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

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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

UCL Statistics for Data Sets with Non-Detects

User Selected Options	
Date/Time of Computation	ProUCL 5.19/24/2025 2:21:58 PM
From File	ProUCL.xls
Full Precision	OFF
Confidence Coefficient	95%
Number of Bootstrap Operations	2000

Arsenic

General Statistics

Total Number of Observations	52	Number of Distinct Observations	47
		Number of Missing Observations	0
Minimum	1.785	Mean	5.489
Maximum	30	Median	4.525
SD	4.236	Std. Error of Mean	0.587
Coefficient of Variation	0.772	Skewness	4.02

Normal GOF Test

Shapiro Wilk Test Statistic	0.654	**Shapiro Wilk GOF Test**
5% Shapiro Wilk P Value	7.327E-15	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.191	**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	6.473	95% Adjusted-CLT UCL (Chen-1995)	6.805
		95% Modified-t UCL (Johnson-1978)	6.527

Gamma GOF Test

A-D Test Statistic	0.793	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.757	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.104	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.124	Detected data appear Gamma Distributed at 5% Significance Level

Detected data follow Appr. Gamma Distribution at 5% Significance Level

Gamma Statistics

k hat (MLE)	3.109	k star (bias corrected MLE)	2.943
Theta hat (MLE)	1.765	Theta star (bias corrected MLE)	1.865
nu hat (MLE)	323.4	nu star (bias corrected)	306.1
MLE Mean (bias corrected)	5.489	MLE Sd (bias corrected)	3.199
		Approximate Chi Square Value (0.05)	266.5
Adjusted Level of Significance	0.0454	Adjusted Chi Square Value	265.5

Assuming Gamma Distribution

	A	B	C	D	E	F	G	H	I	J	K	L
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

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						

	A	B	C	D	E	F	G	H	I	J	K	L
145												
146	**Nonparametric Distribution Free UCL Statistics**											
147	**Data do not follow a Discernible Distribution (0.05)**											
148												
149	**Nonparametric Distribution Free UCLs**											
150					95% CLT UCL	1021			95% Jackknife UCL	1027		
151					95% Standard Bootstrap UCL	1010			95% Bootstrap-t UCL	1187		
152					95% Hall's Bootstrap UCL	1031			95% Percentile Bootstrap UCL	1046		
153					95% BCA Bootstrap UCL	1115						
154					90% Chebyshev(Mean, Sd) UCL	1293			95% Chebyshev(Mean, Sd) UCL	1565		
155					97.5% Chebyshev(Mean, Sd) UCL	1943			99% Chebyshev(Mean, Sd) UCL	2685		
156												
157	**Suggested UCL to Use**											
158					95% Chebyshev (Mean, Sd) UCL	1565						
159												
160	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
161	Recommendations are based upon data size, data distribution, and skewness.											
162	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
163	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
164												
165												
166	**Lead**											
167												
168	**General Statistics**											
169					Total Number of Observations	52			Number of Distinct Observations	51		
170									Number of Missing Observations	0		
171					Minimum	1.9			Mean	172.8		
172					Maximum	920			Median	72.85		
173					SD	223.4			Std. Error of Mean	30.98		
174					Coefficient of Variation	1.293			Skewness	1.654		
175												
176	**Normal GOF Test**											
177					Shapiro Wilk Test Statistic	0.748			**Shapiro Wilk GOF Test**			
178					5% Shapiro Wilk P Value	2.832E-11			Data Not Normal at 5% Significance Level			
179					Lilliefors Test Statistic	0.243			**Lilliefors GOF Test**			
180					5% Lilliefors Critical Value	0.122			Data Not Normal at 5% Significance Level			
181	**Data Not Normal at 5% Significance Level**											
182												
183	**Assuming Normal Distribution**											
184	**95% Normal UCL**								**95% UCLs (Adjusted for Skewness)**			
185					95% Student's-t UCL	224.7			95% Adjusted-CLT UCL (Chen-1995)	231.4		
186									95% Modified-t UCL (Johnson-1978)	225.9		
187												
188	**Gamma GOF Test**											
189					A-D Test Statistic	0.598			**Anderson-Darling Gamma GOF Test**			
190					5% A-D Critical Value	0.805			Detected data appear Gamma Distributed at 5% Significance Level			
191					K-S Test Statistic	0.119			**Kolmogorov-Smirnov Gamma GOF Test**			
192					5% K-S Critical Value	0.129			Detected data appear Gamma Distributed at 5% Significance Level			

