Appendix C

Tidal Study

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PORT OF FRIDAY HARBOR
ALBERT JENSEN AND SONS INC. BOATYARD AND MARINA
FRIDAY HARBOR, WA

MODEL TOXICS CONTROL ACT (MTCA)
AGREED ORDER NO. DE 18071

REMEDIAL INVESTIGATION REPORT – UPLAND AREA
TIDAL STUDY

Prepared for
The Port of Friday Harbor
Friday Harbor, WA

PORT OF FRIDAY HARBOR

Prepared by
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September 2025

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1 INTRODUCTION

The Albert Jensen and Sons Inc. Marina and Boatyard (Project) is located at 1293 Turn Point Road, Friday Harbor, Washington on San Juan Island in the Salish Sea. and the purpose of this tidal study was to determinethe extent of the tidal influence to shallow groundwater at the Project. For tidally influenced groundwater monitoring wells, it is a best practice to collect groundwater samples during a negative low tide, as this represents the time of a lowest tide. Groundwater is sampled during the time of low groundwater elevation in each well in order to collect samples that are most representative of the aquifer groundwater and not the surface water body that is influencing the monitoring well.

The purpose of the tidal study is to:

1. Determine the extent of Project monitoring wells which are tidally influenced.
2. For tidally influenced monitoring wells, estimate tidal lag times to determine when groundwater sampling should be performed relative to low tide.
3. Define net groundwater flow conditions.

2 DATA COLLECTION AND ANALYSIS

2.1 METHODOLOGY

The tidal study was conducted from August 5-16, 2022 during a time period including negative and non-negative low tides, allowing for observation across a full tidal response. A 72-hour subset of this transducer data was used for statistical evaluation. This subset data range was August 12 00:00 through August 14 23:59. A select six (6) monitoring wells and the nearest NOAA-monitored tidal station (ID# 94469880 in Friday Harbor, WA) were used to measure tidal variations. These six monitoring wells were generally the closest to the shoreline and spread across the shoreline west to east.

2.2 WATER LEVEL ELEVATION CONVERSIONS

In-Situ pressure transducers level loggers, Rugged TROLL, were placed in each of the six selected monitoring wells and left undisturbed for the duration of the study. Transducer details are included on Table C-1. Water level measurements were collected by hand in all onsite wells using a water level meter at the time of transducer installation and transducer removal as spot checks of the transducer water level calculations (Table C-2). Raw data collected directly from the transducers (water depths as a function of water head pressure) were corrected against barometric pressure recorded concurrently at the Project using a BaroTROLL. The barometric pressure corrections were performed using Win-Situ 5 software. This tidal study used top of casing reference elevation data for MW-2, MW-3, and MW-5 (Whatcom 2018) and survey data from San Juan Surveying for MW-2, MW-7, MW-8, and MW-9. The reference point for each monitoring well is on the approximate north point of the top of well casing. The barometrically-corrected transducer pressure measurements (water head) were then subtracted from the surveyed well casing depth to calculate water level elevations from the transducer data. The barometrically-corrected transducer data were used in the Serfes analysis. No monitoring wells went dry during the tidal study.

2.4 TIDAL EFFICIENCY

Tidal efficiency is the magnitude of the tidal fluctuation of a groundwater monitoring well, expressed as a percentage of the tidal fluctuation in the adjacent water body. Tidal efficiency is used to understand the hydrologic characteristics of the aquifer. The amplitude of the groundwater fluctuation is generally much less than the tidal range and is usually greatest nearest the shoreline and diminishes further from shoreline, although other factors may affect the groundwater level response observed in wells. The tidal efficiency was calculated by dividing the tidal range for one-quarter of a tidal cycle (lower low tide to the corresponding next higher high tide) by the same tidal range for the tidal station. Calculated tidal efficiencies for each monitoring well during each recorded lower low water to higher high water tidal cycles are summarized on Table C-3 and discussed in Section 3.1.

2.5 LAG TIME

In general, tidally influenced groundwater follows the tidal fluctuations of the adjacent waterway on a delayed cycle. The length of time it takes for water in a well to respond to the tidal cycle is known as the “tidal time lag” (Fetter 1994). The lag time was used to predict groundwater sample timing based on the low tides predicted for the reference station.

Tidal lag time was calculated by averaging the difference in time between the two higher high tides and two lower low tides in each monitoring well relative to the reference tidal station #9449880. Tidal Station 9449880 is at the Port of Friday Harbor on the Salish Sea (Figure C-1). The gauging station is a straight-line distance of less than 1.5-miles from the Project. Calculated tidal lag times for each monitoring well during the tidal study period are summarized on Table C-3.

2.6 NET GROUNDWATER FLOW

Net groundwater elevation and flow direction are used to assess contaminant fate and transport at a site. In a tidally influenced area, groundwater elevations and flow directions may vary through the tidal cycle. As the tides rise and fall, they produce pressure waves in the adjacent aquifers and may cause groundwater levels and hydraulic gradients to fluctuate, resulting in a situation where a single synoptic set of groundwater levels may not adequately characterize the groundwater potentiometric surface. To evaluate net groundwater flow direction, average elevations are typically estimated using the Serfes (1991) method. Data from this tidal study was used to evaluate average elevations using a simple averaging and filtering from the modified method of Serfes (1991). Serfes developed a method based on the earlier work of Godin (1966) to filter out tidal influences. Serfes method uses hourly water-level readings taken over a three-day period (72 hours). The hourly readings from each well are processed using a moving average technique.

The Serfes moving average values for each well within the tidal study window (8/12/2022 00:00 to 8/14/2022 23:59) and final Serfes method averages summarized on Table C-3.

3 TIDAL STUDY RESULTS

3.1 TIDAL RANGE AND TIDAL EFFICIENCY RESULTS

The tidal range on the gauging station during this study period was up to 10.19 feet, ranging in elevation from -2.01 feet mean lower low water (MLLW) to 8.18 feet MLLW. Groundwater levels in the observed monitoring wells fluctuated up to 1.72 feet (MW-7) during a single tidal quarter cycle.

Calculated tidal efficiencies (i.e., magnitude of the tidal fluctuation of groundwater at a monitoring well expressed as a percentage of the tidal fluctuation in the adjacent water body) ranged from 2 percent at well MW-3 (within the SRWA), to 17 percent at MW-7 (near top of bank within the BLWA). While measured tidal efficiencies were relatively low for all wells, the wells near the top of bank within the Boat Lift Work Area (MW-7, -8 and -9) exhibited the most significant tidal influence (efficiencies ranging 8 to 17 percent). These wells also exhibited the greatest specific conductivity showing influence of marine water. See Table C-3 for tidal range and tidal efficiency. See Figure C-2 and Figure C-3 for monitoring well and tidal water level charts.

The northwestern one-third of the Project area comprises the greater Boat Lift Work Area and Former OPALCO Storage Area. This land area has undergone historical grading and fill operations which may affect soil density, porosity, and the permeability. Monitoring wells in this area include MW-7, MW-8, MW-9, and MW-2, with wells MW-4, MW-1, and MW-3 along the likely fill perimeter or outermost extents.

