Detailed Human Health Risk Assessment: Lyon's Creek West

Submitted to:

Niagara Peninsula Conservation Authority

Dillon Project No. 04-2907

Submitted by

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EXECUTIVE SUMMARY

The governments of Canada and the United States have identified the Niagara River Watershed as an *Area of Concern* (AOC). Tributaries of the Niagara River, such as Lyon's Creek are considered part of this AOC. Since 1991, several studies have identified the presence of *polychlorinated biphenyls* (PCB) and in sediment and soil on the Lyon's Creek West site. The presence of these contaminants in soil and sediments represents a potential route of exposure for people who live adjacent to the Lyon's Creek West site and for people from the City of Welland and others who may use the site for recreational purposes. A *Human Health Risk Assessment* (HHRA) was undertaken to determine the potential health risks for people who may come into contact with contaminants that originate from within the Lyon's Creek West site. The results of the HHRA will form part of a larger review and will be an important component in support of the development of a remedial action plan for the Lyon's Creek West study area.

The HHRA for the Lyon's Creek West site focused on the presence of PCB and metals in the soil and sediment on the site. The site contains a wetland area, which is made up of the upper portion of Lyon's Creek and two ditches that drain the surrounding lands into Lyon's Creek, and an area of open field (Upland area) that surrounds the wetland area. From observations made during visits to the site, it is evident that members of the local community regularly use the Upland area of the site for recreational activities. There is little evidence to suggest that the wetland area is used for recreational activities. Paths or other forms of access to the Wetlands area were not observed. Based on the difference in use patterns between the two areas of the site, the Lyon's Creek West site was divided into the Upland and Wetlands areas and potential exposures were estimated for each area.

The results of the chemical screening determined that arsenic, iron and manganese were the only contaminants present in the soil on the Upland area that exceeded their respective human health-based screening guidelines. Exposures to these contaminants were evaluated for receptors in all five age groups (infant, toddler, child, teen, adult). On the Wetlands area, arsenic and PCB were the only contaminants present in the sediments at levels that exceeded their respective human health-based screening guidelines. In addition to total PCB, *dioxin-like polychlorinated biphenyls* (DL-PCB) was included in the assessment of sediment-borne contaminants in the Wetlands area. Exposures to arsenic, PCB and DL-PCB in the Wetlands area were assessed for the child, teen and adult receptor. Due to the difficulty in accessing the Wetlands area of the site, the HHRA assumed that infants and toddlers would not be present on the Wetlands area of the Lyon's Creek West site.

Based on the results of the HHRA it was concluded that:

- The *Hazard Quotients* (HQs) associated with exposure to iron and manganese in the soil on the Upland area of the Lyon's Creek West site are below the hazard acceptability benchmark of 0.2 for people in all age groups. Therefore, exposure to iron and manganese in the soil on the Upland area would not be expected to result in any adverse human health effects for recreational users of the site.

- The initial assessment of the potential risks associated with exposure to arsenic in the soil on the Upland area of the Lyon's Creek West site, indicated that the incremental increase in lifetime cancer risk (IILCR) (6.3 x 10^{-6}) exceeds the risk acceptability benchmark of 10^{-6}. However, it should be noted that the *Exposure Point Concentration* used to estimate exposures to arsenic on the Upland area included 3 samples collected from the western end of the south ditch where arsenic levels were substantially higher than arsenic levels across the rest of the Upland area. Removal of these three samples from the data set reduces the *Upper Concentration* Limit (UCL) for arsenic to 5.9 mg/kg that is well below the standard of 20 mg/kg for residential/parkland land use. Therefore, arsenic levels are below the level of concern for human health across the majority of the Upland area. Based on this, exposure to arsenic would not be expected to result in an unacceptable increase in lifetime cancer risk for recreational users of the site.

- Potential concerns related to exposure to arsenic in the soil in the western portion of the south ditch have been addressed through the excavation of the south drainage ditch completed between August and September, 2007. Confirmatory sampling, completed as part of the excavation, showed that arsenic levels were below the MOE Table 3 standards for residential soil.

- Exposure to arsenic, PCB and DL-PCB in the sediments on the Wetlands area of the Lyon's Creek West site would not be expected to result in adverse human health effects. The HQs associated with recreational use exposure to PCB and DL-PCB in the sediments on the Wetlands area were below the 0.2 hazard acceptability benchmark for all three receptor age groups.

- The IILCR associated with exposure to arsenic in the sediment was below the 10^{-6} risk acceptability benchmark. Therefore, exposure to arsenic in the sediment on the Wetlands area of the Lyon's Creek West site, would not be expected to result in an unacceptable increase in life-time cancer risk for the recreational user of the site.

In summary, exposure to contaminants in soil on the Upland area and in sediments on the Wetlands area would not pose a potential concern for human health, based on the exposure estimates used in this risk assessment.

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1 INTRODUCTION

1.1 Background

The governments of Canada and the United States have identified the Niagara River Watershed as an *Area of Concern* (AOC). Tributaries of the Niagara River, such as Lyon's Creek are considered part of this AOC. Over the years, the discharge of chemicals from industrial facilities, sewer overflows and non-point sources have all contributed to contaminant loadings in these tributaries. The movement of contaminants from these tributaries into the Niagara River contributes to the contaminant burden in the Niagara River.

The movement of contaminated sediments from these tributaries into the Niagara River has been identified as a potential concern. Management of sediments has been identified as part of the remediation effort. Prior to the management of sediments, there is a need to identify the environmental fate of contaminants, potential transport pathways and potential toxic effects to determine the potential for these contaminants to contribute to the impairment of the beneficial uses of the environmental resources in the Niagara River AOC.

Canada and Ontario, under the *Canada-Ontario Agreement* (COA), are working to understand, restore and protect environmental quality in the Niagara River AOC. As part of this agreement, contaminated sediments in Lyon's Creek must be dealt with in a manner that is deemed appropriate under the COA and the *Remedial Action Plan* (RAP) that has been developed for the Niagara River AOC. Since 1991, several studies of soil and sediment quality have been undertaken within the Lyon's Creek West study area. These studies have identified the presence of *polychlorinated biphenyls* (PCB), metals and other contaminants in the soil and sediments in Lyon's Creek West.

Previous environmental investigations on the Lyon's Creek West site identified the presence of *polychlorinated biphenyls* (PCB), and metals in soil and sediment. The presence of these contaminants represents a potential route of exposure for people who live adjacent to the site and for people from the City of Welland and others who may use the site for recreational purposes. A *Human Health Risk Assessment* (HHRA) was undertaken to determine the potential health risks for people who may come into contact with contaminants that originate from within the Lyon's Creek West study area. The results of the HHRA will form part of a larger review and will be an important component in support of the development of a remedial action plan for the Lyon's Creek West study area.

1.2 Scope and Objectives

This report provides the HHRA phase in the development of remedial options for the Lyon's Creek West site. It is designed to address potential human health concerns related to the presence of PCB and other contaminants in the soil and sediment on the Lyon's Creek West site. Ecological concerns are not addressed in this report. The HHRA is based on soil and sediment quality data collected on the site from 1991 through 2004. The report has relied on the compiled historical data presented by Golder (Golder 2004, Golder 2005) and additional samples collected by Dillon as part of this HHRA. The data used in this report is discussed in detail in Section 2.

1.3 Organization of the Report

This report is organized in 9 sections and 2 appendices, of which this introduction is the first. Section 2 provides a summary of the environmental monitoring data available for the Lyon's Creek West study area. Section 3 presents the Problem Formulation that identifies the contaminants of concern, the potential receptors and the active or complete exposure pathways. Section 4 presents the results of the Exposure Assessment. Section 5, the Toxicity Assessment provides a listing of the toxicological reference values used to assess the potential hazards/risks associated with exposure to the chemicals of concern on the site. Section 6 characterizes the risks associated with exposure to chemicals in the soil for all identified receptors. Section 7 provides a discussion of the uncertainties associated with the hazard and risk estimates from the HHRA. Section 8 provides a summary of the recommendations and conclusions stemming from the HHRA. Section 9 lists the citations for the reference materials used in the development of the HHRA. Appendix A provides a listing of the sediment and soil monitoring data that has been used to calculate sediment and soil concentrations for PCB and metals, as well as a tabular summary of TEQ calculations for DL-PCB in sediment and soils. Appendix B provides the statistical analysis used to determine the Upper Concentration Limit for PCB and metals.

1.4 Limitations

Risk assessments, by their nature, have inherent limitations and uncertainties. It is believed that these uncertainties have been addressed through the conservative interpretation of site-specific data and parameter selection, and in the conservatism inherent in existing toxicity information. The quantitative estimates of risk provided by this process are valid only for the assumptions and exposure scenarios outlined in this report. However, should knowledge of the site conditions or toxicity information change, the risk posed by the site may differ from that presented in this report.

This report was prepared exclusively for the purposes, project, and site location outlined in the report. The report is based on information provided to, or obtained by Dillon as indicated in the report, and applies solely to site conditions existing at the time of the site investigation. Where the risk assessment has relied on information provided to Dillon by the other parties, Dillon has, within the scope and expectations of the risk assessment process, reviewed this data but Dillon does not warrant the accuracy, completeness and representativeness of this information. Dillon's report represents a reasonable review of available information within an established work scope, work schedule, and budget.

This report was prepared by Dillon for the sole benefit and use of the Niagara Peninsula Conservation Authority and the Ontario Ministry of the Environment. The material in it reflects Dillon's best judgement in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decision made based on it, are the responsibilities of such third parties. Dillon accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

2 SITE CHARACTERIZATION

2.1 Site Description

2.1.1 Site Location and Land Use

Lyon's Creek West is a small segment of the upper reaches of the Lyon's Creek watershed that was separated from Lyon's Creek East by the construction of the Welland Canal Bypass in the 1970's. The site is bounded by the Seaway Service Road to the east, Robert St. to the North, Marc Boulevard to the west and Chantal Ct. and Humberstone Road to the south (see Figure 1). Pedestrian access to the site is possible from all of these roads, and an informal parking area exists at the northeast corner of the site, at the south end of Bradley Avenue. The site includes open vacant fields which, between the adjacent stormwater management facility and surrounding residences, are maintained by the City as manicured lawn. East of the stormwater facility, towards the Welland Canal Bypass, the lawns give way to meadows, shrub thickets and a small remnant woodlot. The site also includes two drainage ditches, one of which leads from Humberstone Road to the south, and the other crosses the northern portion of the site after exiting a stormwater outfall adjacent to the stormwater management facility. These ditches convey drainage to the upper and lower ends of the wetland area that is the remnant of the upper reaches of Lyon's Creek at the site.

The south drainage ditch is a man-made drainage feature that supports intermittent flows from Humberstone Road and drains to the upper end of the wetland. Thick growths of cattail in the south ditch suggest that, despite intermittent flow conditions, it remains wet for significant periods. This ditch is reported to be the main source of water for the upper portion of the wetland area on the property (Golder, 2004). A second ditch, runs across the northern portion of the site (Figure 2). The northern ditch enters the site through a concrete outfall a short distance east of Marc Boulevard and drains a portion of southeast Welland. The north drainage ditch is also an artificial feature, but unlike the south ditch, it has features associated with permanent flow and was observed to be flowing during each site visit. Prior to 1992, this ditch also drained through the wetland to the Welland Canal. In 1992, the City of Welland rerouted the north ditch to bypass the wetland area and relocated its confluence with the remnant section of Lyon's Creek to a location immediately upstream of the outfall to the Welland Canal. The stormwater management facility, located centrally within the site, is protected by a high chain-link fence, such that public access is effectively prevented as a safety measure. The facility is not a naturalized stormwater pond, but is comprised of a large concrete basin, which would not be particularly attractive to potential trespassers.

Based on information provided to Dillon by the NPCA, the site is used by the local community for recreational activities. The site is accessible from the surrounding roads. Footpaths and all-terrain vehicle (ATV) trails are evidence of hiking and other recreational activities at and around the upland portions of the site. However, there was no evidence of trails leading into or within the wetland area of the remnant Lyons Creek. There are no sports fields, baseball diamonds, or playground sets at the site. Use of the site by the public appears entirely informal.

The location of footpaths suggests that the main pedestrian traffic on the site passes along a "short cut" between Bradley Avenue and Chantal Court, making use of the small bridge over the north ditch, passing east of the stormwater management facility and avoiding the extensive patches of poison ivy in the unmanicured meadow to the east. Pedestrian traffic in other areas of the mowed lawn portions of the site has not been of sufficient magnitude to establish footpaths. Based on Dillon's incidental observations of visitors to the site, most of the pedestrian and cyclist activity in the area seems to be focused east of the wetland area, along the Seaway Service Road, which avoids vegetated areas, provides a good surface and affords a view of the canal. Footpaths lead into the small woodlot that is located east of the wetland, and there was some evidence of past mountain bike activity, but these trails were not well-worn and were difficult to traverse in places due to regrowth of vegetation. Trails within the unmanicured meadow surrounding the wetland and woodlot area were mostly due to recreational use of ATVs at the site. Poison ivy is conspicuously and abundantly present at the site, within meadows and within and along the edge of the wooded border of the wetland and the remnant woodlot, and likely acts as a deterrent to pedestrian traffic. The ATV trails are not extensive, being focused mainly on the rolling spoil piles north of the north ditch bypass, and appearing to be only a small portion of the area locally available to riders along the Seaway Service Road.

Evidence of community access to the creek/wetland, the north and south drainage ditches and the adjacent bank areas was very limited. The south drainage ditch is heavily vegetated and is crossed by culvert and limestone gravel path. There was no evidence of intrusion into the ditch or along its banks. The north drainage ditch is surrounded by manicured lawn at its west end and may be visited periodically by children and teenagers in this area. It should be noted that this portion of the north drainage ditch was previously dredged to remove contaminated sediments. The north ditch bypass is a steep-sided trench and there was no evidence of activity in this portion that was excavated through clean soils. The bypassed downstream section of the north ditch remains as a heavily vegetated damp depression, with no evidence of foot traffic or recreational use. The vegetation, including shrub thickets, stands of burdock and poison ivy immediately adjacent to the creek discourages access to these areas. Within the wetland portion of Lyons Creek, deep soft sediments and thick stands of common reed and cattail make access to these areas difficult.

Although some sunfish and minnows were observed within the north drainage ditch, and there is a small open water area at the confluence of the north ditch and the wetland, there was no evidence of recreational fishing at the site. The remnant reach of Lyons Creek is too shallow and heavily vegetated to support significant fish populations or to be attractive to anglers.

Based on these observations, the site was divided into two areas for the purposes of the risk assessment:

- Wetlands Area:
  The wetlands area has been defined as the drainage ditches, wetland area, Lyon's Creek and the banks associated with these areas (see Figure 2).
- Uplands Area:
  The Uplands area is defined as all remaining portions of the site not encompassed within the wetlands area (see Figure 2).

The wetlands area includes areas historically and currently contaminated by metals and PCBs, but also includes the remediated north drainage ditch and the clean reach of the north drainage ditch bypass. The wetlands area is held distinct from the uplands area of the site based both on its physical attributes (i.e., wetness and thick vegetation) and the lack of evidence of human use of that portion of the site.

The uplands area includes the lawns, meadows, thickets, woodlot and trails that surround the wetland portion of the site. These are the areas that are most accessible on the site and showed some sign of use by the public. And as the metals and PCBs contamination on the site are concentrated within the watercourses, the uplands area is also the least contaminated portion of the site.

2.1.2 Site Hydrogeology

The reports included for consideration in the HHRA did not provide any information relating to the hydrogeology of the Lyon's Creek West site of the lands immediately adjacent to it. Because the residential properties in the vicinity of the site are supplied with municipal drinking water that is not derived from groundwater in the area, groundwater does not represent a potentially complete exposure pathway on the site. However, limited groundwater data are available for a portion of the site, and supported a conclusion that PCBs were not being transported in groundwater from contaminated sediments within the Lyons Creek wetland area (AMEC, 2002).

2.2 Summary of Available Data

A number of environmental investigations have been conducted on the site since 1991. A summary of the historical data was developed as part of the Niagara River RAP (Golder, 2004). The studies summarized in the 2004 Golder report include:

- Beak, 1990;
- St Lawrence Seaway Authority (SLSA), 1991;
- Ontario Ministry of the Environment, 1991;
- Environmental Strategies Limited, 1992.

The Beak 1990 data is limited to 21 samples collected during an initial site characterization as part of the planned construction of Highway 406. The information available suggests that the areas where these samples were collected were removed during remediation activities undertaken in 1991. Therefore, these samples have not been included in the current assessment.

Golder collected additional soil, sediment and vegetation samples for arsenic, PCB and zinc analysis (Golder, 2004) and further soil and sediment samples in 2004 (Golder, 2005). The samples collected by Golder focused on the wetlands areas of the site. Environmental data for the uplands areas of the site was limited to the data collected by the SLSA in 1991. Dillon undertook an additional sampling program to provide additional characterization of metal and PCB concentrations in soil in the uplands areas of the site. The sampling data reported and collected by Golder and the additional sampling data collected by Dillon as part of this HHRA for the Wetlands and Upland areas are summarized in Appendix A.

This risk assessment is focused on potential human exposures that could occur during recreational activities on the site. The site is not used for local food production, nor is there evidence that berries or other wild foods, including fish, are collected from the site. As a result, direct exposures to contaminants present in the soil are the only potentially complete exposure pathways for people who use the site for recreational purposes. Therefore, soil and sediment data are the only data that have been considered in this assessment. The mechanisms that govern human exposure to sediments do not differ from those that govern human exposure to soil, and standard risk assessment practice assesses human exposures to sediments in the same manner as human exposures to soil. Therefore, soil and sediment data have been combined to provide a single data set for the wetlands area. Tabular summaries of the PCB and metals (particularly arsenic) data used to characterize soil conditions in the wetlands and uplands areas of the site are provided in Appendix A.

2.2.1 Wetlands Soil and Sediment Data

The historical data summarized by Golder and the additional sampling data collected by Golder between 2003 and 2004 (Golder 2004, Golder 2005) have been combined to provide a single soil and sediment data set that covers the wetlands area. This provides approximately 99 data points for PCB, 29 data points for arsenic and 29 points for zinc. The concentrations of other metals were not reported. Summaries of the soil/sediment quality data sets for the wetlands area are provided in Appendix A.

For each contaminant, minimum, maximum and mean values and the *Upper Confidence Limit* (UCL) were calculated using ProUCL® (Version 3) software available from the US EPA. ProUCL tests datasets for several potential distributions including; normality; log-normality; and gamma distributions, and calculated a conservative 95% UCL of the mean. A detailed summary of ProUCL and the various statistical approaches it applies to the calculation of UCL can be found in the ProUCL User Guidance Manual (Singh et al. 2004) available through the US EPA. ProUCL provides a statistical summary for each chemical constituent and, based on the analysis, recommends the most stable UCL for use as the *Exposure Point Concentration* (EPC) for use as input to the risk assessment. A summary of the recommended UCL and the statistical basis for the value for PCB, arsenic and zinc for the wetland area are provided in Table 2-3. In cases where the ProUCL software recommends more than one possible UCL, the highest recommended value has been selected. The statistical summary outputs from the ProUCL software are provided in Appendix B.

In addition to evaluating exposures to total PCB, the risk assessment considered the potential hazards associated with exposures to dioxin-like PCB (DLPCB). This group of PCB isomers and congeners has similar biological mechanisms of action to polychlorinated Dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF). Where PCB congener analysis data was available, the concentration of DLPCB was calculated. These concentrations were expressed as ng Toxicity Equivalent (TEQ) DLPCB/g soil.

The various isomers and congeners of PCDD, PCDFs and DLPCBs all have the same biological mechanism of action (*ie.* they all work on the body in the same way). However, they differ in their levels of toxicity. In assessing PCDD/PCDF and DLPCB concentrations in soil, the concentrations of the individual isomers and congeners are converted to a *Toxicity Equivalent* (TEQ) concentration which effectively expresses the concentration of individual isomers and congeners as function of its effective concentration relative to the most biologically active congener (2,3,7,8-TCDD) which is assigned an *Toxicity Equivalency Factor* (TEF) of 1.0. The concentrations of the individual PCDD and PCDF isomers and congeners are multiplied by their respective TEF to provide a toxic equivalent concentration or TEQ. For example if the soil concentration of octachlorodibenzo-p-dioxin (OCDD) is reported as 500 ng/g, this is converted to a TEQ concentration by multiplying the reported concentration by the TEF for OCDD (500 ng/g x 0.0001 = 0.5 ng TEQ/g). Similar calculations are completed for each PCDD, PCDF and DLPCB and the TEQ concentrations are summed to provide a total or overall TEQ for the sample. This approach has been used to calculate the TEQ concentration of DLPCB in the wetlands area of the Lyon's Creek West site, as summarized in tabular format in Appendix A. The TEQ concentrations range from 0.0058 ng/g TEQ to 0.5232 ng/g TEQ in the wetland sediments. The maximum TEQ concentration of 0.5232 ng/g TEQ in sediment in the wetlands area is reported in Table 2-3.

Table 2-3: Recommended Upper Concentration Limits for the Wetlands Area

Contaminant	Recommended UCL	
	Statistical Basis	Value (mg/kg)
Arsenic	95% H-UCL	64.9
Zinc	99% Chebyshev (Mean, Sd) UCL	2297
PCB	Adjusted Gamma UCL	24.9
DL-PCB	Maximum Value	0.5232 ng/g TEQ

2.2.2 Uplands Soil Data

The historical data summarized by Golder and the additional sampling data collected by Golder between 2003 and 2004 (Golder 2004, Golder 2005) and Dillon in 2004 have been combined to provide a single soil data set that covers the uplands area. This provides approximately 77 data points for PCB, 37 points for arsenic and 20 points for zinc and other metals. Summaries of the soil quality data sets for the uplands area are provided in Appendix A.

For each contaminant, minimum, maximum and mean values and the *Upper Confidence Limit* (UCL) were calculated using ProUCL®. A summary of the recommended UCL and the statistical basis for the value for PCB, arsenic and other metals for the upland area are provided in Table 2-4. In cases where the ProUCL software recommends more than one possible UCL, the highest recommended value has been selected. The statistical summary outputs from the ProUCL software are provided in Appendix B.

A review of the arsenic data set identified three samples (LC-1, LC-2 and T1-M, Golder 2004), where arsenic levels were substantially higher than arsenic concentrations across the rest of the site. These samples are located at the western end of the south drainage ditch which drains the Hydro One Crowlands Transformer Station to the west of the Lyon's Creek West site. When included in the UCL calculations, these samples resulted in a UCL of 32.4 mg/kg. However, arsenic concentrations in the remainder of the samples are below 14 mg/kg, considered to be representative of background concentrations in Ontario (MOE, 2004) (Table 1 value for agricultural land). This would suggest that arsenic would not be considered a potential concern over much of the site, but would be limited to a relatively small portion of the heavily vegetated south drainage ditch. To determine the potential effect that the inclusion of these samples could have on the risk assessment, these samples were removed from the data set for the upland area and the UCL was recalculated at 5.9 mg/kg. Both values are provided in Table 2-4.

Table 2-4: Recommended UCL Values for Upland Area

Contaminant	Recommended UCL	
	Statistical Basis	Value (mg/kg)
Aluminum	Student's-t UCL	21083
Antimony	Mod-t UCL (Adjusted for skewness)	0.55
Arsenic	95% Chebyshev (Mean, Sd) UCL	32.4
Arsenic (minus LC-1, LC-2 & T1-M)	Student's-t UCL	5.9
Barium	Approximate Gamma UCL	121
Cadmium	Mod-t UCL (Adjusted for skewness)	0.29
Chromium	Mod-t UCL (Adjusted for skewness)	46.3
Cobalt	Student's-t UCL	13.8
Copper	Mod-t UCL (Adjusted for skewness)	29.5
Iron	Student's-t UCL	37120
Lead	Mod-t UCL (Adjusted for skewness)	35.0
Manganese	Student's-t UCL	852
Molybdenum	Mod-t UCL (Adjusted for skewness)	2.5
Nickel	Mod-t UCL (Adjusted for skewness)	44.8
Selenium	Mod-t UCL (Adjusted for skewness)	0.49
Silver	All 20 samples same value	0.50
Strontium	Student's-t UCL	74.8
Titanium	Student's-t UCL	281
Vanadium	Student's-t UCL	42.5
Zinc	95% Chebyshev (Mean, Sd) UCL	315
PCB	97.5% Chebyshev (Mean, Sd) UCL	0.49

3 PROBLEM FORMULATION

3.1 Identification of Contaminants of Potential Concern

The objective of the contaminants screening process is to determine which contaminants are present in the environment at levels that may pose a potential risk to human health or the environment. The identification of contaminants of concern is based on a comparison of contaminant concentrations and applicable screening guidelines. Guidelines have been established for several environmental media including soil, groundwater, surface water and ambient air. These guidelines are established using very conservative assumptions that overestimate exposures. As a result, the guidelines represent contaminant concentrations that do not pose a risk to human health or the environment. Contaminants that are present at concentrations that are lower than their respective guideline concentration are not considered to pose a risk to humans or the environment. If the concentration of a contaminant exceeds the guideline value, it does not mean that the contaminant poses a risk to humans or the environment. An exceedance of a guideline is an indication that additional work must be undertaken to determine if site-specific exposures to contaminants pose a potential risk. This additional work is usually undertaken in the form of a risk assessment. Thus, contaminants that are present at concentrations that exceed their respective guidelines are identified as contaminants of concern and are carried through to a quantitative risk assessment.

Guidelines have been established by regulatory agencies such as the Ontario Ministry of the Environment (MOE), the Canadian Council of Ministers of the Environment (CCME) and the U.S. Environmental Protection Agency (US EPA). It is important to note that most agencies develop guidelines that are based on human health and ecological effects. Where both values are available, the lower of the two values is selected as the generic or common guideline value. This approach provides protection for both human and ecological receptors. Because the focus of this risk assessment is human health, the screening guidelines selected from the various agencies are those that are based on the protection of human health. The Ontario Ministry of the Environment was used as the primary source of human health-based guidelines (MOE, 1996). Where guidelines were not available from the MOE, the USEPA Region III *Risk Based Concentration Table* (RBC) (US EPA, 2004) was used as an additional source of human health based screening guideline values.

3.1.1 Contaminants of Concern in the Wetlands Area

The focus of this risk assessment is the presence of contaminants in the soil in the uplands area and in the soil and sediment in the wetlands area of the Lyon’s Creek West site. The MOE has not developed human health based screening guidelines for sediment. As noted above (Section 2.2) standard risk assessment practice assesses human exposure to sediments in the same manner as exposure to soil. Therefore, the use of human health based soil screening guidelines to identify potential COCs in both soil and sediment in the wetlands area is appropriate.

The recommended UCL values for the contaminants listed in Table 2-3 are compared to the human health-based screening guideline for residential/parkland use. A chemical is identified as a COC if the UCL exceeds the appropriate screening guideline. The screening for contaminants of concern for the wetlands area is provided in Table 3-1. The calculated UCLs for arsenic and PCB exceed their respective human health-based screening criteria. Therefore, arsenic and PCB were identified as COCs for the wetlands area and have been carried through the risk assessment to determine the potential human health risks associated with exposure to these contaminants in the wetlands area of the site.

Table 3-1: Screening for Contaminants of Concern, Wetlands Area

Contaminant	Recommended UCL (mg/kg)	Screening Criteria (mg/kg)		COC
		Value (mg/kg)	Source	
Arsenic	64.94	20.0	MOE, 2004	Yes
Zinc	2297	16000	MOE, 2004	No
PCB	24.9	5.0	MOE, 2004	Yes

Based on this screening, the COCs for the wetlands area are:

- Arsenic; and
- PCB.

These COCs are therefore carried through to the risk assessment.

3.1.2 Contaminants of Concern in the Upland Area

The recommended UCL values for the contaminants in soil in the upland area, listed in Table 2-4, are compared to the human health-based screening guideline for residential/parkland use. The human health based soil screening guidelines established by the MOE are set to ensure that site-related exposures to contaminants do not exceed 20% of their respective tolerable daily intakes. This is referred to as a *Hazard Index* (HI) of 0.2. When selecting guidelines from other agencies, such as the US EPA, it is necessary that the adopted screening guideline values be based on the same HI value of 0.2 to ensure consistency with the MOE screening guidelines. The US EPA Region III screening guidelines are based on a HI of 1.0 and an assumed soil ingestion rate of 200 mg/day for a toddler. Therefore it is necessary to adjust the US EPA Region III values to account for these differences. Screening guidelines from the US EPA have been adjusted as shown in Equation 3-1.

$$EPA_{adj} = EPA_{sv} \times \left(\frac{HI_{MOE}}{HI_{epx}} \times \frac{SI_{EPA}}{SI_{MOE}} \right)$$

EQ 3-1:

$$EPA_{adj} = EPA_{sv} \times \left(\frac{0.2}{1.0} \times \frac{200 mg / day}{100 mg / day} \right)$$

$$EPA_{adj} = EPA_{sv} \times 0.4$$

Where:

EPA_{adj}	= Adjusted screening value from EPA	µg/g
EPA_{sv}	= EPA Region III screening value	µg/g
HI_{MOE}	= Hazard Index used by MOE	Unitless
HI_{EPA}	= Hazard Index used by US EPA Region III	Unitless
SI_{EPA}	= Soil ingestion rate used by US EPA Region III	mg/day
SI_{MOE}	= Soil ingestion rate used by MOE	mg/day

The US EPA screening guidelines listed in Table 3-2 have been adjusted by a factor of 0.4 as described above. The calculated UCLs for iron and manganese exceed their respective screening criteria and have been carried through to the risk assessment. The UCL for arsenic, based on all data-points exceeds the screening criteria. However, removal of the three arsenic samples from the south drainage ditch (LC-1, LC-2 and T1-M) results in a UCL that is below the screening criterion, and, as noted above, below typical background levels of arsenic. This suggests that arsenic concentrations in the soil do not represent a concern over much of the site. However, to ensure that potential risks are adequately characterized, arsenic was identified as a potential COC for the upland area.

Table 3-2: Screening for Contaminants of Concern, Upland Area

Contaminant	Recommended UCL (mg/kg)	Screening Criteria (mg/kg)		COC
		Value (mg/kg)	Source	
Aluminum	21083	31000	US EPA RIII, 2004	
Antimony	0.55	13	MOE, 2004	
Arsenic	32.4	20	MOE, 2004	Yes
Arsenic: LC-1, LC-2 & T1-M removed	5.9	20	MOE, 2004	
Barium	121	3700	MOE, 2004	
Cadmium	0.29	14	MOE, 2004	
Chromium (III)	46.3	4800	US EPA RIII, 2004	
Cobalt	13.8	2700	MOE, 2004	
Copper	29.5	1100	MOE, 2004	
Iron	37120	23000	US EPA RIII, 2004	Yes
Lead	35.0	200	MOE, 2004	
Manganese	852	640	US EPA RIII, 2004	Yes
Molybdenum	2.5	170	MOE, 2004	
Nickel	44.8	310	MOE, 2004	
Selenium	0.49	320	MOE, 2004	
Silver	0.50	98	MOE, 2004	
Strontium	74.8	19000	US EPA RIII, 2004	
Titanium	281	120000	US EPA RIII, 2004	
Vanadium	42.5	470	MOE, 2004	
Zinc	315	16000	MOE, 2004	
PCB	0.49	5.0	MOE, 2004	

Based on this, the COCs for the upland area include:

- Arsenic (Excluded when LC-1, LC-2 and T1-M are removed);
- Iron; and
- Manganese.

These COCs are therefore carried through to the risk assessment.

3.2 Identification of Potential Receptors

The Lyon's Creek West site incorporates the section of Lyon's Creek that lies west of the Welland Canal. The site is surrounded by residential development to the north, west and south and is adjacent to the Welland Canal Bypass to the east. Although the land is owned by the St. Lawrence Seaway Authority, Hydro One and others, the site is accessible, with the exception of the fenced stormwater management facility, and is used for informal recreational purposes by members of the local community. People living outside the community may also make use of the site for recreational purposes. However, the exposures experienced by these non-resident users would be expected to be less frequent than the exposures experienced by people living in the immediate vicinity of the site.

As stated earlier in this report, there are no sports fields, playground areas or other formal recreational facilities on the site. Evidence of recreational use is limited to footpaths, ATV trails and incidental observations of visitors to the site. These uses appeared to be largely confined to the upland area of the site. While the western portion of the north ditch is accessible from the surrounding lawn, all other portions of the wetlands area designated for the purposes of this risk assessment possess features that are uninviting to the public and there was no sign of intrusion into these areas.

For the purposes of the HHRA, recreational users of all ages have been considered as the primary receptors of concern for both the wetlands and upland areas of the Lyon's Creek West site. The age groups that have been considered in the HHRA include:

- Infants (0-6 months of age)
- Toddlers (7 months through 4 years of age)
- Children (5 years through 11 years of age)
- Teens (12 years through 19 years of age)
- Adults (20+ years of age).

The age groupings for the recreational receptors are consistent with the age groupings typically used by the MOE in assessing potential human health risks and are also consistent with the age grouping recommended by Health Canada (Health Canada, 2004). For the purposes of the HHRA, it has been assumed that recreational users of all ages could spend time on the wetlands and uplands areas of the site.

3.3 Site Conceptual Model

The Site Conceptual Model (SCM) is used to define the potential pathways that may contribute to exposure for the various people who could be on site. In assessing potential exposures to contaminants for the recreational user of the Lyon's creek west site, possible exposure pathways have been evaluated to identify those that are potentially complete. Differences in the physical setting and the types and amounts of vegetative cover between the wetlands and upland areas of the site will likely influence the relative amount of time spent on the two areas of the site. The location of pedestrian and ATV trails in upland areas and a lack of same in the wetland area support this conclusion.

In addition, contaminants at the site are generally associated with sediments of the wetlands area and with soil on the uplands area. This can lead to some differences in potential exposure pathways between the two areas of the site. For this reason, potential exposure pathways have been identified separately for the wetland and upland areas of the site. Listing of the pathways considered for the wetlands and upland areas are provided in Table 3-3 and Table 3-4. These tables provide rationales to support the inclusion of active pathways and the exclusion of pathways that are considered incomplete.

