10, 000 mg Ni/kg in dried biomass. Additional feasibility testing will be conducted by Vale Inco in Port Colborne. A future report will discuss the feasibility of phytoremediation for agricultural soils in Port Colborne.

Applying Phytoextraction to Woodlots

Alyssum species used for phytoextraction are studied under typical agricultural conditions where soils are ploughed and sunlight is abundant. Phytoremediation in woodlots would present challenges for successful plant growth due to excessive shading and wet conditions.

Unfortunately, *Alyssum* species are not adapted to shaded and wet conditions, making this species unsuitable for phytoremeditation in woodlots. Furthermore, typical methods of planting and harvesting utilized in open agricultural fields could not be implemented in a woodlot setting.

8.2 Soil Capping To Reduce CoC Exposure Pathways

Capping is a process by which contaminated soils are covered by a layer of soil or a barrier to effectively prevent biota or humans from coming into contact with CoCs. This method is used on small to moderately sized areas. Materials such as concrete, asphalt, or an impermeable polyethylene membrane of sufficient thickness can be used in urban settings where subsequent use of the soils is not desired. Since agricultural land and woodlots in Port Colborne could not exist without surface soils, the aforementioned capping materials are considered impractical for remediating these sites. The following two sub-sections consider using clean soil as the capping material for agricultural land and woodlots.

Applying Soil Capping To Agricultural Land

A minimum soil capping depth of 25 cm would need to be placed on top of agricultural land so that ploughing activities would not come in contact with soil CoCs. The large area of agricultural land that could potentially require such capping would use impractically large quantities of fertile soil (suitable for growing crops) to be transported to Port Colborne and distributed over agricultural land.

An important impact to consider when raising the grade of agricultural land by new soil is that the hydrology of the land will be altered. At this time, it is uncertain how this would affect drainage in the area. However, it is likely that some areas would become more wet, and others areas would become drier. A second environmental impact, as mentioned previously, is that an area outside of Port Colborne would be stripped of its fertile soil, causing those lands to become disrupted and significantly altered.

Applying Soil Capping To Woodlots

Soil capping in woodlots would require trees to be removed for machinery access and would cover herbaceous and shrub plants of the woodlot. It would also raise the grade of the site, causing the site to dry and thereby altering the ecology present in the woodlots. Such effects to enhance earthworm health would likely destroy or jeopardize the entire ecology of such treated woodlots. For this reason, soil capping in woodlots is not recommended.

8.3 Reduced CoC Bioavailability In Soils

It is often desirable to reduce the risk of toxicity of CoCs in soil without having to remove them from the soil. This section describes different soil amendments that can be applied to reduce CoC availability and thereby reduce the risk of toxic doses being received by biota.

Soil amendments are compounds that are added to contaminated soil to stabilize CoCs by inducing the formation of insoluble CoC compounds. Less soluble forms of metal contaminants are unable to interact biologically with plant roots. Rather than the drastic removal of CoCs from the soil, soil amendments can be chosen to alter the chemical forms of CoCs, causing them to become less soluble and less available for biological uptake.

Applying Soil Amendments To Agricultural Land

Soil pH is one of the most important factors affecting the potential for nickel toxicity in crops. On organic soils in Port Colborne, Kukier and Chaney (2004) and Chaney et al. (2003) have shown that liming soil with dolomitic limestone (to raise the pH) in combination with the addition of Mn (to correct for potential Mn deficiency) and N-P-K fertilizer, effectively remediated symptoms of nickel phytotoxicity. Field tests for oats, radish, corn, and soybeans indicated that the aforementioned soil amendments were able to prevent phytotoxicity on organic soil that contained 4500-6000 mg Ni/kg. Given the fact that these experiments were conducted on lands exceeding nickel concentrations for much of the agricultural lands shown in the Study Area on Map H, it is likely that using these soil amendments on agricultural lands would be successful for remediation purposes.

An alternative to limestone as the amending compound is the use of phosphates. Phosphates may be particularly well suited to Port Colborne soils because of the insolubility of Ni, Cu and Co phosphates. Testing of this option should be carried out prior to any remediation strategy being developed for phosphate amendments.

Applying Soil Amendments To Woodlots

The species at potential risk in woodlot soils are earthworms. There are three different ecophysiological groups of earthworms living in the Port Colborne area: epigeic earthworms, which are surface litter-dwelling earthworms that feed off of plant litter; anecic earthworms, which live in deep vertical permanent burrows but come to the surface to feed; and, endogeic earthworms, which feed on soil humus and live in transient horizontal burrows in mineral soil (Morgan et al., 2001). One of the most important factors that influence all groups of earthworm populations is the quality of the food source. Epigeic (e.g., *Dendrodrilus rubidus, Eisenia fetida, Lumbricus rubellus*) and anecic (e.g., *Lumbricus terrestris*) earthworm species both feed predominantly upon plant litter, whereas endogeic earthworms, such as *Allolobophora chlorotica* and *Aporrectodea tuberculata*, feed predominantly on soil organic matter (SOM) derived from plant litter.

Generally, the nature and quality of plant litter and SOM is determined by the quality of the vegetation cover. Vegetation on impoverished acidic soils produce tough, unpalatable litter, low in nutrients and unfavorable for earthworms (Curry,1998). When the pH of the soil is increased, for example via liming, improvements in the food source for earthworms will likely result in improvements to earthworm populations (Bauhus et al., 2004).

The plant species constituting woodlots in Port Colborne's natural environment are typical for the Niagara Region (see the CBRA ERA Report) and thus provide a similar composition of plant litter and SOM for earthworms to eat in Port Colborne as found outside of the Study Area.

Alkaline soil amendments are used extensively throughout the world to reduce or eliminate metal toxicity to plants in areas where soil acidity combined with elevated levels of metals in soil either weaken or kill vegetation. Increasingly, studies pertaining to earthworm response to limestone amendments on acidified and metal impacted soils are emerging. Short term studies investigating the effect of liming on earthworm population health and diversity show no clear effect. However, numerous long term studies have found that earthworm activity, abundance and biomass increase following the addition of lime to soils. A higher abundance of earthworms following liming of acidic soils has been observed in Sweden (Persson et al., 1989) and in Germany by Lorenz et al. (2001) and Schoning (2000).