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												

	A	B	C	D	E	F	G	H	I	J	K	L
241	**Mercury**											
242												
243	**General Statistics**											
244	Total Number of Observations					56	Number of Distinct Observations					47
245	Number of Detects					47	Number of Non-Detects					9
246	Number of Distinct Detects					43	Number of Distinct Non-Detects					5
247	Minimum Detect					0.021	Minimum Non-Detect					0.02
248	Maximum Detect					13	Maximum Non-Detect					1
249	Variance Detects					3.518	Percent Non-Detects					16.07%
250	Mean Detects					0.554	SD Detects					1.876
251	Median Detects					0.183	CV Detects					3.386
252	Skewness Detects					6.628	Kurtosis Detects					44.83
253	Mean of Logged Detects					-1.664	SD of Logged Detects					1.255
254												
255	**Normal GOF Test on Detects Only**											
256	Shapiro Wilk Test Statistic					0.248	**Shapiro Wilk GOF Test**					
257	5% Shapiro Wilk Critical Value					0.946	Detected Data Not Normal at 5% Significance Level					
258	Lilliefors Test Statistic					0.403	**Lilliefors GOF Test**					
259	5% Lilliefors Critical Value					0.128	Detected Data Not Normal at 5% Significance Level					
260	**Detected Data Not Normal at 5% Significance Level**											
261												
262	**Kaplan-Meier (KM) Statistics using Normal Critical Values and other Nonparametric UCLs**											
263	KM Mean					0.473	KM Standard Error of Mean					0.231
264	KM SD					1.71	95% KM (BCA) UCL					0.952
265	95% KM (t) UCL					0.859	95% KM (Percentile Bootstrap) UCL					0.922
266	95% KM (z) UCL					0.853	95% KM Bootstrap t UCL					2.511
267	90% KM Chebyshev UCL					1.166	95% KM Chebyshev UCL					1.48
268	97.5% KM Chebyshev UCL					1.916	99% KM Chebyshev UCL					2.772
269												
270	**Gamma GOF Tests on Detected Observations Only**											
271	A-D Test Statistic					3.402	**Anderson-Darling GOF Test**					
272	5% A-D Critical Value					0.807	Detected Data Not Gamma Distributed at 5% Significance Level					
273	K-S Test Statistic					0.197	**Kolmogorov-Smirnov GOF**					
274	5% K-S Critical Value					0.136	Detected Data Not Gamma Distributed at 5% Significance Level					
275	**Detected Data Not Gamma Distributed at 5% Significance Level**											
276												
277	**Gamma Statistics on Detected Data Only**											
278	k hat (MLE)					0.579	k star (bias corrected MLE)					0.556
279	Theta hat (MLE)					0.957	Theta star (bias corrected MLE)					0.997
280	nu hat (MLE)					54.39	nu star (bias corrected)					52.25
281	Mean (detects)					0.554						
282												
283	**Gamma ROS Statistics using Imputed Non-Detects**											
284	GROS may not be used when data set has > 50% NDs with many tied observations at multiple DLs											
285	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)											
286	For such situations, GROS method may yield incorrect values of UCLs and BTVs											
287	This is especially true when the sample size is small.											
288	For gamma distributed detected data, BTVs and UCLs may be computed using gamma distribution on KM estimates											

