Appendix A:

Remediation/Risk Management Options, Dillon, March, 2016

March 28, 2016

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Attention: Ms. Lisa McFarlane
PWGSC Project Manager

Risk Management/Remediation Options Analysis for Lead Impacted Surface Soil at the Cape Spear Light Station (Parcel 2014-1), Cape Spear, NL (LL 507, DFRP No. 00358)

1.0 Introduction

The Cape Spear Light Station (LL 507, DFRP No. 00358) site (hereafter referred to as the "Site") is located at Cape Spear, roughly 10 km east of St. John's, NL. It is located adjacent to the Parks Canada Cape Spear National Historic Site, which is also famous for being the most easterly point of land in North America. In the summer months, large numbers of tourists visit the National Historic Site facilities and the light station.

Plans have recently been made to transfer a portion of the Site (i.e., Parcel 2014-1, an approximately 689 m² area near the light tower that includes the dwelling structure; referred to as Area 1) to the Canadian Coast Guard Alumni. Previous environmental studies have indicated that lead concentrations in soils at the Site pose a potential human health risk for both Site visitors and Site workers.

2.0 Previous Investigations

The Cape Spear Light Station Site has undergone a number of environmental site assessment (ESA), human health risk assessment (HHRA) and ecological risk assessment (ERA) activities since 1995. This has included the following:

- 1995: Environmental Audit/Baseline Assessment;
- An untitled and undated report on soil impacts and contamination (estimated to be from the late 1990s);
- 2007: An environmental site assessment and human health and ecological risk assessment (JW, 2007);

- 2012-2013: A Phase III ESA and update/validation study of the 2007 HHRA and ERA (Dillon, 2013a); and
- 2013: Letter RE: Liabilities and Recommendations – Cape Spear Light Station (Dillon, 2013b).

The major outcome of these assessments was the conclusion that Site soil is impacted by lead (Pb) at a number of locations, at concentrations that suggest a potential human health risk for both Site visitors (tourists) and Site workers (i.e., DFO and/or CCG employees). Lead-impacted soil at the Site is therefore considered to represent an environmental liability for DFO (Dillon, 2013b).

3.0 Objectives

PWGSC (on behalf of DFO) retained Dillon Consulting (hereafter referred to as "Dillon") to identify the area(s) of the parcel that will require remedial and/or risk management activities by calculating updated Site Specific Target Levels (SSTL's) for lead in soils and the Exposure Point Concentrations (EPC's) for the removal of lead impacted "hotspots" from the Site. The results of this process indicated that the revised SSTL for a toddler tourist receptor at the Site is 740 mg/kg and that removal or capping of soils in two areas (Area 1: TP14, and Area 2: TP22, TP30, TP34, and TP35) would result in an EPC below 740 mg/kg.

The resulting report, "Preliminary Risk Management Planning Activities Related to Lead in Soil at the Cape Spear Light Station, NL" (January, 2016), can be found in Attachment 4.

Based on these findings, Dillon has completed an analysis of remedial/risk management options for these areas, the details of which are outlined below.

4.0 Liabilities

4.1 Lead Concentrations in Soils

As previously outlined, lead concentrations in surface soil represents a potential unacceptable risk to toddler tourist/visitor(s), and is therefore considered to be a DFO liability.

4.2 Lead Contaminated Soil Disposal Options

A majority of the soil samples in the areas to be remediated/ risk managed contained lead (and other metals) at concentrations above the CCME Soil Quality Guideline for the Protection of Environmental and Human Health for an industrial site which is the landfill disposal guideline used by the Government of Newfoundland and Labrador Department of Environment and Conservation (GNLDEC). Leachate analysis has not been completed on these samples which is required in order to determine whether or not the lead concentration in soil is below the provincial lead leachate guideline for landfill disposal. If leachable lead concentrations are below these guidelines, the material may be disposed of at an approved landfill site, pending the approval of the GNLDEC and the landfill.

4.3 Probable Source of Lead Impacts

The source of the lead impacts in surface soil is likely the flaking and peeling lead based paint on the exterior of the buildings on-site, including the dwelling in Area 1 and the maintenance buildings in Area 2.

5.0 Remediation/Risk Management Options

As previously discussed the removal or capping of soils around samples TP14 (Area 1), TP22, TP30, TP34 and TP35 (Area 2) resulted in an EPC below the revised SSTL for the Site tourist exposure scenario for a toddler. The resulting extent of lead impacted soils requiring remediation/risk management in Area 1 and Area 2 are summarized in Table 1.

Table 1 - Extent of LEAD Impacts in Surface Soil Exceeding SSTLs

Item	*Approximate Quantity*		*Total*
	Area 1	**Area 2**	
Impacted Soil Area	16 m^2	82 m^2	98 m^2
Estimated Depth of Impacts	0.15 m	0.15 m	
Total Volume of Impacted Soil (rounded up)	3 m^3	13 m^3	16 m^3

The proposed areas requiring remediation/risk management in Area 1 and Area 2 are shown on Figure 1 and Figure 2 (Attachment 1), respectively.

Remediation/risk management options to address lead impacted surface soil were evaluated based on effectiveness at eliminating risks and liabilities as well as advantages, disadvantages, costs and schedule.

Remediation and/or risk management options for mitigating risks associated with tourist exposure to lead impacted surface soils on the Site included the following:

- Option 1: Do nothing;
- Option 2: Source removal;
- Option 3: Containment on-site (soil capping); and
- Option 4: Institutional controls.

A detailed options analysis is presented in Attachment 2. Based on sampling results within the impacted area, the depth of soil to be removed was assumed to be 0.15 metres below ground surface (mbgs) for cost calculations.

Based on the desire to divest Area 1, the level of concern associated with the impacted soil and the anticipated future use of the Site as a tourist destination, source removal is the preferred remedial / risk management option. While Option 3 (soil capping) is an effective option for eliminating unacceptable risk pathways to tourist receptors and slightly less costly than source removal initially, due to inclement weather experienced on this coastal property, this option would require a long-term monitoring and maintenance effort to protect the integrity of the cap. As such, it is not a preferred option.

6.0 Recommendations

Based on the desire to divest Area 1, the level of concern associated with the impacted soil and the anticipated future use of the Site as a tourist destination, source removal is the preferred remedial/risk management option. Clean backfill material and sod should be used to replace excavated material and reinstate the property to its original grade and condition.

To prevent further contamination, lead based paint on adjacent buildings, including the dwelling in Area 1 and the maintenance buildings in Area 2, should be removed prior to remedial activities. In addition, the use of lead based paint on-site should be discontinued.

The preferred remediation / risk management approach would consist of the following activities:

- Activity 1: Complete lead leachate analysis on soil to be removed from site to determine if it exceeds the lead leachate criteria for landfill disposal.
- Activity 2: Prepare detailed specifications for the source removal work for the contractor.
- Activity 3: Remove lead based paint on the exterior of the dwelling in Area 1 and the maintenance buildings in Area 2 the building surface, bag and disposed of the paint at an approved waste disposal facility to prevent further or future soil contamination on-site and off-site.
- Activity 4: Excavate impacted surface soil in Areas 1 and 2 (approximately 98 m^2 or 16 m^3 of the impacted surface soil). Transport and dispose impacted soil at an approved disposal facility. For costing purposes, it is assumed that the soil can be disposed of at a landfill. Backfill and compact the excavated area to grade (for costing purposes it is assumed that this will require the same volume as was removed (i.e. 16 m^3) with clean fill. Reinstate the backfilled area with seed or sod.
- Activity 5: Collect an appropriate and representative number of confirmatory surface soil samples adjacent to the limit of the excavated areas for lead analysis to confirm extent of excavation area boundaries. If lead concentrations in confirmatory soil samples are below the SSTL of 740 mg/kg, no further remedial or risk management action is required.

A summary of costs associated with the preferred remediation / risk management option is presented in Attachment 3.

7.0 Closing

If you have any questions or concern, please do not hesitate to call the undersigned at your convenience.

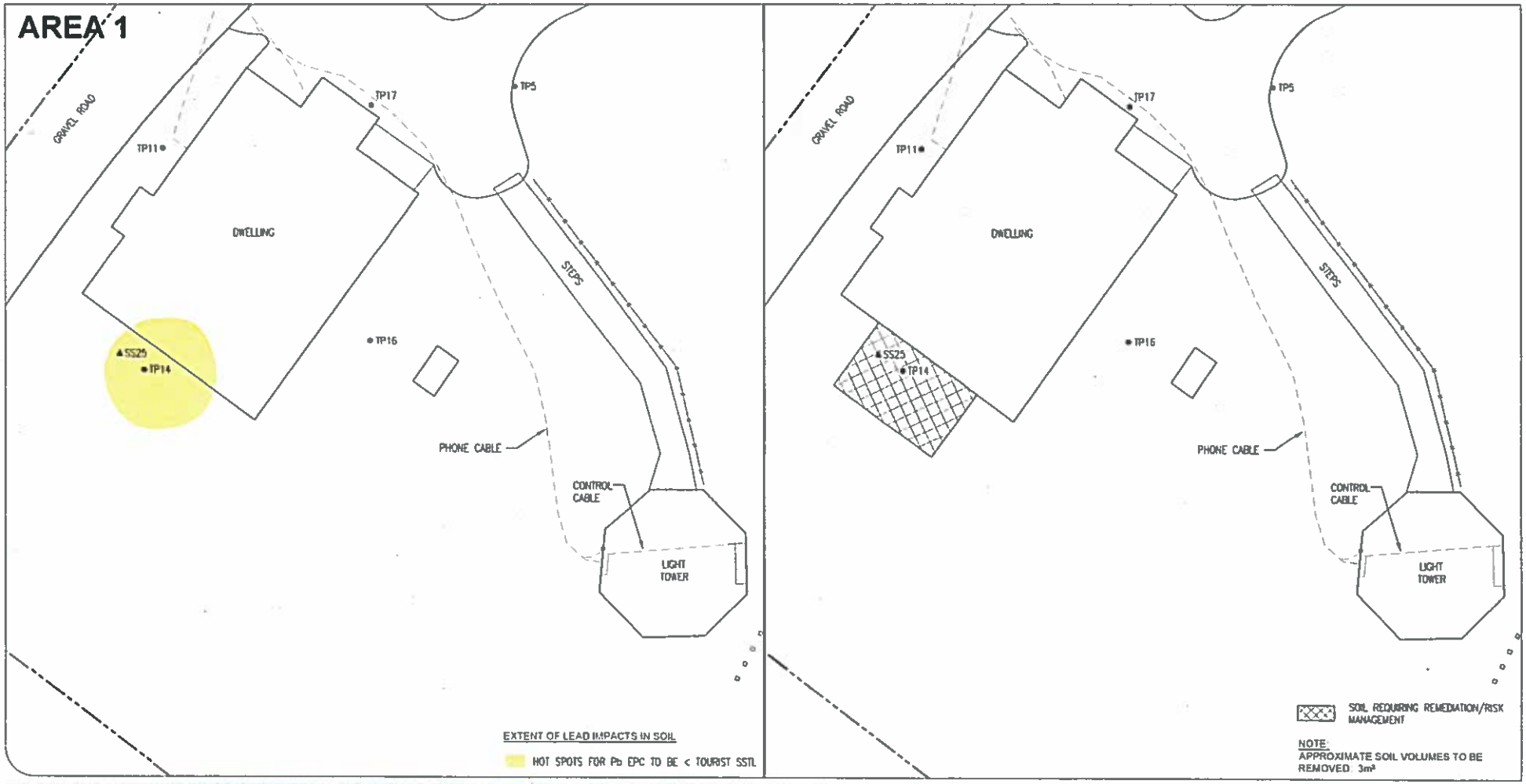
Yours sincerely,

DILLON CONSULTING LIMITED

Dawne Skinner, P.Eng., MASc.
Project Manager

RMA:asr
Our file: 16-3075

ATTACHMENT 1
FIGURES



PUBLIC WORKS & GOVERNMENT SERVICES CANADA
CAPE SPEAR, NL
DFRP# 00358

EXISTING STRUCTURE
UNDERGROUND SERVICES
PROPERTY BOUNDARY
FENCE
SOIL SAMPLE (JACQUES WHITFORD, SEPTEMBER 2007)
SOIL SAMPLE (DILLON CONSULTING, DECEMBER 2012)

AREA 1: PROPOSED AREA WHERE SOIL IS TO BE RISK MANAGED

FIGURE 1

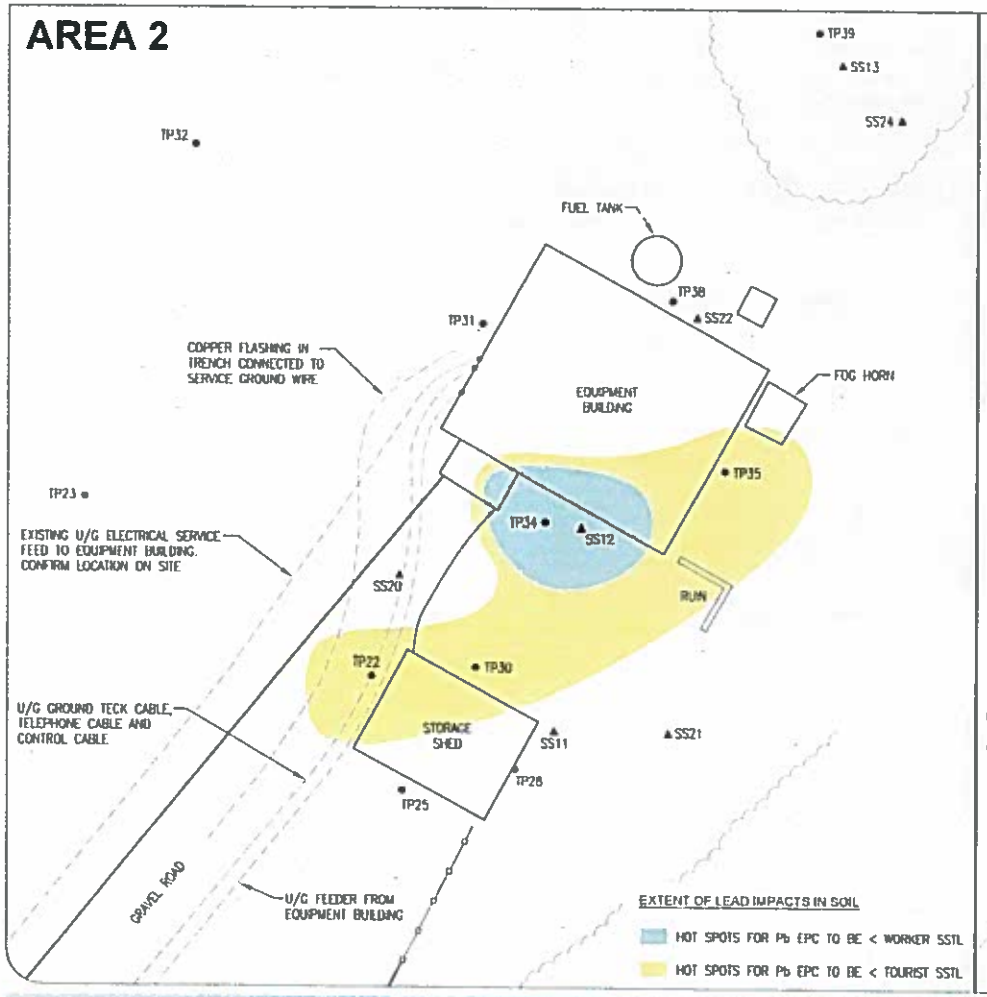
MAP/DRAWING INFORMATION
Dillon Consulting Limited, Phase III ESA and HHERA Update, March 2013 and Jacques Whitford, Soil Sample Location, September 2007

