Proposed Site-Specific Standard for Total Dissolved Solids

Blue Creek, Box Elder County, Utah

Utah Division of Water Quality

March 3, 2015 Draft

EXECUTIVE SUMMARY

New site-specific total dissolved solids (TDS) criteria that are higher than the statewide criteria of 1,200 mg/l are proposed for Blue Creek in Box Elder County, Utah. The site-specific criteria for Blue Creek are based on natural conditions influenced by the irreversible influences of the dam and subsequent management of the water in Blue Creek Reservoir. The criterion for Blue Creek Reservoir is based on natural conditions although the reservoir itself is not natural.

For the summer season (March through October), a maximum criterion of 7,200 mg/l and an average criterion of 3,800 mg/l TDS are recommended. For the winter season (November through February), a maximum criterion of 7,500 mg/l and an average criterion of 4,700 mg/l TDS are recommended. For assessing compliance with the average criterion, the mean of at least 10 samples must not be greater than 4,100 mg/l for the summer season or greater than 5,300 mg/l for the winter season. These will replace the existing site-specific criteria of 6,300 mg/l for the maximum criterion and the average criterion of 3,900 mg/l.

No changes are recommended for the Blue Creek Reservoir maximum criterion of 2,200 mg/l.

Proposed Site-specific Total Dissolved Criteria for Blue Creek and Blue Creek Reservoir (mg/l)			
Blue Creek Summer (March through October)		Blue Creek Winter (November through February)	
Maximum	Average	Maximum	Average
7,200	3,800	7,500	4,700

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Site-specific criteria for total dissolved solids (TDS) were adopted in 2014 for Blue Creek and Blue Creek Reservoir (Table 1). Prior to USEPA action on the standards change, a more detailed review of the historical data demonstrated that the newly adopted criteria were too low for Blue Creek. Specifically, individual and average concentrations in the historical data for Blue Creek exceeded the new criteria. The criteria are representative of natural conditions modified by irreversible conditions and therefore, must be consistent with the existing TDS data.

This document is an update of the *Proposed Site-Specific Standard for Total Dissolved Solid, Blue Creek, Box Elder County, Utah, September 24, 2013 Draft*. The methodology was revised for Blue Creek resulting in different recommendations for the criteria as presented herein. No changes are recommended to the criteria for Blue Creek Reservoir.

The methodology used represents one way of deriving these criteria. Previous derivations of site-specific criteria in Utah used different methods and other methods may be used to support site-specific criteria in the future. Many factors, such as the quantity and quality of the available data, hydrology, variability, and uncertainty, influence how site-specific criteria are developed. The methods used for Blue Creek and Blue Creek Reservoir may or may not be optimal for other site-specific standards.

1.1 INTRODUCTION

ATK Launch Systems-Promontory (ATK), Promontory, UT, recommended that the Utah Division of Water Quality revise the total dissolved solids (TDS) criterion for Blue Creek in Box Elder County, Utah. This document summarizes the technical and regulatory bases to support this change.

This document is an update of the *Proposed Site-Specific Standard for Total Dissolved Solid, Blue Creek, Box Elder County, Utah, September 24, 2013 Draft* (DWQ, 2013).

Additional supporting data and analyses are incorporated by reference and are included as Appendices A and B:

- June 2011 ATK *Work Plan for the Development of a New Site-Specific TDS Criterion for Blue Creek*. (ATK, 2011)
- July 11, 2013 ATK *Blue Creek Site-Specific Standard for Total Dissolved Solids (TDS) Criterion Monitoring Report* (ATK, 2013)

1.1.1 Watershed Summary

Blue Creek Reservoir has no perennial source streams. The water in Blue Creek Reservoir is collected from Blue Springs, a saline warm springs adjacent to the reservoir supplemented by storm runoff. Water control structures allow the reservoir water to be discharged to Blue Creek or to irrigation canals on the east and west sides of the valley. The irrigation canals provide water for flood irrigation and stock watering. Direct conveyances for irrigation return flows to Blue Creek are not apparent and unused water likely returns to Blue Creek via sheet flow, shallow groundwater, and roadside ditches.

Downstream of the dam, Blue Creek has flowing water (except when frozen) even absent any intentional releases from the dam. The source of this water appears to be shallow groundwater (springs) and seepage from the reservoir. As documented in previous studies by USGS, groundwater studies at the ATK facility, and common knowledge amongst locals, most of the groundwater in the area is too salty for agricultural or domestic use without treatment.

Blue Creek flows for approximately 8 miles from the dam to the northern boundary of ATK's property. From there, Blue Creeks continues in a defined channel for approximately 9 miles before becoming sheet flow (assuming water is present) on the Bear River Bay playa. Bear River Bay Class 5E Transitional Waters/Class 5C Bear River Bay are approximately an additional 9 miles to the south of the ATK facility. Based on satellite photos, it appears that water from Blue Creek does not make it to 4208' before infiltrating or evaporating. The photos show a ubiquitous white crust on the playa characteristic of mineralization after water evaporates.

ATK discharges to Blue Creek under UDPES Permit 0024805 and this is the only permitted discharge in the Blue Creek watershed. The locations of the discharges are downstream of sample locations used to derive the site-specific criteria. The majority of agricultural use of the water occurs upstream of the ATK facility.

1.1.2 Uses

UAC R317-2-12 lists the designated uses of Blue Creek as:

- Class 2B, infrequent primary and secondary contact recreation,
- Class 3B warm water aquatic life,
- and Class 4 agriculture.

Only the Class 4 agricultural use has a numeric criterion for TDS,1,200 mg/l. Waters downstream of Blue Creek (Bear River Bay, Great Salt Lake) do not have the agricultural designated use.

As shown on Figure 1 and Figures 1 and 2 in ATK (2013), agricultural uses for water from Blue Creek Reservoir include stock watering and crop irrigation. Crops that are irrigated by flooding are: grass pasture, alfalfa, barley, wheat, and less than 40 acres of corn (USDA, 2012).

Agricultural uses of the water downstream of the ATK facility include stock watering, wildlife propagation, and limited irrigation for salt tolerant crops such as wheat grass and salt grass. Non-farming land uses included grazing and open range.

The Utah Division of Water Rights water right's database was searched and the results are presented in the Appendix E. Water Rights beneficial uses (different than water quality uses) include stock watering, crop irrigation, and wildlife propagation.

The original dam was constructed in 1904 (ATK, 2011). Blue Creek was an intermittent stream until 1975 when an earthquake changed the creek to perennial (ATK, 2011). The TDS criteria proposed in this document are based primarily on natural conditions as irreversibly modified by Blue Creek Reservoir. Existing uses will be protected because the site-specific standards are based on natural conditions.

1.1.3 Regulatory Bases

Site-specific criteria are permitted in the following situations in accordance with UAC R317-2-7.1:

> "Site-specific criterion may be adopted by rulemaking where biomonitoring data, bioassays, or other scientific analyses indicate that the statewide criterion is over or under protective of the designated uses or where natural or un-alterable conditions or other factors as defined in 40 CFR 131.10(g) prevent the attainment of the statewide criterion."

In 2013, Utah adopted a site-specific TDS criterion of a 2,200 mg/l (maximum) for Blue Creek Reservoir and higher TDS standards for Blue Creek based on natural conditions. During a subsequent review, the site-specific standards for Blue Creek were determined to be too low based on historical data not previously used to derive the standards. This document addresses revisions to only Blue Creek.

Site-specific TDS criteria are appropriate for Blue Creek because based on the analyses presented in this document because of the factors of naturally occurring pollutant concentrations (CFR 131.10 (g)1.) and the irreversible conditions created by the dam (CFR 131.10 (g)4.).

1.2 METHODS

1.2.1 Data

TDS data for STORET 4960740 were available from 1989 to 2010. These data were downloaded from the DWQ AWQMS database. These data were supplemented by the data collected for the ATK (2013) study (Appendix B).

The ATK (2013) data were collected by ATK in accordance with the work plan in Appendix A. In summary, TDS monthly water samples were collected from 3 locations on Blue Creek for two years. The 3 sample locations are shown on Figure 3 of ATK (2013) in Appendix B. Sample location Blue Creek Upper is the same as STORET 4960740. The Blue Creek Below Dam site is considered representative of Blue Creek Reservoir TDS concentrations.

Initially for the ATK (2013) study, metals and major ions were quantified in addition to TDS concentrations. Representatives from ATK and DWQ met periodically to review the results and flow measurements were added for the second year and the metals and major ion analyses were discontinued. In addition to TDS concentrations and flow, the irrigation status of the reservoir diversions were recorded on the days that samples were collected.

To obtain additional data to identify the causes of the variation in TDS concentrations between the sites, DWQ and ATK staff investigated the TDS concentrations in surface waters entering Blue Creek in 2013 from other sources such as unnamed springs and drainages upstream of the ATK facility. Potential sources to Blue Creek were initially located using satellite imagery from Google Earth®. The creek was walked and a conductivity meter was used to estimate TDS concentrations by conversion using a site-specific calibration (ATK, 2013).

1.2.2. Data Analyses

The data were summarized, plotted, and reviewed. The data were explored for correlations. Statistical analyses were conducted using either Systat (v. 13) or the USEPA ProUCL (v. 5.0) software. Both exploratory and confirmatory analyses were used. *A priori* assumptions investigated include that TDS concentrations could be influenced by irrigation and/or season and that TDS concentrations from Blue Creek Reservoir were a different population than TDS concentrations for Blue Creek.

The initial evaluations were focused on the ATK (2013) data because data were collected monthly, irrigation status was recorded, and 2 additional sample locations were sampled. These data were specifically used to evaluate potential trends in TDS concentrations between sites and changes attributable to dam and/or irrigation activities. The results of these analyses were used to guide the analyses of the AWQMS data for STORET 4960740.

1.2.3. Criteria Derivation Central Tendency

The existing TDS criteria in Utah's water quality standards are presumed to be maximum criteria because no durations are specified. However, a single maximum-based criterion to represent an ambient-based criterion has a major limitation when determining discharge permit limits. Discharge concentrations that are consistently greater than the mean but less than the maximum would be allowed but this would allow an unintended increase in concentrations above the ambient concentrations. To control for this potential, an average criterion was derived for Blue Creek in addition to maximum criterion. When implemented, the two criteria approach will be much more rigorous than a single criterion approach because long-term variability is characterized by average criterion and short term variability is characterized by the maximum criterion.

USEPA does not provide specific guidance on how ambient-based criteria should be derived. USEPA (2015) guidance is available regarding when ambient-based criteria are appropriate.

The USEPA (2013) ProUCL Technical Guidance does provide recommendations for estimating both central tendencies, such as averages, and upper percentile values (UPVs), such as maximums, for environmental datasets. Although this guidance was developed primarily for supporting risk assessments for the RCRA and CERCLA programs, the statistical applications are similar. Chapter 3 from USEPA (2013) that discusses the statistical characterization of background concentrations is excerpted in Appendix G for the convenience of the reader.

The primary focus of USEPA (2013) for central tendency values is on calculating the most appropriate 95% upper confidence limit of the mean to comply with USEPA risk assessment guidance for calculating an exposure point concentration. For this application, the data quality objective is to minimize the potential that the exposure point concentration will be underestimated and hence the recommendation to use the upper confidence limit of the mean.

The data quality objectives for a central tendency TDS criterion based on ambient concentrations are different. The central tendency criterion has two major applications: assessment and permitting. For assessment, future TDS concentrations will be compared to the criterion to determine if Blue Creek is impaired. False positives (erroneously concluding that TDS concentrations exceed ambient concentrations) have potentially costly implications because resources would be expended on an unnecessary TMDL (total maximum daily load). False negatives (erroneously concluding that TDS concentrations are within ambient concentrations) are also undesirable because the water quality would unknowingly impaired. The potential for false positives and negatives must be balanced because without collecting additional data, the false positive and false negative rates are inversely proportional where decreasing one will increase the other.

For permitting applications, a central tendency value that was too low would unnecessarily require more stringent effluent limits which could be costly. A central tendency value that was too high could potentially allowed unintended degradation of water quality above the natural conditions. To balance the potential for decision errors for permitting applications, the central tendency value recommended is the arithmetic mean without upper or lower confidence limits.

The unadjusted mean however is not viable for assessments. Assessments are conducted every 2 years using the available data. If assessments were conducted by comparing the sample means to the average criterion, the decision error rate would be 0.50, i.e., there is a 50% chance that the sample mean will be greater than the average criterion when the underlying TDS concentrations are actually not different from the ambient concentrations. Statistical tests (e.g., t-test) are available to achieve control for these decision errors but these methods were judged too complicated to implement routinely for assessments. Therefore, separate comparison values for assessing compliance with the average criterion were developed.

USEPA (2013) provides recommendations for setting comparison values *a priori* that are statistically based. The 95% upper confidence limit of the mean was considered but these only consider the variability in the ambient concentrations without considering the variability of the future samples collected for the assessment. The 95% upper prediction limits for the mean consider both the variability in ambient concentrations and variability in the future assessment samples (USEPA, 2013). With an upper prediction limit, the number of future samples used to estimate the mean must be specified. This requirement is one of the limitations of this approach because the resulting comparison value is sensitive to the number of samples. The more samples used to calculate the assessment mean, the closer the comparison value is to the actual mean of the ambient concentrations. If more samples are collected than were used to calculate the 95% upper prediction limit of the mean, the false negative potential is greater than desired 5% .

USEPA (2009) recommends that a minimum of 8 samples be used to construct prediction limits. The performances of prediction limits based on different numbers of future samples were evaluated by comparisons to the existing data. Other considerations include limiting the number of samples required so that an adequate number of samples can likely be collected given resource constraints. Underestimating the number of available samples for calculating the mean is also undesirable because the false negative rate increases. In cases where a sufficient number of samples were collected to assess the average criterion, water quality can still be assessed by comparisons to the maximum criterion described in Section 1.2.4.

1.2.4. Criteria Derivation Maximum

The maximum criteria are derived using estimates of upper percentile values (UPVs). The maximum criteria have the same applications as the average criteria for assessment and permitting. Also similar to the average criterion, the maximum criterion includes the potential for decision errors with similar consequences when implementing the maximum criterion.

USEPA (2013) includes many more choices/approaches for estimating a UPV than for the central tendency (see Appendix G). The ideal UPV would be the true maximum TDS concentration but this concentration is unknown and must be estimated from the sample data.

Statistical methods can be used to estimate percentiles such as the 90^{th}, 95^{th}, and 99^{th}. A 90^{th} percentile would reduce the potential for false negative decisions during assessment but the potential for false positives would be increased because 10 percent of the ambient TDS concentrations are greater than the 90^{th} percentile by definition. This could result in an unacceptably high probability of false positives (the actual probability would be higher because 10 percent assumes that true 90^{th} percentile is known).

The nonparametric options were not preferred for estimating the maximum criterion because distributional testing indicated that the data could be modeled using either a lognormal or normal distribution. The parametric methods are preferred for this application when supported by the data (USEPA, 2009). Upper prediction limits were not preferred because of their sensitivity to the number of future observations and that upper prediction limits with their limitations were already being used for assessing the average criterion.

Either an 95% upper tolerance limit of the 95th or 99th percentile or the 95% upper simultaneous limit (USL) were considered the most appropriate for estimating the maximum criterion because they are insensitive to the number of future comparisons. For the upper tolerance limits, the 99th percentile was preferred over the 95th because the 99th percentile is intended to approximate the maximum. The available number of samples was also considered in selecting the 99th percentile. Variance has a large influence on the calculation of the UPVs and variance is a function of both variability and uncertainty (USEPA, 2001). With adequate sample sizes, the uncertainty component is reduced and the variance estimates will more accurately reflect the actual underlying variability in the data. Therefore, when adequate samples are available, the UPV will approach the percentile value in the sample data and is less likely to overestimate the true percentile. This means that a 95th percentile UPV is more likely to underestimate 5% of the concentrations and the 99th percentile is more appropriate. Finally, the performances of the UPVs were also evaluated by comparisons to the existing dataset.

1.3 RESULTS AND DISCUSSION

1.3.1 Results and Discussion of ATK (2013) Study

The results for TDS and Flow for each sample site from the ATK (2013) study are summarized in Table 1. Box plots of TDS and flow are provided on Figures 2 and 3, respectively. Table 2 summarizes the same data based on whether irrigation was occurring. Box plots based on irrigation status are also included in Figures 2 and 3.

As shown by the flow data on Table 2 and Figure 3, Blue Creek is a gaining stream that increases with volume as it moves down gradient. No tributaries are present which supports that groundwater is the significant source of water. For the Below Dam site, TDS concentrations were higher when irrigation water is being diverted and a low negative correlation with flow was observed with a Pearson Correlation Coefficient of -0.21. TDS concentrations showed relatively little variance with a range of 1,890 to 2,110 mg/l (Table 1). A poor correlation was expected at this site because flow is controlled by dam releases in response to irrigation demands and not water inputs to the reservoir.

At the sample site at the upstream boundary of the ATK property, Blue Creek Upper, a positive correlation between TDS and flow was observed with a Pearson's Correlation Coefficient of 0.29. While the correlation was stronger than observed at the other sites, flow explained less than 10% of the variation in TDS concentrations. TDS concentrations were variable, ranging from 2,260 to 6,270 mg/l at the Blue Creek Upper sample site. TDS concentrations increased when no irrigation was occurring which the opposite of this trend was observed at the Crossing site (Table 1, Figure 2). The mean difference in TDS concentrations between irrigating and not irrigating was a modest 600 mg/l at the Upper site.

TDS concentrations increase moving downstream between the dam and the Blue Creek Upper site as shown by the differences in median concentrations at the dam of 1,990 mg/l, to 3,180 mg/l at the Blue Creek Crossing site, to 4,220 mg/l at the Blue Creek Upper site. These reaches were further investigated to locate and measure specific sources of incoming TDS waters. Several sources of saline inputs that appear to originate from springs were identified (Table 1 in ATK, 2013). The maximum concentration measured in these sources was 31,300 mg/l. The local ranchers report that groundwater in the area was generally unsuitable for irrigation or potable uses.

The precise irreversible impacts of the dam on TDS concentrations in Blue Creek were difficult to discern. Without the dam, the lower TDS water from Blue Springs would flow down Blue Creek instead of being stored. Other inputs to Blue Creek from springs are generally higher in TDS, so the TDS concentrations in Blue Creek should be lower at those times when water from the dam discharges to Blue Creek. However, the changes in TDS concentrations under the different dam operating scenarios (Figure 6 in Appendix B) don't appear to support this hypothesis. Additional analyses to normalize for seasonality or a more robust data set and hydrologic modeling might identify a trend but the existing data suggests that the effect of the dam is small.

The data supports that irrigation return flows are not a significant source of TDS because TDS concentrations in Blue Creek are lower during the irrigation season. Therefore, additional best management practices for irrigation would not result in the compliance with the statewide TDS standard.

Other than the reservoir, no specific hydrological features (e.g., confluence) or marked changes in TDS were observed. The reservoir has relatively consistent TDS concentrations that are greater than the statewide TDS criterion of 1,200 mg/l. Below the dam, TDS concentrations increase rapidly with a larger increase between the dam and the Blue Creek Crossing site than between the Blue Creek Crossing site and the Blue Creek Upper. The distance from ATK's property to the dam is approximately 8 miles. A single site-specific criterion is proposed for this reach, including extending downstream to Great Salt Lake. Although no specific data are available for the reach between ATK and the Great Salt Lake, salinity typically increases as creeks approach the lake and are influenced by saline sediments and future investigations may determine that additional site-specific criteria are appropriate.

Table 1. Summary Statistics for Total Dissolved Solids and Flow for Blue Creek Reservoir and Blue Creek, Box Elder County, Utah

	BCBD_TDS (mg/l)	BCCR_TDS (mg/l)	BCU_TDS (mg/l)	BCBD_FLOW (gal/min)	BCCR_FLOW (gal/min)	BCU_FLOW (gal/min)
N of Cases	29	32	32	28	27	24
Minimum	1,890	2,470	2,260	0	0	0
Maximum	2,110	5,060	6,270	11,162	8,079	11,438
Median	1,990	3,180	4,220	374	1,434	2,428
Arithmetic Mean	2,007	3,297	4,261	774	1,847	2,712
Geometric Mean	2,006	3,254	4,184	.	.	.
Standard Deviation	63.6	572.4	802.7	2094	1,776	2,548
Notes						
BC_BD	Blue Creek below Dam (Representative of Reservoir)					
BCCR	Blue Creek Crossing					
BC_U	Blue Creek Upper					

Table 2. Summary Statistics for Total Dissolved Solids During Irrigation and No Irrigation in Blue Creek Box Elder County, Utah						
	Irrigation	Not Irrigating	Irrigation	Not Irrigating	Irrigation	Not Irrigating
	BCBD_TDS (mg/l)		BCCR_TDS (mg/l)		BCU_TDS (mg/l)	
N of Cases	19	10	19	13	19	13
Minimum	1890	1940	2600	2470	2260	4050
Maximum	2110	2100	4670	5060	5630	6270
Arithmetic Mean	1998	2025	3443	3085	4011	4626
Geometric Mean	1997	2024	3410	3039	3928	4589
Standard Deviation	69.6	48.8	492.4	632.9	818.3	645.5
Notes BC_BD BCCR BC_U	 Blue Creek below Dam Blue Creek Crossing Blue Creek Upper					

1.3.2 Data Summary STORET 4960740/Blue Creek Upper

The Blue Creek Upper sample site is the location of STORET 4960740, the only sample site used by DWQ to assess the water quality of Blue Creek. This site will likely to remain the primary sample site for assessing the future water quality of Blue Creek and the site-specific standards are based on the data from only this location. Assessments to determine if Blue Creek is meeting the standard should also be based on the salinity concentrations observed at this location.

The ATK (2013) and DWQ datasets were combined to derive the site-specific standards for Blue Creek. As shown in the statistical summary Table 3 and Appendix C, TDS data are available for the Blue Creek Upper for 349 days from 1989 to 2013. The following evaluations were based on this data set.

1.3.3. Site-Specific Criteria for Blue Creek

TDS concentrations at the Blue Creek Upper sample location varied much more than the reservoir. The Blue Creek Upper data were plotted, investigated for statistical outliers, and compared to known distributions. No outliers were identified initially using the ProUCL software (Appendix D). Monthly box plots of TDS concentrations were constructed for the Blue Creek Upper sample site (Figure 4). Based on a visual grouping, TDS concentrations from November through February (winter) appear to be more similar to each other than the TDS concentrations in the other months. TDS concentrations in the winter may be higher because of the lack of irrigation return flows in addition to reduced surface runoff due to temperatures below freezing.

In addition to season, the potential influences of irrigation activities on TDS concentrations were explored. The irrigation season was assumed to be from April 15 to December 15 based on the 2-year study conducted by ATK (2013). Figure 5 shows box plots for TDS concentrations at Blue Creek Upper when irrigation is occurring versus when no irrigation is occurring.

Average TDS concentrations are higher in the winter or when irrigation is not occurring. When the data was explored using a parametric analysis of variance (ANOVA) with irrigation and season as factors, season had a much stronger influence (Appendix E). The difference in mean TDS concentrations between irrigating and not-irrigating is only 351 mg/l. The difference in means between seasons was about 900 mg/l ($p<0.0001$).

Based on the low magnitude of differences in TDS concentrations based on irrigation status, subsequent analyses were conducted for seasonal differences in TDS concentrations with November, through February comprising the winter season and March through October

Table 3. Summary Statistics for Sample Site Blue Creek Upper				
Number	Minimum TDS Concentration (mg/L)	Maximum TDS Concentration (mg/L)	Mean TDS Concentration (mg/L)	Standard Deviation TDS Concentration (mg/L)
349	1,649	7,180	4,121	943.7
Notes: TDS = total dissolved solids				

Table 4. Summary Statistics for Sample Site Blue Creek Upper by Season					
Season	Number	Minimum TDS Concentration (mg/L)	Maximum TDS Concentration (mg/L)	Mean TDS Concentration (mg/L)	Standard Deviation TDS Concentration (mg/L)
Summer	235	2,250	6,270	3,822	716
Winter	113	1,649	6,724	4,714	1,035
Notes:					
TDS	total dissolved solids				

comprising the summer season. The datasets were again analyzed for outliers and the October 30, 1992 value of 7,180 mg/l was identified as an outlier. This was the highest TDS concentration observed with the next highest concentration being 6,724 mg/l. This data point (7,180 mg/l) was concluded to be a statistical outlier and was not included in further statistical analyses for the summer season.

Summary statistics based on seasons are summarized in Table 4 and the box plots shown on Figure 6. Distributional testing suggests that the summer TDS concentrations are lognormally or gamma distributed. TDS concentrations for the winter season appear to be normally distributed (Appendix D).

1.3.3.1 Blue Creek Summer Season Criteria

For the summer season, the mean TDS concentration of 3,800 mg/l is recommended for the average criterion (Table 4). This value is based on a log transformation of the data and then converting back to an untransformed value (USEPA, 2009 p. 18-5).

Potential CVs for the summer season were predicted assuming a lognormal distribution. The CVs shown in Table 5 range from 3,900 to 4,300 mg/l. The 4,300 mg/l 95% upper prediction limit for the mean of the next 6 samples was initially selected and evaluated as the CV. However, when compared to possible 6-sample means for the summer season, several of the sample means exceeded 4,300 mg/l.

The performance improved with a CV of 4,100 mg/l (95% upper prediction limit for the mean of the next 10 samples) with only two 10-sample mean exceedances. One of the exceedances (by 400 mg/l) was in 1992 when 22 samples were collected in the summer season. In those 22 samples, there was only one 10 consecutive sample mean exceedance. The other exceedance was in 2012 when 10 samples were collected and the sample mean was 4,300 mg/l. Although not optimal, this performance is judged acceptable and a summer season CV of 4,100 mg/l recommended. Per the derivation, at least 10 samples are recommended to assess compliance with this CTV.

Potential UPVs for the maximum criterion were predicted for the summer season assuming a lognormal distribution and nonparametric assumptions are shown in Table 6 and range from 5,100 to 7,200 mg/l. For Blue Creek in the summer season, the 95% USL of 7,200 mg/l is selected for the maximum criterion. The 95% USL of 7,200 mg/l substantially exceeds the maximum observed concentration of 6,270 mg/l. However, the TDS concentration of 7,180 was dropped from the dataset based on its identification as a statistical outlier. The 95% USL suggests that this measurement is not an outlier. The 95% upper tolerance limit of the 99^{th} percentile of 6,000 mg/l appears to perform well with only exceedance assuming that the 7,180

Table 5. Potential Comparison Values (CVs) for Assessing the Summer Season TDS Average Criterion of 3,800 (mg/l)	
95% Adjusted-CLT UCL (Adjusted for Skewness, Chen-1995)	3,900
95% Modified-t UCL (Adjusted for Skewness, Johnson-1978))	3,900
95% Hall's Bootstrap UCL	3,900
95% Bootstrap t UCL	3,900
95% BCA Bootstrap UCL	3,900
95% Chebyshev (Mean, Sd) UCL	4,000
97.5% Chebyshev (Mean, Sd) UCL	4,100
99% Chebyshev (Mean, Sd) UCL	4,300
95% H-UCL	3,900
95% Chebyshev (MVUE) UCL	4,000
97.5% Chebyshev (MVUE) UCL	4,100
99% Chebyshev (MVUE) UCL	4,300
95% UPL for Mean of Next 6 Observations	4,300
95% UPL for Mean of Next 10 Observations	**4,100**
Notes: UCL = upper confidence limit	

mg/l was an outlier. However, given the uncertainty regarding the 7,180 mg/l value, the 95% USL is preferred. Six TDS measurements exceed the 95% upper tolerance limit of the 95th percentile suggesting that this UPV is an underestimate (but potentially accurate for the 95th percentile) in addition to be less desirable by definition. Figure 7 shows a histogram of the summer season TDS data with both the proposed average and the maximum criteria.

Table 6. Potential Upper Percentile Values (UPVs) for a Summer Season TDS Maximum Criterion (mg/l)

Lognormal 95% UTL with 99% Coverage	6,000
Lognormal 95% UTL with 95% Coverage	5,300
Lognormal 95% UPL(t)	5100
Lognormal 95% UPL for Next 10 Observations	6,100
Lognormal 95% USL	**7,200**
Nonparametric 95% Percentile Bootstrap UTL with 99% Coverage	6,100
Nonparametric 95% UPL	5,200
Nonparametric 95% Chebyshev UPL	6,900
Nonparametric 95% USL	6,300
Nonparametric 95% UTL with 99% Coverage	5,900
95% BCA Bootstrap UTL with 99% Coverage	6,100

Notes:
UPL = Upper Prediction Limit
UTL = Upper Tolerance Limit
USL = Upper Simultaneous Limit

1.3.3.2. Derivation of Winter Season Criteria

For the winter season, the mean TDS concentration of 4,700 mg/l is recommended for the average criterion (Table 4). Potential assessment CVs for the winter season were predicted assuming a normal distribution. The CVs shown in Table 7 range from 3,900 to 5,400 mg/l. The 5,400 mg/l 95% upper prediction limit for the mean of the next 6 samples was initially selected and evaluated. However, when compared to possible 6-sample means, several of the sample means exceeded 5,400 mg/l.

The performance improved with a CV of 5,300 mg/l (95% upper prediction limit for the mean of the next 10 samples) with no 10-sample mean exceedances and a winter season CV of 5,300 mg/l is recommended. Per the derivation, at least 10 samples are recommended to assess compliance with this CV.

UPVs for a potential maximum criterion for the winter season were predicted assuming a normal distribution. As for summer, only parametric UPVs were considered. The 95 upper tolerance limits of the 95^{th} and 99^{th} percentiles and the 95% USL range from 6,700 to 8,100 mg/l (Table 8). The 7,500 mg/l 95% upper tolerance limit with 99% coverage is selected as the maximum criterion. None of the existing 113 observations exceed this concentration. The 6,700 mg/l 95% upper tolerance limit of the 95^{th} percentile was not selected because it is based on the 95^{th} percentile and the maximum observed concentration was the same. Selecting this UPV would indicate that the actual maximum concentration was sampled which is improbable. The 8,100 mg/l 95% USL appears to be unnecessarily elevated above the existing data. Figure 7 shows a histogram of the winter season TDS data with both the proposed average and no-to-exceed criteria.

1.3.3.3. Duration and Frequency

Both the winter and summer criteria were derived using the same methods and the same duration and frequency are recommended for both. The duration for the maximum criterion is recommended to be daily because the derivation was based on daily measurements. The frequency of exceedance is recommended to be no more than 10 percent in accordance with UAC R317-2-7.1. The methods used to derive the average criteria support an averaging time (duration) of 23 years. However, a 23 year averaging time is impractical and one year, or shorter, is recommended. One year or shorter averaging times will be protective of longer averaging times. For assessment purposes, the requirement for a minimum of 10 samples is more important than the one year averaging time.

Table 7. Potential Comparison Values (CVs) for Assessing the Winter Season Average TDS Criterion of 4,700 (mg/l)	
95% UCL(t)	4,900
95% UPL for Mean of Next 6 Observations	5,400
95% UPL for Mean of Next 10 Observations	**5,300**

Table 8. Potential Upper Percentile Values (UPVs) for Winter Season TDS Maximum Criterion (mg/l)	
Normal 95% UTL with 99% Coverage	**7,500**
Normal 95% UTL with 95% Coverage	6,700
Normal 95% UPL(t)	6,400
Normal 95% UPL for Next 10 Observations	7,400
Normal 95% USL	8,100
Nonparametric 95% Percentile Bootstrap UTL with 99% Coverage	6,700
Nonparametric 95% UPL	6,200
Nonparametric 95% Chebyshev UPL	9,200
Nonparametric 95% USL	6,700
Nonparametric 95% UTL with 99% Coverage	6,700
95% BCA Bootstrap UTL with 99% Coverage	6,700
Notes: UPL = Upper Prediction Limit UTL = Upper Tolerance Limit USL = Upper Simultaneous Limit	

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United States Environmental Protection Agency (USEPA) 2001. Risk Assessment Guidance for Superfund: Volume III – Part A, Process for Conducting Probabilistic Risk Assessment. December. EPA 540-R-02-002

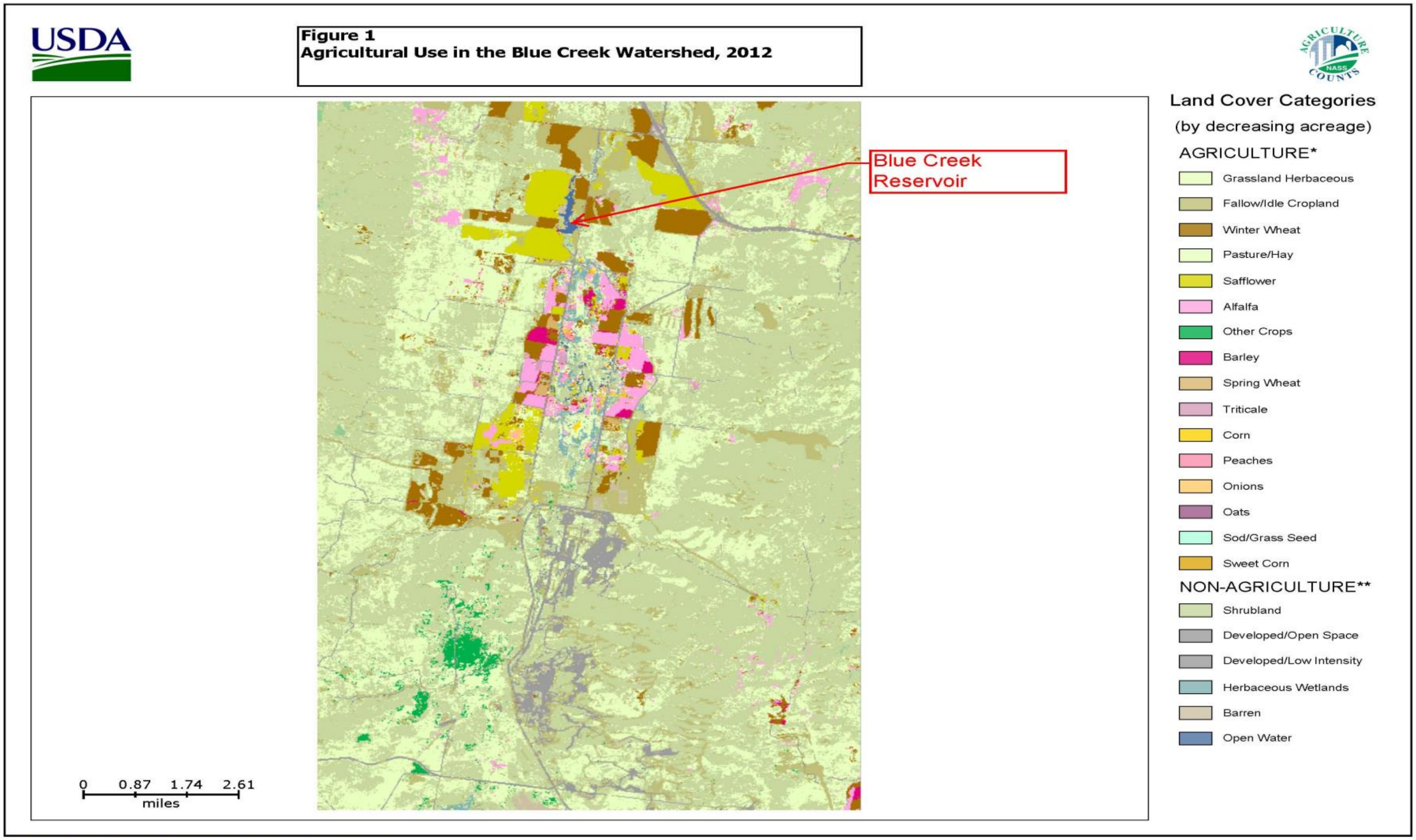
United States Environmental Protection Agency (USEPA) 2009. Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities Unified Guidance. EPA 530/R-09-007. March

United States Environmental Protection Agency (USEPA) 2013. ProUCL Version 5.0.00 Technical Guide. Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations. EPA/600/R-07/041. September. EPA/600/R-07/041

United States Environmental Protection Agency (USEPA) 2015. A Framework for Defining and Documenting Natural Conditions for Development of Site-Specific Natural Background Aquatic Life Criteria for Temperature, Dissolved Oxygen, and pH: Interim Document.

Utah Division of Water Quality (DWQ), 2013. Proposed Site-Specific Standard for Total Dissolved Solids, Blue Creek, Box Elder County, Utah. September 4.

Figures



Produced by CropScape - http://nassgeodata.gmu.edu/CropScape

* Only top 16 agriculture categroies are listed. ** Only top 6 non-agriculture categroies are listed.