The most direct influence that liming has on earthworm populations is the increase of soil pH; this is more important than the increased availability of calcium (Edwards and Lofty, 1977). Soil pH affects the feeding rate and metabolic turnover of earthworms (Eijsackers, 1998). A response of earthworm populations to lime is not likely to occur if the initial pH of the soil is 4.5 to 5.0 or above, since above this pH most earthworm species are insensitive to further increases in pH or addition of calcium (Edwards and Lofty, 1977).

Literature not specific to Port Colborne generally has focused on determining the effect of liming soils that are both acidified and metal impacted. Overwhelmingly, these studies indicate that liming of these impacted soils has a positive affect on earthworm populations due to an increase in pH. In Port Colborne, organic soil pH is in the range of 4.8 to 5.6, and clay soils are generally in the range of 5.5 to 7.2.

Port Colborne soils are unlike many metal impacted regions since they have not been impacted by the degree of acidification commonly associated with smelting of ores. Therefore, excessively low pH of soils in Port Colborne is not a concern, and one would not expect to see a positive correlation in earthworm numbers by increasing pH alone. However, it has been demonstrated that plant health was improved for some crop species in Port Colborne when lime amendments were applied to the soil. The reason for improved plant health is attributed to the reduction of CoC bioavailability. Similarly, one can predict that lime amendments will reduce the potential for metal toxicity to earthworms living in Port Colborne soils by reducing the bioavailability of CoCs.

There are no known adverse effects to earthworms as a result of liming. The addition of calcium to soil via liming is not likely to present an additional stress to individual earthworms or to populations. Calcium is a highly regulated macronutrient in earthworms across a wide soil calcium concentration range. All earthworms have substantial intracellular calcium storage sites in the chloragogenous tissue and some earthworm species possess physiologically active calciferous glands, which contain calcitic excretory products (Morgan et al., 2001). Eijsackers (1998) has noted that calcium binds to oxygen sites in biological ligands and hence acts as a macronutrient. The ability to regulate calcium varies depending on the species and eco-physiological group. Epigeic earthworms have well developed mineralizing calciferous glands. Anecic earthworms possess non-mineralizing calciferous glands. Endogeic earthworms possess inactive, non-mineralizing calciferous glands (Morgan et al., 2001). Generally it is known that earthworms exhibit a strong ability to regulate calcium in the environment. Therefore, it is not anticipated that additional calcium in soils from liming will have an adverse impact on earthworms.

9.0 PATH FORWARD

The CBRA has demonstrated that nickel is the appropriate element within soil to serve as a surrogate for all CoCs, so that nickel risk reduction will also yield negligible risks for copper, cobalt and arsenic. At this time, soil data collected for the CBRA and by the MOE in Port Colborne has been used to provide a good delineation of land that is above PNEC criteria. However, the variance associated with these data can be significant. For this reason, the Integration Report has chosen to map a nickel contour at 95%LCL of the PNEC (a larger land area than PNEC above) as the area that will require more intensive site-specific soil sampling. This approach provides a buffer to account for soil data uncertainty and ensures that all lands estimated to be above PNEC criteria receive detailed site-specific soil analyses.

Let it be clear that not all land within the 95%LCL of the PNEC shown on Map H (agricultural land), Map J2 (vegetable gardens), or Map D (woodlots) will necessarily be remediated. Results of site-specific soil sampling will determine what portion of a site is above the respective PNEC value and only this portion of a site will be a candidate for remediation. Using results of the site-specific soil sampling, the site will be remediated up to the sample point where the soil nickel analysis is <PNEC.

Each landowner within the areas shown on Map H, Map J2 and Map D will take part in the decision diagrams shown in Figures 1 through 5. Prior to site-specific soil sampling and the implementation of remediation on a site, the landowner will make the decision as to whether his or her site will be included in these activities.

Upon the completion of site-specific soil sampling, all landowners will receive a letter containing results of the soil sampling. For sites having nickel values below PNEC, no remedial action will be required. Sites having a portion or all land above PNEC will become candidates for remediation, and the landowner will determine with Vale Inco whether and how the site remediation will occur and what remediation options are favoured. When a site is remediated, the landowner will receive a letter (from the company conducting the remediation) verifying the remediation and the MOE will provide a letter to the landowner acknowledging such action.

The implementation of the strategy proposed in this document can be summarized as follows:

(1) Vale Inco will submit the entire CBRA Final Report, consisting of three technical risk assessments and the Integration Report, to the Ministry of the Environment. This submission will include all comments received on the technical reports. In addition, the PLC is expected to submit its own report to the MOE on the CBRA process in general and on specific issues where they believe the technical reports or Integration Report are inadequate.

(2) The MOE will make their decision concerning both the technical aspects and the policy aspects of the CBRA Final Report: the Ministry may reject the findings of the risk assessments and/or Vale Inco's proposed remediation strategy; the Ministry may accept the Report; or the Ministry may ask for further work to be performed by Vale Inco. Only if the MOE accepts the Report would the remediation process continue.

(3) An Advisory Committee, if necessary, will be formed by Vale Inco. Consideration will be given to having a member of the public serve on this Committee, which would have the task of reviewing priorities for the site-specific work needed.

(4) A priority ranking for sampling agricultural areas, woodlots and residential vegetable gardens, according to the strategy presented in the Integration Report, will be submitted to the MOE by Vale Inco.

(5) Vale Inco will hire a reputable company to carry out site sampling. Results of each site will be reviewed by Vale Inco and the individual property owner of each site.

(6) The options for remediating each site will be discussed between Vale Inco and the property owner, with the MOE serving in an advisory capacity, and decisions on the type of remediation to be applied and the precise extent of the area of the site to be treated will be agreed to by Vale Inco and the property owner.

(7) Remediation will be carried out by a reputable company hired by Vale Inco. This company will be responsible for verifying the remediation. Any audits by the MOE on the remediation will be carried out with the cooperation of the company doing the remediation.

(8) Certification of remediation will be supplied by the company doing the remediation to the owner stating, and verifying, what had been done.

(9) If a property owner, who initially refused remediation, decides at some later time that remediation is desired, then Vale Inco will honour its sampling and remediation plans for that property.