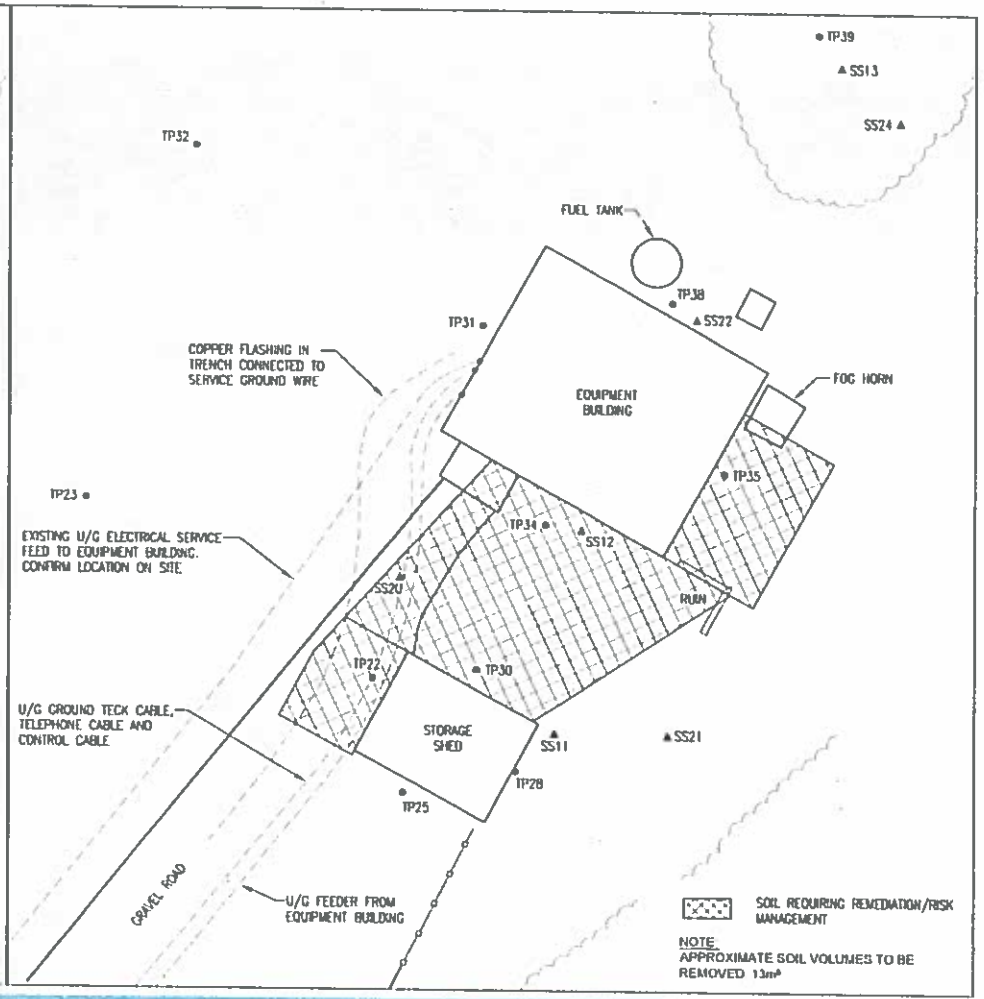
CREATED BY: TLR
CHECKED BY: SH
DESIGNED BY: RMA

SCALE 1:150

DILLON CONSULTING

AREA 2





PUBLIC WORKS & GOVERNMENT SERVICES CANADA
CAPE SPEAR, NL
DFRP# 00358

AREA 2: PROPOSED AREA WHERE SOIL IS TO BE RISK MANAGED

FIGURE 2

EXISTING STRUCTURE
UNDERGROUND SERVICES
PROPERTY BOUNDARY
TREE LINE
GUARD RAIL
SOIL SAMPLE (JACQUES WHITFORD, SEPTEMBER 2007)
SOIL SAMPLE (DILLON CONSULTING, DECEMBER 2010)

MAP DRAWING INFORMATION
Dillon Consulting Limited, Phase III ESA and HHERA Update, March 2012 and Jacques Whitford, Soil Sample Location, September 2007.

CREATED BY: TLR
CHECKED BY: RH
DISPROVED BY: HMA

SCALE 1:150

DILLON CONSULTING

ATTACHMENT 2
OPTIONS ANALYSIS TABLE

Table 1: Qualitative Remedial/Risk Management Options Evaluation
Cape Spear, Newfoundland (DFRP No. 00358)
PWGSC (March 2016)

Environmental Concern: Lead impacted surface soil above SSTLs in two areas (1 - near dwelling; 2 - near maintenance buildings; total area requiring remediation / risk management: 98 m^2)

Remedial Approach	Application	Advantages	Disadvantages	Time Frame	Costs	Other Considerations/Comments	Ranking
OPTION 1. Do nothing	No on-site work conducted	No further work (i.e. assessment, remediation or risk management activities) and no costs.	- Will not reduce lead concentration in site surface soils to below the Site Specific Target Levels (SSTLs). - Impacted soil and the associated liability will remain on-site.	0	[redacted]	The Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA) concluded there is a potential for adverse effects to tourist visitors (toddler receptors) on the Site associated with the elevated lead concentrations in surface soil	4
OPTION 2. Source Removal (excavation and off-site disposal of lead impacted soil)	- Excavate impacted surface soil and dispose off-site at a Government of Newfoundland and Labrador Department of Environment and Conservation approved soil disposal facility - Backfill the excavations with clean backfill soil material - Seed or sod the backfilled areas	- Removes risks and liabilities associated with impacted surface soils on site - Impacted soils are easily accessible at surface - Low volumes of soil given the shallow depth to bedrock and surficial nature of impacts. Vertical extent of excavation would likely extend to bedrock in some areas. - A Risk Management Plan (RMP) (specifically long term monitoring) would not be required - Straightforward implementation. Proven track record for addressing most impacted soil. - Short timeframe to complete work (small soil volume requiring capping)	- Remediation should be conducted outside of tourist season. - Requires impacted material to be trucked off site and associated tipping fees for impacted soil disposal. - Outer limits of the impacted soil areas are near cliff edge which can pose a health and safety concern during excavation. - Impacted soil areas are adjacent to or between buildings which will require more manual labour to access pockets of soil within the contaminated area	1 week on site	[redacted]	- Tourist/Visitor(s) are known to frequent the Site. - Remediation would not be recommended during the tourist season. - Cost is based on the excavation of approximately 16 m^3 of impacted surface soil, assuming an average soil depth of 0.15 m. Cost includes leachate testing, excavation, trucking, disposal at a GNLDEC approved landfill, backfill, analytical testing of backfill material, restoration (sod) with a 15% contingency on the total cost. Tax not included. Notes. - Assumes the contractor can be retained under an existing PWGSC Standing Offer Cost does not include cost to dispose of soil at a hazardous soil disposal facility. - Cost of developing specifications, cost of third party oversight and closure reporting, and costs associated with removing and restoring paint in the buildings is not included in the cost estimate	1
OPTION 3: Source Containment On-site (e.g. soil capping)	- Place a geotextile fabric over the impacted surface soil areas Place 0.3 meters of clean backfill soil material on top of the geotextile to create a barrier between impacted soil and potential receptors - Seed or sod the soil cover and install an erosion control blanket for protection during seed growth / sod establishment - Develop a long term monitoring plan to monitor integrity of soil cap	- Isolates the impacted soil above SSTLs from potential receptors - Reduces risk and eliminates exposure pathway for potential receptors - Materials are easily accessible. - Straightforward implementation. Reliable method of addressing on-site risks from impacted soil. - Short timeframe to install soil cap (small areas requiring capping)	- Impacted soil will remain on-site - Requires more imported backfill material than option 2 (0.3 meters soil cap versus 0.15 meters of backfill material) - Ongoing monitoring/maintenance program required to assess and maintain the integrity of the cover material - Outer limits of the impacted soil areas are near cliff edge which can pose a health and safety concern during work. - Due to site location and exposure to elements (coastal property with inclement weather), erosion of clean topsoil and sod may be extensive and will required monitoring and maintenance.	1 week on site (+ long-term monitoring / maintenance plan effort)	[redacted]	- Tourist/Visitors(s) are known to frequent the Site - Risk management activities will have to be completed during tourist season to allow sods to become established. - Cost is based on capping an approximate area of 98 m^2 (plus additional area for sloping). Cost includes capping impacted soil areas with geotextile, clean fill (0.3 m), vegetation (e.g. sod and erosion control blanket) and the development of a long-term monitoring plan for the site with a 15% contingency on the total cost. Tax not included Notes. - Assumes the contractor can be retained under an existing PWGSC Standing Offer. - Cost of developing specifications and costs associated with removing and restoring paint in the buildings is not included in the cost estimate	2
OPTION 4. Institutional / Administrative Controls	- Implement institutional and administrative controls on-site. These could include fencing or other means of restricting tourist access to the areas of impacted soil.	- Low cost compared to Options 2 and #3 - Removes a portion of the risk associated with soil contact.	- Impacted material remains on-site - Does not alleviate all risks and liabilities associated with impacted soil on-site. - Requires additional controls to ensure personnel are not exposed to impacted soil material. Ongoing monitoring/maintenance program required to assess and maintain the integrity of the cover material. - May not be feasible due to the prevalence of shallow bedrock at this site.	1 week on-site (+ long-term monitoring / maintenance plan effort)	[redacted]	- Tourist/Visitors(s) are known to frequent the Site. Notes. - Assumes the contractor can be retained under an existing PWGSC Standing Offer - Cost of developing specifications and costs associated with removing and restoring paint in the buildings is not included in the cost estimate.	3

Notes:

(1) Estimated time frames are based on typical remediation programs.

(2) To prevent further or continuous surface soil contamination, the lead based exterior paint on the source buildings (e.g. dwelling in Area 1, maintenance buildings in Area 2) will need to be removed prior to soil remediation program.

(3) Costs presented do not include the following items (which are common to both Option 2 and 3):

(a) developing detailed specifications for the work

(b) costs associated with removing paint from the light station and associated reinstatement effort

(c) third party owner's representative site supervision effort during work

(4) Costs assume that soil leachate samples do not exceed the landfill guidelines.

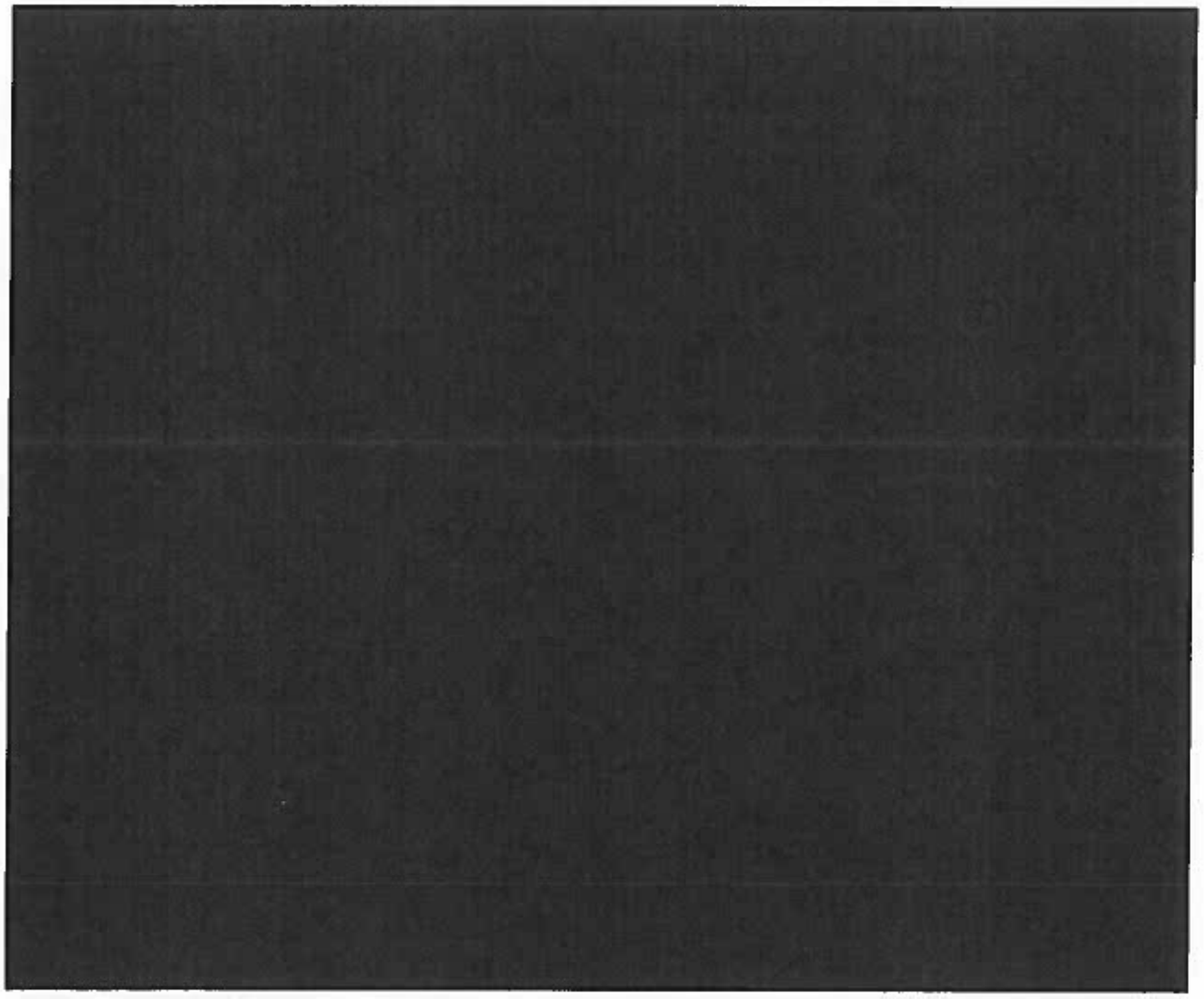
(5) Estimated costs to dispose of soils that exceed the landfill leachate guidelines of 5000 mg/kg for lead is [redacted]

ATTACHMENT 3
COST TABLE

Attachment 3: Cost Table

Cape Spear, Newfoundland (DFRP No. 00358)

PWGSC (March 2016)



ATTACHMENT 4
PRELIMINARY RISK MANAGEMENT PLANNING ACTIVITIES RELATED TO LEAD IN SOIL AT THE CAPE SPEAR LIGHT STATION, NL (JANUARY, 2016)

January 27, 2016

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Public Works and Government Services Canada
John Cabot Building
10 Barter's Hill
St. John's, NL

Attention: Ms. Lisa McFarlane
Environmental Specialist, Environmental Services

***Preliminary Risk Management Planning Activities Related to Lead in Soil at the Cape Spear Light Station, NL* (LL 507, DFRP No. 00358)**

Dear Ms. McFarlane:

Please find attached a letter report which describes revised soil SSTL calculations for lead for the Cape Spear Lightstation Site, and which illustrates the effect of removing lead hot spots in Site soil on site-wide soil exposure point concentration estimates.

We trust that the information presented in this letter meets your needs and expectations. If there are any questions or concerns, please contact the undersigned at your earliest convenience.

Yours sincerely,

DILLON CONSULTING LIMITED

Dawne Skinner, P.Eng., MASc.
Project Manager

Rob Willis, B.Sc., M.E.S., EP, QPRA
Senior Risk Assessor/Toxicologist

Enclosure(s) or Attachment(s) - [Appendix A, B, C]

Our file: 16-3075

1.0 Background, Scope and Objectives

The Cape Spear Lightstation is located at Cape Spear, roughly 10 km east of St. John's, NL. It is located adjacent to the Parks Canada Cape Spear National Historic Site, which is also famous for being the most easterly point of land in North America. In the summer months, large numbers of tourists visit the National Historic Site facilities and the lightstation.

The Cape Spear Light Station (LL 507, DFRP No. 00358) site (hereafter referred to as the "Site") has undergone a number of environmental site assessment (ESA), human health risk assessment (HHRA) and ecological risk assessment (ERA) activities since 1995. This has included the following:

- 1995: Environmental Audit/Baseline Assessment.
- An untitled and undated report on soil impacts and contamination (estimated to be from the late 1990s).
- 2007: An environmental site assessment and human health and ecological risk assessment (JW, 2007).
- 2012-2013: A Phase III ESA and update/validation study of the 2007 HHRA and ERA (Dillon, 2013a).
- 2013: Letter RE: Liabilities and Recommendations – Cape Spear Light Station (Dillon, 2013b).