Figure 1. Agricultural Use in the Blue Creek Watershed

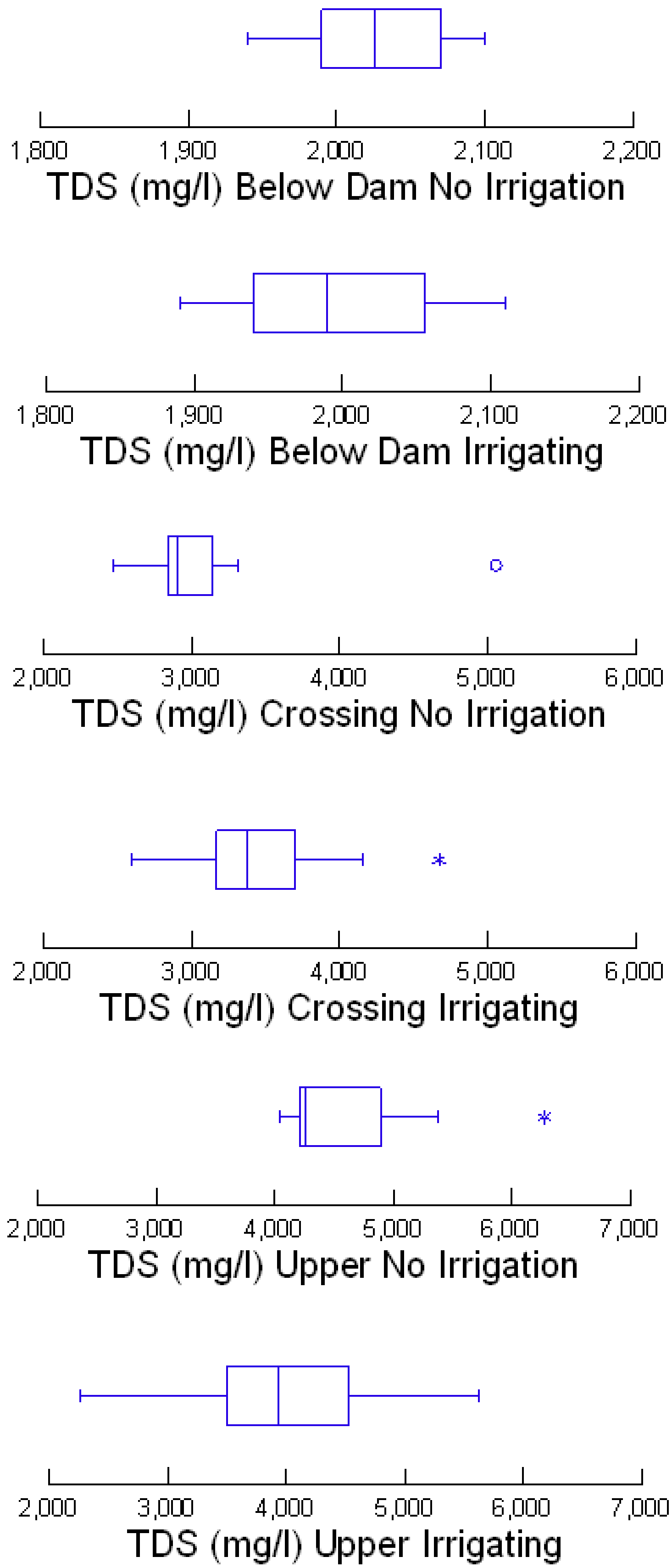


Figure 2. Box Plots for Total Dissolved Solids, Blue Creek, Box Elder County, Utah

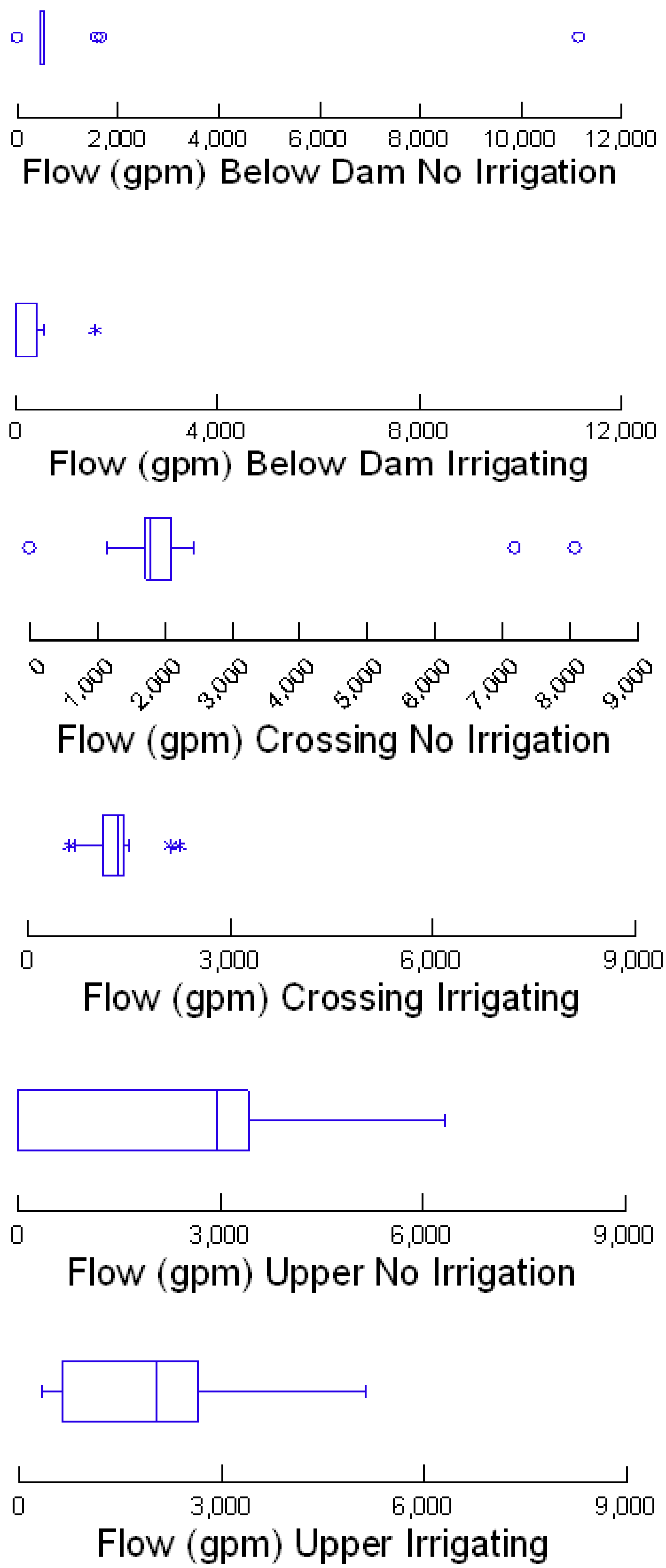


Figure 3. Box Plots for Flow, Blue Creek, Box Elder County, Utah

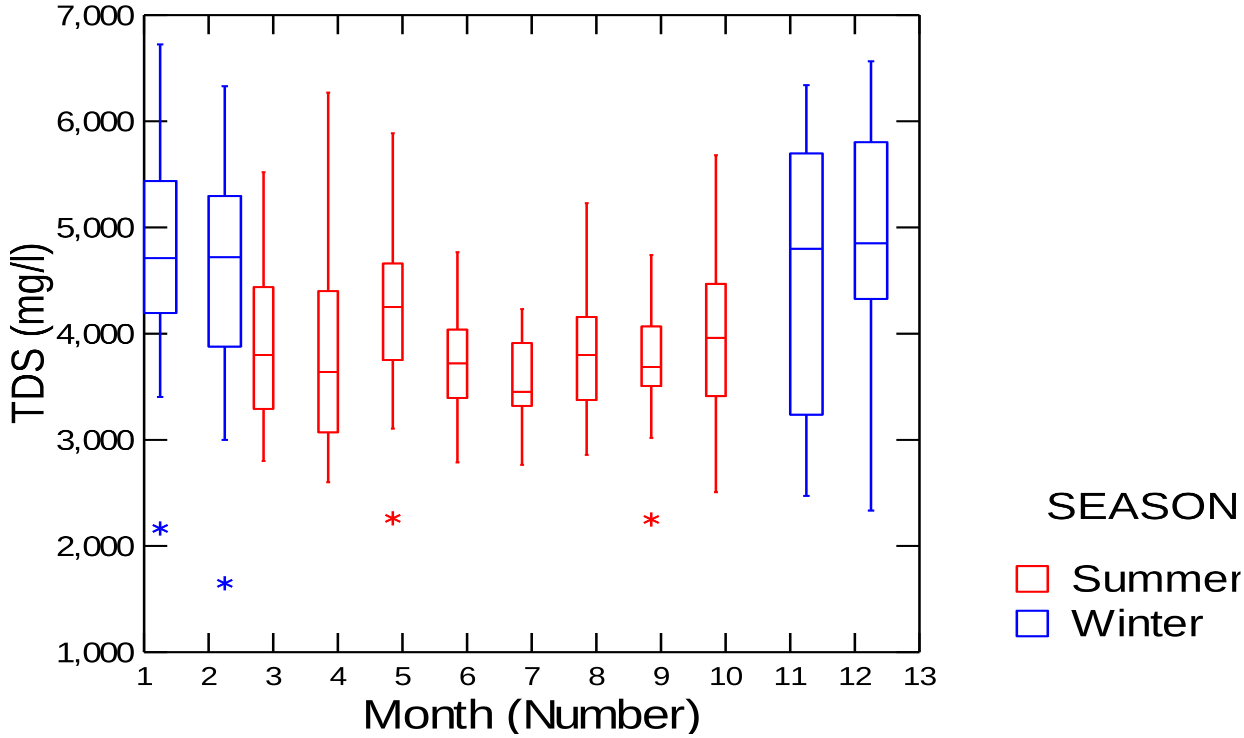


Figure 4. Box Plots of total dissolved solids (TDS) at the Blue Creek Upper Site by Month and Season

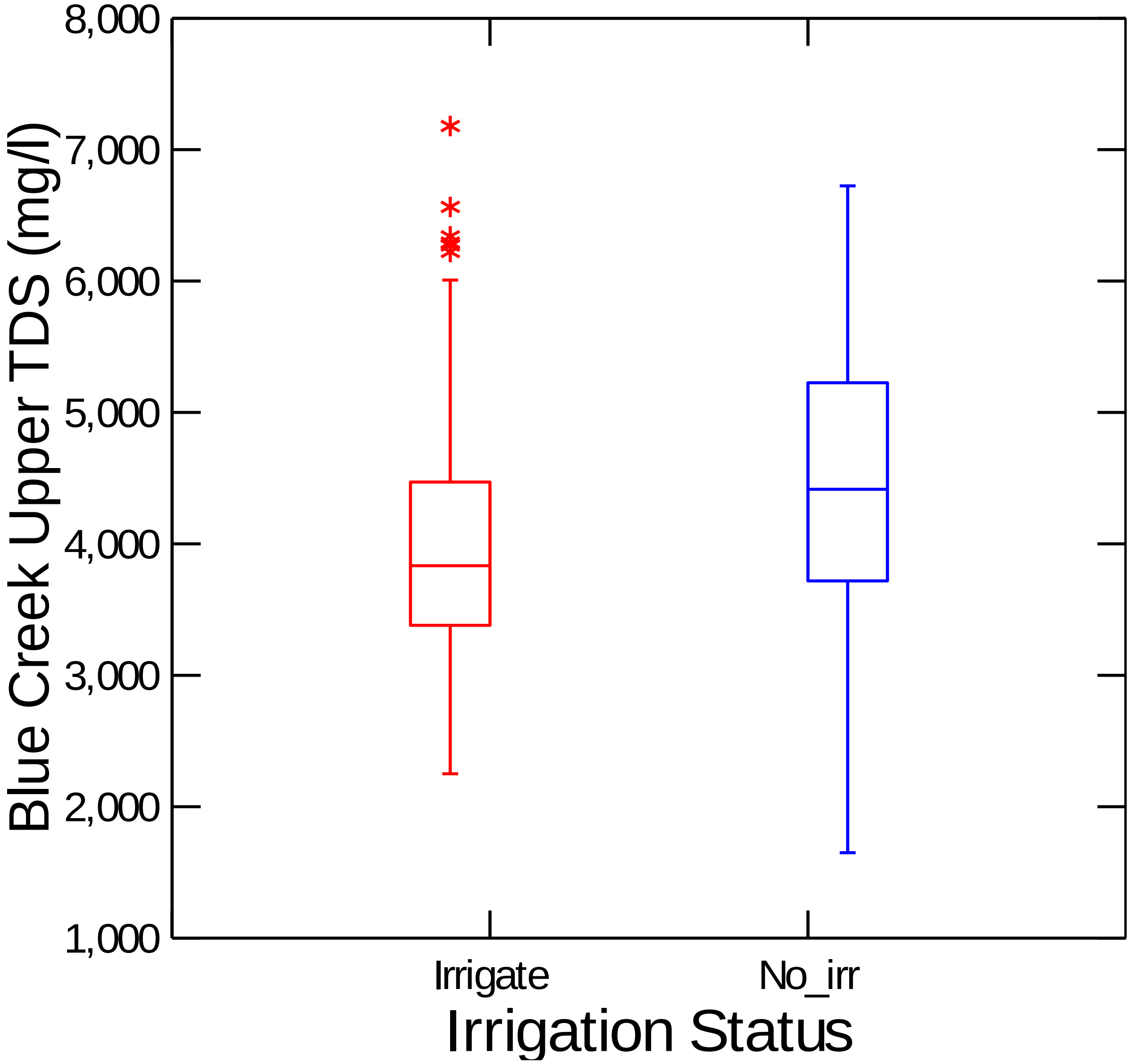


Figure 5. Box Plots of total dissolved solids (TDS) at the Blue Creek Upper Site by Irrigation Season

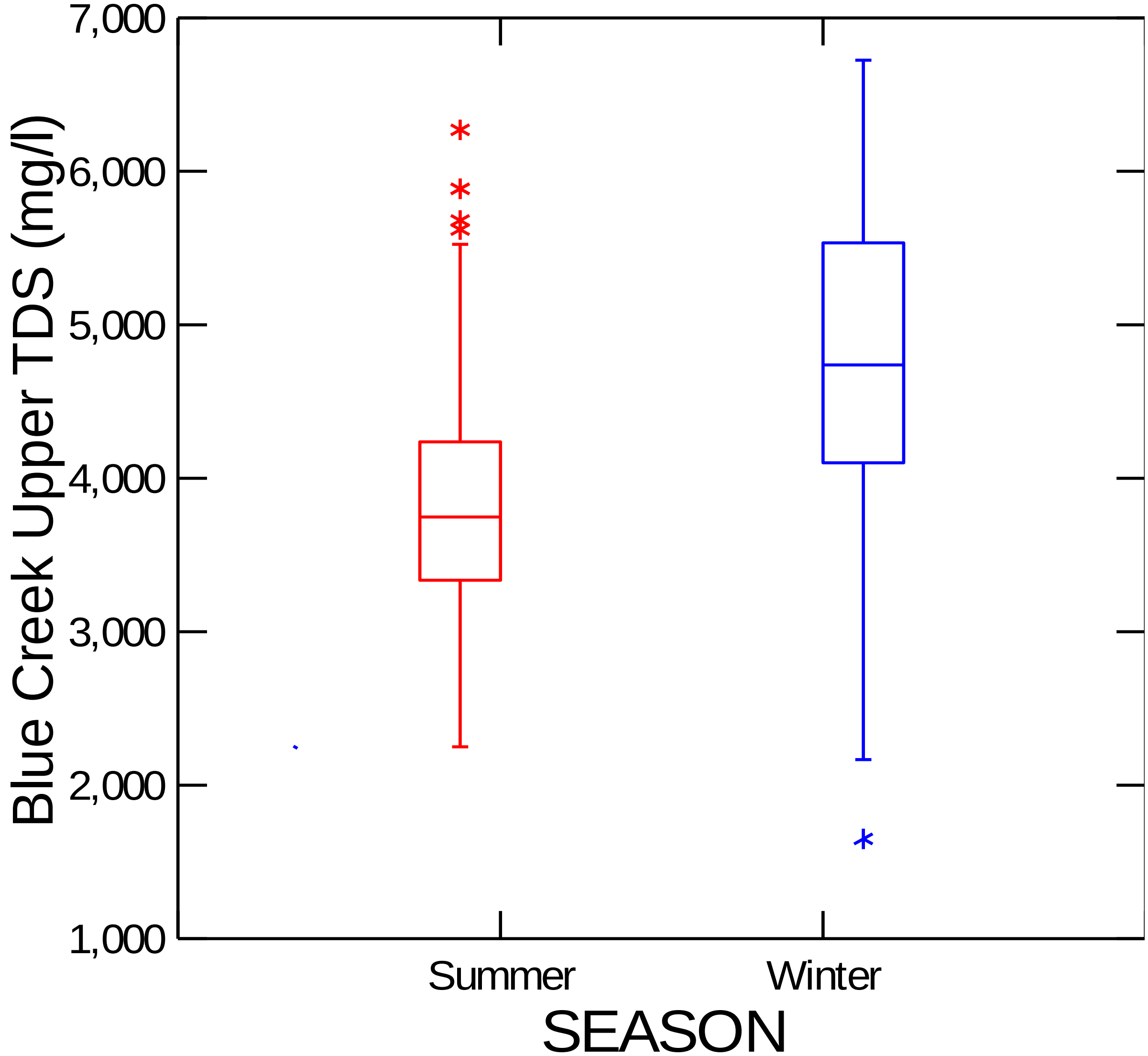


Figure 6. Box Plots of total dissolved solids (mg/l) at the Blue Creek Upper Site by Season

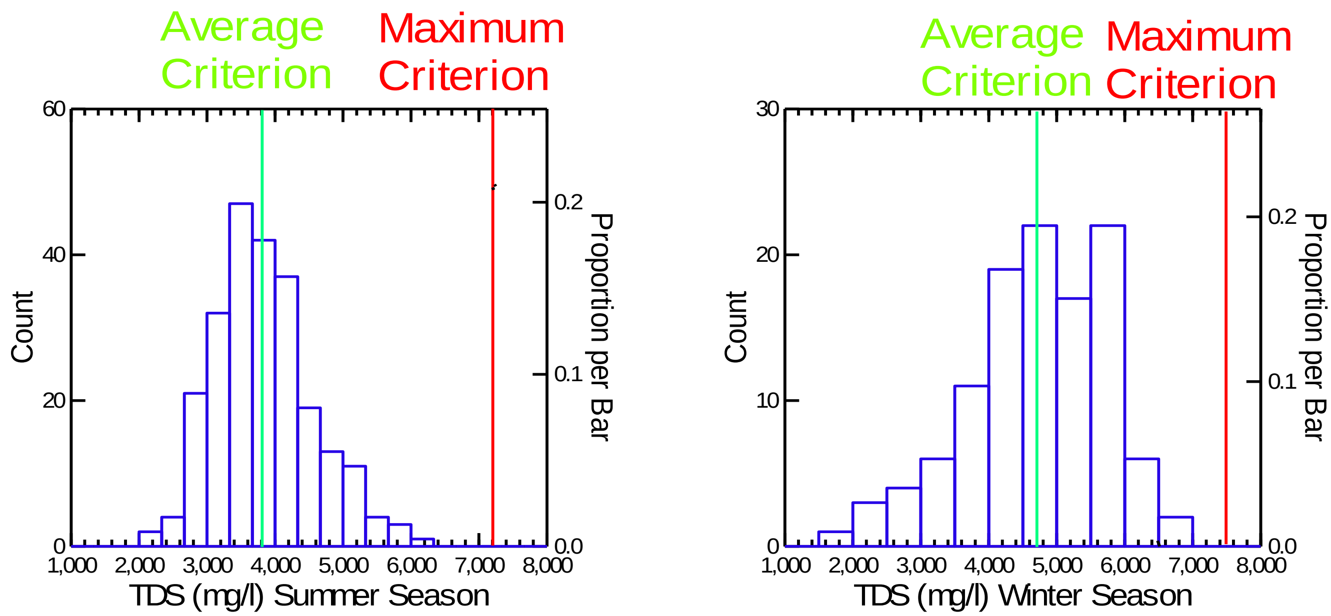


Figure 7. Histograms of Blue Creek summer and winter seasons total dissolved solids concentrations with proposed average and maximum criteria

ATK

Launch Systems Group

Work Plan
For the Development of a New Site-Specific TDS Criterion For Blue Creek

June 2011

1.0 Introduction

ATK Launch Systems Inc. is submitting this work plan for use in the development of a site-specific criterion for Total Dissolved Solids (TDS) in a stream segment of Blue Creek. The stream segment of Blue Creek begins at 41°43'20.40" N, 112°26'33.58" W a location on the northern boundary of ATK's facility along Highway 83 that ATK identifies as Blue Creek Upper with the stream segment ending at the Great Salt Lake. ATK currently has two wastewater treatment discharges along this stream segment under UPDES Permit #UT0024805. (See Figure 1 & 2, Goggle Earth image)

2.0 Background

Blue Creek originates approximately 8 miles north of the ATK Facility from Blue Springs. Blue Springs is a warm springs that has a TDS concentration of 2000 mg/L. The water that flows from Blue Springs is then stored in the Blue Creek Reservoir Dam.

The Blue Creek Reservoir Dam was constructed in 1904. The Blue Creek Dam was modified, enlarged and repaired in 1949, 1967 and 1986. The current capacity of the reservoir is about 2,185 acre-feet (UDWR, 2001). Water from Blue Springs is stored in the reservoir during the winter months and used for agricultural irrigation during the spring through fall season. The water in the reservoir is distributed by canals owned by the Blue Creek Irrigation Company. The two main canals, the East Canal and the West Canal, are used to irrigate a portion of the valley north of ATK's facility (Bolke and Price, 1972).

Several saline springs feed the main channel of Blue Creek once it leaves the Blue Creek Reservoir. These springs are the major source of flow in Blue Creek during most of the year as it passes through the ATK facility.

Prior to 1975, the stream segment of Blue Creek from the irrigation dam flowing southward was an intermittent stream only flowing significantly after rainfall events and snow melts. As a result of an earthquake in March 1975, Blue Creek became a perennial stream with year round flow resulting from the springs located below the Blue Creek Reservoir Dam.

In May 2010, four irrigation wells used for pivot irrigation that are located west and south within ½ mile of the Blue Creek Reservoir were sampled, reporting TDS concentrations of 2910 mg/L, 2600 mg/L, 2450 mg/L and 2270 mg/L. Some

- Mercury Method 245.1;
- Total Dissolved Solids (TDS), Method 160.1; and
- Anions, Method 300 IC to include, Fluoride, Chloride, Nitrite-N, Bromide, Nitrate-N, Orthophosphate-P, Sulfate.

During each sampling event, a visual investigation will be conducted to verify if water is flowing from the Blue Creek Reservoir Dam into either the west or east irrigation canal. This will assist in validating when the irrigation season is occurring and allow the opportunity to coincide possible irrigation return flows with changing TDS levels at the two most southern monitoring sites (Blue Creek at crossing 14400 N, and Blue Creek Upper (north boundary of ATK property, Hwy 83).

A second visual investigation will be done each sampling event to verify if water is being released from the Blue Creek Reservoir Dam into the main Blue Creek channel. This will observation will be used to verify when lower TDS water that is being released from the reservoir dam is mixing with the higher TDS water below the dam, and thereby lowering the TDS levels at the two most southern monitoring sites (Blue Creek at crossing 14400 N, and Blue Creek Upper (north boundary of ATK property, Hwy 83).
Sampling these sites and conducting the visual investigations will allow the development of three datasets:

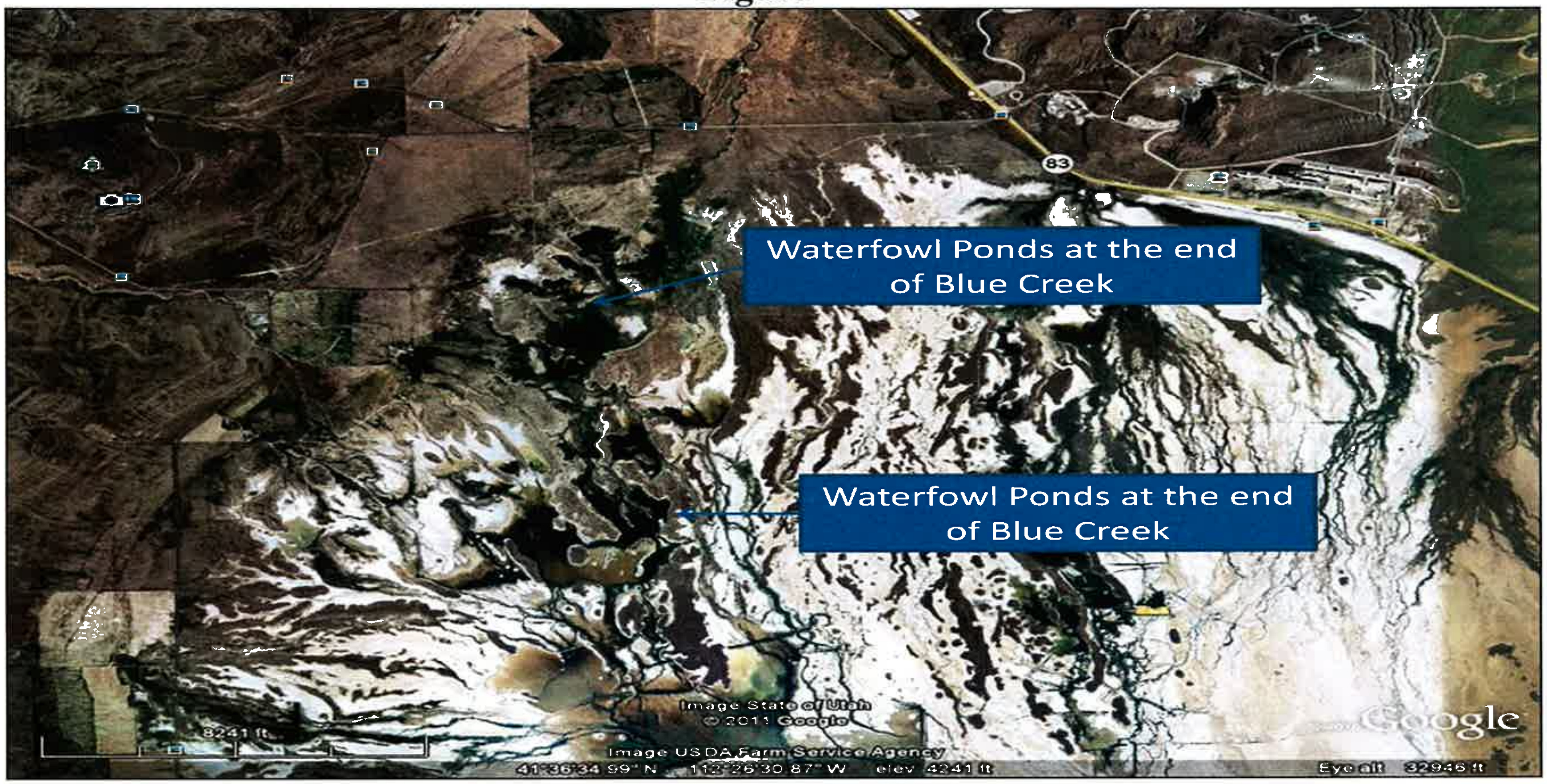
- The existing disturbed conditions, when irrigation is occurring and irrigation return flows are possible;
- When water is being discharged from the Blue Creek Reservoir Dam into the main channel of Blue Creek thereby, lowering the TDS level of Blue Creek by dilution; and
- A dataset for the periods when no irrigation is occurring and no water is being discharged from the Blue Creek Reservoir Dam, which is intended to represent natural conditions that predominate most of the year. This would represent the flow and TDS level in the main channel of Blue Creek that result from springs or seeps that occur below the reservoir dam southward.

The development of these three datasets will help characterize the three different flow conditions, as well as allowing the coordination of the sampling and analytical results with the flow conditions.

Figure 1


Blue Springs, (Source of Blue Creek Reservoir)
Blue Creek Reservoir
Blue Creek
Highway 83
Point of proposed Site Specific Standard (Highway 83 north boundary of ATK) following Blue Creek south to the Great Salt Lake
Sep 12, 2003
84
15
Image USDA Farm Service Agency
© 2009 Tele Atlas
© 2009 Google
Imagery Date Aug 19, 2003
41°43'34.79" N 112°21'43.06" W elev 5182 ft
Eye alt 24.49 mi

Figure 3

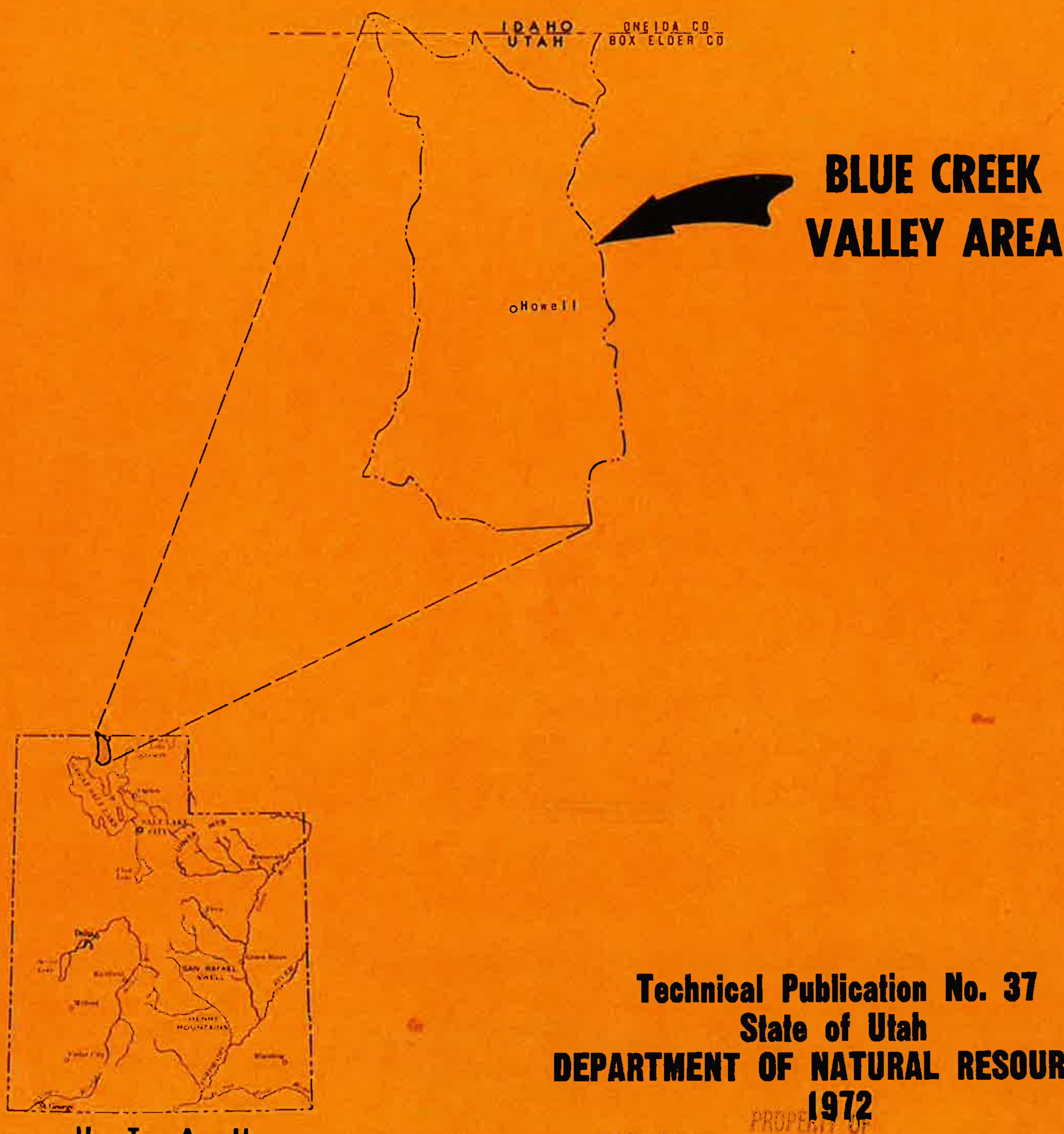

Waterfowl Ponds at the end of Blue Creek
Waterfowl Ponds at the end of Blue Creek
83
Image State of Utah
© 2011 Google
Image USDA Farm Service Agency
8241 ft
41°36'34.99" N 112°26'30.87" W elev 4241 ft
Eye alt 32946 ft
Google

References

Bolke, E.L. and Price D. 1972. Hydrologic Reconnaissance of the Blue Creek Valley Area, Box Elder County, Utah. Utah Department of Natural Resources Technical Publication No. 37.

UDWR (Utah Division of Water Resources). 2001. Utah State Water Plan, West Desert Basin, Salt Lake City, Utah. 3-17p.

HYDROLOGIC RECONNAISSANCE OF THE BLUE CREEK VALLEY AREA, BOX ELDER COUNTY, UTAH



Technical Publication No. 37
State of Utah
DEPARTMENT OF NATURAL RESOURCES
1972

STATE OF UTAH
DEPARTMENT OF NATURAL RESOURCES

Technical Publication No. 37

HYDROLOGIC RECONNAISSANCE OF THE BLUE CREEK VALLEY AREA, BOX ELDER COUNTY, UTAH

by

E. L. Bolke and Don Price, Hydrologists
U. S. Geological Survey

Prepared by the U. S. Geological Survey
in cooperation with the
Utah Department of Natural Resources
Division of Water Rights

1972

ILLUSTRATIONS

TABLES

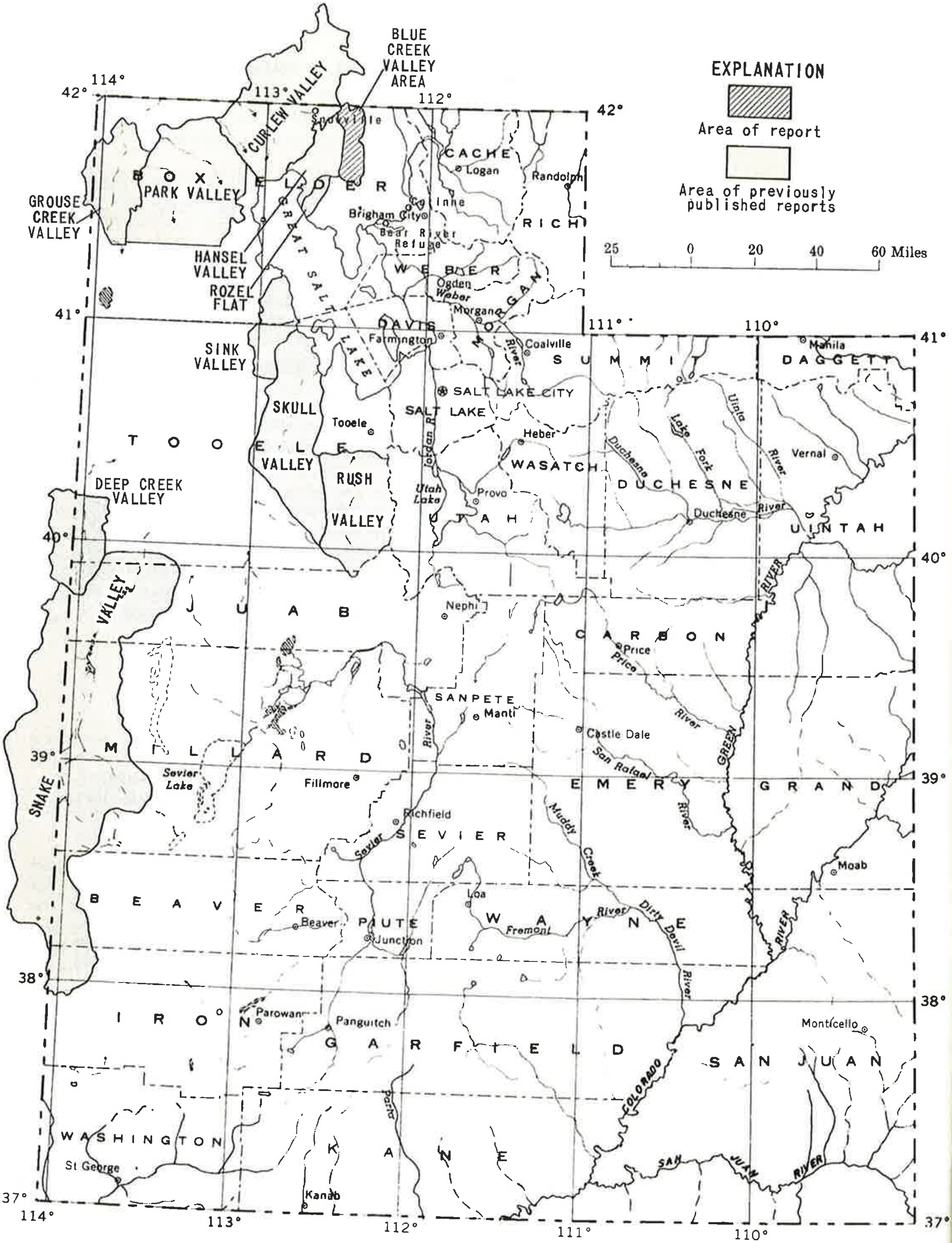


Figure 1.—Location of the Blue Creek Valley area and of other areas described in previously published reports in this reconnaissance series. (See list of technical publications at end of report.)

GEOLOGY

The general geology of the Blue Creek Valley area is shown on plate 1. The age, general lithology, and general hydrologic properties of the principal units are summarized in table 1.

Blue Creek Valley is a structural trough formed by the deformation of rocks of Paleozoic and Tertiary age. The mountain ranges, which consist of rocks of Paleozoic age, were elevated in relation to rocks of the same age that underlie the valley fill by basin- and range-type faulting. Complex folding and faulting accompanied the major structural displacements. The Salt Lake Formation of Tertiary age, which overlies the Paleozoic rocks, was also involved in this structural deformation.

Rocks of Paleozoic and Tertiary age have considerable local relief beneath the valley fill, as indicated by outliers of those rocks (as in Andersons Hill) that protrude above the valley floor. The relief in the consolidated rock is attributed at least in part to faults concealed beneath the valley fill. Such faults are also inferred from (1) the presence of Blue Springs, a thermal spring area that discharges from highly fractured Paleozoic rocks (B. L. Bridges, Geologist, U. S. Soil Conserv. Service, oral commun., 1969) near the north end of Andersons Hill, (2) an apparent "subsurface dam" of upfaulted Paleozoic rocks near the lower end of the valley that impedes drainage from the valley, and (3) local anomalies in the chemical character of the ground water (p. 15). However, subsurface data are not adequate to accurately map any of these inferred faults.

Volcanic activity, which was widespread in adjacent parts of southern Idaho and northern Utah during the Tertiary Epoch, is evidenced in Blue Creek Valley by tuffaceous rocks of the Salt Lake Formation and by layered basaltic lava flows and associated deposits of tuff near the northwest margin of the valley. Lava is reported in logs of several wells drilled in that general area.

The valley fill, which forms the most permeable part of the valley ground-water reservoir, consists largely of detritus eroded from the mountains. Some of the fill was deposited in ancient Lake Bonneville and other pre-existing lakes and reworked by wave action. Shoreline features and deposits of Lake Bonneville are clearly visible at many places along the margins of the valley, especially near the highest level (about 5,200 feet) reached by that lake. Because of the high relief on the underlying rocks, the thickness of the valley fill varies considerably over short distances.

WATER RESOURCES

The quantitative estimates given in this section pertain only to the area within the Blue Creek Valley drainage basin above the narrows in sec. 17, T. 11 N., R. 5 W.

Volume of precipitation

The normal annual (1931-60) precipitation in the Blue Creek Valley drainage basin is shown by isohyets (lines of equal precipitation) on plate 1. The total volume of precipitation was estimated by determining the areas between isohyets, multiplying those areas by the mean value of precipitation between the isohyets and accumulating the total (table 2). The average annual volume of precipitation is about 184,000 acre-feet. Most of this precipitation is returned directly to the atmosphere by evapotranspiration at or near the point of fall; the remaining precipitation becomes runoff or ground-water recharge.