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11.0 GLOSSARY OF TERMS

Abbreviation/Acronym	Definition
95% LCL	The Lower Confidence Level and the Upper Confidence Level define the Confidence Interval and are statistically derived numbers reflecting the certainty of the parameter to which they are referred. For example, the 95% confidence interval on a measured Ni soil concentration describes the upper and lower limits of a range in which one is 95% certain that the true Ni soil concentration lies.
As	Symbol for the metalloid arsenic
Beak	Beak International Inc., the PLC's consultant for the CBRA until 2002. Beak evolved into Stantec and is now Watter's Environmental.
Bioaccessibility	Given a defined route of dose or exposure, the degree to which a substance is accessible to be taken into the bloodstream and thereby gain access to the target tissue.
Bioavailability	The fraction of a total chemical that can interact with a biological target (*e.g.*, a plant, animal or human).
CBRA	Community Based Risk Assessment
CCME	Canadian Council of Ministers of the Environment
City	City of Port Colborne
Clay Till Soil	A shallow clay mapped primarily as the Farmington or Alluvial series or commonly identified locally as a "light clay loam" soil. The origin of this soil is from glacial till.
Co	Symbol for the metal element cobalt
CoCs	Chemicals of concern, identified for the CBRA. The CoCs are as follows, nickel, copper, cobalt, and arsenic.
Cu	Symbol for the metal element copper
Dose Response Testing	A method of determining the impact of CoCs on the growth of plants.
EC, Effects Concentration	A point on a regression-generated dose-response plot above the threshold toxicity concentration.
EC_{25}	The effective total soil CoC concentration in mg CoC/kg at which biomass growth is reduced by 25% due to the phytotoxic impact of CoCs in soil on the plant. This is the first effect level beyond the no observed effects threshold concentration that is considered to represent a significant statistical decline in biomass as a result of factors other than natural variation.
Emissions	That which is sent out, or put in circulation.
EPA	US Environmental Protection Agency
ERA-NE	Ecological Risk Assessment-Natural Environment
Exposure Pathway	Routes for transfer of CoCs to receptors.
GPS	Global Positioning System. Refers to a method for accurately determining locations on the surface of the earth using electronic triangulation using satellites.

Abbreviation/Acronym	Definition
Ha	Hectare
Heavy Clay Soil	A clay soil mapped primarily as the Welland series or commonly identified locally as a "heavy clay" soil. The origin of this soil is glacio-lacustrine.
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient, the ratio of an estimated dose to a reference dose for a particular chemical. The HW serves as an indicator of daily intake to health benchmarks, where a HQ less than 1 indicates that the estimated exposure is within an acceptable limit.
CVRD Inco; Vale Inco; Inco	Vale Inco Limited.
Intervention Limit	A derived CoC limit for land use and soil type beyond which the Integration Report agrees to remediation, on the basis of site-specific soil sampling.
In vitro	Laboratory methods that attempt to simulate *in vivo*.
In vivo	Studies conducted with laboratory animals.
Jacques Whitford	Jacques Whitford Limited.
Liming Agent	An amending agent such as limestone (calcium carbonate), dolomitic limestone (a mixture of calcium and magnesium carbonates), slaked lime, or some other similar calcium–based material used to increase soil pH.
LOEL	Lowest Observable Effects Level, the lowest level of exposure, concentration or dose at which observable effects have been observed.
LOAEL	Lowest Observable Adverse Effects Level, the lowest level of exposure, concentration or dose at which observable adverse effects have been observed.
MOE	Ontario Ministry of the Environment, MOE has been used as the acronym for Ontario Ministry of the Environment and Energy as well.
Ni	Symbol for the metal element nickel.
NOAEL	No Observable Adverse Effects Level, a level of exposure, concentration or dose at which no adverse effects have been observed.
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs.
Organic Soil	An organic soil mapped primarily as the Quarry series or commonly identified locally as "muck" or organic soil.
Phase I	Constitutes the Human Health Risk Assessment (HHRA), Environmental Risk Assessment – Natural Environment (ERA-NE), and Crop Studies that were conducted for the CBRA in Port Colborne.
Phase II	This phase will include site-specific remediation that in Port Colborne that will be conducted with guidance from the Integration Report.
Phytoremediation	A form of bioremediation where the inactivation, transformation, degradation and/or removal of contaminants from a medium (e.g., a soil) is caused, mediated and/or assisted by plants.

Abbreviation/Acronym	Definition
Phytostabilization	A form of phytoremediation involving the conversion to less toxic forms and/or the decrease in bioavailability of metal in soils, thereby inhibiting/preventing their take up by groundwater or plants and/or their entry into food chains.
Phytotoxicity	Toxicity of a chemical towards plants.
PLC	The Public Liaison Committee of the City of Port Colborne CBRA.
PNEC	Predicted No-Effects Concentration.
ppm	Parts per million – equivalent to milligrams of analyte per kilogram of medium (mg/kg) or milligrams per litre (mg/l).
Refinery	The Vale Inco facility at Port Colborne, Ontario.
Risk Assessment	A qualitative or quantitative evaluation of the environmental and/or health risk resulting from exposure to a chemical or physical agent (pollutant); combines exposure assessment results with toxicity assessment results to estimate risk.
Sandy Soil	A sandy soil mapped primarily as the undifferentiated beach-scarp complex or commonly identified locally as “sand” or sandy soil.
Sequential Extraction	An analytical procedure by which soil samples are extracted with a series of progressively more aggressive extractants to estimate the distribution and association of CoCs among different mineral and organic fractions within the soil.
Site	Refers to land (or a portion thereof) that has a title associated with it. A site has definite described boundaries and has an owner identified and is also correlated with a particular land use as may be specified by municipal zoning by-laws.
Soil Amendment	A material applied to soil to reduce or eliminate phytotoxic effects from CoCs.
SSRA	Site Specific Risk Assessment.
Stantec	Stantec Consulting Limited, the PLC’s consultant for the CBRA from 2002 until September 2004.
Study Area	The area of land shown on Map A that was evaluated under the CBRA.
Surface Water	Water at the soil surface in open bodies such as streams, rivers, ponds, lakes and oceans.
Toxicity	Production of any type of damage to the function or structure of any part of the body.
TSC	Technical Sub-Committee to the PLC.
UCLM	Upper Confidence Limit of the Mean, the upper limit that one can be confident, to a specified level of confidence and assuming a normal distribution of data, that the mean value does not exceed that limit.
US EPA	United States Environmental Protection Agency.
VEC	Valued Ecological Component, a species, population or process identified for conducting Risk Assessment.