The major outcome of the above assessments was the conclusion that Site soil was impacted by lead (Pb) at a number of locations, at concentrations that suggest a potential human health risk for both Site visitors (tourists) and Site workers (i.e., DFO and/or CCG employees). Lead-impacted soil at the Site was therefore considered to represent an environmental liability for DFO (Dillon, 2013b). Various remediation and risk management options were reviewed and evaluated by Dillon (2013b). The most preferred options were noted to be either: i) coverage (encapsulation) of impacted soil with clean imported soil, followed by topsoil, gravel or sod as appropriate; and/or, ii) excavation and off-site disposal of Pb-impacted soil at an approved (by Government of Newfoundland and Labrador Department of Environment and Conservation) disposal facility. The relative advantages, disadvantages, costs, timeframes, and other considerations for the reviewed options were previously provided in Dillon (2013b) and are not reproduced herein.

Dillon (2013b) had also suggested that additional surface soil sampling may be necessary to better define the horizontal extent of impacted soil to be covered. However, it is presently believed that Site soil Pb concentrations are sufficiently delineated both horizontally and vertically (which was also a conclusion of the Dillon,

2013a report), and that any additional soil sampling at the Site could occur as part of confirmatory sampling following soil remediation or risk management activities.

Plans have recently been made to transfer a portion of the Site (i.e., Parcel 2014-1, an approximately 689 m^2 area near the light tower that includes the dwelling structure; referred to as Area 1 in the previous JW (2007) and Dillon (2013a) reports (See Appendix A)) to the Canadian Coast Guard Alumni. As a result of this, DFO Real Property wishes to ensure that the transfer of this land parcel will not result in a situation where there could be a potential future human health risk due to the presence of elevated Pb concentrations in Site soil, and are considering remediation of the Pb-impacted soil within this parcel, and potentially elsewhere on the Site, as warranted. At this time, soil hot spot removal and/or coverage remain the most feasible remedial approaches that are being considered.

The remainder of the Site is expected to remain under DFO ownership. As some other land parcels at the Cape Spear Light Station are owned and/or managed by Parks Canada (including a land parcel and building to the immediate north of the Site), it is anticipated that DFO will need to consult with Parks Canada on human safety aspects related to soil Pb impacts at the Site, and the planned remediation/risk management of the Pb-impacted soil.

Current conditions at the Site, based on review of recent photographs, suggest a limited potential for human exposure to Pb in soil, as no bare soil areas are present. Site soils are well vegetated with various mixed grasses and low shrubs. The non-vegetated areas comprise exposed bedrock outcrops or gravel surface coverings on walkways and parking areas. As such, there is presently a low likelihood that Site visitors or workers would actually come into contact with Pb-impacted soil, and there is no immediate potential health risk that needs to be mitigated or managed.

Due to the pending transfer of Parcel 2014-1 to the Canadian Coast Guard Alumni, Dillon was retained by PWGSC (on behalf of DFO) to complete the following tasks.

- Calculate revised and updated soil site-specific target levels (SSTLs) for Pb that reflects the current toxicological and regulatory status of this substance with respect to contaminated site HHRAs in Canada.
- Assuming that soil hot spot removal or coverage will occur as the remedial action for the Site, estimate the new soil Pb exposure point concentrations (EPCs) that result from the successive or sequential removal of maximum Site soil Pb concentrations. In other words, iterate the effect of successive hot spot removal on the soil Pb EPC for the Site.

- Based on the previous two tasks, determine the Site soil sample locations that would require removal or coverage such that the site-wide EPC falls below the updated soil SSTLs for Pb. This information is anticipated to be used to develop a Risk Management Plan/Remedial Action Plan (RMP/RAP) for the Site (development of a Site RMP/RAP is not within the current scope of work).

This approach to soil remediation and risk management has been successfully applied at a number of DFO-owned sites in Atlantic Canada over the past several years.

2.0 Soil SSTLs for Lead (Pb)

JW (2007) HHRA

JW (2007) calculated soil SSTLs for lead using a two-step process. First, standard Health Canada equations for soil ingestion, soil inhalation and dermal contact with soil, along with Health Canada and Atlantic RBCA receptor and exposure parameters, the Site soil lead EPC (at the time), and a human toxicity reference value (TRV) for Pb of 3.57 µg/kg body weight/day, were used to calculate hazard quotients under two exposure scenarios: i) site worker; and, ii) site visitor (tourist). The SSTLs were then calculated as follows:

SSTL = [THQ (i.e., 0.2) X Soil EPC] / HQ

This approach yielded soil SSTLs for Pb of 445 mg/kg and 2982 mg/kg, for the tourist and worker scenarios, respectively. Further details are provided in JW (2007).

Dillon (2013a) HHRA Validation

In the HHRA validation study, it was determined that the original exposure scenarios and their associated conditions and parameters (from the 2007 HHRA) remained reasonable and valid overall, and had been previously accepted by PWGSC. The most significant change since the 2007 HHRA was noted to be a change in the Pb TRV. Specifically, the Pb TRV of 3.57 µg/kg body weight/day (which was formerly a Health Canada-recommended TRV based on a World Health Organization evaluation) was rescinded by Health Canada in 2009, and was no longer considered to be adequately protective of human health. Similar actions were taken in many other countries.

Between 2009 and 2012, Health Canada had recommended that a MOE (1994) Pb TRV of 1.85 µg/kg body weight/day be used instead of 3.57 µg/kg body weight/day. Health Canada rescinded this value as well in late 2012 (for the same reasons), but has yet to develop a new or alternate TRV. At the time of the HHRA validation study

(which began in the Fall of 2012), the MOE (1994) TRV was still widely used in contaminated site HHRAs conducted throughout Atlantic Canada.

Given the change in the Pb TRV status, soil SSTLs for Pb were updated in the Dillon (2013a) validation study. As the original exposure scenarios and their associated conditions and parameters (from the 2007 HHRA) were considered to remain reasonable and valid, the SSTLs were adjusted by simply ratioing the 2007 SSTLs by the change in magnitude between the former Health Canada and MOE (1994) TRVs (i.e., 3.57 µg/kg body weight/day and 1.85 µg/kg body weight/day differ by a factor of 1.93). This was considered a valid estimation approach in that the HHRA and SSTL equations are all linear. Thus, the SSTLs change by the same magnitude as the change in TRV values. This adjustment resulted in revised soil SSTLs for Pb of 231 mg/kg and 1545 mg/kg for the tourist and worker scenarios, respectively.

Based on the revised soil SSTLs, Dillon (2013a) reported that there was now a potential need for soil remediation or risk management at the Site. Further details are provided in Dillon (2013a,b).

Current Soil SSTL Approach

While there are a few different ways that soil SSTLs can be calculated, the most recent HHRA templates for use at DFO sites in NL have tended to rely on the human health-based soil quality guideline equations for both non-carcinogens and carcinogens, from the CCME (2006) Soil Quality Guideline Protocol, or modifications of these CCME equations.

For consistency with most recent HHRAs of DFO-owned sites in NL, this same approach was taken herein to calculate revised and updated soil site-specific target levels (SSTLs) for Pb that reflect the current toxicological and regulatory status of this substance with respect to contaminated site HHRAs in Canada.

Since the Dillon (2013a) validation study was conducted, it has become increasingly less accepted across Canada to continue to rely on the MOE (1994) Pb TRV. It is now widely considered that this value is no longer scientifically defensible, and is likely not sufficiently protective of human health given the current weight of evidence for the human toxicological effects of Pb. As noted, Health Canada rescinded the use of the MOE (1994) TRV for use in federal contaminated site HHRAs in late 2012. MOE (now known as Ontario Ministry of Environment and Climate Change, or MOECC) is currently in the process of reviewing their human health-based TRV for Pb, and while the review is not yet complete, it is expected that a new MOECC Pb TRV will be significantly lower than 1.85 µg/kg body weight/day. While it is acknowledged that

this MOE (1994) TRV is still used in some HHRAs of federally owned contaminated sites in Atlantic Canada (including some within NL), its continued use can no longer be supported.

Due to the continued absence of a TRV option for Pb from Health Canada, a collaborative initiative was undertaken in 2015, on behalf of PWGSC and DFO (Maritimes and Gulf Region), to develop an interim Pb TRV that reflects the current state of the science on Pb human toxicology, and that can be applied at DFO-owned sites throughout Atlantic Canada in a consistent manner. The interim Pb TRV development process is described in Rae et al. (2015), and represents the current consensus of toxicologists and risk assessors from three consulting firms that have been actively involved in Atlantic region federal contaminated site HHRAs for many years. The current recommended interim Pb TRV is a risk-specific dose (RsD) of 1.1 µg/kg body weight/day that applies to all human receptor age classes. It has a very similar basis as a recent BC MOE (2013) interim Pb TRV, and draws upon recent evaluations from international regulatory bodies (including the World Health Organization, European Food Safety Authority and U.S. EPA) that Health Canada currently recommends as sources to be consulted when assessing Pb at federal contaminated sites. The RsD reflects the abundant literature and weight of evidence which suggests Pb does not act as a threshold chemical (e.g., CCME, 2012; Health Canada, 2013; Healy et al., 2010; EFSA, 2010; WHO, 2011), and it applies equally to all environmental routes of exposure. Given the rescinded status of the MOE (1994) TRV and the continuing lack of any TRV option from Health Canada, this RsD is recommended for use as an interim Pb TRV until Health Canada or another major regulatory agency produces an equally or more defensible TRV of their own.

The interim RsD of 1.1 µg/kg body weight/day has therefore been used to calculate the updated soil Pb SSTLs for this Site.

While the TRV change is once again the major change that affects the development of soil SSTLs for Pb, the revised SSTL calculations also reflect current HHRA guidance (primarily from Health Canada) in relation to human exposure and receptor parameters (including oral and dermal RAFs), exposure frequency and duration amortization guidance for Pb (and other developmental toxicants), guidance/approaches for addressing the background estimated daily intake (EDI) term, and NL-specific background soil concentration estimates for Pb (as reported in PWGSC, 2011). Guidance and recommended values for a number of these parameters has changed since 2007 and since 2012-2013.

The revised soil SSTLs for Pb continue to be consistent with the original worker and tourist exposure scenarios that were developed in the JW (2007) HHRA. It is noted

though that these original scenarios were highly conservative and likely substantially overestimate the amount of time that the applicable human receptors would likely spend on the Site. Thus, upon further consideration of current and anticipated future Site use patterns, and discussion with PWGSC and DFO, it was decided that the original assumed exposure duration and frequency terms for the Site exposure scenarios should be modified slightly in order to make them more realistic (yet still appropriately conservative). The revised SSTL calculations for the tourist and worker scenarios therefore utilize modified assumptions for exposure frequency and duration, as follows:

- Tourist Scenario (toddler receptor): Exposure assumptions were modified from 8 hours/day, 3 days/week, 52 weeks/year to 8 hours/day, **1 day/week**, 52 weeks/year.
- Worker Scenario (adult): Exposure assumptions were modified from 10 hours/day, 7 days/week, 52 weeks/year to 10 hours/day, **5 days/week**, 48 weeks/year.

While these modified assumptions are believed to reflect more realistic estimates of exposure frequency and duration for the two exposure scenarios, they are still considered to be conservative and protective, and likely continue to overestimate the amount of time that human receptors would actually spend at the Site.

Another exposure-related modification to the revised SSTLs, discussed with PWGSC and DFO, is the incorporation of a winter cover factor into the SSTL equations. A winter cover factor accounts for the fact that during winter months, contact with Site soil is essentially negligible due to snow/ice cover, and/or frozen soils. Clearly, snow and/or ice cover provides a physical barrier to soil contact. Even when no snow or ice cover layer is present in winter months, frozen soils do not adhere to skin and do not generate dust. Also, during winter months, workers or visitors at the Site would likely have little to no exposed skin that would come into contact with Site soil due to wearing gloves, mitts, and other winter apparel. Winter cover factors are commonly applied in human health risk assessments to provide more realistic and meaningful estimates of exposure and risk.

A winter cover factor of 0.75 was determined for the Site based on Environment Canada climate normals data for Petty Harbour, Logy Bay, St. John's West CDA, and St. John's A climate stations (http://climate.weather.gc.ca/climate_normals/index_e.html). These are the closest Environment Canada climate stations to the Site (i.e., within 10 km of the Site). Climate normals data from these stations (from 1981-2010) for the parameters of average daily temperature, days with snowfall, and snow depth, suggest that Site soil

may conservatively be assumed to be available for direct contact nine (9) months of the year. Site soils would unavailable for direct contact for three (3) winter months of the year due to snow/ice cover and frozen soil conditions. The winter cover factor of 0.75 reflects 9/12 months where the Site soil is available for potential human contact (i.e., 9/12 = 0.75).

The relevant operable exposure pathways and routes that were considered in the soil SSTL equation are: soil ingestion, dermal contact with soil, and inhalation of resuspended soil/dust.

The following equation (modified from CCME, 2006 and BC MOE, 2013 soil quality guideline equations) was used to develop the revised soil SSTLs for Pb.

$$SSTL = \frac{(RsD * SAF) * BW}{([RAF_{ING} * IR_S * ET_{ING}] + [RAF_I * IR_A * ET_I] + [RAF_D * DR * ET_{DERM}])} + BSC$$

Where:	RsD	=	Risk-specific dose (the 2015 interim Pb TRV) (mg/kg bw/day)
	SAF	=	soil allocation factor (unitless)
	BW	=	body weight (kg)
	RAF_{ING}	=	relative absorption factor (oral) (unitless)
	IR_S	=	soil ingestion rate (kg/day)
	ET_{ING}	=	exposure term for soil ingestion pathway (unitless)
	RAF_I	=	relative absorption factor (inhalation) (unitless)
	IR_A	=	soil inhalation rate (kg/day)
	ET_I	=	exposure term for soil inhalation pathway (unitless)
	RAF_D	=	relative absorption factor (dermal) (unitless)
	DR	=	soil dermal contact rate (kg/day)
	ET_{DERM}	=	exposure term for soil dermal contact pathway (unitless)
	BSC	=	background soil concentration (mg/kg)

The SSTL calculations for the worker and tourist exposure scenarios are provided in Appendix B. The winter cover factor of 0.75 was applied to the ET terms in the SSTL calculations (i.e., ET x Winter Cover Factor).

Because the recommended TRV is a RsD, rather than a threshold-based TDI or similar type of TRV (e.g., reference dose), there is no need to subtract an estimated daily intake (EDI) term from the TRV. Precedent for this exists in BC MOE (2013). Also, CCME (2012) acknowledges that the EDI term could arguably be eliminated from the soil quality guideline equation for Pb, in recognition that Pb has no known threshold for its critical toxicological effects in humans.

The SAF term was set at 0.2, which is consistent with current contaminated site risk assessment practices in Canada for many years.

Using the above equation, the revised SSTL for the Site worker scenario is **2300 mg/kg**, and the revised SSTL for the tourist scenario is **740 mg/kg** (the SSTLs are rounded to two significant figures).

3.0 Iteration of New EPCs Via Successive (Sequential) Hot Spot Removal

In most HHRAs, the upper 95% confidence limit of the arithmetic mean (UCLM95) is the most common statistic used to represent the exposure point concentration (EPC). Most regulatory agencies recognize that the best approximation of the EPC, often referred to as the "true mean", or "the concentration most likely to be contacted over time", is the UCLM95. To derive the UCLM95 values for the Site soil lead concentration data, the U.S. EPA computer program, ProUCL™ Version 5.0 was used. The U.S. EPA recommends the use of ProUCL when calculating EPCs for use in HHRAs of contaminated sites. ProUCL determines the most appropriate UCLM95 value for a dataset, given its distribution and characteristics. A number of statistically valid methods to calculate a UCLM95 can be run simultaneously, with the program recommending the most appropriate or statistically robust value(s) to select. However, according to its user guidance, ProUCL can only determine robust and reliable UCLM95 values if the sample size is at least eight (8). As the sample size for Pb concentrations within the Site soil chemistry dataset is larger than this (i.e., N=41), it was possible to calculate adequately robust UCLM95 soil Pb EPCs, throughout the iterative process.