Age	Lithologic unit	General character of material	General hydrologic properties
Mississippian to Permian	Sedimentary and metasedimentary rocks undivided	These rocks form Andersons Hill and the bulk of the mountains that bound Blue Creek Valley. The Oquirrh Formation (Pennsylvanian-Permian age), which consists chiefly of limestone and orthoquartzite with some sandstone, comprises more than 90 percent of the exposures. Manning Canyon Shale (mostly shale and sandstone of Mississippian and Pennsylvanian age) and Great Blue Limestone (mostly massive limestone of Mississippian age) are exposed only locally in Andersons Hill, along the lower slopes of Blue Spring Hills, and in the hills that protrude into the valley from the south. The oldest formation penetrated by oil test (B-11-5)18ddc-1 is reported to be the Laketown Dolomite of Silurian age. All the Paleozoic rocks have undergone considerable deformation and possible local metamorphism. Exposures display intense fracturing, and large solution cavities are evident in several places.	Water-bearing properties are highly variable. The unit as a whole has low permeability, but interconnected fracture zones and solution cavities are capable of transmitting water readily; the possibility of drilling a successful well at any given site is highly unpredictable. The rocks yield less than 10 gpm to most springs in the area; yields to wells range from about 10 to 450 gpm. These rocks probably are the source rocks for most of the flow of Blue Springs and several springs near the south end of Blue Spring Hills.

Table 2.—Estimated average annual volume of precipitation and ground-water recharge from precipitation in the Blue Creek Valley drainage basin

Average annual precipitation: Precipitation zone (inches)	Average annual precipitation: Weighted mean (feet)	Area over which precipitation occurs (acres)	Volume of precipitation (acre-feet)	Precentage of precipitation as recharge	Recharge (acre-feet)
Area where Quaternary and Tertiary sedimentary rocks are exposed					
12-16	1.25	95,770	119,710	5	5,990
16-20	1.50	5,710	8,560	10	860
Subtotals (rounded)		101,500	128,300		6,800
Area where Tertiary igneous rocks and Paleozoic rocks are exposed					
12-16	1.25	21,270	26,590	10	2,660
16-20	1.50	18,950	28,420	15	4,260
More than 20	1.90	440	840	20	170
Subtotals (rounded)		40,700	55,800		7,100
Totals (rounded)		142,000	184,000		14,000

M, Measured by U.S. Geological Survey; F, flowing, but unmeasured (observed by Thiokol Chemical Corp.); E, estimated by U.S. Geological Survey.

Discharge (cfs)	Date
5.0M	Sept. 30, 1959
3.1M	Apr. 19, 1960
4.2M	Oct. 16, 1963
10E	Mar. 19, 1964
11.0M	Apr. 10, 1964
9.0M	Apr. 24, 1964
17.8M	May 7, 1964
2.5M	June 11, 1964
.1E	Sept. 15, 1964
F	Jan. 17, 1969- May 19, 1969
Dry	June 17, 1969
Dry	July 29, 1969
Dry	Aug. 15, 1969
Dry	Sept. 25, 1969
F	Oct. 21, 1969- Dec. 19, 1969
6.8M	Feb. 19, 1970
1.1M	Mar. 18, 1970
1.7M	Apr. 14, 1970
2.4M	May 14, 1970
.5E	July 15, 1970
.3E	Sept. 1, 1970
Dry	Sept. 21, 1970

Ground water

Recharge

The principal source of recharge to the ground-water reservoir in Blue Creek Valley is precipitation that falls on the drainage basin. The volume of recharge was estimated by a method described by Hood and Waddell (1968, p. 22). The estimated recharge is about 14,000 acre-feet annually (table 2) or about 8 percent of the estimated average annual volume of precipitation.

Thiokol Chemical Corp. imports about 150 acre-feet of water per year. About 90 percent of that water is either consumed or percolates into the ground-water reservoir; the remainder is discharged to Blue Creek as treated sewage effluent.

Shallow aquifers in the irrigated segment of the valley below Blue Springs receive some recharge from leaky canals and ditches and from flooded fields; this recharge is regarded as "recycled" ground water and does not add to the total recharge figure. Some additional ground water may enter the Blue Creek Valley area from outside the drainage basin along fault zones and solution cavities. However, data collected for this study were not adequate to confirm this means of recharge or to estimate its magnitude.

Occurence and movement

Ground water in the Blue Creek Valley area occurs under both confined (artesian) and unconfined (water table) conditions. In most of the ground-water reservoir beneath the valley, artesian conditions apparently exist in permeable water-bearing strata that underlie thick beds of clay or other material of poor permeability. Water-table conditions exist in shallow aquifers beneath the valley flat south of Blue Springs. Perched water-table conditions exist locally, especially near the margins of the valley where permeable lakeshore deposits overlie rocks of relatively low permeability. However, the perched aquifers probably are of limited extent and may not be a reliable perennial source of water.

Artesian conditions also exist in the consolidated rocks. These conditions are indicated by Blue Springs and Engineer Spring, which apparently rise along faults in the Paleozoic rocks; and also by the water level in well (B-11-5)5acd-1 (table 3), which taps Paleozoic rocks. Water-table conditions exist in some deep bedrock aquifers such as those tapped by wells (B-11-5)28bba-1 and (B-12-5)27bac-1.

The general direction of ground-water movement in the ground-water reservoir beneath the valley is shown by water-level contours and arrows on plate 1. Ground water moves generally from principal areas of natural recharge on the sides and upper reaches of the valley toward the axis of the valley; movement is then downvalley through the narrow gap near the south boundary of the project area to Great Salt Lake. The overall gradient along the main axis of the valley is slightly more than 500 feet in 25 miles or about 20 feet per mile. The flattening of the gradient near the center of the valley may be due in part to discharge of ground water by evapotranspiration and in part to a subsurface constriction in T. 11 N., R. 5 W., which impedes ground-water movement.

Movement of ground water in the consolidated rocks is controlled largely by geologic structures, such as fault and fracture zones, bedding planes, and solution cavities. Movement is from areas of natural recharge toward the valley fill or toward springs and seeps near the edge of the valley.

Evapotranspiration

Phreatophytes, chiefly greasewood (*Sarcobatus vermiculatus*), rabbitbrush (*Chrysothamnum greenei (?)*), sedges (*Carex* sp.), other marsh grasses, and alfalfa (*Medicago sativa*) discharge ground water by evapotranspiration. Ground water probably was transpired by native vegetation in most of the area presently cultivated; when the land was cleared of native vegetation, evapotranspiration probably was reduced. Excluding the irrigated alfalfa fields, about 200 acres of land below Blue Creek Reservoir contain various amounts of phreatophytes (plant density about 50 percent). In this area the water table is less than 20 feet below land surface. Adjusting the plant density to 100 percent yields about 100 acres covered by phreatophytes. The rate of evapotranspiration is about 2 acre-feet per acre per year (Mower and Nace, 1957, p. 17-21), hence the total evapotranspiration by native phreatophytes is about 200 acre-feet per year.

There are at least 1,000 acres of well-established alfalfa under irrigation in the valley. This alfalfa probably consumes some ground water to supplement the water applied by irrigation. Assuming a ground-water consumption of 0.5 acre-foot per acre per year (J.W. Hood, U.S. Geol. Survey, oral commun., 1971), the evapotranspiration by alfalfa is about 500 acre-feet per year. Thus the total discharge of ground water by evapotranspiration is about 700 acre-feet per year.

Pumpage

Only two large-diameter (more than 6 inches) irrigation wells exist in Blue Creek Valley. In 1969, 256 acre-feet of water was discharged from well (B-13-6)1dbb-1 (estimated from power-consumption records), and about 50 acre-feet was discharged from well (B-13-5)31daa-1. About 30 small-diameter (6 inches or less) domestic and stock wells (pumped at the rate of 1-10 gpm) discharge about 200 acre-feet annually. The total pumpage is about 500 acre-feet annually.

Ground-water outflow

A direct determination of ground-water outflow was not made. The detailed study of the water-bearing properties of the aquifers needed for such a determination is beyond the scope of this investigation. Therefore, the ground-water outflow was estimated as the difference between the total annual recharge (14,000 acre-feet) and the annual discharge by springs, seeps, wells, and evapotranspiration (8,500 acre-feet). The difference is 5,500 acre-feet, which is assumed to be the ground-water outflow from Blue Creek Valley. Ground-water inflow to Blue Creek, unknown but probably small, is included in that amount.

Water-level fluctuations

Changes in ground-water storage resulting from changes in ground-water recharge and discharge are reflected by changes of water levels in wells. Under natural conditions, ground-water recharge and discharge are equal over the long term, and ground-water levels fluctuate in response to changes in precipitation. (See fig. 3.)

A considerable amount of water is stored in the valley fill and in the consolidated rocks that surround and underlie the valley, but no estimate was made of the total amount. Much of this water is probably saline.

Budget

The estimated annual volumes of ground-water recharge and discharge in the Blue Creek Valley drainage basin are given in the following table:

	Acre-feet
Recharge:	
Precipitation (p. 4)	14,000
Total	14,000
Discharge:	
Springs and seeps (p. 11)	7,300
Withdrawal by wells (p. 12)	500
Evapotranspiration (p. 12)	700
Ground-water outflow (p. 12)	5,500
Total	14,000

Of the 8,500 acre-feet of water discharged by wells, springs, and evapotranspiration, about 8,000 acre-feet is used beneficially and about 500 acre-feet is regarded as salvageable.

Perennial yield

The perennial yield of a ground-water system is the maximum amount of water that can be withdrawn from the system each year indefinitely without causing a permanent and continuing depletion of ground water in storage or a deterioration of chemical quality of the ground water. The perennial yield is limited to the amount of natural discharge of water of suitable chemical quality that can economically be salvaged for beneficial use.

Assuming (1) that subsurface outflow is of suitable chemical quality and could be economically intercepted by wells and (2) that the evapotranspiration loss by nonbeneficial phreatophytes could be salvaged, then the perennial yield of the basin would approximate the discharge from the ground-water reservoir or about 14,000 acre-feet.

Chemical quality of water

Chemical analyses of selected water samples from the Blue Creek Valley area are given in table 6. Plate 1 shows diagrams of chemical quality of water. For some analyses, sulfate ion was not determined, and the sulfate values for the diagrams have been estimated by taking the difference (in milliequivalents per liter) of total cations and anions and assuming the difference to be sulfate ion. These estimated values do not appear in table 6.

Most of the water in Blue Creek Valley exceeds these standards in one or more of the categories listed; exceptions are wells (B-13-6)1dbb-1, (B-14-6)3aaa-2, and (B-15-6)35bdb-1 and some mountain springs.

Little information is available concerning the rating of water for stock supplies. The State of Montana (McKee and Wolf, 1963, p. 113) rates water containing less than 2,500 mg/l of dissolved solids as good, 2,500-3,500 mg/l as fair, 3,500-4,000 mg/l as poor, and more than 4,500 mg/l as unfit for stock. Using these criteria, most of the ground-water sampled in Blue Creek Valley is rated as good for stock use.

The principal chemical quality characteristics that affect the usefulness of water for irrigation are: (1) total concentration of soluble salts, (2) relative proportion of sodium to other cations, (3) concentration of boron or other constituents that may be toxic to some plants, and (4) bicarbonate concentration in excess of the concentration of calcium plus magnesium. The U. S. Salinity Laboratory Staff (1954, p. 79-81) has devised a method for classifying water for irrigation use by plotting data on specific conductance (conductivity) versus sodium-absorption ratio (SAR) on a diagram (fig. 4). This method of classification is based on "average conditions" with respect to soil texture, infiltration rate, drainage, quantity of water used, climate, and salt tolerance of crops. Most of the water sampled in Blue Creek Valley has a low- sodium hazard and a high- to very high-salinity hazard (compare table 6 and fig. 4). Well (B-13-6)1dbb-1 (point 7 in fig. 4) is a large-diameter irrigation well; Blue Springs (point 5 in fig. 4) is the largest source of irrigation water in the valley. Crops are raised using water from Blue Springs, which has both a high SAR and a high mineral content.

SUMMARY OF WATER USE

Past and present development

Development of water in the Blue Creek Valley area began prior to 1900 when the first wells were constructed for domestic and stock supplies. The first recorded well in the area was constructed in 1898. However, most of the domestic and stock wells were constructed during the years 1910-20 and 1930-40. Many of those wells are now used only seasonally by the dryland grain farmers.

The water system for the town of Howell began operating in 1947 with the development and diversion of Hillside Spring (table 4). The system was enlarged about 1965 when well (B-12-6)24add-1 was drilled and put into operation. In 1970 the system served about 150 people.

The Thiokol Chemical Corp. plant was constructed about 1957. About that time, Railroad Springs (table 4), which were formerly used for watering of livestock and for wildlife, were developed and diverted to the plant, chiefly for culinary use.

Irrigation in Blue Creek Valley began in 1904 using water from Blue Springs. In 1960 about 2,800 acres of land in the area was irrigated (U. S. Dept. Agriculture, Soil Conserv. Service, 1960, p. 4). Until 1962, Blue Springs was the only major source of irrigation water. An irrigation well was drilled in 1962 and another in 1968; about 300 acres of land is irrigated with water from these two wells.

Future Development

Because most of the land in Blue Creek Valley is cultivated, future development depends chiefly on additional water supplies to provide for increased irrigation. Blue Springs is fully appropriated for irrigation, and surface runoff in the valley is too meager or of too poor quality for irrigation; therefore, any additional irrigation supplies must be obtained from wells. Theoretically, the annual volume of ground water available for additional development is about 6,000 acre-feet—that is, the assumed perennial yield (about 14,000 acre-feet) less the quantity currently used beneficially (about 8,000 acre-feet). However, full development of the 6,000 acre-feet is not feasible because (1) some of the water is chemically unsuitable for irrigation, (2) the valley ground-water reservoir generally has low permeability and in most places yields water too slowly for large-scale irrigation, and (3) pumping may be too costly for irrigation in the upper part of the valley because water levels are several hundred feet below land surface. Therefore, the volume of ground water economically available probably is considerably less than 6,000 acre-feet a year.

PROPOSALS FOR FUTURE STUDIES

As the need for development of ground water in Blue Creek Valley arises, problems resulting from that development will also arise. Problems resulting from increased pumping might be declining water levels, well interference, decrease in flow of Blue Springs, and deterioration of the chemical quality of water. A detailed study of the basin and adjacent areas would help to better understand these problems and bring about a possible solution. Such a study should include:

1. Establishment of streamflow stations, particularly below Blue Springs and on Blue Creek near site (B-10-5)5bab.

2. Test drilling and gravity surveys to determine the subsurface geology and to delineate major aquifers.

3. Inventory of all wells and water sources, expansion of the observation-well network, and monitoring chemical quality of water at selected sites.

4. Aquifer performance tests to determine the water-bearing properties of the aquifers.

5. Collection of climatic records and detailed geologic mapping to more accurately estimate runoff and ground-water recharge.

6. Detailed mapping of phreatophytes.

APPENDIX

TEMPERATURE-CONVERSION TABLE

Temperatures in °C are rounded to nearest 0.5 degree. Underscored temperatures are exact equivalents. To convert from °F to °C where two lines have the same value for °F, use the line marked with an asterisk (*) to obtain equivalent °C.

°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F	°C	°F
-20.0	-4	-10.0	14	0.0	32	10.0	50	20.0	68	30.0	86	40.0	104
-19.5	-3	-9.5	15	+0.5	33	10.5	51	20.5	69	30.5	87	40.5	105
-19.0	-2	-9.0	16	1.0	34	11.0	52	21.0	70	31.0	88	41.0	106
-18.5	-1	-8.5	17	1.5	35	11.5	53	21.5	71	31.5	89	41.5	107
-18.0 *	0	-8.0 *	18	2.0 *	36	12.0 *	54	22.0 *	72	32.0 *	90	42.0 *	108
-17.5	0	-7.5	18	2.5	36	12.5	54	22.5	72	32.5	90	42.5	108
-17.0	1	-7.0	19	3.0	37	13.0	55	23.0	73	33.0	91	43.0	109
-16.5	2	-6.5	20	3.5	38	13.5	56	23.5	74	33.5	92	43.5	110
-16.0	3	-6.0	21	4.0	39	14.0	57	24.0	75	34.0	93	44.0	111
-15.5	4	-5.5	22	4.5	40	14.5	58	24.5	76	34.5	94	44.5	112
-15.0	5	-5.0	23	5.0	41	15.0	59	25.0	77	35.0	95	45.0	113
-14.5	6	-4.5	24	5.5	42	15.5	60	25.5	78	35.5	96	45.5	114
-14.0	7	-4.0	25	6.0	43	16.0	61	26.0	79	36.0	97	46.0	115
-13.5	8	-3.5	26	6.5	44	16.5	62	26.5	80	36.5	98	46.5	116
-13.0	9	-3.0	27	7.0	45	17.0	63	27.0	81	37.0	99	47.0	117
-12.5	10	-2.5	28	7.5	46	17.5	64	27.5	82	37.5	100	47.5	118
-12.0 *	10	-2.0 *	28	8.0 *	46	18.0 *	64	28.0 *	82	38.0 *	100	48.0 *	118
-11.5	11	-1.5	29	8.5	47	18.5	65	28.5	83	38.5	101	48.5	119
-11.0	12	-1.0	30	9.0	48	19.0	66	29.0	84	39.0	102	49.0	120
-10.5	13	-0.5	31	9.5	49	19.5	67	29.5	85	39.5	103	49.5	121

For temperature conversions beyond the limits of the table, use the equations C = 0.5556 (F - 32) and F = 1.8°C + 32. The formulae say, in effect, that from the freezing point of water (0°C, 32°F) the temperature in °C rises (or falls) 5° for every rise (or fall) of 9°F.

BASIC DATA

Table 3.—Records of selected wells—continued

Well number	Owner	Priority date	Well depth (ft)	Casing Diameter (in.)	Casing Depth (ft)	Casing Finish	Altitude of LSD (ft)	Water level (ft)	Date of water-level measurement	Use of water	Log	Other data available
6/(B-13-5)31daa-1	L. D. Nessen	1962C	405	16	20	P	4,610	27A	7-70	I	D	P
33acc-1	Lawrence Hawkes	1900	180	2	-	O	4,780	170G	3-40	H	-	P
(B-13-6)1bdb-1	R. W. Henrie	1904	195	6	-	-	4,870	175G	3-36	S	-	P
1bdb-2	J. E. Deakin	1929	200	4	-	-	4,875	175G	3-40	H	-	-
1cac-1	M. J. Hyde	1929C	200	4	-	-	4,845	150A	10-49	U	-	P
7/1dbb-1	R. W. Henrie	1968C	704	16	482	P	4,835	121A	9-70	I	D	P
2cab-1	D. B. Bradshaw	1941C	275	6	-	-	4,970	237A	7-70	U	-	-
2dab-1	J. E. Deakin	1906	175	6	-	-	4,885	150G	3-36	U	-	-
10dda-1	H. J. Anderson	1926	364	6	-	O	5,075	311A	7-70	U	-	-
12aba-1	R. W. Henrie	1958C	-	8	-	-	4,900	-	-	S	-	P
14bbc-1	O. P. Canfield	1949C	-	-	-	-	5,070	-	-	S	-	-
24add-1	C. H. Miller	1911	250	6	-	-	4,795	-	-	H	-	-
24dcd-1	W. T. Miller	1911	250	6	-	-	4,825	-	-	H	-	P
36acc-1	Alfred Manning	1911	300	6	-	-	4,800	200G	3-36	S	-	P
(B-14-5)4bab-1	Gerald Jessop	1914	185	6	-	O	5,070	160A	7-70	U	-	-
5aaa-1	L. G. Whitney	1922	150	6	-	-	5,065	130G	4-40	H	-	-
5aba-1	Gerald Jessop	1898	430	3	100	-	5,060	125G	8-36	U	-	-
5bab-1	L. G. Whitney	1932	190	4	-	O	5,070	50G	3-40	U	-	-
8dbc-1	Edward Jessop	1917	180	6	-	O	5,160	31A	7-70	S	-	-
8ddd-1	M. S. Jessop	1918	105	6	-	O	5,175	62A	7-70	H	-	P
17aaa-1	Seth Hammond	1915	125	6	113	P	5,175	70A	7-70	U	-	-
19ccc-1	H. M. Schumann	1934	-	-	-	-	4,920	174A	7-70	U	-	-
28cca-1	William Roberts	1935C	610	-	-	X	5,120	Dry	11-35	U	D	-
29abb-1	H. and L. Schumann	1917	340	42	-	W	5,040	297A	7-70	H	-	P
30cbd-1	James Roberts	1924	200	6	191	-	4,960	166G	3-40	U	-	-
31cdd-1	Edward Doutre	1912	160	4	-	-	4,820	96A	7-70	U	-	-
(B-14-6)3aaa-2	W. R. Bishop	1969C	390	6	348	O	5,115	340D	9-69	H	D	P
9aab-1	Deloris Stokes	1967C	409	6	-	-	5,150	390D	8-67	H	D	P
12add-1	W. E. Fridal	1934	462	6	455	O	5,045	287D	-	U	D	-
12caa-1	Coop Security	1933C	480	8	445	P	5,150	406A	7-70	H	-	P
23add-1	Ray Holdaway	1941C	336	4	-	-	5,050	309A	7-70	U	-	-
23ddd-1	Hyer and Turley	1915C	350	6	348	P	5,030	300G	3-40	H	-	K
24cbc-1	R. B. Hyer	1920	330	6	-	-	5,035	304A	7-70	H	-	P
36cba-1	A. H. Rock	1900	200	2	-	O	4,920	149A	7-70	U	-	-
(B-15-5)32cdd-1	L. G. Whitney	1915	200	8	-	-	5,055	50G	8-44	H	-	P
(B-15-6)34ccc-1	R. W. Tolman	1968C	555	6	-	O	5,230	461D	7-68	H	D	P
35bdb-1	Deloris Stokes	1920	-	-	-	-	5,085	-	-	S	-	P

1/ Reported yield and drawdown: 450 gpm and 20 feet, October, 1962.

2/ Reported yield and drawdown: 90 gpm and 32 feet, July, 1956.

3/ Reported yield and drawdown: 80 gpm and 50 feet, June, 1962.

4/ Well destroyed.

5/ Reported yield and drawdown: 290 gpm and 140 feet, April, 1958.

6/ Reported yield and drawdown: 350 gpm and 200 feet, December, 1962.

7/ Reported yield and drawdown: 580 gpm and 192 feet, October, 1968.

Table 5.—Selected drillers' logs of wells.

Altitudes are in feet above sea level for land surface at well, interpolated from U.S. Geological Survey 7.5-minute topographic maps (20-foot contour interval).
Thickness in feet.
Depth in feet below land surface.

Material	Thickness	Depth
(B-11-5)5acd-1. Log by J. Hy Petersen and Sons. Alt. 4,445 ft.		
Topsoil	3	3
Clay, yellow	61	64
Clay, yellow, and gravel	31	95
Clay, sand, and gravel	49	144
Clay, yellow, and streaks of sandstone	20	164
Gravel, sand, and clay	32	196
Clay, sandy, yellow, and gravel	69	265
Gravel, sand, and hard clay	23	288
Gravel, cemented, hard, and sticky and sandy clay	81	369
Clay, yellow, and fine sandy gravel	29	398
Gravel, cemented	7	405
Gravel, hard, and clay	33	438
Gravel, hard, clay, and broken limestone boulders	7	445
Limestone, solid	94	539
Limestone, soft, black	13	552
Limestone, hard, broken	3	555
Limestone, soft, gray	10	565
Limestone, soft, broken	4	569
Limestone, hard, black	41	610
(B-11-5)28bba-1. Log by Melvin Church Drilling Co. Alt. 4,540 ft.		
Soil, rocky	2	2
Clay	3	5
Conglomerate	6	11
Rocks, large, and clay	183	194
Unlogged	1	195
Silt, yellow	5	200
Silt, red, and rocks	10	210
Silt and rocks; water seep	8	218
Limestone, broken	14	232
Shale, black	86	318
Rock; water seepage	6	324
Shale and limestone, lenticular	41	365
(B-11-5)29abb-1. Log by Melvin Church Drilling Co. Alt. 4,410 ft.		
Soil, rocky	4	4
Clay, gumbo	6	10
Conglomerate	26	36
Clay, gumbo	10	46
Conglomerate	37	83
Boulders and clay	4	87
Conglomerate	48	135
Clay, gumbo	6	141
Conglomerate	9	150
Gravel; water bearing	2	152
Clay	7	159
Gravel; water bearing	13	172
Clay	22	194
Gravel	2	196
Clay	4	200
Gravel; water bearing	14	214
Clay	2	216
(B-11-5)29cbd-1. Log by T. J. Burkhart. Alt. 4,340 ft.		
Soil	2	2
Clay, sandy	21	23
Gravel	7	30
Gravel and clay	15	45
Clay, sandy	15	60
Gravel	2	62
Clay, sandy	9	71
Gravel and clay	17	88
Sand, dirty	11	99
Gravel	8	107
Sand	8	115
Gravel	5	120
Clay	6	126
Sand and gravel	20	146
Clay	9	155
Gravel or sand	3	158
Gravel, dirty	26	184
Clay	8	192
Gravel with some clay	40	232
Gravel, loose	19	251
Gravel and boulders, dirty	53	304
Gravel and sand	6	310
(B-11-6)16bcc-1. Log by D. G. Musselman. Alt. 5,040 ft.		
Topsoil	3	3
Sandstone	17	20
Clay, blue	33	53
Clay, white	73	126
Clay, yellow, and gravel	10	136
Sandrock	156	292
(B-12-5)22dbd-1. Log by Robinson Drilling Co. Alt. 4,750 ft.		
Clay, silt, and cobbles	3	3
Sand and gravel	5	8
Clay, yellow, and boulders	7	15
Clay, red	5	20
Clay and boulders	10	30
Boulders	13	43
(B-12-5)22dbd-1 - Continued		
Limestone	18	61
Clay, red and yellow	4	65
Clay and rock	5	70
Limestone	10	80
Clay and rock	7	87
Boulders	6	93
Clay and rock	27	120
Shale, black	26	146
Limestone	53	199
Shale, black	52	251
Limestone, hard	32	283
Limestone, fractured	17	300
Limestone, hard	13	313
Shale, black	20	333
Limestone, hard	9	342
(B-12-6)24add-1. Log by Waymon Yarbrough. Alt. 4,620 ft.		
Clay	6	6
Clay and boulders	17	23
Clay and sand	22	45
Gravel	50	95
Clay and sand	23	118
Limestone	1	119
Limestone and clay	26	145
Clay and sand	10	155
Sand, soft, tight	5	160
Limestone, hard	117	277
Sand, soft	2	279
Sand	12	291
Limestone, hard	2	293
Sand and clay	7	300
(B-12-6)34acd-1. Log by David Musselman. Alt. 5,170 ft.		
Clay, red	10	10
Rocks	4	14
Clay, red	236	250
"Hardpan"	10	260
Clay, red, and gravel	28	288
Clay, white, sandy	10	298
Clay, red, and gravel	54	352
"Hardpan"	10	362
Clay, red, and gravel	10	372
"Hardpan"	12	384
Clay, soft, red	8	392
Sand	46	438
Gravel and clay	20	458
Sand	8	466
Clay	4	470
(B-13-5)5bcb-2. Log by T. J. Burkhart. Alt. 4,820 ft.		
Soil	2	2
Clay, yellow	38	40
Clay, soft, sandy, yellow	12	52
Clay, hard, sandy, light gray	53	105
Clay, yellow, and gravel	82	187
Clay, dense, gray	45	232
Shale, sandy, hard and soft streaks, light gray	28	260
(B-13-5)6aaa-2. Log by R. J. Howell Drilling Co. Alt. 4,840 ft.		
Clay, brown	5	5
Clay, yellow, and sand	30	35
Gravel, dry	2	37
Clay, yellow	33	70
Clay, brown, and conglomerate	12	82
Clay, brown, and lava rock	4	86
Clay, brown, and sand	10	96
Clay, brown, and lava rock	4	100
Clay and gravel	15	115
Clay and boulders	15	130
Sandstone	20	150
Limestone	25	175
Clay, red	10	185
Limestone, hard	3	188
Sand, red, and gravel; water bearing	10	198
Sand and gravel	32	230
Limestone	5	235
(B-13-5)7acc-1. Log by Davis and Davis. Alt. 4,800 ft.		
Sand and shale	±120	±120
Sandstone, sand, and shale	278	398
Sand; water bearing	14	412
(B-13-5)28bab-1. Alt. 4,665 ft.		
Soil, black	1	1
Clay	110	111
Gravel	1	112
(B-13-5)29aaa-1. Log by T. J. Burkhart. Alt. 4,640.		
Soil	2	2
Clay, light gray	21	23
Clay, light brown, and gravel	15	38
Clay, light gray	16	54
(B-13-5)29aaa-1 - Continued		
Gravel and boulders	3	57
Clay, light brown, and gravel	63	120
Clay, sandy, light brown	31	151
Gravel and light brown clay	40	191
Gravel and boulders; some clay	5	196
Gravel and light brown clay	19	215
Boulders, gravel, and light brown clay	88	303
Sand, clay, and gravel	21	324
Gravel and clay	4	328
(B-13-5)31daa-1. Log by Waymon Yarbrough. Alt. 4,610 ft.		
Soil	7	7
Clay	35	42
Unlogged; water bearing	13	55
Clay, gray	23	78
Gravel, coarse, boulders, and sand	12	90
Clay, white	22	112
Shale, hard	3	115
Clay, blue	30	145
Shale, hard	5	150
Clay, white	50	200
Clay, blue green	20	220
Clay, green	50	270
Sandy (sandy streak)	5	275
Shale	5	280
Clay, white	25	305
Clay, soft, blue	10	315
Sandstone, hard	10	325
Sandy (sandy streak)	1	326
Sandstone	4	330
Sandy (sandy streak)	1	331
Shale	4	335
Clay, hard	10	345
Limestone	25	370
Sand, black	10	380
Clay	20	400
Clay, hard	5	405
(B-13-6)1dbb-1. Log by Robinson Drilling Co. Alt. 4,835 ft.		
Soil	9	9
Clay	28	37
Clay and gravel	77	114
Clay	29	143
Clay with lime seams	57	200
Clay	6	206
Clay with limestone seams	6	212
Clay and gravel	69	281
Clay	13	294
Gravel	2	296
Clay	53	349
Gravel	2	351
Clay and sand	23	374
Gravel	11	385
Clay	14	399
Gravel	4	403
Clay and gravel	78	481
Clay	3	484
Gravel	12	496
Clay	16	512
Gravel	7	519
Clay	13	532
Gravel	2	534
Clay and gravel	39	573
Gravel	61	634
Clay and gravel	6	640
Gravel	31	671
Clay	8	679
Gravel	18	697
Clay and gravel	7	704
(B-14-5)28cca-1. Log by Adam Inthurn and F. H. Hughes. Alt. 5,120 ft.		
Conglomerate	140	140
Clay	35	175
Rock	65	240
Conglomerate	80	320
Rock	35	355
Shale	39	394
Rock, black	12	406
Sand and sandstone	77	483
Rock, black	50	533
Conglomerate	10	543
Rock, black	25	568
Conglomerate	15	583
Rock, black	27	610
(B-14-6)3aaa-2. Log by R. H. Howell Drilling Co. (0-320 ft) and R. O. Denton (328-390 ft). Alt. 5,115 ft.		
Lime(stone), white	12	12
Sandstone, red, hard	10	22
Clay, red	28	50
Sandstone, red	18	68
Red rock or hardpan	4	72
Clay, red	15	87
Cobbles	5	92

Table 6.—Chemical analyses of selected water samples.

Sodium and potassium: An entry of C for potassium indicates that sodium and potassium are calculated and reported as sodium.
Agency making analysis: GS, U.S. Geological Survey; IN, Thiokol Chemical Corp.; SU, Utah State University.

Location	Date of collection	Temperature (°C)	Milligrams per liter																	Specific conductance (micromhos/cm at 25°C)	Sodium-adsorption ratio	pH	Agency making analysis
			Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Boron (B)	Hardness as $CaCO_3$	Noncarbonate hardness	Dissolved solids: Determined	Dissolved solids: Calculated				
Wells																							
(B-11-6)2bdc-1	7-14-70	11.5	-	-	122	28	37	-	171	0	-	240	-	-	-	418	278	765	-	1,080	0.8	8.0	GS
14bbb-1	8-10-70	14.0	-	-	184	54	42	-	143	0	-	218	-	-	-	680	563	-	-	1,460	-	7.9	GS
(B-12-5)5cdb-1	7-14-70	9.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3,690	-	-	GS
5d	1913	-	-	-	1/80	-	160	C	310	0	40	155	-	-	-	205	-	570	-	-	4.9	-	GS
7ccc-1	7-13-70	12.0	-	-	131	98	69	-	192	0	-	460	-	-	-	732	575	1,020	-	1,830	1.1	7.8	GS
7ddc-1	7-13-70	9.5	-	-	418	180	1,520	-	539	0	-	2,580	-	-	-	1,780	1,340	6,080	-	9,280	16	7.8	GS
10bca-1	7-14-70	15.5	-	-	66	37	129	-	254	3	-	226	-	-	-	317	104	708	-	1,220	3.2	8.5	GS
19ba	1913	-	-	-	1/80	-	200	C	215	0	40	275	-	-	-	205	-	690	-	-	6.1	-	GS
20bbb-2	7-14-70	9.5	32	-	97	59	1,020	20	525	25	129	1,470	1.2	4.0	0.45	486	14	3,260	3,120	5,270	20	8.7	GS
20bbb-3	7-14-70	10.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7,320	-	-	GS
(B-12-6)13ddd-1	7-13-70	12.5	44	-	61	47	38	3.0	179	0	33	173	.9	5.4	.01	347	200	526	493	885	.9	8.2	GS
36ada-1	7-14-70	16.5	42	-	77	49	67	7.7	183	0	54	230	.7	2.9	.05	391	241	644	620	1,100	1.5	8.2	GS
(B-13-5)5bcb-2	7- 8-70	14.5	53	-	98	40	61	6.9	173	0	20	267	.5	4.2	.03	410	268	717	636	1,140	1.3	8.1	GS
6aaa-2	7- 8-70	19.0	-	-	185	70	108	-	144	0	-	591	-	-	-	750	632	1,230	-	2,120	1.7	7.9	GS
8d	1913	-	-	-	1/80	-	180	C	220	0	40	275	-	-	-	205	-	700	-	-	5.5	-	GS
16ccc-1	7- 7-70	18.5	-	-	572	245	547	-	142	0	-	2,380	-	-	-	2,430	2,320	4,860	-	7,190	4.8	7.8	GS
18adb-1	7-13-70	-	-	-	152	226	176	-	224	0	-	520	-	-	-	1,310	1,130	1,980	-	2,980	2.1	8.0	GS
18c	1913	-	-	-	1/80	-	110	C	215	0	100	105	-	-	-	205	-	480	-	-	3.3	-	GS
22ccc-1	7- 8-70	16.5	-	-	65	24	78	-	269	0	-	128	-	-	-	260	40	501	-	860	2.1	8.2	GS
28b	1913	-	-	-	1/95	-	180	C	240	0	30	405	-	-	-	240	-	900	-	-	5.1	-	GS
28bab-1	7- 8-70	13.0	-	-	233	94	146	-	163	0	-	751	-	-	-	968	834	1,600	-	2,660	2.0	7.8	GS
31daa-1	7-13-70	20.5	-	-	89	41	153	-	343	4	-	274	-	-	-	391	103	1,010	-	1,440	3.4	8.4	GS
33acc-1	7-14-70	19.0	-	-	52	23	101	-	274	3	-	136	-	-	-	224	0	509	-	901	2.9	8.6	GS
(B-13-6)1bdb-1	7- 6-70	16.5	-	-	149	32	41	-	144	0	-	331	-	-	-	506	388	818	-	1,340	.8	7.8	GS
1cac-1	10-17-57	-	53	-	204	44	49	C	140	0	102	395	-	20	-	688	573	-	936	1,650	.8	7.5	GS
1dbb-1	7- 6-70	19.0	47	-	71	19	31	10	160	0	16	127	.4	6.1	.04	260	124	405	407	701	.8	8.2	GS
12aba-1	7- 7-70	16.5	-	-	325	77	62	-	150	0	-	551	-	-	-	1,130	1,000	1,700	-	2,470	.8	7.9	GS
24dcd-1	7-13-70	14.5	-	-	113	75	48	-	204	0	-	325	-	-	-	597	430	936	-	1,450	.9	7.9	GS
36acc-1	7-13-70	17.5	-	-	447	153	143	-	162	0	-	1,340	-	-	-	1,740	1,610	3,450	-	4,270	1.5	8.0	GS
(B-14-5)8ddd-1	7- 7-70	10.5	29	-	91	19	72	1.7	321	0	69	55	.2	7.6	.06	304	41	600	474	878	1.8	8.2	GS
29abb-1	7- 6-70	13.0	40	-	216	56	48	7.6	138	0	49	490	.3	3.9	.00	770	657	1,330	979	1,850	.8	8.1	GS
(B-14-6)3aaa-2	7- 7-70	12.0	29	-	56	22	59	4.5	187	0	26	131	.5	1.9	.05	231	78	440	422	739	1.7	7.6	GS
9aab-1	7- 7-70	20.5	-	-	67	25	213	-	2/258	0	-	341	-	-	-	270	58	870	-	1,530	5.6	8.3	GS
12caa-1	7- 7-70	12.0	26	-	87	17	41	10	143	0	44	176	.3	.0	.06	285	168	517	471	823	1.1	8.2	GS
23ddd-1	7- 8-70	10.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1,270	-	-	GS
24cbc-1	7- 8-70	10.0	-	-	121	30	33	-	183	-	-	230	-	-	-	428	278	773	-	1,080	.7	7.8	GS
(B-15-5)32cdd-1	7- 7-70	12.5	-	-	199	23	119	-	2/249	0	-	234	-	-	-	340	135	772	-	1,230	2.8	8.4	GS
(B-15-6)34ccc-1	7- 7-70	20.5	41	-	60	25	247	5.7	259	0	40	375	1.0	.3	.06	252	40	938	922	1,610	6.8	7.9	GS
35bdb-1	7- 7-70	18.5	-	-	88	16	16	-	258	0	-	64	-	-	-	284	73	417	-	634	.4	8.2	GS
Springs																							
(B-11-5)3cac-S1	7-14-70	17.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	765	-	-	GS
12cca-S1	7-14-70	17.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	631	-	-	GS
21-23-S3/	10- -62	-	13	-	36	5	47	-	-	-	22	75	-	-	0.06	112	-	382	-	-	1.9	8.1	IN
21-23-S3/	11- -62	-	17	-	53	11	73	-	-	-	42	119	-	-	.19	176	-	526	-	-	2.4	8.3	IN
(B-11-6)24ddb-S1	8-11-70	-	-	-	101	19	71	-	187	0	-	190	-	-	-	330	177	-		1,010	-	8.0	GS
(B-12-5)11cdd-S1	7-14-70	11.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	858	-	-	GS
14baa-S1	7-14-70	17.0	-	-	79	15	90	-	243	4	-	140	-	-	-	257	51	543	-	909	2.5	8.5	GS
14ccc-S1	7-14-70	18.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	798	-	-	GS
22dac-S1	7-14-70	20.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	889	-	-	GS
(B-12-6)33dba-S1	7-14-70	20.5	-	-	81	12	54	-	250	0	-	100	-	-	-	252	46	477	-	751	1.5	8.2	GS
(B-13-5)29-S	1913	-	-	-	1/75	-	630	C	240	0	40	840	-	-	-	185	-	1,600	-	-	20	-	GS
29-S	9-10-64	26.5	-	-	83	24	540	32	268	-	68	886	-	-	.2	306	-	-	1,923	3,580	13	8.0	SU
29-S	7- 7-70	28.0	19	-	56	24	636	22	329	0	84	895	0.4	1.0	.22	238	0	2,010	1,900	3,410	18	7.9	GS
Blue Creek [at location (B-10-5)5bab]																							
Discharge (cfs)																							
-	6-29-59	17.5	19	-	112	68	1,810	C	538	20	426	2,530	-	10	8.1	560	86	-	5,270	8,640	33	8.4	GS
5.0	9-30-59	12.0	26	0.04	98	36	941	34	350	16	202	1,380	2.0	1.7	.40	392	79	-	2,910	5,130	21	8.5	GS
3.1	4-19-60	12.0	26	.04	128	72	1,430	41	397	24	372	2,150	-	1.7	.55	615	250	-	4,440	7,710	25	8.5	GS
-	4- 6-61	6.0	21	.03	184	126	2,540	65	552	0	716	3,740	-	12	-	978	526	-	7,700	12,400	35	8.0	GS
4.2	10-16-63	15.0	-	-	-	-	-	-	-	-	350	2,200	-	-	-	510	-	4,220	-	7,170	-	-	GS
4/10	3-19-64	-	-	-	-	-	-	-	-	-	434	2,200	-	-	-	595	-	4,670	-	7,430	-	-	GS
11.0	4-10-64	7.0	-	-	-	-	-	-	-	-	354	1,950	-	-	-	510	-	3,850	-	6,400	-	-	GS
9.0	4-24-64	7.0	-	-	-	-	-	-	-	-	400	2,300	-	-	-	600	-	4,670	-	7,550	-	-	GS
17.8	5- 7-64	7.0	-	-	-	-	-	-	-	-	362	1,900	-	-	-	430	-	3,820	-	6,400	-	-	GS
2.5	6-11-64	13.5	26	-	136	96	2,330	-	628	-	612	3,290	-	4.7	-	735	220	6,740	-	10,800	-	8.1	GS
4/.1	9-15-64	-	-	-	-	-	-	-	-	-	395	2,440	-	-	-	454	-	4,920	-	8,140	-	-	GS
6.8	2-19-70	-	22	-	160	107	2,110	C	592	0	570	3,080	-	.6	-	840	355	6,540	6,340	10,100	32	7.8	GS
1.1	3-18-70	2.5	23	-	140	95	2,080	-	579	0	626	3,080	-	.2	-	740	265	6,560	6,330	10,100	33	8.1	GS
1.7	4-14-70	7.0	23	-	124	75	1,640	-	498	0	392	2,480	-	.0	-	620	212	5,140	4,980	8,330	29	8.1	GS
7.0	5-14-70	18.0	-	-	-	-	-	-	-	-	-	3,280	-	-	-	-	-	-	-	10,500	-	-	GS
4/.3	9- 1-70	18.5	-	-	-	-	-	-	-	-	-	2,350	-	-	-	-	-	-	-	7,980	-	-	GS

1/ Calcium plus magnesium. 2/ Some CO_3 included as HCO_3. 3/ Composite sample from 12 springs (Railroad Springs). 4/ Estimated.