Table 3-3: Potentially Complete Exposure Pathways for the Wetlands Area

Media	Exposure Route	Pathway	Retained	Rationale
Sediment	Inhalation	Inhalation of re-entrained sediment dusts	No	Sediments will either be wet, covered by a layer of live and decomposing vegetation, or under water. Therefore, sediments will not be re-entrained in the air column as a result of wind action.
	Ingestion	Incidental ingestion of sediment	Yes	Incidental ingestion of sediment is a potentially complete exposure pathway.
		Uptake into plants and consumption of plants	No	People are not expected to consume plants from the wetlands area of the Lyon's Creek West site.
		Uptake into animals and consumption of animals	No	Recreational fishing or the collection of wild foods have not been identified as activities on the site. Site characteristics are not favourable for these activities.
	Dermal Contact	Dermal Contact with Sediment	Yes	Dermal contact with sediment is a potentially complete exposure pathway
Soil	Inhalation	Inhalation of re-entrained soil & dust	No	Contaminants in the wetlands area are assumed to be associated with sediments.
	Ingestion	Ingestion of soil		
		Uptake into plants and animals and consumption of plants and animals		
	Dermal Contact	Dermal contact with soil		
Air	Inhalation	Inhalation of compounds in indoor air	No	The COC, (arsenic and PCB) are not volatile and therefore, the inhalation of vapours is not a potentially complete exposure pathway.
		Inhalation of compounds in outdoor air	No	
Drinking Water	Ingestion	Ingestion of compounds in drinking water derived from on-site groundwater	No	There is no access to groundwater on the site and the surrounding community is supplied with municipal water.
Surface Water	Ingestion	Incidental Ingestion of surface water while swimming/wading	No	Access the surface water is limited by the vegetation in the wetlands area. Surface waters are very shallow and, combined with deep soft sediments and thick vegetation, are not conducive to swimming or wading.
	Dermal Contact	Dermal contact with surface water while swimming of wading		
Supermarket Food and Consumer Products			No	These exposures will be the same as the general population.

Based on the information presented in Table 3-3, above, the potentially complete exposure pathways in the wetlands area include;

- Incidental ingestion of sediment; and
- Dermal contact with sediment.

Table 3-4: Potentially Complete Exposure Pathways for the Uplands Area

Media	Exposure Route	Pathway	Retained	Rationale
Sediment	Inhalation	Inhalation of re-entrained sediment dusts	No	Contaminants are associated with soil. There are no sediments in the uplands area.
	Ingestion	Incidental ingestion of sediment		
		Uptake into plants and consumption of plants		
		Uptake into animals and consumption of animals		
	Dermal Contact	Dermal contact with sediment		
Soil	Inhalation	Inhalation of re-entrained soil & dust	Yes	Inhalation of contaminants on re-entrained soil or dust particles is a potentially complete exposure pathway. It should be noted, however, that most of the site soils are stabilized by vegetation.
	Ingestion	Ingestion of soil	Yes	Incidental ingestion of soil is a potentially complete exposure pathway.
		Uptake into plants and consumption of plants	No	People are not expected to consume plants from the upland area of the Lyon's Creek West site. Site observations did not reveal extensive stands wild berries or other plant foods.
		Uptake into animals and consumption of animal products	No	The site is not used for raising domestic livestock and there is no evidence of the collection of country foods on the site.
	Dermal Contact	Dermal contact with soil	Yes	Dermal contact with soil is a potentially complete exposure pathway.
Air	Inhalation	Inhalation of compounds in indoor air	No	The COC, (arsenic, PCB, iron and manganese) are not volatile and therefore, the inhalation of vapours is not a potentially complete exposure pathway.
		Inhalation of compounds in outdoor air	No	
Drinking Water	Ingestion	Ingestion of compounds in drinking water derived from on-site groundwater	No	There is no access to groundwater on the site and the surrounding community is supplied with municipal water.
Surface Water	Ingestion	Incidental Ingestion of surface water while swimming/wading	No	There is no continuous source of surface water on the upland area of the site.
	Dermal Contact	Dermal contact with surface water while swimming of wading		
Supermarket Food and Consumer Products			No	These exposures will be the same as the general population.

The potentially complete exposure pathways for the upland area are presented in Table 3-4. Based on this assessment the potentially complete exposure pathways include;

- Incidental ingestion of soil;
- Dermal contact with soil; and
- Inhalation of re-entrained soil and dust.

4 EXPOSURE ASSESSMENT

4.1 Characterization of Potential Receptors

4.1.1 Identifying Receptor Activity Patterns

The level of exposure to contaminants in the soil and sediments on the Lyon's Creek West site that a person could experience depends on how often a person comes into contact with the soil and/or sediment. How often a person comes into contact with soil and/or sediments is determined by the activity patterns that are assumed for each receptor. Health Canada provides generic exposure assumptions for several land-use categories including; agricultural, residential, commercial and industrial sites (Health Canada, 2004). A summary of the exposure frequency and duration assumptions recommended by Health Canada is provided in Table 4-1. These provide reasonable, conservative estimates of potential exposure for people who may be present on a specific site.

Table 4-1: Exposure Duration and Frequency Assumptions (Health Canada, 2003)

	Land Use Categories			
	Agricultural	Residential	Commercial	Industrial
Hours per day on-site	24	24	8	8
Days per Week On-Site	7	7	5	6
Weeks per Year On-Site	52	52	52	48

However, the Health Canada exposure assumptions do not account for the period of the year when the ground is either frozen or snow-covered. In addition, the assumptions regarding the *Number of Days On-Site* and the *Weeks per Year On-site* for residential or commercial land-use do not adequately describe the amount of time that a person could spend on site for informal recreational purposes. In order to provide exposure estimates for all receptors that are representative of the local conditions, assumptions regarding the potential frequencies for direct contact with soil and/or sediments have been adjusted to account for the times that local residents could spend on the Lyon's Creek West site and to account for the period of the year when access to soils and sediments is restricted due to frozen or snow-covered conditions. For the purposes of this assessment the frost and snow free period is assumed to be 35 weeks (mid March to mid-November).

The length of time a person could be expected to spend on the Lyon's Creek West site is determined by the activity patterns that are assumed for each receptor. Visits to the site conducted by Dillon in the fall of 2004 identified numerous trails across the uplands area of the site, with most of the trails on the spoil piles and other meadow areas associated with the Seaway Service Road closer to the Welland Canal Bypass. However, there was no evidence of trails or access paths in the wetlands area of the site. Additional information provided by Golder (Rein Jaagumagi personal communication) supported these observations.

This information has been used to estimate activities patterns for people who may use the upland and wetlands areas for the Lyon's Creek West site for informal recreational activities. Because the focus of the HHRA is recreational use of the Lyon's Creek West site, activity patterns have been established for all receptor age groups (infant, toddler, child, teen and adult). The activity patterns that have been used to assess potential exposures in the upland and wetland areas are presented in Table 4-2a and Table 4-2b respectively.

Table 4-2a: Activity Patterns for Upland Area

Receptor	Age Group	Activity Pattern Assumptions
Infant	0 – 6 months	Infants up to the age of 6 months would not generally be expected to come into contact with soil on the Lyon's Creek West site. Site characteristics are generally not likely to encourage parents or caregivers to set infants on the ground. For the purposes of the HHRA, it has been assumed that infants would be present on site for 1 hour once per week over the frost-free period of the year (35 weeks), in the company of parents or caregivers walking or cycling through the site. It is expected that this will greatly overestimate potential exposures for infants.
Toddler	7 months – 4 yr	Toddlers are assumed to be on-site for a period of 1 hour once per week during the frost-free period of the year (35 weeks). Similar to the infant group, toddlers are likely to visit the site in the company of parents or caregivers that would be walking or cycling through the site.
Child	5 yr – 11 yr	Children, teens and adults are likely to spend the greatest amount of time on the Lyon's Creek West site. For the purposes of this assessment it has been assumed that children, teen and/or adult receptors would spend up to 2 hours on the site once per week during the frost-free period of the year (35 weeks). This duration of exposure appears consistent with relatively small size of the site relatively to the extent of adjacent trails along the Welland Canal Bypass, and the degree of trail development observed within the site itself.
Teen	12 yr-19 yr	
Adult	20+ yr	

Table 4-2b: Activity Patterns for Wetlands Area

Receptor	Age Group	Activity Pattern Assumptions
Infant	0 – 6 months	Infants and toddlers are not expected to be present in the Wetlands area of the site. Given site conditions, it is assumed that infants and toddlers would be accompanied by parents or caregivers who would prevent access to wet areas of the site. Therefore, these age groups would not generally be expected to come into contact with sediment in the wetlands area.
Toddler	7 months – 4 yr	
Child	5 yr – 11 yr	As noted above, there is little evidence that the local population accesses the Wetlands area of the Lyon's Creek West site on a regular basis. There were no footpaths or ATV trails leading to the wetland area. The western segment of the north ditch portion of the wetland area is relatively accessible from the mowed portion of the site, however this area was previously remediated. For the purposes of this assessment it has been assumed that children, teens and adults will visit the Wetlands area 5 times per year during the frost-free period of the year.
Teen	12 yr-19 yr	
Adult	20+ yr	

4.1.2 Exposure Averaging Factors

The toxicity reference values (TRVs) developed by regulatory agencies are averaged daily exposure values and represent daily exposures that can occur over a life-time without resulting in adverse human health effects or unacceptable increases in life-time cancer risk. The exposures to contaminants in the sediments of Lyon's Creek, experienced by members of the local community who use the Lyon's Creek West site for informal recreational activities, are considered to be intermittent exposures, because exposures will only occur on the days when people are on the Lyon's Creek West site. Before these intermittent exposures can be compared to the appropriate toxicity values, the intermittent exposures must be adjusted to account for the differences in exposure duration between the intermittent exposures on the Lyon's Creek West site and the continuous exposures that were assumed in the development of the toxicity values. The difference in exposure duration is calculated as an *Exposure Averaging Factor* (AF). The activity patterns listed in Table 4-2a and Table 4-2b have been used to calculate the averaging factors for each of the receptor age groups for the Upland and Wetland areas of the site respectively.

The calculation of exposure averaging factors depends on the type of exposure being considered. For example, inhalation occurs on a continuous 24-hour basis regardless of whether a person is on-site or off-site. Therefore, the inhalation exposure experienced by people on a site is a function of the both the time spent on-site in a given day and the number of days spent on-site in a given year. Exposures of this nature are considered to be *Time Driven*. Exposures such as the incidental ingestion of soil or sediment or dermal contact with soil or sediment can only occur when a person is present on-site. These exposures are considered to be *Event Driven*. A discussion of the calculation of the *Event Driven* exposure averaging factors is provided below.

4.1.2.1 Time Driven Exposure Averaging Factors

The calculation of *Time Driven* averaging factors is a function, both of the time spent on the Lyon's Creek West site on a given day and the number of days spent on site in a given year. The *Averaging Factor* (AF) values for *Time Driven* exposures are calculated on the basis of hours per year over which exposures can occur and are calculated as shown in Equation 4-1.

Eq 4-1: Calculation of Exposure Averaging Factor for *Time Driven* Exposures

$$AF = \frac{\left(ED_n \times EF_n \times EW_n \times Years_{(n)}\right)}{\left(24\ {}^{hours}/_{day} \times 365\ {}^{days}/_{year} \times Years_{(a)}\right)}$$

Where:			
	AF	= Averaging Factor	Unitless
	ED_n	= Exposure Duration for receptor "n"	hours/day
	EF_n	= Exposure Frequency for receptor "n"	days/week
	EW_n	= Weeks per year on-site for receptor "n"	weeks/year
	$Years_n$	= Years of exposure	years
	$Years_a$	= Years for averaging exposure	years

Exposure Duration (ED_n)

The exposure duration is defined as the number of hours per day that a person is assumed to be present on site.

Exposure Frequency (EF_n)

The exposure frequency is defined as the number of days per week that a person is expected to be present on-site.

Weeks (EW_n)

The weeks of exposure is defined as the number of weeks per year that a person is assumed to be present on-site.

Years$_{(n)}$

The number of years in an exposure scenario over which exposures are expected to occur. The number of years in the exposure scenario for each receptor is equivalent to the number of years that a receptor spends in each age group. For example, children are considered to be between the ages of 5 and 12 years of age. For this receptor group, the ***Years$_{(n)}$*** would be 7 years.

Years$_{(a)}$

This represents the number of years over which the exposure is to be averaged. The number of years in the exposure scenario for each receptor is equivalent to the number of years that a receptor spends in each age group. For example, children are considered to be between the ages of 5 and 12 years of age. For this receptor group, the ***Years$_{(a)}$*** would be 7 years.

4.1.2.2 Event Driven Exposure Averaging Factors

The calculation of *Event Driven* averaging factors is a function of the number of days spent on the Lyon's Creek West site in a given year. Because scientific information relating to the apportionment of exposures between on-site and off-site sources is limited, the risk assessment process conservatively assumes that on the days that a person is on-site, all of the daily incidental ingestion of soil, or other direct contact exposures, occurs while on-site. The calculation of the AF for *Event Driven* exposures is based on the number of days exposures are assumed to occur compared with the number of days in a given year. The AF for *Event Driven* exposures is calculated as shown in Equation 4-2.

Eq 4-2: Calculation of Exposure Averaging Factor for *Event Driven* Exposures

$$AF_E = \frac{\left(EF_n \times EW_n \times Years_{(n)}\right)}{\left(365\,{}^{days}\!/_{year} \times Years_{(a)}\right)}$$

Where:			
	AF	= Averaging Factor	Unitless
	EF_n	= Exposure Frequency for receptor "n"	days/week
	EW_n	= Weeks per year on-site for receptor "n"	weeks/year
	$Years_n$	= Years of exposure	years
	$Years_a$	= Years for averaging exposure	years

4.1.3 Calculating Exposure Averaging Factors for Upland and Wetland Areas

Exposure averaging factors for *Time Driven* and *Event Driven* exposures for people in the Upland area of the site are provided in Table 4-3a. Exposure averaging factors for *Event Driven* exposures for people who use the Wetlands area of the site are provided in Table 4-3b. Time driven exposures are relevant for inhalation exposures. On the Wetland area of the Lyon's Creek West site, the contaminants are present in the sediments. The re-entrainment of soil and dust particles by wind action does not occur for wet soil or sediment. Therefore, inhalation of soil and dust particulate is not a complete exposure pathway for receptors on the Wetlands area, and time driven exposure averaging factors are not required for this area of the Lyon's Creek West site.

Table 4-3a: Exposure Averaging Factors for the Uplands Area

Time Driven Exposure Factors: Upland Area								
	Hours per day on-site	Days per Week	Weeks per year	Years	Total Hours per day	Days Per Year	Years	AF
Particulate Inhalation								
Infant	1	1	35	0.5	24	365	0.5	0.003995434
Toddler	1	1	35	4.5	24	365	4.5	0.003995434
Child	2	1	35	7	24	365	7	0.007990868
Teen	2	1	35	8	24	365	8	0.007990868
Adult	2	1	35	55	24	365	55	0.007990868
Event Driven Exposure Factors: Upland Area								
Receptor	**Hours per day on-site**	**Days per week**	**Weeks per year**	**Years**	**Total Hours per day**	**Days per year**	**Years**	**AF**
Soil Ingestion, Dermal Contact with Soil								
Infant	NA	1	35	0.5	NA	365	0.5	0.095890411
Toddler	NA	1	35	4.5	NA	365	4.5	0.095890411
Child	NA	1	35	7	NA	365	7	0.095890411
Teen	NA	1	35	8	NA	365	8	0.095890411
Adult	NA	1	35	50	NA	365	50	0.095890411

Table 4-3b: Exposure Averaging Factors for the Wetlands Area

Event Driven Exposure Factors: Wetlands Area					
Receptor	Days/year	Years	Days per year	Years	AF
Soil Ingestion, Dermal Contact with Sediment					
Infant	0	0.5	365	0.5	0
Toddler	0	4.5	365	4.5	0
Child	5	7	365	7	0.01369863
Teen	5	8	365	8	0.01369863
Adult	5	50	365	50	0.01369863

4.2 Physical and Physiological Parameters for Receptors

Physical and physiological factors such as body weight and inhalation rate, and behavioural factors such as the incidental ingestion of soil, all affect the potential daily exposures experienced by each of the receptors considered in the HHRA. Physical and physiological parameters are available from a number of sources including the MOE, Health Canada and the US EPA. The MOE has recently completed a review of available parameters and has identified values that it has used in assessing potential exposures to contaminants in the environment (MOE, 2002). These parameters have been used to assess potential human exposures in the HHRA for Lyon's Creek West. The parameters used to assess incidental ingestion and dermal contact with soils and inhalation of soil and dust particles for people on the Uplands area of the site are summarized in Table 4-4a. The parameters used to assess incidental ingestion of sediments and dermal contact with sediments for people on the Wetlands area of the site are summarized in Table 4-4b.

It should be noted that different skin surface areas have been used to assess potential dermal contact for people in the two areas of the Lyon's Creek West site. On the Uplands area of the site, the area of exposed skin is consistent with the areas of exposed skin assumed for regular outdoor activities on residential or recreational properties. On the Wetlands area it is assumed that only hands, and feet are likely to come into contact with sediments. Therefore, estimates of exposed skin surface area have been adjusted to reflect these differences.

Table 4-4a: Physical, Physiological and Behavioural Parameters: Uplands Receptors

Parameter	Units	Infant	Toddler	Child	Teen	Adult	Reference
Age Range		0-6 m	7 m - 4 yrs	5 - 11 yrs	12-19 yrs	>20yrs	MOE, 2002
Years within an Age Group	years	0.5	4.5	7	8	50	MOE, 2002
Body Weight	kg	8.2	16.5	32.9	59.7	70.7	MOE, 2002
Soil Ingestion Rate	g/day	0.02	0.1	0.1	0.02	0.02	MOE, 2002
Daily Inhalation Rates	m^3/day	2.1	9.3	14.5	15.8	15.8	Health Canada, 2003
Skin Surface Area							
Hands	cm^2	320	430	590	800	890	MOE, 2002
Upper & Lower Arms	cm^2	550	890	1480	2230	2500	MOE, 2002
Upper & Lower Legs	cm^2	910	1690	3070	4970	5720	MOE, 2002
Totals	cm^2	1780	3010	5140	8000	9110	MOE, 2002
Soil Loading to Skin							
Soil Adhesion to Skin	g/cm2	7.0E-05	2.0E-04	2.0E-04	7.0E-05	7.0E-05	MOE, 2002

Table 4-4b: Physical, Physiological and Behavioural Parameters: Wetlands Receptors

Parameter	Units	Infant	Toddler	Child	Teen	Adult	Reference
Age Range		0-6 m	7 m - 4 yrs	5 - 11 yrs	12-19 yrs	>20yrs	MOE, 2002
Years within an Age Group	years	0.5	4.5	7	8	50	MOE, 2002
Body Weight	kg	8.2	16.5	32.9	59.7	70.7	MOE, 2002
Soil Ingestion Rate	g/day	0.02	0.1	0.1	0.02	0.02	MOE, 2002
Skin Surface Area							
Hands	cm^2	320	430	590	800	890	MOE, 2002
Feet	cm^2	250	430	720	1080	1190	MOE, 2002
Totals	cm^2	570	860	1310	1880	2080	MOE, 2002
Soil Loading to Skin							
Soil Adhesion to Skin	g/cm2	7.0E-05	2.0E-04	2.0E-04	7.0E-05	7.0E-05	MOE, 2002

4.3 Quantifying Exposure for Individual Pathways

This section provides an overview of the calculations used to estimate exposures for each of the potentially complete exposure pathways on the Upland and Wetland areas of the Lyon's Creek West site. For the Upland area the potentially complete exposure pathways include:

- Incidental Ingestion of Soil;
- Incidental Dermal Contact with Soil; and
- Inhalation of Re-entrained Soil and Dust.

For the Wetlands area the potentially complete exposure pathways include:

- Incidental Ingestion of Sediment; and
- Incidental Dermal Contact with Sediment.

Calculations are provided for the relevant receptor age groups, for the contaminants of concern in the Upland and Wetlands areas in the following sections.

4.3.1 Incidental Ingestion of Soil or Sediment

The mechanisms that govern human exposure to sediments do not differ from those that govern human exposure to soil, and standard risk assessment practice assesses human exposures to sediments in the same manner as human exposures to soil. Exposure to contaminants in soil or sediment depends on the concentration of the contaminants in the soil or sediment, the amount of soil or sediment ingested on a daily basis and the number of days per year that exposures are likely to occur. The estimated daily intake of contaminants through the incidental ingestion of soil or sediment is calculated as shown in Equation 4-3. For the purposes of this assessment it has conservatively assumed that on the days when people are on the Upland or Wetlands areas of the Lyon's Creek West site, all soil or sediment ingested on that day comes from the Upland or Wetlands area. Thus, soil or sediment ingestions exposures are considered to be *event driven* exposures.

Eq 4-3:

$$EDI_{si} = \frac{Csed \times IR_{sed} \times CF \times AF}{BW}$$

Where:

Parameter	Description	Units
EDI_{si}	= Intake from incidental ingestion of soil/sediment	mg/kg-day
C_{sed}	= Concentration of contaminant in soil/sediment	mg/kg
IR_{sed}	= Daily soil/sediment ingestion rate	g/day
CF	= g to kg conversion factor	0.001
AF	= Exposure averaging Factor	unitless
BW	= Receptor body weight	kg

Estimates of exposure through the incidental ingestion of soil for arsenic, iron and manganese on the Upland area for each of the receptor age groups are shown in Table 4-5a. Estimates of exposure through the incidental ingestion of sediment for arsenic and PCB on the Wetlands area, for the child, teen and adult receptor are provided in Table 4-5b. As noted in Section 4.1.3, infants and toddlers are not expected to be present on the Wetlands area, based on the assumption of parental or caregiver supervision while on site that would prevent access to the wetland and watercourse features by such young age groups. Therefore, exposures have not been estimated for these receptors on the Wetlands area. The incidental soil/sediment ingestion exposures have been used in conjunction with the exposure estimates for other contributing pathways to develop overall estimates of exposure to the COCs in the Upland and Wetlands areas of the Lyon's Creek West site.

Table 4-5a: Exposures From Incidental Ingestion of Soil on the Upland Area

Receptor	Concentration in Soil	Soil Ingestion Rate	Exposure Averaging Factor	Conversion Factor	Body Weight	Estimated Daily Intake
	mg/kg	g/day	Unitless	kg to g	kg	mg/kg-day
Arsenic						
Infant	3.2E+01	0.02	0.10	0.001	8.2	7.6E-06
Toddler	3.2E+01	0.1	0.10	0.001	16.5	1.9E-05
Child	3.2E+01	0.1	0.10	0.001	32.9	9.4E-06
Teen	3.2E+01	0.02	0.10	0.001	59.7	1.0E-06
Adult	3.2E+01	0.02	0.10	0.001	70.7	8.8E-07
Iron						
Infant	3.7E+04	0.02	0.10	0.001	8.2	8.7E-03
Toddler	3.7E+04	0.1	0.10	0.001	16.5	2.2E-02
Child	3.7E+04	0.1	0.10	0.001	32.9	1.1E-02
Teen	3.7E+04	0.02	0.10	0.001	59.7	1.2E-03
Adult	3.7E+04	0.02	0.10	0.001	70.7	1.0E-03
Manganese						
Infant	8.5E+02	0.02	0.10	0.001	8.2	2.0E-04
Toddler	8.5E+02	0.1	0.10	0.001	16.5	4.9E-04
Child	8.5E+02	0.1	0.10	0.001	32.9	2.5E-04
Teen	8.5E+02	0.02	0.10	0.001	59.7	2.7E-05
Adult	8.5E+02	0.02	0.10	0.001	70.7	2.3E-05

Table 4-5b: Exposures From Incidental Ingestion of Sediment on the Wetlands Area

Receptor	Concentration in Soil	Soil Ingestion Rate	Exposure Averaging Factor	Conversion Factor	Body Weight	Estimated Daily Intake
	mg/kg	g/day	Unitless	kg to g	kg	mg/kg-day
Arsenic						
Child	6.5E+01	0.1	0.01	0.001	32.9	2.7E-06
Teen	6.5E+01	0.02	0.01	0.001	59.7	3.0E-07
Adult	6.5E+01	0.02	0.01	0.001	70.7	2.5E-07
PCB						
Child	2.5E+01	0.1	0.01	0.001	32.9	1.0E-06
Teen	2.5E+01	0.02	0.01	0.001	59.7	1.1E-07
Adult	2.5E+01	0.02	0.01	0.001	70.7	9.6E-08
Dioxin-Like PCBs						
Child	5.2E-04	0.1	0.01	0.001	32.9	2.2E-11
Teen	5.2E-04	0.02	0.01	0.001	59.7	2.4E-12
Adult	5.2E-04	0.02	0.01	0.001	70.7	2.0E-12

4.3.2 Dermal Contact with Soil or Sediment

The uptake of contaminants from soil/sediment through the skin depends on the concentration of the chemical in the soil/sediment, the surface area of skin exposed to soil/sediments on a daily basis, the amount of soil/sediment that adheres to the skin and the permeability of the skin to the contaminant. The estimation of the daily exposures to contaminants from dermal contact with soil/sediment is calculated as shown in Equation 4-4. For the purposes of this assessment it has been conservatively assumed that on the days when a person is on the Upland or Wetlands areas of the Lyon's Creek West site, all dermal contact with soil/sediment is derived from the soil or sediment on the site. Thus, dermal contact exposures are considered to be *event driven* exposures. The averaging factors used to assess event driven exposures for dermal contact on the Upland area and sediment on the Wetlands area are shown in Table 4-3a and Table 4-3b respectively. The results have been used in conjunction with the exposure estimates for the other contributing pathways to develop overall estimates of exposure to the contaminants of concern in the Upland and Wetlands areas of the Lyon's Creek West site.

Eq 4-4:

$$EDI_{dc} = \frac{C_{sed} \times SA \times SLF \times DAF \times CF \times AF}{BW}$$

Where:

Parameter	**Description**	**Units**
EDI_{dc}	= Intake from dermal contact with soil/sediment	mg/kg-day
C_{sed}	= Contaminant concentration in soil/sediment	mg/kg
SA	= Surface area of exposed skin	cm^2/day
SLF	= soil/Sediment Loading Factor	g/cm^2
DAF	= Dermal absorption factor	unitless
CF	= g to kg conversion factor	0.001
AF	= Exposure averaging factor	unitless
BW	= Receptor body weight	kg

The soil/sediment loading factor represents the amount of soil/sediment that adheres to the skin over a given surface area. The soil/sediment loading factors used in the present assessment were taken from the values used by the MOE in previous assessments of dermal exposure to contaminants in soil (MOE, 2002). The loading factors are based on soil adhesion to the skin. It is reasonable to expect that a greater amount of sediment could adhere to the skin given that, in general, sediment would be expected to be wetter than soil. Although a thicker layer of sediment may adhere to skin than soil, the area covered by soil and sediment can be expected to be the same. The uptake of contaminants from soil or sediment through the skin is governed by the layer of soil/sediment that is in direct contact with the skin. Contaminants in soil/sediment that are not in direct contact with the skin do not contribute to dermal uptake. Therefore, using soil-loading factors to estimate uptake from sediments will provide reasonable estimates of potential exposure.

The uptake of chemicals through the skin is chemical-specific. The dermal absorption factors used to estimate the absorbed doses of the contaminants of concern are based on default values recommended by the US EPA (US EPA, 2001).

Estimates of exposure to arsenic, iron and manganese through dermal contact with soil on the Upland area for each receptor age groups are shown in Table 4-6a. Estimates of exposure to arsenic and PCB through dermal contact with sediments on the Wetlands area, for the child, teen and adult receptors are provided in Table 4-6b.

Table 4-6a: Exposure from Dermal Contact With Soil: Upland Area

Receptor	Concentration in Soil	Skin Surface Area	Soil Adhesion Factor	Dermal Absorption Factor	Exposure Averaging Factor	Conversion Factor	Body Weight	Estimated Daily Intake
	mg/kg	cm^2	g/cm^2	Unitless	Unitless	kg to g	kg	mg/kg-day
Arsenic								
Infant	3.2E+01	1780	7.0E-05	0.03	0.10	0.001	8.2	1.4E-06
Toddler	3.2E+01	3010	2.0E-04	0.03	0.10	0.001	16.5	3.4E-06
Child	3.2E+01	5140	2.0E-04	0.03	0.10	0.001	32.9	2.9E-06
Teen	3.2E+01	8000	7.0E-05	0.03	0.10	0.001	59.7	8.7E-07
Adult	3.2E+01	9110	7.0E-05	0.03	0.10	0.001	70.7	8.4E-07
Iron								
Infant	3.7E+04	1780	7.0E-05	0.01	0.10	0.001	8.2	5.4E-04
Toddler	3.7E+04	3010	2.0E-04	0.01	0.10	0.001	16.5	1.3E-03
Child	3.7E+04	5140	2.0E-04	0.01	0.10	0.001	32.9	1.1E-03
Teen	3.7E+04	8000	7.0E-05	0.01	0.10	0.001	59.7	3.3E-04
Adult	3.7E+04	9110	7.0E-05	0.01	0.10	0.001	70.7	3.2E-04
Manganese								
Infant	8.5E+02	1780	7.0E-05	0.01	0.10	0.001	8.2	1.2E-05
Toddler	8.5E+02	3010	2.0E-04	0.01	0.10	0.001	16.5	3.0E-05
Child	8.5E+02	5140	2.0E-04	0.01	0.10	0.001	32.9	2.6E-05
Teen	8.5E+02	8000	7.0E-05	0.01	0.10	0.001	59.7	7.7E-06
Adult	8.5E+02	9110	7.0E-05	0.01	0.10	0.001	70.7	7.4E-06

Table 4-6b: Exposure from Dermal Contact With Sediment: Wetlands Area

Receptor	Concentration in Soil	Skin Surface Area	Soil Adhesion Factor	Dermal Absorption Factor	Exposure Averaging Factor	Conversion Factor	Body Weight	Estimated Daily Intake
	mg/kg	cm^2	g/cm^2	Unitless	Unitless	kg to g	kg	mg/kg-day
Arsenic								
Child	6.5E+01	1310	2.0E-04	0.03	0.01	0.001	32.9	2.1E-07
Teen	6.5E+01	1880	7.0E-05	0.03	0.01	0.001	59.7	5.9E-08
Adult	6.5E+01	2080	7.0E-05	0.03	0.01	0.001	70.7	5.5E-08
PCB								
Child	2.5E+01	1310	2.0E-04	0.14	0.01	0.001	32.9	3.8E-07
Teen	2.5E+01	1880	7.0E-05	0.14	0.01	0.001	59.7	1.1E-07
Adult	2.5E+01	2080	7.0E-05	0.14	0.01	0.001	70.7	9.8E-08
Dioxin-Like PCBs								
Child	5.2E-04	1310	2.0E-04	0.14	0.01	0.001	32.9	8.0E-12
Teen	5.2E-04	1880	7.0E-05	0.14	0.01	0.001	59.7	2.2E-12
Adult	5.2E-04	2080	7.0E-05	0.14	0.01	0.001	70.7	2.1E-12

4.3.3 Inhalation of Soil and Dust Particulate

Inhalation exposure to contaminants on re-entrained soil and dust particles depends on the concentration of the contaminant bound to the soil/dust particle and on the concentration of the particles in the air column. Exposure to COCs through the inhalation of re-entrained soil and dust particles is only relevant for the Upland area of the Lyon's Creek West site. Inhalation exposures are calculated as shown in Equation 4-5 and Equation 4-6. Equation 4-5 estimates the concentration of a chemical in air on a mg/m^3 basis, based on the concentration of the chemical in the soil. Chemical concentration estimates are used to characterize risks for chemicals where the *Toxicity Reference values* (TRVs) are expressed on a mg/m^3 basis (arsenic). Equation 4-6 provides dose estimates for inhalation exposure on a mg per kg body weight per day (mg/kg-day) basis for assessing exposures where the TRVs are expressed as reference doses (mg/kg-day) (iron and manganese).

Eq 4-5:

$$C_{air} = C_{soil} \times PA \times AF$$

Where:

Parameter	Description	Units
C_{air}	= Chemical concentration in air	mg/m^3
C_{soil}	= Chemical concentration in soil	mg/kg
PA	= Particulate Concentration in Air	kg/m^3
AF	= Exposure averaging factor	unitless

Eq 4-6:

$$EDI_{Inhal} = \frac{C_{air} \times IR_{inhal} \times ABS_{Inhal}}{BW}$$

Where:

Parameter	Description	Units
EDI_{inhal}	= Estimated Daily intake from particulate inhalation	mg/kg-day
C_{air}	= Chemical concentration in air	mg/m^3
IR_{inhal}	= Inhalation rate	m^3/day
ABS_{inhal}	= Inhalation Absorption Factor	Unitless
BW	= Body weight	kg

The particulate concentration in air of 7.6×10^{-10} kg/m^3 recommended by Health Canada was used to estimate chemical concentrations in the air column (Health Canada, 2003). Inhalation absorption factors for all chemicals were assumed to be 1, representing 100% absorption. Daily inhalation rates for all receptors were based on the values recommended by Health Canada as outlined in Table 4-4a.

In estimating potential exposures to contaminants on re-entrained particles, it has been assumed that the re-entrainment of soil particles can occur every day that the ground is frost-free and does occur every day that a receptor is present in the Upland area of the Lyon's Creek West site. Because the re-entrainment of soil and dust particles only occurs when the ground is dry, it is unlikely that wind action will suspend particles into the air during the spring and fall or during summer rain events when the ground is wet. Therefore, assuming that soil/dust re-entrainment occurs every day that a person is on the Upland area will over estimate potential exposures by this route. Further, most of the Upland area is covered by vegetation in the form of lawn, meadow, thicket or woodlot, with only a relatively small proportion of the area (e.g., footpaths and ATV trails) characterized by exposed soils that might be entrained as dust.

Because inhalation occurs on a 24-hour/day basis, on-site inhalation exposures are considered to be *Time Driven* exposures. The averaging factors used to assess on-site exposures to chemicals in re-entrained soil and dust are calculated as shown in Section 4.1.3. Estimates of exposure to arsenic, iron and manganese on the Upland area of the Lyon's Creek West site are provided in Table 4-7. These results have been used in conjunction with the intake estimates for the other contributing pathways to develop an overall estimate of on-site exposures for members of the local community who may use the Upland area of the Lyon's Creek West site for informal recreational purposes.