The iterative approach involved successively removing the maximum soil Pb concentration (i.e., hot spot removal), then recalculating the UCLM95. This was conducted until the UCLM95-based EPC was below the revised soil SSTLs for Pb. The results of this process indicate which Site soil sample locations merit remediation or

risk management such that a post-remediation/risk management EPC for Pb would not exceed the revised soil SSTLs. The iterative process is shown in Appendix C, and summarized in Table 1, below.

In calculating the UCLM95-based EPCs for Pb in Site soil, the following tasks/conditions were conducted/applied, many of which tend to bias the UCLM95-based EPCs high:

- All off-site background soil samples were removed from the Site soil chemistry dataset.
- For Site soil samples with corresponding laboratory or field duplicates, the higher concentrations out of the original and duplicate samples were retained.
- For Site soil samples with analytical results for Pb below the laboratory reported detection limit (i.e., <RDL), the <RDL values were assumed to equal the RDL.
- Prior to calculating UCLM95-based EPCs, Dillon re-reviewed the laboratory certificates of analysis, as well as the accompanying laboratory quality assurance reports for the Site soil Pb data (which was presented in JW, 2007 and Dillon, 2013a). The review focused on laboratory performance with respect to the RDLs that were achieved, percent surrogate recoveries, lab and field duplicate results and relative per cent difference or absolute difference (when lab duplicates are compared to original sample results), matrix spikes, method blanks, and spiked blanks. No major analytical issues were identified that would affect the use of these data in a HHRA or risk management evaluation. Thus, the Site soil chemistry data were considered to be of adequate quality, and appropriate for the purposes of EPC calculation.
- As the measured Pb concentrations in Site soil represent potential concentrations that human receptors could come into contact with, no attempt was made to conduct statistical outlier tests to remove extreme values (high or low) from the Site soil chemistry datasets. Thus, the EPC calculations for Pb included the presence of potential extreme values.
- As the calculated options for a UCLM95 generated by ProUCL 5.0 can vary considerably (as a function of the underlying assumptions in the statistical models, and the soil data distribution type), some degree of professional judgment is typically necessary in selecting the most appropriate UCLM95 value for use as the EPC. Key considerations often include the data distribution type, the significance level associated with the UCLM95 calculation methods (i.e., ProUCL-recommended values are not always at the 95% significance level), any warnings generated by the ProUCL 5.0 software, and the magnitude of the calculated UCLM95 options.

Table 1 UCLM95-Based EPC Iteration From Successive (Sequential) Hot Spot Removal

Sample Size for Site Pb Soil Concentrations (N)	Maximum Site Soil Pb Concentration (mg/kg) Removed	Sample ID for Removed Maximum Site Soil Pb Concentration (mg/kg)	Resulting UCLM95-Based EPC (mg/kg)
41	None removed	Not applicable	2387[a]
40	11,000	JW TP34-bs1	***1654***
39	7200	JW TP30-bs1	1170
38	4600	JW TP35-bs1	873
36	2400 (two locations)	JW TP14-bs1 JW TP22-bs1	**632**
35	2200	Dillon SS11	351
34	1600	Dillon SS12	290
33	820	Dillon SS13	264
32	780	JW TP17-bs1	222
31	620	JW TP6-bs1	200
30	400	Dillon SS25	191

Notes:
All soil samples were collected from the 0-0.15 m depth interval due to a shallow soil profile and bedrock presence at shallow soil depths across the Site.
Bold and Italics denotes EPC is below DFO/CCG worker scenario SSTL.
Bold denotes EPC is below tourist scenario SSTL.
JW = Jacques Whitford.

a This EPC estimate varies from that presented in Dillon (2013a). In that report, the UCLM95-based EPC was considered to be 1911 mg/kg based on the resemblance of the Pb soil concentration distribution to a lognormal distribution and professional judgment. However, use of a newer version of ProUCL than was available in 2012 and 2013 (which includes updates to the embedded statistical models and algorithms) and review of the statistical output for the UCLM95 calculation suggests that the Pb concentration distribution in Site soil is likely non-parametric rather than lognormal. Thus, the recommended non-parametric UCLM95 value from ProUCL is considered more appropriate than 1911 mg/kg, which assumes a lognormal data distribution.

A figure showing the location of the Pb soil hot spots that would need to be removed in order to have a Pb EPC below the two SSTLs is provided in Appendix C.

Based on the information presented in Table 1, five (5) Site soil Pb hot spots would require removal or coverage for the EPC to be below the tourist scenario SSTL. Only

one (1) Site soil Pb hot spot would require removal or coverage for the EPC to be below the worker scenario SSTL.

4.0 Next Steps for Risk Management Planning

As previously suggested in Dillon (2013a,b), excavation and/or coverage of the Pb hot spots in Site soil remain the most feasible and effective remedial and/or risk management options. Of these, excavation of the hot spot areas, followed by placement of clean imported fill, topsoil and sod would be the most effective and permanent option. Coverage of the hot spots would require some form of long term inspection and maintenance to ensure that the Pb-impacted soils remain under the cover layer.

It is anticipated that the information contained in this letter will be used to develop a remedial action plan (RAP) or risk management plan (RMP) for Pb-impacted Site soils. It is expected that the RAP or RMP would finalize estimates of the areal extent and volume of impacted soil that would require remediation or risk management, and generate applicable cost estimates associated with the selected option.

Some other options that may also reduce/prevent potential Pb exposure, and that may merit consideration in the RAP or RMP, include:

- Diverting current walkways to avoid the areas of greatest Pb soil impacts.
- Building wooden decks and/or walkways over the areas with the highest soil Pb concentrations.
- Develop a maintenance plan for the Site buildings and structures to prevent flaking paint chips from coming off the buildings and structures and potentially re-contaminating the Site surface soil (e.g., this could involve installing vinyl siding over current painted surfaces where feasible).
- Ensure that lead-based paints are no longer used at the Site.

Following RAP or RMP implementation, confirmatory Site soil sampling will be required in order to verify that areas of elevated Pb soil concentrations have been effectively removed and/or covered such that potential exposure is prevented.

Site soil sampling other than for post-remediation/risk management confirmatory purposes does not appear to be warranted in that horizontal and vertical delineation of Site soil Pb impacts was achieved in the Dillon (2013a) assessment.

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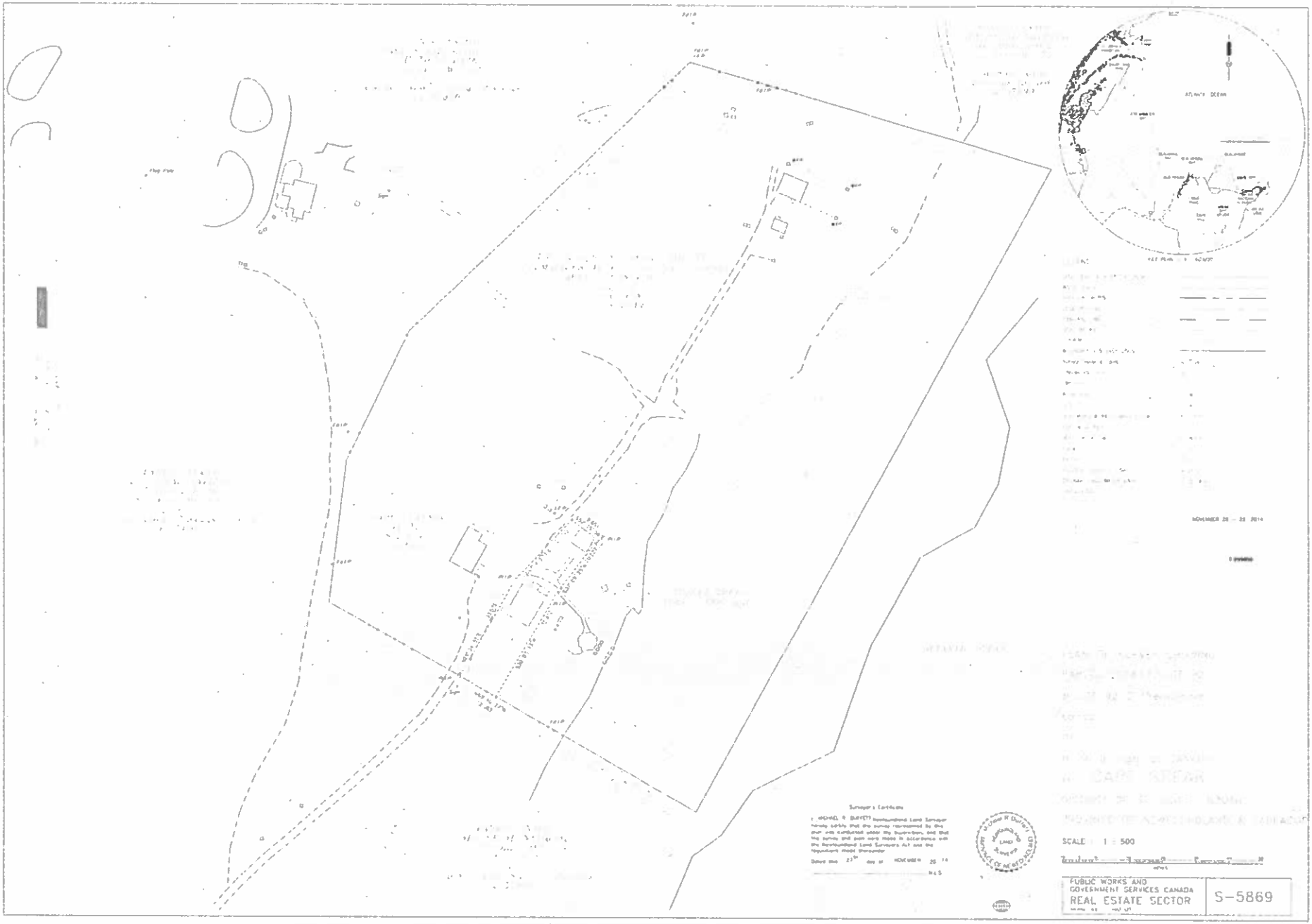
APPENDIX A
LAND PARCEL TO BE TRANSFERRED TO CCG ALUMNI



SCALE 1 : 500

PUBLIC WORKS AND GOVERNMENT SERVICES CANADA
REAL ESTATE SECTOR

S-5869

APPENDIX B
SOIL SSTL CALCULATIONS FOR Pb

Site Specific Target Levels for Human Health (Lead)
Site Name Cape Spear
Scenario DFO/CCG Worker
Receptor Adult

$$SSTL = \frac{(RsD * SAF) * BW}{([RAF_{oral} * IR_s * ET_{oral}] + [RAF_I * IR_A * ET_I] + [RAF_D * DR * ET_{DERM}])} + BSC$$

Chemical	TDI (oral)	EDI	THQ (SAF)	BSC	RAF_{oral}	RAF_I	RAF_D	SSTL (mg/kg)
Lead	0.0011	0	0.2	35	0.6	1	0.006	2,263

Time on Site (same assumptions as JW, 2007) :

Hours per day (inhalation)	10	(soil ingestion and dermal contact are assumed to be daily event-driven exposures that are not affected by hours/day on a site, as per Health Canada, 2010 guidance)
Days per Week	5	
Winter Cover Factor	0.75	conservatively assumed that Site soil is available for contact 9 months of the year due to snow/ice cover and frozen soil conditions in winter months, based on Environment Canada climate normals data for Petty Harbour, Logy Bay, St. John's West CDA, and St. John's A climate stations; data for average daily temperature and days with snowfall, http://climate.weather.gc.ca/climate_normals/index_e.html

Parameter	Definition (units)	Default Values	Reference
RsD	risk-specific Dose (mg/kg bw-day)	0.0011	Rae et al., 2015
EDI	estimated daily intake (from non-site sources - multimedia exposure assessment) (mg/kg bw-day)	0	Not considered since Pb TRV is a RsD and Pb is a non-threshold toxicant.
THQ (SAF)	target hazard quotient or soil allocation factor	0.2	Assumed
BW	body weight (kg)	70.7	Health Canada, 2010
BSC	background soil concentration (mg/kg)	35	PWGSC, 2011 (final background concentration)
RAF_{oral}	relative absorption factor (oral, unitless)	0.6	Assumed based on Health Canada and U.S. EPA (2009) guidance; Based on available information in the literature on lead absorption in humans, the U.S. EPA estimates that the relative bioavailability of lead in soil compared to water and food is about 60%.
RAF_I	relative absorption factor (inhalation, unitless)	1	Assumed
RAF_D	relative absorption factor (dermal; unitless)	0.006	OMOE, 2011 (Value is an absolute absorption factor determined from measured data in *in vitro* human skin studies)
IR_s	soil ingestion rate (kg/day)	0.00002	Health Canada, 2010
IR_A	soil inhalation rate (kg/day) = CRP (kg/m^3)*DIR_{air} (m^3/day)	1.26E-08	Calculated
DR	soil dermal contact rate (kg/day) = {(SA_{hands}*M_{hands})+(SA_{body}*M_{body})}*1E-6 (kg/mg)	0.0001712	Calculated
ET_{oral}	exposure term for soil ingestion pathway (unitless)	0.536	Site specific
ET_I	exposure term for soil inhalation pathway (unitless)	0.223	Site specific
ET_{DERM}	exposure term for soil dermal contact pathway (unitless)	0.536	Site specific
CRP	concentration of respirable soil/dust particles in air (kg/m^3)	7.60E-10	Health Canada, 2010
DIR_{air}	daily inhalation rate (m^3/day)	16.6	Health Canada, 2010
SA_{hands}	skin surface area - hands (cm^2)	890	Health Canada, 2010
SA_{body}	skin surface area - upper and lower arms and legs (cm^2)	8220	Health Canada, 2010
M_{hands}	soil to skin adherence factor - hands (mg/cm^2) per day; assuming 1 dermal contact event per day	0.1	Health Canada, 2010
M_{body}	soil to skin adherence factor - rest of body (mg/cm^2) per day; assuming 1 dermal contact event per day	0.01	Health Canada, 2010

Soil Site Specific Target Levels for Human Health (Lead)
Site Name Cape Spear
Scenario Tourist Facility Visitor

Human Receptor Toddler

$$SSTL = \frac{(RsD * SAF) * BW}{([RAF_{ING} * IR_S * ET_{ING}] + [RAF_I * IR_A * ET_I] + [RAF_D * DR * ET_{DERM}])} + BSC$$