Abbreviation/Acronym	Definition
Vegetable Garden	A portion of a site that is used for the growing of vegetables that are consumed by the landowner or on occasion given to friends or neighbours when the produce exceeds what the landowner can eat.
Watters	Watters Environmental Group Inc., the PLC's consultant for the CBRA since September 2004.
Woodlot	An area on one parcel of land (> 2 acres) or on any number of adjoining parcels of land having a density of not less than 400 trees of any size per acre; 300 trees measuring more than 2 inches diameter at breast height (dbh) per acre; 200 trees measuring more than 5 inches dbh per acre; or 100 trees measuring more than 8 inches dbh per acre.

Appendix 1: Concordance Table

Land	Receptor	Outcome of Risk Assessment	Reference to Main Reports	Suggested Action in Phase II
Residential Soils	Human life-time risks	The CBRA determined that negligible risks exist for humans living in either residential or rural areas (including houses on farms) of Port Colborne[1]. These negligible risks were for any CoC exposure by ingestion or inhalation (both inside and outside air) and took into account recreational uses by residents of other land types in the area (e.g. beaches, nature trails)[2]. Negligible risks exist for soils containing <21,000 ppm Ni and no residential soils have been found to contain in excess of that concentration.	HHRA, Volume1: [1]Chapter 7, Table 7-10. [2] HHRA, Volume1,Chapter 7, Table 7-25.	NO RESIDENTIAL SOIL REMEDIATION IS NEEDED TO REDUCE LIFETIME HUMAN RISKS.
	Young Children	Because of differences in possible exposures, most probably due to increased ingestion of indoor dust[1] and outside soil[2], young children were assessed. While higher exposures for all CoCs existed for young children on a per kilogram weight basis than existed for teens or adults in the same residential setting, all risks still remained negligible for young children and all other age categories.	HHRA, Volume 1: [1]Chapter 7, Table 7-24, Table 7-26, Table 7-27. [2]Chapter 7, Table 7-10 through Table 7-13.	NO RESIDENTIAL SOIL REMEDIATION IS NEEDED TO REDUCE RISKS TO YOUNG CHILDREN.
	Children in School	Negligible risks exist for children present in school classrooms and in schoolyards during recesses.	HHRA, Volume 1: Chapter 7, Table 7-10 through Table 7-13 (Zone C).	NO SCHOOL OR SCHOOLYARD REMEDIATION IS NEEDED.
	Non-Vale Inco Workers	Workers present in workplaces in Port Colborne are not expected to have higher exposures to the CoCs than people who reside in Port Colborne[1]. In cases where workers spend time working in soil, the frequency and exposure duration of such episodes is considered to be small compared to a lifetime exposure[2].	HHRA, Volume 1: [1]Chaper 7, Tables 7-4 through 7-7. [2]Chapter 7, Tables 7-10 through 7-13.	NO SOIL REMEDIATION IS NEEDED TO REDUCE RISKS TO WORKERS.
Residential Soils	Vale Inco Workers	Vale Inco workers would be expected to have higher overall exposures resulting from their occupation. Vale Inco maintains a workroom monitoring program and does personal exposure measurements routinely. These data are necessary to abide by standards put in place by the Ministry of Labour. In addition, Vale Inco conducts intensive epidemiological studies on its workers to determine if excessive disease is occurring in particular areas of the plant. These studies have pointed to certain risks having existed for employees in the Port Colborne refinery's Leaching, Calcining and Sintering Department (process was discontinued about 40 years ago). No other risks associated with the CoCs have been identified for Vale Inco's Port Colborne workers. Occupational exposures continue to be monitored and risks assessed and specific occupational	N/A	NO SOIL REMEDIATION IS NEEDED TO PROTECT Vale INCO WORKERS.

		remedial actions are taken as is necessary by Vale Inco.		
	Humans Eating Vegetable Garden Produce	There exist no human health risks from ingesting reasonable maximum levels of vegetable garden produce.	HHRA, Volume 1: Chapter 7, Table 7-15 through Table 7-18.	NO SOIL REMEDIATION IS NEEDED TO REDUCE HUMAN RISKS FROM INGESTING VEGETABLE GARDEN PRODUCE.
	Humans Eating Local Animal Products (i.e. meat, eggs, milk) and or wild game (i.e. deer, rabbits, fish).	No risks were found for humans ingesting meat from Port Colborne livestock, wild animals such as deer, rabbits and perch fish or from consuming milk and eggs from livestock/poultry.	HHRA, Volume 1: Chapter 7, Table 7-1, pages 7-12 and 7-13.	NO SOIL REMEDIATION IS NEEDED TO REDUCE HUMAN RISKS FROM INGESTING PRODUCTS FROM or FLESH OF LOCAL ANIMALS.
Natural Environment Soils	All Flora and Fauna in Natural Environments Excluding Selected Woodlots	All organisms assessed under the natural environment portion of the CBRA showed negligible risks to the CoCs in soils with the exception of earthworms in certain woodlots (see woodlot section below).	ERA-NE, Volume 1: Tadpoles - Chapter 8, Table 8-2; Fowler's Toad - Chapter 8, Table 8-3; Maple Dose Response - Chapter 8, Table 8-4; Maples in the Natural Environment - Chapter 8, Table 8-5 and Section 8.3.2.4; Woodlot Health - Section 8.3.2.3; Leaf Litter - Section 8.3.3.4, Table 8-20; Red-tailed Hawk - Table 8-21; American Woodcock - Table 8-22; American Robin - Table 8-23; Red-eyed Vireo - Table 8-24; Meadow Vole - Table 8-25; White-tailed Deer - Table 8-26; Racoon - Table 8-27; Red Fox - Table 8-28.	NO NATURAL ENVIRONMENT SOIL REMEDIATION IS NECESSARY FOR THE PROTECTION OF ORGANISMS LIVING IN OR ON (E.G. RECEIVING FOOD FROM) SOILS OR AQUATIC HABITATS IN PORT COLBORNE.