Table 4-7: Exposure From the Inhalation of Soil and Dust: Upland Area

Receptor	Concentration in Soil	Particulate Concentration in Air	Exposure Averaging Factor	Chemical Concentration in Air	Inhalation Rate	Inhalation Absorption Factor	Body weight	Avg Daily Exposure
	mg/kg	kg/m^3	Unitless	mg/m^3	m^3/day	Unitless	kg	mg/kg-day
Arsenic								
Infant	3.2E+01	7.60E-10	4.0E-03	9.84E-11	-	-	-	-
Toddler	3.2E+01	7.60E-10	4.0E-03	9.84E-11	-	-	-	-
Child	3.2E+01	7.60E-10	8.0E-03	1.97E-10	-	-	-	-
Teen	3.2E+01	7.60E-10	8.0E-03	1.97E-10	-	-	-	-
Adult	3.2E+01	7.60E-10	8.0E-03	1.97E-10	-	-	-	-
Iron								
Infant	3.7E+04	7.60E-10	4.0E-03	1.13E-07	2.10E+00	1.0	8.2	2.9E-08
Toddler	3.7E+04	7.60E-10	4.0E-03	1.13E-07	9.30E+00	1.0	16.5	6.4E-08
Child	3.7E+04	7.60E-10	8.0E-03	2.25E-07	1.50E+01	1.0	32.9	1.0E-07
Teen	3.7E+04	7.60E-10	8.0E-03	2.25E-07	1.60E+01	1.0	59.7	6.0E-08
Adult	3.7E+04	7.60E-10	8.0E-03	2.25E-07	1.60E+01	1.0	70.7	5.1E-08
Manganese								
Infant	8.5E+02	7.60E-10	4.0E-03	2.59E-09	2.10E+00	1.0	8.2	6.6E-10
Toddler	8.5E+02	7.60E-10	4.0E-03	2.59E-09	9.30E+00	1.0	16.5	1.5E-09
Child	8.5E+02	7.60E-10	8.0E-03	5.17E-09	1.50E+01	1.0	32.9	2.4E-09
Teen	8.5E+02	7.60E-10	8.0E-03	5.17E-09	1.60E+01	1.0	59.7	1.4E-09
Adult	8.5E+02	7.60E-10	8.0E-03	5.17E-09	1.60E+01	1.0	70.7	1.2E-09

4.4 Quantifying Total Daily Exposures from On-Site Sources

Estimates of the daily averaged intakes from each of the individual exposure pathways have been presented in the preceding sections. In order to properly assess the potential hazards and risks associated with exposure to each of the COC it is necessary to determine the contribution that each exposure pathway makes to the total daily exposure. This section provides a summary of the estimated daily exposure from each pathway for arsenic, iron and manganese on the Upland area and for arsenic and PCB on the Wetlands area for the relevant receptor age groups on the two areas of the Lyon's Creek West site. Iron and manganese are considered to be non-carcinogenic. Exposures to

PCBs are assessed using a non-carcinogenic end-point and exposures to arsenic are assessed using a carcinogenic endpoint. Because the carcinogenic and non-carcinogenic compounds have differing biological mechanisms of action, total daily exposures are assessed differently.

4.4.1 Total Daily Intakes for COCs Assessed on Non-Carcinogenic Endpoints

COCs that are assessed on non-carcinogenic endpoints, such as iron, manganese, PCB and DL-PCB in this assessment, are generally considered to act on the body through threshold mechanisms. This means that at low doses, the body is able to remove the chemical from the body without the chemical causing an adverse effect. As the dose or exposure increases, the body's ability to clear the chemical is reduced. When the exposure exceeds the body's ability to process and excrete the chemical, it can cause adverse or toxic effects. The point at which this occurs in called the threshold. The threshold is different for every chemical. The toxicity values developed for each chemical reflect the threshold for each chemical.

Toxicity values, referred to as Tolerable Daily Intakes (TDIs) by Health Canada and as Reference Doses (RfDs) (Reference Concentrations (RfCs) for inhalation exposures) by the US EPA are developed from toxicological studies of human or animal populations and are set to ensure that adverse human health effects will not occur over a life-time of exposure. Although slight differences exist between agencies, toxicity values for non-carcinogenic chemicals are generally defined as:

> *A quantitative estimate (with uncertainty spanning perhaps an order of magnitude (ten-fold)) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of non-carcinogenic deleterious effects during a life-time (US EPA, 1989).*

The total amount of a chemical to which a person is exposed is determined by the exposures that occur through each of the individual exposure routes. If the biological end-point is the same for all routes of exposure, the total exposure is estimated as a sum of the exposures from all routes as shown in Equation 4-7. The EDIs from all pathways that contribute to the exposure through a given route are also summed in determining the total EDI. If the biological effects differ between the routes of exposure, then the hazards associated with each route must be calculated separately and the individual exposures are not summed. The biological end-point for the iron toxicity value has not been identified by the US EPA (see Section 5). In the absence of data to indicate that biological effects differ by the route of exposure, the risk assessment process assumes that the route of exposure does not alter the biological activity of a compound. Therefore, iron exposures have been summed to provide total daily intake estimates for all routes considered. The oral and inhalation reference doses for manganese listed by the US EPA are both based on neurological effects. Therefore, inhalation, ingestion and dermal contact exposures have been summed for manganese. The TRVs for PCB and DL-PCB recommended by the MOE to be used in this risk assessment is considered to apply to all three routes of exposure (see Section 5).

Eq 4-7:

$$EDI_{total} = \sum_{1}^{n} EDI_{route}$$

Where:

Parameter	Description	Units
EDI_{total}	= Total intake of chemical from all relevant routes	mg/kg-day
EDI_{route}	= Pathway and or route-specific EDI	mg/kg-day

The total daily concentrations are used in conjunction with the TRVs for the non-carcinogenic endpoints for COCs to assess the hazards associated with exposure to each of the chemical for each of the receptors. The total daily intakes for incidental ingestion, dermal contact and inhalation exposures to iron and manganese for all receptor age groups for the Upland area are provided in Table 4-8a. Total daily intakes for incidental ingestion and dermal contact to PCB and DL-PCB for the child, teen and adult receptor on the Wetlands area are provided in Table 4-8b.

Table 4-8a: Total Daily Intakes for Iron and Manganese, Upland Area

Receptor	Estimated Daily Intakes (mg/kg-day)				Combined Total
	Incidental Soil Ingestion	Dermal Contact	Total Soil/Dermal	Inhalation	mg/kg-day
Iron					
Infant	8.7E-03	5.4E-04	9.2E-03	2.9E-08	9.2E-03
Toddler	2.2E-02	1.3E-03	2.3E-02	6.4E-08	2.3E-02
Child	1.1E-02	1.1E-03	1.2E-02	1.0E-07	1.2E-02
Teen	1.2E-03	3.3E-04	1.5E-03	6.0E-08	1.5E-03
Adult	1.0E-03	3.2E-04	1.3E-03	5.1E-08	1.3E-03
Manganese					
Infant	2.0E-04	1.2E-05	2.1E-04	6.6E-10	2.1E-04
Toddler	4.9E-04	3.0E-05	5.2E-04	1.5E-09	5.2E-04
Child	2.5E-04	2.6E-05	2.7E-04	2.4E-09	2.7E-04
Teen	2.7E-05	7.7E-06	3.5E-05	1.4E-09	3.5E-05
Adult	2.3E-05	7.4E-06	3.0E-05	1.2E-09	3.0E-05

Table 4-8b: Total Daily Intakes for PCB, Wetlands Area

Receptor	Estimated Daily Intakes (mg/kg-day)		
	Incidental Sediment Ingestion	Dermal Contact	Total Soil/Dermal
PCB			
Child	1.0E-06	3.8E-07	1.4E-06
Teen	1.1E-07	1.1E-07	2.2E-07
Adult	9.6E-08	9.8E-08	1.9E-07
Dioxin-Like PCBs			
Child	2.2E-11	8.0E-12	3.0E-11
Teen	2.4E-12	2.2E-12	4.6E-12
Adult	2.0E-12	2.1E-12	4.1E-12

4.4.2 Total Daily Intakes for COCs Assessed on Carcinogenic Endpoints

Carcinogenic chemicals are generally considered to work through a non-threshold mechanism. This means that there is no dose below which an adverse effect will not occur. Any exposure to a carcinogen is considered to be associated with some level of risk. At very low doses, the probability that an adverse effect (cancer) will occur is extremely small. The probability of developing cancer increases as the dose increases. Because it is possible for cancer to develop after exposure to a chemical has ceased (latency period), the toxicity values are expressed as the probability of developing cancer over a lifetime. This is based on the assumption that the risk associated with an elevated exposure to a carcinogenic chemical for a short period of time is equivalent to the risk associated with a lower level of exposure over a longer period of time (US EPA, 1999). In other words, what determines the carcinogenic potential associated with a given exposure is not the duration of the exposure, but the total level of exposure that occurs over a lifetime. Therefore, in order to determine the potential risks associated with a specific exposure, it is necessary to determine the lifetime averaged daily dose equivalent for the exposure in question. The Life-Time Averaged Daily Dose (LADD) is calculated as shown in Equation 4-8.

Eq 4-8:

$$LADD^p = \frac{\left[(EDI_i^p \times 0.5yrs) + (EDI_{tod}^p \times 4.5yrs) + (EDI_{ch}^p \times 7yrs) + (EDI_{teen}^P \times 8yrs) + (EDI_a^p \times 50yrs)\right]}{70\,years}$$

Where:

Parameter	Description	Units
LADD	= Life-time averaged daily dose	mg/kg-day
EDI_t^p	= EDI for receptor from pathway p	mg/kg-day
yrs	= Number of years in age group r	years
70 yrs	= Assumed life-time	years

Of the contaminants of concern identified on the Upland and Wetland areas, arsenic is the only one which is assessed on a carcinogenic endpoint in this risk assessment. Therefore, it was necessary to calculate LADDs for exposure to arsenic for people on the Upland and Wetlands areas of the site. In addition, while arsenic is considered to be carcinogenic by the oral, dermal and inhalation routes of exposure, the carcinogenic activity differs between the oral/dermal and inhalation routes. Therefore, to properly assess the potential risks associated with oral/dermal and inhalation exposures to arsenic, it is necessary to calculate the LADDs associated with oral/dermal exposures and inhalation exposures separately. The total daily intakes for oral, dermal and inhalation exposures to arsenic on the Upland and Wetland areas of the Lyon’s Creek West site are presented in Table 4-9a and Table 4-9b, respectively. These total daily intake estimates have been used to calculate the LADDs for the various receptors on the site. The LADDs for oral/dermal exposures and inhalation exposures on the Upland area are provided in Table 4-10a and Table 4-10b, respectively. The LADDs associated with oral/dermal exposures on the Wetlands area are provided in Table 4-10c. The values are used in conjunction with the TRVs for arsenic to determine the potential risks associated with exposure to arsenic on the Upland and Wetlands areas of the Lyon’s Creek West site.

Table 4-9a: Total Daily Intakes for Arsenic: Upland Area

Receptor	Estimated Daily Intakes (mg/kg-day)			
	Soil	Dermal Contact	Total Soil/Dermal	Inhalation
Infant	7.6E-06	1.4E-06	9.0E-06	2.5E-11
Toddler	1.9E-05	3.4E-06	2.2E-05	5.5E-11
Child	9.4E-06	2.9E-06	1.2E-05	9.0E-11
Teen	1.0E-06	8.7E-07	1.9E-06	5.3E-11
Adult	8.8E-07	8.4E-07	1.7E-06	4.5E-11

Table 4-9b: Total Daily Intakes for Arsenic: Wetlands Area

Receptor	Estimated Daily Intakes (mg/kg-day)		
	Soil	Dermal Contact	Total Soil/Dermal
Child	2.7E-06	2.1E-07	2.9E-06
Teen	3.0E-07	5.9E-08	3.6E-07
Adult	2.5E-07	5.5E-08	3.1E-07

Table 4-10a: Oral/Dermal Life-Time Averaged Daily Doses Arsenic: Upland Area

Oral/Dermal Exposures										Total Years	Life-Time Averaged Daily Dose (LADD)
Infant		Toddler		Child		Teen		Adult			
Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration		
mg/kg-day	Years	mg/kg-day	Years	mg/kg-day	Years	mg/kg-day	Years	mg/kg-day	Years	Years	mg/kg-day
9.0E-06	0.5	2.2E-05	4.5	1.2E-05	7	1.9E-06	8	1.7E-06	50	70	4.2E-06

Table 4-10b: Inhalation Life-Time Averaged Daily Doses Arsenic: Upland Area

Particulate Inhalation										Total Years	Life-Time Averaged Daily Dose (LADD)
Infant		Toddler		Child		Teen		Adult			
Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration		
mg/m^3	Years	mg/m^3	Years	mg/m^3	Years	mg/m^3	Years	mg/m^3	Years	Years	mg/m3
2.5E-11	0.5	5.5E-11	4.5	9.0E-11	7	5.3E-11	8	4.5E-11	50	70	5.1E-11

Table 4-10c: Oral/Dermal Life-Time Averaged Daily Doses Arsenic: Wetlands Area

Oral/Dermal Exposures						Total Years	Life-Time Averaged Daily Dose (LADD)
Child		Teen		Adult			
Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration	Avg Daily Exposure	Exposure Duration		
mg/kg-day	Years	mg/kg-day	Years	mg/kg-day	Years	Years	mg/kg-day
2.9E-06	7	3.6E-07	8	3.1E-07	50	70	5.5E-07

5 TOXICITY ASSESSMENT

An essential part of the risk assessment process is the identification of toxicologically based toxicity values that can be compared to exposure estimates. This section provides a listing of the toxicological reference values (TRVs) used in the HHRA. In selecting appropriate TRVs, toxicity values from the Ontario Ministry of the Environment, Health Canada and the US EPA *Integrated Risk Information System* (IRIS) were considered. Preference was given to the most recently developed TRVs because these values incorporate the most up-to-date assessments of available toxicological information and may include toxicological information that was unavailable during the development of older toxicity values. Where TRV values were not available from the MOE, Health Canada or the US EPA IRIS database, values were taken from the US EPA Region III *Risk Based Concentration* (RBC) tables.

Table 5-1 lists the TRVs for arsenic, iron, manganese, PCB and DL-PCB used in the assessment. Ingestion, dermal exposure and inhalation were identified as the potentially complete exposure pathways for all COCs except PCB and DL-PCB, for which inhalation exposure was excluded based on their presence in wetland sediments that are not likely to be entrained as dust. TRVs are not generally available for dermal exposures. Oral TRVs have been used to assess dermal exposures.

Table 5-1: Toxicological Reference Values for the Chemicals of Concern

Chemical	Exposure Route	Toxicity Value	Biological End-point	Agency
COCs with Non-carcinogenic Endpoints				
Iron	Oral/Dermal	0.6 mg/kg-day	unspecified	US EPA, RIII, 2003
	Inhalation	0.6 mg/kg-day	unspecified	US EPA, RIII, 2003
Manganese	Oral/Dermal	0.14 mg/kg-day	Neurological effects	US EPA, 1996
	Inhalation	0.000014 mg/kg-day	neurological effects	US EPA, 1996
PCB	Oral/Dermal	0.00002 mg/kg-day	Hepatic and immunological effects	WHO, 2003
DL-PCB	Oral/Dermal	2.3 pg/kg-day	Reproductive Effects	Health Canada, 2004
COCs with Carcinogenic Endpoints				
Arsenic	Oral/Dermal	1.5 $(mg/kg\text{-}day)^{-1}$	Skin Cancer	Health Canada, 2004
	Inhalation	6.4 $(mg/m^3)^{-1}$	Lung Cancer	Health Canada, 2004

Toxicity profiles that outline the biological effects associated with exposure to each of the COCs and the basis of the TRV selected for each COC, are provided in Appendix C.

6 RISK CHARACTERIZATION

The risk characterization stage of the HHRA process compares the exposures to the contaminants of concern for each of the receptors with the toxicity reference values to determine if site-related exposures exceed the identified limits. Because of the differences in the biological mechanisms of action between COCs assessed on non-carcinogenic and carcinogenic endpoints, the potential hazards/risks are determined differently. The characterization of hazards associated with exposure to COCs assessed on non-carcinogenic endpoints (iron, manganese and PCB) and the risks associated with exposure to carcinogenic endpoints (arsenic) are presented in the following sections.

6.1 Characterizing Hazards for Exposures to Non-Carcinogenic Compounds

For non-carcinogenic chemicals or assessment endpoints, such as apply to iron, manganese, PCB and DL-PCB, the potential for exposures to result in adverse human health effects is based on the ratio between the estimated exposure and the identified toxicity reference value. This ratio is called the *Hazard Quotient* (HQ) and is calculated as shown in Equation 6-1. The HQ provides an indication of whether estimated exposures are large enough to be of concern for human health. A HQ of less than 1.0 indicates that exposures are below the toxicity reference value and would not be expected to result in adverse human health effects. Because of the conservative assumptions used by regulatory agencies in the development of toxicity reference values, HQ values greater than 1.0 do not mean that adverse human health effects will occur, but the likelihood that an adverse effect will occur increases as the HQ value rises above 1.0.

Eq: 6-1:

$$HQ = \frac{EDI_{total}}{TRV}$$

Where:

Parameter	Description	Units
HQ	= Hazard Quotient	unitless
$EDI_{t(r)}$	= Estimated Daily Intake EDI_{total} for receptor r	mg/kg-day
TRV	= Identified toxicological reference value	mg/kg-day

The HHRA for the Lyon’s Creek West site considered exposures that result from contact with materials from soil or sediment on the Lyon’s Creek West site. Exposures from other sources, such as diet, have not been considered. In cases where exposures from all sources are not considered, standard risk assessment practice estimates potential hazards against a hazard benchmark of 0.2. This ensures that site-related exposures do not exceed twenty percent (20%) of the TRV on a daily basis. If the estimated exposures to the COCs with non-carcinogenic endpoints on the Uplands or Wetlands areas of the Lyon’s Creek West site do not exceed 20% of their respective TRVs, it can be concluded that these exposures to not pose a potential hazard for recreational users of the site.

The hazard quotients associated with exposure to iron and manganese in soil on the Upland area and to PCB and DL-PCB in the sediment on the Wetlands area are provided in Table 6-1a and Table 6-1b respectively. All are below the HQ benchmark of 0.2, Therefore, exposures to the iron and manganese in the soil on the Upland area and PCB and DL-PCB in the sediment in the Wetlands area would not be expected to result in any adverse human health effects for people in any age group considered in the assessment (infants through adults).

Table 6-1a: Hazard Quotient Calculations for Relevant Receptors: Upland Area

Receptor	Estimated Daily Intakes (mg/kg-day)	Toxicity Value (mg/kg-day)	Hazard Quotient
Iron			
Infant	9.2E-03	6.0E-01	0.015
Toddler	2.3E-02	6.0E-01	0.038
Child	1.2E-02	6.0E-01	0.020
Teen	1.5E-03	6.0E-01	0.0025
Adult	1.3E-03	6.0E-01	0.0023
Manganese			
Infant	2.1E-04	1.4E-01	0.0015
Toddler	5.2E-04	1.4E-01	0.0037
Child	2.7E-04	1.4E-01	0.0020
Teen	3.5E-05	1.4E-01	0.00025
Adult	3.0E-05	1.4E-01	0.00022

Table 6-1b: Hazard Quotient Calculations for Relevant Receptors: Wetlands Area

Receptor	Estimated Daily Intakes (mg/kg-day)	Toxicity Value (mg/kg-day)	Hazard Quotient
PCB			
Infant	0.0E+00	2.0E-05	0
Toddler	0.0E+00	2.0E-05	0
Child	1.4E-06	2.0E-05	0.071
Teen	2.2E-07	2.0E-05	0.011
Adult	1.9E-07	2.0E-05	0.0097
Dioxin-Like PCBs			
Infant	0.0E+00	2.3E-09	0
Toddler	0.0E+00	2.3E-09	0
Child	3.0E-11	2.3E-09	0.013
Teen	4.6E-12	2.3E-09	0.0020
Adult	4.1E-12	2.3E-09	0.0018

6.2 Characterizing Risks for Exposures to Arsenic.

For carcinogenic chemicals, such as arsenic, the potential for exposure to result in adverse human health effects is based on the level of exposure averaged over a lifetime. This is calculated as the LADD, as shown in Section 4.4.2. As noted in Section 4.4.2, any exposure to a carcinogenic chemical is associated with some level of risk. Therefore, it is not possible to identify a level of exposure below which there is no potential risk. At very low levels of exposure, the risks of developing cancer become vanishingly small. Risk acceptability benchmarks determine at what level the risks of developing cancer can be considered to be minimal or *de minimus*. In Ontario, the risk acceptability benchmark for assessing exposures to carcinogens is one-in-a-million (1 x 10^{-6} or 0.000001). This means that exposures to carcinogenic compounds that are predicted to result in less than one additional cancer per million population are considered to be below the level of concern. Exposures that are below the 10^{-6} level of risk would not be expected to result in an unacceptable increase in lifetime cancer risk. The probability of developing cancer as a result of environmental exposure to a carcinogenic substance is expressed as the *Incremental Increase in Lifetime Cancer Risk* (IILCR) and is calculated as shown in Equation 6-2.

Eq 6-2:

$$IILCR = LADD \times CSF$$

Where:

Parameter	Description	Units
IILCR	= Incremental Increase in Lifetime Cancer Risk	unitless
LADD	= Lifetime Averaged Daily Dose	mg/kg-day
CSF	= Cancer Slope Factor (TRV)	$(mg/kg\text{-}day)^{-1}$

For the Upland area IILCR values have been calculated separately for oral/dermal exposures and inhalation exposures, because the biological end-points differ between oral/dermal and inhalation exposures. The IILCRs associated with exposure to arsenic on the Upland area are provided in Table 6-2a and Table 6-2b. The IILCR associated with oral/dermal exposures to arsenic on the Wetlands area is provided in Table 6-2c.

Table 6-2a: IILCR for Oral/Dermal Exposures to Arsenic: Upland Area

LADD	Cancer Slope Factor	IILCR
mg/kg-day	$(mg/\text{-}kg\text{-}day)^{-1}$	Unitless
4.2E-06	1.5	**6.3E-06**

Table 6-2b: IILCR for Inhalation Exposures to Arsenic: Upland Area

LADD	Cancer Slope Factor	IILCR
mg/m^3	$(mg/m^3)^{-1}$	Unitless
5.1E-11	6.4	3.2E-10

Table 6-2c: IILCR for Oral/Dermal Exposures to Arsenic: Wetlands Area

LADD	Cancer Slope Factor	IILCR
mg/kg-day	$(mg/\text{-}kg\text{-}day)^{-1}$	Unitless
5.5E-07	1.5	8.3E-07

The IILCR for oral/dermal exposure to arsenic on the Upland site exceeds the 1 x 10^{-6} risk acceptability benchmark. This would suggest that exposures to arsenic on the Upland area of the Lyon's Creek West site could lead to unacceptable increases in lifetime cancer risk for people who use the site for recreational purposes. However, it is important to recall that the exposure point concentration (EPC) used to estimate potential exposures to arsenic included three samples where arsenic concentrations were substantially higher than arsenic concentrations across the majority of the site (see Section 3.1.2 and Table 3.2). As noted in Section 3.1.2, these samples are located along the western end of the south drainage ditch. Limited removal of materials from the area around these sample locations would reduce the potential risks associated with exposure to arsenic on the Upland area to levels well below the risk acceptability benchmark.

6.2.1 Remediation of South Drainage Ditch

In August and September 2007, approximately 300 meters of the south drainage ditch was excavated. The excavation ranged in depth from 0.3 m to 0.6 m below ground surface and in width from 3.6 m to 7.9 m in width (O'Connor, 2007). The area of the excavation included three sample locations where elevated arsenic levels were reported in the original site investigations (LC-1, LC-2 & T1-M). Thirty-nine confirmatory samples were collected from the completed excavation and submitted for arsenic analyses. The results showed that arsenic concentrations ranged between 4 mg/kg and 12 mg/kg. The maximum reported arsenic concentration (12 mg/kg) is below the MOE Table 3 standard for residential properties. Incorporating this additional data into the risk assessment for the Uplands area lowers the maximum concentration to 12 mg/kg and the 95% UCL to 5. 7 mg/kg. Both of these values are below the MOE Table 3 Standard of 20 mg/kg for residential soil. Therefore, as a result of the removal of arsenic from the south drainage ditch, exposures to arsenic in the Upland area does not represent a potential concern for human health.

7 DISCUSSION OF UNCERTAINTIES

Uncertainty is an important consideration in quantitative risk assessment. It is important to define uncertainty in the risk assessment process in order to quantify the range of possibilities of the results. If the uncertainty associated with a particular input factor is great, the range of possibilities for that specific value may produce a profound difference in the resulting risk calculation, depending on the particular value that is selected for that factor. An example of the potential impact of uncertainty on the results of the risk assessment may be illustrated by the soil ingestion factor for a child. The range of possibilities for daily soil ingestion may be anywhere from 0 to 100 milligrams per day per child. Even for a site-specific risk assessment, it is impossible to assess the amount of soil ingested by a particular child so that a unique value may be selected for each child in a study area. For this reason a value must be predicted from the scientific literature and inserted into the risk assessment calculations to represent the soil ingestion rate. If a value close to zero, such as 1 milligram per day is selected, the resulting predicted potential risk for a child will be 100-fold lower than the potential risks that would be predicted if a soil ingestion rate of 100 milligrams per day were used.

7.1 Arsenic Concentrations in Soil

As noted in Section 3.1.2 and Section 6.2, the IILCRs calculated of oral/dermal exposures to arsenic on the Upland area suggest that exposures could results in IILCRs that exceed the 10^{-6} risk acceptability benchmark. However, the EPC used in the assessment is biased by the inclusion of three samples, limited to the southwestern portion of the site. The inclusion of these samples in the risk assessment has resulted in an overestimation of the arsenic concentration assumed to be present over the entire site. This, in turn, has resulted in an overestimation of the potential cancer risks associated with exposure to arsenic on the Upland area of the Lyon's Creek West site. Exposure to arsenic can reasonably be expected to be substantially lower than the estimates presented in the current report. If the three points of elevated concentration are not considered, arsenic levels do not exceed screening criteria. This area represents less than 1% of the total area of the site that has been modeled for human exposure. As a result, the potential human risks would also be expected to be reduced accordingly. Therefore, exposure to arsenic is unlikely to pose a potential concern for human health on the Lyon's Creek West site. Potential risks could be further reduced through the removal of soil from the affected area on the southwestern portion of the site.

Excavation activities in the south drainage ditch in August and September 2007 have removed the elevated arsenic levels and reduced arsenic levels across the site to levels that are below the MOE Table 3 standards for residential soil. As a result, arsenic is no longer a concern for human health in the Upland area of the site.

7.2 Sediment Contact Activity Patterns

Estimates of potential health hazards and risks associated with exposure to contaminants in the sediment on the Wetlands area of the site are based on the assumption of limited activity on this area of the site. The assumptions used in this study are based on observations made at the site, which suggest that the Wetlands area is not frequented by the local population as evidenced by the absence of obvious pathways through the area or the existence of access points to the water and wetland on the site. Further, the heavy vegetative cover in the area and soft, deep sediments would discourage access to the area and would serve to largely prevent access to the sediments on the Wetlands area. Therefore, should the assumptions regarding the frequency of access to the site underestimate occupancy, it is likely that exposures experienced by members of the public would be higher than those assumed in the assessment.

8 CONCLUSIONS AND RECOMMENDATIONS

The HHRA for the Lyon's Creek West site focused on the presence of PCB and metals in the soil and sediment on the site. The Lyon's Creek West site is defined as the upper portion of Lyon's Creek to the west of the Welland Canal Bypass. The site contains a Wetland area, which is made up of the upper portion of Lyon's Creek and two ditches that drain the surrounding lands into Lyon's Creek, and an Upland area of lawn, meadow, thicket and woodlot that surrounds the wetland area. From observations made during visits to the site, it is evident that members of the local community regularly use portions of the Upland area of the site for informal recreational activities including walking, cycling and riding ATVs. There was no evidence to suggest that the wetland area is used for recreational activities, apart from possible access to the western segment of the north drainage ditch where is is abutted by gentle grades and manicured lawn. This portion of the north ditch was cleaned out as part of previously completed remediation activities. Paths or other signs of access to the remaining portions of the Wetlands area were not observed. Based on the difference in use patterns between the two areas of the site, the Lyon's Creek West site was divided into the Upland and Wetlands areas and potential exposures were estimated for each area.

The results of the chemical screening determined that arsenic, iron and manganese were the only contaminants present in the soil on the Upland area that exceeded their respective human health-based screening guidelines. Exposures to these contaminants were evaluated for receptors in all five age groups (infant, toddler, child, teen, adult). In the Wetlands area, arsenic and PCB were the only contaminants present in the sediments at levels that exceeded their respective human health-based screening guidelines. Exposures to arsenic, PCB and DL-PCB on the Wetlands area were assessed for the child, teen and adult receptor. Due to the difficulty in accessing the Wetlands area of the site and the likelihood of parental supervision as a preventative factor, the HHRA assumed that infants and toddlers would not be present on the Wetlands area of the Lyon's Creek West site.

Based on the results of the HHRA it was concluded that:

- The Hazard Quotients (HQs) associated with exposure to iron and manganese in the soil on the Upland area of the Lyon's Creek West site are below the hazard acceptability benchmark of 0.2 for people in all age groups (infant, toddler, child, teen and adult). Therefore, exposure to iron and manganese in the soil on the Upland area would not be expected to result in any adverse human health effects for recreational users of the site.

- The initial assessment of the potential risks associated with exposure to arsenic in the soil on the Upland area of the Lyon's Creek West site indicated that the incremental increase in lifetime cancer risk (IILCR) (6.3×10^{-6}) exceeds the risk acceptability benchmark of 10^{-6}. However, it should be noted that the *Exposure Point Concentration* used to estimate exposures to arsenic on the Upland area included 3 samples collected from the western end of the south ditch where arsenic levels were substantially higher than arsenic levels across the rest of the Upland area. As noted in Section 2.2.2, the removal of samples LC-1, LC-2 and T1-M, from the data set reduces the UCL for arsenic to 5.9 mg/kg, which is well below the standard of 20 mg/kg for residential/parkland land use. Therefore, arsenic levels are below the level of concern for human health across the majority of the Upland area. Based on this, exposure to arsenic would not be expected to result in an unacceptable increase in lifetime cancer risk for recreational users of the site.

- Potential concerns related to exposure to arsenic in the soil in the area of LC-1, LC-2 and T1-M have been addressed through the excavation of the south drainage ditch completed between August and September, 2007. Confirmatory sampling, completed as part of the excavation, showed that arsenic levels were below the MOE Table 3 standards for residential soil in the area around LC-1, LC-2 and T1-M.

- Exposure to arsenic, PCB and DL-PCB in the sediments on the Wetlands area of the Lyon's Creek West site for the child, teen and adult receptors were well below the 0.2 hazard acceptability benchmark for all three receptor age groups. Further, based on observations made during site visits, there is limited evidence of recreational access to the Wetlands area. Infants and toddlers were assumed not to have access to the Wetlands area based on the assumption of parental supervision for these age groups that would prevent access to the perceived dangers of water and soft sediments. Therefore, exposure to PCB would not be expected to result in adverse human health effects for recreational used of the Wetlands area of the Lyon's Creek West site.

- The IILCR associated with exposure to arsenic in the sediment was below the 10^{-6} risk acceptability benchmark. Therefore, exposure to arsenic in the sediment on the Wetlands area of the Lyon's Creek West site would not be expected to result in an unacceptable increase in lifetime cancer risk for the recreational user of the site.

Based on the exposure estimates employed in the current risk assessment, it can be concluded that exposure to contaminants in soil on the Upland area and in sediments on the Wetlands area would not pose a potential concern for human health.