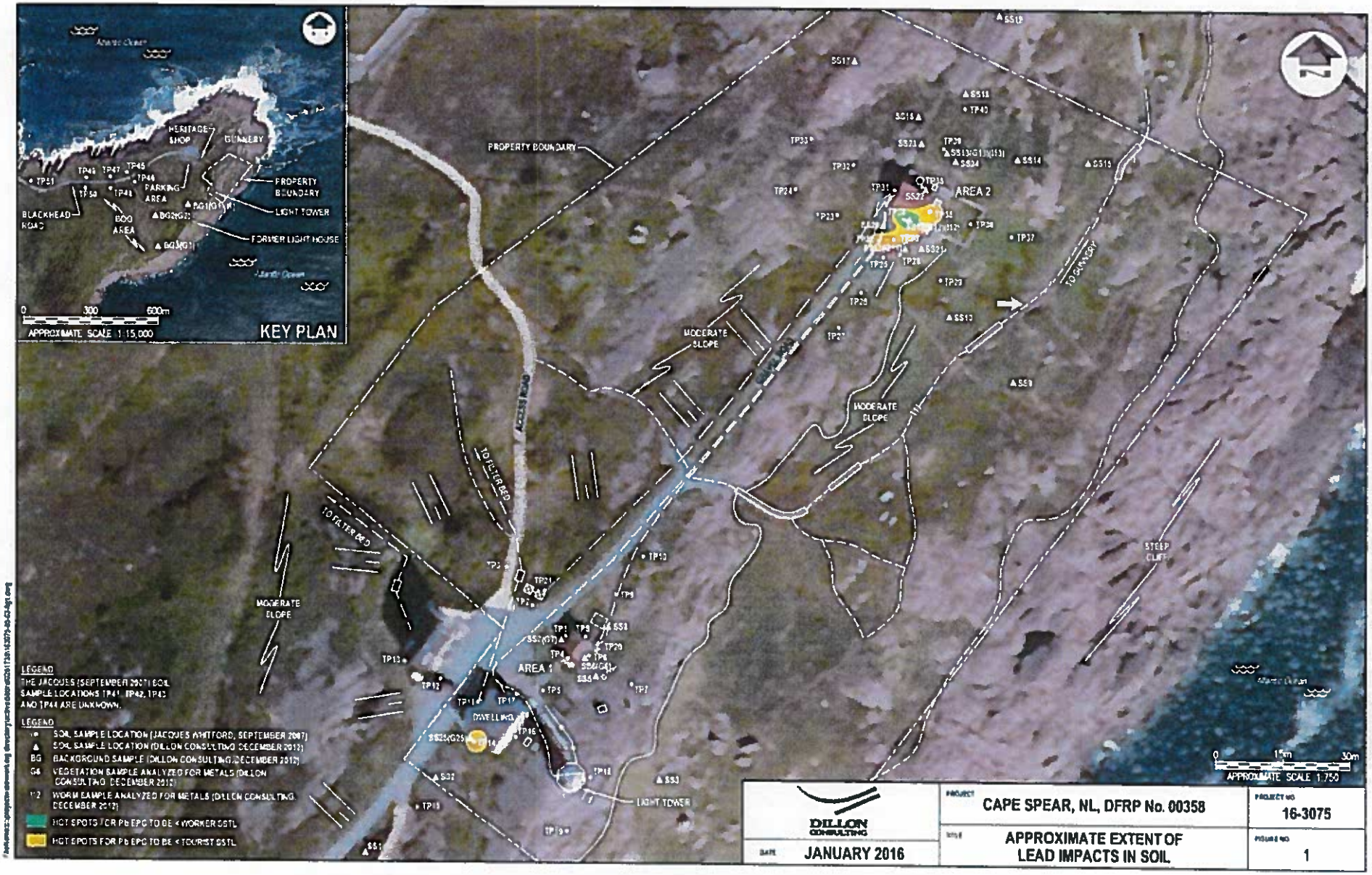
Chemical	RsD (all routes)	EDI	THQ (SAF)	BSC	RAF_{ING}	RAF_I	RAF_D	SSTL (mg/kg)
Lead	0.0011	0	0.2	35	0.6	1	0.006	735

Time on Site (same assumptions as JW, 2007) :

Hours per day (inhalation)	8	(soil ingestion and dermal contact are assumed to be daily event-driven exposures that are not affected by hours/day on a site, as per Health Canada, 2010 guidance)
Days per Week	1	
Winter Cover Factor	0.75	conservatively assumed that Site soil is available for contact 9 months of the year due to snow/ice cover and frozen soil conditions in winter months; based on Environment Canada climate normals data for Petty Harbour, Logy Bay, St. John's West CDA, and St. John's A climate stations; data for average daily temperature and days with snowfall; http://climate.weather.gc.ca/climate_normals/index_e.html.

Parameter	Definition (units)	Default Values	Reference
RsD	risk-specific Dose (mg/kg bw-day)	0.0011	Rae et al., 2015
EDI	estimated daily intake (from non-site sources - multimedia exposure assessment) (mg/kg bw-day)	0	Not considered since Pb TRV is a RsD and Pb is a non-threshold toxicant.
THQ (SAF)	target hazard quotient or soil allocation factor	0.2	Assumed
BW	body weight (kg)	16.5	Health Canada, 2010
BSC	background soil concentration (mg/kg)	35	PWGSC, 2011 (final background concentration)
RAF_{ING}	relative absorption factor (oral, unitless)	0.6	Assumed based on Health Canada and U.S. EPA (2009) guidance; Based on available information in the literature on lead absorption in humans, the U.S. EPA estimates that the relative bioavailability of lead in soil compared to water and food is about 60%.
RAF_I	relative absorption factor (inhalation, unitless)	1	Assumed
RAF_D	relative absorption factor (dermal; unitless)	0.006	OMOE, 2011 (Value is an absolute absorption factor determined from measured data in *in vitro* human skin studies)
IR_S	soil ingestion rate (kg/day)	0.00008	Health Canada, 2010
IR_A	soil inhalation rate (kg/day) = CRP (kg/m^3)*DIR$_{air}$ (m^3/day)	6.31E-09	Calculated
DR	soil dermal contact rate (kg/day) = ((SA_{hands}*M_{hands})+(SA_{body}*M_{body}))*1E-6 (kg/mg)	0.0000688	Calculated
ET_{ING}	exposure term for soil ingestion pathway (unitless)	0.107	Site specific
ET_I	exposure term for soil inhalation pathway (unitless)	0.036	Site specific
ET_{DERM}	exposure term for soil dermal contact pathway (unitless)	0.107	Site specific
CRP	concentration of respirable soil/dust particles in air (kg/m^3)	7.60E-10	Health Canada, 2010
DIR_{air}	daily inhalation rate (m^3/day)	8.3	Health Canada, 2010
SA_{hands}	skin surface area - hands (cm^2)	430	Health Canada, 2010
SA_{body}	skin surface area - upper and lower arms and legs (cm^2)	2580	Health Canada, 2010
M_{hands}	soil to skin adherence factor - hands (mg/cm^2) per day; assuming 1 dermal contact event per day	0.1	Health Canada, 2010
M_{body}	soil to skin adherence factor - rest of body (mg/cm^2) per day; assuming 1 dermal contact event per day	0.01	Health Canada, 2010

APPENDIX C
Pb SOIL EPC ITERATIONS


KEY PLAN
APPROXIMATE SCALE 1:15,000
0
300
600m
HERITAGE SHOP
GUNALLEY
PARKING AREA
BLACKHEAD ROAD
BOG AREA
LIGHT TOWER
FORMER LIGHT HOUSE
PROPERTY BOUNDARY
AREA 1
AREA 2
ACCESS ROAD
TO FILTER BED
TO GUNALLEY
MODERATE SLOPE
STEEP CLIFF
DWELLING
LEGEND
THE JACQUES (SEPTEMBER 2007) SOIL SAMPLE LOCATIONS TP41, TP42, TP43 AND TP44 ARE UNKNOWN.
LEGEND
SOIL SAMPLE LOCATION (JACQUES WHITFORD, SEPTEMBER 2007)
SOIL SAMPLE LOCATION (DILLON CONSULTING, DECEMBER 2012)
BG BACKGROUND SAMPLE (DILLON CONSULTING, DECEMBER 2012)
VEGETATION SAMPLE ANALYZED FOR METALS (DILLON CONSULTING, DECEMBER 2012)
WORM SAMPLE ANALYZED FOR METALS (DILLON CONSULTING, DECEMBER 2012)
HOT SPOTS FOR Pb EPC TO BE < WORKER SSTL
HOT SPOTS FOR Pb EPC TO BE < TOURIST SSTL
0
15m
30m
APPROXIMATE SCALE 1:750
DILLON CONSULTING
PROJECT
CAPE SPEAR, NL, DFRP No. 00358
PROJECT NO.
16-3075
DATE
JANUARY 2016
TITLE
APPROXIMATE EXTENT OF LEAD IMPACTS IN SOIL
FIGURE NO.
1

UCLM95-Based EPC Iteration From Successive (Sequential) Hot-Spot Removal

Transposed soil Pb data (ALL data)

240
89
330
820
90
230
93
120
58
2400
270
780
130
27
200
24
2400
120
280
8 9
290
7200
100
27
11000
4600
33
200
230
180
150
250
350
220
2200
1400
820
180
140
190
400

UCL Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	1/8/2016 9 43
From File	WorkSheet als
Full Precision	ON
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

CO

General Statistics

Total Number of Observations	41	Number of Distinct Observations	34
		Number of Missing Observations	0
Minimum	8 9	Mean	947 3146
Maximum	11000	Median	220
SD	2115 408	Std Error of Mean	330 3718
Coefficient of Variation	2 233258	Skewness	3 61484

Normal GOF Test

Shapiro Wilk Test Statistic	0 476413	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0 941	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0 358175	Lilliefors GOF Test	
5% Lilliefors Critical Value	0 13817	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	1501 611	95% Adjusted-CLT UCL (Chen-1995)	1690 015
		95% Modified-t UCL (Johnson-1978)	1534 896

Gamma GOF Test

A-D Test Statistic	3 85043	Anderson-Darling Gamma GOF Test	
5% A D Critical Value	0 81724	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0 267316	Kolmogrov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0 146258	Data Not Gamma Distributed at 5% Significance Level	

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0 482091	k star (bias corrected MLE)	0 463077
Theta hat (MLE)	1965 011	Theta star (bias corrected MLE)	2045 698
nu hat (MLE)	39 53149	nu star (bias corrected)	37 97228
MLE Mean (bias corrected)	947 3146	MLE Sd (bias corrected)	1392 097
		Approximate Chi Square Value (0 05)	24 86153
Adjusted Level of Significance	0 044116	Adjusted Chi Square Value	24 47352

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	1446 882	95% Adjusted Gamma UCL (use when n<50)	1469 813

Lognormal GOF Test

Shapiro Wilk Test Statistic	0 95711	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0 941	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0 147963	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0 13817	Data Not Lognormal at 5% Significance Level	

Data appear Approximate Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	2 186351	Mean of logged Data	5 728572
Maximum of Logged Data	9 305491	SD of logged Data	1 35739

Assuming Lognormal Distribution

95% H UCL	1796 012	90% Chebyshev (MVUE) UCL	1963 724
95% Chebyshev (MVUE) UCL	1911 125	97 5% Chebyshev (MVUE) UCL	2133 304
99% Chebyshev (MVUE) UCL	2440 45		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	1490 727	95% Jackknife UCL	1503 611
95% Standard Bootstrap UCL	1491 637	95% Bootstrap-t UCL	2109 033
95% Hall's Bootstrap UCL	3041 777	95% Percentile Bootstrap UCL	1512 122
95% BCA Bootstrap UCL	1680 9		
90% Chebyshev(Mean, Sd) UCL	1938 429	95% Chebyshev(Mean, Sd) UCL	2387 37
97 5% Chebyshev(Mean, Sd) UCL	3010 483	99% Chebyshev(Mean, Sd) UCL	4284 463

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL 2387 37

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL. These recommendations are based upon the results of the simulation studies summarized in Singh, Singh and Iaci (2002) and Singh and Singh (2003). However, simulations results will not cover all Real World data sets. For additional insight the user may want to consult a statistician.

Transposed soil Pb data (less 1st max)

240
89
330
820
90
230
93
120
58
2400
270
780
130
27
200
24
2400
120
280
8 9
290
7200
100
27
4600
33
200
230
180

UCL Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	1/8/2016 9 46
From File	WorkSheet als
Full Precision	ON
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

CO

General Statistics

Total Number of Observations	40	Number of Distinct Observations	33
		Number of Missing Observations	0
Minimum	8 9	Mean	695 9975
Maximum	7200	Median	210
SD	1390 384	Std Error of Mean	219 8706
Coefficient of Variation	1 997973	Skewness	3 448943

Normal GOF Test

Shapiro Wilk Test Statistic	0 512243	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0 94	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0 353281	Lilliefors GOF Test	
5% Lilliefors Critical Value	0 140089	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	

150
290
350
220
2200
1600
820
180
140
180
400

95% Student's t UCL 1066.452 95% Adjusted CLT UCL (Chen 1995) 1185.769
95% Modified t UCL (Johnson 1978) 1086.436

Gamma GOF Test
A-D Test Statistic 2.524339 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.807205 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.219071 Kolmogorov-Smirnov Gamma GOF Test
5% K-S Critical Value 0.146913 Data Not Gamma Distributed at 5% Significance Level
Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics
k hat (MLE) 0.561553 k star (bias corrected MLE) 0.536109
Theta hat (MLE) 1239.423 Theta star (bias corrected MLE) 1298.24
nu hat (MLE) 44.9247 nu star (bias corrected) 42.88868
MLE Mean (bias corrected) 695.9975 MLE Sd (bias corrected) 950.364
Approximate Chi Square Value (0.05) 28.87332
Adjusted Level of Significance 0.044 Adjusted Chi Square Value 28.44161

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=50) 1033.641 95% Adjusted Gamma UCL (use when n<50) 1049.533

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.963702 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.94 Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.133581 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0.147089 Data appear Lognormal at 5% Significance Level
Data appear Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186051 Mean of logged Data 5.441145
Maximum of Logged Data 8.881836 SD of logged Data 1.453316

Assuming Lognormal Distribution
95% H-UCL 1319.899 90% Chebyshev (MVUE) UCL 1183.958
99% Chebyshev (MVUE) UCL 1484.985 97.5% Chebyshev (MVUE) UCL 1784.879
99% Chebyshev (MVUE) UCL 2472.324

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 1057.653 95% Jackknife UCL 1066.452
95% Standard Bootstrap UCL 1062.357 95% Bootstrap-t UCL 1120.104
95% Hall's Bootstrap UCL 1144.774 95% Percentile Bootstrap UCL 1100.25
95% BCA Bootstrap UCL 1085.17
90% Chebyshev(Mean, Sd) UCL 1155.609 [redacted] 1434.393
97.5% Chebyshev(Mean, Sd) UCL 1583.089 99% Chebyshev(Mean, Sd) UCL 2081.683

Suggested UCL to Use
95% H-UCL 1319.899

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulation results will not cover all Real World data sets.
For additional insight, the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the "ProUCL Guide"
It is therefore recommended to avoid the use of H-statistic based 95% UCLs
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a discernible distribution

given ProUCL recommendation H-UCL this UCL was considered the most robust and appropriate value

transposed and Pb data (less 1st, 2nd max)

280
99
330
620
50
230
61
120
58
2400
270
780
130
27
200
24
2400
120
280
8.9
290
100
27
4800
33
200
230
180
150
250
360
220
2200
1600
820
180
140
180
400

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 2/8/2016 9:52
From File WorkSheet.xls
Full Precision On
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

Pb

General Statistics
Total Number of Observations 42 Number of Distinct Observations 42
Number of Missing Observations 0
Minimum 8.9 Mean 529.2262
Maximum 4800 Median 200
SD 958.0715 Std. Error of Mean 147.8041
Coefficient of Variation 1.810187 Skewness 3.035587

Normal GOF Test
Shapiro Wilk Test Statistic 0.562815 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0.939 Data Not Normal at 5% Significance Level
Lilliefors Test Statistic 0.353842 Lilliefors GOF Test
5% Lilliefors Critical Value 0.141814 Data Not Normal at 5% Significance Level
Data Not Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCLs (Adjusted for Skewness)
95% Student's t UCL 777.0789 95% Adjusted-CLT UCL (Chen 1995) 841.1982
95% Modified-t UCL (Johnson 1978) 788.9886

Gamma GOF Test
A-D Test Statistic 2.247144 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.797645 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.224378 Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.147813 Data Not Gamma Distributed at 5% Significance Level
Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics
k hat (MLE) 0.658523 k star (bias corrected MLE) 0.624962
Theta hat (MLE) 803.6571 Theta star (bias corrected MLE) 846.8271
nu hat (MLE) 55.36481 nu star (bias corrected) 48.74701
MLE Mean (bias corrected) 529.2262 MLE Sd (bias corrected) 669.4472
Approximate Chi Square Value (0.05) 33.72964
Adjusted Level of Significance 0.0437 Adjusted Chi Square Value 33.22598

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=50) 761.782 95% Adjusted Gamma UCL (use when n<50) 776.4494

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.966619 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.939 Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.121706 Lilliefors Lognormal GOF Test

5% Lilliefors Critical Value 0.141874 Data appear Lognormal at 5% Significance Level
Data appear Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186051 Mean of logged Data 5.145743
Maximum of Logged Data 8.433812 SD of logged Data 1.35922

Assuming Lognormal Distribution
95% H UCL 989.8605 90% Chebyshev (MVUE) UCL 922.8469
95% Chebyshev (MVUE) UCL 1111.646 97.5% Chebyshev (MVUE) UCL 1373.691
99% Chebyshev (MVUE) UCL 1848.428

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 771.0366 95% Jackknife UCL 777.0789
95% Standard Bootstrap UCL 773.1552 95% Bootstrap-t UCL 927.3497
95% Hall's Bootstrap UCL 865.5538 95% Percentile Bootstrap UCL 794.5815
95% BCA Bootstrap UCL 880.6667