3.2 LAG TIME RESULTS

The averaged tidal lag time for wells at the Project during the 72-hour tidal ranged from 3 hours and 48 minutes (MW-5) to 6 hours and 57 minutes (MW-3). Both monitoring wells are considered nearshore wells and in areas understood to predominantly native soils with little to no fill material present, suggesting that the native, undisturbed soil properties are hydrogeologically different that the site fill soil properties. See Table C-3 for lag times and tidal efficiency. Considering the more immediate proximity of MW-7, MW-8, and MW-9 to the Salish Sea, it would typically be expected that these wells would have the shortest tidal lag times, but MW-3 has this shortest lag time. Due to the relative heterogeneity of the BLWA shoreline soils from the infilling and grading of the BLWA shoreline (sometime between 1941 and 1971), these variable shoreline soils are likely a main factor in tidal lag time variability among these BLWA shoreline wells (MW-7, MW-8, and MW-9) and MW-3. Considering the more immediate proximity of MW-7, MW-8, and MW-9 to the Salish Sea, it would typically be expected that these wells would have the shortest tidal lag times, but MW-3 has this shortest lag time.

3.3 NET GROUNDWATER FLOW

The net groundwater flow direction for the Project was obtained by interpolating elevation contours from the average, filtered groundwater elevations for each well (Figure C-4). The net groundwater flow direction at the Project is to the north towards the Salish Sea. Of the six monitoring wells studied at the Project, the Serfes average groundwater elevations during the tidal study period ranged from 5.8 feet MLLW (MW-7) to 6.2 feet MLLW (MW-3). In general, the hydraulic gradient across the Project is very low. Hydraulic gradient calculations for the water level elevations among the monitoring wells across the site range from 0.00128 to 0.00672 ft/ft.

3.4 GROUNDWATER SAMPLE TIMING

Table C-3 also provides a summary of groundwater sample timing for each well included in the tidal study at the Project based on the logic presented in the introduction to this report (Section 1). Suggested sample collection times based on observed tidal lag times are summarized on Table C-3 and discussed in Section 3.2. Suggested sample collection times vary from 4-hours to approximately 6.5-hours following the lower low tide of a given tidal diurnal tidal cycle. Although data logging was not conducted on MW-1, MW-4, or MW-6, estimated lag times can be inferred for these wells based on proximity and known lithology. MW-1 and MW-4 would likely have a similar of longer lag time than MW-2 and MW-3, so greater than 6-hours. MW-6 would likely have the longest lag time or no appreciable tidal efficiency.

4 REFERENCES

Fetter 1994. Applied Hydrogeology, 376 pp., Prentice-Hall, Englewood Cliffs, N. J., 1994

NOAA Tide Level Observations for Friday Harbor (Station 94498800) retrieved from: https://tidesandcurrents.noaa.gov/noaatidepredictions.html?id=9449880. Accessed October 2022.

Serfes 1991. Determining the Mean Hydraulic Gradient of Ground Water Affected by Tidal Fluctuations. Groundwater Journal, Volume 29, Number 4, July-August 1991.

Whatcom 2018. Draft Remedial Investigation Report, Jensen's Shipyard and Marina, 1293 Turn Point Road, Friday Harbor, Washington. Prepared by Whatcom Environmental Services, October 15, 2018.

TABLES

Table C-1 Albert Jensen and Sons Boatyard - Level Logger Type and P

Level Logger ID	Level Logger Serial Number	Level Logger Type	Total Well Depth (ft BTOC)
MW-2	675163	In-Situ Rugged TROLL 100	14.74
MW-3	675070	In-Situ Rugged TROLL 100	13.03
MW-5	675049	In-Situ Rugged TROLL 100	14.15
MW-7	675229	In-Situ Rugged TROLL 100	12.85
MW-8	675102	In-Situ Rugged TROLL 100	11.79
MW-9	675029	In-Situ Rugged TROLL 100	11.84
Barometer	643290	In-Situ Rugged BaroTROLL	N/A

NOTES:
BTOC - below top of casing
ft - feet
N/A - not applicable

Table C-2 Albert Jensen and Sons Boatyard - Monitoring Well Gauging, Select Transducer Readings

Well ID	Date	Time	Elevation Top of PVC Casing (ft MLLW)	Gauged DTW (ft BTOC)	Water Level Elevation (ft)	Transducer Level Reading (Head ft)	Difference in Gauged DTW and Transducer Measured Head (ft)
MW-2	8/5/2022	10:15	11.31	5.77	5.54	5.80	-0.03
	8/16/2022	8:28	11.31	5.59	5.72	5.63	-0.04
MW-3	8/5/2022	10:32	10.16	4.27	5.89	4.34	-0.07
	8/16/2022	8:11	10.16	4.15	6.01	4.21	-0.06
MW-5	8/5/2022	10:55	16.36	10.44	5.92	10.45	-0.01
	8/16/2022	8:02	16.36	10.34	6.02	10.39	-0.05
MW-7	8/5/2022	9:47	10.76	6.05	4.71	6.05	0.00
	8/16/2022	8:41	10.76	5.43	5.33	5.66	-0.23
MW-8	8/5/2022	9:36	11.24	5.90	5.34	5.90	0.00
	8/16/2022	8:46	11.24	5.68	5.56	5.75	-0.07
MW-9	8/5/2022	9:30	11.25	5.85	5.40	5.85	0.00
	8/16/2022	8:52	11.25	5.60	5.65	5.77	-0.17

NOTES:

Top of casing data taken from Draft Remedial Investigation Report by Whatcom Environmental dated October 15, 2018 and Star Surveying Inc memorandum dated September 19, 2022.

PVC - polyvinyl chloride

ft - feet

DTW - depth to water

BTOC - below top of casing

MLLW - Mean Lower Low Water

Table C-3 - Albert Jensen and Sons Boatyard - Tidal Lag Time Analysis at Monitoring Wells

Well ID	Elevation	Tidal Range for a Quarter Cycle				Tidal Range for a Quarter Cycle				Tidal Range for a Quarter Cycle				Tidal Timing						Lag Time				Sample Collection Time
	Serfes Method Mean Elevation (72-Hour Period)	First Low Low Elevation	First High High Elevation	Tidal Range	Tidal Efficiency (Quarter Cycle)	Second Low Low Elevation	Second High High Elevation	Tidal Range	Tidal Efficiency (Quarter Cycle)	Third Low Low Elevation	Third High High Elevation	Tidal Range	Tidal Efficiency (Quarter Cycle)	Time of First Low Low Water Level	Time of First High High Water Level	Time of Second Low Low Water Level	Time of Second High High Water Level	Time of Third Low Low Water Level	Time of Third High High Water Level	Lag Time (1st Low Low Tides Only)	Lag Time (2nd Low Low Tides Only)	Lag Time (3rd Low Low Tides Only)	Average Lag Time (3 Low Low tides)	Suggested Sample Collection Time
	MLLW	MLLW	MLLW	ft		MLLW	MLLW	ft		MLLW	MLLW	ft								hr:min	hr:min	hr:min	hr:min	
MW-2	6.09	5.75	6.45	0.70	7%	5.85	6.42	0.57	6%	5.60	6.10	0.50	6%	8/12/2022 18:02	8/12/2022 6:02	8/13/2022 18:32	8/13/2022 7:44	8/14/2022 18:35	8/14/2022 8:32	6:26	6:20	5:47	6:11	6 hours after low low tide
MW-3	6.23	6.07	6.24	0.17	2%	6.22	6.32	0.10	1%	6.01	6.21	0.20	2%	8/12/2022 18:15	8/12/2022 5:51	8/13/2022 19:21	8/13/2022 11:42	8/14/2022 19:51	8/14/2022 8:39	6:39	7:09	7:03	6:57	6.5-7 hours after low low tide
MW-5	6.22	5.83	6.48	0.65	6%	5.98	6.52	0.54	6%	5.85	6.40	0.55	6%	8/12/2022 15:21	8/12/2022 5:03	8/13/2022 16:00	8/13/2022 7:27	8/14/2022 16:39	8/14/2022 8:15	3:45	3:48	3:51	3:48	3.5 hours after low low tide
MW-7	5.80	4.95	6.67	1.72	17%	4.97	6.49	1.52	16%	4.57	6.05	1.48	17%	8/12/2022 15:57	8/12/2022 5:48	8/13/2022 16:12	8/13/2022 6:42	8/14/2022 16:48	8/14/2022 7:42	4:21	4:00	4:00	4:07	4 hours after low low tide
MW-8	5.79	5.70	6.56	0.86	8%	5.75	6.42	0.67	7%	5.39	6.01	0.62	7%	8/12/2022 17:20	8/12/2022 6:14	8/13/2022 18:11	8/13/2022 7:38	8/14/2022 18:44	8/14/2022 8:00	5:44	5:59	5:56	5:53	5.5 hours after low low tide
MW-9	6.16	6.10	6.96	0.86	8%	6.19	6.74	0.55	6%	5.76	6.62	0.86	10%	8/12/2022 16:24	8/12/2022 4:57	8/13/2022 17:48	8/13/2022 5:318:00 AM	8/14/2022 17:30	8/14/2022 7:15	4:48	5:36	4:42	5:02	4.5 hours after low low tide
Tidal Station #9449880	4.45	-2.01	8.18	10.19	NA	-1.64	7.81	9.45	NA	-0.68	7.90	8.58	NA	8/12/2022 11:36	8/12/2022 19:42	8/13/2022 12:12	8/13/2022 20:12	8/14/2022 12:48	8/14/2022 20:36	NA	NA	NA	NA	ND