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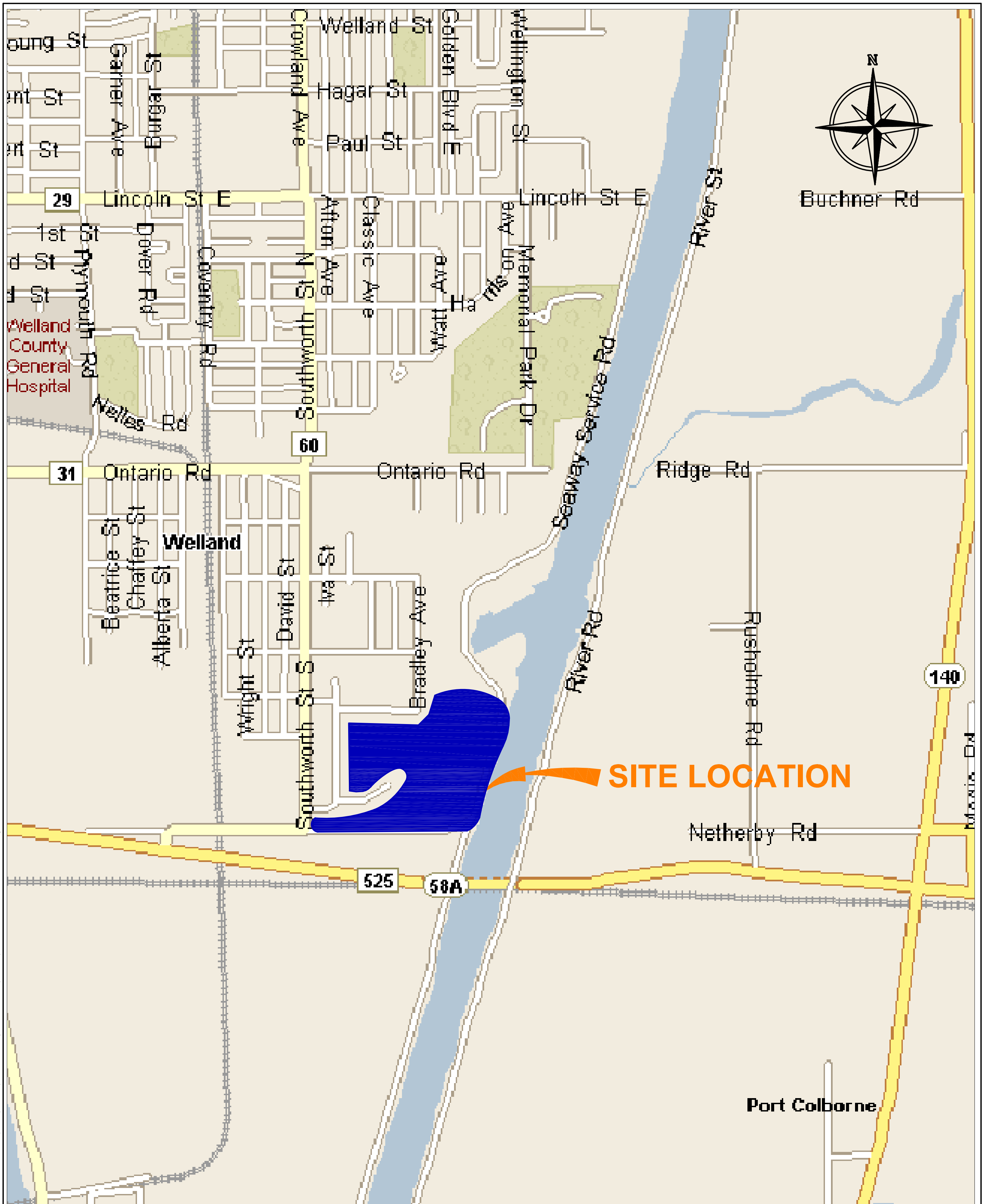
FIGURES



DILLON CONSULTING	SITE LOCATION	PROJECT NO. 04-2907
DATE DECEMBER 2007	LYON'S CREEK WEST Welland, Ontario	FIGURE NO. 1

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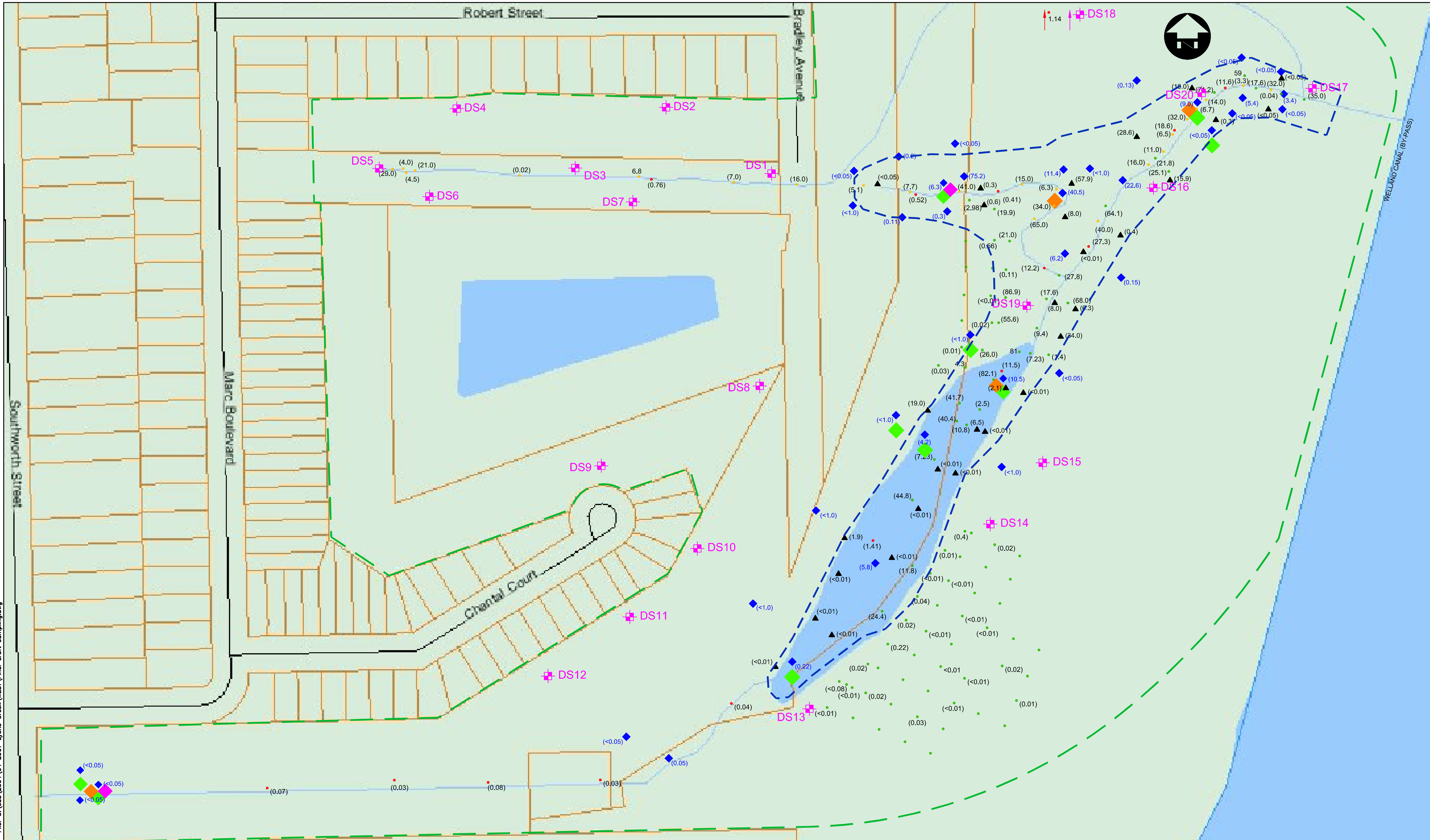

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LEGEND

- LIMIT OF SITE
- LIMIT OF WETLAND INVESTIGATION
- DS8 DILLON 2004 SOIL SAMPLE
- GOLDER SOIL SAMPLE 2004
- SAINT LAWRENCE SEAWAY AUTHORITY 1991
- GOLDER 2003
- ONTARIO MINISTRY OF ENVIRONMENT 1991

FINAL DRAFT

DILLON CONSULTING

DATE DECEMBER 2007

SAMPLING LOCATIONS

LYON'S CREEK WEST
Welland, Ontario

PROJECT NO. **04-2907**

FIGURE NO. **2**

APPENDIX A
Summary of Sediment and Soil Quality Data
And
DLPCB TEQ Calculations

Wetland Sediment/Soil PCB Data Summary 1990-2004

Report	Sample Location	Depth (cm)	PCB_{total} mg/kg	Report	Sample Location	Depth (cm)	PCB_{total} mg/kg	Report	Sample Location	Depth (cm)	PCB_{total} mg/kg
SLSA 1991	LC-41	0-20	2.98	ESL 1992	A1-1	0-50	0.58	Golder 2004	T8N+5(LC)	0-5	0.50
SLSA 1991	LC-42	0-20	19.90	ESL 1992	A2-1	0-50	0.01	Golder 2004	T10S+5(LC)	0-5	0.025
SLSA 1991	LC-45A	0-20	21.00	ESL 1992	C2-1	0-50	0.01	Golder 2004	T5-S	0-5	0.50
SLSA 1991	LC-51A	0-18	86.90	ESL 1992	F1	0-30	0.01	Golder 2004	T6-N	0-5	0.50
SLSA 1991	LC-54	0-24	55.60	ESL 1992	G3-10	0-10	78.00	Golder 2004	T6-S	0-5	0.025
SLSA 1991	LC-56	0-18	26.00	ESL 1992	G1	0-50	0.01	Golder 2004	T7-N	0-5	11.40
SLSA 1991	LC-58A	0-20	4.30	ESL 1992	G2-1	0-50	19.00	Golder 2004	T8-N	0-5	6.19
SLSA 1991	LC-59	0-16	41.70	ESL 1992	I1	0-50	0.01	Golder 2004	T8-S	0-5	0.15
SLSA 1991	LC-67A	0-23	35.00	ESL 1992	A-1'	0-50	0.01	Golder 2004	T9-N	0-5	0.13
SLSA 1991	LC-68A	0.21	0.04	ESL 1992	I2	0-50	2.13	Golder 2004	T9-S	0-5	0.025
SLSA 1991	LC-69A	0-20	17.60	ESL 1992	L1-1	0-40	1.89	Golder 2004	T10-N	0-5	0.025
SLSA 1991	LC-70A	0-22	71.20	ESL 1992	M1	0-50	0.38	Golder 2004	T10-S	0-5	5.36
SLSA 1991	LC-71A	0-16	21.80	ESL 1992	N1	0-20	0.01	Golder 2004	T11-N	0-5	0.025
SLSA 1991	LC-72A	0-19	64.10	ESL 1992	O2	0-50	8.00	Golder 2004	T11-S	0-5	0.025
SLSA 1991	LC-73A	0-22	27.80	ESL 1992	P2-1	0-50	57.90	Golder 2004	T12-N	0-5	75.20
SLSA 1991	LC-74A	0-23	9.40	ESL 1992	Q2	0-50	28.60	Golder 2004	T2-M (LC)	0-5	0.05
SLSA 1991	LC-75A	0-20	82.10	ESL 1992	R2-1	0-50	10.00	Golder 2004	T3-M (LC)	0-5	0.22
SLSA 1991	LC-76A	0-20	7.23	MOE 1991	A1	0-20	32.00	Golder 2004	T4-M (LC)	0-5	5.83
SLSA 1991	LC-77A	0-19	44.80	MOE 1991	B1	0-20	3.30	Golder 2004	T5-M (LC)	0-5	4.16
SLSA 1991	LC-78A	0-20	11.80	MOE 1991	C1	0-20	14.00	Golder 2004	T6-M (LC)	0-5	10.5
SLSA 1991	LC-79A	0-16	24.40	MOE 1991	D1	0-20	6.70	Golder 2004	T7-M (LC)	0-5	40.5
SLSA 1991	LC-80A	0-16	17.60	MOE 1991	E1	0-20	32.00	Golder 2004	T8-M (LC)	0-5	22.6
SLSA 1991	LC-81A	0-23	9.40	MOE 1991	F1	0-20	6.50	Golder 2004	T9-M (LC)	0-5	9.03
SLSA 1991	LC-82A	0-24	1.41	MOE 1991	G1	0-20	11.00	Golder 2004	T10-M (LC)	0-5	3.42
SLSA 1991	LC-83A	0-19	45.00	MOE 1991	H1	0-20	16.00	Golder 2004	T12-M(LC)	0-5	6.26
SLSA 1991	LC-84A	0-22	72.60	MOE 1991	I1	0-20	40.00	Golder 2004	LC-6	0-5	11.60
SLSA 1991	LC-85A	0-22	25.10	MOE 1991	J1	0-20	65.00	Golder 2004	LC-7	0-5	18.60
SLSA 1991	LC-86A	0-20	43.90	MOE 1991	K1	0-20	34.00	Golder 2004	LC-8	0-5	27.30
SLSA 1991	LC-87A	0-20	8.59	MOE 1991	L1	0-20	6.30	Golder 2004	LC-11	0-5	0.41
SLSA 1991	LC-88A	0-22	68.00	MOE 1991	M1	0-20	15.00	Golder 2004	LC-12	0-5	0.52
SLSA 1991	LC-89A	0-23	40.40	MOE 1991	N1	0-20	42.00	Golder 2004	LC-13	0-5	12.20
SLSA 1991	LC-90A	0-17	10.80	MOE 1991	O1	0-20	7.70	Golder 2004	LC-14	0-5	11.50
SLSA 1991	LC-91A	0-19	2.48	MOE 1991	P1	0-20	5.10	Golder 2004	LC-15	0-5	1.41

Number of Samples		99
Minimum		0.01
Maximum		86.90

Upland Soil PCB Data Summary 1990-2004

Report	Sample Location	Depth (cm)	PCB_{total} mg/kg	Report	Sample Location	Depth (cm)	PCB_{total} mg/kg	Report	Sample Location	Depth (cm)	PCB_{total} mg/kg
SLSA 1991	LC-05A	0-17	0.01	SLSA 1991	LC-62	0-20	0.01	Golder 2004	T13-N	0-5	0.20
SLSA 1991	LC-07	0	0.03	SLSA 1991	LC-63	0-20	0.02	Golder 2004	T14-S	0-5	0.50
SLSA 1991	LC-09	0-20	0.02	ESL 1992	A-3'	0-50	0.01	Golder 2004	T14-N	0-5	0.025
SLSA 1991	LC-10	0-20	0.01	ESL 1992	P1	0-50	0.41	Golder 2004	T12-N+15	0-5	0.025
SLSA 1991	LC-11	0-20	0.08	ESL 1992	R1	0-50	0.28	Golder 2004	T1-M (LC)	0-5	0.025
SLSA 1991	LC-13	0	0.01	ESL 1992	R3	0-30	0.05	Dillon 2004	1		0.55
SLSA 1991	LC-17	0-10	0.03	ESL 1992	T1-1	0-50	0.01	Dillon 2004	2		0.025
SLSA 1991	LC-18	0-18	0.01	ESL 1992	T2-1	0-50	0.01	Dillon 2004	3		3.58
SLSA 1991	LC-19A	0-20	0.01	ESL 1992	DITSED-A	0-10	0.01	Dillon 2004	4		0.025
SLSA 1991	LC-21	0-20	0.22	ESL 1992	DITSED-B	0-10	0.01	Dillon 2004	5		0.87
SLSA 1991	LC-23	0-20	0.01	ESL 1992	117-3	0-30	0.01	Dillon 2004	6		0.025
SLSA 1991	LC-24	0-21	0.02	Golder 2004	LC-1	0-5	0.07	Dillon 2004	7		0.07
SLSA 1991	LC-25	0-14	0.01	Golder 2004	LC-2	0-5	0.015	Dillon 2004	8		0.025
SLSA 1991	LC-26A	0-13	0.01	Golder 2004	LC-3	0-5	0.08	Dillon 2004	9		0.025
SLSA 1991	LC-28A	0-19	0.04	Golder 2004	LC-4	0-5	0.015	Dillon 2004	10		0.025
SLSA 1991	LC-31A	0-15	0.01	Golder 2004	LC-5	0-5	0.04	Dillon 2004	11		0.025
SLSA 1991	LC-32	0-20	0.01	Golder 2004	LC-9	0-5	1.14	Dillon 2004	12		0.025
SLSA 1991	LC-36A	0-20	0.01	Golder 2004	LC-10	0-5	0.76	Dillon 2004	13		0.025
SLSA 1991	LC-38	0-20	0.02	Golder 2004	T1-N	0-5	0.025	Dillon 2004	14		0.025
SLSA 1991	LC-40	0-20	0.40	Golder 2004	T1-S	0-5	0.025	Dillon 2004	15		0.025
SLSA 1991	LC-55	0-19	0.01	Golder 2004	T2-N	0-5	0.025	Dillon 2004	16		0.14
SLSA 1991	LC-57	0-19	0.03	Golder 2004	T3-N	0-5	0.50	Dillon 2004	17		0.025
SLSA 1991	LC-53	0-20	0.02	Golder 2004	T4-N	0-5	0.50	Dillon 2004	18		0.025
SLSA 1991	LC-44A	0-22	0.56	Golder 2004	T5-N	0-5	0.50	Dillon 2004	19		0.025
SLSA 1991	LC-48	0-17	0.11	Golder 2004	T12-S	0-5	0.30	Dillon 2004	20		0.025
SLSA 1991	LC-50	0-20	0.01	Golder 2004	T13-S	0-5	0.11				

Number of Samples		77
Minimum		0.01
Maximum		3.58

Wetland Sediment/Soil Arsenic Data Summary 2004

Report	Sample Location	Depth (cm)	As mg/kg	Report	Sample Location	Depth (cm)	As mg/kg	Report	Sample Location	Depth (cm)	As mg/kg
Golder 2004	T8N+5(LC)	0-5	5.3	Golder 2004	T10-N	0-5	2.9	Golder 2004	T3-M (LC)	0-5	480
Golder 2004	T10S+5(LC)	0-5	4.5	Golder 2004	T10-S	0-5	24.5	Golder 2004	T4-M (LC)	0-5	19
Golder 2004	T5-S	0-5	5.2	Golder 2004	T11-N	0-5	2.9	Golder 2004	T5-M (LC)	0-5	58.7
Golder 2004	T6-N	0-5	23.9	Golder 2004	T11-S	0-5	2.4	Golder 2004	T6-M (LC)	0-5	95.2
Golder 2004	T6-S	0-5	2.3	Golder 2004	T12-N	0-5	45.7	Golder 2004	T7-M (LC)	0-5	13.8
Golder 2004	T7-N	0-5	18.5	Golder 2004	LC-6	0-5	8.2	Golder 2004	T8-M (LC)	0-5	33.9
Golder 2004	T8-N	0-5	11.0	Golder 2004	LC-8	0-5	71.1	Golder 2004	T9-M (LC)	0-5	16.8
Golder 2004	T8-S	0-5	3.9	Golder 2004	LC-12	0-5	4.4	Golder 2004	T10-M (LC)	0-5	8.6
Golder 2004	T9-N	0-5	3.1	Golder 2004	LC-13	0-5	14.3	Golder 2004	T12-M(LC)	0-5	16.0
Golder 2004	T9-S	0-5	2.8	Golder 2004	T2-M (LC)	0-5	80.2				

Number of Samples		29
Minimum		2.3
Maximum		480.0

Upland Soil Arsenic Data Summary 2004

Report	Sample Location	Depth (cm)	As mg/kg	Report	Sample Location	Depth (cm)	As mg/kg	Report	Sample Location	Depth (cm)	As mg/kg
Golder 2004	T12-S	0-5	4.8	Golder 2004	LC-1	0-5	167.0	Dillon 2004	10		4.9
Golder 2004	T13-S	0-5	8.4	Golder 2004	LC-2	0-5	47.0	Dillon 2004	11		6.2
Golder 2004	T13-N	0-5	5.0	Golder 2004	LC-9	0-5	5.1	Dillon 2004	12		6.6
Golder 2004	T14-S	0-5	6.6	Golder 2004	LC-10	0-5	5.5	Dillon 2004	13		4.7
Golder 2004	T14-N	0-5	5.2	Dillon 2004	1		6.0	Dillon 2004	14		5.0
Golder 2004	T1-N	0-5	3.2	Dillon 2004	2		6.3	Dillon 2004	15		4.6
Golder 2004	T1-S	0-5	2.8	Dillon 2004	3		8.9	Dillon 2004	16		9.9
Golder 2004	T2-N	0-5	3.7	Dillon 2004	4		6.2	Dillon 2004	17		6.5
Golder 2004	T3-N	0-5	2.6	Dillon 2004	5		6.2	Dillon 2004	18		4.8
Golder 2004	T4-N	0-5	3.2	Dillon 2004	6		5.0	Dillon 2004	19		5.8
Golder 2004	T5-N	0-5	2.4	Dillon 2004	7		5.2	Dillon 2004	20		5.5
Golder 2004	T12-N+15	0-5	7.8	Dillon 2004	8		5.8				
Golder 2004	T1-M (LC)	0-5	53.3	Dillon 2004	9		5.0				

Number of Samples		37
Minimum		2.4
Maximum		167.0

Upland Soil Metals Data Summary 2004

Parameter	1 mg/kg Soil	2 mg/kg Soil	3 mg/kg Soil	4 mg/kg Soil	5 mg/kg Soil	6 mg/kg Soil	7 mg/kg Soil	8 mg/kg Soil	9 mg/kg Soil	10 mg/kg Soil	11 mg/kg Soil	12 mg/kg Soil	13 mg/kg Soil	14 mg/kg Soil	15 mg/kg Soil	16 mg/kg Soil	17 mg/kg Soil	18 mg/kg Soil	19 mg/kg Soil	20 mg/kg Soil	Number of Samples	Max.	Min
As	6	6.3	8.9	6.2	6.2	5	5.2	5.8	5	4.9	6.2	6.6	4.7	5	4.6	9.9	6.5	4.8	5.8	5.5	20	9.9	4.6
Se	0.5	0.7	0.4	0.6	0.4	0.5	0.4	0.4	0.4	0.3	0.4	0.6	0.3	0.3	0.6	0.4	0.6	0.4	0.3	0.3	20	0.7	0.3
Sb	0.5	0.5	0.9	0.5	0.5	0.3	0.4	0.5	0.4	0.3	0.5	0.6	0.5	0.5	0.5	0.7	0.5	0.3	0.5	0.5	20	0.9	0.3
Ag	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	20	0.5	0.5
Al	19800	23400	14400	19400	16300	20100	17400	20900	18900	19800	20800	26400	20100	20200	12900	19800	25800	21000	18600	20900	20	26400	*12900*
Ba	115	112	95	92	104	130	112	104	107	128	131	96	133	120	48	119	131	135	109	116	20	135	48
Be	1	1.1	0.7	0.9	0.8	1	0.9	0.9	0.9	1	1	1.1	0.9	1	0.4	0.9	1.2	1	0.9	1	20	1.2	0.4
Ca	20000	4140	35300	8710	25900	41800	41800	20000	35600	46100	41600	2920	47300	33700	2430	25400	6870	52400	32400	26100	20	52400	2430
Cd	0.25	0.25	0.5	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	20	0.5	0.25
Co	15	13	12	12	11	13	12	13	13	13	15	15	13	13	6	13	17	14	12	15	20	17	6
Cr	31	37	48	127	35	30	29	33	29	28	31	38	30	31	21	36	36	29	31	32	20	127	21
Cu	24	18	57	20	30	24	28	21	22	25	27	21	27	23	10	39	22	26	27	25	20	57	10
Fe	35800	33800	49800	29200	42000	33800	31700	33000	31500	33100	34700	39200	33900	32800	15700	38200	40000	35500	34500	35100	20	49800	*15700*
K	3300	2900	2340	2560	2490	3660	3060	3140	3260	3990	3970	2980	3960	3830	1050	3430	3950	4270	2990	3860	20	4270	1050
Mg	9800	6960	17800	6770	8640	12300	13500	9040	11500	13300	12800	6630	13700	14100	2980	10000	7960	14300	13500	11600	20	17800	2980
Mn	987	996	997	816	720	746	761	788	699	626	691	903	634	687	451	674	1220	719	602	941	20	1220	*451*
Mo	1.5	1.5	4	7	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	20	7	1.5
Na	102	116	240	119	117	180	159	137	185	197	168	130	165	134	58	154	86	280	112	137	20	280	58
Ni	36	45	44	91	34	32	32	41	33	33	35	39	32	33	38	40	44	31	38	38	20	91	31
P	800	597	815	578	780	742	715	626	625	676	723	401	677	695	358	936	800	689	685	804	20	936	*358*
Pb	24	24	46	25	26	17	93	24	17	14	18	27	21	20	21	37	26	13	37	28	20	93	13
Sr	51.7	27.5	59.2	32	56.2	89.4	83.4	59	86.3	99.1	88.2	27.5	98.4	61.3	14.7	70.7	34.6	111	66	68.9	20	111	*14.7*
Ti	256	202	183	239	248	289	267	241	277	305	300	199	302	272	264	283	262	351	269	297	20	351	*183*
V	40	47	33	42	34	40	36	42	38	39	41	54	39	40	27	40	52	41	36	43	20	54	27
Zn	126	111	707	115	207	100	126	110	79	73	102	97	83	77	80	515	117	71	128	136	20	707	71

Lyon's Creek West: Coplanar and Mono-Orth PCBs in Soil and Sediment and Calculated TEQs

All values in ng/g d.w.	3,3',4,4'-TeCB	3,4,4',5-TeCB	2,3,3',4,4'-PeCB	2,3,4,4',5-PeCB	2,3',4,4',5-PeCB	2',3,4,4',5-PeCB	3,3',4,4',5-PeCB	2,3,3',4,4',5-HxCB	2,3,3',4,4',5'-HxCB	2,3',4,4',5,5'-HxCB	3,3',4,4',5,5'-HxCB	2,3,3',4,4',5,5'-HpCB	Total toxic PCB congeners
IUPAC No.	**77**	**81**	**105**	**114**	**118**	**123**	**126**	**156**	**157**	**167**	**169**	**189**	ng/g
TEF $_{mamm}$	0.0001	0.0001	0.0001	0.0005	0.0001	0.0001	0.1	0.0005	0.0005	0.00001	0.01	0.0001	
Concentration in soil (ng/g d.w.)													
T1-N	0.031	0.002	0.17	0.007	0.29	0.008	0.006	0.063	0.063	0.028 <	0.004	0.009	0.681
T5-N	0.48	0.023	1.5	0.055	2.8	0.081	0.018	0.3	0.3	0.094 <	0.007	0.031	5.689
T6-N	16	0.44	45	1.6	85	2.4	0.34	6.2	6.2	1.8 <	0.15	0.43	165.56
T7-N	53 <	0.51	110	1.9	390	16	1.7	29	29	14 <	0.82	3.5	649.43
T9-S	0.38 <	0.01	1.3	0.018	4.2	0.25	0.016	0.43	0.43	0.19 <	0.006	0.043	7.273
T12-S	0.82	0.025	3	0.11	6.1	0.14	0.052	2.2	2.2	0.95 <	0.095	0.74	16.432
Calculated TEQs (ng/g d.w) based on mammalian TEF													
T1-N TEQ	0.0000031	0.0000002	0.000017	0.0000035	0.000029	0.0000008	0.0006	0.0000315	0.0000315	0.00000028	0.00004	0.0000009	0.001
T5-N TEQ	0.000048	0.0000023	0.00015	0.0000275	0.00028	0.0000081	0.0018	0.00015	0.00015	0.00000094	0.00007	0.0000031	0.003
T6-N TEQ	0.0016	0.000044	0.0045	0.0008	0.0085	0.00024	0.034	0.0031	0.0031	0.000018	0.0015	0.000043	0.057
T7-N TEQ	0.0053	0.000051	0.011	0.00095	0.039	0.0016	0.17	0.0145	0.0145	0.00014	0.0082	0.00035	0.266
T9-S TEQ	0.000038	0.000001	0.00013	0.000009	0.00042	0.000025	0.0016	0.000215	0.000215	0.0000019	0.00006	0.0000043	0.003
T12-S TEQ	0.000038	0.000001	0.00013	0.000009	0.00042	0.000025	0.0016	0.000215	0.000215	0.0000019	0.00006	0.0000043	0.003
Concentration in sediment (ng/g d.w.)													
T3-M	0.2 <W	4	3	1	4	3 MPC	0.1 <W	0.2 <W	0.2 <W	0.2 <W	2	0.2 <W	17
T5-M	2	0.5 <W	52	3	120	12 MPC	0.1 <W	8	0.2 <W	3	14	1	215
T7-M	13	0.5 <W	340	16	730	99 MPC	0.1 <W	38	0.2 <W	16	90	5	1347
T8-M	7	0.5 <W	250	11	480	45 MPC	0.1 <W	29	0.2 <W	10	65	2	899
T11-M	1	0.5 <W	43	4	85	10 MPC	0.1 <W	6	0.2 <W	2	13	1	165
T12-M	3	0.5 <W	22	6	310	41 MPC	0.1 <W	13	0.2 <W	5	30	2	432
Calculated TEQs (ng/g d.w) based on mammalian TEF													
T3-M	0.0000194	<D.L.	0.001674	0.001885	0.001032	0.001143	<D.L.	<D.L.	<D.L.	<D.L.	<D.L.	<D.L.	0.0058
T5-M	0.000194	<D.L.	0.029016	0.005655	0.03096	0.004572	<D.L.	0.01596	<D.L.	0.00001056	<D.L.	<D.L.	0.0864
T7-M	0.001261	<D.L.	0.18972	0.03016	0.18834	0.037719	<D.L.	0.07581	<D.L.	0.0001584	<D.L.	<D.L.	0.5232
T8-M	0.000679	<D.L.	0.1395	0.020735	0.12384	0.017145	<D.L.	0.057855	<D.L.	0.0008448	<D.L.	<D.L.	0.3606
T11-M	0.000097	<D.L.	0.023994	0.00754	0.02193	0.00381	<D.L.	0.01197	<D.L.	0.000528	<D.L.	<D.L.	0.0699
T12-M	0.000291	<D.L.	0.012276	0.01131	0.07998	0.015621	<D.L.	0.025935	<D.L.	0.0001056	<D.L.	<D.L.	0.1455

APPENDIX B
Statistical Analysis of Sediment and Soil Quality Data

Appendix B: Statistical Data Summaries

The statistical analyses outputs from ProUCL, the datasets that these analyses are based on and histograms showing the distribution of concentrations of contaminants in soil and sediments for the Wetlands and Upland areas are provided on the following pages.

Wetland Area COCs

Lyon's Creek West: Arsenic Concentrations in Sediment (Wetland Area)

ProUCL Statistical Summary:		Arsenic Wetlands	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	29	Shapiro-Wilk Test Statisitic	0.39440147
Number of Unique Samples	28	Shapiro-Wilk 5% Critical Value	0.926
Minimum	2.3	Data not normal at 5% significance level	
Maximum	480		
Mean	37.21034	95% UCL (Assuming Normal Distribution)	
Median	13.8	Student's-t UCL	65.2560327
Standard Deviation	88.78251		
Variance	7882.334	Gamma Distribution Test	
Coefficient of Variation	2.385963	A-D Test Statistic	1.68278053
Skewness	4.746599	A-D 5% Critical Value	0.8018797
		K-S Test Statistic	0.19872487
Gamma Statistics		K-S 5% Critical Value	0.17104066
k hat	0.586486	Data do not follow gamma distribution	
k star (bias corrected)	0.548803	at 5% significance level	
Theta hat	63.44628		
Theta star	67.80269	95% UCLs (Assuming Gamma Distribution)	
nu hat	34.01618	Approximate Gamma UCL	59.4124909
nu star	31.8306	Adjusted Gamma UCL	61.1391372
Approx.Chi Square Value (.05)	19.93566		
Adjusted Level of Significance	0.0407	Lognormal Distribution Test	
Adjusted Chi Square Value	19.37266	Shapiro-Wilk Test Statisitic	0.9376633
		Shapiro-Wilk 5% Critical Value	0.926
Log-transformed Statistics		Data are lognormal at 5% significance level	
Minimum of log data	0.832909		
Maximum of log data	6.173786	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	2.559504	95% H-UCL	64.9400626
Standard Deviation of log data	1.332174	95% Chebyshev (MVUE) UCL	68.9904842
Variance of log data	1.774688	97.5% Chebyshev (MVUE) UCL	85.9627889
		99% Chebyshev (MVUE) UCL	119.301595
		95% Non-parametric UCLs	
		CLT UCL	64.3282208
		Adj-CLT UCL (Adjusted for skewness)	79.8553924
		Mod-t UCL (Adjusted for skewness)	67.6779577
		Jackknife UCL	65.2560327
		Standard Bootstrap UCL	64.0780176
		Bootstrap-t UCL	131.419727
RECOMMENDATION		Hall's Bootstrap UCL	156.42377
Data are lognormal (0.05)		Percentile Bootstrap UCL	67.6172414
		BCA Bootstrap UCL	86.1551724
Use H-UCL		95% Chebyshev (Mean, Sd) UCL	109.073323
		97.5% Chebyshev (Mean, Sd) UCL	140.168491
		99% Chebyshev (Mean, Sd) UCL	201.248928

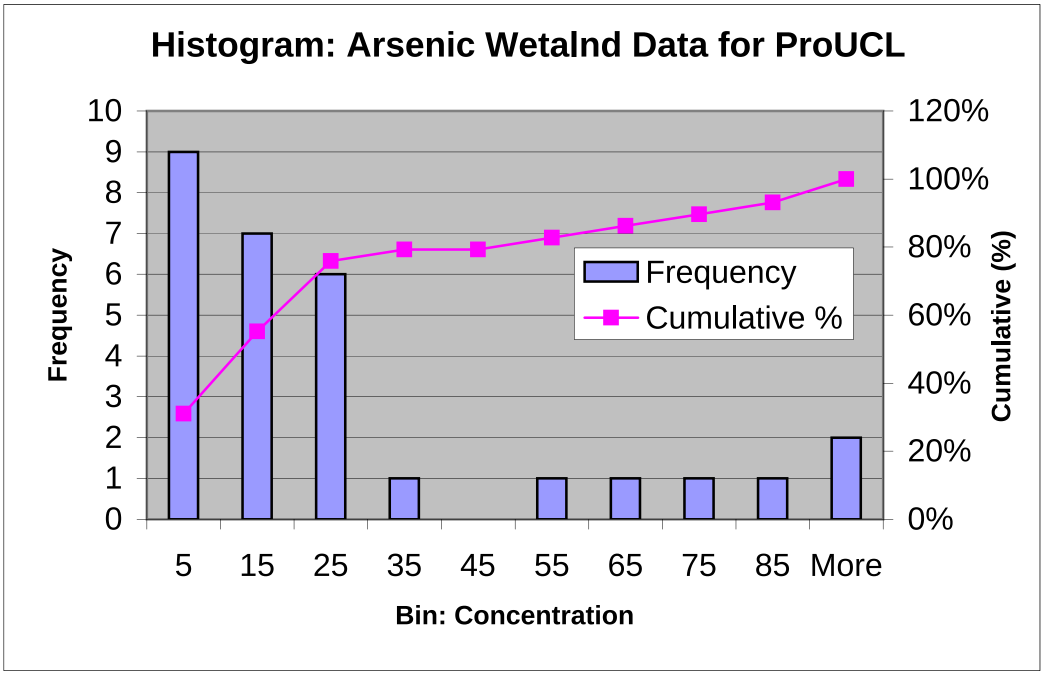
Lyon's Creek West: Arsenic Concentrations in Sediment (Wetland Area)

Raw data

As
5.3
4.5
5.2
23.9
2.3
18.5
11.0
3.9
3.1
2.8
2.9
24.5
2.9
2.4
45.7
8.2
71.1
4.4
14.3
80.2
480
19
58.7
95.2
13.8
33.9
16.8
8.6
16.0

Histogram data

Bin	*Frequency*	*Cumulative %*
5	9	31.0%
15	7	55.2%
25	6	75.9%
35	1	79.3%
45	0	79.3%
55	1	82.8%
65	1	86.2%
75	1	89.7%
85	1	93.1%
More	2	100.0%



Lyon's Creek West: Zinc Concentration in Soil (Wetland Area)

ProUCL Statistical Summary:		Zinc Wetlands	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	29	Shapiro-Wilk Test Statisitic	0.536971
Number of Unique Samples	28	Shapiro-Wilk 5% Critical Value	0.926
Minimum	78	Data not normal at 5% significance level	
Maximum	4120		
Mean	537.3793	95% UCL (Assuming Normal Distribution)	
Median	149	Student's-t UCL	838.1657
Standard Deviation	952.181		
Variance	906648.7	Gamma Distribution Test	
Coefficient of Variation	1.771897	A-D Test Statistic	4.419378
Skewness	2.615779	A-D 5% Critical Value	0.791953
		K-S Test Statistic	0.381903
Gamma Statistics		K-S 5% Critical Value	0.169926
k hat	0.675819	Data do not follow gamma distribution	
k star (bias corrected)	0.628895	at 5% significance level	
Theta hat	795.153		
Theta star	854.4818	95% UCLs (Assuming Gamma Distribution)	
nu hat	39.19749	Approximate Gamma UCL	828.8178
nu star	36.47591	Adjusted Gamma UCL	851.045
Approx.Chi Square Value (.05)	23.64983		
Adjusted Level of Significance	0.0407	Lognormal Distribution Test	
Adjusted Chi Square Value	23.03215	Shapiro-Wilk Test Statisitic	0.741521
		Shapiro-Wilk 5% Critical Value	0.926
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	4.356709		
Maximum of log data	8.323608	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	5.388036	95% H-UCL	769.2676
Standard Deviation of log data	1.161565	95% Chebyshev (MVUE) UCL	874.9088
Variance of log data	1.349233	97.5% Chebyshev (MVUE) UCL	1074.327
		99% Chebyshev (MVUE) UCL	1466.045
		95% Non-parametric UCLs	
		CLT UCL	828.215
		Adj-CLT UCL (Adjusted for skewness)	919.9855
		Mod-t UCL (Adjusted for skewness)	852.4801
		Jackknife UCL	838.1657
		Standard Bootstrap UCL	819.4028
		Bootstrap-t UCL	1056.529
RECOMMENDATION		Hall's Bootstrap UCL	882.1334
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	855.6552
		BCA Bootstrap UCL	885.4828
Use 99% Chebyshev (Mean, Sd) UCL		95% Chebyshev (Mean, Sd) UCL	1308.101
		97.5% Chebyshev (Mean, Sd) UCL	1641.592
		99% Chebyshev (Mean, Sd) UCL	2296.672