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(*)—Out of Print

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*No. 6. Ground water in the Escalante Valley, Beaver, Iron, and Washington Counties, Utah, by P. F. Fix, W. B. Nelson, B. E. Lofgren, and R. G. Butler, U. S. Geological Survey, in Utah State Eng. 27th Bienn. Rept., p. 107-210, pls. 1-10, 1950.

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*No. 13. Ground-water resources of selected basins in southwestern Utah, by G. W. Sandberg, U. S. Geological Survey, 1966.

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*No. 14. Consumptive use of water by native vegetation and irrigated crops in the Virgin River area of Utah, by Wayne D. Criddle, Jay M. Bagley, R. Keith Higginson, and David W. Hendricks, through cooperation of Utah Agricultural Experiment Station, Agricultural Research Service, Soil and Water Conservation Branch, Western Soil and Water Management Section, Utah Water and Power Board, and Utah State Engineer, Salt Lake City, Utah, 1964.

*No. 15. Ground-water conditions and related water-administration problems in Cedar City Valley, Iron County, Utah, February, 1966, by Jack A. Barnett and Francis T. Mayo, Utah State Engineer's Office.

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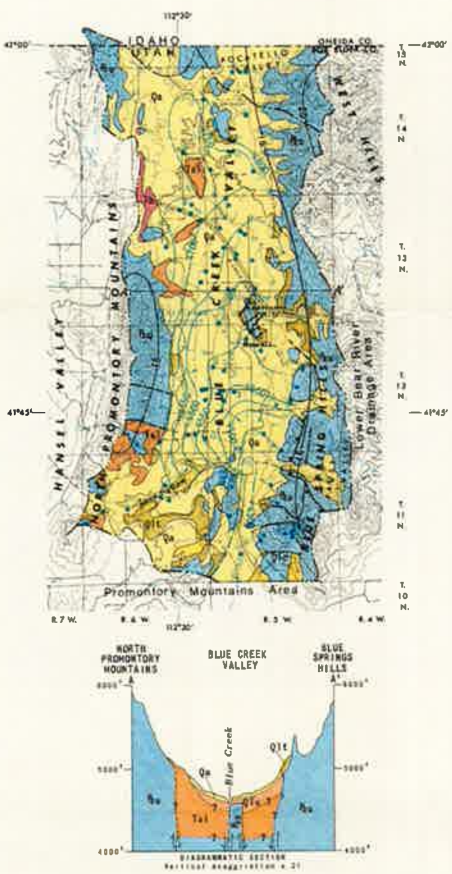


Generalized hydrogeology

EXPLANATION

GEOLOGY
(See table 1)

Cenozoic

QUATERNARY

Qa — Surficial alluvial deposits
Mostly clay and silt; some gravel and scattered boulders; generally transmit water slowly

Qlb — Lake-bottom deposits
Mostly clay and silt; some very fine sand; transmit water slowly

Qlt — Lakeshore deposits
Sand and gravel in spits, bars, and on terraces; transmit water readily

TERTIARY and QUATERNARY

Valley-fill deposits
Not exposed, but underlie mapped Quaternary units in much of the area. Mostly clay or clay mixed with sand and gravel strata which yield water readily

TERTIARY

Extrusive igneous rocks
Layered basaltic lava flows with some local associated tuff deposits; interflow zones transmit water readily

Salt Lake Formation
Mostly tuffaceous sandstone; some limestone, conglomerate, and volcanic debris; generally transmits water slowly, but some loosely cemented zones transmit water readily

Paleozoic

MISSISSIPPIAN to PERMIAN

Ps — Sedimentary and metasedimentary rocks undivided
Mostly limestone; some sandstone, quartzite, and shale; generally transmit water slowly, but interconnected fracture zones and solution cavities transmit water readily

Approximate contact
Dashed where inferred

Fault
Dashed where concealed, dotted where inferred

Thrust fault
Barbs on side of thrust sheet

A — A'
Line of diagrammatic section

HYDROLOGY

20
Line of equal normal annual precipitation
Interval 4 inches

4300
Water-level contour
Shows altitude of water level; dashed where approximately located; contour interval 50 feet; datum is mean sea level; arrows denote direction of ground-water movement

Spring
Number by spring symbol indicates number of springs shown in the same location

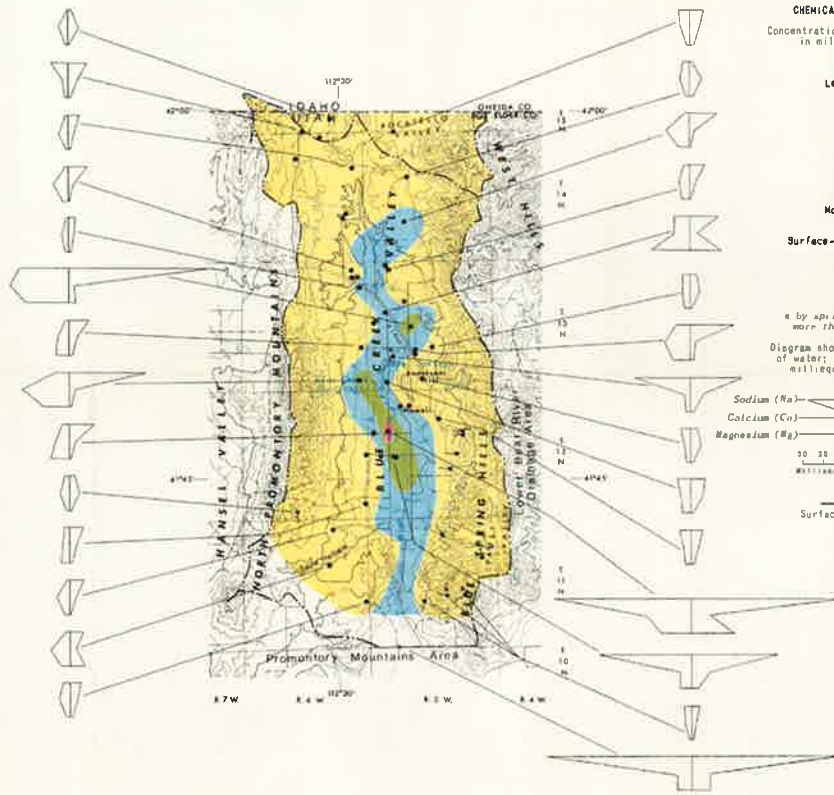
Well
Open circle indicates well used for water-level control; number by symbol indicates number of wells shown in the same location

Miscellaneous stream discharge measuring site

Partial-record gaging station

Surface-drainage divide

Hydrogeology by E. L. Bolke and Don Price, 1970. Geology adapted from Stokes (1964). Climatologic data from U.S. Weather Bureau, 1963



Chemical quality of water and location of sampling sites

EXPLANATION

CHEMICAL QUALITY OF WATER

Concentration of dissolved solids, in milligrams per liter

Less than 1000

1000-3000

3000-6000

More than 6000

Surface-water sampling site

Well

Spring
2 by spring symbol indicates more than one spring area

Diagram showing chemical analyses of water; constituents given in milliequivalents per liter

Sodium (Na) — Chloride (Cl)
Calcium (Ca) — Bicarbonate (HCO_3)
Magnesium (Mg) — Sulfate (SO_4)

30 20 10 0 10 20 30
Milliequivalents per liter

Surface drainage divide

Compiled by E. L. Bolke and Don Price, 1970

Base from U.S. Geological Survey Pocatello and Brigham City, 1954

0 — 5 MILES
CONTOUR INTERVAL 200 FEET
DATUM IS MEAN SEA LEVEL

HYDROGEOLOGIC MAPS OF THE BLUE CREEK VALLEY AREA, BOX ELDER COUNTY, UTAH

APPENDIX A WORK PLAN FOR THE DEVELOPMENT OF A NEW SITE-SPECIFIC TDS CRITERION FOR BLUE CREEK, JUNE, 2011

APPENDIX B BLUE CREEK SITE-SPECIFIC STANDARD FOR TOTAL DISSOLVED SOLIDS (TDS) CRITERION MONITORING REPORT, ATK LAUNCH SYSTEMS PROMONTORY, JULY 11, 2013

ATK

July 11, 2013
8200-FY14-033

Mr. Walter L Baker, Director
Division of Water Quality
Utah Department of Environmental Quality
195 N. 1950 W.
P.O. Box 144870
Salt Lake City, Utah 84114-4870

Attention: Chris Bittner

Re: ATK Launch Systems-Promontory UPDES Permit #0024805, Blue Creek Site-Specific Standard for Total Dissolved Solids (TDS) Criterion Monitoring Report

Dear Mr. Baker:

In June 2011 ATK Launch Systems Inc. ("ATK") submitted a work plan for the development of a new site-specific TDS standard for Blue Creek. ATK, in cooperation with Chris Bittner of your staff, has completed the monitoring and data collection outlined in the work plan. Enclosed are the monitoring results and data from the sampling that was collected.

ATK appreciates the opportunity to work with the Division in the development of this new stream criterion for Blue Creek.

Please contact me if you have any questions concerning this report. My telephone number is (435)863-2018 or you can contact Blair Palmer at (435)863-2430.

Sincerely

George E. Gooch, Manager
Environmental Services

1.0 Introduction

In June 2011 ATK Launch Systems Inc. submitted a work plan for use in the development of a site-specific criterion for Total Dissolved Solids (TDS) on a stream segment of Blue Creek. The stream segment of Blue Creek begins at 41°43'20.40" N, 112°26'33.58" W a location on the northern boundary of ATK's facility along Highway 83 that ATK identifies as Blue Creek Upper with the stream segment ending at the Great Salt Lake. ATK currently has two wastewater treatment discharges along this stream segment under UPDES Permit #UT0024805. (See Figures 1 & 2, Goggle Earth image) The objective of this monitoring report is to assist in the establishment of a site specific standard for the stream segment of Blue Creek from the Blue Creek Reservoir Dam flowing southward to the Great Salt Lake.

2.0 Background

Blue Creek originates approximately 8 miles north of the ATK Facility from Blue Springs. Blue Springs is a warm springs that has a TDS concentration of 2000 mg/L. The primary constituents of the TDS are sodium, chloride, and sulfate which are naturally found in the soils throughout the valley. These soils were generated from localized deposits from the ancient lake Bonneville. It is likely the source feeding the warms springs circulates slowly through these fine-grained sediments allowing these soluble minerals to leach into the groundwater.

The Blue Creek Reservoir Dam was constructed in 1904 and modified, enlarged and repaired in 1949, 1967 and 1986. The current capacity of the reservoir is about 2,185 acre-feet (UDWR, 2001). Water from Blue Springs is stored in the reservoir during the winter months and used for agricultural irrigation during the spring through fall season. The water in the reservoir is distributed by canals owned by the Blue Creek Irrigation Company. The two main canals, the East Canal and the West Canal, are used to irrigate a portion of the valley north of ATK's facility (Bolke and Price, 1972).

Several saline springs feed the main channel of Blue Creek once it leaves the Blue Creek Reservoir. These springs are the major source of flow in Blue Creek during most of the year as it passes through the ATK facility.

Prior to 1975, the stream segment of Blue Creek from the irrigation dam flowing southward was an intermittent stream only flowing significantly after rainfall events and snow melts. As a result of an earthquake in March 1975, Blue Creek became a perennial stream with year round flow resulting from the springs located below the Blue Creek Reservoir Dam.

3.0 Sampling and Investigation

The sampling and investigation was focused on determining the natural and unaltered TDS concentration for the stream segment of Blue Creek beginning at the Blue Creek Reservoir Dam flowing south to Blue Creek Upper (north boundary of ATK property, Hwy 83). This flow is predominantly made up of the springs below the dam.

ATK sampled each site identified below, once a month. During periods of transition, i.e. when conditions changed at the reservoir such as water being discharged or not discharged from the dam to Blue Creek or the irrigation channels, sampling was conducted once a week for a three week period.

- Blue Creek Reservoir below the dam;
- Blue Creek at crossing 14400 N; and
- Blue Creek Upper (north boundary of ATK property, Hwy 83).

These sites are illustrated in Figure 3 (Goggle Earth image), and are all north of the ATK facility.

The samples collected from these sites were analyzed for:

- Metals, Method 200.7 to include, Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Ni, P, Pb, Sb, Se, Sn, Ti, Tl, V, Zn, Sr;
- Mercury Method 245.1;
- Total Dissolved Solids (TDS), Method 160.1; and
- Anions, Method 300 IC to include, Fluoride, Chloride, Nitrite-N, Bromide, Nitrate-N, Orthophosphate-P, Sulfate.
- Flow (gallons/minute)

During each sampling event, a visual investigation was conducted to verify if water discharged from the Blue Creek Reservoir Dam was flowing into either of the irrigation canals or if it is being discharged directly to Blue Creek.

Sampling these sites and conducting the visual investigations allowed the development of two datasets:

- When water is being discharged from the Blue Creek Reservoir Dam into the main channel of Blue Creek thereby, lowering the TDS level of Blue Creek by dilution; and
- Periods when water is being discharged from the Blue Creek Reservoir into irrigation canals with no flow going to Blue Creek, which is intended to represent natural conditions that predominate most of the year. This would represent the flow and TDS level in the main channel of Blue Creek that result from springs or seeps that occur below the reservoir dam southward.

The development of these datasets will help characterize different flow conditions, as well as allowing the coordination of the sampling and analytical results with the flow conditions.

In addition to collecting samples, a velocity meter was used to measure the average flow velocity of Blue Creek at each sample site. The water depth was measured and used to determine a cross sectional area of the channel at each site providing an estimate for flow in gallons per minute. The flow measurements were used to determine if TDS concentrations correlated with the changing flows over the course of a year.

Field electrical conductivity measurements were also taken from several sources that flow to Blue Creek during a multi-day sampling event. These sources originate from springs and seeps in the property adjacent to Blue Creek as it flows from the reservoir below the dam to the Blue Creek Upper (north boundary of ATK property, Hwy 83) site (see figures 4 & 5). These electrical conductivity measurements were then correlated to calculate TDS concentrations and can be seen in Table 1.

4.0 Sampling Results

Sampling and visual investigations began April 14, 2011 and have been completed monthly for the past two years. The TDS concentrations of each sampling event have been collected over the course of that time and can be found in Table 2. This data has been plotted in Figure 6 to illustrate seasonal trends in concentrations.

Figure 6 shows the plotted results of the TDS concentrations for each of the sampling sites along with correlating flow measurements. The chart has been color coded to distinguish the two datasets listed on the previous page. The time period where Blue Creek was receiving additional flow from the dam is highlighted in blue. The time period when Blue Creek receives no flow from the dam is highlighted in yellow.

Concentrations have also been color coded to match the measured flow for each site to help decipher which concentration belongs to which flow reading. It can be seen that the flow in Blue Creek does not correlate with the TDS concentrations measured at each site along the stream. TDS concentrations below the dam remain consistent at around 2,000 mg/L while the Upper site and Crossing site show a greater deviation in concentrations and continuously fluctuate over the course of a year, however, they do show TDS levels increase due to the influence of the high TDS springs.

The variation in TDS concentrations and lack of correlation with flow data is most likely the combination of seasonal weather patterns and upstream irrigation practices. Due to the ever changing dynamics of the stream it is difficult to distinguish a specific dataset that would be considered the "natural and unaltered" state for the entire length of Blue Creek. As a result, the focus of the investigation has been directed toward determining the 95% Upper Tolerance Limit (UTL) based on data collected from the Blue Creek Upper site.

ProUCL 4.1 was used to calculate the 95% UTL of 5,918 mg/L for the Blue Creek Upper dataset found in column 4 of Table 2. The same method was used to calculate a second 95% UTL for historical data previously collected each quarter at the Upper site from year 2000 to year 2010. The results from the historical data showed a 95% UTL of 6,123 mg/L. Both levels are much higher than the current standard of 1,200 mg/L set for Blue Creek.

Electrical conductivity measurements taken from several sources that discharge to Blue Creek are identified in Figures 4 and 5 along with Table 1. The conductivity measurements show that those sources have higher levels of TDS than the average concentrations measured at the Upper site. This demonstrates that the high levels of TDS measured in Blue Creek are a result of naturally occurring saline springs that contribute to the TDS loading after the dam and prior to entering ATK property.

The high TDS levels seen in the upstream sources are consistent with concentrations found in groundwater wells and other springs in the area. Historical groundwater monitoring data shows TDS concentrations in wells located in the valley near Blue Creek range from 2,800 mg/L to 8,800 mg/L. Samples taken from nearby springs have TDS concentrations ranging from 4,500 mg/L to 7,170 mg/L. Therefore, it can be seen that the groundwater feeding the springs contributing to the flow of Blue Creek is naturally high in TDS.

5.0 Summary and Conclusions

The objective of this monitoring report is to assist in the establishment of a site specific standard for the stream segment of Blue Creek from the Blue Creek Reservoir Dam flowing southward to the Great Salt Lake. Through the sampling and investigation that was conducted, TDS concentrations, and the concentrations of the individual water constituents that contribute to the Blue Creek TDS have been sampled and monitored along with the different stream flow conditions that occur in Blue Creek. This information will allow a site-specific standard for TDS in Blue Creek to be established that represents the natural and unaltered TDS concentration that is protective of current uses.

ATK believes that the sampling and monitoring that has been completed is sufficient to allow the establishment of a site specific standard for the TDS in Blue Creek. The 95% upper tolerance limits for data from the time period of 2011-2013 and 2000-2010 are 5,918 mg/L and 6,123 mg/L respectively.

Figure 1. Point of Proposed Site Specific Standard for Blue Creek

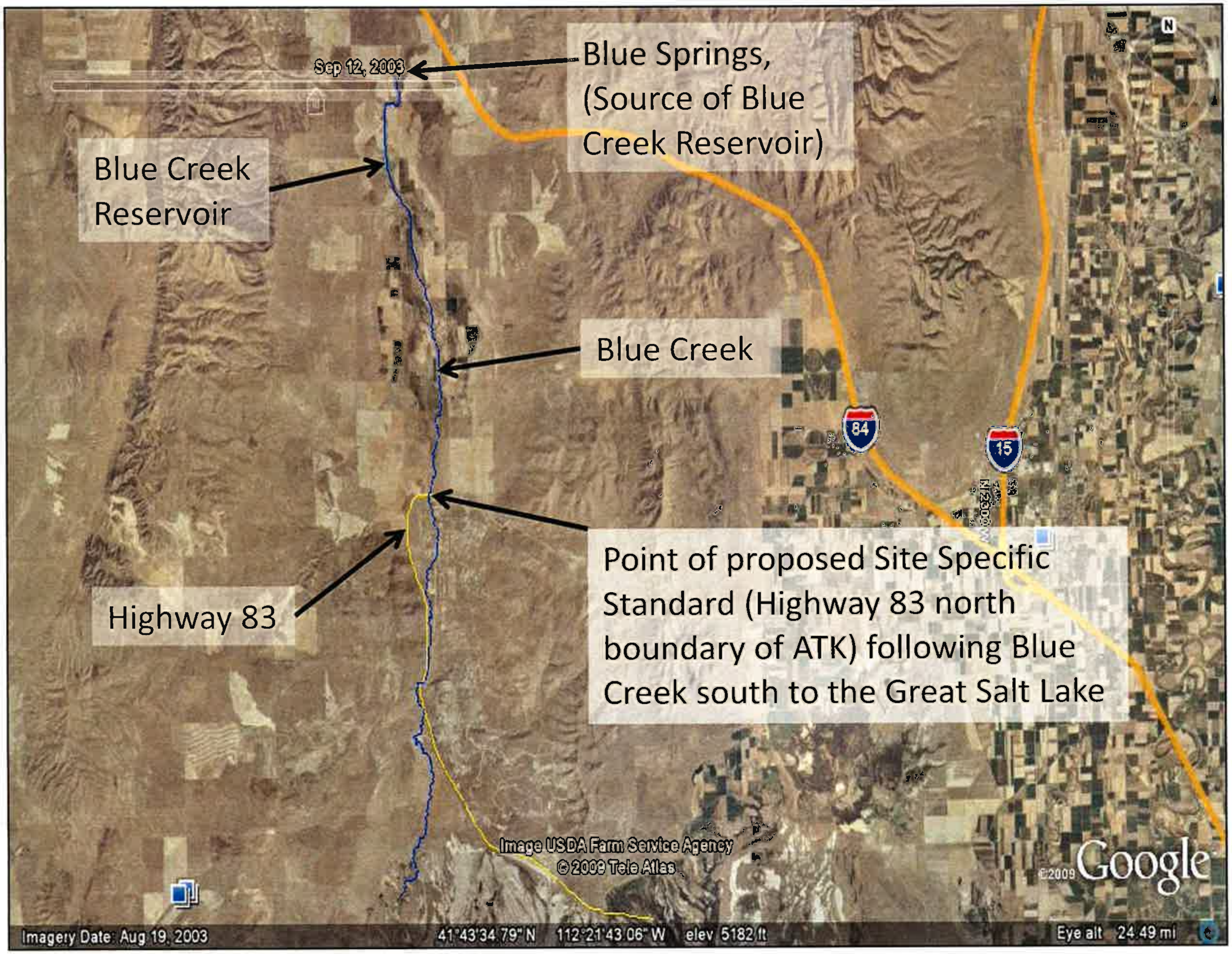


Figure 2. ATK Outfall Locations

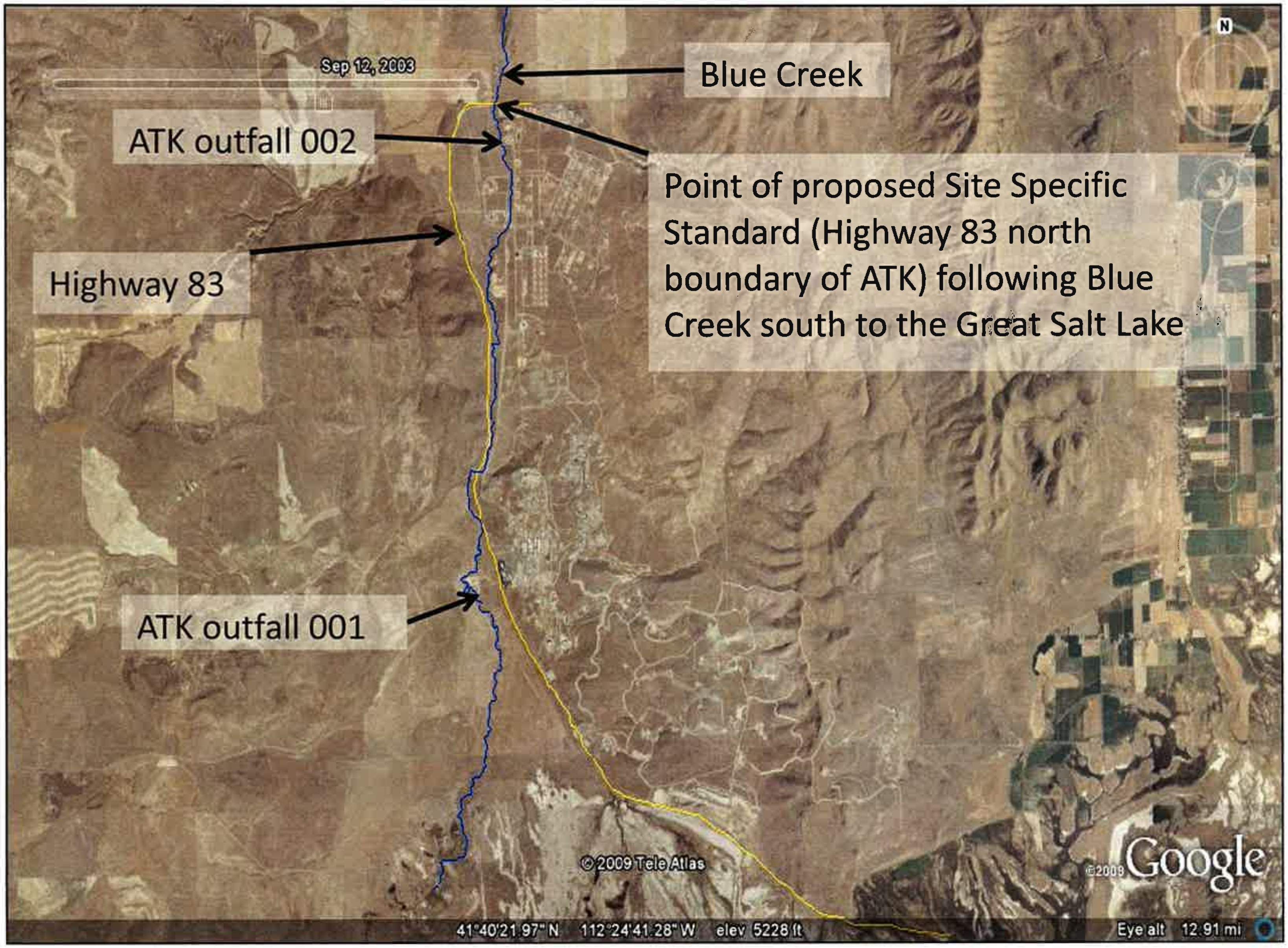


Figure 3. Blue Creek Source and Sample Sites

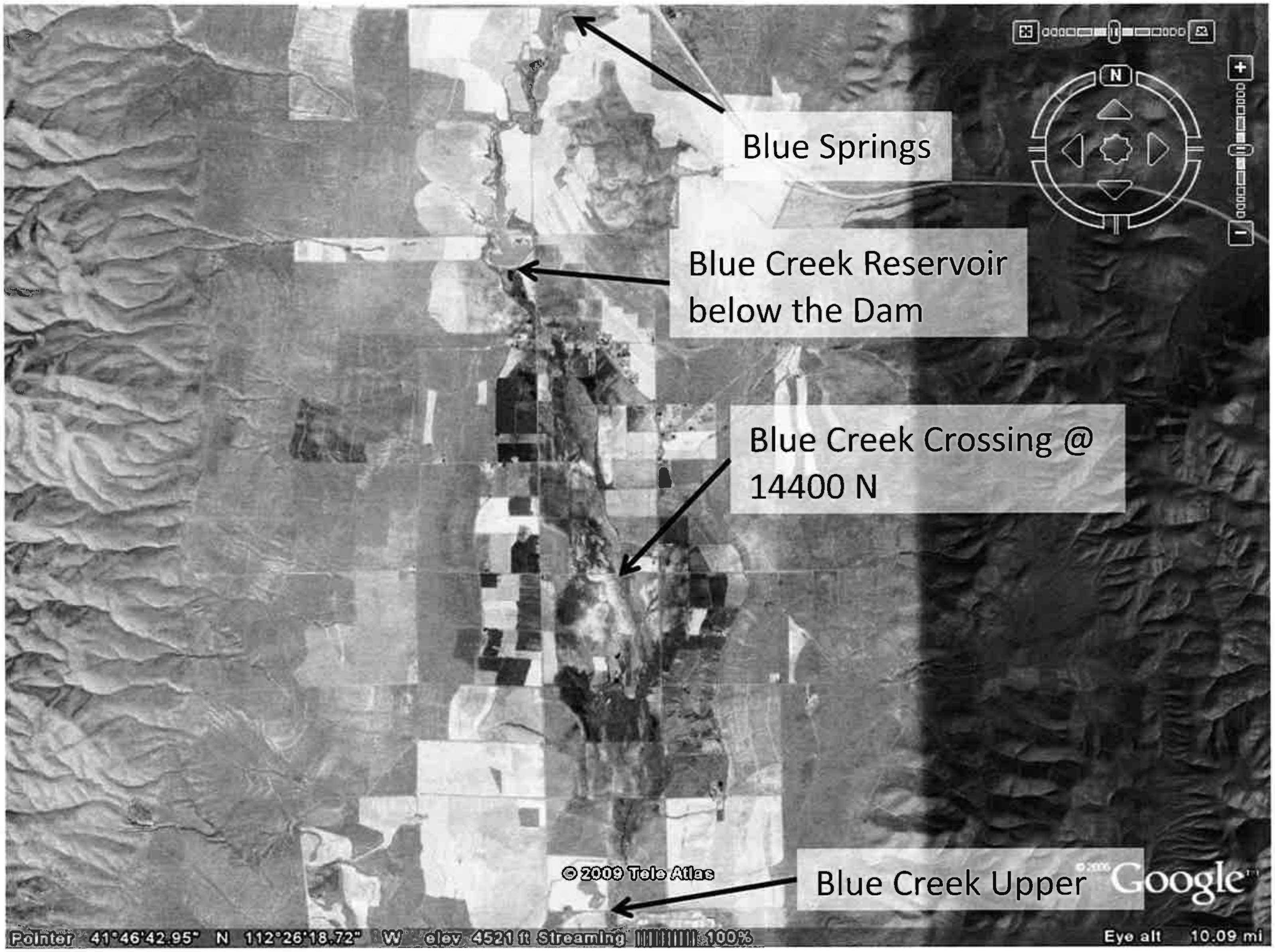


Figure 4. Conductivity Sample Sites of Blue Creek Sources

Figure 5. Conductivity Sample Sites of Blue Creek Sources (Continued)

Table 1. Conductivity Sample Site Descriptions and Concentrations

Sample Point	Site Description	Concentration (mg/L)	Sample Point	Site Description	Concentration (mg/L)
1	Below Dam	2,260	13	Cornwall Blue Creek	4,290
2	Blue Creek at Diversion	2,340	14	Cornwall 4	5,950
3	Sorensen 1	3,170	15	Cornwall 3	4,960
4	Irrigation (no sample)	-	16	Snowmelt	-
5	Sorensen 4	2,900	17	Douglass 2	5,050
6	Sorensen 3	5,690	18	Douglass 3.5	28,200
7	Odel 2	3,770	19	Douglass 3	31,300
8	Odel 1	3,840	20	Douglass 1	9,390
9	Blue Creek Crossing	9,320	21	Cornwall 2	4,930
10	Odel 3	448	22	Cornwall 1	4,800
11	Cornwall Pond	6,320	23	East Culvert	4,350
12	Odell's Discharge	6,330			

Table 2. TDS Concentrations from Blue Creek Study (mg/L)

Sample Date	Below Dam	Crossing	Upper
4-14-2011	1,890	3,350	5,270
5-26-2011	1,920	2,600	2,260
6-8-2011	1,910	3,370	3,930
7-26-2011	2,090	2,820	3,380
8-16-2011	1,990	3,310	3,230
9-29-2011	1,980	3,220	3,780
10-21-2011	1,960	4,020	4,260
11-17-2011	2,030	4,160	3,380
12-20-2011	2,080	3,740	4,850
1-27-2012	2,070	3,140	4,570
2-1-2012	2,020	3,140	4,550
2-9-2012	2,040	2,900	4,210
2-16-2012	2,030	3,310	4,890
3-19-2012	1,940	2,470	4,160
4-16-2012	2,070	5,060	6,270
4-23-2012	1,910	3,490	4,710
4-30-2012	1,990	3,410	4,730
5-7-2012	1,990	3,650	4,350
6-4-2012	1,990	2,930	3,720
7-10-2012	2,060	3,040	4,230
8-8-2012	2,110	3,220	2,980
9-5-2012	2,100	3,780	4,140
10-5-2012	2,050	3,120	3,760
11-5-2012	1,990	3,510	3,620
12-6-2012	1,920	4,670	5,630
1-14-2013	2,020	2,840	4,210
1-22-2013	2,100	2,810	4,050
1-30-2013	2,009	2,870	4,180
2-7-2013	2,009	2,640	5,170
3-4-2013	2,009	2,870	5,370
4-1-2013	1,990	2,980	4,260
5-7-2013	1,970	3,080	4,250
Average	2,009	3,298	4,261
95% UTL	2,115	4,315	5,918

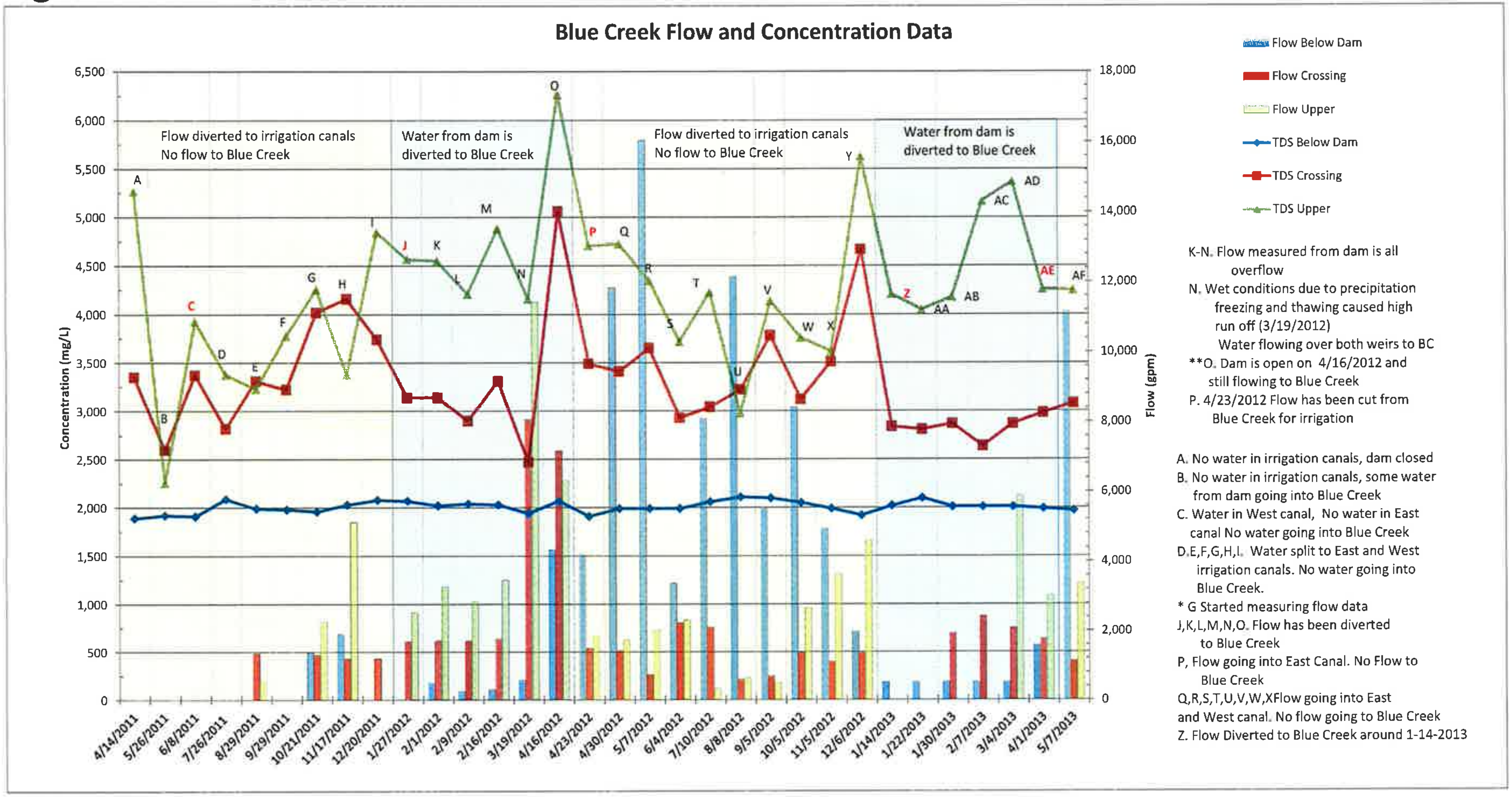
Table 3. ProUCL Results for 2010-2013 Upper Site Concentrations

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Coverage	90%
Different or Future K Values	1
Number of Bootstrap Operations	2,000
Log-Transformed Statistics	
Number of Valid Observations	32
Number of Distinct Observations	29
Minimum	7.723
Maximum	8.744
Second Largest	8.636
Mean	8.339
First Quartile	8.236
Median	8.348
Third Quartile	8.459
SD	0.198
Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.959
5% Shapiro Wilk Critical Value	0.93
Background Statistics Assuming Lognormal Distribution	
90% Percentile (z)	5,395
95% Percentile (z)	5,797
99% Percentile (z)	6,636
95% UPL	5,887
Tolerance Factor K	1.75
95% UTL with 90% Coverage	**5,918**
Some Nonparametric Background Statistics	
95% Chebyshev UPL	7,814
95% Bootstrap BCA UTL with 90% Coverage	5,604
95% Percentile Bootstrap UTL with 90% Coverage	5,604

Table 4. ProUCL Results for 2000-2010 Upper Site Concentrations

User Selected Options	
From File	WorkSheet.wst
Full Precision	OFF
Confidence Coefficient	95%
Coverage	90%
Different or Future K Values	1
Number of Bootstrap Operations	2000
Log-Transformed Statistics	
Number of Valid Observations	43
Number of Distinct Observations	40
Minimum	7.99
Maximum	8.753
Second Largest	8.723
Mean	8.341
First Quartile	8.162
Median	8.324
Third Quartile	8.5
SD	0.226
Lognormal Distribution Test	
Shapiro Wilk Test Statistic	0.938
5% Shapiro Wilk Critical Value	0.943
Background Statistics Assuming Lognormal Distribution	
90% Percentile (z)	5,604
95% Percentile (z)	6,084
99% Percentile (z)	7,098
95% UPL	6,162
Tolerance Factor K	1.67
95% UTL with 90% Coverage	**6,123**
Some Nonparametric Background Statistics	
95% Chebyshev UPL	8,690
95% Bootstrap BCA UTL with 90% Coverage	5,990
95% Percentile Bootstrap UTL with 90% Coverage	6,050

Figure 6.