90% Chebyshev(Mean, Sd) UCL 970.2555 95% Chebyshev(Mean, Sd) UCL 1174.046
97.5% Chebyshev(Mean, Sd) UCL 1447.3 99% Chebyshev(Mean, Sd) UCL 1991.95

given ProUCL narrative on H-UCL, this UCL was considered the most robust and appropriate value

Suggested UCL to Use
95% H UCL 989.8605

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets
For additional insight the user may want to consult a statistician

ProUCL computes and outputs H-statistic based UCLs for historical reasons only
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide
It is therefore recommended to avoid the use of H-statistic based 95% UCLs
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

[redacted]

transposed soil Pb data (less 1st, 2nd, 3rd max)

260
99
330
620
50
230
93
120
58
2400
270
780
130
27
200
24
2400
120
280
82
290
100
27
33
200
230
180
120
290
350
220
2700
1800
820
180
140
190
400

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 9:58
From File WorkSheet.wst
Full Precision ON
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

Cd

General Statistics
Total Number of Observations 38 Number of Distinct Observations 31
Number of Missing Observations 0
Minimum 8.3 Mean 423.3026
Maximum 2400 Median 200
SD 637.165 Std. Error of Mean 103.3618
Coefficient of Variation 1.504503 Skewness 2.417231

Normal GOF Test
Shapiro Wilk Test Statistic 0.588979 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0.918 Data Not Normal at 5% Significance Level
Lilliefors Test Statistic 0.334523 Lilliefors GOF Test
5% Lilliefors Critical Value 0.143728 Data Not Normal at 5% Significance Level
Data Not Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCLs (Adjusted for Skewness)
95% Student's-t UCL 596.4837 95% Adjusted-CLT UCL (Chen-1995) 635.7819
95% Modified-t UCL (Johnson-1978) 603.7947

Gamma GOF Test
A-D Test Statistic 1.653715 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.787884 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.202703 Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.148705 Data Not Gamma Distributed at 5% Significance Level
Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics
k hat (MLE) 0.764713 k star (bias corrected MLE) 0.721881
Theta hat (MLE) 553.973 Theta star (bias corrected MLE) 586.7328
nu hat (MLE) 58.11821 nu star (bias corrected) 54.86326
MLE Mean (bias corrected) 423.3026 MLE Sd (bias corrected) 496.8078
Approximate Chi Square Value (0.05) 38.84287
Adjusted Level of Significance 0.0414 Adjusted Chi Square Value 38.2859

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=50) 596.195 95% Adjusted Gamma UCL (use when n<50) 604.9

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.961483 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.918 Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.112367 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0.143728 Data appear Lognormal at 5% Significance Level
Data appear Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186051 Mean of logged Data 5.264378
Maximum of Logged Data 7.783724 SD of logged Data 1.277848

Assuming Lognormal Distribution
95% H UCL 776.8468 90% Chebyshev (MVUE) UCL 725.9646
95% Chebyshev (MVUE) UCL 892.8381 97.5% Chebyshev (MVUE) UCL 1096.814
99% Chebyshev (MVUE) UCL 1497.413

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 592.1177 95% Jackknife UCL 596.4837
95% Standard Bootstrap UCL 595.9126 95% Bootstrap-t UCL 688.145
95% Hall's Bootstrap UCL 596.5476 95% Percentile Bootstrap UCL 604.5237
95% BCA Bootstrap UCL 637.6158

90% Chebyshev(Mean, Sd) UCL 732.1881 95% Chebyshev(Mean, Sd) UCL 872.6461
97.5% Chebyshev(Mean, Sd) UCL 1067.597 99% Chebyshev(Mean, Sd) UCL 1450.54

given ProUCL narrative on H-UCL, this UCL was considered the most robust and appropriate value

Suggested UCL to Use

95 % H-UCL 776.8168

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

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transposed soil Pb data (less 1st, 2nd, 3rd, 4th (which occurred at two discrete sample locations) max)

280
99
330
620
50
230
93
120
58
270
780
130
27
200
24
130
295
8.9
280
100
27
33
200
230
180
150
250
390
270
2200
1600
820
190
140
190
400

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 10:04
From File WorkSheet.xls
Full Precision OK
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

Pb

General Statistics
Total Number of Observations 16 Number of Distinct Observations 10
Number of Missing Observations 0
Minimum 8.9 Mean 312.2194
Maximum 2200 Median 195
SD 489.5583 Std. Error of Mean 73.25971
Coefficient of Variation 1.567785 Skewness 3.170496

Normal GOF Test
Shapiro Wilk Test Statistic 0.594131 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0.845 Data Not Normal at 5% Significance Level
Lilliefors Test Statistic 0.299086 Lilliefors GOF Test
5% Lilliefors Critical Value 0.21866 Data Not Normal at 5% Significance Level
Data Not Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL
95% Student's-t UCL 481.991 95% Adjusted-CLT UCL (Chen-1995) 478.1887
95% Modified-t UCL (Johnson-1978) 482.449

Gamma GOF Test
A-D Test Statistic 0.995248 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.779139 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.19[illegible]2 Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.151811 Data Not Gamma Distributed at 5% Significance Level
Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics
k hat (MLE) 0.919252 k star (bias corrected MLE) 0.879606
Theta hat (MLE) 332.4101 Theta star (bias corrected MLE) 354.9941
nu hat (MLE) 87.62666 nu star (bias corrected) 83.32444
MLE Mean (bias corrected) 312.2194 MLE Sd (bias corrected) 332.9205
Approximate Chi Square Value (0.05) 66.0182
Adjusted Level of Significance 0.0428 Adjusted Chi Square Value 65.34773

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=30) 429.687 95% Adjusted Gamma UCL (use when n<30) 439.9872

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.967819 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.845 Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.116144 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0.237667 Data appear Lognormal at 5% Significance Level
Data appear Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186051 Mean of logged Data 5.124367
Maximum of Logged Data 7.696214 SD of logged Data 1.159128

Assuming Lognormal Distribution
95% H-UCL 544.4185 90% Chebyshev (MVUE) UCL 541.8736
95% Chebyshev (MVUE) UCL 642.6218 97.5% Chebyshev (MVUE) UCL 782.4563
99% Chebyshev (MVUE) UCL 1057.134

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Gamma Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 481.7209 95% Jackknife UCL 481.991
95% Standard Bootstrap UCL 479.7961 95% Bootstrap-t UCL 968.176
95% Hall's Bootstrap UCL 984.5733 95% Percentile Bootstrap UCL 468.9694
95% BCA Bootstrap UCL 491.0806

90% Chebyshev(Mean, Sd) UCL 531.9986 95% Chebyshev(Mean, Sd) UCL 611.5531
97.5% Chebyshev(Mean, Sd) UCL 769.7262 99% Chebyshev(Mean, Sd) UCL 1041.144

given ProUCL narrative on H-UCL, this UCL was considered the most robust and appropriate value

Suggested UCL to Use
95% H-UCL 544.4185

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

ProUCL computes and outputs H-statistic based UCLs for historical reasons only.
H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.
It is therefore recommended to avoid the use of H-statistic based 95% UCLs.
Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.

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transposed soil Pb data (less 1st, 2nd, 3rd, 4th (which occurred at two discrete sample locations), 5th max)

280
99
330
620
50
230
93
120
58
270

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 10:19
From File WorkSheet.xls
Full Precision OK
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

780
130
27
200
24
120
280
8.9
290
100
27
33
200
230
180
150
290
350
220
1400
820
180
140
190
400

CD

General Statistics

Total Number of Observations		Number of Distinct Observations	29
		Number of Missing Observations	0
Minimum	8 9	Mean	258 2829
Maximum	1600	Median	190
SD	301 6017	Std Error of Mean	51 0138
Coefficient of Variation	1 168493	Skewness	3 040875

Normal GOF Test

Shapiro Wilk Test Statistic	0 672783	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0 934	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0 258151	Lilliefors GOF Test	
5% Lilliefors Critical Value	0 167761	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

		95% UCL (Adjusted for Skewness)	
95% Normal UCL			
95% Student's t UCL	344 5433	95% Adjusted-CLT UCL (Chen-1995)	370 2108
		95% Modified-t UCL (Johnson-1978)	348 9135

Gamma GOF Test

A-D Test Statistic	0 576539	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0 773296	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0 129952	Kolmogrov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0 152635	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1 151615	k star (bias corrected MLE)	1 053688
Theta hat (MLE)	228 2386	Theta star (bias corrected MLE)	245 1233
nu hat (MLE)	72 21447	nu star (bias corrected)	73 75799
MLE Mean (bias corrected)	258 2829	MLE Sd (bias corrected)	251 6171
		Approximate Chi Square Value (0 05)	54 98009
Adjusted Level of Significance	0 0425	Adjusted Chi Square Value	54 31095

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	346 4768	95% Adjusted Gamma UCL (use when n<50)	351 4128

Lognormal GOF Test

Shapiro Wilk Test Statistic	0 963484	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0 934	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0 123324	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0 149761	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	2 186051	Mean of logged Data	5 051071
Maximum of Logged Data	7 377759	SD of logged Data	1 041651

Assuming Lognormal Distribution

95% H-UCL	453 1749	90% Chebyshev (MVUE) UCL	454 1199
95% Chebyshev (MVUE) UCL	515 2439	97 5% Chebyshev (MVUE) UCL	647 8456
99% Chebyshev (MVUE) UCL	869 026		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	342 1911	95% Jackknife UCL	344 5433
95% Standard Bootstrap UCL	340 7411	95% Bootstrap-t UCL	400 3148
95% Hall's Bootstrap UCL	669 2117	95% Percentile Bootstrap UCL	350 54
95% BCA Bootstrap UCL	370 1371		
90% Chebyshev(Mean, Sd) UCL	411 3213	95% Chebyshev(Mean, Sd) UCL	480 6469
97 5% Chebyshev(Mean, Sd) UCL	576 9619	99% Chebyshev(Mean, Sd) UCL	765 8617

Suggested UCL to Use

97 5% Chebyshev (Mean, Sd) UCL	576 9619

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets
For additional insight the user may want to consult a statistician

---

transposed soil Pb data (less 1st, 2nd, 3rd, 4th (which occurred at two discrete sample locations), 9th, 8th max)

260
99
330
620
50
130
93
120
58
270
780
130
27
200
24
120
280
8 9
290
100
27
33
200
230
180
150
290
350
220
820
180
140
190
400

UCL Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	1/8/2016 10 29
From File	Worksheet xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

CD

General Statistics

Total Number of Observations		Number of Distinct Observations	28
		Number of Missing Observations	0
Minimum	8 9	Mean	218 8206
Maximum	820	Median	185
SD	193 1347	Std Error of Mean	33 29182
Coefficient of Variation	0 887187	Skewness	1 870414

Normal GOF Test

Shapiro Wilk Test Statistic	0 807903	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0 933	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0 190151	Lilliefors GOF Test	
5% Lilliefors Critical Value	0 151943	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCL (Adjusted for Skewness)	
95% Student's t UCL	275 1857	95% Adjusted-CLT UCL (Chen-1995)	284 6904
		95% Modified-t UCL (Johnson-1978)	276 8981

Gamma GOF Test

A-D Test Statistic	0 386607	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0 7683	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0 089359	Kolmogrov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0 154152	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1 375536	k star (bias corrected MLE)	1 273173

Theta hat (MLE)	159.0833	Theta star (bias corrected MLE)	171.7894
nu hat (MLE)	93.53642	nu star (bias corrected)	86.61654
MLE Mean (bias corrected)	218.8206	MLE Sd (bias corrected)	193.8841
		Approximate Chi Square Value (0.05)	66.16244
Adjusted Level of Significance	0.0422	Adjusted Chi Square Value	65.27849

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n<=50)	236.4689	95% Adjusted Gamma UCL (use when n<50)	290.348

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.941205	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.931	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.143216	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.152948	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.186251	Mean of logged Data	4.982838
Maximum of Logged Data	6.709304	SD of logged Data	1.024679

Assuming Lognormal Distribution

95% H-UCL	281.3166	90% Chebyshev (MVUE) UCL	368.8244
95% Chebyshev (MVUE) UCL	455.7591	97.5% Chebyshev (MVUE) UCL	568.6619
99% Chebyshev (MVUE) UCL	731.1515		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	273.5841	95% Jackknife UCL	275.1617
95% Standard Bootstrap UCL	273.206	95% Bootstrap-t UCL	297.625
95% Hall's Bootstrap UCL	298.3672	95% Percentile Bootstrap UCL	278.5853
95% BCA Bootstrap UCL	288.614		
90% Chebyshev(Mean, Sd) UCL	318.7221	95% Chebyshev(Mean, Sd) UCL	363.941
97.5% Chebyshev(Mean, Sd) UCL	426.7424	99% Chebyshev(Mean, Sd) UCL	550.0899

[redacted]	
95% Approx. Gamma UCL	261.245

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

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transposed soil Pb data (less 1st, 2nd, 3rd, 4th (which occurred at two discrete sample locations), 5th, 6th, 7th max)

290
89
330
650
50
230
95
129
58
270
780
130
27
200
24
120
280
8.9
210
100
27
33
200
230
180
190
290
350
270
180
140
190
400

UCL Statistics for Data Set with Full Data Set

User Selected Options

Date/Time of Computation	1/8/2016 10:32
From File	WorkSheet.xls
Full Precision	On
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

CO

General Statistics

Total Number of Observations	33	Number of Distinct Observations	27
		Number of Missing Observations	0
Minimum	8.9	Mean	200.403
Maximum	780	Median	190
SD	165.3137	Std. Error of Mean	28.77519
Coefficient of Variation	0.8225888	Skewness	1.808139

Normal GOF Test

Shapiro Wilk Test Statistic	0.842499	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.931	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.151223	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.154233	Data Not Normal at 5% Significance Level	

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	249.2803	95% Adjusted-CLT UCL (Chen-1995)	257.5107
		95% Modified-t UCL (Johnson-1978)	250.7672

Gamma GOF Test

A-D Test Statistic	0.388299	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.765312	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.104195	Kolmogorov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0.156656	Detected data appear Gamma Distributed at 5% Significance Level	

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	1.492443	k star (bias corrected MLE)	1.376317
Theta hat (MLE)	134.2124	Theta star (bias corrected MLE)	145.6844
nu hat (MLE)	98.56216	nu star (bias corrected)	90.88002
MLE Mean (bias corrected)	200.403	MLE Sd (bias corrected)	170.9574
		Approximate Chi Square Value (0.05)	69.89816
Adjusted Level of Significance	0.0423	Adjusted Chi Square Value	68.95094

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n<=50)	252.8135	95% Adjusted Gamma UCL (use when n<50)	264.4526

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.922358	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.931	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.143726	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.154239	Data appear Lognormal at 5% Significance Level	

Data appear Lognormal at 5% Significance Level

Lognormal Statistics

Minimum of Logged Data	2.186251	Mean of logged Data	4.980316
Maximum of Logged Data	6.659294	SD of logged Data	0.991372

Assuming Lognormal Distribution

95% H-UCL	347.4618	90% Chebyshev (MVUE) UCL	454.8565
95% Chebyshev (MVUE) UCL	614.788	97.5% Chebyshev (MVUE) UCL	838.2482
99% Chebyshev (MVUE) UCL	1402.1896		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	247.8518	95% Jackknife UCL	249.2603
95% Standard Bootstrap UCL	247.6952	95% Bootstrap-t UCL	262.2984

95% Hall's Bootstrap UCL	283.596	95% Percentile Bootstrap UCL	251.3333
95% BCA Bootstrap UCL	256.7273		
90% Chebyshev(Mean, Sd) UCL	286.7786	95% Chebyshev(Mean, Sd) UCL	325.8132
97.5% Chebyshev(Mean, Sd) UCL	373.2918	99% Chebyshev(Mean, Sd) UCL	486.4151

Suggested UCL to Use
95% Adjusted Gamma UCL 284.9026

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

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transposed soil Pb data (lines 1st, **2nd**, 3rd, **4th** (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th max)

280
98
330
620
90
230
93
120
58
270
130
27
200
24
120
280
89
290
900
27
33
200
230
180
150
250
360
220
180
140
130
400

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 10:36
From File WorkSheet.xls
Full Precision On
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