Natural Environment Soils	Selected Woodlots	As the presence of earthworms has been verified with acceptable species diversity in all soil types, the risk certain woodlots may have is a lower density of earthworms. All fallow field were found to have acceptable species diversity and density of earthworms. Earthworm abundance is known to vary widely from site to site and from region to region and is known to have a negligible effect on the overall health of flora and fauna living on soils. In point of fact, all but two earthworm species that occur in Canada were introduced from Europe, and thus were not part of forest ecosystems prior to European settlement (Reynolds 1977 and Tomlin 2005). For this reason, it is not considered mandatory to achieve certain population densities of earthworms in soils. Nevertheless, remediation of certain sites in Port Colborne should be considered so that earthworm populations are as healthy as possible. For the purposes of CBRA remediation decisions on a site-specific basis, a woodlot is defined as an area of at least 2 acres (0.8 hectares) in size having a density of not less than 400 trees of any size per acre. This criteria has been taken from "The Regional Niagara Tree Conservation By-law" (Regional Niagara 1996) for the purpose of distinguishing a woodlot from other treed areas. If a site has such a woodlot area within its boundaries, then the position of the woodlot relative to the estimated earthworm PNEC contour will be used to determine if the woodlot is a candidate for remediation.	ERA-NE, Volume 1: Earthworm Quotient Method - Table 8-6 and Table 8-7; Dose Reponse - Table 8-11 and 8-14; Field Surveys - Table 8-16, Table 8-19. Integration of Three Lines of Evidence - Section 11.4. See Map D for illustration of selected woodlots on organic and clay soils predeicted to exceed 3500 and 3000 mg Ni/kg respectively.	REMEDIATION OF CERTAIN WOODLOTS MAY BE CARRIED OUT DEPENDING ON THE FEASIBILITY OF PRACTICING REMEDIATION WITHOUT JEOPARDIZING THE HEALTH OF NON-EARTHWORM ORGANISMS THAT FORM THE WOODLOT OR THAT COULD POTENTIALLY UTILIZE THE WOODLOT.
Agricultural Soils	Agricultural Crops	It is clear that sensitive crops can suffer metal toxicity for certain soils and that the intervention level (mandatory remediation) is dependent on soil type. Any existing farmland or historical farmland that is found to be above the intervention level for its particular soil type should be remediated so that sensitive crops are completely protected against metal toxicity. Such remediation is to be carried out on all agricultural soils independent of the specific crops being grown currently or planned to be grown in the coming years. The objective of remediation of such agricultural soils is to render them suitable for growing any crop desired by protecting soils for growing one of the most sensitive crops.	Crop Studies, Volume 1, Part 3:Table 3-2 (PNEC and EC_{25} values).	REMEDIATION IS REQUIRED FOR ANY PART OF AN AGRICULTURAL SITE THAT IS DETERMINED TO CONTAIN A NICKEL CONCENTRATION HIGHER THAN THE PREDICTED NO EFFECT CONCENTRATION (PNEC) FOR THAT SITE'S SPECIFIC SOIL TYPE. IF THE SOIL TYPE VARIES ACROSS THE SITE, THEN PORTIONS OF THE SITE SHOULD BE REMEDIATED IN ACCORDANCE WITH THE PNECs ASSOCIATED WITH EACH SOIL TYPE.

Agricultural Soils	Livestock	Since negligible risks exist for large wild mammals such as deer, it is concluded that negligible risks exist for horses, cattle, hogs, chickens etc.	ERA-NE, Volume 1: Red-tailed Hawk - Table 8-21; American Woodcock - Table 8-22; American Robin - Table 8-23; Red-eyed Vireo - Table 8-24; Meadow Vole - Table 8-25; White-tailed Deer - Table 8-26; Racoon - Table 8-27; Red Fox - Table 8-28.	NO SOIL REMEDIATION IS NEEDED TO REDUCE RISKS FOR LIVESTOCK OR POULTRY.
Entire Study Area	Vegetable Gardens	Remediation of vegetable gardens may be necessary at certain sites to yield optimum productivity of metal-sensitive vegetables, when vegetable garden soil CoC concentrations exceed the soil-type-specific PNEC given for agricultural crops. In this way, the agricultural PNEC becomes the vegetable garden PNEC for remediation decisions, but such remediation decisions pertain only to the vegetable garden areas. For the purposes of decision-making, vegetable gardens are defined as an area of a site, generally a relatively small portion of the total site, devoted to growing vegetables for individual or family consumption and for providing, in a non-commercial manner, friends and relatives with produce when the garden's productivity exceeds the needs of the individual or family.	Crops Report - Volume 1, Part 3, Table 3-2 (PNEC and EC25 values).	VEGETABLE GARDENS ARE SUBJECT TO REMEDIATION BASED ON SAFE CoC LEVELS DETERMINED FOR FARMLANDS.
Entire Study Area	Household Pets	Pets such as dogs, cats, rabbits and rodents are expected to have less exposure to CoCs than wild animals. Since wild small mammals have been shown to have negligible risks, it is concluded that household mammalian pets would have negligible risks as well. Pets such as birds and amphibians would be expected to have significantly lower exposure to soil CoCs than birds and amphibians in the environment. Since negligible risks have been found for such environmental receptors, it is concluded that negligible risks exist for bird and amphibian pets.	ERA-NE, Volume 1: Tadpoles - Chapter 8, Table 8-2; Fowler's Toad - Chapter 8, Table 8-3; Red-tailed Hawk - Table 8-21; American Woodcock - Table 8-22; American Robin - Table 8-23; Red-eyed Vireo - Table 8-24; Meadow Vole - Table 8-25; White-tailed Deer - Table 8-26; Racoon - Table 8-27; Red Fox - Table 8-28.	NO SOIL REMEDIATION IS NEEDED TO PROTECT HOUSEHOLD PETS.
Note: References made to the HHRA are made to Chapter 7 (Sensitivity Analysis) which gives the reader the most conservative outcomes from the risk assessment. Less conservative estimates of potential risk are given in Chapter 6 of the HHRA, which would lead to the same suggested action in Phase II.				

Appendix 2

Determination Of Sample Spacing For Site-Specific Soil Sampling

The following information provides rational for using 30 meter spacing for detailed site-specific soil sampling. The objective of site-specific soil sampling is to determine, with a reasonable degree of confidence, what CoC concentrations are present on an agricultural or woodlot site.

To achieve this objective the determination of an adequate sample size on a typical sized site it the first step. Then, knowing this sample size, one can determine what sample spacing is required based on the sample size needed and the area of the site. How this sample size and sample spacing was determined is the subject of this appendix.