Blue Creek Flow and Concentration Data
Concentration (mg/L)
Flow (gpm)
Flow diverted to irrigation canals
No flow to Blue Creek
Water from dam is
diverted to Blue Creek
Flow diverted to irrigation canals
No flow to Blue Creek
Water from dam is
diverted to Blue Creek
Flow Below Dam
Flow Crossing
Flow Upper
TDS Below Dam
TDS Crossing
TDS Upper
K-N. Flow measured from dam is all overflow
N. Wet conditions due to precipitation freezing and thawing caused high run off (3/19/2012)
Water flowing over both weirs to BC
**O. Dam is open on 4/16/2012 and still flowing to Blue Creek
P. 4/23/2012 Flow has been cut from Blue Creek for irrigation
A. No water in irrigation canals, dam closed
B. No water in irrigation canals, some water from dam going into Blue Creek
C. Water in West canal, No water in East canal No water going into Blue Creek
D,E,F,G,H,I. Water split to East and West irrigation canals. No water going into Blue Creek.
* G Started measuring flow data
J,K,L,M,N,O. Flow has been diverted to Blue Creek
P, Flow going into East Canal. No Flow to Blue Creek
Q,R,S,T,U,V,W,XFlow going into East and West canal. No flow going to Blue Creek
Z. Flow Diverted to Blue Creek around 1-14-2013

References

Bolke, E.L. and Price D. 1972. Hydrologic Reconnaissance of the Blue Creek Valley Area, Box Elder County, Utah. Utah Department of Natural Resources Technical Publication No. 37.

UDWR (Utah Division of Water Resources). 2001. Utah State Water Plan, West Desert Basin, Salt Lake City, Utah. 3-17p.

APPENDIX C TOTAL DISSOLVED SOLIDS DATA

- Blue Creek Upper ATK and DWQ STORET 4960740 Data

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
6/2/1989	4038	Irrigate	1989	4038	Summer	June
6/16/1989	3348	Irrigate	1989	3348	Summer	June
6/29/1989	3536	Irrigate	1989	3536	Summer	June
7/7/1989	3910	Irrigate	1989	3910	Summer	July
7/21/1989	4200	Irrigate	1989	4200	Summer	July
8/11/1989	3726	Irrigate	1989	3726	Summer	Aug
8/25/1989	4864	Irrigate	1989	4864	Summer	Aug
9/8/1989	3130	Irrigate	1989	3130	Summer	Sept
9/22/1989	3020	Irrigate	1989	3020	Summer	Sept
10/6/1989	3022	Irrigate	1989	3022	Summer	Oct
10/20/1989	3066	Irrigate	1989	3066	Summer	Oct
11/3/1989	2916	Irrigate	1989	2916	Winter	Nov
11/16/1989	2472	Irrigate	1989	2472	Winter	Nov
12/1/1989	2334	Irrigate	1989	2334	Winter	Dec
12/12/1989	3824	Irrigate	1989	3824	Winter	Dec
1/5/1990	3404	No_irr	1990	3404	Winter	Jan

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
1/19/1990	4408	No_irr	1990	4408	Winter	Jan
2/2/1990	3876	No_irr	1990	3876	Winter	Feb
2/16/1990	3752	No_irr	1990	3752	Winter	Feb
3/2/1990	2800	No_irr	1990	2800	Summer	March
3/16/1990	2850	No_irr	1990	2850	Summer	March
3/30/1990	4068	No_irr	1990	4068	Summer	March
4/13/1990	3112	Irrigate	1990	3112	Summer	April
4/27/1990	3308	Irrigate	1990	3308	Summer	April
5/11/1990	3768	Irrigate	1990	3768	Summer	May
5/25/1990	4588	Irrigate	1990	4588	Summer	May
6/7/1990	4030	Irrigate	1990	4030	Summer	June
6/22/1990	3172	Irrigate	1990	3172	Summer	June
7/6/1990	3744	Irrigate	1990	3744	Summer	July
7/20/1990	3664	Irrigate	1990	3664	Summer	July
8/3/1990	4202	Irrigate	1990	4202	Summer	Aug
8/17/1990	3880	Irrigate	1990	3880	Summer	Aug

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
8/31/1990	3660	Irrigate	1990	3660	Summer	Aug
9/14/1990	3672	Irrigate	1990	3672	Summer	Sept
9/28/1990	2250	Irrigate	1990	2250	Summer	Sept
10/12/1990	2572	Irrigate	1990	2572	Summer	Oct
10/26/1990	2624	Irrigate	1990	2624	Summer	Oct
11/9/1990	2536	Irrigate	1990	2536	Winter	Nov
11/21/1990	5596	Irrigate	1990	5596	Winter	Nov
12/7/1990	4328	Irrigate	1990	4328	Winter	Dec
12/21/1990	4286	No_irr	1990	4286	Winter	Dec
1/4/1991	4744	No_irr	1991	4744	Winter	Jan
1/18/1991	3700	No_irr	1991	3700	Winter	Jan
2/12/1991	3558	No_irr	1991	3558	Winter	Feb
2/22/1991	3320	No_irr	1991	3320	Winter	Feb
3/8/1991	3212	No_irr	1991	3212	Summer	March
3/22/1991	4222	No_irr	1991	4222	Summer	March
4/5/1991	2868	No_irr	1991	2868	Summer	April

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
4/19/1991	3742	Irrigate	1991	3742	Summer	April
5/3/1991	4364	Irrigate	1991	4364	Summer	May
5/17/1991	3380	Irrigate	1991	3380	Summer	May
5/31/1991	5620	Irrigate	1991	5620	Summer	May
6/12/1991	3394	Irrigate	1991	3394	Summer	June
6/18/1991	3172	Irrigate	1991	3172	Summer	June
6/21/1991	3842	Irrigate	1991	3842	Summer	June
6/25/1991	4766	Irrigate	1991	4766	Summer	June
7/12/1991	3038	Irrigate	1991	3038	Summer	July
7/26/1991	3698	Irrigate	1991	3698	Summer	July
8/6/1991	3800	Irrigate	1991	3800	Summer	Aug
8/23/1991	4200	Irrigate	1991	4200	Summer	Aug
9/6/1991	3700	Irrigate	1991	3700	Summer	Sept
9/20/1991	3500	Irrigate	1991	3500	Summer	Sept
9/24/1991	3550	Irrigate	1991	3550	Summer	Sept
10/1/1991	3500	Irrigate	1991	3500	Summer	Oct

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
10/16/1991	3400	Irrigate	1991	3400	Summer	Oct
11/1/1991	4400	Irrigate	1991	4400	Winter	Nov
11/12/1991	4084	Irrigate	1991	4084	Winter	Nov
11/13/1991	4200	Irrigate	1991	4200	Winter	Nov
11/27/1991	5300	Irrigate	1991	5300	Winter	Nov
12/13/1991	4700	Irrigate	1991	4700	Winter	Dec
12/23/1991	3900	No_irr	1991	3900	Winter	Dec
1/10/1992	4600	No_irr	1992	4600	Winter	Jan
1/16/1992	4120	No_irr	1992	4120	Winter	Jan
1/24/1992	3800	No_irr	1992	3800	Winter	Jan
2/7/1992	3000	No_irr	1992	3000	Winter	Feb
2/21/1992	4100	No_irr	1992	4100	Winter	Feb
2/25/1992	3832	No_irr	1992	3832	Winter	Feb
3/6/1992	3600	No_irr	1992	3600	Summer	March
3/20/1992	3000	No_irr	1992	3000	Summer	March
4/3/1992	2600	No_irr	1992	2600	Summer	April

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
4/14/1992	2718	Irrigate	1992	2718	Summer	April
4/17/1992	2800	Irrigate	1992	2800	Summer	April
4/29/1992	4500	Irrigate	1992	4500	Summer	April
5/15/1992	3800	Irrigate	1992	3800	Summer	May
5/29/1992	4400	Irrigate	1992	4400	Summer	May
6/2/1992	4702	Irrigate	1992	4702	Summer	June
6/12/1992	3400	Irrigate	1992	3400	Summer	June
6/25/1992	4000	Irrigate	1992	4000	Summer	June
7/9/1992	4000	Irrigate	1992	4000	Summer	July
7/21/1992	3924	Irrigate	1992	3924	Summer	July
7/22/1992	3600	Irrigate	1992	3600	Summer	July
8/6/1992	3930	Irrigate	1992	3930	Summer	Aug
8/21/1992	4490	Irrigate	1992	4490	Summer	Aug
9/2/1992	3530	Irrigate	1992	3530	Summer	Sept
9/9/1992	3686	Irrigate	1992	3686	Summer	Sept
10/2/1992	4020	Irrigate	1992	4020	Summer	Oct

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
10/13/1992	5020	Irrigate	1992	5020	Summer	Oct
10/20/1992	5242	Irrigate	1992	5242	Summer	Oct
10/30/1992	7180	Irrigate	1992		Summer	Oct
11/13/1992	5916	Irrigate	1992	5916	Winter	Nov
11/25/1992	3094	Irrigate	1992	3094	Winter	Nov
12/8/1992	4468	Irrigate	1992	4468	Winter	Dec
12/10/1992	5812	Irrigate	1992	5812	Winter	Dec
12/23/1992	4736	No_irr	1992	4736	Winter	Dec
1/13/1993	4749	No_irr	1993	4749	Winter	Jan
1/29/1993	5534	No_irr	1993	5534	Winter	Jan
2/11/1993	5116	No_irr	1993	5116	Winter	Feb
2/23/1993	5280	No_irr	1993	5280	Winter	Feb
2/26/1993	4296	No_irr	1993	4296	Winter	Feb
3/12/1993	4437	No_irr	1993	4437	Summer	March
3/26/1993	3293	No_irr	1993	3293	Summer	March
4/9/1993	4488	No_irr	1993	4488	Summer	April

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
4/28/1993	3264	Irrigate	1993	3264	Summer	April
5/4/1993	3750	Irrigate	1993	3750	Summer	May
5/13/1993	3106	Irrigate	1993	3106	Summer	May
5/27/1993	4136	Irrigate	1993	4136	Summer	May
6/4/1993	4231	Irrigate	1993	4231	Summer	June
6/15/1993	4124	Irrigate	1993	4124	Summer	June
6/18/1993	4528	Irrigate	1993	4528	Summer	June
6/30/1993	3668	Irrigate	1993	3668	Summer	June
7/9/1993	3536	Irrigate	1993	3536	Summer	July
7/20/1993	3116	Irrigate	1993	3116	Summer	July
8/6/1993	3652	Irrigate	1993	3652	Summer	Aug
8/20/1993	4115	Irrigate	1993	4115	Summer	Aug
8/24/1993	4728	Irrigate	1993	4728	Summer	Aug
9/2/1993	3853	Irrigate	1993	3853	Summer	Sept
9/16/1993	4233	Irrigate	1993	4233	Summer	Sept
9/30/1993	4561	Irrigate	1993	4561	Summer	Sept

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
10/12/1993	3556	Irrigate	1993	3556	Summer	Oct
10/15/1993	3522	Irrigate	1993	3522	Summer	Oct
10/29/1993	2918	Irrigate	1993	2918	Summer	Oct
11/11/1993	2783	Irrigate	1993	2783	Winter	Nov
11/23/1993	5702	Irrigate	1993	5702	Winter	Nov
12/10/1993	5803	Irrigate	1993	5803	Winter	Dec
12/22/1993	5592	No_irr	1993	5592	Winter	Dec
1/7/1994	5385	No_irr	1994	5385	Winter	Jan
1/21/1994	5334	No_irr	1994	5334	Winter	Jan
2/4/1994	4737	No_irr	1994	4737	Winter	Feb
2/18/1994	3881	No_irr	1994	3881	Winter	Feb
3/9/1994	3735	No_irr	1994	3735	Summer	March
3/23/1994	4933	No_irr	1994	4933	Summer	March
4/13/1994	3336	No_irr	1994	3336	Summer	April
4/19/1994	2986	Irrigate	1994	2986	Summer	April
4/29/1994	3456	Irrigate	1994	3456	Summer	April

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
5/11/1994	5042	Irrigate	1994	5042	Summer	May
5/26/1994	3333	Irrigate	1994	3333	Summer	May
6/9/1994	3935	Irrigate	1994	3935	Summer	June
6/24/1994	3710	Irrigate	1994	3710	Summer	June
7/8/1994	3419	Irrigate	1994	3419	Summer	July
7/19/1994	3321	Irrigate	1994	3321	Summer	July
7/20/1994	3890	Irrigate	1994	3890	Summer	July
8/4/1994	3934	Irrigate	1994	3934	Summer	Aug
8/18/1994	3820	Irrigate	1994	3820	Summer	Aug
9/1/1994	3846	Irrigate	1994	3846	Summer	Sept
9/16/1994	3394	Irrigate	1994	3394	Summer	Sept
9/26/1994	3512	Irrigate	1994	3512	Summer	Sept
10/12/1994	3961	Irrigate	1994	3961	Summer	Oct
10/28/1994	4048	Irrigate	1994	4048	Summer	Oct
11/10/1994	4775	Irrigate	1994	4775	Winter	Nov
11/23/1994	2983	Irrigate	1994	2983	Winter	Nov

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
12/6/1994	4227	Irrigate	1994	4227	Winter	Dec
12/23/1994	4849	No_irr	1994	4849	Winter	Dec
1/12/1995	2166	No_irr	1995	2166	Winter	Jan
1/17/1995	4592	No_irr	1995	4592	Winter	Jan
1/26/1995	4031	No_irr	1995	4031	Winter	Jan
2/7/1995	5423	No_irr	1995	5423	Winter	Feb
2/20/1995	5437	No_irr	1995	5437	Winter	Feb
3/8/1995	4803	No_irr	1995	4803	Summer	March
3/22/1995	4003	No_irr	1995	4003	Summer	March
4/13/1995	3122	Irrigate	1995	3122	Summer	April
4/28/1995	5016	Irrigate	1995	5016	Summer	April
5/4/1995	4567	Irrigate	1995	4567	Summer	May
5/22/1995	5047	Irrigate	1995	5047	Summer	May
5/24/1995	5264	Irrigate	1995	5264	Summer	May
6/8/1995	3491	Irrigate	1995	3491	Summer	June
6/21/1995	2787	Irrigate	1995	2787	Summer	June

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
7/6/1995	3380	Irrigate	1995	3380	Summer	July
7/13/1995	3081	Irrigate	1995	3081	Summer	July
7/28/1995	3455	Irrigate	1995	3455	Summer	July
8/10/1995	2859	Irrigate	1995	2859	Summer	Aug
8/21/1995	3796	Irrigate	1995	3796	Summer	Aug
9/7/1995	3315	Irrigate	1995	3315	Summer	Sept
9/20/1995	4589	Irrigate	1995	4589	Summer	Sept
10/4/1995	5097	Irrigate	1995	5097	Summer	Oct
10/20/1995	4196	Irrigate	1995	4196	Summer	Oct
10/27/1995	5016	Irrigate	1995	5016	Summer	Oct
11/2/1995	5997	Irrigate	1995	5997	Winter	Nov
11/13/1995	6293	Irrigate	1995	6293	Winter	Nov
11/28/1995	4824	Irrigate	1995	4824	Winter	Nov
12/13/1995	6007	Irrigate	1995	6007	Winter	Dec
12/20/1995	5433	No_irr	1995	5433	Winter	Dec
1/11/1996	5468	No_irr	1996	5468	Winter	Jan

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
1/23/1996	5652	No_irr	1996	5652	Winter	Jan
1/26/1996	5407	No_irr	1996	5407	Winter	Jan
2/6/1996	4263	No_irr	1996	4263	Winter	Feb
2/20/1996	1649	No_irr	1996	1649	Winter	Feb
3/7/1996	3800	No_irr	1996	3800	Summer	March
3/20/1996	3070	No_irr	1996	3070	Summer	March
4/1/1996	2950	No_irr	1996	2950	Summer	April
4/17/1996	4240	Irrigate	1996	4240	Summer	April
5/8/1996	4074	Irrigate	1996	4074	Summer	May
5/22/1996	4660	Irrigate	1996	4660	Summer	May
6/7/1996	4240	Irrigate	1996	4240	Summer	June
6/19/1996	3040	Irrigate	1996	3040	Summer	June
7/16/1996	3780	Irrigate	1996	3780	Summer	July
7/30/1996	3352	Irrigate	1996	3352	Summer	July
7/31/1996	4170	Irrigate	1996	4170	Summer	July
8/7/1996	3310	Irrigate	1996	3310	Summer	Aug

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
8/22/1996	2970	Irrigate	1996	2970	Summer	Aug
9/10/1996	4270	Irrigate	1996	4270	Summer	Sept
9/25/1996	4740	Irrigate	1996	4740	Summer	Sept
10/9/1996	4070	Irrigate	1996	4070	Summer	Oct
10/24/1996	4824	Irrigate	1996	4824	Summer	Oct
11/8/1996	5770	Irrigate	1996	5770	Winter	Nov
11/20/1996	6340	Irrigate	1996	6340	Winter	Nov
12/3/1996	5980	Irrigate	1996	5980	Winter	Dec
12/18/1996	5590	No_irr	1996	5590	Winter	Dec
1/15/1997	4710	No_irr	1997	4710	Winter	Jan
1/30/1997	5170	No_irr	1997	5170	Winter	Jan
2/6/1997	5314	No_irr	1997	5314	Winter	Feb
2/10/1997	4940	No_irr	1997	4940	Winter	Feb
2/26/1997	3380	No_irr	1997	3380	Winter	Feb
3/12/1997	3570	No_irr	1997	3570	Summer	March
3/26/1997	3420	No_irr	1997	3420	Summer	March

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
4/8/1997	3070	No_irr	1997	3070	Summer	April
4/29/1997	3640	Irrigate	1997	3640	Summer	April
5/8/1997	4728	Irrigate	1997	4728	Summer	May
8/7/1997	3086	Irrigate	1997	3086	Summer	Aug
10/22/1997	2506	Irrigate	1997	2506	Summer	Oct
1/28/1998	4738	No_irr	1998	4738	Winter	Jan
5/14/1998	4254	Irrigate	1998	4254	Summer	May
7/14/1998	2766	Irrigate	1998	2766	Summer	July
10/27/1998	3182	Irrigate	1998	3182	Summer	Oct
1/20/1999	4422	No_irr	1999	4422	Winter	Jan
4/13/1999	2794	No_irr	1999	2794	Summer	April
8/18/1999	3662	Irrigate	1999	3662	Summer	Aug
4/3/2000	3136	No_irr	2000	3136	Summer	April
4/12/2000	2802	No_irr	2000	2802	Summer	April
6/22/2000	3372	Irrigate	2000	3372	Summer	June
7/12/2000	2977	Irrigate	2000	2977	Summer	July

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
8/9/2000	3548	Irrigate	2000	3548	Summer	Aug
10/6/2000	4485	Irrigate	2000	4485	Summer	Oct
1/25/2001	3638	No_irr	2001	3638	Winter	Jan
4/5/2001	3814	No_irr	2001	3814	Summer	April
7/2/2001	2952	Irrigate	2001	2952	Summer	July
7/26/2001	3958	Irrigate	2001	3958	Summer	July
10/2/2001	3436	Irrigate	2001	3436	Summer	Oct
11/6/2001	5192	Irrigate	2001	5192	Winter	Nov
11/7/2001	5692	Irrigate	2001	5692	Winter	Nov
1/11/2002	5765	No_irr	2002	5765	Winter	Jan
1/15/2002	5740	No_irr	2002	5740	Winter	Jan
4/2/2002	3812	No_irr	2002	3812	Summer	April
7/11/2002	2968	Irrigate	2002	2968	Summer	July
8/13/2002	4338	Irrigate	2002	4338	Summer	Aug
10/29/2002	4910	Irrigate	2002	4910	Summer	Oct
11/11/2002	5138	Irrigate	2002	5138	Winter	Nov

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
1/8/2003	5324	No_irr	2003	5324	Winter	Jan
2/4/2003	5526	No_irr	2003	5526	Winter	Feb
4/4/2003	4121	No_irr	2003	4121	Summer	April
5/15/2003	5886	Irrigate	2003	5886	Summer	May
7/8/2003	4147	Irrigate	2003	4147	Summer	July
7/15/2003	4198	Irrigate	2003	4198	Summer	July
8/19/2003	5228	Irrigate	2003	5228	Summer	Aug
9/23/2003	3996	Irrigate	2003	3996	Summer	Sept
10/2/2003	3965	Irrigate	2003	3965	Summer	Oct
10/28/2003	5524	Irrigate	2003	5524	Summer	Oct
12/2/2003	6222	Irrigate	2003	6222	Winter	Dec
1/13/2004	6724	No_irr	2004	6724	Winter	Jan
2/3/2004	5990	No_irr	2004	5990	Winter	Feb
2/17/2004	5250	No_irr	2004	5250	Winter	Feb
3/16/2004	5520	No_irr	2004	5520	Summer	March
4/7/2004	4590	Irrigate	2004	4590	Summer	April

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
7/2/2004	3450	Irrigate	2004	3450	Summer	July
10/12/2004	4470	Irrigate	2004	4470	Summer	Oct
1/13/2005	4700	No_irr	2005	4700	Winter	Jan
4/4/2005	4400	No_irr	2005	4400	Summer	April
4/20/2005	4942	Irrigate	2005	4942	Summer	April
8/2/2005	3044	Irrigate	2005	3044	Summer	Aug
8/3/2005	3860	Irrigate	2005	3860	Summer	Aug
10/7/2005	3640	Irrigate	2005	3640	Summer	Oct
10/18/2005	3716	Irrigate	2005	3716	Summer	Oct
1/13/2006	6140	No_irr	2006	6140	Winter	Jan
2/21/2006	4772	No_irr	2006	4772	Winter	Feb
4/6/2006	3660	No_irr	2006	3660	Summer	April
7/5/2006	3336	Irrigate	2006	3336	Summer	July
7/10/2006	3560	Irrigate	2006	3560	Summer	July
10/11/2006	2939	Irrigate	2006	2939	Summer	Oct
1/10/2007	4710	No_irr	2007	4710	Winter	Jan

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
1/12/2007	5960	No_irr	2007	5960	Winter	Jan
4/3/2007	3440	No_irr	2007	3440	Summer	April
5/14/2007	3180	Irrigate	2007	3180	Summer	May
7/2/2007	2792	Irrigate	2007	2792	Summer	July
7/10/2007	3160	Irrigate	2007	3160	Summer	July
10/9/2007	3754	Irrigate	2007	3754	Summer	Oct
10/11/2007	4260	Irrigate	2007	4260	Summer	Oct
12/11/2007	6564	Irrigate	2007	6564	Winter	Dec
4/9/2008	2996	No_irr	2008	2996	Summer	April
5/5/2008	3570	Irrigate	2008	3570	Summer	May
7/2/2008	3450	Irrigate	2008	3450	Summer	July
7/15/2008	3386	Irrigate	2008	3386	Summer	July
8/4/2008	3438	Irrigate	2008	3438	Summer	Aug
9/22/2008	3544	Irrigate	2008	3544	Summer	Sept
10/12/2008	4470	Irrigate	2008	4470	Summer	Oct
12/3/2008	4486	Irrigate	2008	4486	Winter	Dec

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
1/26/2009	5804	No_irr	2009	5804	Winter	Jan
2/10/2009	4700	No_irr	2009	4700	Winter	Feb
3/2/2009	5202	No_irr	2009	5202	Summer	March
4/8/2009	4140	No_irr	2009	4140	Summer	April
7/1/2009	3320	Irrigate	2009	3320	Summer	July
10/6/2009	3410	Irrigate	2009	3410	Summer	Oct
2/4/2010	5700	No_irr	2010	5700	Winter	Feb
2/17/2010	6330	No_irr	2010	6330	Winter	Feb
2/25/2010	5620	No_irr	2010	5620	Winter	Feb
5/10/2010	4010	Irrigate	2010	4010	Summer	May
7/14/2010	3970	Irrigate	2010	3970	Summer	July
10/6/2010	5680	Irrigate	2010	5680	Summer	Oct
2/8/2011	4580	No_irr	2011	4580	Winter	Feb
4/14/2011	5270	No_irr	2011	5270	Summer	April
5/26/2011	2260	Irrigate	2011	2260	Summer	May
6/8/2011	3930	Irrigate	2011	3930	Summer	June

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
7/26/2011	3380	Irrigate	2011	3380	Summer	July
8/29/2011	3230	Irrigate	2011	3230	Summer	Aug
9/29/2011	3780	Irrigate	2011	3780	Summer	Sept
10/21/2011	4260	Irrigate	2011	4260	Summer	Oct
11/17/2011	3380	Irrigate	2011	3380	Winter	Nov
12/20/2011	4850	No_irr	2011	4850	Winter	Dec
1/2/2012	4570	No_irr	2012	4570	Winter	Jan
2/1/2012	4550	No_irr	2012	4550	Winter	Feb
2/9/2012	4210	No_irr	2012	4210	Winter	Feb
2/16/2012	4890	No_irr	2012	4890	Winter	Feb
3/19/2012	4160	No_irr	2012	4160	Summer	March
4/16/2012	6270	Irrigate	2012	6270	Summer	April
4/23/2012	4710	Irrigate	2012	4710	Summer	April
4/30/2012	4730	Irrigate	2012	4730	Summer	April
5/7/2012	4350	Irrigate	2012	4350	Summer	May
6/4/2012	3720	Irrigate	2012	3720	Summer	June

Date	BC_Upper_ TDS (mg/l)	Irr_Season	Year	BC_Upper_ NoOutlier TDS mg/l	Season	Month
7/10/2012	4230	Irrigate	2012	4230	Summer	July
8/8/2012	2980	Irrigate	2012	2980	Summer	Aug
9/5/2012	4140	Irrigate	2012	4140	Summer	Sept
10/5/2012	3760	Irrigate	2012	3760	Summer	Oct
11/5/2012	3620	Irrigate	2012	3620	Winter	Nov
12/6/2012	5630	Irrigate	2012	5630	Winter	Dec
1/14/2013	4210	No_irr	2013	4210	Winter	Jan
1/22/2013	4050	No_irr	2013	4050	Winter	Jan
1/30/2013	4180	No_irr	2013	4180	Winter	Jan
2/7/2013	5170	No_irr	2013	5170	Winter	Feb
3/4/2013	5370	No_irr	2013	5370	Summer	March
4/1/2013	4260	No_irr	2013	4260	Summer	April
5/7/2013	4250	Irrigate	2013	4250	Summer	May

APPENDIX D GOODNESS OF FIT AND OUTLIER STATISTICS

- Blue Creek Below Dam Site, Blue Creek Crossing, and Blue Creek Upper ATK (2013)
- Blue Creek Upper all ATK and DWQ Data
- Blue Creek Upper all data by irrigation status (outlier out)
- Blue Creek Upper all data by season (outlier out)
- Outlier all Blue Creek Upper data
- Outlier all Blue Creek Upper data by irrigation status
- Outlier all Blue Creek Upper data by season
- Outlier Blue Creek Upper data by season with 7,180 dropped as outlier

Goodness-of-Fit Test Statistics for Full Data Sets without Non-Detects

From File	F:\Permits\ATK Blue Creek\WriteUp\Blue Creek ProUCL.xls.wst
Full Precision	OFF
Confidence Coefficient	0.95

Blue Creek Below Dam TDS (mg/l)

Raw Statistics	
Number of Valid Observations	29
Number of Missing Values	3
Number of Distinct Observations	18
Minimum	1890
Maximum	2110
Mean of Raw Data	2007
Standard Deviation of Raw Data	63.63
Kstar	920.8
Mean of Log Transformed Data	7.604
Standard Deviation of Log Transformed Data	0.0318

Normal Distribution Test Results

Correlation Coefficient R	0.985
Shapiro Wilk Test Statistic	0.954
Shapiro Wilk Critical (0.95) Value	0.926
Approximate Shapiro Wilk P Value	0.258
Lilliefors Test Statistic	0.124
Lilliefors Critical (0.95) Value	0.165

Data appear Normal at (0.05) Significance Level

Gamma Distribution Test Results

Correlation Coefficient R	0.982
A-D Test Statistic	0.406
A-D Critical (0.95) Value	0.742
K-S Test Statistic	0.122
K-S Critical(0.95) Value	0.162

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal Distribution Test Results

Correlation Coefficient R	0.984
Shapiro Wilk Test Statistic	0.953
Shapiro Wilk Critical (0.95) Value	0.926
Approximate Shapiro Wilk P Value	0.243
Lilliefors Test Statistic	0.118
Lilliefors Critical (0.95) Value	0.165

Data appear Lognormal at (0.05) Significance Level

Blue Creek Crossing TDS (mg/L)

Raw Statistics	
Number of Valid Observations	32
Number of Distinct Observations	28
Minimum	2470
Maximum	5060
Mean of Raw Data	3298
Standard Deviation of Raw Data	572.4
Kstar	34.52
Mean of Log Transformed Data	8.088
Standard Deviation of Log Transformed Data	0.161
Normal Distribution Test Results	
Correlation Coefficient R	0.944
Shapiro Wilk Test Statistic	0.898
Shapiro Wilk Critical (0.95) Value	0.93
Approximate Shapiro Wilk P Value	0.00543
Lilliefors Test Statistic	0.141
Lilliefors Critical (0.95) Value	0.157
Data not Normal at (0.05) Significance Level	
Gamma Distribution Test Results	
Correlation Coefficient R	0.964
A-D Test Statistic	0.628
A-D Critical (0.95) Value	0.745
K-S Test Statistic	0.115
K-S Critical(0.95) Value	0.155
Data appear Gamma Distributed at (0.05) Significance Level	
Lognormal Distribution Test Results	
Correlation Coefficient R	0.974
Shapiro Wilk Test Statistic	0.95
Shapiro Wilk Critical (0.95) Value	0.93
Approximate Shapiro Wilk P Value	0.175
Lilliefors Test Statistic	0.105
Lilliefors Critical (0.95) Value	0.157
Data appear Lognormal at (0.05) Significance Level	

Blue Creek Upper TDS (mg/L)

Raw Statistics	
Number of Valid Observations	32
Number of Distinct Observations	29
Minimum	2260
Maximum	6270
Mean of Raw Data	4261
Standard Deviation of Raw Data	802.7
Kstar	25.04
Mean of Log Transformed Data	8.339
Standard Deviation of Log Transformed Data	0.198
Normal Distribution Test Results	
Correlation Coefficient R	0.986
Shapiro Wilk Test Statistic	0.984
Shapiro Wilk Critical (0.95) Value	0.93
Approximate Shapiro Wilk P Value	0.917
Lilliefors Test Statistic	0.125
Lilliefors Critical (0.95) Value	0.157
Data appear Normal at (0.05) Significance Level	
Gamma Distribution Test Results	
Correlation Coefficient R	0.986
A-D Test Statistic	0.381
A-D Critical (0.95) Value	0.745
K-S Test Statistic	0.122
K-S Critical(0.95) Value	0.155
Data appear Gamma Distributed at (0.05) Significance Level	
Lognormal Distribution Test Results	
Correlation Coefficient R	0.971
Shapiro Wilk Test Statistic	0.959
Shapiro Wilk Critical (0.95) Value	0.93
Approximate Shapiro Wilk P Value	0.307
Lilliefors Test Statistic	0.135
Lilliefors Critical (0.95) Value	0.157
Data appear Lognormal at (0.05) Significance Level	

	A	B	C	D	E	F	G	H	I	J	K	L
1				Goodness-of-Fit Test Statistics for Full Data Sets without Non-Detects								
2			User Selected Options									
3			From File	U:\ENG_WQ\CBITTNER\Permits\ATK Blue Creek\2014 Analyses\Blue Creek upper proUCL.wst								
4			Full Precision	OFF								
5			Confidence Coefficient	0.95								
6												
7												
8	BC_upper Sample Site All Data											
9												
10				Raw Statistics								
11					Number of Valid Observations	349						
12					Number of Distinct Observations	304						
13					Minimum	1649						
14					Maximum	7180						
15					Mean of Raw Data	4121						
16					Standard Deviation of Raw Data	943.7						
17					Kstar	19.14						
18					Mean of Log Transformed Data	8.298						
19					Standard Deviation of Log Transformed Data	0.23						
20												
21				Normal Distribution Test Results								
22												
23					Correlation Coefficient R	0.99						
24					Approximate Shapiro Wilk Test Statistic	0.969						
25					Approximate Shapiro Wilk P Value	0.0003089						
26					Lilliefors Test Statistic	0.0704						
27					Lilliefors Critical (0.95) Value	0.0474						
28	Data not Normal at (0.05) Significance Level											
29												
30				Gamma Distribution Test Results								
31												
32					Correlation Coefficient R	0.997						
33					A-D Test Statistic	0.724						
34					A-D Critical (0.95) Value	0.751						
35					K-S Test Statistic	0.0411						
36					K-S Critical(0.95) Value	0.0486						
37	Data appear Gamma Distributed at (0.05) Significance Level											
38												
39				Lognormal Distribution Test Results								
40												
41					Correlation Coefficient R	0.996						
42					Approximate Shapiro Wilk Test Statistic	0.986						
43					Approximate Shapiro Wilk P Value	0.648						
44					Lilliefors Test Statistic	0.0303						
45					Lilliefors Critical (0.95) Value	0.0474						
46	Data appear Lognormal at (0.05) Significance Level											

Goodness-of-Fit Test Statistics for Full Data Sets without Non-Detects

User Selected Options	
From File	U:\ENG_WQ\CBITTNER\Permits\ATK Blue Creek\2014 Analyses\Blue Creek upper proUCL.wst
Full Precision	OFF
Confidence Coefficient	0.95

TDS_Final Upper Blue Creek (irrigate)

Raw Statistics

Number of Valid Observations	233
Number of Missing Values	1
Number of Distinct Observations	210
Minimum	2250
Maximum	6564
Mean of Raw Data	3977
Standard Deviation of Raw Data	876.2
Kstar	21.42
Mean of Log Transformed Data	8.265
Standard Deviation of Log Transformed Data	0.215

Normal Distribution Test Results

Correlation Coefficient R	0.98
Approximate Shapiro Wilk Test Statistic	0.944
Approximate Shapiro Wilk P Value	8.278E-10
Lilliefors Test Statistic	0.0857
Lilliefors Critical (0.95) Value	0.058

Data not Normal at (0.05) Significance Level

Gamma Distribution Test Results

Correlation Coefficient R	0.992
A-D Test Statistic	1.049
A-D Critical (0.95) Value	0.751
K-S Test Statistic	0.0589
K-S Critical(0.95) Value	0.0597

Data follow Appr. Gamma Distribution at (0.05) Significance Level

Lognormal Distribution Test Results

Correlation Coefficient R	0.996
Approximate Shapiro Wilk Test Statistic	0.975
Approximate Shapiro Wilk P Value	0.0704
Lilliefors Test Statistic	0.0469
Lilliefors Critical (0.95) Value	0.058

Data appear Lognormal at (0.05) Significance Level

TDS_Final Upper Blue Creek (no_irr)