Notes:

The tidal study window for this analysis and these table values is from 8/12/2022 00:00 (AM) to 8/14/2022 23:59 (PM).

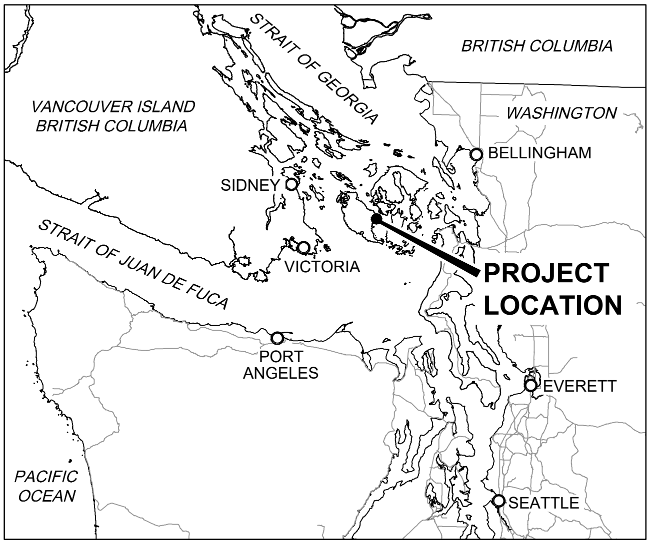
hr:min - Time in hours and minutes

ft - feet

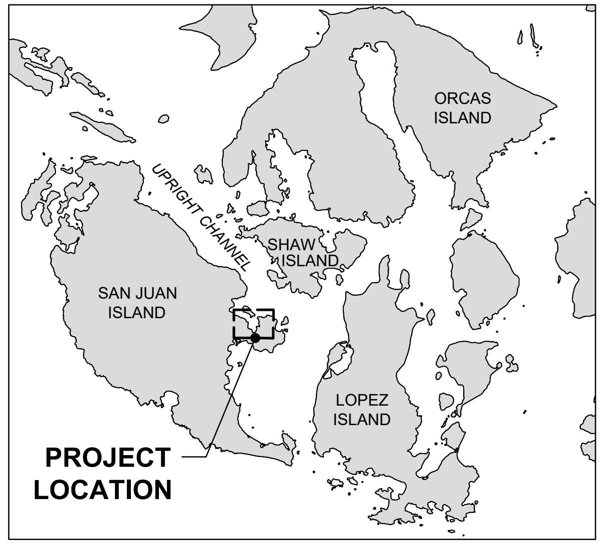
MLLW - mean lower low water

NA - not applicable

FIGURES



VICINITY MAP



VICINITY MAP - SAN JUAN ISLANDS

LOCATION MAP

0 1,250 2,500

SCALE IN FEET

File: PoFH_2025_RI-Cover.dwg Layout: Layout1

CRETE CONSULTING, INC.

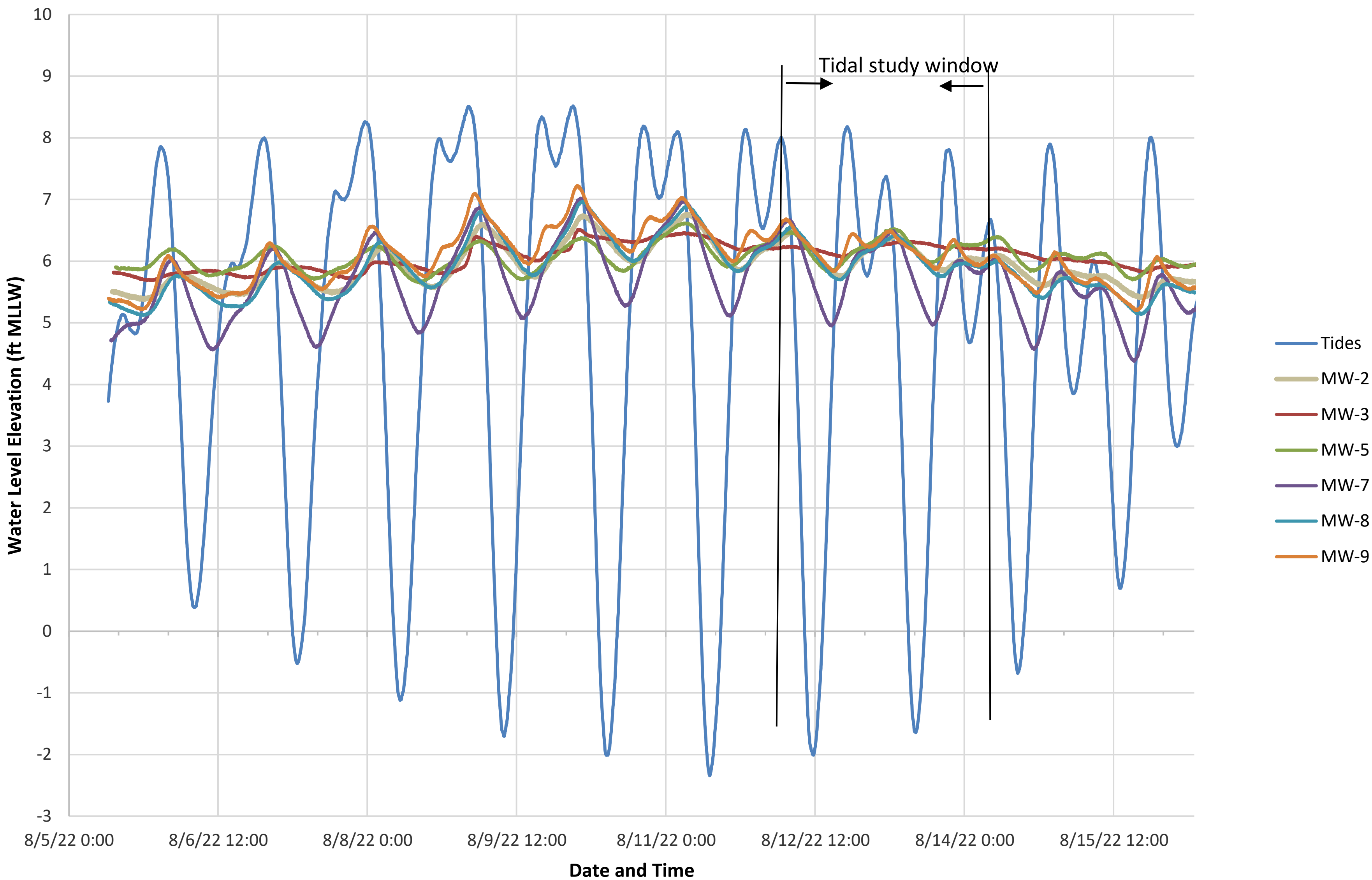
LEON Environmental, LLC

Port of Friday Harbor
Upland Remedial
Investigation Report
September 26, 2025

Figure C-1

Site Location
Map

Figure C-2
Monitoring Well and Tide Water Levels (Unabridged)