Step 1-Determining A Sample Size

Determining a sample size for a typical site in Port Colborne was determined using the following formula (Johnson, 1996). Maximum Error Formula:

$$E = z(\alpha/2) \bullet \frac{\sigma}{\sqrt{n}}$$

The components of this formula are:

E = Maximum error (one half the SD of the hypothetical data set)
Z(α/2) = Level of confidence
σ = Standard deviation
n = Sample size

Rearrange to solve for n (sample size). Sample Size Formula:

$$n = \left(z(\alpha/2) \bullet \frac{\sigma}{E} \right)^2$$

To solve for n (sample size), a hypothetical data set was used based on a range between 400 mg Ni/kg and 1400 mg Ni/kg for a 1.4-hectare site. Based on professional judgement, this range exhibits a realistic but relatively high range of CoC concentrations and therefore provides a conservative estimate for calculating a sample size. Within this range, values were randomly generated to obtain a hypothetical data set that is summarized below. Using this data set, a standard deviation of 255 mg Ni/kg and a maximum error of 127.5 (assumed max error of half the standard deviation) were determined for input into the equation. The level of confidence was based on 95% confidence so that Z (α/2) equals 1.96. Thus, the required sample size that provides a good estimate of CoC concentrations on the site at a 95% confidence level is equal to 16. Having a sample size of 16 now enables a sample density to be determined.

Step 2 – Determining Sample Spacing/Density

Knowing that a sample size of 16 would be required to achieve 95% confidence using Step 1, the sample spacing between soil sampling points can be determined using the following equation (EPA, 2002). Spacing Formula:

$$L = \sqrt{\frac{A}{n}}$$

L = Distance between grid lines/sample spacing
A = Area of the site=14 000 m^2 (1.4 hectares)
n = Sample size=16

Solving for this equation determines that sample spacing (L) should be at intervals of 30 meters to achieve the appropriate density at a 95% confidence that the sampling effort is representative of the soil CoC values on the site.

Appendix 3

CoC concentration contour mapping

All soil sampling sites in the CBRA were geographically referenced in field with a GPS unit and field mapped on a hardcopy map for verification purposes. UTM coordinates were inputted into the database and appended to other information such as chemical analytical results.

Statistical analyses were carried out on replicate samples collected from various sites in the Study Area. The criterion for acceptability between replicates was that their standard deviation was less than 30% of their mean value.

Contour Mapping and Data Interpolation

CoC concentration contours (see Map B1) were produced using Surfer™ (Version 8.0 for Windows 95/NT, by Golden Software Inc.). The output from Surfer™ was then imported into ArcView™ GIS (Version 3.3, by Environmental Systems Research Institute Inc.) and combined with base maps and air photos to produce the final maps[φ]. The same software will be used to create site-specific maps using new sampling data.

These maps are statistically derived approximations of the spatial distribution based on measurements at discrete sampling points. Soil concentrations are only known with certainty at those sites for which soil was actually sampled and chemically analyzed. The contours produced by the program are significantly affected by the spatial distribution of the sampling sites, the density of the sampling sites, and the program options used to generate the contours.

The accuracy of the contours diminishes at the edges of the map and in large areas where there are sparse sample sites. For example, contours may have a higher uncertainty on the west side of the canal where there are significantly less sampling points.

In the mapping of soil contours, the most conservative approach was taken regardless of the historical site-specific activities. In cases where there were single sites with significantly elevated concentrations of some elements surrounded by sites with much lower contaminant levels, the local maximum was used to generate the contour.

[φ] See A. G. Journel and CH. J. Huijbregts, Mining Geostatistics, Academic Press 1981, and Isaaks and Srivastava, An Introduction to Applied Geostatistics,Oxford University Press 1989, and M. A. Oliver and R. Webster Kriging: A method of interpolation for geographical information system, Int. J. Geographical Information Systems, 4(3), 313-332 (1990), and Noel A.C.Cressie, Statistics for Spatial Data, Wiley-Interscience , 1991.

In cases where there was a great difference between densities (especially in very small areas), the algorithm attempts to average out a value for the small area.   For example, it was very difficult to integrate the observations and data from the residential community directly to the west of the Vale Inco refinery into the rest of the study area. This small residential community (the Rodney St. area)accounts for a very small fraction of the total Study Area, but had a significantly greater sampling density than other areas. Care had to be taken to prevent "swamping" of the larger Study Area by this very small portion.

Kriging and Data Interpolation

The data from the Study Area in the CBRA was kriged using the kriging options in the Surfer Software.

Kriging is a geostatistical method of spatial data interpolation that can be used to visually portray the distrubution and patterning of chemical distributions in an area[γ]. Kriging is an interpolation method that optimally predicts data values by using data taken at known discrete nearby locations. Interpolation is the estimation of values between two known values. In regard to GIS software, interpolation is a process where the software adds an estimation of a parameter or gradation based on the values of the surrounding discrete points. The software then maps the isolines between the discrete points of the gradients.

The word "kriging" is synonymous with "optimal prediction". It is a method of interpolation which predicts unknown values from data observed at known locations. This method uses variogram to express the spatial variation , and it minimizes the error of predicted values which are estimated by spatial distribution of the predicted values.

In theory, ordinary kriging, which estimates the unknown value using weighted linear combinations of the available sample:

$$\hat{v} = \sum_{j=1}^{n} w_j * v \qquad \sum_{i=1}^{n} w_i = 1$$

Equation (1)

The error of i-th estimate, r_i, is the difference of estimated value and true value at that same location:

$$r_i = \hat{v} - v_i$$

Equation (2)

The average error of a set of k estimates is:

[γ] In 1963, G. Matheron named Kriging after D.G. Krige, a South African mining engineer, who used the technique to more accurately predict the extent of gold deposits in un sampled areas.

$$m_r = \frac{1}{k}\sum_{i=1}^{k} r_i = \frac{1}{k}\sum_{i=1}^{k} \hat{v}_i - v_i$$

Equation (3)

The error variance is:

$$\delta_R^2 = \frac{1}{k}\sum_{i=1}^{k} (r_i - m_R)^2 = \frac{1}{k}\sum_{i=1}^{k} \left[\hat{v}_i - v_i - \frac{1}{k}\sum_{i=1}^{k}(\hat{v}_i - v_i)\right]^2$$

Equation (4)

Unfortunately, we can not use the equation because we do not know the true value $V_1,...,V_k$. In order to solve this problem, we apply a stationary random function that consists of several random variables, $V(X_i)$. X_i is the location of observed data for i > 0 and i <= n. (n is the total number of observed data). The unknown value at the location X_0 we are trying to estimate is $V(X_0)$. The estimated value represented by random function is:

$$\tilde{V}(x_0) = \sum_{i=1}^{n} w_i * V(x_i)$$

$$R(x_0) = \tilde{V}(x_0) - V(x_0)$$

Equation (5)

The error variance is :

$$\tilde{\delta}_R^2 = \tilde{\delta}^2 + \sum_{i=1}^{n}\sum_{j=1}^{n} w_i w_j \tilde{C}_{ij} - 2\sum_{i=1}^{n} w_i \tilde{C}_{i0} + 2\mu\left(\sum_{i=1}^{n} w_i - 1\right)$$

Equation (6)

$\tilde{\delta}^2$ is the covariance of the random variable $V(X_0)$ with itself and we assume that all of our random variables have the same variance.