289					Minimum	0.01					Mean	0.467
290					Maximum	13					Median	0.163
291					SD	1.727					CV	3.702
292					k hat (MLE)	0.467					k star (bias corrected MLE)	0.454
293					Theta hat (MLE)	0.999					Theta star (bias corrected MLE)	1.028
294					nu hat (MLE)	52.31					nu star (bias corrected)	50.84
295					Adjusted Level of Significance (β)	0.0457						
296					Approximate Chi Square Value (50.84, α)	35.47					Adjusted Chi Square Value (50.84, β)	35.13
297					95% Gamma Approximate UCL (use when n>=50)	0.669					95% Gamma Adjusted UCL (use when n<50)	0.675
298												
299					**Estimates of Gamma Parameters using KM Estimates**							
300					Mean (KM)	0.473					SD (KM)	1.71
301					Variance (KM)	2.925					SE of Mean (KM)	0.231
302					k hat (KM)	0.0764					k star (KM)	0.0842
303					nu hat (KM)	8.56					nu star (KM)	9.434
304					theta hat (KM)	6.187					theta star (KM)	5.613
305					80% gamma percentile (KM)	0.248					90% gamma percentile (KM)	1.156
306					95% gamma percentile (KM)	2.754					99% gamma percentile (KM)	8.17
307												
308					**Gamma Kaplan-Meier (KM) Statistics**							
309					Approximate Chi Square Value (9.43, α)	3.591					Adjusted Chi Square Value (9.43, β)	3.496
310					95% Gamma Approximate KM-UCL (use when n>=50)	1.242					95% Gamma Adjusted KM-UCL (use when n<50)	1.276
311												
312					**Lognormal GOF Test on Detected Observations Only**							
313					Shapiro Wilk Test Statistic	0.937					**Shapiro Wilk GOF Test**	
314					5% Shapiro Wilk Critical Value	0.946					Detected Data Not Lognormal at 5% Significance Level	
315					Lilliefors Test Statistic	0.128					**Lilliefors GOF Test**	
316					5% Lilliefors Critical Value	0.128					Detected Data Not Lognormal at 5% Significance Level	
317					**Detected Data Not Lognormal at 5% Significance Level**							
318												
319					**Lognormal ROS Statistics Using Imputed Non-Detects**							
320					Mean in Original Scale	0.471					Mean in Log Scale	-1.988
321					SD in Original Scale	1.726					SD in Log Scale	1.411
322					95% t UCL (assumes normality of ROS data)	0.857					95% Percentile Bootstrap UCL	0.906
323					95% BCA Bootstrap UCL	1.309					95% Bootstrap t UCL	2.566
324					95% H-UCL (Log ROS)	0.649						
325												
326					**Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution**							
327					KM Mean (logged)	-1.96					KM Geo Mean	0.141
328					KM SD (logged)	1.354					95% Critical H Value (KM-Log)	2.875
329					KM Standard Error of Mean (logged)	0.185					95% H-UCL (KM -Log)	0.595
330					KM SD (logged)	1.354					95% Critical H Value (KM-Log)	2.875
331					KM Standard Error of Mean (logged)	0.185						
332												
333					**DL/2 Statistics**							
334					**DL/2 Normal**						**DL/2 Log-Transformed**	
335					Mean in Original Scale	0.479					Mean in Log Scale	-1.919
336					SD in Original Scale	1.725					SD in Log Scale	1.37

337				95% t UCL (Assumes normality)		0.865					95% H-Stat UCL	0.641
338	**DL/2 is not a recommended method, provided for comparisons and historical reasons**											
339												
340	**Nonparametric Distribution Free UCL Statistics**											
341	**Data do not follow a Discernible Distribution at 5% Significance Level**											
342												
343	**Suggested UCL to Use**											
344				95% KM (Chebyshev) UCL		1.48						
345												
346	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
347	Recommendations are based upon data size, data distribution, and skewness.											
348	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
349	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
350												
351												
352	**Zinc**											
353												
354	**General Statistics**											
355				Total Number of Observations		51					Number of Distinct Observations	48
356											Number of Missing Observations	0
357				Minimum		16.7					Mean	341
358				Maximum		2300					Median	108
359				SD		481.7					Std. Error of Mean	67.45
360				Coefficient of Variation		1.413					Skewness	2.321
361												
362	**Normal GOF Test**											
363				Shapiro Wilk Test Statistic		0.681					**Shapiro Wilk GOF Test**	
364				5% Shapiro Wilk P Value		1.589E-13					Data Not Normal at 5% Significance Level	
365				Lilliefors Test Statistic		0.264					**Lilliefors GOF Test**	
366				5% Lilliefors Critical Value		0.123					Data Not Normal at 5% Significance Level	
367	**Data Not Normal at 5% Significance Level**											
368												
369	**Assuming Normal Distribution**											
370				**95% Normal UCL**							**95% UCLs (Adjusted for Skewness)**	
371				95% Student's-t UCL		454					95% Adjusted-CLT UCL (Chen-1995)	475.4
372											95% Modified-t UCL (Johnson-1978)	457.7
373												
374	**Gamma GOF Test**											
375				A-D Test Statistic		1.75					**Anderson-Darling Gamma GOF Test**	
376				5% A-D Critical Value		0.793					Data Not Gamma Distributed at 5% Significance Level	
377				K-S Test Statistic		0.175					**Kolmogorov-Smirnov Gamma GOF Test**	
378				5% K-S Critical Value		0.129					Data Not Gamma Distributed at 5% Significance Level	
379	**Data Not Gamma Distributed at 5% Significance Level**											
380												
381	**Gamma Statistics**											
382				k hat (MLE)		0.752					k star (bias corrected MLE)	0.72
383				Theta hat (MLE)		453.7					Theta star (bias corrected MLE)	473.3
384				nu hat (MLE)		76.66					nu star (bias corrected)	73.48

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												