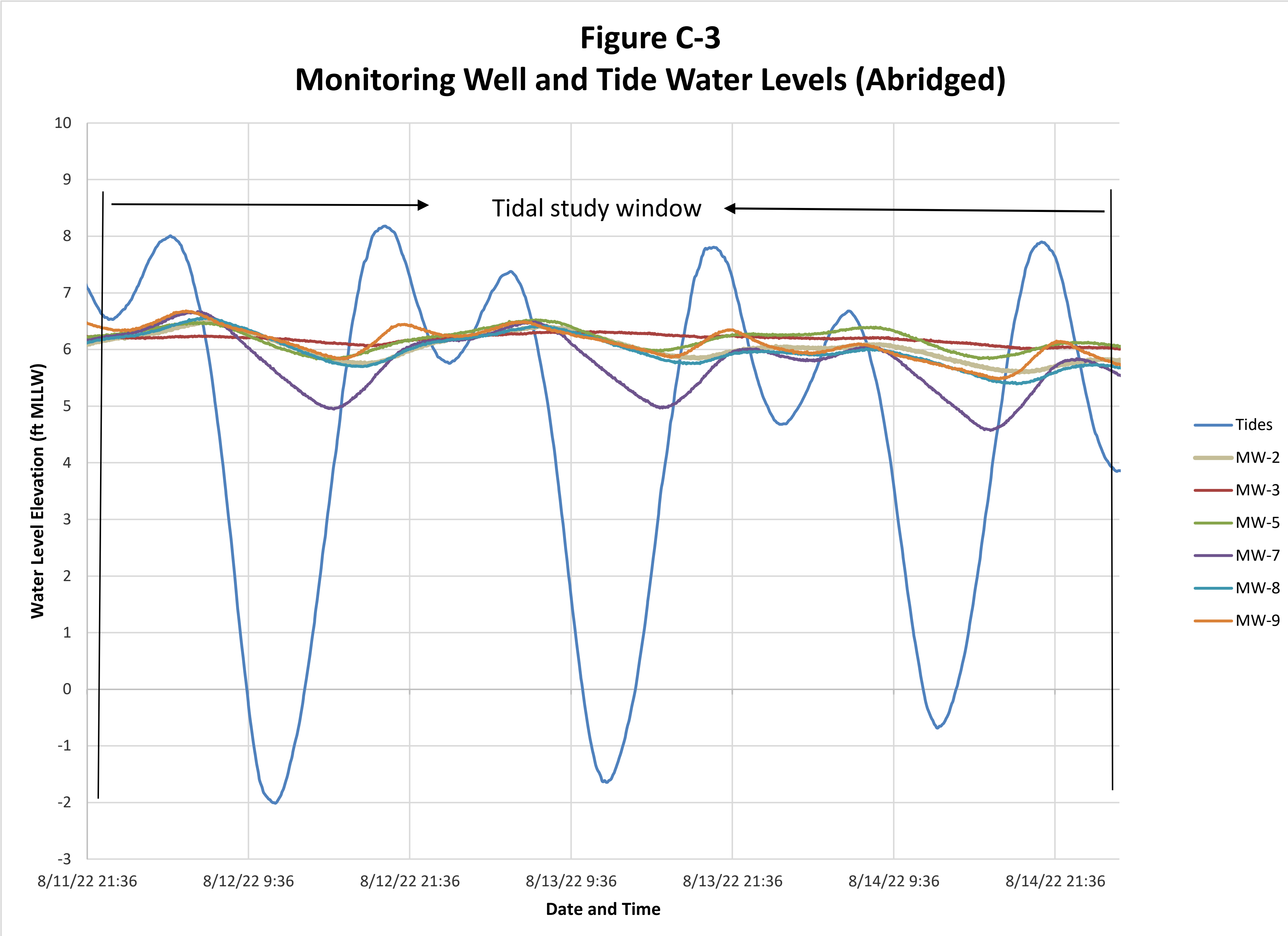


Figure C-3
Monitoring Well and Tide Water Levels (Abridged)
Tidal study window
Water Level Elevation (ft MLLW)
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
8/11/22 21:36
8/12/22 9:36
8/12/22 21:36
8/13/22 9:36
8/13/22 21:36
8/14/22 9:36
8/14/22 21:36
Date and Time
Tides
MW-2
MW-3
MW-5
MW-7
MW-8
MW-9

File: PoFH_2025_RI.dwg Layout: GW

CRETE CONSULTING, INC.

LEON Environmental, LLC

0 50 100
Scale in Feet

Port of Friday Harbor
Upland Remedial Investigation Report
September 26, 2025

Appendix C-4

Net Groundwater Flow

Appendix D

Terrestrial Ecological Evaluation

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TERRESTRIAL ECOLOGICAL EVALUATION

Albert Jensen and Sons Boatyard and Marina
1293 Turn Point Road
Friday Harbor, Washington

Prepared for:

CRETE CONSULTING, INC.
Tukwila, WA

PORT OF FRIDAY HARBOR
Friday Harbor, WA

For submittal to:

Washington Department of Ecology
Lacey, WA

September 2025

Prepared by:

Coho Environmental
Seattle, WA

Table of Contents

Tables

Acronyms

MTCA	Model Toxic Control Act
PAHs	polycyclic aromatic hydrocarbons
TEE	Terrestrial Ecological Evaluation
UCL	upper confidence limit
WAC	Washington Administrative Code

1 Introduction

The Washington State Department of Ecology's Model Toxics Control Act (MTCA) Cleanup Regulation (WAC Chapter 173-340) includes procedures for "characterizing existing or potential threats to terrestrial plants or animals exposed to hazardous substances in soil." These procedures, collectively designated as a Terrestrial Ecological Evaluation (TEE), provide a tiered approach of increasing complexity, depending on the characteristics of the site, resulting in one of three outcomes:

- Document an exclusion from further TEE evaluations (WAC 173-340-7491)
- Conduct a simplified TEE (WAC 173-340-7492)
- Conduct a site-specific TEE (WAC 173-340-7493)

The Albert Jensen and Sons (Jensen) Boatyard and Marina site does not meet any of the exclusions from conducting a TEE:

- The soil contaminated with hazardous substances is located above the point of compliance
- Some soil areas are not and will not be covered by buildings or pavement
- There is more than 0.25 acre of undeveloped land within 500 feet of areas of the site contaminated with one or more of the organic hazardous substances identified in WAC 173-340-7491(1)(b)(2).