CD

General Statistics
Total Number of Observations 32 Number of Distinct Observations 26
Number of Missing Observations 0
Minimum 8.9 Mean 182.4969
Maximum 620 Median 180
SD 130.1551 Std. Error of Mean 23.00943
Coefficient of Variation 0.713192 Skewness 1.226041

Normal GOF Test
Shapiro Wilk Test Statistic 0.917129 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0.93 Data Not Normal at 5% Significance Level
Lilliefors Test Statistic 0.094447 Lilliefors GOF Test
5% Lilliefors Critical Value 0.156624 Data appear Normal at 5% Significance Level
Data appear Approximate Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCLs (Adjusted for Skewness)
95% Student's-t UCL 221.5081 95% Adjusted-CLT UCL (Chen-1995) 225.6621
95% Modified-t UCL (Johnson-1978) 222.3379

Gamma GOF Test
A-D Test Statistic 0.495043 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.762691 Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.127593 Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.158266 Detected data appear Gamma Distributed at 5% Significance Level
Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics
k hat (MLE) 1.662206 k star (Bias corrected MLE) 1.529395
Theta hat (MLE) 109.8243 Theta star (Bias corrected MLE) 119.3191
nu hat (MLE) 106.3532 nu star (Bias corrected) 97.82527
MLE Mean (bias corrected) 182.4969 MLE Sd (bias corrected) 147.7625
Approximate Chi Square Value (0.05) 75.83324
Adjusted Level of Significance 0.0416 Adjusted Chi Square Value 74.80542

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=50) 284.9486 95% Adjusted Gamma UCL (use when n<50) 288.1687

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.912392 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.93 Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.160664 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0.156624 Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186051 Mean of logged Data 5.076285
Maximum of Logged Data 6.429972 SD of logged Data 0.958736

Assuming Lognormal Distribution
95% H-UCL 313.0345 90% Chebyshev (MVUE) UCL 328.7677
95% Chebyshev (MVUE) UCL 375.3359 97.5% Chebyshev (MVUE) UCL 443.8865
99% Chebyshev (MVUE) UCL 595.7139

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 220.3424 95% Jackknife UCL 221.5081
95% Standard Bootstrap UCL 220.7978 95% Bootstrap-t UCL 237.4759
95% Hall's Bootstrap UCL 234.2609 95% Percentile Bootstrap UCL 219.5781
95% BCA Bootstrap UCL 225.6875
90% Chebyshev(Mean, Sd) UCL 251.5222 95% Chebyshev(Mean, Sd) UCL 282.7883
97.5% Chebyshev(Mean, Sd) UCL 326.1845 99% Chebyshev(Mean, Sd) UCL 411.4279

Suggested UCL to Use
95% Student's-t UCL 221.5081

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

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transposed soil Pb data (lines 1st, 2nd, 3rd, 4th (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th, 9th max)

280
98
330
620
90
230
93
120
58
270
130
27
200
24
120
280
89

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 10:39
From File WorkSheet.xls
Full Precision On
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

CD

General Statistics
Total Number of Observations 33 Number of Distinct Observations 25
Number of Missing Observations 0
Minimum 8.9 Mean 168.3939

280
100
27
33
200
230
180
150
250
300
220
190
140
180
400

Maximum		400 Median	180
SD		104.4939 Std. Error of Mean	18.76766
Coefficient of Variation		0.62757 Skewness	0.290137
Normal GOF Test			
Shapiro Wilk Test Statistic		0.963022 Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value		0.929 Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic		0.080406 Lilliefors GOF Test	
5% Lilliefors Critical Value		0.13913 Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's t UCL	200.2375	95% Adjusted-CLT UCL (Chen-1995)	200.2269
		95% Modified-t UCL (Johnson-1978)	200.1893
Gamma GOF Test			
A-D Test Statistic		0.718747 Anderson-Darling Gamma GOF Test	
5% A-D Critical Value		0.762575 Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic		0.14897 Kolmogorov-Smirnoff Gamma GOF Test	
5% K-S Critical Value		0.26012 Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)		1.815147 k star (bias corrected MLE)	1.660991
Theta hat (MLE)		92.76595 Theta star (bias corrected MLE)	101.3754
nu hat (MLE)		112.5371 nu star (bias corrected)	102.9826
MLE Mean (bias corrected)		168.3899 MLE Sd (bias corrected)	130.8421
		Approximate Chi Square Value (0.05)	80.56406
Adjusted Level of Significance		0.0411 Adjusted Chi Square Value	79.46448
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50)	218.2328	95% Adjusted Gamma UCL (use when n<50)	218.2161
Lognormal GOF Test			
Shapiro Wilk Test Statistic		0.882113 Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value		0.929 Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic		0.189324 Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value		0.13913 Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	2.186051	Mean of logged Data	4.826175
Maximum of Logged Data	5.991465	SD of logged Data	0.981511
Assuming Lognormal Distribution			
95% H-UCL	230.5981	90% Chebyshev (MVUE) UCL	296.127
95% Chebyshev (MVUE) UCL	344.7791	97.5% Chebyshev (MVUE) UCL	413.3083
99% Chebyshev (MVUE) UCL	544.9554		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			
Nonparametric Distribution Free UCLs			
95% CLT UCL	199.2319	95% Jackknife UCL	200.2375
95% Standard Bootstrap UCL	198.2618	95% Bootstrap-t UCL	200.8122
95% Hall's Bootstrap UCL	200.9148	95% Percentile Bootstrap UCL	197.9677
95% BCA Bootstrap UCL	201.0645		
90% Chebyshev(Mean, Sd) UCL	224.6867	95% Chebyshev(Mean, Sd) UCL	254.1902
97.5% Chebyshev(Mean, Sd) UCL	285.5879	99% Chebyshev(Mean, Sd) UCL	355.1197
Suggested 95% UCL			
Recommended UCL	200.2375		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

transposed soil Pb data (less 1st, 2nd, 3rd, 4th (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th, 9th, 10th max)

280
99
330
50
230
81
120
58
272
130
27
200
24
120
260
8.9
240
100
27
33
200
230
180
150
250
300
220
180
140
180

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 10:11
From File Work Sheet.xls
Full Precision On
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

CD

General Statistics
Total Number of Observations 24 Number of Distinct Observations 24
Number of Missing Observations 0
Minimum 8.9 Mean 160.6833
Maximum 330 Median 186
SD 96.87687 Std. Error of Mean 19.77682
Coefficient of Variation 0.602943 Skewness 0.193198

Normal GOF Test
Shapiro Wilk Test Statistic 0.957845 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0.927 Data appear Normal at 5% Significance Level
Lilliefors Test Statistic 0.088719 Lilliefors GOF Test
5% Lilliefors Critical Value 0.161761 Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCLs (Adjusted for Skewness)
95% Student's t UCL 200.7143 95% Adjusted-CLT UCL (Chen-1995) 196.1138
95% Modified-t UCL (Johnson-1978) 200.7646

Gamma GOF Test
A-D Test Statistic 0.539641 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.759173 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.196829 Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.162542 Detected data appear Gamma Distributed at 5% Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics
k hat (MLE) 1.861804 k star (bias corrected MLE) 1.697845
Theta hat (MLE) 86.29441 Theta star (bias corrected MLE) 94.64774
nu hat (MLE) 111.7083 nu star (bias corrected) 101.8708
MLE Mean (bias corrected) 160.6633 MLE Sd (bias corrected) 123.3013
Approximate Chi Square Value (0.05) 79.58817
Adjusted Level of Significance 0.041 Adjusted Chi Square Value 78.4478

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=50) 205 6578 95% Adjusted Gamma UCL (use when n<50) 208 6342

Lognormal GOF Test
Shapiro Wilk Test Statistic 0 871559 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0 927 Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic 0 170179 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0 161761 Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2 186051 Mean of logged Data 4 787332
Maximum of Logged Data 5 857933 SD of logged Data 0 971074

Assuming Lognormal Distribution
95% H-UCL 275 4707 90% Chebyshev (MVUE) UCL 282 4022
95% Chebyshev (MVUE) UCL 328 858 97 5% Chebyshev (MVUE) UCL 391 3168
99% Chebyshev (MVUE) UCL 519 9929

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 189 7544 95% Jackknife UCL 190 7143
95% Standard Bootstrap UCL 189 4242 95% Bootstrap t UCL 191 4877
95% Hall's Bootstrap UCL 188 914 95% Percentile Bootstrap UCL 189 19
95% BCA Bootstrap UCL 189 3667
90% Chebyshev(Mean, Sd) UCL 213 7217 95% Chebyshev(Mean, Sd) UCL 237 7554
97 5% Chebyshev(Mean, Sd) UCL 271 1131 99% Chebyshev(Mean, Sd) UCL 336 638

Suggested UCL to Use
95% Student's t UCL 190 7143

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulation results will not cover all Real World data sets
For additional insight the user may want to consult a statistician

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Transformed soil Pb data (less 1st, 2nd, 3rd, 4th (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th, 9th, 10th, 11th max)

260
99
330
50
230
81
120
59
270
130
97
200
24
120
260
89
290
100
97
97
200
230
180
150
250
220
180
140
180

UCL Statistics for Transformed Full Data Set

User Selected Options
Date/Time of Computation 1/8/2018 10 47
From File Worksheet xls
Full Precision On
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

CD

General Statistics
Total Number of Observations 29 Number of Distinct Observations 23
Number of Missing Observations 0
Minimum 8 3 Mean 154 1315
Maximum 330 Median 150
SD 91 62238 Std Error of Mean 17 01385
Coefficient of Variation 0 594431 Skewness 0 018257

Normal GOF Test
Shapiro Wilk Test Statistic 0 97454 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0 926 Data appear Normal at 5% Significance Level
Lilliefors Test Statistic 0 094347 Lilliefors GOF Test
5% Lilliefors Critical Value 0 164526 Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCLs (Adjusted for Skewness)
95% Student's t UCL 183 0771 95% Adjusted CLT UCL (Chen 1995) 182 1814
95% Modified t UCL (Johnson 1978) 183 0869

Gamma GOF Test
A-D Test Statistic 0 881532 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0 758462 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0 160337 Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0 164911 Detected data appear Gamma Distributed at 5% Significance Level
Detected data follow Appr Gamma Distribution at 5% Significance Level

Gamma Statistics
k hat (MLE) 1 239292 k star (bias corrected MLE) 1 716837
Theta hat (MLE) 81 58314 Theta star (bias corrected MLE) 89 77818
nu hat (MLE) 109 579 nu star (bias corrected) 99 57654
MLE Mean (bias corrected) 154 1345 MLE Sd (bias corrected) 117 6347
Approximate Chi Square Value (0 05) 77 55543
Adjusted Level of Significance 0 0437 Adjusted Chi Square Value 76 39485

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=50) 197 8935 95% Adjusted Gamma UCL (use when n<50) 200 9059

Lognormal GOF Test
Shapiro Wilk Test Statistic 0 866402 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0 926 Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic 0 171343 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0 164526 Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2 186051 Mean of logged Data 4 750414
Maximum of Logged Data 5 799093 SD of logged Data 0 914458

Assuming Lognormal Distribution
95% H-UCL 264 2511 90% Chebyshev (MVUE) UCL 271 1273
95% Chebyshev (MVUE) UCL 315 9275 97 5% Chebyshev (MVUE) UCL 378 0965
99% Chebyshev (MVUE) UCL 500 2253

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 182 1198 95% Jackknife UCL 183 0771
95% Standard Bootstrap UCL 182 5517 95% Bootstrap t UCL 183 9577
95% Hall's Bootstrap UCL 181 8206 95% Percentile Bootstrap UCL 183 0931
95% BCA Bootstrap UCL 182 4118
90% Chebyshev(Mean, Sd) UCL 205 176 95% Chebyshev(Mean, Sd) UCL 228 2961
97 5% Chebyshev(Mean, Sd) UCL 260 3859 99% Chebyshev(Mean, Sd) UCL 323 4701

Suggested UCL to Use

[redacted]

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

[redacted]

transposed soil Pb data (less 1st, 2nd, 3rd , 4th (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th max)

280
89
50
230
93
120
58
270
130
27
200
24
120
280
8.9
290
100
27
33
200
230
180
150
250
220
180
140
180

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 12:51
From File WorkSheet.xls
Full Precision 0%
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

CD

General Statistics
Total Number of Observations 28 Number of Distinct Observations 22
Number of Missing Observations 0
Minimum 8.9 Mean 147.8536
Maximum 290 Median 149
SD 86.71907 Std. Error of Mean 16.38729
Coefficient of Variation 0.586479 Skewness -0.07591

Normal GOF Test
Shapiro Wilk Test Statistic 0.940319 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0.924 Data appear Normal at 5% Significance Level
Lilliefors Test Statistic 0.108861 Lilliefors GOF Test
5% Lilliefors Critical Value 0.167418 Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCL (Adjusted for Skewness)
95% Student's-t UCL 179.7658 95% Adjusted-CLT UCL (Chen-1995) 179.9557
95% Modified-t UCL (Johnson-1978) 179.7266

Gamma GOF Test
A-D Test Statistic 0.448849 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.758765 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.164018 Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.167496 Detected data appear Gamma Distributed at 5% Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics
k hat (MLE) 1.915027 k star (bias corrected MLE) 1.733611
Theta hat (MLE) 77.22705 Theta star (bias corrected MLE) 85.38412
nu hat (MLE) 107.3415 nu star (bias corrected) 97.08467
MLE Mean (bias corrected) 147.8536 MLE Sd (bias corrected) 112.2924
Approximate Chi Square Value (0.05) 75.35632
Adjusted Level of Significance 0.0434 Adjusted Chi Square Value 74.17325

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=50) 190.4854 95% Adjusted Gamma UCL (use when n<50) 191.5242

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.858209 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.924 Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.175335 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0.167418 Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186251 Mean of logged Data 4.771962
Maximum of Logged Data 5.669881 SD of logged Data 0.908106

Assuming Lognormal Distribution
95% H-UCL 253.3774 90% Chebyshev (MVUE) UCL 260.1402
95% Chebyshev (MVUE) UCL 301.3928 97.5% Chebyshev (MVUE) UCL 361.5914
99% Chebyshev (MVUE) UCL 481.4488

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 174.8282 95% Jackknife UCL 175.7958
95% Standard Bootstrap UCL 174.6819 95% Bootstrap-t UCL 176.804
95% Hall's Bootstrap UCL 174.2247 95% Percentile Bootstrap UCL 172.9286
95% BCA Bootstrap UCL 173.2786
90% Chebyshev(Mean, Sd) UCL 197.0138 95% Chebyshev(Mean, Sd) UCL 219.2839
97.5% Chebyshev(Mean, Sd) UCL 250.1918 99% Chebyshev(Mean, Sd) UCL 310.9044

[redacted]
95% Student's-t UCL 179.7658

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Note: For highly negatively skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

[redacted]

transposed soil Pb data (less 1st, 2nd, 3rd , 4th (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th max)

280
89
50
230
93
120
58
270
130
27
200
24
120
280
8.9
290
100
27
33
200

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 12:26
From File WorkSheet.xls
Full Precision 0%
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

CD

General Statistics
Total Number of Observations 27 Number of Distinct Observations 21
Number of Missing Observations 0
Minimum 8.9 Mean 141.5839
Maximum 290 Median 140
SD 83.68054 Std. Error of Mean 16.10431
Coefficient of Variation 0.586846 Skewness -0.08745

230
180
150
250
220
180
140
190

Normal GOF Test
Shapiro Wilk Test Statistic 0.934074 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0.923 Data appear Normal at 5% Significance Level
Lilliefors Test Statistic 0.117032 Lilliefors GOF Test
5% Lilliefors Critical Value 0.170511 Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCLs (Adjusted for Skewness)
95% Student's-t UCL 170.0567 95% Adjusted-CLT UCL (Chen-1995) 168.7846
95% Modified-t UCL (Johnson-1978) 170.0116

Gamma GOF Test
A-D Test Statistic 0.915571 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.75762 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.161498 Kolmogrov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.170616 Detected data appear Gamma Distributed at 5% Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics
k hat (MLE) 1.920171 k star (bias corrected MLE) 1.73151
Theta hat (MLE) 74.25845 Theta star (bias corrected MLE) 82.34946
nu hat (MLE) 103.6832 nu star (bias corrected) 93.50152
MLE Mean (bias corrected) 142.5889 MLE Sd (bias corrected) 108.3611
Approximate Chi Square Value (0.05) 72.20133
Adjusted Level of Significance 0.0431 Adjusted Chi Square Value 71.00491

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n>=50) 184.6543 95% Adjusted Gamma UCL (use when n<50) 187.7656

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.85717 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.923 Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.177953 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0.170511 Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186051 Mean of logged Data 4.67752
Maximum of Logged Data 5.598422 SD of logged Data 0.905665

Assuming Lognormal Distribution
95% H-UCL 248.1483 90% Chebyshev (MVUE) UCL 251.7184
95% Chebyshev (MVUE) UCL 291.893 97.5% Chebyshev (MVUE) UCL 352.3879
99% Chebyshev (MVUE) UCL 467.2879

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 169.0782 95% Jackknife UCL 170.0567
95% Standard Bootstrap UCL 167.9616 95% Bootstrap-t UCL 169.7408
95% Hall's Bootstrap UCL 169.036 95% Percentile Bootstrap UCL 168.1037
95% BCA Bootstrap UCL 168.2511
90% Chebyshev(Mean, Sd) UCL 190.9017 95% Chebyshev(Mean, Sd) UCL 212.786
97.5% Chebyshev(Mean, Sd) UCL 241.1604 99% Chebyshev(Mean, Sd) UCL 302.8249

Suggested UCL to Use
95% Student's-t UCL 170.0567

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real-World data sets.
For additional insight the user may want to consult a statistician.