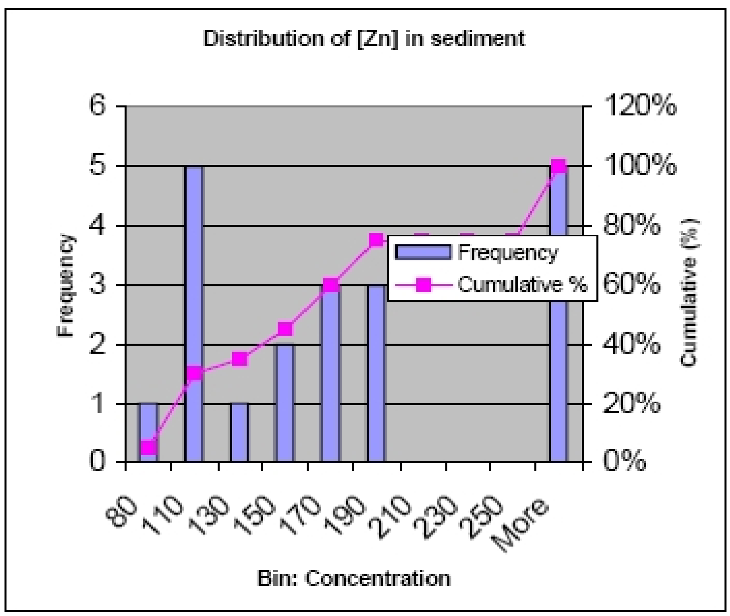
Lyon's Creek West: Zinc Concentration in Soil (Wetland Area)

Raw data

Zn
121
98
2110
149
900
165
273
94
101
109
184
78
172
185
140
167
93
2260
848
150
101
88
96
2290
120
90
4120
176
106

Histogram data

Bin	Frequency	Cumulative %
80	1	5.0%
110	5	30.0%
130	1	35.0%
150	2	45.0%
170	3	60.0%
190	3	75.0%
210	0	75.0%
230	0	75.0%
250	0	75.0%
More	5	100.0%



Lyon's Creek West: PCB Concentrations in Sediment (Wetland Area)

ProUCL Statistical Summary:		**PCB_{Total} Wetlands**	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	99	Lilliefors Test Statisitic	0.2089766
Number of Unique Samples	82	Lilliefors 5% Critical Value	0.0890464
Minimum	0.01	Data not normal at 5% significance level	
Maximum	86.9		
Mean	18.6896	95% UCL (Assuming Normal Distribution)	
Median	9.4	Student's-t UCL	22.46081
Standard Deviation	22.59678		
Variance	510.6145	Gamma Distribution Test	
Coefficient of Variation	1.209057	A-D Test Statistic	1.4656011
Skewness	1.427574	A-D 5% Critical Value	0.840618
		K-S Test Statistic	0.0947304
Gamma Statistics		K-S 5% Critical Value	0.0962328
k hat	0.409826	Data follow approximate gamma distibution	
k star (bias corrected)	0.404141	at 5% significance level	
Theta hat	45.60377		
Theta star	46.24526	95% UCLs (Assuming Gamma Distribution)	
nu hat	81.14549	Approximate Gamma UCL	24.758519
nu star	80.01987	Adjusted Gamma UCL	24.861739
Approx.Chi Square Value (.05)	60.40503		
Adjusted Level of Significance	0.047576	Lognormal Distribution Test	
Adjusted Chi Square Value	60.15424	Lilliefors Test Statisitic	0.1904266
		Lilliefors 5% Critical Value	0.0890464
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	-4.60517		
Maximum of log data	4.464758	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	1.328571	95% H-UCL	490.4665
Standard Deviation of log data	2.722957	95% Chebyshev (MVUE) UCL	411.48245
Variance of log data	7.414494	97.5% Chebyshev (MVUE) UCL	532.85117
		99% Chebyshev (MVUE) UCL	771.25651
		95% Non-parametric UCLs	
		CLT UCL	22.42516
		Adj-CLT UCL (Adjusted for skewness)	22.77333
		Mod-t UCL (Adjusted for skewness)	22.515117
		Jackknife UCL	22.46081
		Standard Bootstrap UCL	22.397034
		Bootstrap-t UCL	22.792479
RECOMMENDATION		Hall's Bootstrap UCL	23.044784
Assuming gamma distribution (0.05)		Percentile Bootstrap UCL	22.440101
		BCA Bootstrap UCL	22.891364
Use Adjusted Gamma UCL		95% Chebyshev (Mean, Sd) UCL	28.588925
		97.5% Chebyshev (Mean, Sd) UCL	32.872373
		99% Chebyshev (Mean, Sd) UCL	41.286376

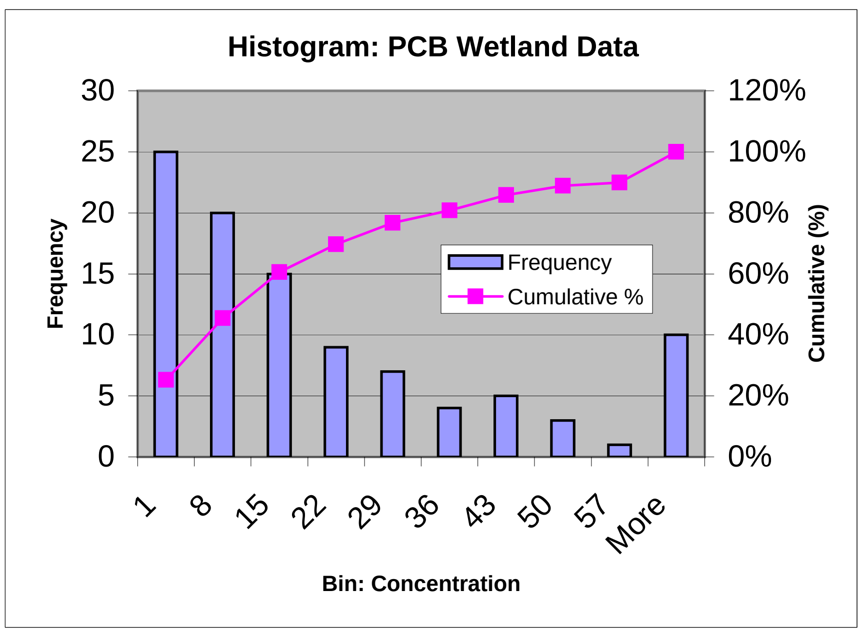
Lyon's Creek West: PCB Concentrations in Sediment (Wetlands Area)

Raw data

PCB_{total}		
2.98	78.00	0.13
19.90	0.01	0.025
21.00	19.00	0.025
86.90	0.01	5.36
55.60	0.01	0.025
26.00	2.13	0.025
4.30	1.89	75.20
41.70	0.38	0.05
35.00	0.01	0.22
0.04	8.00	5.83
17.60	57.90	4.16
71.20	28.60	10.5
21.80	10.00	40.5
64.10	32.00	22.6
27.80	3.30	9.03
9.40	14.00	3.42
82.10	6.70	6.26
7.23	32.00	11.60
44.80	6.50	18.60
11.80	11.00	27.30
24.40	16.00	0.41
17.60	40.00	0.52
9.40	65.00	12.20
1.41	34.00	11.50
45.00	6.30	1.41
72.60	15.00	
25.10	42.00	
43.90	7.70	
8.59	5.10	
68.00	0.50	
40.40	0.025	
10.80	0.50	
2.48	0.50	
0.58	0.025	
0.01	11.40	
0.01	6.19	
0.01	0.15	

Histogram data

Bin	*Frequency*	*Cumulative %*
1	25	25.3%
8	20	45.5%
15	15	60.6%
22	9	69.7%
29	7	76.8%
36	4	80.8%
43	5	85.9%
50	3	88.9%
57	1	89.9%
More	10	100.0%



Upland Area COCs

Lyon's Creek West: Aluminum Concentration in Soil (Upland Area)

ProUCL Statistical Summary:	Aluminum		
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.930383
Number of Unique Samples	16	Shapiro-Wilk 5% Critical Value	0.905
Minimum	12900	Data are normal at 5% significance level	
Maximum	26400		
Mean	19845	95% UCL (Assuming Normal Distribution)	
Median	19950	Studen	21083.25
Standard Deviation	3202.544		
Variance	10256289	Gamma Distribution Test	
Coefficient of Variation	0.161378	A-D Test Statistic	0.788414
Skewness	-0.02821	A-D 5% Critical Value	0.739927
		K-S Test Statistic	0.191454
Gamma Statistics		K-S 5% Critical Value	0.193443
k hat	38.66627	Data follow approximate gamma distibution	
k star (bias corrected)	32.89967	at 5% significance level	
Theta hat	513.238		
Theta star	603.1976	95% UCLs (Assuming Gamma Distribution)	
nu hat	1546.651	Approximate Gamma UCL	21185.2
nu star	1315.987	Adjusted Gamma UCL	21294.93
Approx.Chi Square Value (.05)	1232.736		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	1226.383	Shapiro-Wilk Test Statisitic	0.914
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data are lognormal at 5% significance level	
Minimum of log data	9.464983		
Maximum of log data	10.18112	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	9.88272	95% H-UCL	21263.02
Standard Deviation of log data	0.168121	95% Chebyshev (MVUE) UCL	23121.26
Variance of log data	0.028265	97.5% Chebyshev (MVUE) UCL	24535.2
		99% Chebyshev (MVUE) UCL	27312.62
		95% Non-parametric UCLs	
		CLT UCL	21022.9
		Adj-CLT UCL (Adjusted for skewness)	21018.07
		Mod-t UCL (Adjusted for skewness)	21082.5
		Jackknife UCL	21083.25
		Standard Bootstrap UCL	21021.93
		Bootstrap-t UCL	21100.35
F		Hall's Bootstrap UCL	21143.21
Da		Percentile Bootstrap UCL	20985
		BCA Bootstrap UCL	21015
Use St		95% Chebyshev (Mean, Sd) UCL	22966.45
		97.5% Chebyshev (Mean, Sd) UCL	24317.11
		99% Chebyshev (Mean, Sd) UCL	26970.21

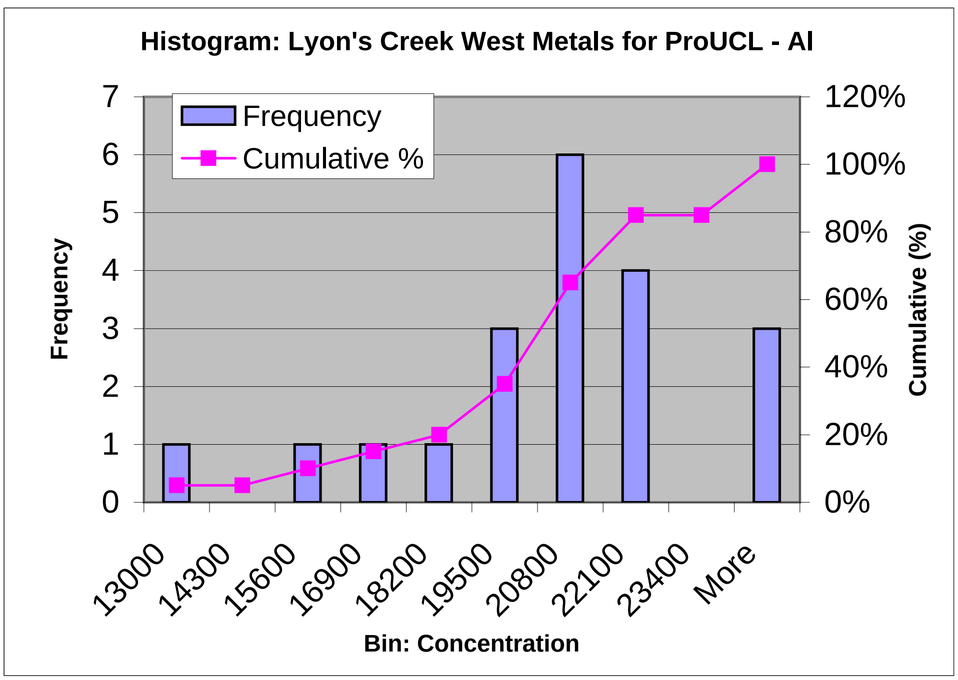
Lyon's Creek West Metals for ProUCL - Aluminum

Raw data

Al
19800
23400
14400
19400
16300
20100
17400
20900
18900
19800
20800
26400
20100
20200
12900
19800
25800
21000
18600
20900

Histogram data

Bin	*Frequency*	*Cumulative %*
13000	1	5.0%
14300	0	5.0%
15600	1	10.0%
16900	1	15.0%
18200	1	20.0%
19500	3	35.0%
20800	6	65.0%
22100	4	85.0%
23400	0	85.0%
More	3	100.0%



Lyon's Creek West: Antimony Concentration in Soil (Upland Area)

ProUCL Statistical Summary:	Antimony					
Raw Statistics		Normal Distribution Test				
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic				0.7950689
Number of Unique Samples	6	Shapiro-Wilk 5% Critical Value				0.905
Minimum	0.3	Data not normal at 5% significance level				
Maximum	0.9					
Mean	0.495	95% UCL (Assuming Normal Distribution)				
Median	0.5	Studen				0.54743969
Standard Deviation	0.135627					
Variance	0.018395	Gamma Distribution Test				
Coefficient of Variation	0.273994	A-D Test Statistic				1.79676058
Skewness	1.224639	A-D 5% Critical Value				0.7412779
		K-S Test Statistic				0.30025471
Gamma Statistics		K-S 5% Critical Value				0.19366263
k hat	15.06398	Data do not follow gamma distribution				
k star (bias corrected)	12.83771	at 5% significance level				
Theta hat	0.03286					
Theta star	0.038558	95% UCLs (Assuming Gamma Distribution)				
nu hat	602.559	Approximate Gamma UCL				0.55025165
nu star	513.5085	Adjusted Gamma UCL				0.55488553
Approx.Chi Square Value (.05)	461.9463					
Adjusted Level of Significance	0.038	Lognormal Distribution Test				
Adjusted Chi Square Value	458.0885	Shapiro-Wilk Test Statisitic				0.83146245
		Shapiro-Wilk 5% Critical Value				0.905
Log-transformed Statistics		Data not lognormal at 5% significance level				
Minimum of log data	-1.20397					
Maximum of log data	-0.10536	95% UCLs (Assuming Lognormal Distribution)				
Mean of log data	-0.73676	95% H-UCL				0.55376721
Standard Deviation of log data	0.265204	95% Chebyshev (MVUE) UCL				0.62421899
Variance of log data	0.070333	97.5% Chebyshev (MVUE) UCL				0.68017576
		99% Chebyshev (MVUE) UCL				0.79009199
		95% Non-parametric UCLs				
		CLT UCL				0.54488374
		Adj-CLT UCL (Adjusted for skewness)				0.55375746
		Mod-t U				0.54882381
		Jackknife UCL				0.54743969
		Standard Bootstrap UCL				0.54389893
		Bootstrap-t UCL				0.56071261
F		Hall's Bootstrap UCL				0.59459503
Data		Percentile Bootstrap UCL				0.545
		BCA Bootstrap UCL				0.55
Use St		95% Chebyshev (Mean, Sd) UCL				0.62719304
or Mod		97.5% Chebyshev (Mean, Sd) UCL				0.68439307
		99% Chebyshev (Mean, Sd) UCL				0.79675147

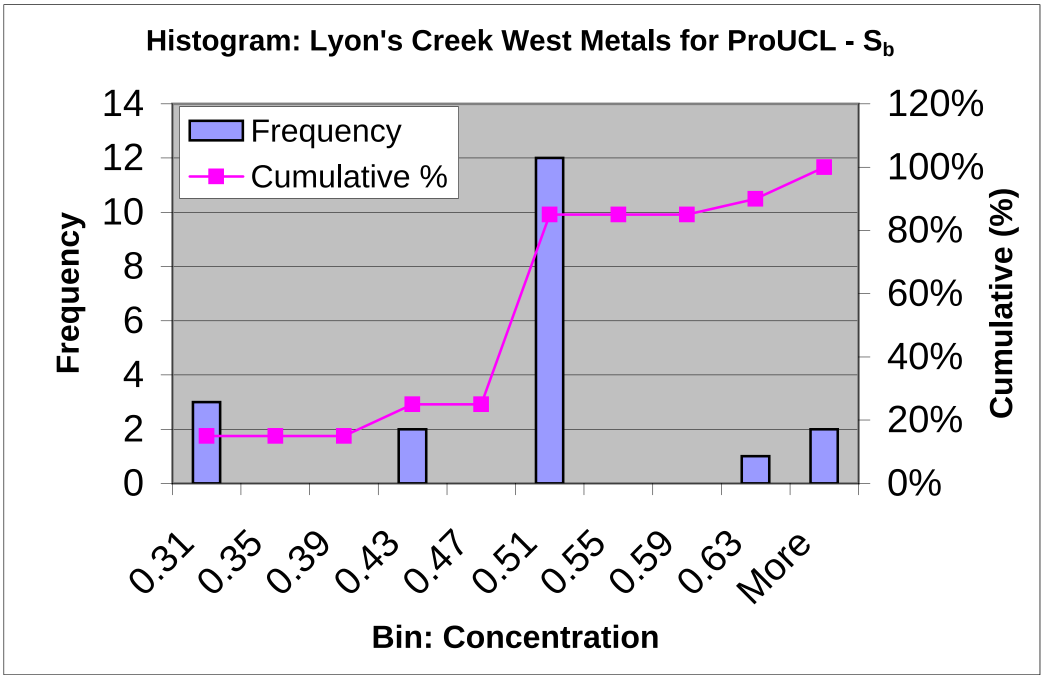
Lyon's Creek West: Antimony Concentration in Soil (Upland Area)

Raw data

S_b
0.5
0.5
0.9
0.5
0.5
0.3
0.4
0.5
0.4
0.3
0.5
0.6
0.5
0.5
0.5
0.7
0.5
0.3
0.5
0.5

Histogram data

Bin	*Frequency*	*Cumulative %*
0.31	3	15.0%
0.35	0	15.0%
0.39	0	15.0%
0.43	2	25.0%
0.47	0	25.0%
0.51	12	85.0%
0.55	0	85.0%
0.59	0	85.0%
0.63	1	90.0%
More	2	100.0%



Lyon's Creek West: All Arsenic Concentrations in Soil (Upland Area)

ProUCL Statistical Summary:		Arsenic Uplands (all samples)	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	37	Shapiro-Wilk Test Statisitic	0.3243695
Number of Unique Samples	26	Shapiro-Wilk 5% Critical Value	0.936
Minimum	2.4	Data not normal at 5% significance level	
Maximum	167		
Mean	12.23514	95% UCL (Assuming Normal Distribution)	
Median	5.5	Student's-t UCL	20.04522
Standard Deviation	28.13893		
Variance	791.7996	Gamma Distribution Test	
Coefficient of Variation	2.299847	A-D Test Statistic	7.1115226
Skewness	5.015932	A-D 5% Critical Value	0.7809627
		K-S Test Statistic	0.377384
Gamma Statistics		K-S 5% Critical Value	0.1497985
k hat	0.910668	Data do not follow gamma distribution	
k star (bias corrected)	0.854848	at 5% significance level	
Theta hat	13.43535		
Theta star	14.31265	95% UCLs (Assuming Gamma Distribution)	
nu hat	67.3894	Approximate Gamma UCL	16.840686
nu star	63.25873	Adjusted Gamma UCL	17.07877
Approx.Chi Square Value (.05)	45.95888		
Adjusted Level of Significance	0.0431	Lognormal Distribution Test	
Adjusted Chi Square Value	45.3182	Shapiro-Wilk Test Statisitic	0.6907239
		Shapiro-Wilk 5% Critical Value	0.936
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	0.875469		
Maximum of log data	5.117994	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	1.863291	95% H-UCL	12.156276
Standard Deviation of log data	0.818755	95% Chebyshev (MVUE) UCL	14.733329
Variance of log data	0.670359	97.5% Chebyshev (MVUE) UCL	17.255025
		99% Chebyshev (MVUE) UCL	22.208407
		95% Non-parametric UCLs	
		CLT UCL	19.844248
		Adj-CLT UCL (Adjusted for skewness)	23.920283
		Mod-t UCL (Adjusted for skewness)	20.680999
		Jackknife UCL	20.04522
		Standard Bootstrap UCL	19.761986
		Bootstrap-t UCL	36.969068
RECOMMENDATION		Hall's Bootstrap UCL	39.55503
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	20.87027
		BCA Bootstrap UCL	25.621622
Use 95% Chebyshev (Mean, Sd) UCL		95% Chebyshev (Mean, Sd) UCL	32.399455
		97.5% Chebyshev (Mean, Sd) UCL	41.124572
		99% Chebyshev (Mean, Sd) UCL	58.263375

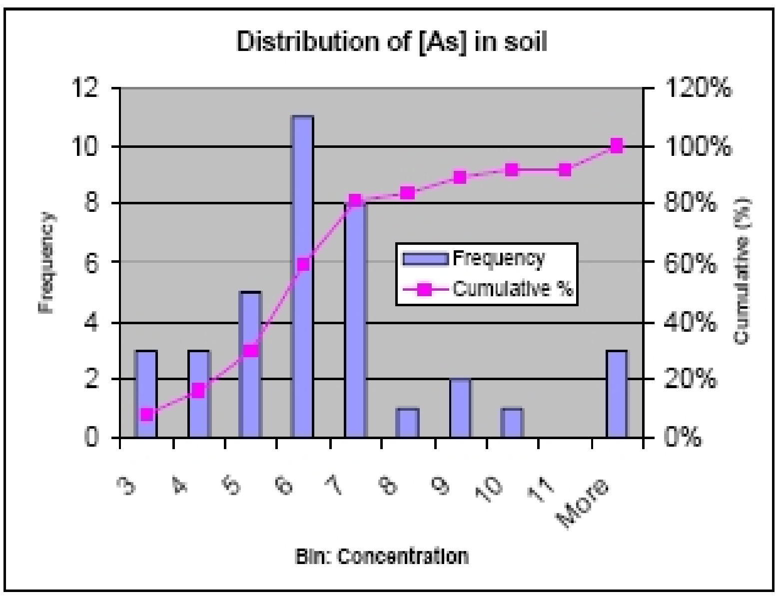
Lyons Creek West: All Arsenic Concentrations in soil (Upland Area)

Raw data

As
2.4
2.6
2.8
3.2
3.2
3.7
4.6
4.7
4.8
4.8
4.9
5.0
5.0
5.0
5.0
5.1
5.2
5.2
5.5
5.5
5.8
5.8
6.0
6.2
6.2
6.2
6.3
6.5
6.6
6.6
7.8
8.4
8.9
9.9
47.0
53.3
167.0

Histogram data

Bin	Frequency	Cumulative %
3	3	8.1%
4	3	16.2%
5	5	29.7%
6	11	59.5%
7	8	81.1%
8	1	83.8%
9	2	89.2%
10	1	91.9%
11	0	91.9%
More	3	100.0%



Lyon's Creek West: Arsenic Concentration in Soil LC-1, LC-2 and T1-M Removed (Upland Area)

ProUCL Statistical Summary:		**Arsenic Upland LC-1, LC-2 and T1-M Removed**	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	34	Shapiro-Wilk Test Statisitic	0.949190251
Number of Unique Samples	23	Shapiro-Wilk 5% Critical Value	0.933
Minimum	2.4	Data are normal at 5% significance level	
Maximum	9.9		
Mean	5.452941	95% UCL (Assuming Normal Distribution)	
Median	5.2	Student's-t UCL	5.942174484
Standard Deviation	1.685632		
Variance	2.841355	Gamma Distribution Test	
Coefficient of Variation	0.309123	A-D Test Statistic	0.725178634
Skewness	0.489911	A-D 5% Critical Value	0.747664796
		K-S Test Statistic	0.15843639
Gamma Statistics		K-S 5% Critical Value	0.150887722
k hat	10.33381	Data follow approximate gamma distibution	
k star (bias corrected)	9.441611	at 5% significance level	
Theta hat	0.52768		
Theta star	0.577544	95% UCLs (Assuming Gamma Distribution)	
nu hat	702.6991	Approximate Gamma UCL	5.992365623
nu star	642.0295	Adjusted Gamma UCL	6.020362287
Approx.Chi Square Value (.05)	584.2349		
Adjusted Level of Significance	0.0422	Lognormal Distribution Test	
Adjusted Chi Square Value	581.5181	Shapiro-Wilk Test Statisitic	0.938629643
		Shapiro-Wilk 5% Critical Value	0.933
Log-transformed Statistics		Data are lognormal at 5% significance level	
Minimum of log data	0.875469		
Maximum of log data	2.292535	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	1.646991	95% H-UCL	6.070394888
Standard Deviation of log data	0.327445	95% Chebyshev (MVUE) UCL	6.833855437
Variance of log data	0.10722	97.5% Chebyshev (MVUE) UCL	7.424782009
		99% Chebyshev (MVUE) UCL	8.585542833
		95% Non-parametric UCLs	
		CLT UCL	5.928441182
		Adj-CLT UCL (Adjusted for skewness)	5.95439379
		Mod-t UCL (Adjusted for skewness)	5.946222567
		Jackknife UCL	5.942174484
		Standard Bootstrap UCL	5.920986832
		Bootstrap-t UCL	5.980724043
RECOMMENDATION		Hall's Bootstrap UCL	5.974947666
Data are normal (0.05)		Percentile Bootstrap UCL	5.938235294
		BCA Bootstrap UCL	5.947058824
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	6.713026838
		97.5% Chebyshev (Mean, Sd) UCL	7.258266911
		99% Chebyshev (Mean, Sd) UCL	8.329285454

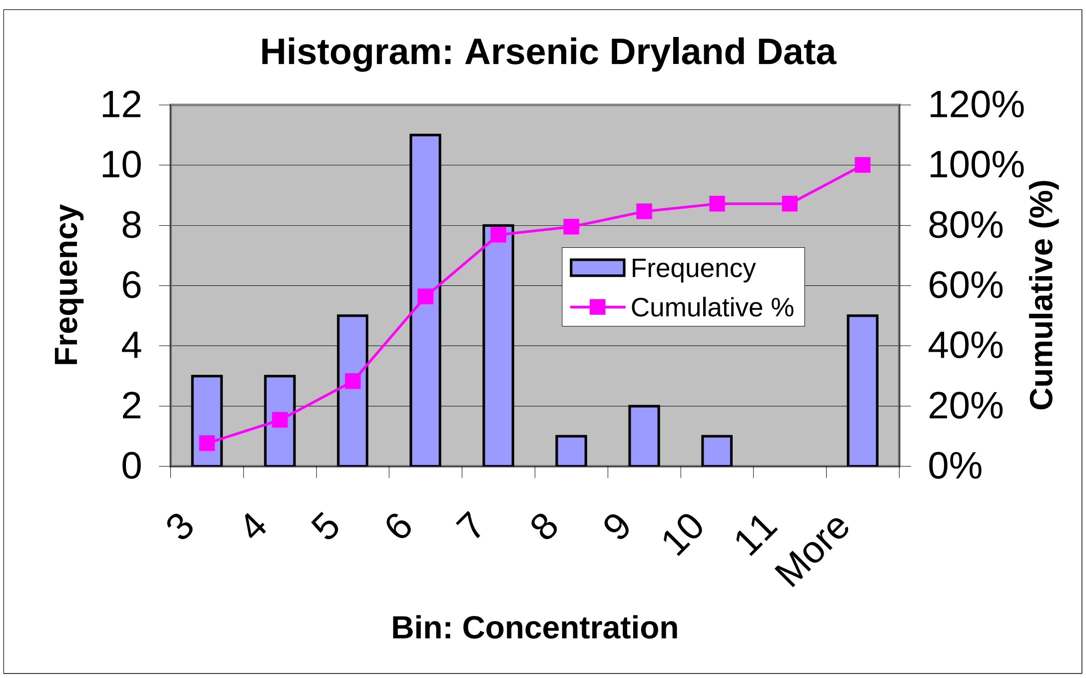
Arsenic Dryland Data for ProUCL LC1 TM1LCLC-2 Removed

Raw data

As
2.4
2.6
2.8
3.2
3.2
3.7
4.6
4.7
4.8
4.8
4.9
5.0
5.0
5.0
5.0
5.1
5.2
5.2
5.5
5.5
5.8
5.8
6.0
6.2
6.2
6.2
6.3
6.5
6.6
6.6
7.8
8.4
8.9
9.9

Histogram data

Bin	*Frequency*	*Cumulative %*
3	3	7.7%
4	3	15.4%
5	5	28.2%
6	11	56.4%
7	8	76.9%
8	1	79.5%
9	2	84.6%
10	1	87.2%
11	0	87.2%
More	5	100.0%



Lyon's Creek West: Barium Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Barium	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.8556275
Number of Unique Samples	17	Shapiro-Wilk 5% Critical Value	0.905
Minimum	48	Data not normal at 5% significance level	
Maximum	135		
Mean	111.85	95% UCL (Assuming Normal Distribution)	
Median	113.5	Student's-t UCL	119.5893
Standard Deviation	20.01651		
Variance	400.6605	Gamma Distribution Test	
Coefficient of Variation	0.178958	A-D Test Statistic	1.1272946
Skewness	-1.683571	A-D 5% Critical Value	0.7405374
		K-S Test Statistic	0.1867186
Gamma Statistics		K-S 5% Critical Value	0.193471
k hat	24.47973	Data follow approximate gamma distibution	
k star (bias corrected)	20.8411	at 5% significance level	
Theta hat	4.569086		
Theta star	5.366798	95% UCLs (Assuming Gamma Distribution)	
nu hat	979.1892	Approximate Gamma UCL	121.46991
nu star	833.6441	Adjusted Gamma UCL	122.26563
Approx.Chi Square Value (.05)	767.623		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	762.6272	Shapiro-Wilk Test Statisitic	0.7234661
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	3.871201		
Maximum of log data	4.905275	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	4.696595	95% H-UCL	123.40626
Standard Deviation of log data	0.226602	95% Chebyshev (MVUE) UCL	137.27167
Variance of log data	0.051348	97.5% Chebyshev (MVUE) UCL	148.08749
		99% Chebyshev (MVUE) UCL	169.33305
		95% Non-parametric UCLs	
		CLT UCL	119.21208
		Adj-CLT UCL (Adjusted for skewness)	117.41167
		Mod-t UCL (Adjusted for skewness)	119.30847
		Jackknife UCL	119.58930
		Standard Bootstrap UCL	119.04317
		Bootstrap-t UCL	117.99752
RECOMMENDATION		Hall's Bootstrap UCL	118.12776
Assuming gamma distribution (0.05)		Percentile Bootstrap UCL	118.5
		BCA Bootstrap UCL	117.35
Use Approximate Gamma UCL		95% Chebyshev (Mean, Sd) UCL	131.35968
		97.5% Chebyshev (Mean, Sd) UCL	139.80153
		99% Chebyshev (Mean, Sd) UCL	156.38392

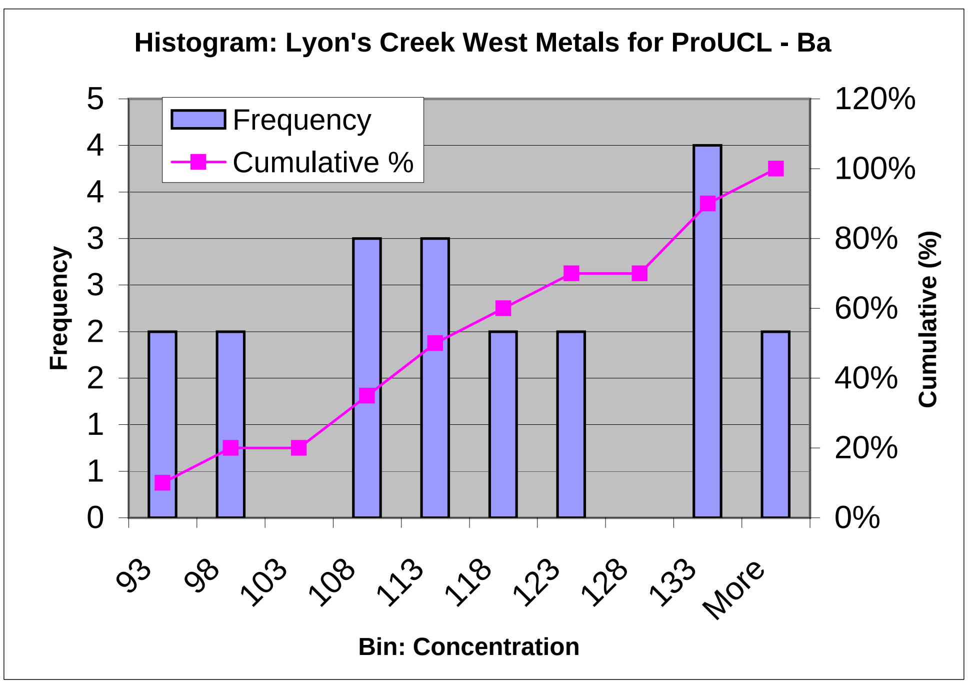
Lyon's Creek West: Barium Concentration in Soil (Upland Area)

Raw data

Ba
115
112
95
92
104
130
112
104
107
128
131
96
133
120
48
119
131
135
109
116

Histogram data

Bin	*Frequency*	*Cumulative %*
93	2	10.0%
98	2	20.0%
103	0	20.0%
108	3	35.0%
113	3	50.0%
118	2	60.0%
123	2	70.0%
128	0	70.0%
133	4	90.0%
More	2	100.0%



Lyon's Creek West: Cadmium Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Cadmium	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.235903
Number of Unique Samples	2	Shapiro-Wilk 5% Critical Value	0.905
Minimum	0.25	Data not normal at 5% significance level	
Maximum	0.5		
Mean	0.2625	95% UCL (Assuming Normal Distribution)	
Median	0.25	Student's-t UCL	0.284114
Standard Deviation	0.055902		
Variance	0.003125	Gamma Distribution Test	
Coefficient of Variation	0.212959	A-D Test Statistic	7.235096
Skewness	4.472136	A-D 5% Critical Value	0.740062
		K-S Test Statistic	0.541873
Gamma Statistics		K-S 5% Critical Value	0.193449
k hat	35.54456	Data do not follow gamma distribution	
k star (bias corrected)	30.24621	at 5% significance level	
Theta hat	0.007385		
Theta star	0.008679	95% UCLs (Assuming Gamma Distribution)	
nu hat	1421.782	Approximate Gamma UCL	0.281031
nu star	1209.848	Adjusted Gamma UCL	0.28255
Approx.Chi Square Value (.05)	1130.073		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	1123.995	Shapiro-Wilk Test Statisitic	0.235903
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	-1.386294		
Maximum of log data	-0.693147	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	-1.351637	95% H-UCL	0.278789
Standard Deviation of log data	0.154992	95% Chebyshev (MVUE) UCL	0.301481
Variance of log data	0.024023	97.5% Chebyshev (MVUE) UCL	0.318658
		99% Chebyshev (MVUE) UCL	0.352399
		95% Non-parametric UCLs	
		CLT UCL	0.283061
		Adj-CLT UCL (Adjusted for skewness)	0.296417
		Mod-t UCL (Adjusted for skewness)	0.286197
		Jackknife UCL	0.284114
		Standard Bootstrap UCL	N/R
		Bootstrap-t UCL	N/R
RECOMMENDATION		Hall's Bootstrap UCL	N/A
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	N/R
		BCA Bootstrap UCL	N/R
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	0.316986
or Modified-t UCL		97.5% Chebyshev (Mean, Sd) UCL	0.340562
		99% Chebyshev (Mean, Sd) UCL	0.386873