For sites that do not qualify for an exclusion, a site-specific TEE shall be conducted if any of the following criteria apply to the site:

- Located on, or directly adjacent to, an area where management or land use plans will maintain or restore native or semi-native vegetation
- Used by a threatened or endangered species, priority species, or species of concern
- At least ten acres of native vegetation occurs within 500 feet of the site
- Ecology determines that the site may present a risk to significant wildlife populations

None of these criteria apply to this site. Consequently, a simplified TEE was conducted for this site. A simplified TEE is structured with an intent to protect terrestrial wildlife at industrial or commercial sites and consists of these steps: 1) exposure analysis, 2) pathways analysis, and 3) contaminants analysis. Any one of these steps can result in a determination that no further evaluation is necessary to conclude that a site does not pose a substantial threat of significant adverse effects to terrestrial ecological receptors. Each of these steps is described and evaluated in subsequent sections.

2 Exposure Analysis

The exposure analysis was performed to determine the potential for significant exposure to ecological receptors that inhabit or use the site. The first criterion considered in this analysis is whether the total area of soil contamination is less than 350 square feet. The lateral footprint of contamination at the site exceeds this area, so the TEE was continued.

The next criterion in the exposure analysis considers whether land use at the site and surrounding area makes substantial wildlife exposure unlikely using the procedure outlined in MTCA Table 749-1, which is summarized here as Table 1.

Table 1. Exposure analysis

Estimate the area of contiguous (connected) undeveloped land on the site or within 500 feet of any area of the site to the nearest 1/2 acre	
1) Find the number of points corresponding to the area and enter this number in the box to the right. Area (acres) — Points 0.25 or less — 4 0.5 — 5 1.0 — 6 1.5 — 7 2.0 — 8 2.5 — 9 3.0 — 10 3.5 — 11 4.0 or more — 12	12
2) Is this an industrial or commercial property? If yes, enter a score of 3 in the box to the right. If no, enter a score of 1.	3
3) Enter a score in the box to the right for the habitat quality of the site, using the rating system shown below (High = 1, Intermediate = 2, Low = 3)	3
4) Is the undeveloped land likely to attract wildlife? If yes, enter a score of 1 in the box to the right. If no, enter a score of 2.	2
5) Are there any of the following soil contaminants present: Chlorinated dioxins/furans, PCB mixtures, DDT, DDE, DDD, aldrin, chlordane, dieldrin, endosulfan, endrin, heptachlor, benzene hexachloride, toxaphene, hexachlorobenzene, pentachlorophenol, pentachlorobenzene? If yes, enter a score of 1 in the box to the right. If no, enter a score of 4.	1
6) Add the numbers in the boxes on lines 2 through 5 and enter this number in the box to the right. If this number is larger than the number in the box on line 1, the simplified terrestrial ecological evaluation may be ended.	9

Based on input from Ecology, there is greater than 4 acres of open space within 500 feet of the site that constitutes contiguous undeveloped land. The roads and other structures present in this area are considered unlikely to reduce potential use by wildlife. The calculated score (Step 6) in Table 1 (9 points) is not higher than Step 1 score (12 points), therefore the simplified TEE may not be ended at the exposure analysis step.

3 Pathways Analysis

The pathway analysis is used to determine whether there are complete pathways by which soil biota, plants or wildlife may be exposed to soil contamination. The site is zoned rural industrial and therefore only potential exposures to wildlife (e.g., small mammals, birds) need to be considered [WAC 173-340-7492(2)(b)]. The areas with the greatest concentrations of soil contamination are presently covered by gravel parking areas and driveways. However, other areas of the site are unpaved, so complete exposure pathways exist at the site.

4 Contaminants Analysis

The contaminants analysis involves a comparison between soil chemistry data from the site and concentrations listed in MTCA Table 749-2 for priority contaminants of ecological concern. The soil chemistry data were collected from locations shown in the Remedial Investigation report. For the purposes of the TEE, only soil collected within six feet of the surface were considered. This is the conditional point of compliance for the TEE for this site, which includes an institutional control to prevent excavation between six and fifteen feet below the surface, which is the standard point of compliance in MTCA.

All applicable soil chemistry data were first evaluated to determine whether the maximum detected concentrations of any hazardous substance exceeded the values for an industrial or commercial site listed in MTCA Table 749-2 (Table 2). The maximum concentrations of arsenic, copper, dioxin toxicity equivalent (TEQ), furan TEQ, lead, mercury, and zinc were identified as chemicals of potential ecological concern. Many detected chemicals, particularly polycyclic aromatic hydrocarbons (PAHs) do not have values in Table 749-2. However, the maximum concentration of the one PAH with a value in that table, benzo(a)pyrene, was less than 1% of the screening value. Based on this comparison, it is unlikely that any of the other PAHs represent an ecological concern for terrestrial wildlife at this site.

Table 2. Identification of chemicals of potential ecological concern

Chemical	Units	Detection Frequency	Maximum Detected Concentration	Table 749-2 Concentration for Industrial or Commercial Site
1-Methylnaphthalene	µg/kg	6/41	910	n/a
2-Methylnaphthalene	µg/kg	8/41	450	n/a
Acenaphthene	µg/kg	3/41	130	n/a
Acenaphthylene	µg/kg	9/41	260	n/a
Anthracene	µg/kg	16/41	370	n/a
Arsenic	mg/kg	82/83	**30**	20
Benz(a)anthracene	µg/kg	35/67	1,200	n/a
Benzo(a)pyrene	µg/kg	42/67	1,100	300,000

Chemical	Units	Detection Frequency	Maximum Detected Concentration	Table 749-2 Concentration for Industrial or Commercial Site
Benzo(b)fluoranthene	µg/kg	44/67	1,400	n/a
Benzo(ghi)perylene	µg/kg	26/41	950	n/a
Benzo(k)fluoranthene	µg/kg	19/67	280	n/a
Butyltin	µg/kg	5/6	86.8	n/a
Cadmium	mg/kg	28/83	10	36
Chromium	mg/kg	83/83	44	135
Chrysene	µg/kg	34/67	1,300	n/a
Copper	mg/kg	95/95	**12,000**	550
Dibenzo(a,h)anthracene	µg/kg	14/67	200	n/a
Dibutyltin	µg/kg	5/6	62.7	n/a
Diesel Range Organics	mg/kg	17/79	8,000	15,000
Dimethyl phthalate	µg/kg	1/1	290	n/a
Dioxin TEQ	ng/kg	5/5	**22.5**	5
Fluoranthene	µg/kg	26/41	2,200	n/a
Fluorene	µg/kg	2/41	130	n/a
Furan TEQ	ng/kg	5/5	**3.6**	3
Gasoline Range Organics	mg/kg	2/21	37	12,000
Indeno(1,2,3-cd)pyrene	µg/kg	39/67	800	n/a
Lead	mg/kg	83/83	**1,200**	220
Lube oil	mg/kg	3/24	2,200	n/a
Mercury	mg/kg	63/91	**13**	9[a]
Motor oil	mg/kg	24/44	10,000	n/a
Naphthalene	µg/kg	6/41	140	n/a
Nickel	mg/kg	3/3	10.3	1,850
PCBs (total)	µg/kg	6/15	460	2,000
Phenanthrene	µg/kg	20/41	1,200	n/a
Pyrene	µg/kg	26/41	1,900	n/a
Residual Range Organics	mg/kg	5/11	1,100	n/a
Tributyltin	µg/kg	5/6	55.5	n/a
Zinc	mg/kg	82/82	**2,600**	570

[a] Inorganic mercury

The metals identified as chemicals of potential ecological concern were further evaluated using statistical techniques. Two or more samples, at different depths, were collected at many of the sampling locations. Before conducting additional statistical evaluations, the results for arsenic, copper, lead, mercury, and zinc were averaged for each location where multiple samples were collected. The reporting limit was used in the average for non-detect results. Upper confidence limits (UCLs) on the mean concentrations were calculated using ProUCL (v5.1) software. Only five samples were analyzed for dioxins and furans, which is not enough data to calculate reliable UCLs.