	A–E	F
51	**Raw Statistics**	
52	Number of Valid Observations	115
53	Number of Distinct Observations	108
54	Minimum	1649
55	Maximum	6724
56	Mean of Raw Data	4386
57	Standard Deviation of Raw Data	980.3
58	Kstar	17.96
59	Mean of Log Transformed Data	8.359
60	Standard Deviation of Log Transformed Data	0.243
61		
62	**Normal Distribution Test Results**	
63		
64	Correlation Coefficient R	0.995
65	Approximate Shapiro Wilk Test Statistic	0.981
66	Approximate Shapiro Wilk P Value	0.565
67	Lilliefors Test Statistic	0.0664
68	Lilliefors Critical (0.95) Value	0.0826
69	**Data appear Normal at (0.05) Significance Level**	
70		
71	**Gamma Distribution Test Results**	
72		
73	Correlation Coefficient R	0.985
74	A-D Test Statistic	0.746
75	A-D Critical (0.95) Value	0.75
76	K-S Test Statistic	0.0734
77	K-S Critical(0.95) Value	0.0854
78	**Data appear Gamma Distributed at (0.05) Significance Level**	
79		
80	**Lognormal Distribution Test Results**	
81		
82	Correlation Coefficient R	0.976
83	Approximate Shapiro Wilk Test Statistic	0.954
84	Approximate Shapiro Wilk P Value	0.00298
85	Lilliefors Test Statistic	0.0808
86	Lilliefors Critical (0.95) Value	0.0826
87	**Data appear Lognormal at (0.05) Significance Level**	

Goodness-of-Fit Test Statistics for Full Data Sets without Non-Detects

User Selected Options	
From File	U:\ENG_WQ\CBITTNER\Permits\ATK Blue Creek\2014 Analyses\Blue Creek upper proUCL.wst
Full Precision	OFF
Confidence Coefficient	0.95

TDS_Final Blue Creek Upper (summer season)

Raw Statistics

Number of Valid Observations	235
Number of Missing Values	1
Number of Distinct Observations	206
Minimum	2250
Maximum	6270
Mean of Raw Data	3822
Standard Deviation of Raw Data	715.7
Kstar	29.05
Mean of Log Transformed Data	8.231
Standard Deviation of Log Transformed Data	0.185

Normal Distribution Test Results

Correlation Coefficient R	0.989
Approximate Shapiro Wilk Test Statistic	0.968
Approximate Shapiro Wilk P Value	0.00439
Lilliefors Test Statistic	0.0587
Lilliefors Critical (0.95) Value	0.0578

Data not Normal at (0.05) Significance Level

Gamma Distribution Test Results

Correlation Coefficient R	0.998
A-D Test Statistic	0.383
A-D Critical (0.95) Value	0.751
K-S Test Statistic	0.0376
K-S Critical(0.95) Value	0.0595

Data appear Gamma Distributed at (0.05) Significance Level

Lognormal Distribution Test Results

Correlation Coefficient R	0.999
Approximate Shapiro Wilk Test Statistic	0.985
Approximate Shapiro Wilk P Value	0.693
Lilliefors Test Statistic	0.0319
Lilliefors Critical (0.95) Value	0.0578

Data appear Lognormal at (0.05) Significance Level

TDS_Final Blue Creek Upper (winter season)

	A	B	C	D	E	F	G	H	I	J	K	L
51	**Raw Statistics**											
52	Number of Valid Observations					113						
53	Number of Distinct Observations					107						
54	Minimum					1649						
55	Maximum					6724						
56	Mean of Raw Data					4714						
57	Standard Deviation of Raw Data					1035						
58	Kstar					17.37						
59	Mean of Log Transformed Data					8.43						
60	Standard Deviation of Log Transformed Data					0.251						
61												
62	**Normal Distribution Test Results**											
63												
64	Correlation Coefficient R					0.988						
65	Approximate Shapiro Wilk Test Statistic					0.965						
66	Approximate Shapiro Wilk P Value					0.0425						
67	Lilliefors Test Statistic					0.0705						
68	Lilliefors Critical (0.95) Value					0.0833						
69	**Data appear Normal at (0.05) Significance Level**											
70												
71	**Gamma Distribution Test Results**											
72												
73	Correlation Coefficient R					0.968						
74	A-D Test Statistic					1.683						
75	A-D Critical (0.95) Value					0.75						
76	K-S Test Statistic					0.0928						
77	K-S Critical(0.95) Value					0.0859						
78	**Data not Gamma Distributed at (0.05) Significance Level**											
79												
80	**Lognormal Distribution Test Results**											
81												
82	Correlation Coefficient R					0.953						
83	Approximate Shapiro Wilk Test Statistic					0.908						
84	Approximate Shapiro Wilk P Value					3.755E-09						
85	Lilliefors Test Statistic					0.106						
86	Lilliefors Critical (0.95) Value					0.0833						
87	**Data not Lognormal at (0.05) Significance Level**											

	A	B	C	D	E	F	G	H	I	J	K	L
1					**Outlier Tests for Selected Variables**							
2				**User Selected Options**								
3				From File	U:\ENG_WQ\CBITTNER\Permits\ATK Blue Creek\2014 Analyses\Blue Creek upper proUCL.wst							
4				Full Precision	OFF							
5				Test for Suspected Outliers with Dixon test	1							
6				Test for Suspected Outliers with Rosner test	1							
7												
8												
9				**Rosner's Outlier Test for BC_upper**								
10												
11												
12			**Mean**	**4121**								
13			**Standard Deviation**	**943.7**								
14			**Number of data**	**349**								
15			**Number of suspected outliers**	**1**								
16												
17				Potential	Obs.	Test	Critical	Critical				
18	#	Mean	sd	outlier	Number	value	value (5%)	value (1%)				
19	1	4121	942.4	7180	99	3.246	3.767	4.137				
20												
21	For 5% Significance Level, there is no Potential Outlier											
22												
23	For 1% Significance Level, there is no Potential Outlier											
24												

Outlier Tests for Selected Variables

User Selected Options	
From File	U:\ENG_WQ\CBITTNER\Permits\ATK Blue Creek\2014 Analyses\Blue Creek upper proUCL.wst
Full Precision	OFF
Test for Suspected Outliers with Dixon test	1
Test for Suspected Outliers with Rosner test	1

Rosner's Outlier Test for BC_upper (irrigate)

Mean	**3990**
Standard Deviation	**899**
Number of data	**234**
Number of suspected outliers	**1**

			Potential	Obs.	Test	Critical	Critical
#	Mean	sd	outlier	Number	value	value (5%)	value (1%)
1	3990	897.1	7180	74	3.555	3.65	4.021

For 5% Significance Level, there is no Potential Outlier

For 1% Significance Level, there is no Potential Outlier

Rosner's Outlier Test for BC_upper (no_irr)

Mean	**4386**
Standard Deviation	**980.3**
Number of data	**115**
Number of suspected outliers	**1**

			Potential	Obs.	Test	Critical	Critical
#	Mean	sd	outlier	Number	value	value (5%)	value (1%)
1	4386	976	1649	56	2.804	3.422	3.792

For 5% Significance Level, there is no Potential Outlier

For 1% Significance Level, there is no Potential Outlier

Outlier Tests for Selected Variables

User Selected Options	
From File	U:\ENG_WQ\CBITTNER\Permits\ATK Blue Creek\2014 Analyses\Blue Creek upper proUCL.wst
Full Precision	OFF
Test for Suspected Outliers with Dixon test	1
Test for Suspected Outliers with Rosner test	1

Rosner's Outlier Test for BC_upper (summer)

Mean	**3836**
Standard Deviation	**746.9**
Number of data	**236**
Number of suspected outliers	**1**

#	Mean	sd	Potential outlier	Obs. Number	Test value	Critical value (5%)	Critical value (1%)
1	3836	745.3	7180	71	4.486	3.653	4.023

For 5% Significance Level, there is 1 Potential Outlier

Therefore, Observation 7180 is a Potential Statistical Outlier

For 1% Significance Level, there is 1 Potential Outlier

Therefore, Observation 7180 is a Potential Statistical Outlier

Rosner's Outlier Test for BC_upper (winter)

Mean	**4714**
Standard Deviation	**1035**
Number of data	**113**
Number of suspected outliers	**1**

#	Mean	sd	Potential outlier	Obs. Number	Test value	Critical value (5%)	Critical value (1%)
1	4714	1030	1649	65	2.975	3.416	3.786

For 5% Significance Level, there is no Potential Outlier

For 1% Significance Level, there is no Potential Outlier

Outlier Tests for Selected Variables

User Selected Options	
From File	U:\ENG_WQ\CBITTNER\Permits\ATK Blue Creek\2014 Analyses\Blue Creek upper proUCL.wst
Full Precision	OFF
Test for Suspected Outliers with Dixon test	1
Test for Suspected Outliers with Rosner test	1

Rosner's Outlier Test for TDS_Final (summer)

Mean	3822
Standard Deviation	715.7
Number of data	235
Number of suspected outliers	1

#	Mean	sd	Potential outlier	Obs. Number	Test value	Critical value (5%)	Critical value (1%)
1	3822	714.2	6270	224	3.427	3.651	4.022

For 5% Significance Level, there is no Potential Outlier

For 1% Significance Level, there is no Potential Outlier

Rosner's Outlier Test for TDS_Final (winter)

Mean	4714
Standard Deviation	1035
Number of data	113
Number of suspected outliers	1

#	Mean	sd	Potential outlier	Obs. Number	Test value	Critical value (5%)	Critical value (1%)
1	4714	1030	1649	65	2.975	3.416	3.786

For 5% Significance Level, there is no Potential Outlier

For 1% Significance Level, there is no Potential Outlier

APPENDIX E HYPOTHESIS TESTING RESULTS

- Blue Creek Upper TDS Concentration ANOVA with season and irrigation status as Factors
- Blue Creek Upper TDS Concentrations in Winter versus Summer Seasons

▼Analysis of Variance with Irrigation Status and Season

Effects coding used for categorical variables in model.
The categorical values encountered during processing are

Variables	Levels	
IRR_STATUS$ (2 levels)	Irrigate	No_irr
SEASON$ (2 levels)	Summer	Winter
Summer irrigations status (2 levels)	Irrigate	No_irr

2 case(s) are deleted due to missing data.

Dependent Variable	TDS Blue Creek Upper Final (no outlier)
N	349
Multiple R	0.443
Squared Multiple R	0.197

Estimates of Effects B = $(X'X)^{-1}X'Y$

Factor	Level	TDS Blue Creek Upper no outlier
CONSTANT		4,266.409
IRR_STATUS$	Irrigate	13.152
SEASON$	Summer	-449.473
IRR_STATUS$*SEASON$	Irrigate*Summer	8.297

Analysis of Variance

Source	Type III SS	df	Mean Squares	F-Ratio	p-Value
IRR_STATUS$	40,011.452	1	40,011.452	0.057	0.812
SEASON$	46,733,061.177	1	46,733,061.177	66.082	0.000
IRR_STATUS$*SEASON$	15,922.964	1	15,922.964	0.023	0.881
Error	2.440E+008	345	707,194.753		

▼Nonparametric: Kruskal-Wallis Test for TDS Concentrations by Season

Mann-Whitney U Test for 351 Cases

```
The categorical values encountered during processing are

Variables                            ¦      Levels
-------------------------------------+------------------
SEASON$ (2 levels)                   ¦ Summer     Winter

Dependent Variable   ¦ TDS Blue Creek
                     ¦ Upper no
                     ¦ outlier
Grouping  Variable   ¦ SEASON$

Group    Count     Rank Sum
---------------------------
Summer     236   34,167.000
Winter     113   26,908.000

Mann-Whitney U Test Statistic : 6,201.000
p-Value                       : 0.000
Chi-Square Approximation      : 65.414
df                            : 1

Kruskal-Wallis Test Statistic: 65.414
The p-value is 0.000 assuming chi-square distribution with 1 df.
```

APPENDIX F UTAH WATER RIGHTS DATABASE FOR BLUE CREEK

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-196** APPLICATION/CLAIM NO.: **A29767** CERT. NO.: 7733

==

OWNERSHIP*

==

NAME: Merlin H. Larsen
ADDR: Promontory Route
Corinne UT 84307

==

DATES, ETC.

==

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 03/11/1958|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [Approved]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: |LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [123a]|PUB DATE:

TYPE -- DOCUMENT -- STATUS---

Type of Right: Application to Appropriate Source of Info: Proposed Determination Status: Certificate

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

==

FLOW: 2.39 cfs SOURCE: Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION:

POINTS OF DIVERSION -- SURFACE:
(1) S 2030 ft W 2310 ft from NE cor, Sec 07, T 10N, R 5W, SLBM
Diverting Works:
Source:
(2) S 3250 ft W 2530 ft from NE cor, Sec 07, T 10N, R 5W, SLBM
Diverting Works:
Source:
(3) S 4010 ft W 1040 ft from NE cor, Sec 07, T 10N, R 5W, SLBM
Diverting Works:
Source:
(4) S 5240 ft W 1700 ft from NE cor, Sec 07, T 10N, R 5W, SLBM

Diverting Works:
Source:
(5) N 30 ft W 700 ft from SE cor, Sec 18, T 10N, R 5W, SLBM
Diverting Works:
Source:
(6) S 1460 ft W 1650 ft from NE cor, Sec 18, T 10N, R 5W, SLBM
Diverting Works:
Source:

Stream Alt Required?: No
==
==
USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.)* ******** *EDU -- Equivalent Domestic Unit or 1 Family***
==
==
SUPPLEMENTAL GROUP NO.: 6272.

....
....
IRRIGATION: 349.0 acres
Div Limit: 0.0 acft. PERIOD OF USE: 04/01 TO 10/31
....
....
###PLACE OF USE: *-------NORTH WEST QUARTER------*-------NORTH EAST QUARTER------*-------SOUTH WEST QUARTER------*-------SOUTH EAST QUARTER------* Section
* NW | NE | SW | SE * NW | NE | SW | SE * NW | NE | SW | SE * NW | NE | SW | SE * Totals
Sec 07 T 10N R 5W SLBM
*_______|_______|_______|_______*_______|_______|23.5000|11.0000*_______|_______|_______|_______*30.8000|12.1000|30.0000|26.8000* 134.2000
Sec 08 T 10N R 5W SLBM
*_______|_______|_______|_______*_______|_______|_______|_______*
9.5000|_______|30.4000|_______*_______|_______|_______|_______*
39.9000
Sec 18 T 10N R 5W SLBM *_______|_______|_______|_______*
6.3000|18.4000|
8.3000|21.8000*_______|_______|_______|13.6000*22.6000|31.3000|31.5000|
21.1000* 174.9000

GROUP ACREAGE TOTAL: 349.0000
****
****
***E N D O F D
A T A***
****
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2043** APPLICATION/CLAIM NO.: CERT. NO.:

==

OWNERSHIP

==

NAME: Salt Wells Cattle Company, LLC
ADDR: 192 North Highland Blvd
Brigham UT 84302
INTEREST: 100% REMARKS:

==

DATES, ETC.

==

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 00/00/1869|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/28/1967|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [108]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

==

FLOW: SOURCE: Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION: Howell Valley

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point at S 660 ft. E 660 ft. from W4 corner, Sec 20, T11N, R5W, SLBM,
to a point at N 660 ft. W 660 ft. from S4 corner, Sec 32, T11N, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

==

USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.)* ******** *EDU -- Equivalent Domestic Unit or 1 Family***

==

SUPPLEMENTAL GROUP NO.: 6183. Water Rights Appurtenant to the following use(s):
13-1796(WUC),2043(DIL),2634(DIL)

....
STOCKWATER: Sole Supply: UNEVALUATED ELUs Group Total: 1000.0000
Div Limit: 28.0 acft. PERIOD OF USE: 01/01 TO 12/31
==

PLACE OF USE for STOCKWATERING*

==

```
                               NORTH-WEST¼       NORTH-EAST¼
SOUTH-WEST¼       SOUTH-EAST¼
                               NW NE SW SE       NW NE SW SE       NW
NE SW SE       NW NE SW SE
Sec 20 T 11N R  5W SLBM       *  :  :  :  *     *  :  :  :  *     * X:
:  :  *     *  :  :  :  *
Sec 32 T 11N R  5W SLBM       *  :  :  :  *     *  :  :  :  *     *  :
:  : X*     *  :  :  :  *
```

E N D O F D A T A*

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2044** APPLICATION/CLAIM NO.: CERT. NO.:

==

OWNERSHIP*

==

NAME: Conner Cattle Company
ADDR: c/o Parley Holmgren
Bear River City UT 84301

==

DATES, ETC.*

==

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 00/00/1869|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/23/1967|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [123a]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)************MAP VIEWER******************

==

FLOW: SOURCE: Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION: Howell Valley

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point at S 660 ft. W 660 ft. from N4 corner, Sec 05, T10N, R5W, SLBM,
to a point at N 660 ft. E 660 ft. from SW corner, Sec 05, T10N, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

==

USES OF WATER RIGHT******** ***ELU -- Equivalent Livestock Unit (cow, horse, etc.) ******** EDU -- Equivalent Domestic Unit or 1 Family***

==

SUPPLEMENTAL GROUP NO.: 5791. Water Rights Appurtenant to the following use(s):
13-1104(DIL),1105(DIL),2044(DIL),2047(DIL),2050(DIL)
2201(DIL),2202(DIL),2203(DIL)

....
STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 400.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
===

SUPPLEMENTAL GROUP NO.: 7097. Water Rights Appurtenant to the following use(s):
13-1104(DIL),1105(DIL),2044(DIL),2047(DIL),2050(DIL)
2201(DIL),2202(DIL),2203(DIL),3407(WUC)

....
STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 500.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31

==

PLACE OF USE for STOCKWATERING

==

	NORTH-WEST¼	NORTH-EAST¼	SOUTH-WEST¼	SOUTH-EAST¼
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 05 T 10N R 5W SLBM	* : X: : *	* : : : *	* : : X: *	* : : : *

** **END OF DATA** **

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2045** APPLICATION/CLAIM NO.: CERT. NO.:

==
OWNERSHIP*
==

NAME: Merlin H. Larsen
ADDR: Promontory Route
Corrine UT 84307

==
DATES, ETC.*
==

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 00/00/1869|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 08/22/1967|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [123a]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

==
LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************
==

FLOW: SOURCE: Blue creek
COUNTY: Box Elder COMMON DESCRIPTION: Lampo Junction

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point at N 660 ft. W 660 ft. from SE corner, Sec 06, T10N, R5W, SLBM,
to a point at N 660 ft. W 660 ft. from SE corner, Sec 18, T10N, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

==

USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.) ******** EDU -- Equivalent Domestic Unit or 1 Family***

==
==
SUPPLEMENTAL GROUP NO.: 6267. Water Rights Appurtenant to the following use(s):
13-284(UGWC),1955(DIL),1956(DIL),1957(UGWC),1958(UGWC)
1959(UGWC),1960(UGWC),1961(UGWC),1962(UGWC),1963(UGWC)
1964(UGWC),1965(UGWC),1966(UGWC),1967(UGWC),2045(DIL)

....
....
STOCKWATER: Sole Supply: UNEVALUATED ELUs Group Total: 210.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
==
==
PLACE OF USE for STOCKWATERING
==
==

	NORTH-WEST¼	NORTH-EAST¼	SOUTH-WEST¼	SOUTH-EAST¼
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 06 T 10N R 5W SLBM	* : : : *	* : : : *	* : : : *	* : : : X*
Sec 18 T 10N R 5W SLBM	* : : : *	* : : : *	* : : : *	* : : : X*

****
E N D O F D A T A
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2046** APPLICATION/CLAIM NO.: CERT. NO.:

===

OWNERSHIP

===

NAME: Security Title Company
ADDR: 330 East 4th South
Salt Lake City UT 84111

===

DATES, ETC.*

===

LAND OWNED BY APPLICANT? COUNTY TAX ID#:
FILED: |PRIORITY: 00/00/1869|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate: |PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: 11/01/1967|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-3]|MAP: [123d]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Diligence Claim Source of Info: Proposed Determination Status:

===

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*******************

===

FLOW: SOURCE: Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION: Lampo Junction

POINT OF DIVERSION -- POINT TO POINT:
(1)Stockwatering directly on stream from a point at S 660 ft. W 660 ft. from NE corner, Sec 19, T10N, R5W, SLBM,
to a point at N 660 ft. W 660 ft. from SE corner, Sec 19, T10N, R5W, SLBM.
COMMENT: Administratively updated by State Engineer.

===

USES OF WATER RIGHT******** ***ELU -- Equivalent Livestock Unit (cow, horse, etc.)* ******** *EDU -- Equivalent Domestic Unit or 1 Family***

==

SUPPLEMENTAL GROUP NO.: 5903. Water Rights Appurtenant to the following use(s):
13-481(DIL),1248(DIL),1250(DIL),1347(DIL),1413(DIL)
1415(DIL),1467(DIL),1860(DIL),1873(DIL),2046(DIL)
2051(DIL)

....

  STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 100.0000
Div Limit: 2.8 acft.   PERIOD OF USE: 01/01 TO 12/31

===

SUPPLEMENTAL GROUP NO.: 6332. Water Rights Appurtenant to the following use(s):
13-2046(DIL),2048(DIL),2051(DIL)

....

  STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 300.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31

==

PLACE OF USE for STOCKWATERING

==

	NORTH-WEST¼	NORTH-EAST¼	SOUTH-WEST¼	SOUTH-EAST¼
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 19 T 10N R 5W SLBM	* : : : *	* : X: : *	* : : : *	* : : : X*

****
E N D O F D A T A
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-2873** APPLICATION/CLAIM NO.: **A42932** CERT. NO.:

CHANGES: a13790 Water User's Claim (Issued: 05/05/1987)

==

OWNERSHIP

==

NAME: Stangl B-21 Associates Inc.
ADDR: 90 East 7200 South, Suite 200
Midvale UT 84047
INTEREST: 100% REMARKS:

==

DATES, ETC.

==

LAND OWNED BY APPLICANT? Yes COUNTY TAX ID#:
FILED: 09/26/1973|PRIORITY: 09/26/1973|PUB BEGAN: |PUB ENDED: |NEWSPAPER:
ProtestEnd: |PROTESTED: [No]|HEARNG HLD: |SE ACTION: [ ]|ActionDate:12/14/1974|PROOF DUE: 01/04/1988
EXTENSION: |ELEC/PROOF:[Election]|ELEC/PROOF:12/04/1985|CERT/WUC: 05/05/1987|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-]|MAP: [123d,c]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Application to Appropriate Source of Info: Water User's Claim Status: Water User's Claim

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER******************

==

FLOW: 3300.0 acre-feet SOURCE: Unnamed Stream (Blue Creek)
COUNTY: Box Elder COMMON DESCRIPTION: 4 1/2 miles SW of Lampo Jnct.

POINTS OF DIVERSION -- SURFACE:
(1) N 1900 ft E 2650 ft from NW cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(2) S 1900 ft W 730 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:

(3) S 2050 ft W 1250 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(4) S 2200 ft W 2450 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(5) S 2700 ft W 2600 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(6) S 2800 ft W 1400 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(7) S 1850 ft E 2350 ft from NW cor, Sec 20, T 10N, R 5W, SLBM
Diverting Works:
Source:
(8) S 2100 ft E 1520 ft from NW cor, Sec 20, T 10N, R 5W, SLBM
Diverting Works:
Source:
(9) S 1700 ft W 500 ft from NE cor, Sec 29, T 10N, R 5W, SLBM
Diverting Works:
Source:
(10)S 1750 ft E 100 ft from NW cor, Sec 29, T 10N, R 5W, SLBM
Diverting Works:
Source:
(11)S 2150 ft W 500 ft from NE cor, Sec 30, T 10N, R 5W, SLBM
Diverting Works:
Source:
(12)S 2800 ft W 480 ft from NE cor, Sec 30, T 10N, R 5W, SLBM
Diverting Works:
Source:
(13)N 50 ft E 800 ft from SW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(14)S 800 ft E 450 ft from NW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(15)S 1000 ft E 2100 ft from NW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(16)S 1100 ft W 1950 ft from NE cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(17)S 1250 ft W 2250 ft from NE cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(18)S 1600 ft W 1000 ft from NE cor, Sec 36, T 10N, R 6W, SLBM
Diverting Works:
Source:

Stream Alt Required?: No

==

USES OF WATER RIGHT ******** ***ELU -- Equivalent Livestock Unit (cow, horse, etc.)*** ******** ***EDU -- Equivalent Domestic Unit or 1 Family***

==

SUPPLEMENTAL GROUP NO.: 6642.

13-2873(WUC)

....
....
  STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 50.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
....
....
  WILDLIFE: Waterfowl propogation in marshes and ponds
PERIOD OF USE: 01/01 TO 12/31
                Acre Feet Contributed by this Right for this Use:
Unevaluated
A network of earth dikes are used to impound water for wildlife
propagation.
*==
===
=========================*
SUPPLEMENTAL GROUP NO.: 7337. Water Rights Appurtenant to the
following use(s):
13-2873(WUC),3632(APP)

....
....
  IRRIGATION: Sole Supply: UNEVALUATED acres   Group Total: 2900.0
Div Limit: 0.0 acft.   PERIOD OF USE: 04/01 TO 10/31
....
....
  STOCKWATER: Sole Supply: UNEVALUATED ELUs   Group Total: 399.0000
Div Limit: PERIOD OF USE: 01/01 TO 12/31
....
....
  ###PLACE OF USE: *-------NORTH WEST QUARTER------*-------NORTH
EAST QUARTER------*-------SOUTH WEST QUARTER------*-------SOUTH EAST
QUARTER------*   Section
                         * NW | NE | SW | SE   * NW | NE
| SW | SE   * NW | NE | SW | SE   * NW | NE | SW
| SE   *   Totals
 Sec 05 T 9N R 5W SLBM *X |X |X |X   *X |X
|X |X   *X |X |X |X   *X |X |X
|X   *   0.0000
 Sec 19 T 10N R 5W SLBM *X |X |X |X   *X |X
|X |X   *X |X |X |X   *X |X |X
|X   *   0.0000
 Sec 29 T 10N R 5W SLBM *X |X |X |X   *X |X
|X |X   *X |X |X |X   *X |X |X
|X   *   0.0000
 Sec 31 T 10N R 5W SLBM *X |X |X |X   *X |X
|X |X   *X |X |X |X   *X |X |X
|X   *   0.0000

GROUP ACREAGE TOTAL: 0.0000
===
==
PLACE OF USE for
STOCKWATERING*
****

==
===
                                NORTH-WEST¼   NORTH-EAST¼
SOUTH-WEST¼   SOUTH-EAST¼
                                NW NE SW SE   NW NE SW SE   NW
NE SW SE   NW NE SW SE
Sec 05 T 9N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * :
X: : X*   * X: X: X: X*
Sec 19 T 10N R 5W SLBM   * : X: : X*   * X: X: X: X*   * :
X: : *   * X: X: X: X*
Sec 20 T 10N R 5W SLBM   * X: X: X: X*   * : : : *   * X:
X: X: X*   * : : : *
Sec 29 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 30 T 10N R 5W SLBM   * : : : *   * X: X: X: X*   * :
: : *   * X: X: X: X*
Sec 31 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 32 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 36 T 10N R 5W SLBM   * : : : *   * : X: : X*   * :
: : *   * : X: : X*
==
===
Storage from 01/01 to 12/31, inclusive, in Earthen Dikes and Ditches
with a maximum capacity of 3300.000 acre-feet, located in:
   Height of Dam: 4   NORTH-WEST¼   NORTH-EAST¼
SOUTH-WEST¼   SOUTH-EAST¼
   Area Inundated: 2200.00   NW NE SW SE   NW NE SW SE   NW
NE SW SE   NW NE SW SE

Small Dam Required?: No
****
****
***E N D   O F   D
A T A***
****
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-3642** APPLICATION/CLAIM NO.: **A69440** CERT. NO.:

===

OWNERSHIP

===

NAME: Randy Marriott
ADDR: 5238 West 2150 North
Plain City UT 84404

===

DATES, ETC.

===

LAND OWNED BY APPLICANT? Yes COUNTY TAX ID#:
FILED: 11/02/1995|PRIORITY: 11/02/1995|PUB BEGAN: 11/22/1995|PUB ENDED: 11/29/1995|NEWSPAPER: The Leader
ProtestEnd:12/19/1995|PROTESTED: [HearHeld]|HEARNG HLD: |SE ACTION: [Approved]|ActionDate:06/25/1997|PROOF DUE: 08/31/2002
EXTENSION: |ELEC/PROOF:[Proof]|ELEC/PROOF:09/03/2002|CERT/WUC: |LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-]|MAP: [123d,c]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**---*

Type of Right: Application to Appropriate Source of Info: Application to Appropriate Status: Approved

===

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)***********MAP VIEWER*****************

===

FLOW: 20000.0 acre-feet SOURCE: Unnamed Stream (Blue Creek)
COUNTY: Box Elder COMMON DESCRIPTION: 4 1/2 miles SW of Lampo Jnct.

POINTS OF DIVERSION -- SURFACE:
(1) N 1900 ft E 2650 ft from NW cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(2) S 1900 ft W 730 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(3) S 2050 ft W 1250 ft from NE cor, Sec 19, T 10N, R 5W, SLBM

Diverting Works:
Source:
(4) S 2200 ft W 2450 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(5) S 2700 ft W 2600 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(6) S 2800 ft W 1400 ft from NE cor, Sec 19, T 10N, R 5W, SLBM
Diverting Works:
Source:
(7) S 1850 ft E 2350 ft from NW cor, Sec 20, T 10N, R 5W, SLBM
Diverting Works:
Source:
(8) S 2100 ft E 1520 ft from NW cor, Sec 20, T 10N, R 5W, SLBM
Diverting Works:
Source:
(9) S 1700 ft W 500 ft from NE cor, Sec 29, T 10N, R 5W, SLBM
Diverting Works:
Source:
(10)S 1750 ft E 100 ft from NW cor, Sec 29, T 10N, R 5W, SLBM
Diverting Works:
Source:
(11)S 2150 ft W 500 ft from NE cor, Sec 30, T 10N, R 5W, SLBM
Diverting Works:
Source:
(12)S 2800 ft W 480 ft from NE cor, Sec 30, T 10N, R 5W, SLBM
Diverting Works:
Source:
(13)N 50 ft E 800 ft from SW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(14)S 800 ft E 450 ft from NW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(15)S 1000 ft E 2100 ft from NW cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(16)S 1100 ft W 1950 ft from NE cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(17)S 1250 ft W 2250 ft from NE cor, Sec 31, T 10N, R 5W, SLBM
Diverting Works:
Source:
(18)S 1600 ft W 1000 ft from NE cor, Sec 36, T 10N, R 6W, SLBM
Diverting Works:
Source:

Stream Alt Required?: No

===
==

USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.)* ******** *EDU -- Equivalent Domestic Unit or 1 Family***

===
==

SUPPLEMENTAL GROUP NO.: 7345.

....
....
IRRIGATION: 3000.0 acres
Div Limit: 0.0 acft.   PERIOD OF USE: 04/01 TO 10/31
....
....
STOCKWATER: 300.0000 Stock Units
Div Limit: PERIOD OF USE: 01/01 TO 12/31
....
....
WILDLIFE: Waterfowl propogation in marshes and ponds
PERIOD OF USE: 01/01 TO 12/31
Acre Feet Contributed by this Right for this Use:
10991.6
A network of earth dikes are used to impound water for wildlife
propagation.
....
....
###PLACE OF USE: *-------NORTH WEST QUARTER------*-------NORTH
EAST QUARTER------*-------SOUTH WEST QUARTER------*-------SOUTH EAST
QUARTER------*   Section

	NORTH WEST QUARTER				NORTH EAST QUARTER				SOUTH WEST QUARTER				SOUTH EAST QUARTER				Section Totals
	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	NW	NE	SW	SE	
Sec 05 T 9N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 19 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 20 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 29 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 30 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 31 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 32 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000
Sec 36 T 10N R 5W SLBM	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	0.0000

GROUP ACREAGE TOTAL: 0.0000
===
===
PLACE OF USE for STOCKWATERING
===
===

                                NORTH-WEST¼   NORTH-EAST¼
SOUTH-WEST¼   SOUTH-EAST¼
                                NW NE SW SE   NW NE SW SE   NW
NE SW SE   NW NE SW SE
Sec 05 T 9N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 19 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 20 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 29 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 30 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 31 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 32 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
Sec 36 T 10N R 5W SLBM   * X: X: X: X*   * X: X: X: X*   * X:
X: X: X*   * X: X: X: X*
==
==
Storage from 01/01 to 12/31, inclusive, in Earthen Dikes and Ditches
with a maximum capacity of 3300.000 acre-feet, located in:
   Height of Dam: 4   NORTH-WEST¼   NORTH-EAST¼
SOUTH-WEST¼   SOUTH-EAST¼
   Area Inundated: 2200.00   NW NE SW SE   NW NE SW SE   NW
NE SW SE   NW NE SW SE

Small Dam Required?: No

==
==

OTHER
COMMENTS*
****

==
==

The applicant has a prior application 13-2873 to fill marsh habitat. This water right is being filed to create year-round waterfowl habitat and will be diverted as needed to keep water levels constant in existing ponds through each year.

==
==

PROTESTANTS*
****

==
==

NAME: Blue Creek Irrigation Company
NAME: Stangl B-21 Inc.
ADDR: c/o Ray D. Sorensen, President
ADDR: c/o F.C. Stangl III, President
      Box 67
1515 West 2200 South, Suite B-2

Howell UT 84316
Salt Lake City UT 84119
===
===
****
****
***E N D   O F   D
A T A***
****
****

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010

WATER RIGHT: **13-3810** APPLICATION/CLAIM NO.: **A75052** CERT. NO.:

==

OWNERSHIP

==

NAME: Stangl B-21 Associates Inc.
ADDR: 90 East 7200 South, Suite 200
Salt Lake City UT 84047

==

DATES, ETC.

==

LAND OWNED BY APPLICANT? Yes COUNTY TAX ID#:
FILED: 08/04/2003|PRIORITY: 08/04/2003|PUB BEGAN: 08/20/2003|PUB ENDED: 08/27/2003|NEWSPAPER: The Leader
ProtestEnd:09/16/2003|PROTESTED: [No Hear]|HEARNG HLD: |SE ACTION: [Approved]|ActionDate:03/17/2004|PROOF DUE: 03/31/2013
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF: |CERT/WUC: |LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
PD BOOK: [13-]|MAP: [ ]|PUB DATE:

***TYPE -- DOCUMENT -- STATUS**--*

Type of Right: Application to Appropriate Source of Info: Application to Appropriate Status: Approved

==

LOCATION OF WATER RIGHT*(Points of Diversion: Click on Location to access PLAT Program.)*************MAP VIEWER*****************

==

FLOW: 2.5 cfs SOURCE: Shotgun Springs & Blue Creek
COUNTY: Box Elder COMMON DESCRIPTION: Lampo Junction

POINT OF DIVERSION -- SURFACE:
(1) N 634 ft W 1050 ft from SE cor, Sec 07, T 10N, R 5W, SLBM
Diverting Works:
Source: Blue Creek

Stream Alt Required?: No

POINT OF SPRING:
(1) N 2307 ft W 312 ft from S4 cor, Sec 09, T 10N, R 5W, SLBM

Diverting Works:
Source: Shotgun Springs
==
==
USES OF WATER RIGHT****** *ELU -- Equivalent Livestock Unit (cow, horse, etc.) ******** EDU -- Equivalent Domestic Unit or 1 Family***
==
==
SUPPLEMENTAL GROUP NO.: 7526.

....
....
WILDLIFE:
PERIOD OF USE: 09/01 TO 10/30
Acre Feet Contributed by this Right for this Use: 1809.94995
....
....
OTHER:
PERIOD OF USE: 03/01 TO 04/30
Acre Feet Contributed by this Right for this Use: 1809.94995
Wetland
==
==
PLACE OF USE for STOCKWATERING*
==
==

	NORTH-WEST¼	NORTH-EAST¼	SOUTH-WEST¼	SOUTH-EAST¼
	NW NE SW SE	NW NE SW SE	NW NE SW SE	NW NE SW SE
Sec 09 T 10N R 5W SLBM	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*
Sec 16 T 10N R 5W SLBM	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*
Sec 20 T 10N R 5W SLBM	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*
Sec 21 T 10N R 5W SLBM	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*	* X: X: X: X*

==
==
OTHER COMMENTS*
==
==
The applicant proposes to construct 35 small retention ponds to enhance vegetative growth.
==
==
PROTESTANTS*

==

NAME: Connor Cattle Company
NAME:
ADDR: c/o Clair Holmgren
ADDR:
      13599 West Hwy 102
      Tremonton UT 84337
==
==

APPLICATIONS FOR EXTENSIONS OF TIME WITHIN WHICH TO SUBMIT PROOF*

==

FILED: 03/15/2007|PUB BEGAN: |PUB ENDED: |NEWSPAPER: No Adv Required
ProtestEnd: |PROTESTED: [No   ]|HEARNG HLD: |SE
ACTION: [Approved]|ActionDate:03/26/2007|PROOF DUE: 03/31/2010
==
FILED: 03/31/2010|PUB BEGAN: |PUB ENDED: |NEWSPAPER: No Adv Required
ProtestEnd: |PROTESTED: [   ]|HEARNG HLD: |SE
ACTION: [Approved]|ActionDate:04/29/2010|PROOF DUE: 03/31/2013
==

E N D   O F   D A T A

(WARNING: Water Rights makes NO claims as to the accuracy of this data.) RUN DATE: 08/24/2010 Page 1

CHANGE: **a13790** WATER RIGHT: 13-2873 CERT. NO.:
COUNTY TAX ID#: AMENDATORY? Yes
BASE WATER RIGHTS: 13-2873
RIGHT EVIDENCED BY: A42932
CHANGES: Point of Diversion [X], Place of Use [X], Nature of Use [X], Reservoir Storage [X].