Note: For highly negatively skewed data, confidence limits (e.g., Chen, Johnson-Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

Transposed Sed Pb data (less 1st, 2nd, 3rd, 4th [which occurred at two discrete sample locations], 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th max)

280
90
50
230
83
120
58
130
37
200
24
170
260
8.9
100
27
23
200
230
180
150
250
270
180
140
190

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 12:28
From File Worksheet.xls
Full Precision OFF
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

CD

General Statistics
Total Number of Observations 26 Number of Distinct Observations 20
Number of Missing Observations 0
Minimum 8.9 Mean 137.6885
Maximum 280 Median 135
SD 81.29091 Std. Error of Mean 15.94246
Coefficient of Variation 0.590397 Skewness -0.07019

Normal GOF Test
Shapiro Wilk Test Statistic 0.934202 Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value 0.92 Data appear Normal at 5% Significance Level
Lilliefors Test Statistic 0.121718 Lilliefors GOF Test
5% Lilliefors Critical Value 0.171759 Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCLs (Adjusted for Skewness)
95% Student's-t UCL 164.3204 95% Adjusted-CLT UCL (Chen-1995) 161.877
95% Modified-t UCL (Johnson-1978) 164.8819

Gamma GOF Test
A-D Test Statistic 0.890002 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.758011 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.157486 Kolmogrov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.173512 Detected data appear Gamma Distributed at 5% Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics
k hat (MLE) 1.921345 k star (bias corrected MLE) 1.721754
Theta hat (MLE) 71.81205 Theta star (bias corrected MLE) 79.96989
nu hat (MLE) 99.70194 nu star (bias corrected) 89.5312
MLE Mean (bias corrected) 137.6885 MLE Sd (bias corrected) 104.933
Approximate Chi Square Value (0.05) 66.73494
Adjusted Level of Significance 0.0198 Adjusted Chi Square Value 67.51061

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n=57) 179.1493 95% Adjusted Gamma UCL (use when n=57) 182.5996

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.860312 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.93 Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.187581 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0.173759 Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186051 Mean of logged Data 4.642101
Maximum of Logged Data 5.566682 SD of logged Data 0.904329

Assuming Lognormal Distribution
95% H-UCL 243.9291 90% Chebyshev (MVUE) UCL 249.9027
95% Chebyshev (MVUE) UCL 285.1262 97.5% Chebyshev (MVUE) UCL 342.1428
99% Chebyshev (MVUE) UCL 454.7337

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 163.9115 95% Jackknife UCL 164.9204
95% Standard Bootstrap UCL 163.4675 95% Bootstrap-t UCL 164.8329
95% Hall's Bootstrap UCL 163.3202 95% Percentile Bootstrap UCL 163.8731
95% BCA Bootstrap UCL 163.5848
90% Chebyshev(Mean, Sd) UCL 185.3158 95% Chebyshev(Mean, Sd) UCL 207.218
97.5% Chebyshev(Mean, Sd) UCL 237.2491 99% Chebyshev(Mean, Sd) UCL 296.3139

Suggested UCL to Use
95% Student-t UCL 164.9204

Note: Suggestions regarding the selection of a 95% UCL are provided to help the users to select the most appropriate 95% UCL
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight, the user may want to consult a statistician.

Note: For highly negatively skewed data, confidence limits (e.g., Chen-Jackman, Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

[redacted]

transposed soil Pb data (less 1st, 2nd, 3rd, 4th (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 15th (which occurred at two discrete sample locations) max)

39
50
210
83
130
51
130
27
200
24
170
8.9
120
27
33
200
230
180
150
250
220
190
140
190

UCL Statistics for Uncensored Full Data Sets

User Selected Options
Date/Time of Computation 1/8/2016 12:34
From File WorkSheet.xls
Full Precision On
Confidence Coefficient 95%
Number of Bootstrap Operations 2000

CD

General Statistics
Total Number of Observations 34 Number of Distinct Observations 19
Number of Missing Observations 0
Minimum 8.9 Mean 127.4958
Maximum 250 Median 125
SD 75.4819 Std. Error of Mean 15.51215
Coefficient of Variation 0.599472 Skewness 0.047.98

Normal GOF Test
Shapiro-Wilk Test Statistic 0.918.41 Shapiro-Wilk GOF Test
5% Shapiro-Wilk Critical Value 0.916 Data appear Normal at 5% Significance Level
Lilliefors Test Statistic 0.130218 Lilliefors GOF Test
5% Lilliefors Critical Value 0.1868.4 Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level

Assuming Normal Distribution
95% Normal UCL 95% UCLs (Adjusted for Skewness)
95% Student's-t UCL 154.8782 95% Adjusted-CLT UCL (Chen-1995) 152.8454
95% Modified-t UCL (Johnson-1978) 154.0929

Gamma GOF Test
A-D Test Statistic 0.819781 Anderson-Darling Gamma GOF Test
5% A-D Critical Value 0.756132 Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic 0.147217 Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value 0.180158 Detected data appear Gamma Distributed at 5% Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics
k hat (MLE) 1.919628 k star (bias corrected MLE) 1.707412
Theta hat (MLE) 66.41695 Theta star (bias corrected MLE) 74.67022
nu hat (MLE) 92.14214 nu star (bias corrected) 81.9577
Mean (bias corrected) 127.4958 MLE Sd (bias corrected) 97.51122
Approximate Chi Square Value (.05) 62.09546
Adjusted Level of Significance 0.0392 Adjusted Chi Square Value 60.87981

Assuming Gamma Distribution
95% Approximate Gamma UCL (use when n=34) 168.2775 95% Adjusted Gamma UCL (use when n=34) 171.8476

Lognormal GOF Test
Shapiro Wilk Test Statistic 0.867161 Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value 0.916 Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic 0.193725 Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value 0.180154 Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level

Lognormal Statistics
Minimum of Logged Data 2.186051 Mean of logged Data 4.563371
Maximum of Logged Data 5.521461 SD of logged Data 0.899687

Assuming Lognormal Distribution
95% H-UCL 226.3283 90% Chebyshev (MVUE) UCL 237.2617
95% Chebyshev (MVUE) UCL 266.3231 97.5% Chebyshev (MVUE) UCL 309.4206
99% Chebyshev (MVUE) UCL 427.2776

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs
95% CLT UCL 153.3078 95% Jackknife UCL 154.3782
95% Standard Bootstrap UCL 152.9757 95% Bootstrap-t UCL 153.7978
95% Hall's Bootstrap UCL 153.1995 95% Percentile Bootstrap UCL 152.7088
95% BCA Bootstrap UCL 152.8833

90% Chebyshev(Mean, Sd) UCL	174.0263	95% Chebyshev(Mean, Sd) UCL	195.901
97.5% Chebyshev(Mean, Sd) UCL	224.1567	99% Chebyshev(Mean, Sd) UCL	281.8299

Suggested UCL to Use	
95% Student's-t UCL	154.0782

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Note: For highly negatively skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

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transposed soil Pb data (less 1st, 2nd, 3rd , 4th (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 15th (which occurred at two discrete sample locations), 16th max)

99
90
230
83
120
58
130
27
200
24
120
89
100
27
33
200
230
180
150
220
180
140
190

UCL Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	1/8/2016 12:19
From File	WorkSheet.xls
Full Precision	On
Confidence Coefficient	95%
Number of Bootstrap Operations	1000

CD

General Statistics

Total Number of Observations	23	Number of Distinct Observations	18
		Number of Missing Observations	0
Minimum	39	Mean	122.1696
Maximum	230	Median	120
SD	72.96898	Std. Error of Mean	15.21467
Coefficient of Variation	0.597226	Skewness	0.062213

Normal GOF Test

Shapiro Wilk Test Statistic	0.931441	Shapiro Wilk GOF Test
5% Shapiro Wilk Critical Value	0.914	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.133808	Lilliefors GOF Test
5% Lilliefors Critical Value	0.184734	Data appear Normal at 5% Significance Level
Data appear Normal at 5% Significance Level		

Assuming Normal Distribution

95% Normal UCL		95% UCLs (Adjusted for Skewness)	
95% Student's-t UCL	148.2953	95% Adjusted-CLT UCL (Chen-1995)	147.8136
		95% Modified-t UCL (Johnson-1978)	148.2678

Gamma GOF Test

A-D Test Statistic	0.804428	Anderson-Darling Gamma GOF Test
5% A-D Critical Value	0.755529	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.151465	Kolmogorov-Smirnoff Gamma GOF Test
5% K-S Critical Value	0.184183	Detected data appear Gamma Distributed at 5% Significance Level
Detected data follow Appr. Gamma Distribution at 5% Significance Level		

Gamma Statistics

k hat (MLE)	1.926615	k star (bias corrected MLE)	1.704168
Theta hat (MLE)	63.40936	Theta star (bias corrected MLE)	71.68628
nu hat (MLE)	88.62772	nu star (bias corrected)	78.40092
MLE Mean (bias corrected)	122.1696	MLE Sd (bias corrected)	93.57968
		Approximate Chi Square Value (0.05)	59.002
Adjusted Level of Significance	0.0159	Adjusted Chi Square Value	57.78213

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	162.31	95% Adjusted Gamma UCL (use when n<50)	165.7613

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.867047	Shapiro Wilk Lognormal GOF Test
5% Shapiro Wilk Critical Value	0.914	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.199485	Lilliefors Lognormal GOF Test
5% Lilliefors Critical Value	0.184744	Data Not Lognormal at 5% Significance Level
Data Not Lognormal at 5% Significance Level		

Lognormal Statistics

Minimum of Logged Data	3.686051	Mean of logged Data	4.821991
Maximum of Logged Data	5.438079	SD of logged Data	0.896041

Assuming Lognormal Distribution

95% H-UCL	217.6298	90% Chebyshev (MVUE) UCL	218.2707
95% Chebyshev (MVUE) UCL	256.1845	97.5% Chebyshev (MVUE) UCL	304.8082
99% Chebyshev (MVUE) UCL	412.1772		

Nonparametric Distribution Free UCL Statistics
Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	147.1955	95% Jackknife UCL	148.2953
95% Standard Bootstrap UCL	146.2931	95% Bootstrap-t UCL	148.3952
95% Hall's Bootstrap UCL	146.7752	95% Percentile Bootstrap UCL	146.2174
95% BCA Bootstrap UCL	145.9917		
90% Chebyshev(Mean, Sd) UCL	167.8136	95% Chebyshev(Mean, Sd) UCL	188.1883
97.5% Chebyshev(Mean, Sd) UCL	217.1851	99% Chebyshev(Mean, Sd) UCL	273.5516

Suggested UCL to Use	
95% Student's-t UCL	148.2953

Note: Suggestions regarding the selection of a 95% UCL are presented to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Note: For highly negatively skewed data, confidence limits (e.g., Chen, Johnson, Lognormal, and Gamma) may not be
reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.

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transposed soil Pb data (less 1st, 2nd, 3rd , 4th (which occurred at two discrete sample locations), 5th, 6th, 7th, 8th, 9th, 10th, 11th, 12th, 13th, 14th, 15th (which occurred at two discrete sample locations), 16th, 17th (which occurred at two discrete sample locations) max)

99
90
83
120
58
130
27
200
24
120

UCL Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	1/8/2016 12:43
From File	WorkSheet.xls
Full Precision	On
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

89
102
27
33
200
180
150
220
180
140
190

CO

General Statistics

Total Number of Observations	21	Number of Distinct Observations	17
		Number of Missing Observations	0
Minimum	89	Mean	131.9
Maximum	219	Median	120
SD	47.8487	Std. Error of Mean	14.77308
Coefficient of Variation	0.604993	Skewness	0.01211

Normal GOF Test

Shapiro Wilk Test Statistic	0.933998	Shapiro Wilk GOF Test	
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.128489	Lilliefors GOF Test	
5% Lilliefors Critical Value	0.191341	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			

Assuming Normal Distribution

95% Normal UCL		95% UCL (Adjusted for Skewness)	
95% Student's t UCL	157.1768	95% Adjusted-CLT UCL (Chen-1995)	136.1578
		95% Modified-t UCL (Johnson-1978)	157.3129

Gamma GOF Test

A-D Test Statistic	0.723964	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.754412	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.145048	Kolmogrov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0.191388	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			

Gamma Statistics

k hat (MLE)	1.911471	k star (bias corrected MLE)	1.687293
Theta hat (MLE)	57.96512	Theta star (bias corrected MLE)	68.11926
nu hat (MLE)	80.12178	nu star (bias corrected)	70.86629
MLE Mean (bias corrected)	131.9	MLE Sd (bias corrected)	86.14596
		Approximate Chi Square Value (0.05)	52.48513
Adjusted Level of Significance	0.0383	Adjusted Chi Square Value	51.37362

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50)	156.3872	95% Adjusted Gamma UCL (use when n<50)	154.6781

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.873824	Shapiro Wilk Lognormal GOF Test	
5% Shapiro Wilk Critical Value	0.908	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.279478	Lilliefors Lognormal GOF Test	
5% Lilliefors Critical Value	0.191341	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			

Lognormal Statistics

Minimum of Logged Data	4.488636	Mean of logged Data	4.816935
Maximum of Logged Data	5.389072	SD of logged Data	0.389755

Assuming Lognormal Distribution

95% H-UCL	201.1806	90% Chebyshev (MVUE) UCL	201.1082
95% Chebyshev (MVUE) UCL	236.717	97.5% Chebyshev (MVUE) UCL	286.1885
99% Chebyshev (MVUE) UCL	383.3263		

Nonparametric Distribution Free UCL Statistics

Data appear to follow a Discernible Distribution at 5% Significance Level

Nonparametric Distribution Free UCLs

95% CLT UCL	136.1996	95% Jackknife UCL	137.1794
95% Standard Bootstrap UCL	135.7731	95% Bootstrap-t UCL	138.5208
95% Hall's Bootstrap UCL	134.2754	95% Percentile Bootstrap UCL	134.3331
95% BCA Bootstrap UCL	134.2857		
90% Chebyshev(Mean, Sd) UCL	156.2192	95% Chebyshev(Mean, Sd) UCL	176.2944
97.5% Chebyshev(Mean, Sd) UCL	204.1578	99% Chebyshev(Mean, Sd) UCL	253.8963

Suggested 95% UCL

Non-Student-t UCL 142.4764

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.
These recommendations are based upon the results of the simulation studies summarized in Singh, Singh, and Iaci (2002)
and Singh and Singh (2003). However, simulations results will not cover all Real World data sets.
For additional insight the user may want to consult a statistician.

Note: For highly negatively skewed data, confidence limits (e.g., Chen-Jenssen, Lognormal, and Gamma) may not be reliable. Chen's and Johnson's methods provide adjustments for positively skewed data sets.