The 95% UCLs for copper and lead were above the values in MTCA Table 749-2, but the UCLs for arsenic, mercury, and zinc were not (Table 3). The ProUCL calculations are provided in Appendix A. Additional evaluation of individual results was conducted in consideration of MTCA requirements for compliance monitoring. None of the arsenic and mercury concentrations exceeded the Table 749-2 values by more than two times and less than 10% of the results exceeded the Table 749-2 values. Therefore, arsenic and mercury are not considered to be chemicals of ecological concern. Several zinc results exceeded the Table 749-2 value by more than two times, so zinc is still considered to be a chemical of ecological concern, along with copper, lead, and dioxins/furans.

Table 3. UCLs for metals of potential ecological concern

Chemical	Units	95% UCL	Table 749-2 Concentration for Industrial or Commercial Site
Arsenic	mg/kg	6.3	20
Copper	mg/kg	1,565	550
Lead	mg/kg	239	220
Mercury	mg/kg	1.5	9
Zinc	mg/kg	551	570

Appendix A. ProUCL Calculations

	A	B	C	D	E	F	G	H	I	J	K	L
1	UCL Statistics for Data Sets with Non-Detects											
2												
3	User Selected Options											
4	Date/Time of Computation			ProUCL 5.19/24/2025 2:21:58 PM								
5	From File			ProUCL.xls								
6	Full Precision			OFF								
7	Confidence Coefficient			95%								
8	Number of Bootstrap Operations			2000								
9												
10												
11	Arsenic											
12												
13	General Statistics											
14	Total Number of Observations					52	Number of Distinct Observations					47
15							Number of Missing Observations					0
16	Minimum					1.785	Mean					5.489
17	Maximum					30	Median					4.525
18	SD					4.236	Std. Error of Mean					0.587
19	Coefficient of Variation					0.772	Skewness					4.02
20												
21	Normal GOF Test											
22	Shapiro Wilk Test Statistic					0.654	Shapiro Wilk GOF Test					
23	5% Shapiro Wilk P Value					7.327E-15	Data Not Normal at 5% Significance Level					
24	Lilliefors Test Statistic					0.191	Lilliefors GOF Test					
25	5% Lilliefors Critical Value					0.122	Data Not Normal at 5% Significance Level					
26	Data Not Normal at 5% Significance Level											
27												
28	Assuming Normal Distribution											
29	95% Normal UCL						95% UCLs (Adjusted for Skewness)					
30	95% Student's-t UCL					6.473	95% Adjusted-CLT UCL (Chen-1995)					6.805
31							95% Modified-t UCL (Johnson-1978)					6.527
32												
33	Gamma GOF Test											
34	A-D Test Statistic					0.793	Anderson-Darling Gamma GOF Test					
35	5% A-D Critical Value					0.757	Data Not Gamma Distributed at 5% Significance Level					
36	K-S Test Statistic					0.104	Kolmogorov-Smirnov Gamma GOF Test					
37	5% K-S Critical Value					0.124	Detected data appear Gamma Distributed at 5% Significance Level					
38	Detected data follow Appr. Gamma Distribution at 5% Significance Level											
39												
40	Gamma Statistics											
41	k hat (MLE)					3.109	k star (bias corrected MLE)					2.943
42	Theta hat (MLE)					1.765	Theta star (bias corrected MLE)					1.865
43	nu hat (MLE)					323.4	nu star (bias corrected)					306.1
44	MLE Mean (bias corrected)					5.489	MLE Sd (bias corrected)					3.199
45							Approximate Chi Square Value (0.05)					266.5
46	Adjusted Level of Significance					0.0454	Adjusted Chi Square Value					265.5
47												
48	Assuming Gamma Distribution											

49	95% Approximate Gamma UCL (use when n>=50)	6.303	95% Adjusted Gamma UCL (use when n<50)	6.327
50				
51	**Lognormal GOF Test**			
52	Shapiro Wilk Test Statistic	0.967	**Shapiro Wilk Lognormal GOF Test**	
53	5% Shapiro Wilk P Value	0.282	Data appear Lognormal at 5% Significance Level	
54	Lilliefors Test Statistic	0.0662	**Lilliefors Lognormal GOF Test**	
55	5% Lilliefors Critical Value	0.122	Data appear Lognormal at 5% Significance Level	
56	**Data appear Lognormal at 5% Significance Level**			
57				
58	**Lognormal Statistics**			
59	Minimum of Logged Data	0.579	Mean of logged Data	1.533
60	Maximum of Logged Data	3.401	SD of logged Data	0.549
61				
62	**Assuming Lognormal Distribution**			
63	95% H-UCL	6.24	90% Chebyshev (MVUE) UCL	6.67
64	95% Chebyshev (MVUE) UCL	7.259	97.5% Chebyshev (MVUE) UCL	8.077
65	99% Chebyshev (MVUE) UCL	9.683		
66				
67	**Nonparametric Distribution Free UCL Statistics**			
68	**Data appear to follow a Discernible Distribution at 5% Significance Level**			
69				
70	**Nonparametric Distribution Free UCLs**			
71	95% CLT UCL	6.455	95% Jackknife UCL	6.473
72	95% Standard Bootstrap UCL	6.419	95% Bootstrap-t UCL	7.165
73	95% Hall's Bootstrap UCL	10.91	95% Percentile Bootstrap UCL	6.505
74	95% BCA Bootstrap UCL	6.867		
75	90% Chebyshev(Mean, Sd) UCL	7.251	95% Chebyshev(Mean, Sd) UCL	8.049
76	97.5% Chebyshev(Mean, Sd) UCL	9.157	99% Chebyshev(Mean, Sd) UCL	11.33
77				
78	**Suggested UCL to Use**			
79	95% Approximate Gamma UCL	6.303		
80				
81	When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test			
82	When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL			
83				
84	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
85	Recommendations are based upon data size, data distribution, and skewness.			
86	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
87	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
88				
89				
90	Copper			
91				
92	**General Statistics**			
93	Total Number of Observations	58	Number of Distinct Observations	57
94			Number of Missing Observations	0
95	Minimum	8.32	Mean	691.7
96	Maximum	6700	Median	94.25