--

NAME: Stangle B-21 Associates Inc.
ADDR: 90 East 7200 South, Suite 200
Midvale UT 84047
INTEREST: 100% REMARKS:

--

FILED: 12/26/1986|PRIORITY: 12/26/1986|ADV BEGAN: 01/14/1987|ADV ENDED: |NEWSPAPER: The Leader
ProtestEnd:02/27/1987|PROTESTED: [Yes]|HEARNG HLD: |SE ACTION: [Approved]|ActionDate:04/17/1987|PROOF DUE:
EXTENSION: |ELEC/PROOF:[ ]|ELEC/PROOF:
|CERT/WUC: 05/05/1987|LAP, ETC: |LAPS LETTER:
RUSH LETTR: |RENOVATE: |RECON REQ: |TYPE: [ ]
Status: Water User's Claim

H E R E T O F O R E

H E R E A F T E R

|FLOW: 76.0 cfs
||FLOW: 3300.0 acre-feet |

|SOURCE: Unnamed Springs & Streams (Blue Cr.)
||SOURCE: Unnamed Streams (Blue Creek) |

|COUNTY: Box Elder
||COUNTY: Box Elder COM DESC: 4-1/2 mi SW Lampo Junction |

| ||
A network of earth dikes is used to |
| ||
impound water for wildlife propagation. |

|POINT(S) OF DIVERSION ------> MAP VIEWER
||CHANGED AS FOLLOWS: (Click Location link for WRPLAT) |

```
|---------------------------------------------------------------------||----
---------------------------------------------------------------|
|Point Surface:
||Point Surface:                                                      |
|(1)  N 2400 ft E    5 ft from SW cor, Sec 05, T  9N, R  5W, SLBM||(1)
S 1900 ft W  730 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                      ||
Dvrting Wks:                                                    |
| Source:                                                           ||
Source:                                                         |
|(2)  N 1850 ft E    5 ft from SW cor, Sec 05, T  9N, R  5W, SLBM||(2)
S 2050 ft W 1250 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                      ||
Dvrting Wks:                                                    |
| Source:                                                           ||
Source:                                                         |
|(3)  N  200 ft E 4500 ft from SW cor, Sec 17, T 10N, R  5W, SLBM||(3)
S 2800 ft W 1400 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                      ||
Dvrting Wks:                                                    |
| Source:                                                           ||
Source:                                                         |
|(4)  N  300 ft E 5050 ft from SW cor, Sec 17, T 10N, R  5W, SLBM||(4)
S 2200 ft W 2450 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                      ||
Dvrting Wks:                                                    |
| Source:                                                           ||
Source:                                                         |
|(5)  S  100 ft E    5 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(5)
S 2700 ft W 2600 ft from NE cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                      ||
Dvrting Wks:                                                    |
| Source:                                                           ||
Source:                                                         |
|(6)  S 3150 ft E    5 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(6)
N 1900 ft E 2650 ft from SW cor, Sec 19, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                      ||
Dvrting Wks:                                                    |
| Source:                                                           ||
Source:                                                         |
|(7)  S 4830 ft E    5 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(7)
S 1850 ft E 2350 ft from NW cor, Sec 20, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                      ||
Dvrting Wks:                                                    |
| Source:                                                           ||
Source:                                                         |
|(8)  S    5 ft E 1450 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(8)
S 2100 ft E 1520 ft from NW cor, Sec 20, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                      ||
Dvrting Wks:                                                    |
| Source:                                                           ||
Source:                                                         |
|(9)  S    5 ft E  300 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(9)
S 1750 ft E  100 ft from NW cor, Sec 29, T 10N, R  5W, SLBM|
```

```
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(10) S    5 ft E 4125 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(10)
S 1700 ft W  500 ft from NE cor, Sec 29, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(11) S    5 ft E 4810 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(11)
S 2150 ft W  500 ft from NE cor, Sec 30, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(12) S    5 ft E 2250 ft from NW cor, Sec 19, T 10N, R  5W, SLBM||(12)
S 2800 ft W  480 ft from NE cor, Sec 30, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(13) S    5 ft E 1180 ft from NW cor, Sec 20, T 10N, R  5W, SLBM||(13)
S 1100 ft W 1950 ft from NE cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(14) S    5 ft E 1725 ft from NW cor, Sec 20, T 10N, R  5W, SLBM||(14)
S 1250 ft W 2250 ft from NE cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(15) S    5 ft E 1700 ft from NW cor, Sec 20, T 10N, R  5W, SLBM||(15)
S 1000 ft E 2100 ft from NW cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(16) S    5 ft E 3050 ft from NW cor, Sec 20, T 10N, R  5W, SLBM||(16)
S  800 ft E  450 ft from NW cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(17) N 2080 ft E    5 ft from SW cor, Sec 29, T 10N, R  5W, SLBM||(17)
N   50 ft E  800 ft from SW cor, Sec 31, T 10N, R  5W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
| Source:                                                     ||
Source:                                                     |
|(18) N 2780 ft E    5 ft from SW cor, Sec 29, T 10N, R  5W, SLBM||(18)
S 1600 ft W 1000 ft from NE cor, Sec 36, T 10N, R  6W, SLBM|
| Dvrting Wks:                                                ||
Dvrting Wks:                                                |
```

| Source: ||
Source: |
|(19) N 3300 ft E 5 ft from SW cor, Sec 29, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(20) N 3700 ft E 5 ft from SW cor, Sec 29, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(21) N 4550 ft E 2325 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(22) N 5 ft E 100 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(23) N 4180 ft E 350 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(24) N 1880 ft E 5 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(25) N 3490 ft E 5 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
|(26) N 4750 ft E 3300 ft from SW cor, Sec 31, T 10N, R 5W, SLBM||
| Dvrting Wks: ||
|
| Source: ||
|
| ||
|
|
||Stream Alt?: No |
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|PLACE OF USE ------>
||CHANGED as follows: |
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```
|                              --NW¼--  --NE¼--  --SW¼--  --SE¼-- ||
--NW¼--  --NE¼--  --SW¼--  --SE¼-- |
|                             |N N S S||N N S S||N N S S||N N S S|||
|N N S S||N N S S||N N S S||N N S S||
|                             |W E W E||W E W E||W E W E||W E W E|||
|W E W E||W E W E||W E W E||W E W E||
|Sec 05 T  9N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*||Sec
05 T  9N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X: :X**X:X:X:X*|
|Sec 19 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*||Sec
19 T 10N R  5W SLBM     * :X: :X**X:X:X:X** :X: :X**X:X:X:X*|
|Sec 20 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*||Sec
20 T 10N R  5W SLBM     *X:X:X:X** : : : **X:X:X:X** : : : *|
|Sec 29 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*||Sec
29 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|Sec 31 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*||Sec
30 T 10N R  5W SLBM     * : : : **X:X:X:X** : : : **X:X:X:X*|
|                                                                 ||Sec
31 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|                                                                 ||Sec
32 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|                                                                 ||Sec
36 T 10N R  6W SLBM     * : : : ** :X: :X** : : : ** :X: :X*|
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|NATURE OF USE ------>
||CHANGED as follows: **|**

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|-----------------------------------------------------------------||----
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|IRR = values are in acres. ||
|
|STK = values are in ELUs meaning Cattle or Equivalent. ||
|
|DOM = values are in EDUs meaning Equivalent Domestic Units (F ||
|

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|-----------------------------------------------------------------||----
-----------------------------------------------------------|
|SUPPLEMENTAL to Other Water Rights: No
||SUPPLEMENTAL to Other Water Rights: No                          |
|-----------------------------------------------------------------||----
-----------------------------------------------------------|
|IRR:   3184.0000 acres.                       USED 04/01 - 10/31||
|
|.................................................................||....
...........................................................|
|.................................................................||....
...........................................................|
|STK:   1000.0000 Cattle or Equivalent         USED 01/01 - 12/31||STK:
50.0000 Cattle or Equivalent         USED 01/01 - 12/31|
|.................................................................||....
...........................................................|
|.................................................................||....
...........................................................|
|OTH: WILDLIFE:        Waterfowl propogation  USED 01/01 - 12/31||OTH:
OTHER:            Waterfowl Propagation  USED 01/01 - 12/31|
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|     in marshes and ponds                                         ||
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|RESERVOIR STORAGE -->
||CHANGED as follows:                                              |
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||Storage 01/01 to 12/31, in Earthen Dikes and Ditches              |
|                                                                  ||
with a maximum capacity of 3300.000 acre-feet, located in:     |
|                                                                  ||
--NW¼--  --NE¼--  --SW¼--  --SE¼-- |
|                                                                  ||
Height of Dam:       4 ft |N N S S||N N S S||N N S S||N N S S||
|                                                                  ||
Area Inundat  2200.000 acs|W E W E||W E W E||W E W E||W E W E||
|                                                                  ||Sec
05 T  9N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X: :X**X:X:X:X*|
|                                                                  ||Sec
19 T 10N R  5W SLBM     * :X: :X**X:X:X:X** :X: :X**X:X:X:X*|
|                                                                  ||Sec
20 T 10N R  5W SLBM     *X:X:X:X** : : : **X:X:X:X** : : : *|
|                                                                  ||Sec
29 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|                                                                  ||Sec
30 T 10N R  5W SLBM     * : : : **X:X:X:X** : : : **X:X:X:X*|
|                                                                  ||Sec
31 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|                                                                  ||Sec
32 T 10N R  5W SLBM     *X:X:X:X**X:X:X:X**X:X:X:X**X:X:X:X*|
|                                                                  ||Sec
36 T 10N R  6W SLBM     * : : : ** :X: :X** : : : ** :X: :X*|
|-----------------------------------------------------------------||----
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|
||Small Dam Permit Required?: No                                    |
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_________________________________________________________________
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********************************************************E N D   O F   D
A T A***********************************************************
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ProUCL Version 5.0.00
Technical Guide

Statistical Software for Environmental Applications for Data Sets with and without Nondetect Observations

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CHAPTER 3

Computing Upper Limits to Estimate Background Threshold Values Based Upon Uncensored Data Sets without Nondetect Observations

3.1 Introduction

In background evaluation studies, site-specific (e.g., soils, groundwater) background level constituent concentrations are needed to compare site concentrations with background level concentrations also known as background threshold values (BTVs). The BTVs are estimated, based upon sampled data collected from reference areas and/or unimpacted site-specific background areas (e.g., upgradient wells) as determined by the project team. The first step in establishing site-specific background level constituent concentrations is to collect an appropriate number of samples from the designated background or reference areas. The Stats/Sample Sizes module of ProUCL software can be used to compute DQOs based sample sizes. Once an adequate amount of data has been collected, the next step is to determine the data distribution. This is typically done using exploratory graphical tools (e.g., quantile-quantile [Q-Q] plot) and formal goodness-of-fit (GOF) tests. Depending upon the data distribution, one uses parametric or nonparametric methods to estimate BTVs. An onsite observation in exceedance of a BTV may be considered as not coming from the background population; such a site observation may be considered as exhibiting some evidence of contamination due to site-related activities. Sometimes, locations exhibiting concentrations higher than a BTV estimate are re-sampled to verify the possibility of contamination. Onsite values less than BTVs potentially represent unimpacted locations and are considered coming from the background (or comparable to the background) population. This approach, comparing individual site or groundwater monitoring well (MW) observations with BTVs, is particularly helpful to: 1) identify and screen constituents/contaminants of concern (COCs); and 2) use after some remediation activities (e.g., installation of a GW treatment plant) have already taken place and the objective is to determine if the remediated areas have been remediated close enough to the background level constituent concentrations.

BTV estimation methods described in this chapter are useful when not enough site data are available to perform hypotheses tests such as the two-sample t-test or the nonparametric Wilcoxon Rank Sum (WRS) test. When enough (e.g., more than 8 to10 observations) site data are available, one may use hypotheses testing approaches to compare onsite and background data or onsite data with some pre-established threshold or screening values. The single-sample hypothesis tests (e.g., t-test, WRS test, proportion test) are used when screening levels or BTVs are known or pre-established. The two-sample hypotheses tests are used when enough data (e.g., at least 8-10 observations from each population) are available from background (e.g., upgradient wells) as well as site (e.g., monitoring wells) areas. This chapter describes statistical limits that may be used to estimate the BTVs for full uncensored data sets without any nondetect (ND) observations. Statistical limits for data sets consisting of NDs are discussed in Chapter 5.

It is implicitly assumed that the background data set used to estimate BTVs represents a single statistical population. However, since outliers (well-separated from the main dominant data) are inevitable in most environmental applications, some outliers such as the observations coming from populations other than the background population may also be present in a background data set. Outliers, when present, distort decision statistics of interest (e.g., upper prediction limits [UPLs], upper tolerance limits [UTLs]), which in turn may lead to incorrect remediation decisions that may not be cost-effective or protective of human health and the environment. The BTVs should be estimated by statistics representing the dominant background population represented by the majority of the data set. *Upper limits computed by including a few low probability high outliers (e.g., coming from the far tails of data distribution) tend to represent locations with those elevated concentrations rather than representing the main dominant background population.* It is suggested to compute all relevant statistics using data sets with outliers and without outliers, and compare the results. This extra step often helps the project team to see the potential influence of outlier(s) on the various decision making statistics (e.g., upper confidence limits [UCLs], UPLs, UTLs), and to make informative decisions about the disposition of outliers. That is, the project team and experts familiar with the site should decide which of the computed statistics (with outliers or without outliers) represent more accurate estimate(s) of the population parameters (e.g., mean, exposure point concentration [EPC], BTV) under consideration. Since the treatment and handling of outliers in environmental applications is a subjective and controversial topic, it is also suggested that the outliers be treated on a site-specific basis using all existing knowledge about the site and reference areas under investigation. A couple of classical outlier tests, incorporated in ProUCL, are described in Chapter 7.

<u>Extracting a Site-Specific Background Data Set From a Broader Mixture Data Set:</u> In practice, not many background samples are collected due to resource constraints and difficulties in identifying suitable background areas with anthropogenic activities and natural geological characteristics comparable to onsite areas (e.g., at large Federal Facilities). Under these conditions, due to confounding of site related chemical releases with anthropogenic influences and natural geological variability, it becomes challenging to: 1) identify background/reference areas with comparable anthropogenic activities and geological conditions/formations; and 2) collect adequate amount of data needed to perform meaningful and defensible site versus background comparisons for each geological stratum to determine chemical releases only due to the site related operations and releases. Moreover, a large number of background samples (not impacted by site related chemical releases) may need to be collected representing the various soil types and anthropogenic activities present at the site; which may not be feasible due to several reasons including resource constraints and difficulties in identifying background areas with anthropogenic activities and natural geological characteristics comparable to onsite areas. The lack of sufficient amount of background data makes it difficult to perform defensible background versus site comparisons and computing reliable estimates of BTVs. A small background data set may not adequately represent the background population; and due to uncertainty and larger variability, the use of a small data set tends to yield non-representative estimates of BTVs.

Under these complex conditions present at a site, and using the known fact that that within all environmental site samples (data sets) exist both background level concentrations and concentrations indicative of site-related releases, sometimes it is desirable to extract a site-specific background data set from a mixture data set consisting of all available onsite and offsite concentrations. Several researchers (e.g., Sinclair [1976], Holgresson and Jorner [1978], Fleischhauer and Korte [1990]) have used normal Q-Q plots/probability plots methods to delineate multiple populations potentially present in a mixture data set collected from environmental, geological and mineral exploration studies.

Therefore, when not enough observations are available from reference areas with geological and anthropogenic influences comparable to onsite areas, the project team may want to use population partitioning methods (e.g., Singh, Singh, and Flatman [1994], Fleischhauer and Korte [1990]) on a broader mixture data set to extract a site-specific background data set with geological conditions and anthropogenic influences comparable to those of the various onsite areas. The extraction of a site-specific background data set from a mixture data set is useful when not enough background data are available to properly represent the background of larger sites (e.g., Federal Facilities covering hundreds of acres of land) consisting of areas with varying geological formations and soil types where it becomes necessary to establish site-specific background.

The topics of population partitioning and the extraction of a site-specific background data set from a mixture data set are beyond the scope of ProUCL software and this technical guidance document. It requires developing a separate chapter describing the iterative population partitioning method including the identification and extraction of a defensible background data set from a mixture data set consisting of all available data collected from background areas (if available), and unimpacted and impacted onsite locations. Currently, work is in progress to develop a background issue paper describing population methods to extract a site-specific background data set from a mixture data set consisting of concentrations from the various onsite areas and offsite areas (if available).

A review of the environmental literature reveals that one or more of the following statistical upper limits are used to estimate BTVs:

- Upper percentiles
- Upper prediction limits (UPLs)
- Upper tolerance limits (UTLs)
- Upper Simultaneous Limits (USLs) – New in ProUCL 5.0

It is noted that the differences between the various limits used to estimate BTVs are not clear to many practitioners. Therefore, a detailed discussion about the use of the various limits with their interpretation is provided in the following sections. Since 0.95 is the commonly used confidence coefficient (CC), these limits are described for a CC of 0.95 and coverage probability of 0.95 associated with a UTL. ProUCL can compute these limits for any valid combination of CC and coverage probabilities including some commonly used values of CC levels (e.g., 0.80, 0.90, 0.95, 0.99) and coverage probabilities (e.g., 0.80, 0.90, 0.95, 0.975).

Caution: To provide a proper balance between false positives and false negatives, the upper limits described above, especially a 95% USL (USL95) should be used only when the background data set represents a single environmental population without outliers (observations not belonging to background). Inclusion of multiple populations and/or outliers tends to yield elevated values of USLs (and also of UPLs and UTLs) which can result in a high number (and not necessarily high percentage) of undesirable false negatives, especially for data sets of larger sizes (e.g., $n > 30$).

Note on Computing Lower Limits: In many environmental applications (e.g., groundwater monitoring), one needs to compute lower limits including: lower prediction limits (LPLs), lower tolerance limits (LTLs), or lower simultaneous limit (LSLs). At present, ProUCL does not directly compute a LPL, LTL, or a LSL. It should be noted that for data sets with and without nondetects, ProUCL outputs the several intermediate results and critical values (e.g., khat, nuhat, K, d2max) needed to compute the interval estimates and lower limits. For data sets with and without nondetects, except for the bootstrap methods, the same critical value (e.g., normal z value, Chebyshev critical value, or t-critical value) can be used to compute a parametric LPL, LSL, or a LTL (for samples of size >30 to be able to use Natrella's approximation in LTL) as used in the computation of a UPL, USL, or a UTL (for samples of size >30). Specifically, to compute a LPL, LSL, and LTL (n>30) the '+' sign used in the computation of the corresponding UPL, USL, and UTL (n>30) needs to be replaced by the '-' sign in the equations used to compute UPL, USL, and UTL (n>30). For specific details, the user may want to consult a statistician. For data sets *without nondetect* observations, the user may want to use the Scout 2008 software package (EPA 2009c) to compute the various parametric and nonparametric LPLs, LTLs (all sample sizes), and LSLs.

3.1.1 Description and Interpretation of Upper Limits used to Estimate BTVs

Based upon a background data set, upper limits such as a 95% upper confidence limit of the 95th percentile (UTL95-95) are used to estimate upper threshold value(s) of the background population. It is expected that observations coming from the background population will lie below that BTV estimate with a specified CC. BTVs should be estimated based upon an "established" data set representing the background population under consideration.

Established background data set: represents background conditions free of outliers which potentially represent locations impacted by the site and/or other activities. An established background data set should be representative of a single environmental background population. This can be determined by using a normal Q-Q plot on a background data set. If there are no jumps and breaks in the normal Q-Q plot, the data set may be considered to represent a single environmental population. Outliers when present in a data set result in inflated values of the various decision statistics including: UPL, UTL, and USL. The use of inflated statistics as BTV estimates tends to result in a higher number of false negatives.

Notes: The user specifies the allowable false positive error rate, α (=1-CC), and the false negative error rate (declaring a location clean when in fact it is contaminated) is controlled by making sure that one is dealing with a defensible/established background data set representing a single background population and the data set is free of outliers.

Let x_1, x_2, x_n represent sampled concentrations of an established background data set collected from some site-specific or general background reference area.

Upper Percentile, $x_{0.95}$: Based upon an established background data set, a 95th percentile represents that statistic such that 95% of the sampled data will be less than or equal to (≤) $x_{0.95}$. It is expected that an observation coming from the background population (or comparable to the background population) will be ≤ $x_{0.95}$ with probability 0.95.

Upper Prediction Limit (UPL): Based upon an established background data set, a 95% UPL (UPL95) represents that statistic such that an independently collected new/future observation from the target population (e.g., background, comparable to background) will be less than or equal to the UPL95 with CC of 0.95. We are 95% sure that a *single future value* from the background population will be less than the UPL95 with CC= 0.95. A parametric UPL takes data variability into account.

In practice, many onsite observations are compared with a BTV estimate. It is noted that the use of a UPL95 to compare many observations may result in a higher number of false positives; that is the use of a UPL95 to compare many observations just by chance tends to incorrectly classify observations coming from the background or comparable to background population as coming from the impacted site locations. For example, if many (e.g., 30) independent onsite comparisons (e.g., Ra-226 activity from 10 onsite locations) are made with the same UPL95, each onsite value may exceed that UPL95 with a probability of 0.05 just by chance. The overall probability, α_{actual} of at least one of those 30 comparisons being significant (exceeding BTV) just by chance is given by:

$\alpha_{actual} = 1-(1-\alpha)^k = 1 - 0.95^{30} \sim 1-0.21 = 0.79$ (false positive rate).

This means that the probability (overall false positive rate) is 0.79 (and is not equal to 0.05) that at least one of the 30 onsite locations will be considered contaminated even when they are comparable to background. The use of a UPL95 is not recommended when multiple comparisons are to be made.

Upper Tolerance Limit (UTL): Based upon an established background data set, a UTL95-95 represents that statistic such that 95% observations (current and future) from the target population (background, comparable to background) will be less than or equal to the UTL95-95 with CC of 0.95. A UTL95-95 represents a 95% UCL of the 95^{th} percentile of the data distribution (population). A UTL95-95 is designed to simultaneously provide coverage for 95% of all potential observations (current and future) from the background population (or comparable to background) with a CC of 0.95. A UTL95-95 can be used when many (unknown) current or future onsite observations need to be compared with a BTV. A parametric UTL95-95 takes the data variability into account.

By definition a UTL95-95 computed based upon a background data set just by chance can classify 5% of background observations as not coming from the background population with CC 0.95. This percentage (false positive error rate) stays the same irrespective of the number of comparisons that will be made with a UTL95-95. However, when a large number of observations coming from the target population (background, comparable to background) are compared with a UTL95-95, the number of exceedances (not the percentage of exceedances) of UTL95-95 by background observations can be quite large. This implies that a larger number (but not greater than 5%) of onsite locations comparable to background may be falsely declared as requiring additional investigation which may not be cost-effective.

To avoid this situation, it is suggested to use a USL95 to estimate the BTV provided the background data set represents a single population free of outliers.

Upper Simultaneous Limit (USL): Based upon an established background data set free of outiers and representing a single statistical population, a USL95 represents that statistic such that *all* observations from the "established" background data set are less than or equal to the USL95 with a CC of 0.95. A parametric USL takes the data variability into account. It is expected that all current or future observations coming from the background population (comparable to background population, unimpacted site locations) will be less than or equal to the USL95 with CC, 0.95 (Singh and Nocerino, 2002). The use of a USL as a BTV estimate is suggested when a large number of onsite observations (current or future) need to be compared with a BTV.

It is noted that by definition, USL95 does not discard any observation. The false positive error rate does not change with the number of comparisons, as the USL95 is designed to perform many comparisons simultaneously. Furthermore, the USL95 also has a built in outlier test (Wilks, 1963), and if an observation (current or future) exceeds USL95, then that value definitely represents an outlier and may not come from the background population. The false negative error rate is controlled by making sure that the background data set represents a single background population free of outliers. Typically, the use of a USL95 tends to result in a smaller number of false positives than a UTL95-95, especially when the size of the background data set is greater than 15.

3.1.2 Confidence Coefficient (CC) and Sample Size

This section briefly discusses sample sizes and the selection of CCs associated with various upper limits used to estimate BTVs.

- Higher statistical limits are associated with higher levels of CCs. For an example, a 95% UPL is higher than a 90% UPL.

- Higher values of a CC (e.g., 99%) tend to decrease the power of a test, resulting in a higher number of false negatives- dismissing contamination when present.

Therefore, the CC should not be set higher than necessary.

- Smaller values of the CC (e.g., 0.80) tend to result in a higher number of false positives (e.g., declaring contamination when it is not present).

- In most practical applications, choice of a 95% CC provides a good compromise between confidence and power.

- Higher level of uncertainty in a background data set (e.g., due to a smaller background data set) and higher values of critical values associated with smaller (e.g., <15-20) samples tend to dismiss contamination as representing background conditions (results in higher number of false negatives, i.e., identifying a location that may be dirty as background). This is especially true when one uses UTLs and UPLs to estimate BTVs.

- Nonparametric upper limits based upon order statistics (e.g., the largest, the second largest,…) may not provide the desired coverage as they do not take data variability into account. Nonparametric methods are less powerful than the parametric methods; and they require larger data sets to achieve power comparable to parametric methods.

3.2 Treatment of Outliers

The inclusion of outliers in a background data set tends to yield distorted (inflated) estimates of BTVs. Outlying observations which are significanly higher than the majority of the background data may not be used in establishing background data sets and in the computation of BTV estimates. A couple of classical outlier tests cited in environmental literature (EPA, 2006b, Navy, [2002a, 2002b]) are available in the ProUCL software. It is noted that the classical outlier procedures suffer from masking effects as they get distorted by the same outlying observations that they are supposed to find! It is therefore recommended to supplement outlier tests with graphical displays such as box plots, Q-Q plots. On a Q-Q plot, elevated observations which are well-separated from the majority of data represent potential outliers.

It is noted that nonparametric upper percentiles, UPLs, and UTLs are often represented by higher order statistics such as the largest value or the second largest value. When high outlying observations are present in a background data set, the higher order statistics may represent observations coming from the contaminated onsite/offsite areas. Decisions made based upon outlying observations or distorted upper limits can be incorrect and misleading. Therefore, special attention should be given to outlying observations. The project team and the decision makers involved should decide about the proper disposition of outliers, to include or not include them, in the computation of the various decision making statistics such as the UCL95 and the UTL95-95. Sometimes, performing statistical analyses twice on the same data set – once using the data set with outliers and once using the data set without outliers can help the project team in determining the proper disposition of high outliers. Some examples elaborating on these issues have been discussed in this document.

Notes: It should be pointed out that methods incorporated in ProUCL can be used on any data set with or without nondetects and with or without outliers. It may not be misinterpreted that ProUCL 5.0 is restricted and can only be used on data sets without outliers. It is not a requirement to exclude outliers before using any of the statistical methods incorporated in ProUCL. The intent of the developers of ProUCL software is to inform the users how the inclusion of a few outliers coming from the *low probability tails of the data distribution* can yield distorted values of UCL95, UPLs, UTLs, and various other statistics. The decision limits and test statistics should be computed based upon the majority of data representing the main dominant population and not by accommodating a few low probability outliers resulting in distorted and inflated values of the decision statistics. The inflated decision statistics tend to represent the locations with those elevated observations rather than representing the main dominant population. The outlying observations may be separately investigated to determine the reasons for their occurrences (e.g., errors or contaminated locations). It is suggested to compute the statistics with and without the outliers, and compare the potential impact of outliers on the decision making processes.

Let $x_1, x_2, \ldots, x_n$ represent concentrations of a contaminant/constituent of concern (COC) collected from some site-specific or general background reference area. The data are arranged in ascending order and the ordered sample (called ordered statistics) is denoted by $x_{(1)} \le x_{(2)} \le \ldots \le x_{(n)}$. The ordered statistics are used as nonparametric estimates of upper percentiles, UPLs, UTLs and USLs. Also, let $y_i = \ln(x_i)$; $i = 1, 2, \ldots, n$, and $\bar{y}$ and s_y represent the mean and standard deviation (*sd*) of the log-transformed data. Statistical details of some parametric and nonparametric upper limits used to estimate BTVs are described in the following sections.

3.3 Upper p*100% Percentiles as Estimates of BTVs

In most statistical textbooks (e.g., Hogg and Craig, 1995), the p^{th} (e.g., $p = 0.95$) sample percentile of the measured sample values is defined as that value, $\hat{x}_p$, such that p*100% of the sampled data set lies at or below it. The carat sign over x_p, indicates that it represents a statistic/estimate computed using the sampled data. The same use of the carat sign is found throughout this guidance document. The statistic $\hat{x}_p$ represents an estimate of the p^{th} population percentile. It is expected that about p*100% of the population values will lie below the p^{th} percentile. Specifically, $x_{0.95}$ represents an estimate of the of the 95^{th} percentile of the background population.

*3.3.1 Nonparametric p*100% Percentile*

Nonparametric 95% percentiles are used when the background data (raw or transformed) do not follow a discernible distribution at some specified (e.g., α = 0.05, 0.1) level of significance. It is noted that different software packages (e.g., SAS, Minitab, and Microsoft Excel) use different formulae to compute nonparametric percentiles, and therefore yield slightly different estimates of population percentiles, especially when the sample size is small such as less than 20-30. Specifically, some software packages estimate the p^{th} percentile by using the $p*n^{\text{th}}$ order statistic, which may be a whole number between 1 and n or a fraction lying between 1 and n, while other software packages compute the p^{th} percentile by the $p*(n+1)^{\text{th}}$ order statistic (e.g., used in ProUCL versions 4.00.02 and 4.00.04) or by the $(pn+0.5)^{\text{th}}$ order statistic. For example, if $n = 20$, and $p = 0.95$, then 20*0.95 = 19, thus the 19^{th} ordered statistic represents the 95^{th} percentile. If $n = 17$, and $p = 0.95$, then 17*0.95= 16.15, thus the 16.15^{th} ordered value represents the 95^{th} percentile. The 16.15^{th} ordered value lies between the 16^{th} and the 17^{th} order statistics and can be computed by using a simple linear interpolation given by:

$$x_{(16.15)} = x_{(16)} + 0.15\,(x_{(17)} - x_{(16)}). \qquad (3\text{-}1)$$

It should be noted that the earlier versions (e.g., ProUCL 4.00.02, 4.00.04) of ProUCL used $p*(n+1)^{th}$ order statistic to estimate the nonparametric p^{th} percentile. However, since most users are familiar with Excel and some consultants have developed statistical software packages using Excel, at the request of some users, it was decided to use the same algorithm as incorporated in Excel to compute nonparametric percentiles. ProUCL 4.1 and higher versions compute nonparametric percentiles using the same algorithm as used in Excel 2007. This algorithm is used on data sets with and without ND observations.

Notes: From a practical point of view, nonparametric percentiles computed using the various percentile computation methods described in the literature are comparable unless the data set is small (e.g., n <20-30) and/or comes from a mixed population consisting of some extreme high values. No single percentile computation method should be considered superior to other percentile computation methods available in the statistical literature. In addition to nonparametric percentiles, ProUCL also computes several parametric percentiles described as follows.

*3.3.2 Normal p*100% Percentile*

The sample mean, $\bar{x}$. and *sd*, *s*, are computed first. For normally distributed data sets, the p*100th sample percentile is given by the following statement:

$$\hat{x}_p = \bar{x} + sz_p \tag{3-2}$$

Here z_p is the p*100th percentile of a standard normal, N(0, 1), distribution, which means that the area (under the standard normal curve) to the left of z_p is p. If the distributions of the site and background data are comparable, then it is expected that an observation coming from a population (e.g., site) comparable to the background population would lie at or below the p*100% upper percentile, $\hat{x}_p$, with probability p.

*3.3.3 Lognormal p*100% Percentile*

To compute the p^{th} percentile, $\hat{x}_p$, of a lognormally distributed data set, the sample mean, $\bar{y}$, and *sd*, s_y, of log-transformed data, y are computed first. For lognormally distributed data sets, the p*100th percentile is given by the following statement:

$$\hat{x}_p = \exp(\bar{y} + s_y z_p), \tag{3-3}$$

z_p is the p*100th percentile of a standard normal, N(0,1), distribution.

*3.3.4 Gamma p*100% Percentile*

Since the introduction of a gamma distribution, G (k, θ), is relatively new in environmental applications, a brief description of the gamma distribution is given first; more details can be found in Section 2.3.3. The maximum likelihood estimator (*MLE*) equations to estimate gamma parameters, k (shape parameter) and θ (scale parameter), can be found in Singh, Singh, and Iaci (2002). A random variable (RV), X (arsenic concentrations), follows a gamma distribution, G(k,θ), with parameters $k > 0$ and $\theta > 0$, if its probability density function is given by the following equation:

$$\begin{aligned} f(x;k,\theta) &= \frac{1}{\theta^k \Gamma(k)} x^{k-1} e^{-x/\theta}; & x > 0 \\ &= 0; & \textit{otherwise} \end{aligned} \tag{3-4}$$

The mean, variance, and skewness of a gamma distribution are: $\mu = k\theta$, variance = $\sigma^2 = k\theta^2$, and skewness $= 2/\sqrt{k}$. Note that as k increases, the skewness decreases, and, consequently, a gamma distribution starts approaching a normal distribution for larger values of *k* (e.g., $k \geq 10$). In practice, *k* is not known and a normal approximation may be used even when the MLE estimate of k is as small as 6. If needed, the user may want to use graphical Q-Q plots and perform GOF tests to verify if data sets with smaller values of the *MLE* estimates of *k* follow normal distributions.

Let $\hat{k}$ and $\hat{\theta}$ represent the *MLE*s of *k* and θ respectively. The relationship between a gamma RV, X = G (k, θ), and a chi-square RV, Y, is given by X = Y * θ/2, where Y follows a chi-square distribution with 2*k* degrees of freedom (*df*). Thus, the percentiles of a chi-square distribution (as programmed in ProUCL) can be used to determine the percentiles of a gamma distribution. In practice, *k* is replaced by its *MLE*. Once an α*100% percentile, $y_{(\alpha)\ 2k}$, of a chi-square distribution with 2*k df* is obtained, the α*100% percentile for a gamma distribution is computed using the following equation:

$$x_{\alpha} = y_{\alpha} * \theta / 2 \qquad (3\text{-}5)$$

3.4 Upper Tolerance Limits

A UTL (1-α)-*p* (e.g., UTL95-95) based upon an established background data set represents that limit such that *p**100% of the observations (current and future) from the target population (background, comparable to background) will be less than or equal to UTL with a *CC*, (1-α). It is expected that *p**100% of the observations belonging to the background population will be less than or equal to a UTL with a *CC*, (1-α). A UTL (1-α)-*p* represents a (1 – α) 100% UCL for the unknown p^{th} percentile of the underlying background population.

A UTL95-95 is designed to provide coverage for 95% of all observations potentially coming from the background or comparable to background population(s) with a CC of 0.95. A UTL95-95 will be exceeded by all (current and future) values coming from the background population less than 5% of the time with a CC of 0.95, that is 5 exceedances per 100 comparisons (of background values) can result just by chance for an overall CC of 0.95. Unlike a UPL95, a UTL95-95 can be used when many ,or unknown number of, current or future onsite observations need to be compared with a BTV. A parametric UTL95-95 takes the data variability into account.

When a large number of comparisons are made with a UTL95-95, the number of exceedances (not the percentage of exceedances) of the UTL95-95 by those observations can also be large just by chance. This implies that just by chance, a larger number (but not larger than 5%) of onsite locations comparable to background can be greater than a UTL95-95 potentially requiring unnecessary investigation which may not be cost-effective. In order to avoid this situation, it is suggested to use a USL95 to estimate a BTV, provided the background data set represents a single statistical population, free of outliers.

3.4.1 Normal Upper Tolerance Limits

First, compute the sample mean, $\bar{x}$, and *sd*, *s*, using a defensible data set representing a single background population. For normally distributed data sets, an upper (1 – α)*100% UTL with coverage coefficient, *p*, is given by the following statement.

$$UTL = \bar{x} + K * s \qquad (3\text{-}6)$$

Here, *K* = *K* (*n*, α, *p*) is the tolerance factor and depends upon the sample size, *n*, CC = (1 – α), and the coverage proportion = *p*. For selected values of *n, p,* and (1-α), values of the tolerance factor, *K*, have been tabulated extensively in the various statistical books (e.g., Hahn and Meeker 1991). Those *K* values are based upon the non-central t-distribution. Also, some large sample approximations (e.g., Natrella, 1963) are available to compute the K values for one-sided tolerance intervals (same for both UTLs and lower tolerance limits). The approximate value of K is also a function of the sample size, n, coverage coefficient, p, and the CC, $(1 - \alpha)$. For samples of small sizes, $n \leq 30$, ProUCL uses the tabulated (Hahn and Meeker, 1991) K values. Tabulated K values are available only for some selected combinations of p (e.g., 0.90, 0.95, 0.975) and $(1-\alpha)$ values (e.g., 0.90, 0.95, 0.99). For sample sizes larger than 30, ProUCL computes the K values using the large sample approximations, as given in Natrella (1963). The Natrella's approximation seems to work well for samples of sizes larger than 30. ProUCL computes these K values for all valid values of p and $(1-\alpha)$ and samples of sizes as large as 5000.

3.4.2 Lognormal Upper Tolerance Limits

The procedure to compute UTLs for lognormally distributed data sets is similar to that for normally distributed data sets. First, the sample mean, $\bar{y}$, and *sd*, s_y, of the log-transformed data are computed. An upper $(1 - \alpha)$*100% tolerance limit with tolerance or coverage coefficient, p is given by the following statement:

$$UTL = \exp(\bar{y} + K * s_y) \quad (3\text{-}7)$$

The K factor in (3-7) is the same as the one used to compute the normal UTL.

Notes: It is noted that even though there in no back-transformation bias present in the computation of a lognormal UTL, a lognormal distribution based UTL is typically higher (sometimes unrealistically higher as shown in the following example) than other parametric and nonparametric UTLs; especially when the sample size is less than 20. Therefore, the use of a lognormal UTLs to estimate BTVs should be avoided when skewness is high (e.g., *sd* of logged data > 1 or 1.5) and sample size is small (e.g., < 20-30).

3.4.3 Gamma Distribution Upper Tolerance Limits

Positively skewed environmental data can often be modeled by a gamma distribution. ProUCL software has two goodness-of-fit tests: the Anderson-Darling (A-D) and Kolmogorov-Smirnov (K-S) tests for a gamma distribution. These GOF tests are described in Chapter 2. UTLs based upon normal approximation to the gamma distribution (Krishnamoorthy *et al*., 2008) have been incorporated in ProUCL. Those approximations are based upon Wilson-Hilferty (WH; 1931) and Hawkins-Wixley (H-W; 1986) approximations. A description of the procedure to compute gamma UTLs is given as follows.

Let $x_1, x_2, \ldots, x_n$ represent a data set of size n from a gamma distribution, $G(k, \theta)$ with shape parameter, k and scale parameter θ.

- According to the WH approximation, the transformation, $Y = X^{1/3}$ follows an approximate normal distribution.
- According to the HW approximation, the transformation, $Y = X^{1/4}$ follows an approximate normal distribution.

Let $\bar{y}$ and s_y represent the mean and *sd* of the observations in the transformed scale (Y).

Using the WH approximation, the gamma UTL (in original scale, X), is given by:

$$UTL = \max\left(0, \left(\bar{y} + K * s_y\right)^3\right) \tag{3-8}$$

Similarly, using the HW approximation, the gamma UTL in original scale is given by:

$$UTL = \left(\bar{y} + K * s_y\right)^4 \tag{3-9}$$

The tolerance factor, K is defined earlier in (3-6) while computing a UTL based upon normal distribution.