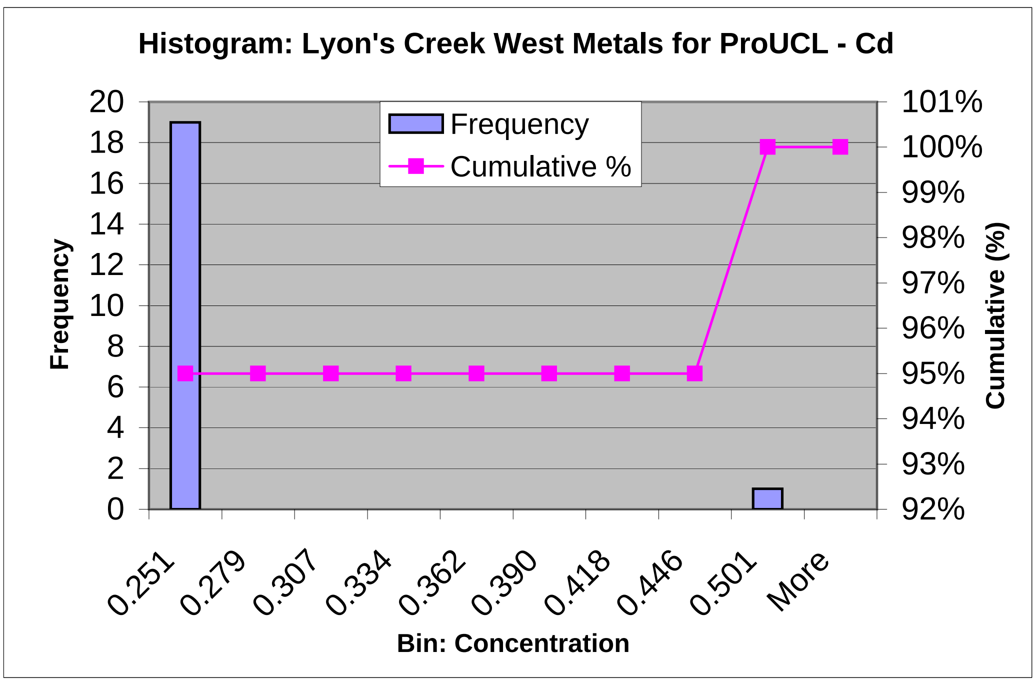
Lyon's Creek West: Cadmium Concentration in Soil (Upland Area)

Raw data

Cd
0.25
0.25
0.5
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25
0.25

Histogram data

Bin	*Frequency*	*Cumulative %*
0.251	19	95.0%
0.279	0	95.0%
0.307	0	95.0%
0.334	0	95.0%
0.362	0	95.0%
0.390	0	95.0%
0.418	0	95.0%
0.446	0	95.0%
0.501	1	100.0%
More	0	100.0%



Lyon's Creek West: Chromium Concentration in Soil (Upland Area)

ProUCL Statistical Summary:	**Chromium (Total)**		
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.442555
Number of Unique Samples	13	Shapiro-Wilk 5% Critical Value	0.905
Minimum	21	Data not normal at 5% significance level	
Maximum	127		
Mean	37.1	95% UCL (Assuming Normal Distribution)	
Median	31	Student's-t UCL	45.53366
Standard Deviation	21.81236		
Variance	475.7789	Gamma Distribution Test	
Coefficient of Variation	0.587934	A-D Test Statistic	3.001941
Skewness	4.054459	A-D 5% Critical Value	0.744291
		K-S Test Statistic	0.323509
Gamma Statistics		K-S 5% Critical Value	0.194298
k hat	6.385362	Data do not follow gamma distribution	
k star (bias corrected)	5.460891	at 5% significance level	
Theta hat	5.810164		
Theta star	6.793764	95% UCLs (Assuming Gamma Distribution)	
nu hat	255.4145	Approximate Gamma UCL	43.75244
nu star	218.4356	Adjusted Gamma UCL	44.33025
Approx.Chi Square Value (.05)	185.2231		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	182.8089	Shapiro-Wilk Test Statisitic	0.655699
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	3.044522		
Maximum of log data	4.844187	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	3.533274	95% H-UCL	42.23845
Standard Deviation of log data	0.347723	95% Chebyshev (MVUE) UCL	48.76787
Variance of log data	0.120912	97.5% Chebyshev (MVUE) UCL	54.18261
		99% Chebyshev (MVUE) UCL	64.81882
		95% Non-parametric UCLs	
		CLT UCL	45.1226
		Adj-CLT UCL (Adjusted for skewness)	49.84742
		Mod-t UCL (Adjusted for skewness)	46.27063
		Jackknife UCL	45.53366
		Standard Bootstrap UCL	44.73633
		Bootstrap-t UCL	70.0035
RECOMMENDATION		Hall's Bootstrap UCL	82.51444
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	46.3
		BCA Bootstrap UCL	51.9
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	58.36006
or Modified-t UCL		97.5% Chebyshev (Mean, Sd) UCL	67.5593
		99% Chebyshev (Mean, Sd) UCL	85.62943

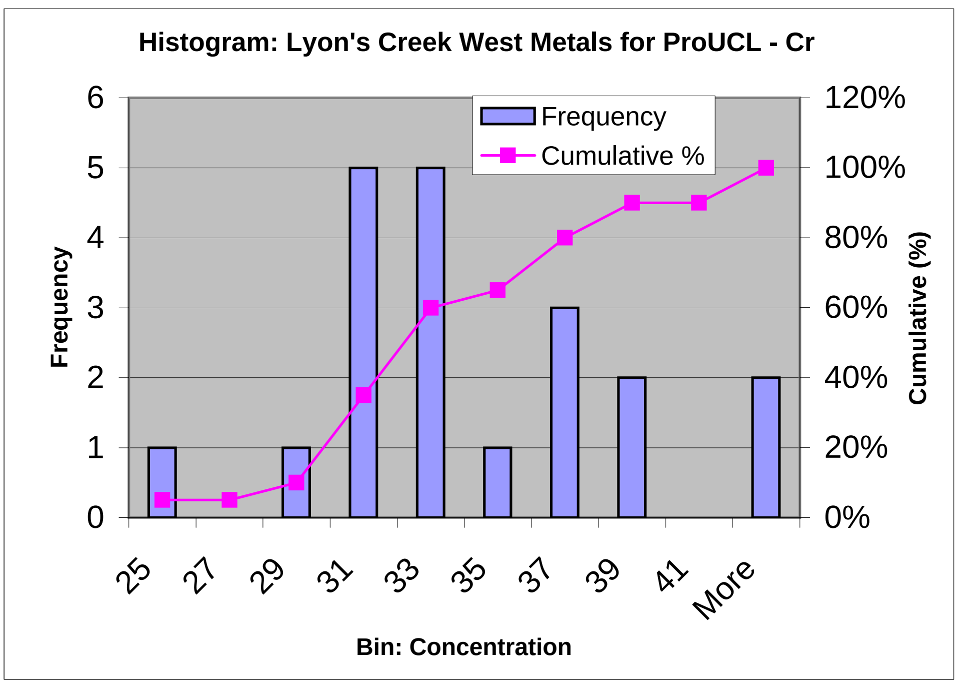
Lyon's Creek West: Chromium Concentration in Soil (Upland Area)

Raw data

Cr
31
37
48
127
35
30
29
33
29
28
31
38
30
31
21
36
36
29
31
32

Histogram data

Bin	*Frequency*	*Cumulative %*
25	1	5.0%
27	0	5.0%
29	1	10.0%
31	5	35.0%
33	5	60.0%
35	1	65.0%
37	3	80.0%
39	2	90.0%
41	0	90.0%
More	2	100.0%



Lyon's Creek West: Cobalt Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Cobalt	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.833169
Number of Unique Samples	7	Shapiro-Wilk 5% Critical Value	0.905
Minimum	6	Data not normal at 5% significance level	
Maximum	17		
Mean	13	95% UCL (Assuming Normal Distribution)	
Median	13	Student's-t UCL	13.841507
Standard Deviation	2.176429		
Variance	4.736842	Gamma Distribution Test	
Coefficient of Variation	0.167418	A-D Test Statistic	1.5859989
Skewness	-1.463492	A-D 5% Critical Value	0.7403388
		K-S Test Statistic	0.2579907
Gamma Statistics		K-S 5% Critical Value	0.1934618
k hat	29.09758	Data do not follow gamma distribution	
k star (bias corrected)	24.76628	at 5% significance level	
Theta hat	0.446773		
Theta star	0.524907	95% UCLs (Assuming Gamma Distribution)	
nu hat	1163.903	Approximate Gamma UCL	14.020046
nu star	990.651	Adjusted Gamma UCL	14.104072
Approx.Chi Square Value (.05)	918.575		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	913.1025	Shapiro-Wilk Test Statisitic	0.7075025
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	1.791759		
Maximum of log data	2.833213	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	2.547667	95% H-UCL	14.195423
Standard Deviation of log data	0.205804	95% Chebyshev (MVUE) UCL	15.669059
Variance of log data	0.042355	97.5% Chebyshev (MVUE) UCL	16.808091
		99% Chebyshev (MVUE) UCL	19.045499
		95% Non-parametric UCLs	
		CLT UCL	13.800491
		Adj-CLT UCL (Adjusted for skewness)	13.630321
		Mod-t UCL (Adjusted for skewness)	13.814964
		Jackknife UCL	13.841507
		Standard Bootstrap UCL	13.782286
		Bootstrap-t UCL	13.707107
RECOMMENDATION		Hall's Bootstrap UCL	13.730262
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	13.7
		BCA Bootstrap UCL	13.6
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	15.12132
or Modified-t UCL		97.5% Chebyshev (Mean, Sd) UCL	16.039217
		99% Chebyshev (Mean, Sd) UCL	17.842248

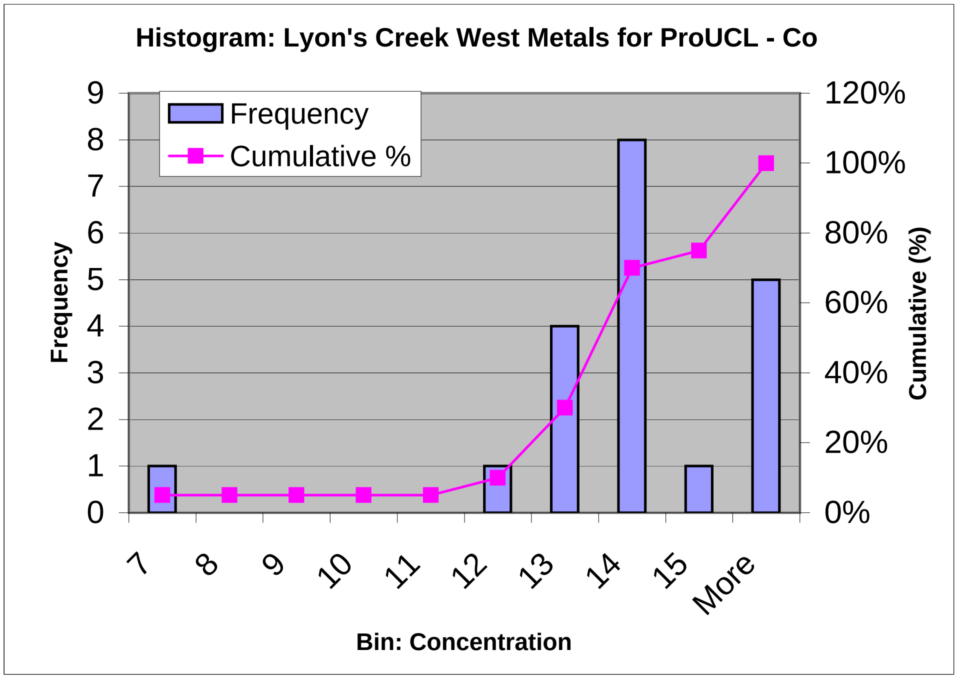
Lyon's Creek West: Cobalt Concentration in Soil (Upland Area)

Raw data

Co
15
13
12
12
11
13
12
13
13
13
15
15
13
13
6
13
17
14
12
15

Histogram data

Bin	*Frequency*	*Cumulative %*
7	1	5.0%
8	0	5.0%
9	0	5.0%
10	0	5.0%
11	0	5.0%
12	1	10.0%
13	4	30.0%
14	8	70.0%
15	1	75.0%
More	5	100.0%



Lyon's Creek West: Copper Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		**Copper**	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.7819182
Number of Unique Samples	14	Shapiro-Wilk 5% Critical Value	0.905
Minimum	10	Data not normal at 5% significance level	
Maximum	57		
Mean	25.8	95% UCL (Assuming Normal Distribution)	
Median	24.5	Student'	29.358291
Standard Deviation	9.202974		
Variance	84.69474	Gamma Distribution Test	
Coefficient of Variation	0.356704	A-D Test Statistic	1.0783332
Skewness	2.084384	A-D 5% Critical Value	0.7419436
		K-S Test Statistic	0.2071534
Gamma Statistics		K-S 5% Critical Value	0.193869
k hat	9.847124	Data do not follow gamma distribution	
k star (bias corrected)	8.403389	at 5% significance level	
Theta hat	2.620054		
Theta star	3.07019	95% UCLs (Assuming Gamma Distribution)	
nu hat	393.885	Approximate Gamma UCL	29.432947
nu star	336.1356	Adjusted Gamma UCL	29.742355
Approx.Chi Square Value (.05)	294.6459		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	291.5807	Shapiro-Wilk Test Statisitic	0.879098998
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	2.302585		
Maximum of log data	4.043051	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	3.19874	95% H-UCL	29.725207
Standard Deviation of log data	0.327298	95% Chebyshev (MVUE) UCL	34.135716
Variance of log data	0.107124	97.5% Chebyshev (MVUE) UCL	37.752333
		99% Chebyshev (MVUE) UCL	44.856478
		95% Non-parametric UCLs	
		CLT UCL	29.184858
		Adj-CLT UCL (Adjusted for skewness)	30.209699
		Mod-t U	29.518146
		Jackknife UCL	29.358291
		Standard Bootstrap UCL	29.105423
		Bootstrap-t UCL	31.496739
RI		Hall's Bootstrap UCL	50.176385
Data a		Percentile Bootstrap UCL	29.35
		BCA Bootstrap UCL	30.65
Use Stud		95% Chebyshev (Mean, Sd) UCL	34.76995
or Modi		97.5% Chebyshev (Mean, Sd) UCL	38.651254
		99% Chebyshev (Mean, Sd) UCL	46.275325

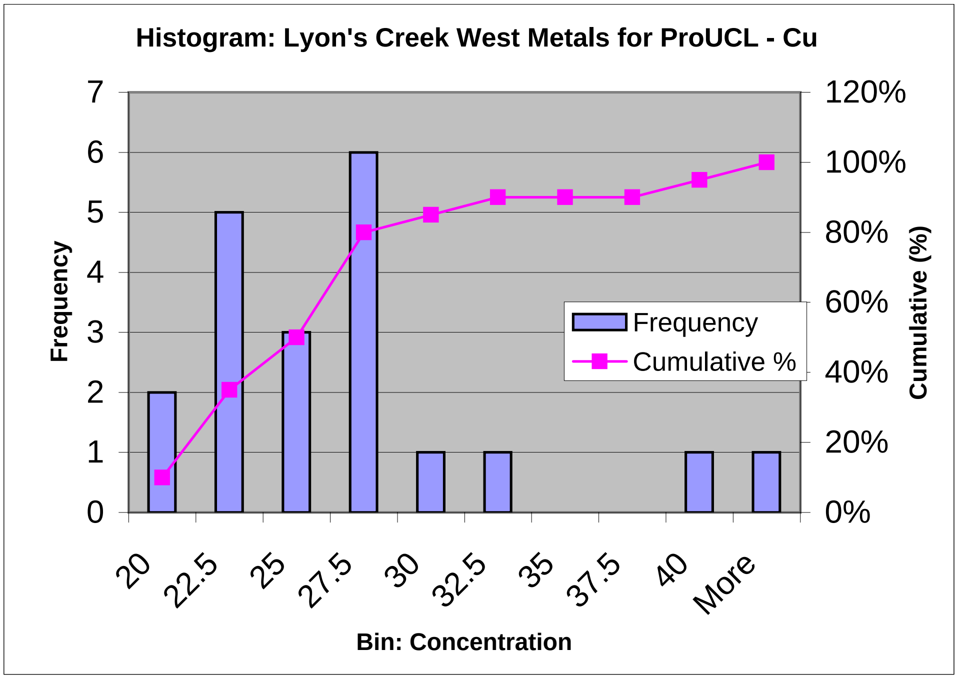
Lyon's Creek West: Copper Concentration in Soil (Upland Area)

Raw data

Cu
24
18
57
20
30
24
28
21
22
25
27
21
27
23
10
39
22
26
27
25

Histogram data

Bin	*Frequency*	*Cumulative %*
20	2	10.0%
22.5	5	35.0%
25	3	50.0%
27.5	6	80.0%
30	1	85.0%
32.5	1	90.0%
35	0	90.0%
37.5	0	90.0%
40	1	95.0%
More	1	100.0%



Lyon's Creek West: Iron Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Iron	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.8600797
Number of Unique Samples	19	Shapiro-Wilk 5% Critical Value	0.905
Minimum	15700	Data not normal at 5% significance level	
Maximum	49800		
Mean	34665	95% UCL (Assuming Normal Distribution)	
Median	34200	Student's-t UCL	37119.557
Standard Deviation	6348.334		
Variance	40301342	Gamma Distribution Test	
Coefficient of Variation	0.183134	A-D Test Statistic	1.4242462
Skewness	-0.664195	A-D 5% Critical Value	0.7404809
		K-S Test Statistic	0.2400229
Gamma Statistics		K-S 5% Critical Value	0.1934684
k hat	25.79254	Data do not follow gamma distribution	
k star (bias corrected)	21.95699	at 5% significance level	
Theta hat	1343.993		
Theta star	1578.768	95% UCLs (Assuming Gamma Distribution)	
nu hat	1031.701	Approximate Gamma UCL	37564.714
nu star	878.2796	Adjusted Gamma UCL	37804.259
Approx.Chi Square Value (.05)	810.483		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	805.3474	Shapiro-Wilk Test Statisitic	0.748394
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	9.661416		
Maximum of log data	10.81577	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	10.43398	95% H-UCL	38031.657
Standard Deviation of log data	0.21651	95% Chebyshev (MVUE) UCL	42148.807
Variance of log data	0.046877	97.5% Chebyshev (MVUE) UCL	45346.018
		99% Chebyshev (MVUE) UCL	51626.32
		95% Non-parametric UCLs	
		CLT UCL	36999.92
		Adj-CLT UCL (Adjusted for skewness)	36774.649
		Mod-t UCL (Adjusted for skewness)	37084.419
		Jackknife UCL	37119.557
		Standard Bootstrap UCL	36927.825
		Bootstrap-t UCL	36929.275
RECOMMENDATION		Hall's Bootstrap UCL	37225.63
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	36910
		BCA Bootstrap UCL	36555
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	40852.59
or Modified-t UCL		97.5% Chebyshev (Mean, Sd) UCL	43529.966
		99% Chebyshev (Mean, Sd) UCL	48789.151

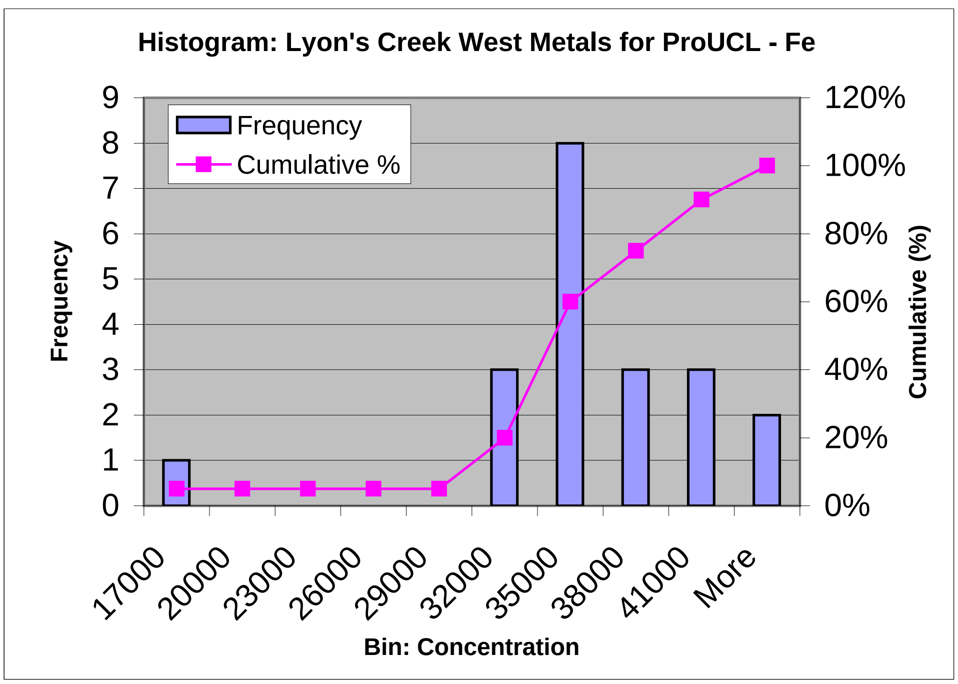
Lyon's Creek West: Iron Concentration in Soil (Upland Area)

Raw data

Fe
35800
33800
49800
29200
42000
33800
31700
33000
31500
33100
34700
39200
33900
32800
15700
38200
40000
35500
34500
35100

Histogram data

Bin	*Frequency*	*Cumulative %*
17000	1	5.0%
20000	0	5.0%
23000	0	5.0%
26000	0	5.0%
29000	0	5.0%
32000	3	20.0%
35000	8	60.0%
38000	3	75.0%
41000	3	90.0%
More	2	100.0%



Lyon's Creek West: Lead Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Lead	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.651984852
Number of Unique Samples	14	Shapiro-Wilk 5% Critical Value	0.905
Minimum	13	Data not normal at 5% significance level	
Maximum	93		
Mean	27.9	95% UCL (Assuming Normal Distribution)	
Median	24	Student's-t UCL	34.59795887
Standard Deviation	17.32324		
Variance	300.0947	Gamma Distribution Test	
Coefficient of Variation	0.620905	A-D Test Statistic	1.05188426
Skewness	3.064363	A-D 5% Critical Value	0.745346609
		K-S Test Statistic	0.23502557
Gamma Statistics		K-S 5% Critical Value	0.194536078
k hat	4.611303	Data do not follow gamma distribution	
k star (bias corrected)	3.952941	at 5% significance level	
Theta hat	6.050351		
Theta star	7.058036	95% UCLs (Assuming Gamma Distribution)	
nu hat	184.4521	Approximate Gamma UCL	33.92352736
nu star	158.1176	Adjusted Gamma UCL	34.45622864
Approx.Chi Square Value (.05)	130.042		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	128.0315	Shapiro-Wilk Test Statisitic	0.900475626
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	2.564949		
Maximum of log data	4.532599	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	3.216297	95% H-UCL	33.50626373
Standard Deviation of log data	0.44198	95% Chebyshev (MVUE) UCL	39.47394167
Variance of log data	0.195346	97.5% Chebyshev (MVUE) UCL	44.72041041
		99% Chebyshev (MVUE) UCL	55.02608233
		95% Non-parametric UCLs	
		CLT UCL	34.2714965
		Adj-CLT UCL (Adjusted for skewness)	37.10758558
		Mod-t UCL (Adjusted for skewness)	35.04033146
		Jackknife UCL	34.59795887
		Standard Bootstrap UCL	34.1784295
		Bootstrap-t UCL	41.3716881
RECOMMENDATION		Hall's Bootstrap UCL	62.03458787
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	34.85
		BCA Bootstrap UCL	37
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	44.78460838
or Modified-t UCL		97.5% Chebyshev (Mean, Sd) UCL	52.09059191
		99% Chebyshev (Mean, Sd) UCL	66.44178184

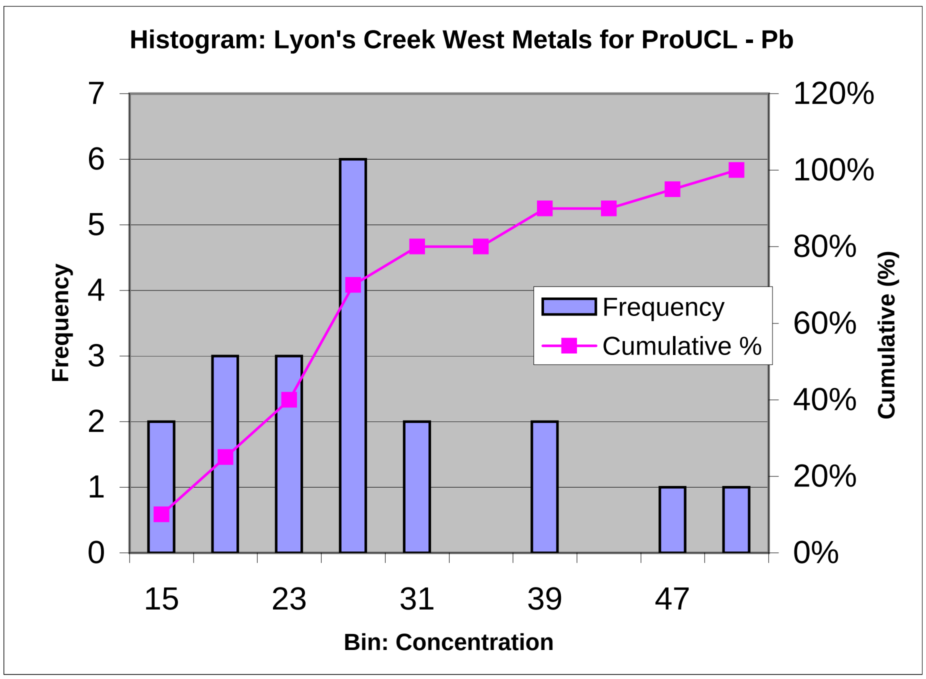
Lyon's Creek West: Lead Concentration in Soil (Upland Area)

Raw data

Pb
24
24
46
25
26
17
93
24
17
14
18
27
21
20
21
37
26
13
37
28

Histogram data

Bin	Frequency	Cumulative %
15	2	10.0%
19	3	25.0%
23	3	40.0%
27	6	70.0%
31	2	80.0%
35	0	80.0%
39	2	90.0%
43	0	90.0%
47	1	95.0%
More	1	100.0%



Lyon's Creek West: Manganese Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Manganese	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.947442
Number of Unique Samples	20	Shapiro-Wilk 5% Critical Value	0.905
Minimum	451	Data are normal at 5% significance level	
Maximum	1220		
Mean	782.9	95% UCL (Assuming Normal Distribution)	
Median	733	Student's-t UCL	851.643
Standard Deviation	177.7932		
Variance	31610.41	Gamma Distribution Test	
Coefficient of Variation	0.227096	A-D Test Statistic	0.391723
Skewness	0.66042	A-D 5% Critical Value	0.740689
		K-S Test Statistic	0.122424
Gamma Statistics		K-S 5% Critical Value	0.193478
k hat	20.96413	Data follow gamma distribution	
k star (bias corrected)	17.85285	at 5% significance level	
Theta hat	37.34473		
Theta star	43.85295	95% UCLs (Assuming Gamma Distribution)	
nu hat	838.56536	Approximate Gamma UCL	856.0445
nu star	714.1139	Adjusted Gamma UCL	862.1193
Approx.Chi Square Value (.05)	653.0966		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	648.4947	Shapiro-Wilk Test Statisitic	0.966625
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data are lognormal at 5% significance level	
Minimum of log data	6.111467		
Maximum of log data	7.106606	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	6.638965	95% H-UCL	860.0366
Standard Deviation of log data	0.225289	95% Chebyshev (MVUE) UCL	956.2125
Variance of log data	0.050755	97.5% Chebyshev (MVUE) UCL	1031.191
		99% Chebyshev (MVUE) UCL	1178.472
		95% Non-parametric UCLs	
		CLT UCL	848.2924
		Adj-CLT UCL (Adjusted for skewness)	854.5656
		Mod-t UCL (Adjusted for skewness)	852.6215
		Jackknife UCL	851.643
		Standard Bootstrap UCL	847.2804
		Bootstrap-t UCL	859.0112
RECOMMENDATION		Hall's Bootstrap UCL	862.8348
Data are normal (0.05)		Percentile Bootstrap UCL	849.65
		BCA Bootstrap UCL	852.2
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	956.1913
		97.5% Chebyshev (Mean, Sd) UCL	1031.175
		99% Chebyshev (Mean, Sd) UCL	1178.465

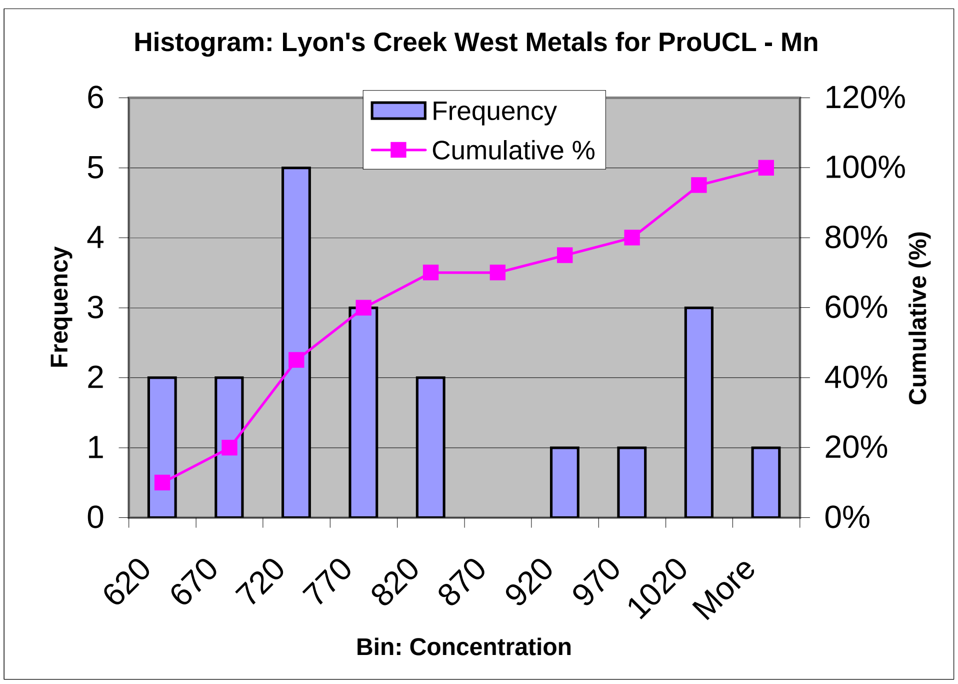
Lyon's Creek West: Manganese Concentration on Soil (Upland Area)

Raw data

Mn
987
996
997
816
720
746
761
788
699
626
691
903
634
687
451
674
1220
719
602
941

Histogram data

Bin	*Frequency*	*Cumulative %*
620	2	10.0%
670	2	20.0%
720	5	45.0%
770	3	60.0%
820	2	70.0%
870	0	70.0%
920	1	75.0%
970	1	80.0%
1020	3	95.0%
More	1	100.0%



Lyon's Creek West: Molybdenum Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Molybdenum	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.348466
Number of Unique Samples	3	Shapiro-Wilk 5% Critical Value	0.905
Minimum	1.5	Data not normal at 5% significance level	
Maximum	7		
Mean	1.9	95% UCL (Assuming Normal Distribution)	
Median	1.5	Student's-t UCL	2.411869
Standard Deviation	1.32387		
Variance	$1.752632	Gamma Distribution Test	
Coefficient of Variation	$0.696774	A-D Test Statistic	6.340754
Skewness	$3.547703	A-D 5% Critical Value	0.745322
		K-S Test Statistic	0.531284
Gamma Statistics		K-S 5% Critical Value	0.194522
k hat	4.69232	Data do not follow gamma distribution	
k star (bias corrected)	4.021806	at 5% significance level	
Theta hat	0.404917		
Theta star	0.472425	95% UCLs (Assuming Gamma Distribution)	
nu hat	187.6928	Approximate Gamma UCL	2.306108
nu star	160.8722	Adjusted Gamma UCL	2.341986
Approx.Chi Square Value (.05)	132.5424		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	130.512	Shapiro-Wilk Test Statisitic	0.361378
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	0.405465		
Maximum of log data	1.94591	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	0.531529	95% H-UCL	2.194457
Standard Deviation of log data	0.398494	95% Chebyshev (MVUE) UCL	2.563879
Variance of log data	0.158798	97.5% Chebyshev (MVUE) UCL	2.879548
		99% Chebyshev (MVUE) UCL	3.499618
		95% Non-parametric UCLs	
		CLT UCL	2.38692
		Adj-CLT UCL (Adjusted for skewness)	2.637844
		Mod-t UCL (Adjusted for skewness)	2.451008
		Jackknife UCL	2.411869
		Standard Bootstrap UCL	N/R
		Bootstrap-t UCL	N/R
RECOMMENDATION		Hall's Bootstrap UCL	N/R
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	N/R
		BCA Bootstrap UCL	N/R
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	3.190349
or Modified-t UCL		97.5% Chebyshev (Mean, Sd) UCL	3.748684
		99% Chebyshev (Mean, Sd) UCL	4.845425

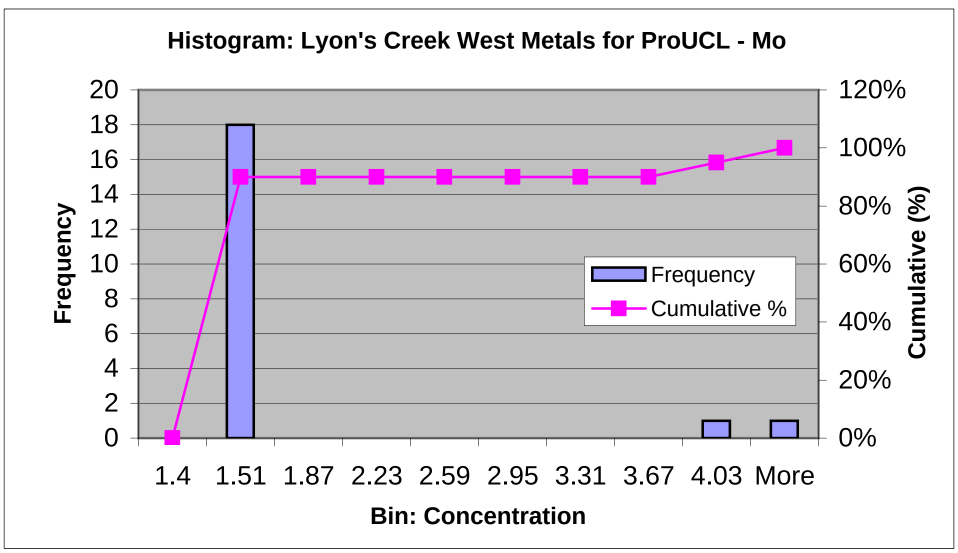
Lyon's Creek West: Molybdenum Concentration in Soil (Upland Area)