In order to get the minimum variance of error, we calculate the partial first derivatives of the equation (6) for each w and setting the result to 0. Here is the example of differentiation with respect to w_1:

$$\frac{\partial(\tilde{\sigma}_R{}^2)}{\partial w_1} = 2\sum_{j=1}^{n} w_j \tilde{C}_{1j} - 2\tilde{C}_{10} + 2\mu = 0 \qquad \sum_{j=1}^{n} w_j \tilde{C}_{1j} + \mu = \tilde{C}_{10}$$

Equation (7)

All of weight W_i can be represented as:

$$\sum_{j=1}^{n} w_j \tilde{C}_{ij} + \mu = \tilde{C}_{i0}$$

For each ***i, 1 <= i <= n*** Equation (8)

One can get the each weight W_i through equation (8). After getting the value, one can estimate the value located in X_0.

The program (Surfer) uses variogram instead of covariance to calculate each weight of equation (8). The variogram is :

$$\gamma_{ij} = \tilde{\delta}^2 - \tilde{C}_{ij}$$

Equation (9)

The minimized estimated variance is:

$$\tilde{\delta_R}^2 = \sum_{i=1}^{n} w_i \gamma_{i0} + \mu$$

Equation (10)

The kriging module includes two variogram models:
(A): spherical

$$\tilde{\gamma}(h) = \begin{cases} C_0 + C_1 \left(1.5 \frac{h}{a} - 0.5 \left(\frac{h}{a} \right)^3 \right) & if\ |h| \le a \\ C_0 + C_1 & if\ |h| > 0 \end{cases}$$

(B): exponential

$$\tilde{\gamma}(h) = \begin{cases} 0 & if\ |h| = 0 \\ C_0 + C_1 \left(1 - exp\left(\frac{-3|h|}{a} \right) \right) & if\ |h| > 0 \end{cases}$$

Note that though the value of the variogram for h = 0 is strictly 0, several factors, such as sampling error and short scale variability, may cause sample values separated by extremely small distances to be quite dissimilar. This causes a discontinuity at the origin of the variogram. The vertical jump from the value of 0 at the origin to the value of the variogram at extremely small separation distances is called the nugget effect.

As the distance of two pairs increases, the variogram of those two pairs also increases. Eventually, the increase of the distance cannot cause the variogram increase. The distance which causes the variogram to reach a plateau is called the range, represented by "a" (see Figure A1).

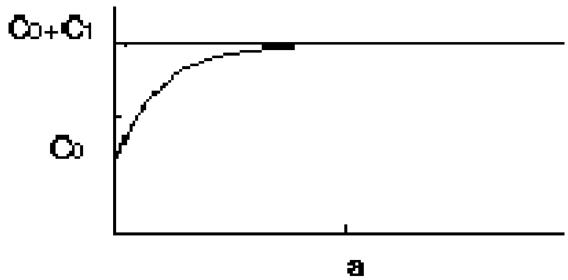


Figure A1. An example of an exponential variogram model

Equation (8) can be written in matrix notation as

V * W = D

V is an (n+1) by (n+1) matrix which contains the variogram of each known datum. The components of last column and row are 1 and the last component of the matrix is 0.

W is an (n+1) matrix which contains the weight corresponding to each location. The last of component of this matrix is the Lagrange Parameter.

D is an (n+1) matrix which contains the variogram of known data and estimated data. The last component of the matrix is 1.

Since V and D are known, one can get the unknown matrix W by :

W = invert(V) * D

Applying equation (5), one can get the estimated value for a specific location. One also can get the error variance from the square root of equation(10).

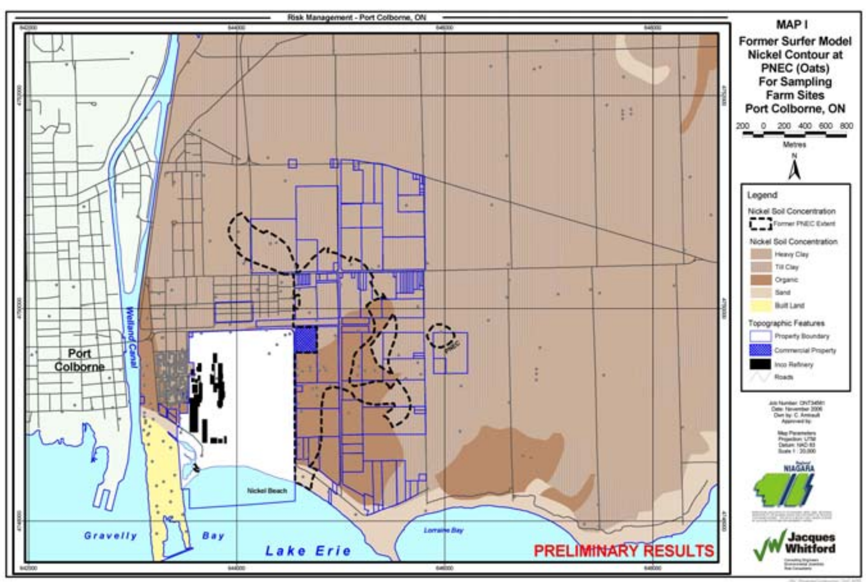
Results

Map B1 shows the sampling points taken by Jacques Whitford and the Ministry of the Environment. The contours of Ni in soils are shown as heavy blue lines. The property boundaries and roads are shown as light blue lines.