	A	B	C	D	E	F	G	H	I	J	K	L
97					SD	1526					Std. Error of Mean	200.3
98					Coefficient of Variation	2.206					Skewness	3.02
99												
100	**Normal GOF Test**											
101					Shapiro Wilk Test Statistic	0.49	**Shapiro Wilk GOF Test**					
102					5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level					
103					Lilliefors Test Statistic	0.333	**Lilliefors GOF Test**					
104					5% Lilliefors Critical Value	0.116	Data Not Normal at 5% Significance Level					
105	**Data Not Normal at 5% Significance Level**											
106												
107	**Assuming Normal Distribution**											
108	**95% Normal UCL**						**95% UCLs (Adjusted for Skewness)**					
109					95% Student's-t UCL	1027					95% Adjusted-CLT UCL (Chen-1995)	1106
110											95% Modified-t UCL (Johnson-1978)	1040
111												
112	**Gamma GOF Test**											
113					A-D Test Statistic	4.534	**Anderson-Darling Gamma GOF Test**					
114					5% A-D Critical Value	0.837	Data Not Gamma Distributed at 5% Significance Level					
115					K-S Test Statistic	0.244	**Kolmogorov-Smirnov Gamma GOF Test**					
116					5% K-S Critical Value	0.125	Data Not Gamma Distributed at 5% Significance Level					
117	**Data Not Gamma Distributed at 5% Significance Level**											
118												
119	**Gamma Statistics**											
120					k hat (MLE)	0.412					k star (bias corrected MLE)	0.402
121					Theta hat (MLE)	1679					Theta star (bias corrected MLE)	1720
122					nu hat (MLE)	47.8					nu star (bias corrected)	46.66
123					MLE Mean (bias corrected)	691.7					MLE Sd (bias corrected)	1091
124											Approximate Chi Square Value (0.05)	31.98
125					Adjusted Level of Significance	0.0459					Adjusted Chi Square Value	31.68
126												
127	**Assuming Gamma Distribution**											
128					95% Approximate Gamma UCL (use when n>=50))	1009					95% Adjusted Gamma UCL (use when n<50)	1019
129												
130	**Lognormal GOF Test**											
131					Shapiro Wilk Test Statistic	0.919	**Shapiro Wilk Lognormal GOF Test**					
132					5% Shapiro Wilk P Value	6.7293E-4	Data Not Lognormal at 5% Significance Level					
133					Lilliefors Test Statistic	0.139	**Lilliefors Lognormal GOF Test**					
134					5% Lilliefors Critical Value	0.116	Data Not Lognormal at 5% Significance Level					
135	**Data Not Lognormal at 5% Significance Level**											
136												
137	**Lognormal Statistics**											
138					Minimum of Logged Data	2.119					Mean of logged Data	4.95
139					Maximum of Logged Data	8.81					SD of logged Data	1.699
140												
141	**Assuming Lognormal Distribution**											
142					95% H-UCL	1283					90% Chebyshev (MVUE) UCL	1096
143					95% Chebyshev (MVUE) UCL	1337					97.5% Chebyshev (MVUE) UCL	1671
144					99% Chebyshev (MVUE) UCL	2327						

Nonparametric Distribution Free UCL Statistics

Data do not follow a Discernible Distribution (0.05)

Nonparametric Distribution Free UCLs

95% CLT UCL	1021	95% Jackknife UCL	1027
95% Standard Bootstrap UCL	1010	95% Bootstrap-t UCL	1187
95% Hall's Bootstrap UCL	1031	95% Percentile Bootstrap UCL	1046
95% BCA Bootstrap UCL	1115		
90% Chebyshev(Mean, Sd) UCL	1293	95% Chebyshev(Mean, Sd) UCL	1565
97.5% Chebyshev(Mean, Sd) UCL	1943	99% Chebyshev(Mean, Sd) UCL	2685

Suggested UCL to Use

95% Chebyshev (Mean, Sd) UCL	1565		

Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.

Recommendations are based upon data size, data distribution, and skewness.

These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).

However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.

Lead

General Statistics

Total Number of Observations	52	Number of Distinct Observations	51
		Number of Missing Observations	0
Minimum	1.9	Mean	172.8
Maximum	920	Median	72.85
SD	223.4	Std. Error of Mean	30.98
Coefficient of Variation	1.293	Skewness	1.654

Normal GOF Test

Shapiro Wilk Test Statistic	0.748	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	2.832E-11	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.243	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.122	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	224.7	95% Adjusted-CLT UCL (Chen-1995)	231.4
		95% Modified-t UCL (Johnson-1978)	225.9

Gamma GOF Test

A-D Test Statistic	0.598	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.805	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.119	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.129	Detected data appear Gamma Distributed at 5% Significance Level

	A–E	F	G–K	L
193	**Detected data appear Gamma Distributed at 5% Significance Level**			
194				
195	**Gamma Statistics**			
196	k hat (MLE)	0.614	k star (bias corrected MLE)	0.592
197	Theta hat (MLE)	281.3	Theta star (bias corrected MLE)	292.1
198	nu hat (MLE)	63.89	nu star (bias corrected)	61.53
199	MLE Mean (bias corrected)	172.8	MLE Sd (bias corrected)	224.7
200			Approximate Chi Square Value (0.05)	44.49
201	Adjusted Level of Significance	0.0454	Adjusted Chi Square Value	44.08
202				
203	**Assuming Gamma Distribution**			
204	95% Approximate Gamma UCL (use when n>=50)	239	95% Adjusted Gamma UCL (use when n<50)	241.3
205				
206	**Lognormal GOF Test**			
207	Shapiro Wilk Test Statistic	0.95	**Shapiro Wilk Lognormal GOF Test**	
208	5% Shapiro Wilk P Value	0.0536	Data appear Lognormal at 5% Significance Level	
209	Lilliefors Test Statistic	0.0736	**Lilliefors Lognormal GOF Test**	
210	5% Lilliefors Critical Value	0.122	Data appear Lognormal at 5% Significance Level	
211	**Data appear Lognormal at 5% Significance Level**			
212				
213	**Lognormal Statistics**			
214	Minimum of Logged Data	0.642	Mean of logged Data	4.15
215	Maximum of Logged Data	6.824	SD of logged Data	1.654
216				
217	**Assuming Lognormal Distribution**			
218	95% H-UCL	511.9	90% Chebyshev (MVUE) UCL	457.5
219	95% Chebyshev (MVUE) UCL	558.3	97.5% Chebyshev (MVUE) UCL	698.3
220	99% Chebyshev (MVUE) UCL	973.1		
221				
222	**Nonparametric Distribution Free UCL Statistics**			
223	**Data appear to follow a Discernible Distribution at 5% Significance Level**			
224				
225	**Nonparametric Distribution Free UCLs**			
226	95% CLT UCL	223.8	95% Jackknife UCL	224.7
227	95% Standard Bootstrap UCL	222.9	95% Bootstrap-t UCL	237.7
228	95% Hall's Bootstrap UCL	231	95% Percentile Bootstrap UCL	224.8
229	95% BCA Bootstrap UCL	233.1		
230	90% Chebyshev(Mean, Sd) UCL	265.8	95% Chebyshev(Mean, Sd) UCL	307.9
231	97.5% Chebyshev(Mean, Sd) UCL	366.3	99% Chebyshev(Mean, Sd) UCL	481.1
232				
233	**Suggested UCL to Use**			
234	95% Approximate Gamma UCL	239		
235				
236	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
237	Recommendations are based upon data size, data distribution, and skewness.			
238	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
239	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
240				

Mercury

General Statistics

Total Number of Observations	56	Number of Distinct Observations	47
Number of Detects	47	Number of Non-Detects	9
Number of Distinct Detects	43	Number of Distinct Non-Detects	5
Minimum Detect	0.021	Minimum Non-Detect	0.02
Maximum Detect	13	Maximum Non-Detect	1
Variance Detects	3.518	Percent Non-Detects	16.07%
Mean Detects	0.554	SD Detects	1.876
Median Detects	0.183	CV Detects	3.386
Skewness Detects	6.628	Kurtosis Detects	44.83
Mean of Logged Detects	-1.664	SD of Logged Detects	1.255

Normal GOF Test on Detects Only

Shapiro Wilk Test Statistic	0.248	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.946	Detected Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.403	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.128	Detected Data Not Normal at 5% Significance Level

Detected Data Not Normal at 5% Significance Level

Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs

KM Mean	0.473	KM Standard Error of Mean	0.231
KM SD	1.71	95% KM (BCA) UCL	0.952
95% KM (t) UCL	0.859	95% KM (Percentile Bootstrap) UCL	0.922
95% KM (z) UCL	0.853	95% KM Bootstrap t UCL	2.511
90% KM Chebyshev UCL	1.166	95% KM Chebyshev UCL	1.48
97.5% KM Chebyshev UCL	1.916	99% KM Chebyshev UCL	2.772

Gamma GOF Tests on Detected Observations Only

A-D Test Statistic	3.402	**Anderson-Darling GOF Test**
5% A-D Critical Value	0.807	Detected Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.197	**Kolmogorov-Smirnov GOF**
5% K-S Critical Value	0.136	Detected Data Not Gamma Distributed at 5% Significance Level

Detected Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics on Detected Data Only

k hat (MLE)	0.579	k star (bias corrected MLE)	0.556
Theta hat (MLE)	0.957	Theta star (bias corrected MLE)	0.997
nu hat (MLE)	54.39	nu star (bias corrected)	52.25
Mean (detects)	0.554		

Gamma ROS Statistics using Imputed Non-Detects

GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs

GROS may not be used when kstar of detects is small such as <1.0, especially when the sample size is small (e.g., <15-20)

For such situations, GROS method may yield incorrect values of UCLs and BTVs

This is especially true when the sample size is small.