Raw data

Mo
1.5
1.5
4
7
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5
1.5

Histogram data

Bin	Frequency	Cumulative %
1.4	0	.0%
1.51	18	90.0%
1.87	0	90.0%
2.23	0	90.0%
2.59	0	90.0%
2.95	0	90.0%
3.31	0	90.0%
3.67	0	90.0%
4.03	1	95.0%
More	1	100.0%



Lyon's Creek West: Nickel Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Nickel	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.544185
Number of Unique Samples	13	Shapiro-Wilk 5% Critical Value	0.905
Minimum	31	Data not normal at 5% significance level	
Maximum	91		
Mean	39.45	95% UCL (Assuming Normal Distribution)	
Median	37	Student's-t UCL	44.43865
Standard Deviation	12.90237		
Variance	166.4711	Gamma Distribution Test	
Coefficient of Variation	0.327056	A-D Test Statistic	1.996157
Skewness	3.659362	A-D 5% Critical Value	0.741224
		K-S Test Statistic	0.219481
Gamma Statistics		K-S 5% Critical Value	0.193645
k hat	15.54796	Data do not follow gamma distribution	
k star (bias corrected)	13.2491	at 5% significance level	
Theta hat	2.537311		
Theta star	2.977561	95% UCLs (Assuming Gamma Distribution)	
nu hat	621.9183	Approximate Gamma UCL	43.77866
nu star	529.9639	Adjusted Gamma UCL	44.14133
Approx.Chi Square Value (.05)	477.5632		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	473.6395	Shapiro-Wilk Test Statisitic	0.699136
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	3.433987		
Maximum of log data	4.51086	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	3.642531	95% H-UCL	43.27148
Standard Deviation of log data	0.235594	95% Chebyshev (MVUE) UCL	48.28817
Variance of log data	0.055505	97.5% Chebyshev (MVUE) UCL	52.21748
		99% Chebyshev (MVUE) UCL	59.93584
		95% Non-parametric UCLs	
		CLT UCL	44.1955
		Adj-CLT UCL (Adjusted for skewness)	46.71796
		Mod-t UCL (Adjusted for skewness)	44.8321
		Jackknife UCL	44.4386
		Standard Bootstrap UCL	44.2787
		Bootstrap-t UCL	51.7599
RECOMMENDATION		Hall's Bootstrap UCL	62.6467
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	44.55
		BCA Bootstrap UCL	47.65
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	52.02567
or Modified-t UCL		97.5% Chebyshev (Mean, Sd) UCL	57.46717
		99% Chebyshev (Mean, Sd) UCL	68.15595

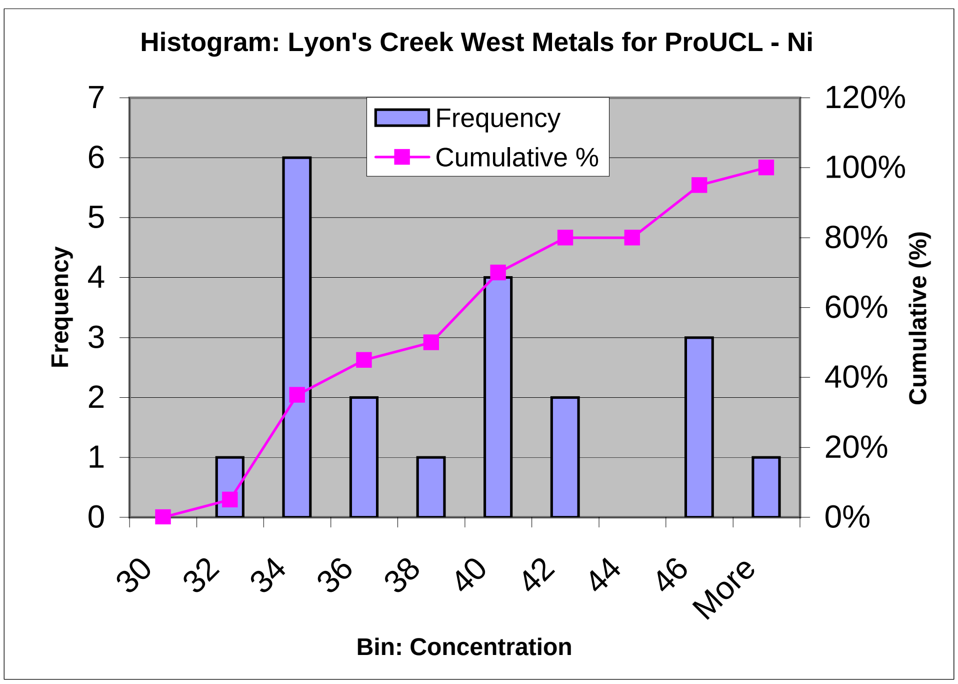
Lyon's Creek West: Nickel Concentration in Soil (Upland Area)

Raw data

Ni
36
45
44
91
34
32
32
41
33
33
35
39
32
33
38
40
44
31
38
38

Histogram data

Bin	*Frequency*	*Cumulative %*
30	0	.0%
32	1	5.0%
34	6	35.0%
36	2	45.0%
38	1	50.0%
40	4	70.0%
42	2	80.0%
44	0	80.0%
46	3	95.0%
More	1	100.0%



Lyon's Creek West: Selenium Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Selenium	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.865418672
Number of Unique Samples	5	Shapiro-Wilk 5% Critical Value	0.905
Minimum	0.3	Data not normal at 5% significance level	
Maximum	0.7		
Mean	0.44	95% UCL (Assuming Normal Distribution)	
Median	0.4	Student's-t UCL	0.487602825
Standard Deviation	0.123117		
Variance	0.015158	Gamma Distribution Test	
Coefficient of Variation	0.279812	A-D Test Statistic	1.084382767
Skewness	0.631737	A-D 5% Critical Value	0.741383285
		K-S Test Statistic	0.253693113
Gamma Statistics		K-S 5% Critical Value	0.193697762
k hat	14.11455	Data do not follow gamma distribution	
k star (bias corrected)	12.0307	at 5% significance level	
Theta hat	0.031174		
Theta star	$0.036573	95% UCLs (Assuming Gamma Distribution)	
nu hat	564.5819	Approximate Gamma UCL	0.490877458
nu star	481.2279	Adjusted Gamma UCL	0.495153609
Approx.Chi Square Value (.05)	431.3506		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	427.6255	Shapiro-Wilk Test Statisitic	0.879936828
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	-1.203973		
Maximum of log data	-0.356675	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	-0.856823	95% H-UCL	0.493817351
Standard Deviation of log data	0.272748	95% Chebyshev (MVUE) UCL	0.558001212
Variance of log data	0.074392	97.5% Chebyshev (MVUE) UCL	0.60916811
		99% Chebyshev (MVUE) UCL	0.709675572
		95% Non-parametric UCLs	
		CLT UCL	0.485282636
		Adj-CLT UCL (Adjusted for skewness)	0.48943797
		Mod-t UCL (Adjusted for skewness)	0.488250974
		Jackknife UCL	0.487602825
		Standard Bootstrap UCL	0.483458441
		Bootstrap-t UCL	0.490596443
RECOMMENDATION		Hall's Bootstrap UCL	0.488029151
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	0.485
		BCA Bootstrap UCL	0.485
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	0.56
or Modified-t UCL		97.5% Chebyshev (Mean, Sd) UCL	0.611924096
		99% Chebyshev (Mean, Sd) UCL	0.713918928

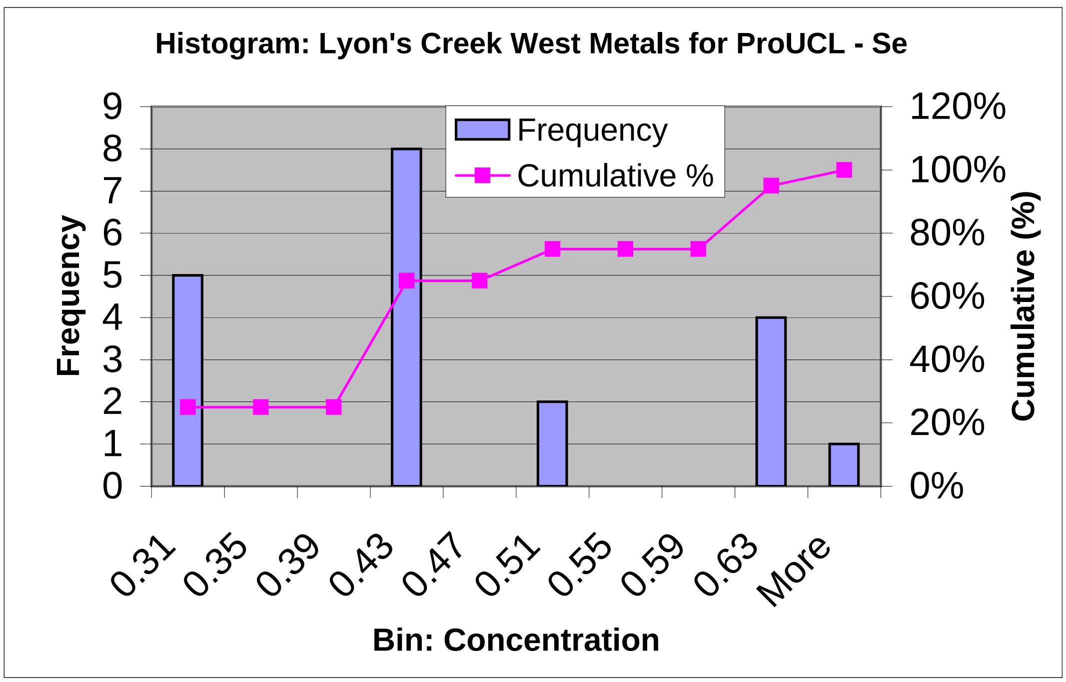
Lyon's Creek West: Selenium Concentration in Soil (Upland ARea)

Raw data

Se
0.5
0.7
0.4
0.6
0.4
0.5
0.4
0.4
0.4
0.3
0.4
0.6
0.3
0.3
0.6
0.4
0.6
0.4
0.3
0.3

Histogram data

Bin	*Frequency*	*Cumulative %*
0.31	5	25.0%
0.35	0	25.0%
0.39	0	25.0%
0.43	8	65.0%
0.47	0	65.0%
0.51	2	75.0%
0.55	0	75.0%
0.59	0	75.0%
0.63	4	95.0%
More	1	100.0%



Lyon's Creek West: Silver Concentration in Soil (Upland Area)

ProUCL Statistical Summary:	Silver			
Raw Statistics				
Number of Valid Samples	20			
Number of Unique Samples	1			
Minimum	0.5			
Maximum	0.5			
Mean	0.5			
Median	0.5			
Data contains constant observations with no distinct values				
There is no need to calculate lognormal statistics				

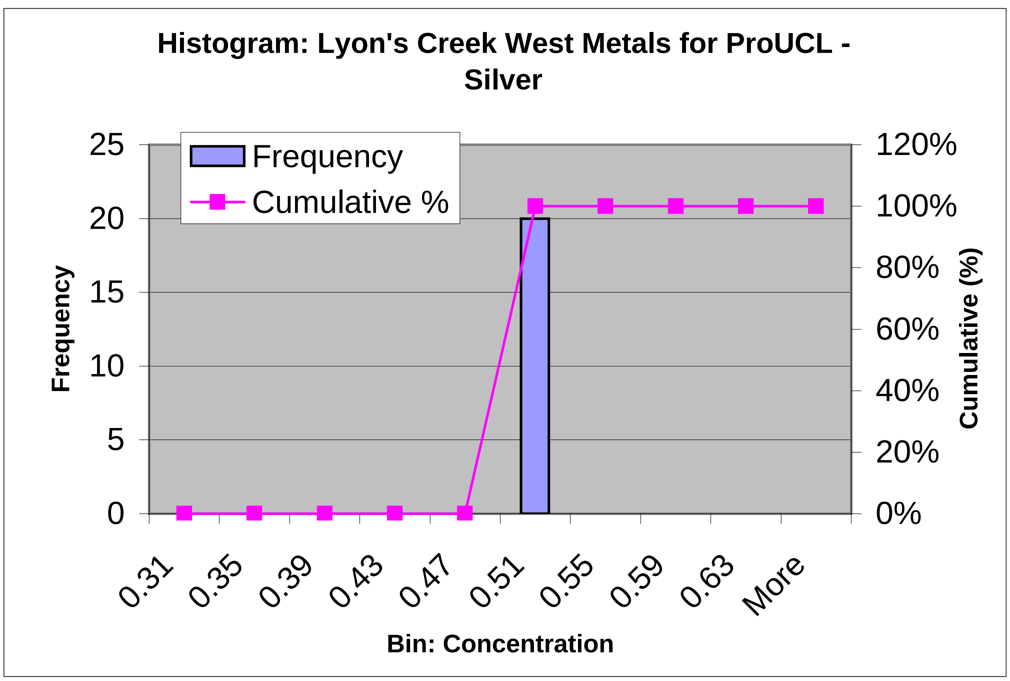
Lyon's Creek West: Silver Concentration in Soil (Upland Area)

Raw data

Ag
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.5

Histogram data

Bin	*Frequency*	*Cumulative %*
0.31	0	.0%
0.35	0	.0%
0.39	0	.0%
0.43	0	.0%
0.47	0	.0%
0.51	20	100.0%
0.55	0	100.0%
0.59	0	100.0%
0.63	0	100.0%
More	0	100.0%



Lyon's Creek West: Strontium Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Strontium	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.965048177
Number of Unique Samples	19	Shapiro-Wilk 5% Critical Value	0.905
Minimum	14.7	Data are normal at 5% significance level	
Maximum	111		
Mean	64.255	95% UCL (Assuming Normal Distribution)	
Median	63.65	Student's-t UCL	74.76962166
Standard Deviation	27.19446		
Variance	739.5384	Gamma Distribution Test	
Coefficient of Variation	0.423227	A-D Test Statistic	0.539416753
Skewness	-0.149596	A-D 5% Critical Value	0.745350469
		K-S Test Statistic	0.150997949
Gamma Statistics		K-S 5% Critical Value	0.194538266
k hat	4.598437	Data follow gamma distribution	
k star (bias corrected)	3.942005	at 5% significance level	
Theta hat	13.97323		
Theta star	16.30008	95% UCLs (Assuming Gamma Distribution)	
nu hat	183.9375	Approximate Gamma UCL	78.14983183
nu star	157.6802	Adjusted Gamma UCL	79.37885331
Approx.Chi Square Value (.05)	129.6451		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	127.6378	Shapiro-Wilk Test Statisitic	0.899919049
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	2.687847		
Maximum of log data	4.70953	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	4.050204	95% H-UCL	84.6755414
Standard Deviation of log data	0.531148	95% Chebyshev (MVUE) UCL	100.9327979
Variance of log data	0.282118	97.5% Chebyshev (MVUE) UCL	116.2272175
		99% Chebyshev (MVUE) UCL	146.2701432
		95% Non-parametric UCLs	
		CLT UCL	74.25713294
		Adj-CLT UCL (Adjusted for skewness)	74.03978697
		Mod-t UCL (Adjusted for skewness)	74.73572008
		Jackknife UCL	74.76962166
		Standard Bootstrap UCL	73.98745139
		Bootstrap-t UCL	74.20774714
RECOMMENDATION		Hall's Bootstrap UCL	74.04877522
Data are normal (0.05)		Percentile Bootstrap UCL	73.94
		BCA Bootstrap UCL	74.045
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	90.76087624
		97.5% Chebyshev (Mean, Sd) UCL	102.2299901
		99% Chebyshev (Mean, Sd) UCL	124.7588433

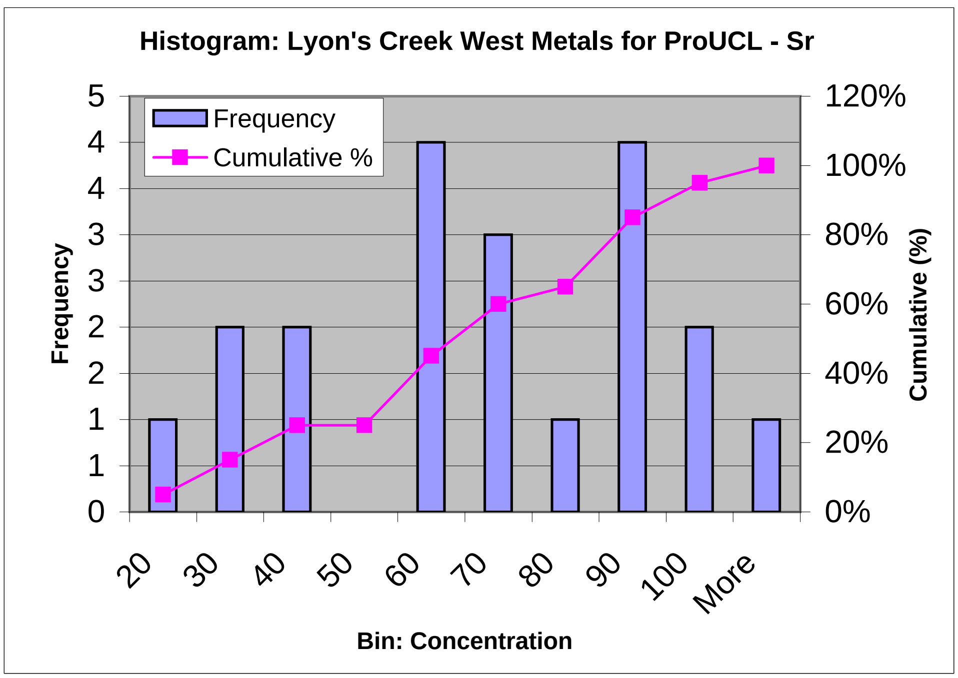
Lyon's Creek West: Strontium Concentration in Soil (Upland Area)

Raw data

Sr
51.7
27.5
59.2
32
56.2
89.4
83.4
59
86.3
99.1
88.2
27.5
98.4
61.3
14.7
70.7
34.6
111
66
68.9

Histogram data

Bin	*Frequency*	*Cumulative %*
20	1	5.0%
30	2	15.0%
40	2	25.0%
50	0	25.0%
60	4	45.0%
70	3	60.0%
80	1	65.0%
90	4	85.0%
100	2	95.0%
More	1	100.0%



Lyon's Creek West: Titanium Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Titanium	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.961842
Number of Unique Samples	20	Shapiro-Wilk 5% Critical Value	0.905
Minimum	183	Data are normal at 5% significance level	
Maximum	351		
Mean	265.3	95% UCL (Assuming Normal Distribution)	
Median	268	Student's-t UCL	280.7674
Standard Deviation	40.00408		
Variance	1600.326	Gamma Distribution Test	
Coefficient of Variation	0.150788	A-D Test Statistic	0.495693
Skewness	-0.278785	A-D 5% Critical Value	0.739708
		K-S Test Statistic	0.137164
Gamma Statistics		K-S 5% Critical Value	0.193432
k hat	43.77446	Data follow gamma distribution	
k star (bias corrected)	37.24162	at 5% significance level	
Theta hat	6.060612		
Theta star	7.123749	95% UCLs (Assuming Gamma Distribution)	
nu hat	1750.978	Approximate Gamma UCL	282.0868
nu star	1489.665	Adjusted Gamma UCL	283.458
Approx.Chi Square Value (.05)	1401.016		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	1394.239	Shapiro-Wilk Test Statisitic	0.93677
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data are lognormal at 5% significance level	
Minimum of log data	5.209486		
Maximum of log data	5.860786	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	5.569396	95% H-UCL	283.0272
Standard Deviation of log data	0.158125	95% Chebyshev (MVUE) UCL	306.4728
Variance of log data	0.025003	97.5% Chebyshev (MVUE) UCL	324.2419
		99% Chebyshev (MVUE) UCL	359.1458
		95% Non-parametric UCLs	
		CLT UCL	280.0135
		Adj-CLT UCL (Adjusted for skewness)	279.4177
		Mod-t UCL (Adjusted for skewness)	280.6745
		Jackknife UCL	280.7674
		Standard Bootstrap UCL	279.5258
		Bootstrap-t UCL	279.6858
RECOMMENDATION		Hall's Bootstrap UCL	280.3135
Data are normal (0.05)		Percentile Bootstrap UCL	279.45
		BCA Bootstrap UCL	279
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	304.2912
		97.5% Chebyshev (Mean, Sd) UCL	321.1627
		99% Chebyshev (Mean, Sd) UCL	354.3035

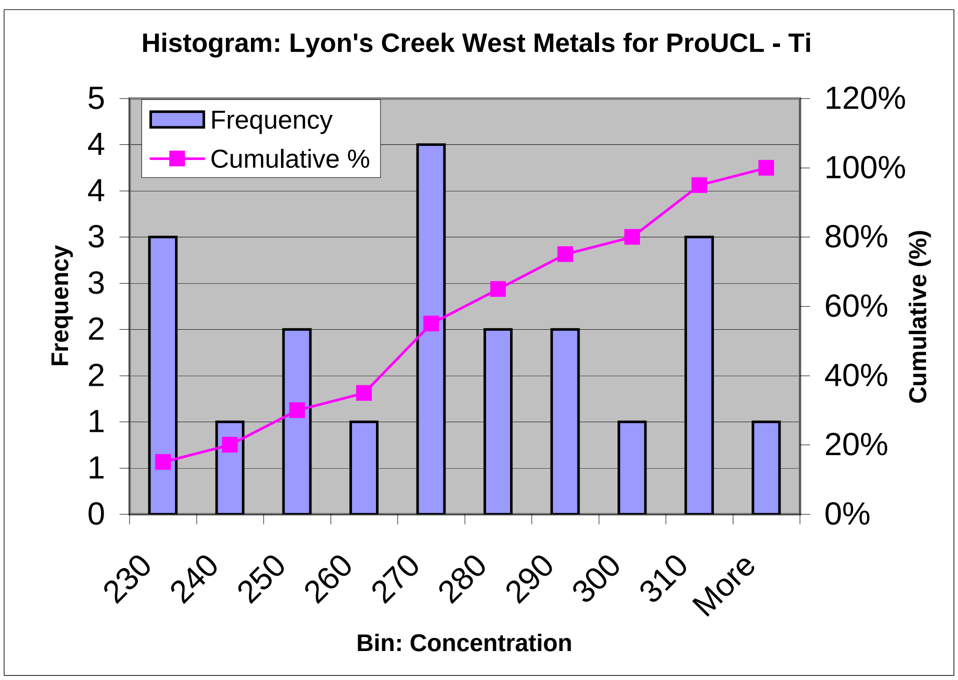
Lyon's Creek West: Titanium Concentration in Soil (Upland Area)

Raw data

Ti
256
202
183
239
248
289
267
241
277
305
300
199
302
272
264
283
262
351
269
297

Histogram data

Bin	*Frequency*	*Cumulative %*
230	3	15.0%
240	1	20.0%
250	2	30.0%
260	1	35.0%
270	4	55.0%
280	2	65.0%
290	2	75.0%
300	1	80.0%
310	3	95.0%
More	1	100.0%



Lyon's Creek West: Vanadium Concentration in Soil (Upland Area)

ProUCL Statistical Summary:	Vanadium		
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.934863
Number of Unique Samples	13	Shapiro-Wilk 5% Critical Value	0.905
Minimum	27	Data are normal at 5% significance level	
Maximum	54		
Mean	40.2	95% UCL (Assuming Normal Distribution)	
Median	40	Student's-t UCL	42.54551
Standard Deviation	6.0663		
Variance	36.8	Gamma Distribution Test	
Coefficient of Variation	0.150903	A-D Test Statistic	0.604619
Skewness	0.405071	A-D 5% Critical Value	0.739604
		K-S Test Statistic	0.163635
Gamma Statistics		K-S 5% Critical Value	0.193428
k hat	46.18307	Data follow gamma distribution	
k star (bias corrected)	39.28894	at 5% significance level	
Theta hat	0.870449		
Theta star	1.023189	95% UCLs (Assuming Gamma Distribution)	
nu hat	1847.323	Approximate Gamma UCL	42.67326
nu star	1571.558	Adjusted Gamma UCL	42.87509
Approx.Chi Square Value (.05)	1480.473		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	1473.504	Shapiro-Wilk Test Statisitic	0.938548
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data are lognormal at 5% significance level	
Minimum of log data	3.295837		
Maximum of log data	3.988984	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	3.683001	95% H-UCL	42.7629
Standard Deviation of log data	0.152081	95% Chebyshev (MVUE) UCL	46.1858
Variance of log data	0.023128	97.5% Chebyshev (MVUE) UCL	48.77387
		99% Chebyshev (MVUE) UCL	53.85762
		95% Non-parametric UCLs	
		CLT UCL	42.43119
		Adj-CLT UCL (Adjusted for skewness)	42.56247
		Mod-t UCL (Adjusted for skewness)	42.56599
		Jackknife UCL	42.54551
		Standard Bootstrap UCL	42.39493
		Bootstrap-t UCL	42.78341
RECOMMENDATION		Hall's Bootstrap UCL	43.13947
Data are normal (0.05)		Percentile Bootstrap UCL	42.4
		BCA Bootstrap UCL	42.55
Use Student's-t UCL		95% Chebyshev (Mean, Sd) UCL	46.1127
		97.5% Chebyshev (Mean, Sd) UCL	48.67113
		99% Chebyshev (Mean, Sd) UCL	53.69667

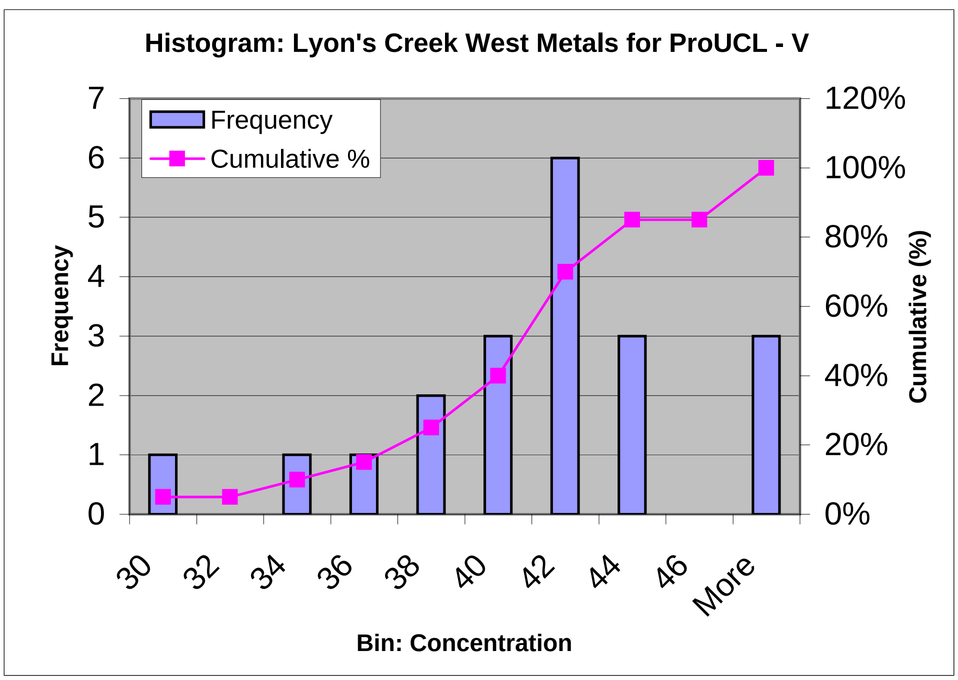
Lyon's Creek West: Vanadium Concentration in Soil (Upland Area)

Raw data

V
40
47
33
42
34
40
36
42
38
39
41
54
39
40
27
40
52
41
36
43

Histogram data

Bin	*Frequency*	*Cumulative %*
30	1	5.0%
32	0	5.0%
34	1	10.0%
36	1	15.0%
38	2	25.0%
40	3	40.0%
42	6	70.0%
44	3	85.0%
46	0	85.0%
More	3	100.0%



Lyon's Creek West: Zinc Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		Zinc Uplands	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	20	Shapiro-Wilk Test Statisitic	0.521729
Number of Unique Samples	19	Shapiro-Wilk 5% Critical Value	0.905
Minimum	71	Data not normal at 5% significance level	
Maximum	707		
Mean	158	95% UCL (Assuming Normal Distribution)	
Median	110.5	Student's-t UCL	220.2344
Standard Deviation	160.9596		
Variance	25908	Gamma Distribution Test	
Coefficient of Variation	1.018732	A-D Test Statistic	2.724644
Skewness	2.900442	A-D 5% Critical Value	0.751443
		K-S Test Statistic	0.345054
Gamma Statistics		K-S 5% Critical Value	0.195896
k hat	2.198217	Data do not follow gamma distribution	
k star (bias corrected)	1.901817	at 5% significance level	
Theta hat	71.87645		
Theta star	83.07843	95% UCLs (Assuming Gamma Distribution)	
nu hat	87.92866	Approximate Gamma UCL	210.9453
nu star	76.0727	Adjusted Gamma UCL	215.8921
Approx.Chi Square Value (.05)	56.97917		
Adjusted Level of Significance	0.038	Lognormal Distribution Test	
Adjusted Chi Square Value	55.67357	Shapiro-Wilk Test Statisitic	0.741809
		Shapiro-Wilk 5% Critical Value	0.905
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	4.26268		
Maximum of log data	6.561031	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	4.81822	95% H-UCL	198.3193
Standard Deviation of log data	0.602003	95% Chebyshev (MVUE) UCL	237.3467
Variance of log data	0.362408	97.5% Chebyshev (MVUE) UCL	276.5321
		99% Chebyshev (MVUE) UCL	353.5043
		95% Non-parametric UCLs	
		CLT UCL	217.201
		Adj-CLT UCL (Adjusted for skewness)	242.143
		Mod-t UCL (Adjusted for skewness)	224.1248
		Jackknife UCL	220.2344
		Standard Bootstrap UCL	215.9425
		Bootstrap-t UCL	431.2143
RECOMMENDATION		Hall's Bootstrap UCL	486.2615
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	222.75
		BCA Bootstrap UCL	245.65
Use 95% Chebyshev (Mean, Sd) UCL		95% Chebyshev (Mean, Sd) UCL	314.884
		97.5% Chebyshev (Mean, Sd) UCL	382.7679
		99% Chebyshev (Mean, Sd) UCL	516.1126

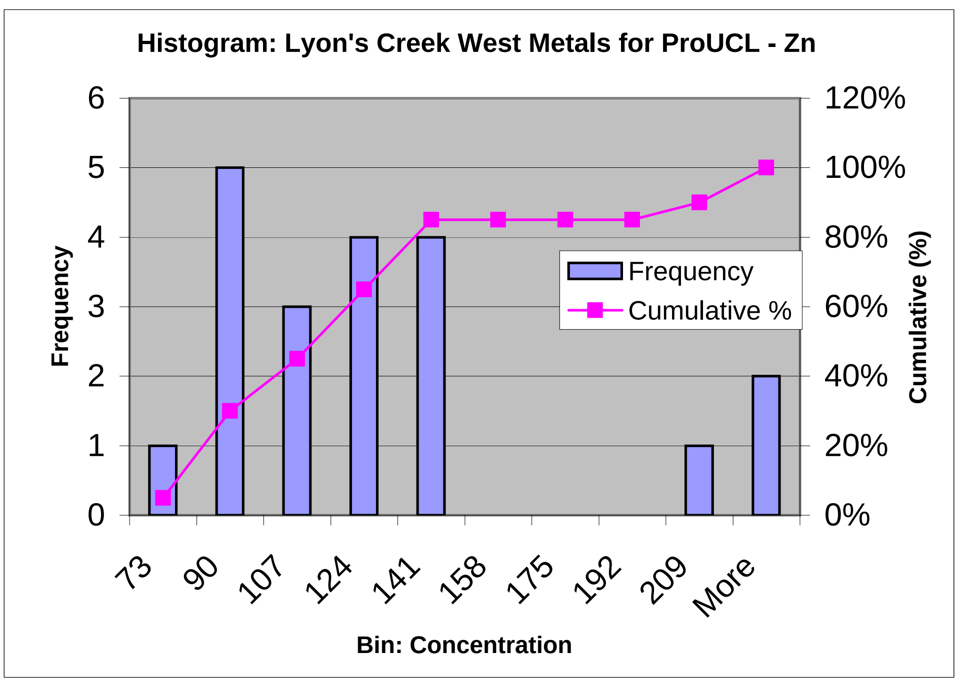
Lyon's Creek West: Zinc Concentration in Soil (Upland Area)

Raw data

Zn
126
111
707
115
207
100
126
110
79
73
102
97
83
77
80
515
117
71
128
136

Histogram data

Bin	*Frequency*	*Cumulative %*
73	1	5.0%
90	5	30.0%
107	3	45.0%
124	4	65.0%
141	4	85.0%
158	0	85.0%
175	0	85.0%
192	0	85.0%
209	1	90.0%
More	2	100.0%



Lyon's Creek West: PCB Concentration in Soil (Upland Area)

ProUCL Statistical Summary:		**Upland PCB$_{total}$**	
Raw Statistics		Normal Distribution Test	
Number of Valid Samples	77	Lilliefors Test Statisitic	0.362677681
Number of Unique Samples	24	Lilliefors 5% Critical Value	0.100969071
Minimum	0.01	Data not normal at 5% significance level	
Maximum	3.58		
Mean	0.168896	95% UCL (Assuming Normal Distribution)	
Median	0.025	Student's-t UCL	0.254724324
Standard Deviation	0.452295		
Variance	0.204571	Gamma Distribution Test	
Coefficient of Variation	2.677948	A-D Test Statistic	8.430004385
Skewness	6.024427	A-D 5% Critical Value	0.827595739
		K-S Test Statistic	0.314654579
Gamma Statistics		K-S 5% Critical Value	0.108186207
k hat	0.460234	Data do not follow gamma distribution	
k star (bias corrected)	0.450961	at 5% significance level	
Theta hat	0.366979		
Theta star	0.374525	95% UCLs (Assuming Gamma Distribution)	
nu hat	70.87606	Approximate Gamma UCL	0.22881912
nu star	69.44799	Adjusted Gamma UCL	0.230154388
Approx.Chi Square Value (.05)	51.26099		
Adjusted Level of Significance	0.046883	Lognormal Distribution Test	
Adjusted Chi Square Value	50.9636	Lilliefors Test Statisitic	0.259034306
		Lilliefors 5% Critical Value	0.100969071
Log-transformed Statistics		Data not lognormal at 5% significance level	
Minimum of log data	-4.60517		
Maximum of log data	1.275363	95% UCLs (Assuming Lognormal Distribution)	
Mean of log data	-3.176612	95% H-UCL	0.197626793
Standard Deviation of log data	1.476802	95% Chebyshev (MVUE) UCL	0.241010336
Variance of log data	2.180945	97.5% Chebyshev (MVUE) UCL	0.29307907
		99% Chebyshev (MVUE) UCL	0.395358016
		95% Non-parametric UCLs	
		CLT UCL	0.253678116
		Adj-CLT UCL (Adjusted for skewness)	0.291489912
		Mod-t UCL (Adjusted for skewness)	0.2606222
		Jackknife UCL	0.254724324
		Standard Bootstrap UCL	0.252595306
		Bootstrap-t UCL	0.351470168
RECOMMENDATION		Hall's Bootstrap UCL	0.590978531
Data are Non-parametric (0.05)		Percentile Bootstrap UCL	0.260194805
		BCA Bootstrap UCL	0.309480519
Use 97.5% Chebyshev (Mean, Sd) UCL		95% Chebyshev (Mean, Sd) UCL	0.393570335
		97.5% Chebyshev (Mean, Sd) UCL	0.490787055
		99% Chebyshev (Mean, Sd) UCL	0.681750475

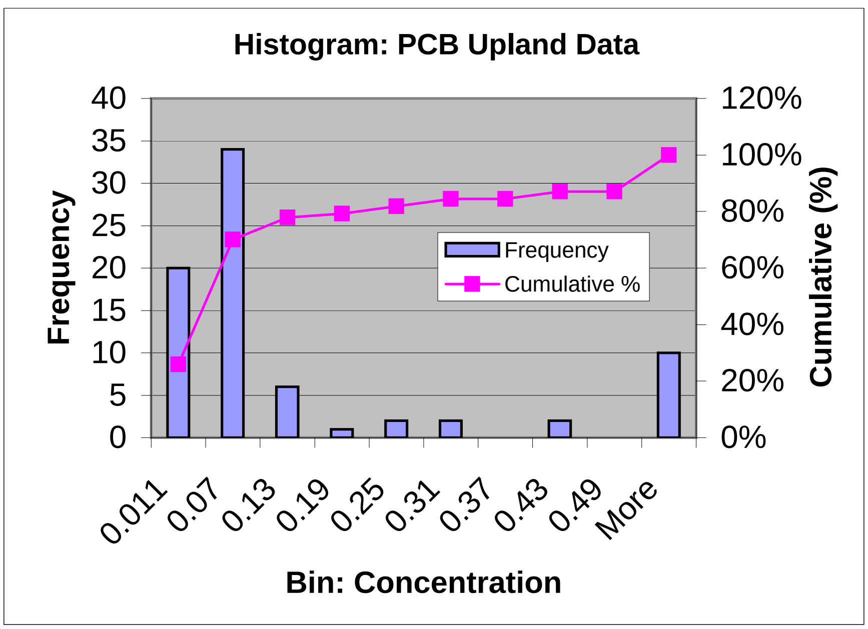
Lyon's Creek West: PCB Concentration in Soil (Upland Area)

Raw data

PCB_{total} (mg/kg)		
0.01	0.07	0.025
0.03	0.015	0.025
0.02	0.08	0.025
0.01	0.015	
0.08	0.04	
0.01	1.14	
0.03	0.76	
0.01	0.025	
0.01	0.025	
0.22	0.025	
0.01	0.50	
0.02	0.50	
0.01	0.50	
0.01	0.30	
0.04	0.11	
0.01	0.20	
0.01	0.50	
0.01	0.025	
0.02	0.025	
0.40	0.025	
0.01	0.55	
0.03	0.025	
0.02	3.58	
0.56	0.025	
0.11	0.87	
0.01	0.025	
0.01	0.07	
0.02	0.025	
0.01	0.025	
0.41	0.025	
0.28	0.025	
0.05	0.025	
0.01	0.025	
0.01	0.025	
0.01	0.025	
0.01	0.14	
0.01	0.025	

Histogram data

Bin	*Frequency*	*Cumulative %*
0.011	20	26.0%
0.07	34	70.1%
0.13	6	77.9%
0.19	1	79.2%
0.25	2	81.8%
0.31	2	84.4%
0.37	0	84.4%
0.43	2	87.0%
0.49	0	87.0%
More	10	100.0%



APPENDIX C
Toxicity Profiles

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Appendix C
Toxicity Profiles

1 Introduction

An essential part of the risk assessment process is the identification of toxicologically based toxicity values against which exposures can be compared. Toxicity values have been established by several regulatory agencies including Health Canada, the United States Environmental Protection Agency (US EPA), and the World Health Organization (WHO). Additional detailed review of the toxicological information for individual chemicals is available from the Agency for Toxic Substances and Disease Registry (ATSDR). In addition to these primary sources of toxicological information, secondary sources such as the US based Health Effects Assessment Summary Tables (HEAST) can provide additional toxicity information. This latter source must be used with some caution because the data available from this source is not updated as frequently as the primary regulatory sources and often contains information that has been withdrawn by other agencies.