Map B1

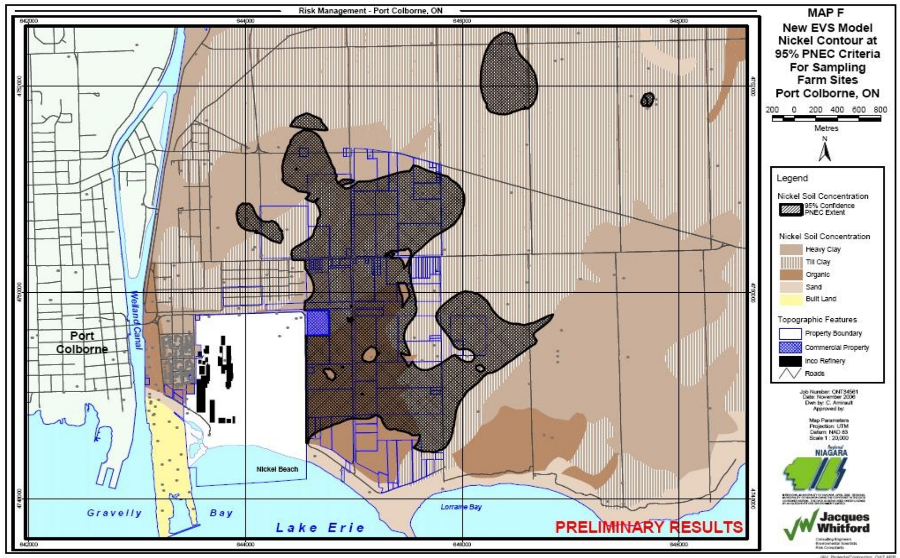
In some areas the sampling density is fairly high and the resulting contours have a high certainty. In other areas, however, a low sampling density results in a relatively high contour uncertainty. If one were to apply the existing sampling to determine which properties have Ni concentrations in soil > PNEC (oats), those properties lying within the dashed bold line in Map I would be remediated.

Map I



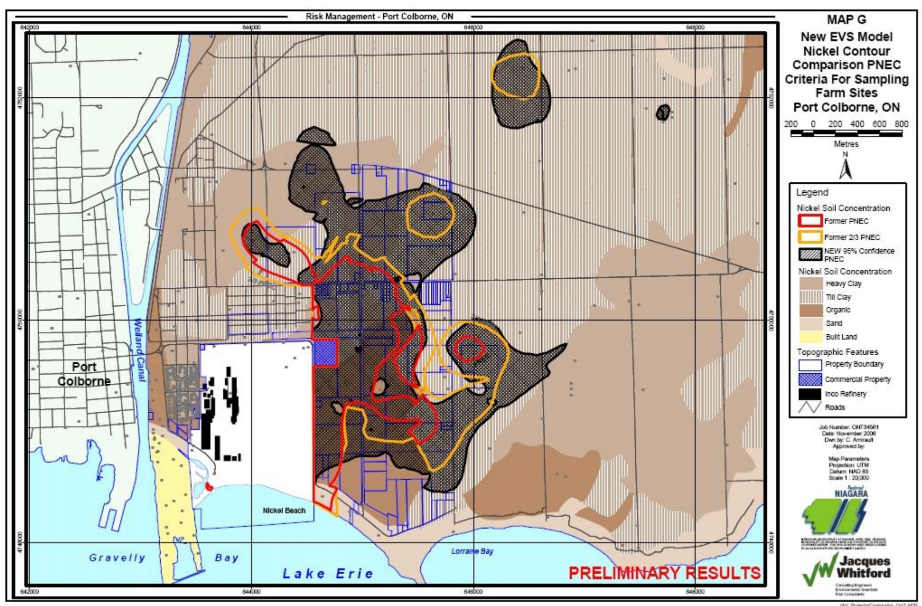
The PNEC (oats) contour in Map I has a strange shape because the PNECs for different soil types are all given together. This results in sharp turns in the contour when the soil type changes. Vale Inco believes that using this PNEC contour for decisions about remediation is not appropriate because too much uncertainty in the contour exists due to a lack of sampling density of the existing data. More sampling is needed for particular properties. In order to decide which properties need to be sampled, a larger area was defined by the 95% lower confidence interval (LCI) of the PNEC (oats), and this is shown in Map F.

Map F is shown to the right. The contour modelling program was used to calculate the 95%LCI for the PNECs (oats). By comparing Map F and Map I, it can be seen that the area shaded in Map F is larger.



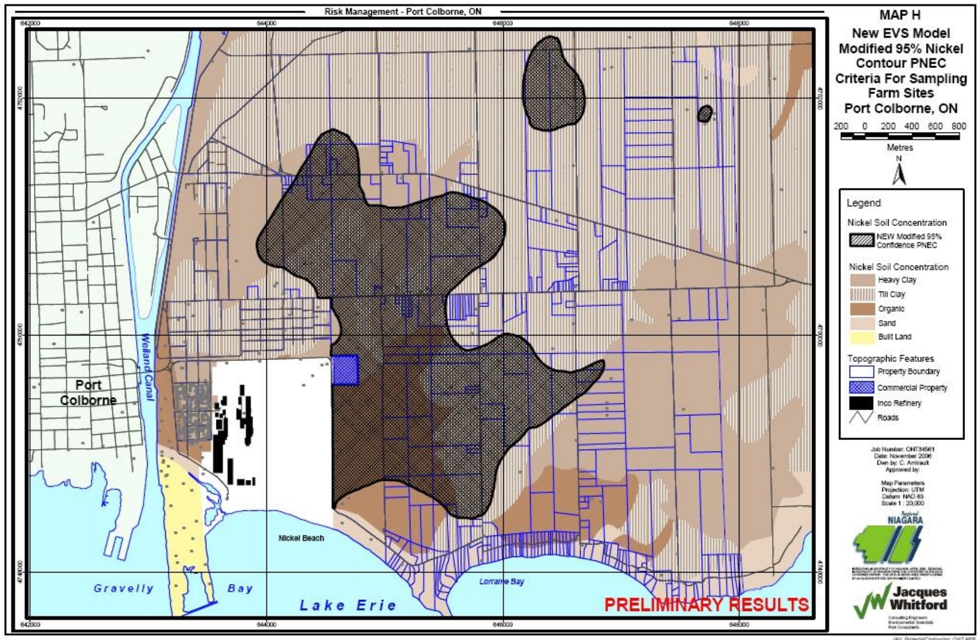
Map F

One can also compare the 95% LCI area with the initial proposed criterion of 2/3 of the PNEC (oats) shown in Map G. The red line is the PNEC and the yellow line is the 2/3 PNEC contour. In each case the new 95% LCI shaded area is larger and therefore results in more farms being sampled.



Map G

It was further decided to smooth the shaded area in Map G. This smoothing was done by hand and is shown in Map H. This map shows the final shaded area which defines the farm properties qualifying for additional site-specific sampling. Any portion of a farm that lies within the shaded area qualifies that farm for sampling. Remediation decisions about that farm will be made based on the results of that sampling as compared to the PNEC (oats) for the particular soil type present.



Map H