For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates

Minimum	0.01	Mean	0.467
Maximum	13	Median	0.163
SD	1.727	CV	3.702
k hat (MLE)	0.467	k star (bias corrected MLE)	0.454
Theta hat (MLE)	0.999	Theta star (bias corrected MLE)	1.028
nu hat (MLE)	52.31	nu star (bias corrected)	50.84
Adjusted Level of Significance (β)	0.0457		
Approximate Chi Square Value (50.84, α)	35.47	Adjusted Chi Square Value (50.84, β)	35.13
95% Gamma Approximate UCL (use when n>=50)	0.669	95% Gamma Adjusted UCL (use when n<50)	0.675
Estimates of Gamma Parameters using KM Estimates			
Mean (KM)	0.473	SD (KM)	1.71
Variance (KM)	2.925	SE of Mean (KM)	0.231
k hat (KM)	0.0764	k star (KM)	0.0842
nu hat (KM)	8.56	nu star (KM)	9.434
theta hat (KM)	6.187	theta star (KM)	5.613
80% gamma percentile (KM)	0.248	90% gamma percentile (KM)	1.156
95% gamma percentile (KM)	2.754	99% gamma percentile (KM)	8.17
Gamma Kaplan-Meier (KM) Statistics			
Approximate Chi Square Value (9.43, α)	3.591	Adjusted Chi Square Value (9.43, β)	3.496
95% Gamma Approximate KM-UCL (use when n>=50)	1.242	95% Gamma Adjusted KM-UCL (use when n<50)	1.276
Lognormal GOF Test on Detected Observations Only			
Shapiro Wilk Test Statistic	0.937	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.946	Detected Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.128	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.128	Detected Data Not Lognormal at 5% Significance Level	
Detected Data Not Lognormal at 5% Significance Level			
Lognormal ROS Statistics Using Imputed Non-Detects			
Mean in Original Scale	0.471	Mean in Log Scale	-1.988
SD in Original Scale	1.726	SD in Log Scale	1.411
95% t UCL (assumes normality of ROS data)	0.857	95% Percentile Bootstrap UCL	0.906
95% BCA Bootstrap UCL	1.309	95% Bootstrap t UCL	2.566
95% H-UCL (Log ROS)	0.649		
Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution			
KM Mean (logged)	-1.96	KM Geo Mean	0.141
KM SD (logged)	1.354	95% Critical H Value (KM-Log)	2.875
KM Standard Error of Mean (logged)	0.185	95% H-UCL (KM -Log)	0.595
KM SD (logged)	1.354	95% Critical H Value (KM-Log)	2.875
KM Standard Error of Mean (logged)	0.185		
DL/2 Statistics			
DL/2 Normal		**DL/2 Log-Transformed**	
Mean in Original Scale	0.479	Mean in Log Scale	-1.919
SD in Original Scale	1.725	SD in Log Scale	1.37

95% t UCL (Assumes normality)	0.865	95% H-Stat UCL	0.641
DL/2 is not a recommended method, provided for comparisons and historical reasons			
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution at 5% Significance Level			
Suggested UCL to Use			
95% KM (Chebyshev) UCL	1.48		
Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
Recommendations are based upon data size, data distribution, and skewness.			
These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
Zinc			
General Statistics			
Total Number of Observations	51	Number of Distinct Observations	48
		Number of Missing Observations	0
Minimum	16.7	Mean	341
Maximum	2300	Median	108
SD	481.7	Std. Error of Mean	67.45
Coefficient of Variation	1.413	Skewness	2.321
Normal GOF Test			
Shapiro Wilk Test Statistic	0.681	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk P Value	1.589E-13	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.264	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.123	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	454	95% Adjusted-CLT UCL (Chen-1995)	475.4
		95% Modified-t UCL (Johnson-1978)	457.7
Gamma GOF Test			
A-D Test Statistic	1.75	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.793	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.175	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.129	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.752	k star (bias corrected MLE)	0.72
Theta hat (MLE)	453.7	Theta star (bias corrected MLE)	473.3
nu hat (MLE)	76.66	nu star (bias corrected)	73.48

	A	B	C	D	E	F	G	H	I	J	K	L
385	MLE Mean (bias corrected)					341	MLE Sd (bias corrected)					401.8
386							Approximate Chi Square Value (0.05)					54.74
387	Adjusted Level of Significance					0.0453	Adjusted Chi Square Value					54.27
388												
389	**Assuming Gamma Distribution**											
390	95% Approximate Gamma UCL (use when n>=50))					457.7	95% Adjusted Gamma UCL (use when n<50)					461.7
391												
392	**Lognormal GOF Test**											
393	Shapiro Wilk Test Statistic					0.956	**Shapiro Wilk Lognormal GOF Test**					
394	5% Shapiro Wilk P Value					0.0975	Data appear Lognormal at 5% Significance Level					
395	Lilliefors Test Statistic					0.119	**Lilliefors Lognormal GOF Test**					
396	5% Lilliefors Critical Value					0.123	Data appear Lognormal at 5% Significance Level					
397	**Data appear Lognormal at 5% Significance Level**											
398												
399	**Lognormal Statistics**											
400	Minimum of Logged Data					2.815	Mean of logged Data					5.036
401	Maximum of Logged Data					7.741	SD of logged Data					1.271
402												
403	**Assuming Lognormal Distribution**											
404	95% H-UCL					551.2	90% Chebyshev (MVUE) UCL					561.6
405	95% Chebyshev (MVUE) UCL					663.9	97.5% Chebyshev (MVUE) UCL					805.9
406	99% Chebyshev (MVUE) UCL					1085						
407												
408	**Nonparametric Distribution Free UCL Statistics**											
409	**Data appear to follow a Discernible Distribution at 5% Significance Level**											
410												
411	**Nonparametric Distribution Free UCLs**											
412	95% CLT UCL					451.9	95% Jackknife UCL					454
413	95% Standard Bootstrap UCL					451.2	95% Bootstrap-t UCL					487.2
414	95% Hall's Bootstrap UCL					486.9	95% Percentile Bootstrap UCL					454.7
415	95% BCA Bootstrap UCL					472.4						
416	90% Chebyshev(Mean, Sd) UCL					543.3	95% Chebyshev(Mean, Sd) UCL					635
417	97.5% Chebyshev(Mean, Sd) UCL					762.2	99% Chebyshev(Mean, Sd) UCL					1012
418												
419	**Suggested UCL to Use**											
420	95% H-UCL					551.2						
421												
422	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
423	Recommendations are based upon data size, data distribution, and skewness.											
424	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
425	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
426												
427	**ProUCL computes and outputs H-statistic based UCLs for historical reasons only.**											
428	**H-statistic often results in unstable (both high and low) values of UCL95 as shown in examples in the Technical Guide.**											
429	**It is therefore recommended to avoid the use of H-statistic based 95% UCLs.**											
430	**Use of nonparametric methods are preferred to compute UCL95 for skewed data sets which do not follow a gamma distribution.**											
431												