In the selection of toxicity values, preference has been given to the most recently developed values because it was felt that these would incorporate the most recent toxicological information and would provide the best basis upon which to assess potential health hazards/risks. Additional consideration was given to toxicity values for which the underlying toxicological rationales were available. The high degree of scrutiny to which this project will be subject means that it is essential that each decision be transparent and fully defensible. Therefore, it is essential that the toxicological rationale behind the development of each toxicity value be available for evaluation and scrutiny. If supporting documentation was not available for a given toxicity value, the toxicity value was not selected for use in the current risk assessment.

This toxicity assessment presents brief toxicological profiles for each of the contaminants of concern considered and outlines the toxicological effects associated with chronic ingestion, dermal contact and inhalation exposures.

2 Arsenic

The majority of information included in the following toxicity profile was taken from ATSDR (2000). It should be noted that a 2005 Draft version of the toxicity profile is also available and is open for public review and comment. As a result, information presented in the draft version may change with the review process. Information presented in the 2000 version will not change and, therefore, was deemed more appropriate for use as the basis of this toxicity profile.

Arsenic is widely distributed in the Earth's crust. In its elemental form, arsenic is a steel grey metal-like material. It is a naturally occurring substance, usually found combined with other elements. More specifically, inorganic arsenic compounds are formed when arsenic combines with oxygen, chlorine or sulphur; organic arsenic compounds occur when arsenic combines with carbon and hydrogen. It is important to differentiate between organic and inorganic forms of arsenic, as the organic forms are often less harmful (ATSDR, 2000). In the present risk assessment, only inorganic compounds are of concern.

Most arsenic compounds are white or colorless powders that do not evaporate. Because these compounds do not smell and have no distinct taste, it is difficult to detect their presence in food, water or air. Approximately 90% of all arsenic produced is used as a preservative for wood in order to render it resistant to rotting and decay. Copper chromated arsenic (CCA) is used to make this 'pressure-treated' wood. Due to the human health implications associated with exposure to arsenic, in 2003, U.S. manufacturers of wood preservatives containing arsenic voluntarily transitioned from CCA to arsenic-free preservatives to treat wood products for certain residential uses. In addition, past uses of inorganic arsenic compounds included application to cotton fields and orchards as a pesticide. Although inorganic compounds can no longer be used for agrcicultural purposes, organic arsenic compounds including cacodylic acid, disodium methylarsenate (DSMA) and monosodium methylarsenate (MSMA) are still used as pesticides. Presently, the greatest use of arsenic in alloys is in lead-acid batteries for automobiles. Arsenic compounds are also used in semiconductors and light-emitting diodes (ATSDR, 2000).

There are numerous studies that have looked at human exposures to inorganic arsenic in the air, but there are no reports of fatalities associated with short-term occupational exposures to arsenic levels as high as 100 mg As/m^3 (ATSDR, 2000). There are a large number of cases of human fatalities following the ingestion of inorganic arsenicals. In most cases, the doses resulting in death have been difficult to quantify. However, two reports indicate that doses ranging between 1 and 22 mg As per kg body weight per day (mg/kg-day) have resulted in death. No studies were found regarding mortality subsequent to inhalation or ingestion of organic arsenicals (ATSDR, 2000).

Inhalation exposures to inorganic arsenic dusts in the workplace have been reported to cause irritation of the nose and throat, laryngitis, and bronchitis. Cases of very high exposures have been reported to result in perforation of the nasal septum (Dunlap 1921; Pinto and McGill 1953; Sandstrom *et al.* 1989). However, respiratory effects have not been noted at exposure levels that range between 0.1 and 1.0 mg/m^3 (ATSDR, 2000). There is some limited evidence of respiratory tract effects following oral exposure to inorganic arsenic, but this is thought to be a secondary effect that is due to vascular damage that results from the ingestion of arsenic (ATSDR, 2000).

There is limited and equivocal epidemiological evidence that suggests that inhalation exposures to arsenic trioxide dust may result in cardiovascular effects. However, there are a number of studies that indicate that oral exposure to inorganic arsenic can lead to serious damage of the cardiovascular system (ATSDR, 2000). Both acute and long-term exposures can result in myocardial depolarization and cardiac arrhythmias. Long-term exposures to low levels of arsenic can also result in damage to the vascular system, characterized by a progressive loss of circulation in the hands and feet (Chen *et al*. 1988b; Ch'i and Blackwell 1968; Tseng 1977, 1989; Tseng *et al*. 1968, 1995, 1996). In areas of Taiwan, with elevated levels of arsenic in the drinking water, evidence of circulatory effects related to arsenic exposures begin to occur at a dose of approximately 0.014 mg As/kg-day (ATSDR, 2000).

In almost all reported cases of acute ingestion exposures to inorganic arsenicals, a number of gastrointestinal effects including; nausea, vomiting, diarrhea and abdominal pain have been found to occur (ATSDR, 2000). Although similar effects are often seen with long-term exposures to lower doses of arsenic, effects are not generally reported at doses lower than 0.01 mg As/kg-day (ATSDR, 2000).

A number of hematological effects including anemia and leukopenia have been reported in humans as a result of acute, intermediate and chronic oral exposures to arsenic (ATSDR, 2000).

Oral exposures to inorganic arsenic have been reported to cause several toxic effects in the liver including elevated levels of hepatic enzymes in the blood, portal tract fibrosis and swelling of the liver (Guha Mazumder *et al*. 1988; Morris *et al*. 1974; Piontek *et al*. 1989; Szuler *et al*. 1979). These effects are generally seen in cases where chronic exposures range between 0.019 to 0.1 mg/kg-day (ATSDR, 2000). It has been suggested by several researchers that these effects are secondary to the damage of hepatic blood vessels resulting from the damaging effects that inorganic arsenic has on the circulatory system. However, there is insufficient clinical information available to confirm this (Morris *et al*. 1974; Rosenberg 1974).

There is little clinical evidence of renal damage following oral exposures to inorganic arsenic compounds (ATSDR, 2000). A few cases of renal failure have been reported in cases of arsenic poisoning, but this is felt to be due to fluid imbalances of vascular damage caused by arsenic, and not directly attributable to arsenic (ATSDR, 1993).

The most common dermal effect associated with the ingestion of inorganic arsenic is the development of a pattern of skin changes which include; hyperkeratosis, the development of hyperkeratotic warts, areas of hyperpigmentation and hypopigmentation (Rosenberg 1974; Zaldívar 1974.

Numerous studies have shown that dermal effects are common in humans exposed to inorganic arsenic levels that range between 0.01 and 0.1 mg As/kg-day. These studies have also demonstrated that, below a dose level of 0.01 mg As/kg-day, dermal effects are not reported (ATSDR, 2000).

There are several studies that have indicated that inhalation exposures to inorganic arsenic can lead to a number of neurological effects in humans, including peripheral neuropathy of sensory and motor neurons that are manifested as numbness, loss of reflexes and muscle weakness. In extreme cases, frank encephalopathy including, hallucinations and memory loss have been reported (Beckett *et al.* 1986; Bolla-Wilson and Bleecker 1987; Morton and Caron 1989). These effects generally cease once exposures have ended (ATSDR, 1993). There are a large number of studies that indicate that the acute ingestion of large amounts of inorganic arsenic can cause a number of injuries to the nervous system including; headache, lethargy, mental confusion, hallucination, seizures and in extreme cases, coma (ATSDR, 2000). Chronic exposures to lower levels of arsenic, ranging between 0.019 and 0.5 mg/kg-day, are typically characterized by a peripheral neuropathy similar to that seen with inhalation exposures. Neurological effects have not been detected in populations chronically exposed to arsenic levels of less than 0.01 mg/kg-day (ATSDR, 2000).

There is sufficient convincing epidemiological evidence to show that inhalation exposure to inorganic arsenic can increase the risk of developing lung cancer. Many studies provide only qualitative evidence of an association between the duration of and/or level of exposure to arsenic and the increase in the rate of lung cancer. There is sufficient epidemiological information available from occupational studies for the US EPA to develop cancer potency estimates for inhalation exposures to inorganic arsenic (USEPA, 1998). There are a large number of epidemiological studies that provide convincing evidence that the ingestion of inorganic arsenic increases the risk of developing skin cancer. The most common effect is the development of squamous cell carcinomas. Basal cell carcinomas also occur. In the majority of cases, skin cancer only develops after prolonged exposure (ATSDR, 2000). There is sufficient human epidemiological data available for the US EPA to develop estimates of cancer risk associated with oral exposure to inorganic arsenic (USEPA, 1998).

The estimates of the carcinogenic potencies of inhaled and ingested inorganic arsenic, developed by Health Canada, will be used to assess potential human health risks associated with exposure to inorganic arsenic at this site. The potency estimates established by the US EPA and the health effects upon which they are based are summarized below.

Source	Route of Exposure	TRV	Basis
US EPA (1998)	Inhalation	Unit Risk: 4.3 x 10^{-3} $(\mu g/m^3)^{-1}$	Lung Cancer
Health Canada (2004)	Inhalation	6.4 $(mg/m3)^{-1}$	Lung Cancer
Health Canada (2004)	Oral	1.5 $(mg/kg\text{-}d)^{-1}$	Skin Cancer
US EPA (1998)	Oral	Unit Risk: 5.0 x 10^{-5} $(\mu g/L)^{-1}$	Squamous Cell Carcinoma
US EPA (1998)	Oral	Slope Factor: 1.5 $(mg/kg\text{-}day)^{-1}$	Squamous Cell Carcinoma
US EPA (1998)	Oral/Dermal	1.5 $(mg/kg\text{-}d)^{-1}$	Skin Cancer

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3 Iron

Iron is one of the most abundant elements in the earth's crust and it is the most abundant heavy metal. In the environment, it is present mainly as Fe(II) or Fe(III). In Canada, the main use of iron ores is in the production of steel. In addition, iron is also used in the production of paint pigments, polishing agents and electrical materials.

Iron is an essential element for the maintenance of proper human health. More specifically, it is an integral component of cytochromes, porphyrins and metalloenzymes. The intake of iron from a typical Canadian diet is more than required to meet minimum daily requirements (Health Canada, 1987). The Canadian Recommended Nutrient Intake for adults is 8 mg/d for men, 14 mg/d for women of menstrual age and 7 mg/d for post-menopausal women (Department of National Health and Welfare, 1983). Iron deficiency can result in impaired mental development and performance in children (Anonymous, 1983), elevated catecholamines and restlessness in children (Voorhess, 1975) and reduced work performance in adults. In severe cases of deficiency, anaemia and impaired oxygen delivery can result (Sproule, 1960).

Although iron is a required nutrient, the ingestion of large quantities of this compound can result in haemochromatosis, a condition in which normal regulatory mechanisms do not operate effectively. This condition can lead to tissue damage, however, this rarely develops as a result of simple dietary overloading (Watt and Merrill, 1963; Hopps, 1972; Jacobs, 1977). In two year old children, three grams of Fe(II) sulphate is considered to be the lethal dose (National Academy of Sciences, 1980).

Sampling results from a limited number of Canadian drinking water stations indicate that the concentration of iron in drinking water is usually below 1 mg/L and is often less than 0.3 mg/L (Hem, 1972). The presence of iron in drinking water can result in the reaction of Fe(II) salts with water to form insoluble hydroxides, which settle out as rust-coloured silt. Iron can also promote the growth of bacteria that derive energy from the oxidation of Fe(II) to Fe(III). Both conditions usually occur when the iron concentration in the water exceeds 0.3 mg/L (Health Canada, 1987).

Studies describing the potential adverse effects resulting from the exposure of humans to iron via inhalation are quite rare. However, iron has been found to be a local irritant to the lung and gastrointestinal tract (International Labour Office, 1998). In an epidemiological study, bronchial obstruction was observed in workers exposed to iron in an iron foundry (Bingham *et al*., 2001).

Oral exposure studies involving iron were not found. However, the estimated toxic dose for a child is believed to be 20 mg Fe/kg (Bingham *et al*., 2001).

Iron is not classifiable as to human carcinogenicity (American Conference of Governmental Industrial Hygienists TLVs and BEIs, 2005).

The USEPA's Federal Drinking Water Standard is 300 ug/L (HSDB, 2006). Health Canada has based their drinking water quality guideline value of $\leq$ 0.3 mg/L on aesthetic objectives (Health Canada, 1978).

The American Conference of Governmental Industrial Hygienists (ACGIH) 8-hour Time Weighted Average (TWA) is 5 mg/m^3 for iron oxide (ACGIH, 2005). The United States Environmental

Protection Agency Region III Risk-Based Concentration values for iron are 11000 ug/L in tap water, 1100 ug/m^3 in ambient air, 410 mg/kg in fish, 310000 mg/kg in industrial soil, and 23000 mg/kg in residential soil (US EPA, 2006).

The United States Environmental Protection Agency (US EPA) Integrated Risk Information System did not provide any TRVs for iron. As a result, the USEPA Region III Risk-Based Concentration Table values are presented below.

Source	Route of Exposure	TRV	Basis
USEPA RIII (2006)	Oral	RfD: 0.3 mg/kg-d	Not provided.

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4 Manganese

Manganese is a naturally occurring metal, found in numerous types of rock. It is mined for use in the production of various types of steel. More specifically, in Canada, the primary use of manganese is in the steel industry, where it is used to counteract the effects of sulphur, as a deoxidizing agent, and as an ingredient in special alloys (Health Canada, 1987). Manganese compounds are also used to produce batteries, dietary supplements, as well as some ceramics, pesticides and fertilizers (ATSDR, 2000).

Manganese is an essential element necessary to maintain proper health in humans. It functions as both an enzyme co-factor and as a constituent of metalloenzymes (Health Canada, 1987). The amount of manganese in a typical western diet ranges from 1-10 mg Mn/day, which appears to be sufficient to meet dietary requirements (ATSDR, 2000). More specifically, in Canada, the dietary intake of manganese is estimated to be 4.7 mg/day (Hill, 1988). The Food and Nutrition Board of the National Research Council (NRC) has suggested an Estimated Safe and Adequate Daily Dietary Intake for manganese of 0.3-0.6 mg/d for infants (0-6 months), 0.6-1 mg/d for infants (6 months – 1 year), 1-1.5 mg/d for children (1-3 years), 1-2 mg/day for children (4-10 years) and 2-5 mg/d for children (10 years to adult). More recently; however, it was suggested that the dose should instead range from 3.5 – 7.0 mg/d in adults (Zidenberg-Cherr and Keen, 1987).

Although manganese is an essential element, an excess of this compound can cause adverse effects. Of particular concern is the onset of manganism, a condition characterized by mental and emotional disturbances, as well as neurological effects (ATSDR, 2000). In addition, in drinking water, concentrations exceeding 0.15 mg/L have been found to cause stains to plumbing fixtures and laundry, as well as cause undesirable tastes in beverages (Griffin, 1960).

Manganese can exist in both inorganic ($MnCl_2$, $MnSO_4$, MnOAc, $MnPO_4$, MnO_2, Mn_30_4) and organic forms (manganese trocarbonyl, maneb, mancozeb and mangafodipir). Inorganic manganese compounds are not volatile, however, they can exist as aerosols and suspended particulate matter.

Inhalation exposure to inorganic manganese can cause an inflammatory response in the lung (ATSDR, 2000). In addition, cardiovascular effects have been noted after occupational exposure to both inorganic and organic manganese. Based on available studies, it appears that manganese causes only minor adverse effects to the gastrointestinal system. Although inorganic manganese has not been found to cause adverse musculoskeletal effects, exposures to maneb and mancozeb have been found to cause muscular weakness (Koizumi *et al*., 1979), tremors (Meco *et al*., 1994) and convulsions (Israeli *et al*., 1983). Renal effects have not been reported for inorganic manganese, however studies by Koizumi *et al*. (1979) and de Carvalho *et al*. (1989) report acute renal failure after exposure to maneb and mancozeb. Although few studies have reported endocrine effects in humans exposed to inorganic manganese, studies by Alessio *et al*. (1989) and Smargiassi and Mutti (1999) report adverse effects to the endocrine system in workers occupationally exposed to inorganic manganese at elevated levels. Immunological and lymphoreticular effects have been noted after inhalation exposure to inorganic manganese. No studies have been found that unequivocally attribute the onset of genotoxic effects to inorganic manganese exposure (ATSDR, 2000). However, occupational exposure studies do suggest that organic manganese can cause adverse genotoxic effects (Jablonicka *et al*., 1989).

There is conclusive evidence to suggest that exposure to high levels of manganese compounds leads to neurological effects, namely manganism. This progressive condition begins with mild symptoms which eventually turn into more severe symptoms including dull affect, altered gait, fine tremor and occasionally psychiatric disturbances. Numerous studies documenting this condition are available. Reproductive effects have also been noted in workers suffering from manganism (ATSDR, 2000).

Unfortunately, the majority of oral exposure studies of manganese involve animals rather than humans. It has been noted (ATSDR, 2000), that there is a lack of data regarding the potential for manganese to cause adverse systemic effects in humans via ingestion. It has been suggested that this is most likely due to the strong homeostatic control the body exerts on the amount of manganese absorbed following oral exposure (ATSDR, 2000). Unlike inhalation exposure to manganese, there is only limited evidence that oral exposure to this compound causes neurological effects in humans. Although information concerning the developmental effects due to oral exposure to inorganic manganese is limited, an exposed population was observed and evaluated by He *et al*. (1994) and Zhang *et al*. (1995). It was reported that the children drank water containing manganese levels of at least 0.241 ± 0.051 mg/L for at least 3 years and ate food high in manganese. They were given the WHO nerurobehaviousal core test and compared to a control group of children. The negative test results correlated with hair manganese concentration and the control group preformed better in school compared to the exposed group of children (ATSDR, 2000).

With respect to inorganic manganese, dermal exposure is not of concern as this compound does not readily penetrate the skin surface (ATSDR, 2000). Dermal exposure to organic manganese, however, is of potential concern, especially in an occupational exposure setting. Localized allergic contact dermatitis was found to occur after dermal exposure to organic manganese (ATSDR, 2000).

Studies of the carcinogenic potential of manganese subsequent to inhalation exposure to either inorganic or organic manganese are not available. Likewise, no studies were located regarding carcinogenic effects in humans subsequent to oral and dermal exposure to manganese (ATSDR, 2000).

The EPA and FDA recommend that manganese in drinking water not exceed 0.05 ppm. OSHA has set a concentration limit of 5 mg/m^3 for the average amount of manganese in workplace air over an 8-hour workday (OSHA 1998, ATSDR, 2000). Health Canada (1987) suggests a drinking water quality guideline of $\leq$0.05 mg/L based on aesthetic objectives.

Source	**Route of Exposure**	**TRV**	**Basis**
US EPA (1995)	Oral	RfD: 0.14 mg/kg-d	CNS Effects
US EPA (1995)	Inhalation	RfC: 5×10^{-5} mg/m^3	Impairment of neurobehavioral function

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5 Total PCBs

Polychlorinated biphenyls (PCBs) are a group of synthetic, organic chemicals known to cause adverse health effects in humans. PCBs exist as either oily liquids or solids, are colourless to light yellow, and are potentially volatile in some cases (ATSDR, 2000). In the past, PCBs were used as coolants and lubricants in transformers, capacitors, and other electrical equipment (ATSDR, 2000). PCBs are no longer produced in North America, due to the health implications associated with their presence in the environment. These compounds do not readily degrade and are, thus, quite environmentally persistent. In addition, many PCBs are subject to long-range transport resulting in the presence of these compounds worldwide. The bioaccumulative nature of PCBs is of concern, as concentrations of these chemicals increase with each trophic level of the food chain. As a result, humans are not only exposed to PCBs via the environment, but also via food sources. Of particular concern are women who breastfeed, as PCBs accumulate in fat compartments, i.e. breast milk, and may be passed on to breastfed infants (ATSDR, 2000).

Typically, PCBs were produced in mixtures, with seven mixtures accounting for the majority of PCBs in the environment. These mixtures are often referred to as Aroclor mixtures and are made up of numerous individual PCB congeners. For example, Aroclor 1254 represents a mixture of which 54% is chlorine, by weight (ATSDR, 2000). In a carcinogenic assessment by MOE (MOE, 2005), Arocolor 1254 was found to be the most toxic congener followed by Aroclor 1260, Aroclor 1242 and Aroclor 1016.

Data regarding the respiratory effects of inhalation exposure to PCBs are limited. Occupational exposure studies reported upper respiratory tract irritation, chest pain and changes in lung function (Fischbein *et al*., 1979; Warshaw *et al*., 1979; Emmett *et al*., 1988; Kuratsune, 1989; Rogan, 1989; Nakanishi *et al*., 1985; Shigematsu *et al*., 1971). Gastrointestinal damage, characterized by loss of appetite, anorexia, nausea, vomiting, abdominal pain, and/or epigastric distress, was also reported in workers exposed to airborne PCBs (Emmett *et al*., 1988; Fischbein *et al*., 1979; Smith *et al*., 1982; Maroni *et al*., 1981a; Kuratsune, 1989). Clinical studies of PCB workers reported associations between increased serum levels of liver-related enzymes, lipids and cholesterol and serum PCBs, suggesting PCBs cause hepatic effects (ATSDR, 2000). The results of a number of studies suggest that PCBs can induce thyroid toxicity and a variety of changes in thyroid hormone levels. Increased thyroid gland volume was reported in workers at a PCB manufacturing facility (Langer *et al*., 1998). Chloracne and other dermal alterations were also reported in workers exposed to PCBs (ATSDR, 2000). Occular effects, including general eye irritation, hypersecretion of the Meibomian glands and abnormal pigmentation of the conjunctiva, were reported in subjects occupationally exposed to PCBs (Emmett *et al*. 1988; Ouw *et al*. 1976; Smith *et al*. 1982; Fischbein *et al*., 1985). Limited information is available concerning the immunological effects of PCBs in humans, as the majority of studies available do not include an assessment of immunocompetence. Reports of neurological effects subsequent to occupational exposure to PCBs are also limited and inconclusive.

The majority of oral exposure data for PCBs was derived from the Yusho and Yu-Cheng incidents, where humans were exposed to contaminated rice oil, and contaminated fish and animal products, respectively. Respiratory effects noted in both Yusho and Yu-Cheng patients included severe respiratory infections and chronic bronchitis (Kuratsune, 1989; Rogan, 1989; Nakanishi *et al*., 1985; Shigematsu *et al*., 1971, 1977). Cardiovascular effects were noted in Alabama residents exposed to PCBs via the consumption of contaminated fish (Kreiss *et al*., 1981). Hematological effects, such as normocytic anemia and leukocytosis, were noted in Yu-Cheng patients (Rogan, 1989). Hepatic effects (serum cholesterol and triglycerides) were found to occur in consumers of contaminated fish. An elevated odds ratio for goiter was found among the Yu-Cheng cohort, indicating the potential for adverse effects to the endocrine system (Guo *et al.* 1999).

As with inhalation exposure, chloracne and other dermal alterations were reported with oral exposure, i.e., the Yusho and Yu-Cheng cohorts (Fischbein *et al*. 1979, 1982; Guo *et al*. 1999; Hsu *et al*. 1994; Maroni *et al.* 1981a, 1981b; Masuda 1994). Also similar to inhalation exposure, ocular effects consisting of hypersecretion of the Meibomian glands and abnormal pigmentation of the conjunctiva, were reported in the Yusho and Yu-Cheng cohorts (Masuda, 1994). Although studies of immunological effects are limited, they do suggest an increased susceptibility to respiratory tract infections, increased prevalence of ear infections in children, decreased serum IgA and IgM antibody levels, and/or changes in T lymphocyte subsets (ATSDR, 2000).

With respect to neurological effects, there is a great deal of concern surrounding the transfer of PCBs to the fetus of women who consume contaminated food. In addition, there is concern for these same women who may breastfeed their infants, as PCBs tend to accumulate in breast milk. Studies have provided evidence that PCBs contribute to subtle neurobehavioral alterations in newborn children. In addition, neurodevelopmental changes were noted in women who accidentally consumed rice oil contaminated with PCBs (ATSDR, 2000).

Reproductive effects in orally exposed humans include menstrual disturbances in females and effects on fertility in males. Increased PCB levels were observed in women with late miscarriages, and a reduction in the months of lifetime lactation was associated with increasing PCB levels in breast milk (ATSDR, 2000). The results of studies examining the developmental effects (anthropometric measures at birth and physical growth during infancy) associated with exposure to PCBs are conflicting. Some studies found significant positive associations, some found significant negative associations and some found no association at all between PCB exposure and developmental effects (ATSDR, 2000).

The results of numerous studies indicate that exposure to PCBs is related to cancer at several sites, namely the liver, biliary tract, intestines, and skin (melanoma). In contrast, there is no clear association between occupational exposures to PCBs and cancer in the brain, hematopoietic and lymphatic systems (ATSDR, 2000). There is some indication that certain subgroups of women may be at an increased risk for breast cancer. Overall, human study results do provide evidence that commercial PCB mixtures are carcinogenic (ATSDR, 2000). The IARC (1987) has concluded that the evidence for carcinogenicity to humans is limited. US EPA IRIS (1987), has classified total PCBs as a probable human carcinogen (B2) based on sufficient evidence of carcinogenicity in animals. More specifically, the US EPA based their oral slope factors for total PCB on the development of liver hepatocellular adenomas, carcinomas, cholangiomas or cholandiocarcinomas on female Sprague-Dawley rats exposed to PCBs via the diet (Brunner *et al*., 1996; Norback and Weltman, 1985).

It should be noted, however, that the majority of information on the carcinogenic potential of PCBs is based on cohort mortality epidemiological studies of workers exposed to PCBs. The ATSDR (2000) has concluded that, although the results of some of these studies do suggest carcinogenicity with high exposures to PCBs, many of the studies are confounded by possible exposures to chlorinated dioxins and related compounds. In addition, PCBs are not genotoxic and would, therefore, not initiate neoplastic transformation, which is believed to be an initial step in the onset of cancer. SDB recommends that PCBs be assessed via threshold (non-genotoxic) dose response only, and that they be assessed as total PCBs and as dioxin-like PCBs.

Source	Route of Exposure	TRV	Basis
Total PCBs			
US EPA IRIS (1997)	Oral	Slope Factor: 0.04 mg/kg-d	Lowest risk and persistence; central-estimate slope factor; linear extrapolation below LED10s
US EPA IRIS (1997)	Oral	Slope Factor: 2.0 mg/kg-d	High risk and persistence; upper-bound slope factor; linear extrapolation below LED10s
US EPA IRIS (1997)	Oral	Drinking Water Unit Risk: $1x10^{-5}$ per ug/L	Low risk and persistence, upper-bound slope factor
Health Canada (2004)	Oral	PTDI: 1.0 ug/kg-d	
WHO (2003)	Oral	0.02 ug/kg-d	Hepatic and immunological effects
US EPA IRIS (1997)	Inhalation	Air Unit Risk: $1x10^{-4}$ per ug/m^3	Linear extrapolation below LED10s. Low risk and persistence; upper-bound unit risk. Based on oral exposure study (Brunner *et al*., 1996; Norback and Weltman, 1985).
Aroclor 1016			
US EPA IRIS (1993)	Oral	RfD: $7x10^{-5}$ mg/kg-d	Based on reduced birth weights in a monkey reproductive bioassay (Barsotti and van Miller, 1984; Levin *et al*., 1988; Schantz *et al*., 1989, 1991). NOAEL: 0.007 mg/kg-d, UF = 100
Balagopal *et al*. (2005)	Oral	0.880 ug/kg-d	
Aroclor 1254			
US EPA IRIS (1996)	Oral	RfD: $2x10^{-5}$ mg/kg-d	Based on ocular exudates, inflamed and prominent Meibomian glands, distorted growth of finger and toe nails, decreased antibody (IgG and IgM) response to sheep erythrocytes from monkey clinical and immunologic studies (Arnold *et al*., 1994a,b; Tryphonas *et al*., 1989, 1991 a,b). LOAEL: 0.005 mg/kg-d, UF = 300.
Balagopal *et al*. (2005)	Oral	0.032 ug/kg-d	

Source	Route of Exposure	TRV	Basis
Aroclor 1242			
Balagopal *et al*. (2005)	Oral	0.170 ug/kg-d	
Aroclor 1260			
Balagopal *et al*. (2005)	Oral	0.110 ug/kg-d	

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6 Dioxin-Like PCBs

The various isomers and congeners of polychlorinated dibenzo-*p*-dioxins (PCDDs), polychclorinated dibenzofurans (PCDFs) and dioxin-like PCBs (DL-PCBs) all have the same biological mechanism of action (*ie.* they all work on the body in the same way). However, they differ in their levels of toxicity. The WHO TEFs are used to relate the toxicities of the various PCDDs, PCDFs and DL-PCBs to the most potent PCDD in the group (2,3,7,8-PCDD), which is assigned a potency factor or TEF of 1.0. The concentrations of the individual PCDD, PCDF and DL-PCB isomers and congeners are multiplied by their respective TEF to provide a toxic equivalent concentration or TEQ. For example if the soil concentration of octachlorodibenzo-p-dioxin (OCDD) is reported as 500 pg/g, this is converted to a TEQ concentration by multiplying the reported concentration by the TEF for OCDD (500 pg/g x 0.0001 = 0.5 pg TEQ/g). Similar calculations are completed for each PCDD, PCDF and DLPCB and the TEQ concentrations are summed to provide a total or overall TEQ for the sample. These overall TEQ concentrations are then used in the HHRA to estimate exposure and potential hazards. The MOE supports the use of the TEQ approach for the assessment of exposures to PCB mixtures (Manca *et al*., 2005).

Officially, the Health Canada and TDI for PCDD/PCDF is 10 pg TEQ/kg-d (Health Canada, 2004); however, the WHO/FAO Joint Expert Committee on Food Additives and Contaminants (JECFA) recently proposed a revised Provisional Tolerable Monthly Intake (PTMI) of 70 pg/kg-month (JECFA, 2002). On a daily basis, this PTMI is equivalent to a Provisional Tolerable Daily Intake (PTDI) of 2.3 pg TEQ.kg-d. This revised TDI is being implemented by the federal government and MOE. This TDI is in use by the MOE Sport fish Advisory group and will be incorporated into upcoming revisions of MOE's soil and air guidelines. The current model for calculating TEQ is the 1997 WHO TEF scheme for mammals (applies to humans) (van den Berg *et al*., 1998)

The JECFA PTMI is based on the most sensitive adverse effects of dioxin on developmental endpoints in rats (specifically, effects on the reproductive system of male offspring of female rats treated with dioxin) similar to those and other endpoints considered by WHO, 1998 and SCF, 2001. Essentially, WHO 1998 set a range (1-4 pg/kg/day) and the SCF, 2001 and JECFA, 2002 select midpoints in this range (SCF = 2 pg/kg/d, JECFA = 2.3 pg/kg/d).

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