<u>Note:</u> that for mildly skewed to moderately skewed gamma distributed data sets, HW and WH approximations yield fairly comparable UTLs. However for highly skewed data sets (e.g., k<0.5) with higher variability, HW method tends to yield higher limits than the WH method. A couple of examples are discussed as follows.

3.4.4 Nonparametric Upper Tolerance Limits

The computation of nonparametric UTLs and associated achieved confidence levels are described as follows. A nonparametric $UTL_{p,(1-\alpha)}$ =UTL p-(1 - α) providing coverage to p*100% observations with CC, (1 – α) represents an (1 – α)*100% UCL for the p^{th} percentile of the target population under study. It is expected that about p*100% of the observations (current and future) coming from the target population (e.g., background, comparable to background) will be ≤ $UTL_{p,(1-\alpha)}$ with CC, (1 – α)*100.

Let $x_{(1)} \le x_{(2)} \le ... x_{(r)} \le ... \le x_{(n)}$ represent n ordered statistics (arranged in ascending order) of a given data set, $x_{1,} x_2, ..., x_n$. A nonparametric UTL is computed by the higher order statistics such as the largest, the second largest, the third largest, and so on. The order, r of the statistic, $x_{(r)}$ used to compute a nonparametric UTL depends upon the sample size, n, coverage probability, p, and the desired CC, (1 - α). It is noted that in comparison with parametric UTLs, nonparametric UTLs require larger data sets to achieve the desired CC; a nonparametric UTL p-(1 - α) computed by order statistics often fails to exactly achieve the specified CC, (1 – α). The formula to compute the order statistic, sample size, and CC achieved by nonparametric UTLs are described as follows. More details can be found in David and Nagaraja (2003), Conover (1999), Hahn and Meeker (1991), Wald (1963), Scheffe and Tukey (1944) and Wilks (1941).

3.4.4.1 Determining the Order, r, of the Statistic, $x_{(r)}$, to Compute UTLp,(1-α)

Using the cumulative binomial probabilities, a number, r: 1 ≤ r ≤ n, is chosen such that the cumulative binomial probability: $\sum_{i=0}^{i=r} \binom{n}{i} p^i (1-p)^{(n-i)}$ becomes as close as possible to (1 – α). The binomial distribution (BD) based algorithm has been incorporated in ProUCL for data sets of sizes up to 2000. For data sets of size, n >2000, ProUCL computes the r^{th} (r: 1 ≤ r ≤ n) order statistic by using the normal approximation (Conover, 1999) given by the equation (3-10).

$$r = np + z_{(1-\alpha)} \sqrt{np(1-p)} + 0.5 \tag{3-10}$$

Depending upon the sample size, p, and (1 - α) the largest, the second largest, the third largest, and so forth order statistic is used to estimate the UTL. As mentioned earlier for a given data set of size n, the r^{th}

order statistic, $x_{(r)}$ may or may not achieve the specified CC, (1 - α). ProUCL uses the following F-distribution based probability statement to compute the CC achieved by the UTL determined by the r^{th} order statistic.

3.4.4.2 Determining the Achieved Confidence Coefficient, $CC_{achieve}$, Associated with $x_{(r)}$

For a given data set of size, *n*, once the r^{th} order statistic, $x_{(r)}$, has been determined, ProUCL can be used to determine if a UTL computed using $x_{(r)}$ achieves the specified CC, (1 - α). ProUCL computes the achieved CC by using the following approximate probability statement based upon the F-distribution with ν_1 and ν_2 *df*.

$$CC_{Achieve} = (1-\alpha_*) = \text{ Probability } (F_{(\nu_1,\nu_2)} \le f); \; \nu_1 = 2(n-r+1), \text{ and } \nu_2 = 2r$$

$$f = \frac{r(1-p)}{(n-r+1)p} \qquad (3\text{-}11)$$

For a given data set of size *n*, ProUCL 5.0 first computes the order statistic that is used to compute a nonparametric UTL*p,(1-α)*. Once the order statistic has been determined, ProUCL 5.0 computes the CC actually achieved by that UTL.

3.4.4.3 Determining the Sample Size

For specified values of *p* and (1 - α), the minimum sample size can be computed using Scheffe and Tukey (1944) approximate sample size formula given by equation (3-12). The minimum sample size formula should be used before collecting any data /samples. Once the data set of size, *n* has been collected, using the binomial distribution or approximate normal distribution, one can compute the order, *r* of the statistic that can be used to compute a UTL. As mentioned earlier, the UTLs based upon order statistics often do not achieve the desired confidence level. One can use equation (3-11) to compute the CC achieved by a UTL.

$$n_{needed} = 0.25 * \chi^2_{2m,(1-\alpha)} * (1+p)/(1-p) + (m-1)/2 \qquad (3\text{-}12)$$

In equation (3-12), $\chi^2_{2m,(1-\alpha)}$ represents the (1 - α) quantile of a chi-square distribution with *2m df*. It should be noted that in addition to *p* and (1 - α), the Scheffe and Tukey (1944) approximate minimum sample size formula (3-12) also depends upon the order, *r* of the statistic, $x_{(r)}$ used to compute the UTL*p,* (1 - α)*)*. Here m: $1 \le m \le n$; and m=1 when the largest value, $x_{(n)}$, is used to compute the UTL; and m=2, when the second largest value, $x_{(n-1)}$ is used to compute a UTL, and $m=n-r+1$ when the r^{th} order statistic, $x_{(r)}$, is used to compute a UTL. For an example, if the largest sample value, $x_{(n)}$, is used to compute a UTL95-95, then a minimum sample size of 59 (see equation (3-12)) will be needed to achieve a confidence level of 0.95 providing coverage to 95% of the observations coming from the target population. A UTL95-95 computed based upon a data set of size less than 59 may not achieve the desired confidence of 0.95 for the 95^{th} percentile of the target population.

For example, when the largest order statistic (with m=1) is used to compute a nonparametric UTL95-95, the approximate minimum sample size needed 0.25*5.99*1.95/0.05 ≈ 58.4 which is rounded upward to 59; and when the second largest value (with m=2) is used to compute a UTL95-95, the approximate minimum sample size needed [(0.25*9.488*1.95)/0.05]+0.5 ≈ 93. Similarly to compute a UTL90-95 by the largest sample value, about 29 observations will be needed to provide coverage for 90% of the observations from the target population with CC = 0.95. In environmental applications, the number of available observations from the target population is much smaller than 29, 59 or 93 and a UTL computed based upon those data sets may not provide specified coverage with the desired CC.

3.4.4.4 Nonparametric UTL Based Upon the Percentile Bootstrap Method

A couple of bootstrap methods to compute nonparametric UTLs are also available in ProUCL 5.0. Like the percentile bootstrap UCL computation method, for data sets without a discernible distribution, one can use percentile bootstrap resampling method to compute $UTL_{p,(1-\alpha)}$ =UTL p,(1 - α). The N bootstrapped nonparametric p^{th} percentiles, p,(i:=$1,2,...,N$), are arranged in ascending order: $p_1 \le p_2 \le .... \le p_N$. The $UTL_{p,(1-\alpha)}$ for the target population is given by the value that exceeds the (1 – α)*100 of the N bootstrap percentile values. The UTL95-95 is the 95th percentile and is given by:

95% Percentile UTL = 95th percentile of p_i *values; i*: = *1, 2, ..., N*

For example when N = 1000, the ULT95-95 is given by the 950th order percentile value of the 1000 bootstrapped 95th percentiles. Typically, this method yields the largest value in the data set to compute a UTL which may not provide the desired coverage (e.g., 0.95) to the 95th population percentile.

3.4.4.5 Nonparametric UTL Based Upon the Bias-Corrected Accelerated (BCA) Percentile Bootstrap Method

Like the percentile bootstrap method, one can use the BCA bootstrap method (Efron and Tibshirani 1993) to compute nonparametric UTLs. However, this method needs further investigation. This method is incorporated in ProUCL 4.00.04 and higher versions for interested users. In this method one replaces the sample mean, bootstrap and jackknife (deleting one observation at a time) means by the corresponding bootstrap percentiles and jackknife (computed using (n - 1) observations by deleting one observation at a time) percentiles. The details of the BCA bootstrap method are given in Section 2.4.9.4.

3.5 Upper Prediction Limits

Based upon a background data set, UPLs are computed for a single (UPL_1) and k (UPL_k) future observations. Additionally, in groundwater monitoring applications, an upper prediction limit of the mean of the k future observations, UPL_k (mean) is also used. A brief description of parametric and nonparametric upper prediction limits is provided in this section.

<u>UPL_1 for a Single Future Observation:</u> A UPL_1 computed based upon an established background data set represents that statistic such that a single future observation from the target population (e.g., background, comparable to background) will be less than or equal to $UPL_1$95 with a CC of 0.95. A parametric UPL takes the data variability into account. A UPL_1 is designed for a *single future* observation comparison; however in practice users tend to use $UPL_1$95 to perform many future comparisons which results in a high number of false postives (observations declared contaminated when in fact they are clean).

When k>1 future comparisons are made with a UPL_1, some of those future observations will exceed the UPL_1 just by chance, each with probability 0.05. For proper comparison, a UPL needs to be computed accounting for the number of comaprisons that will be performed. For example, if 30 independent onsite comparisons (e.g., Pu-238 activity from 30 onsite locations) are made with the same background $UPL_1$95, each onsite value comparable to background may exceed that $UPL_1$95 with probability 0.05. The overall probability of at least one of those 30 comparisons being significant (exceeding the BTV) just by chance is given by:

$\alpha_{actual} = 1\text{-}(1\text{-}\alpha)^k = 1 - 0.95^{30} \sim 1\text{-}0.21 = 0.79$ (false positive rate).

This means that the probability (overall false positive rate) is 0.79 (and not 0.05) that at least one of the 30 onsite observations will be considered contaminated even when they are comparable to background. Similar arguments hold when multiple *(=j,* a positive integer*)* constituents are analyzed, and status (clean or impacted) of an onsite location is determined based upon *j* comparisons (one for each analyte). The use of a UPL_1 is not recommended when multiple comparisons are to be made.

3.5.1 Normal Upper Prediction Limit

The sample mean, $\bar{x}$, and the *sd, s*, are computed first based upon a defensible background data set. For normally distributed data sets, an upper (1 – *α*)*100% prediction limit is given by the following well known equation:

$$UPL = \bar{x} + t_{((1-\alpha),(n-1))} * s * \sqrt{(1+1/n)} \tag{3-13}$$

Here $t_{((1-\alpha),(n-1))}$ is a critical value from the Student's t-distribution with (*n*–1) *df*.

3.5.2 Lognormal Upper Prediction Limit

An upper (1 – *α*)*100% lognormal UPL is similarly given by the following equation:

$$UPL = \exp(\bar{y} + t_{((1-\alpha),(n-1))} * s_y * \sqrt{(1+1/n)}) \tag{3-14}$$

Here $t_{((1-\alpha),(n-1))}$ is a critical value from the Student's t-distribution with (*n*–1) *df*.

3.5.3 Gamma Upper Prediction Limit

Given a sample, $x_1, x_2, \ldots, x_n$ of size n from a gamma distribution $G(k, \theta)$, approximate (based upon WH and HW approximations described earlier in Section 3.4.3, Gamma Distribution Upper Tolerance Limits), (1 – *α*)*100% upper prediction limits for a future observation from the same gamma distributed population are given by:

$$\textit{Wilson-Hilferty (WH) UPL} = \max\left(0, \left(\bar{y} + t_{((1-\alpha),(n-1))} * s_y * \sqrt{1+ 1/n}\right)^3\right) \tag{3-15}$$

$$\textit{Hawkins-Wixley (HW) UPL} = \left(\bar{y} + t_{((1-\alpha),(n-1))} * s_y * \sqrt{1+ 1/n}\right)^4 \tag{3-16}$$

Here $t_{((1-\alpha),(n-1))}$ is a critical value from the Student's t-distribution with (*n*–1)*df*.

3.5.4 Nonparametric Upper Prediction Limit

A one-sided nonparametric UPL is simple to compute and is given by the following mth order statistic. One can use linear interpolation if the resulting number, m, given below does not represent a whole number (a positive integer).

$$UPL = X_{(m)}, \text{ where } m = (n + 1) * (1 - \alpha). \qquad (3\text{-}17)$$

For example, for a nonparametric data set of size *n*=25, a 90% UPL is desired. Then *m* = (26*0.90) = 23.4. Thus, a 90% nonparametric UPL can be obtained by using the 23rd and the 24th ordered statistics and is given by the following equation:

$$UPL = X_{(23)} + 0.4 * (X_{(24)} - X_{(23)})$$

Similarly, if a nonparametric 95% UPL is desired, then m = 0.95 * (25 + 1) = 24.7, and a 95% UPL can be similarly obtained by using linear interpolation between the 24th and 25th order statistics. However, if a 99% UPL needs to be computed, then m = 0.99 * 26 = 25.74, which exceeds 25, the sample size; for such cases, the highest order statistic is used to compute the 99% UPL of the background data set. The largest value(s) should be used with caution (as they may represent outliers) to estimate the BTVs.

Since nonparametric upper limits (e.g., UTLs, UPLs) are based upon higher order statistics, often the CC achieved by these nonparametric upper limits is much lower than the specified CC of 0.95, especially when the sample size is small. In order to address this issue, one may want to compute a UPL based upon the Chebyshev inequality. In addition to various parametric and nonparametric upper limits, ProUCL computes Chebyshev inequality based UPL.

3.5.4.1 Upper Prediction Limit Based Upon the Chebyshev Inequality

Like UCL of mean, the Chebyshev inequality can be used to obtain a reasonably conservative but stable UPL and is given by the following equation:

$$UPL = \bar{x} + [\sqrt{((1/\alpha) - 1) * (1 + 1/n)}]s_x$$

This is a nonparametric method since the Chebyshev inequality does not require any distributional assumptions. It should be noted that just like the Chebyshev UCL, a UPL based upon the Chebyshev inequality tends to yield higher estimates of BTVs than the various other methods. This is especially true when skewness is mild (e.g., *sd* of log-transformed data is low < 0.75), and the sample size is large (e.g., > 30). The user is advised to use professional judgment before using this method to compute a UPL. Specifically, for larger skewed data sets, instead of using a 95% UPL based upon the Chebyshev inequality, the user may want to compute a Chebyshev UPL with a lower CC (e.g., 85%, 90%) to estimate a BTV. ProUCL can compute a Chebyshev UPL (and all other UPLs) for any user specified CC in the interval [0.5, 1].

3.5.5 Normal, Lognormal, and Gamma Distribution based Upper Prediction Limits for k Future Comparisons

A UPL_k95 computed based upon an established background data set represents that statistic such that k future (next, independent andnot belonging to the current data set) observations from the target population (e.g., background, comparable to background) will be less than or equal to the UPL_k95 with a CC of 0.95.

A UPL_k95 for k (≥1) future observations is designed to compare k future observations; we are 95% sure that "k" future values from the background population will be less than or equal to UPL_k95 with CC of 0.95. In addition to UPL_k, ProUCL also computes an upper prediction limit of the mean of k future observations, UPL_k (mean). A UPL_k (mean) is commonly used in groundwater monitoring applications. A UPL_k controls the false positive error rate by using the Bonferroni inequality based critical values to perform k future comparisons. These UPLs satisfy the relationship: $UPL_1 \leq UPL_2 \leq UPL_3 \leq \ldots \leq UPL_k \ldots$

A normal distribution based UPL_k (1 - α) for k future observations, $x_{n+1}, x_{n+2}, ..., x_{n+k}$ is given by the probability statement:

$$P\left(x_{n+1}, x_{n+2}, ..., x_{n+k} \leq \bar{x} + t_{((1-\alpha/k),n-1)} s\sqrt{1+\frac{1}{n}}\right) = 1-\alpha \qquad (3\text{-}18)$$

$$UPL_k = \bar{x} + s * t_{(1-\alpha/k),n-1}\sqrt{1+\frac{1}{n}}$$

$$UPL_k 95 = \left(\bar{x} + t_{((1-0.05/k),n-1)} s\sqrt{1+\frac{1}{n}}\right)$$

For an example, a UPL_3 95 for 3 future observations: $x_{01,} x_{02}, x_{03}$ is given by:

$$UPL_3 95 = \left(\bar{x} + t_{((1-0.05/3),n-1)} s\sqrt{1+\frac{1}{n}}\right)$$

A lognormal distribution based UPL_k (1 - α) for k future observations, $x_{n+1}, x_{n+2}, ..., x_{n+k}$ is given by the following equation:

$$UPL_k = \exp(\bar{y} + s_y * t_{(1-\alpha/k),n-1}\sqrt{1+\frac{1}{n}})$$

A gamma distribution based UPL_k for the next k > 1 (k future observations) are computed similarly using the WH and HW approximations described in Section 3.4.3.

3.5.6 Proper Use of Upper Prediction Limits

It is noted that some users tend to use UPLs without taking their definition and intended use into consideration; this is an incorrect application of a UPL. Some important points to note about the proper use of UPL_1 and UPL_k for $k>1$ are described as follows.

- When a UPL_k is computed to compare k future observations collected from a site area or a group of MW within an operating unit (OU), it is assumed that the project team will make a decision about the status (clean or not clean) of the site (MWs in an OU) based upon those *k* future observations.

- The use of an UPL_k implies that a decision about the site-wide status will be made only after k comparisons have been made with the UPL_k. It does not matter if those k observations are collected (and compared) simultaneously or successively. The k observations are compared with the UPL_k as they become available and a decision (about site status) is made based upon those k observations.

- An incorrect use of a UPL_1 95 is to compare many (e.g., 5, 10, 20,…) future observations. This results in a higher than 0.05 false positive rate. Similarly, an inappropriate use of a UPL_{100} would be to compare less than 100 (i.e., 10, 20, or 50 observations) future observations.. Using a UPL_{100} to compare 10 or 20 observations can potentially result in a high number of false negatives (a test with reduced power) declaring contaminated areas comparable to background.

- The use of other statistical limits such as 95%-95% UTLs (UTL95-95) is preferred to estimate BTVs and not-to-exceed values. The computation of a UTL does not depend upon the number of future comparisons which will be made with the UTL.

3.6 Upper Simultaneous Limits

An $(1 - \alpha)$ * 100% upper simultaneous limit (USL) based upon an established background data set is meant to provide coverage for all observations, x_i, $i = 1, 2, n$ simultaneously in the background data set. It is implicitly assumed that the data set comes from a single background population and is free of outliers (established background data set). A USL95 represents that statistic such that_all observations from the "established" background data set will be less than or equal to the USL95 with a CC of 0.95. It is expected that observations coming from the background population will be less than or equal to the USL95 with a 95% CC. A USL95 can be used to perform any number (unknown) of comparisons of future observations. The false positive error rate does not change with the number of comparisons as the purpose of the USL95 is to perform any number of comparisons simultaneously.

Notes: If a background population is established based upon a small data set; as one collects more observations from the background populations, some of the new background observations will exceed the largest value in the existing data set. In order to address these uncertainties, the use of a USL is recommended, provided the data set represents a single population without outliers.

3.6.1 Upper Simultaneous Limits for Normal, Lognormal and Gamma Distributions

The normal distribution based two-sided $(1 - \alpha)$ 100% simultaneous interval obtained using the first order Bonferroni inequality (Singh and Nocerino, 1995, 1997) is given as follows:

$$P\left(\bar{x} - sd_{\alpha}^{b} \le x_i \le \bar{x} + sd_{\alpha}^{b}; i := 1, 2, ..., n\right) = 1 - \alpha . \qquad (3\text{-}19)$$

Here, $(d_{\alpha}^{b})^2$ represents the critical value (obtained using the Bonferroni inequality) of the maximum Mahalanobis distance (Max (MDs)) for α level of significance (Singh, 1993). The details about the Mahalanobis distances and computation of the critical values, $(d_{\alpha}^{b})^2$ can be found in Singh (1993) and Singh and Nocerino (1997). These values have been programmed in ProUCL 5.0 to compute USLs for any combination of the sample size, *n,* and CC, $(1 - \alpha)$.

The normal distribution based, one-sided (1 – α) 100% USL providing coverage for all n sample observations is given as follows:

$$P\left(x_i \le \bar{x} + sd_{2\alpha}^b; i := 1, 2, ..., n\right) = 1 - \alpha \ ;$$

$$USL = \bar{x} + s * d_{2\alpha}^b; \qquad (3\text{-}20)$$

Here $(d_{2\alpha}^b)^2$ is the critical value of Max (MDs) for a 2*α level of significance.

The lognormal distribution based one-sided (1 – α) 100% USL providing coverage for all n sample observations is given by the following equation:

$$USL = \exp(\bar{x} + s * d_{2\alpha}^b) \qquad (3\text{-}21)$$

A gamma distribution based (using WH approximation), one-sided (1 – α) 100% USL providing coverage to all sample observations is given by:

$$USL = \max\left(0, \left(\bar{y} + d_{2\alpha}^b * s_y\right)^3\right)$$

A gamma distribution based (using the HW approximation), one-sided (1 – α) 100% USL providing coverage to all sample observations is given as follows:

$$USL = \left(\bar{y} + d_{2\alpha}^b * s_y\right)^4$$

Nonparametric USL: For nonparametric data sets, the largest value, $x_{(n)}$ is used to compute a nonparametric USL. Just like a nonparametric UTL, a nonparametric USL may fail to provide the specified coverage, especially when the sample size is small (e.g., <60). The confidence coefficient actually achieved by a USL can be computed using the same process as used for a nonparametric UTL described in Sections 3.4.4.2 and 3.4.4.3. Specifically, by substituting r=n in equation (3-11), the confidence coefficient achieved by a USL can be computed, and by substituting m=1 in equation (3-12), one can compute the sample size needed to achieve the desired confidence.

Notes: Nonparametric USLs, UTLs or UPLs should be used with caution; nonparametric upper limits are based upon order statistics and therefore do not take the variability of the data set into account. Often nonparametric BTVs estimated by order statistics do not achieve the specified CC unless the sample size is fairly large.

Some examples illustrating the computations of the various upper limits described in this chapter are discussed as follows.

Example 3-1. Consider a real Superfund site data set. The data set has several inorganic constituents of potential concern, including aluminum, arsenic, chromium (Cr), and lead. The computation of background statistics obtained using ProUCL are summarized as follows. The complete data set is given in Appendix 5 of the *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA, 2002a).

Upper Limits Based upon a Normally Distributed Data Set: The aluminum data set follows a normal distribution as shown in the following GOF Q-Q plot of Figure 3-1.

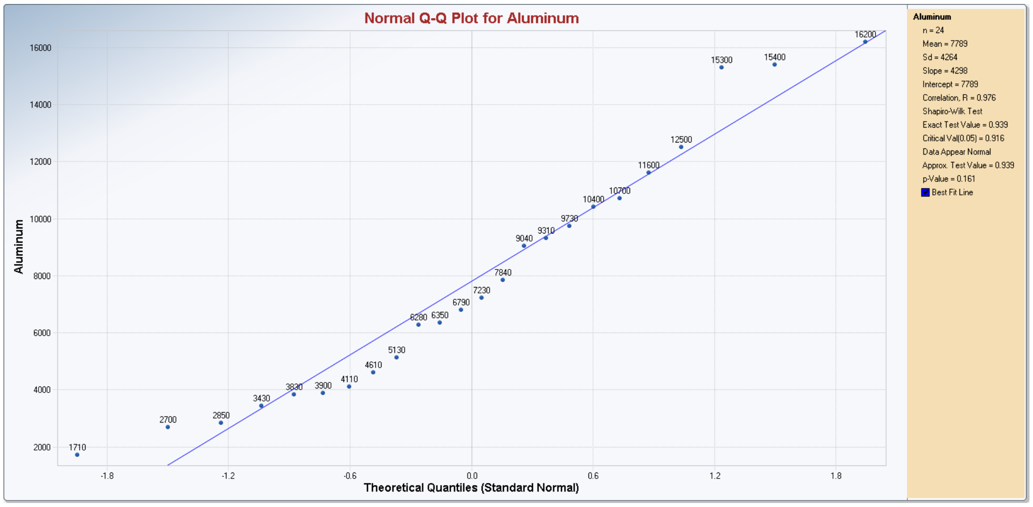

Figure 3-1. Normal Q-Q plot of aluminum with GOF Statistics

From the normal Q-Q plot shown in Figure 3-1, it is noted that the 3 largest values are higher (but not extremely high) than the rest of the 21 observations. These observations may or may not be coming from the same population as the rest of the 21 observations. The classical outlier tests (e.g., Dixon and Rosner tests) did not identify these 3 data points as outliers. Robust outlier tests (e.g., MCD [Rousseeuw and Leroy, 1987)] and PROP influence function [Singh and Nocerino, 1995] based tests) identified the 3 high values as statistical outliers. The project team should decide whether or not the 3 higher concentrations represent outliers. A brief discussion about robust outlier identification methods is given in Chapter 7. The inclusion of the 3 higher values in the data set resulted in higher upper limits. The various upper limits have been computed with (Table 3-1) and without the 3 high observations (Table 3-2).

Table 3-1. BTV Estimated Based upon All 24 Observations

Aluminum			
General Statistics			
Total Number of Observations	24	Number of Distinct Observations	24
Minimum	1710	First Quartile	4058
Second Largest	15400	Median	7010
Maximum	16200	Third Quartile	10475
Mean	7789	SD	4264
Coefficient of Variation	0.547	Skewness	0.542
Mean of logged Data	8.798	SD of logged Data	0.61
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.309	d2max (for USL)	2.644
Normal GOF Test			
Shapiro Wilk Test Statistic	0.939	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.916	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.109	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.181	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Background Statistics Assuming Normal Distribution			
95% UTL with 95% Coverage	17635	90% Percentile (z)	13254
95% UPL (t)	15248	95% Percentile (z)	14803
95% USL	19063	99% Percentile (z)	17708

Table 3-2. BTV Estimated Based upon 21 Observations without 3 Higher Values

Aluminum			
General Statistics			
Total Number of Observations	21	Number of Distinct Observations	21
		Number of Missing Observations	3
Minimum	1710	First Quartile	3900
Second Largest	11600	Median	6350
Maximum	12500	Third Quartile	9310
Mean	6669	SD	3215
Coefficient of Variation	0.482	Skewness	0.25
Mean of logged Data	8.676	SD of logged Data	0.549
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.371	d2max (for USL)	2.58
Normal GOF Test			
Shapiro Wilk Test Statistic	0.955	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.908	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.12	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.193	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Background Statistics Assuming Normal Distribution			
95% UTL with 95% Coverage	14291	90% Percentile (z)	10789
95% UPL (t)	12344	95% Percentile (z)	11957
95% USL	14964	99% Percentile (z)	14147

The project team should make a determination of which statistics (with outliers or without outliers) should be used to estimate BTVs.

Example 3-2. Chromium concentrations of the superfund site data set used in Example 3-1 follow a lognormal distribution. The computation of background statistics using a lognormal model are shown in -3 3. Figure 3-2 is the lognormal Q-Q plot with GOF statistics.

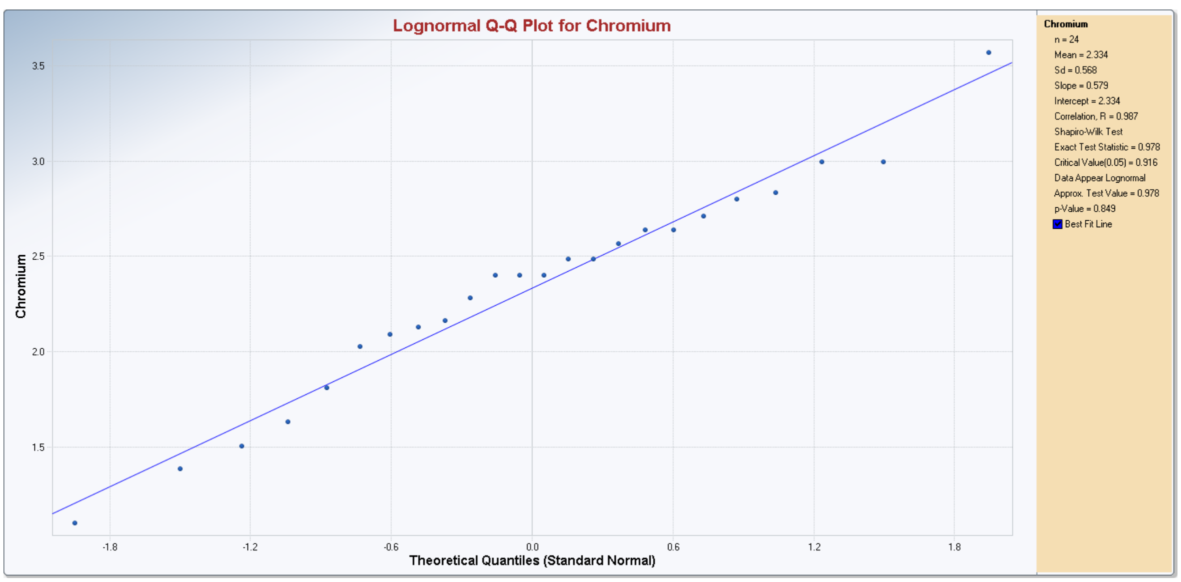

Figure 3-2. Lognormal Q-Q plot of Chromium with GOF Statistics

Table 3-3. Lognormal Distribution Based UPLs, UTLs, and USLs

Chromium			
General Statistics			
Total Number of Observations	24	Number of Distinct Observations	19
Minimum	3	First Quartile	7.975
Second Largest	20	Median	11
Maximum	35.5	Third Quartile	14.25
Mean	11.97	SD	6.892
Coefficient of Variation	0.576	Skewness	1.728
Mean of logged Data	2.334	SD of logged Data	0.568
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.309	d2max (for USL)	2.644
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.978	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.916	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.128	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.181	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Background Statistics assuming Lognormal Distribution			
95% UTL with 95% Coverage	38.3	90% Percentile (z)	21.37
95% UPL (t)	27.87	95% Percentile (z)	26.27
95% UPL for Next 5 Observations	43.96	99% Percentile (z)	38.68
95% UPL for Mean of 5 Observations	16.66	95% USL	46.33

Example 3-3. Arsenic concentrations of the superfund site data set used in Example 3-1 follow a gamma distribution. The background statistics, obtained using a gamma model, are shown in Table 3-4. Figure 3-3 is the gamma Q-Q plot with GOF statistics.

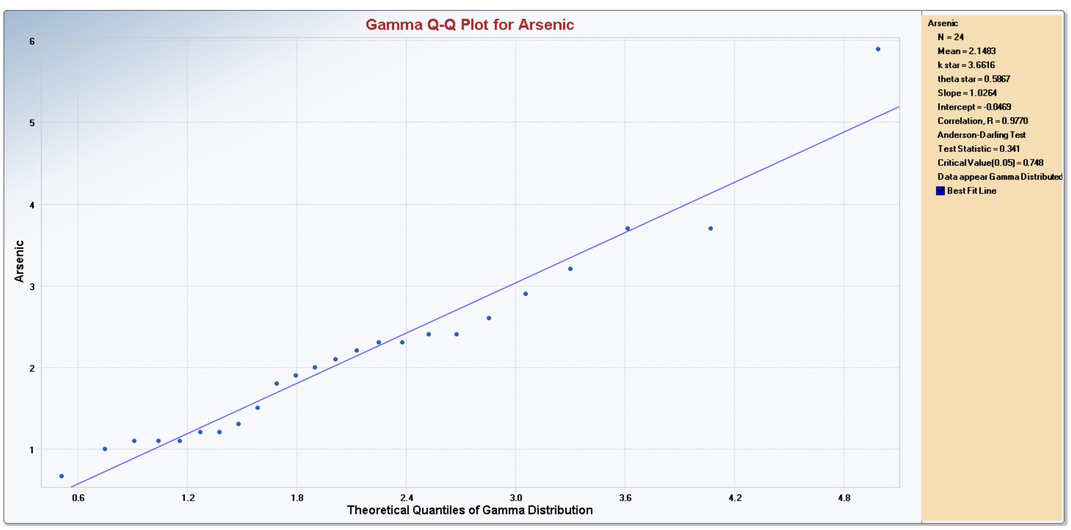

Figure 3-3. Gamma Q-Q plot of Arsenic with GOF Statistics

Table 3-4. Gamma Distribution Based UPLs, UTLs, and USLs

Arsenic			
General Statistics			
Total Number of Observations	24	Number of Distinct Observations	18
Minimum	0.66	First Quartile	1.2
Second Largest	3.7	Median	2.05
Maximum	5.9	Third Quartile	2.45
Mean	2.148	SD	1.159
Coefficient of Variation	0.54	Skewness	1.554
Mean of logged Data	0.639	SD of logged Data	0.51
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.309	d2max (for USL)	2.644
Gamma GOF Test			
A-D Test Statistic	0.341	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.748	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.114	**Kolmogrov-Smirnoff Gamma GOF Test**	
5% K-S Critical Value	0.179	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	4.153	k star (bias corrected MLE)	3.662
Theta hat (MLE)	0.517	Theta star (bias corrected MLE)	0.587
nu hat (MLE)	199.3	nu star (bias corrected)	175.8
MLE Mean (bias corrected)	2.148	MLE Sd (bias corrected)	1.123
Background Statistics Assuming Gamma Distribution			
95% Wilson Hilferty (WH) Approx. Gamma UPL	4.345	90% Percentile	3.654
95% Hawkins Wixley (HW) Approx. Gamma UPL	4.397	95% Percentile	4.264
95% WH Approx. Gamma UTL with 95% Coverage	5.382	99% Percentile	5.574
95% HW Approx. Gamma UTL with 95% Coverage	5.524		
95% WH USL	6.074	95% HW USL	6.294

Example 3-4. Lead concentrations of the superfund site data set used in Example 3-1 do not follow a discernible distribution. The various nonparametric background statistics for lead are shown in Table 3-5.

Table 3-5. Nonparametric UPLs, UTLs, and USLs for Lead in Soils

Lead			
General Statistics			
Total Number of Observations	24	Number of Distinct Observations	18
Minimum	4.9	First Quartile	10.43
Second Largest	98.5	Median	14
Maximum	109	Third Quartile	19.25
Mean	22.49	SD	26.83
Coefficient of Variation	1.193	Skewness	2.665
Mean of logged Data	2.743	SD of logged Data	0.771
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.309	d2max (for USL)	2.644
Nonparametric Distribution Free Background Statistics			
Data do not follow a Discernible Distribution (0.05)			
Nonparametric Upper Limits for Background Threshold Values			
Order of Statistic, r	24	95% UTL with 95% Coverage	109
Approximate f	1.263	Confidence Coefficient (CC) achieved by UTL	0.708
95% Percentile Bootstrap UTL with 95% Coverage	109	95% BCA Bootstrap UTL with 95% Coverage	109
95% UPL	106.4	90% Percentile	44.81
90% Chebyshev UPL	104.6	95% Percentile	91.72
95% Chebyshev UPL	141.8	99% Percentile	106.6
95% USL	109		

Notes: As mentioned before, nonparametric upper limits are computed by higher order statistics, or by some value in between (based upon linear interpolation) the higher order statistics. In practice, nonparametric upper limits do not provide the desired coverage to the population parameter (upper threshold) unless the sample size is large. From Table 3-5, it is noted that a UTL95-95 is estimated by the maximum value in the data set of size 24. However, the CC actually achieved by UTL95-95 (and also by USL95) is only 0.708. *Therefore, one may want to use other upper limits such as 95% Chebyshev UPL = 141.8 to estimate a BTV.*

Example 3-5: Why Use a Gamma Distribution to Model Positively Skewed Data Sets?

The data set considered in Example 2-2 of Chapter 2 is used to illustrate the deficiencies and problems associated with the use of a lognormal distribution to compute UCL95 of the mean. As noted earlier, the data set follows a lognormal as well as a gamma model; the various upper limits, based upon a lognormal and a gamma model, are summarized as follows. The largest value in the data set is 169.8, the UTL95-95 and UPL95 based upon a lognormal model are 799.7 and 319 both of which are significantly higher than the maximum value of 169.8. A UPL95 (UTL95-95) based upon a gamma model are 245.3(or 285.6) and 163.5 (or 178.2) which appear to represent more reasonable estimates of the BTV. These statistics are summarized in Table 3-6 (lognormal) and Table 3-7 (gamma) below.

Table 3-6. Background Statistics Based Upon a Lognormal Model

X			
General Statistics			
Total Number of Observations	25	Number of Distinct Observations	25
Minimum	0.349	First Quartile	5.093
Second Largest	164.3	Median	18.77
Maximum	169.8	Third Quartile	72.62
Mean	44.09	SD	51.34
Coefficient of Variation	1.164	Skewness	1.294
Mean of logged Data	2.835	SD of logged Data	1.68
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.292	d2max (for USL)	2.663
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.948	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.918	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.135	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.177	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Background Statistics assuming Lognormal Distribution			
95% UTL with 95% Coverage	799.7	90% Percentile (z)	146.5
95% UPL (t)	319	95% Percentile (z)	269.7

Table 3-7. Background Statistics Based Upon a Gamma Model

X			
General Statistics			
Total Number of Observations	25	Number of Distinct Observations	25
Minimum	0.349	First Quartile	5.093
Second Largest	164.3	Median	18.77
Maximum	169.8	Third Quartile	72.62
Mean	44.09	SD	51.34
Coefficient of Variation	1.164	Skewness	1.294
Mean of logged Data	2.835	SD of logged Data	1.68
Critical Values for Background Threshold Values (BTVs)			
Tolerance Factor K (For UTL)	2.292	d2max (for USL)	2.663
Gamma GOF Test			
A-D Test Statistic	0.374	Anderson-Darling Gamma GOF Test	
5% A-D Critical Value	0.794	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.113	Kolmogrov-Smirnoff Gamma GOF Test	
5% K-S Critical Value	0.183	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.643	k star (bias corrected MLE)	0.592
Theta hat (MLE)	68.58	Theta star (bias corrected MLE)	74.42
nu hat (MLE)	32.15	nu star (bias corrected)	29.62
MLE Mean (bias corrected)	44.09	MLE Sd (bias corrected)	57.28
Background Statistics Assuming Gamma Distribution			
95% Wilson Hilferty (WH) Approx. Gamma UPL	163.5	90% Percentile	115
95% Hawkins Wixley (HW) Approx. Gamma UPL	178.2	95% Percentile	159.4
95% WH Approx. Gamma UTL with 95% Coverage	245.3	99% Percentile	266.8
95% HW Approx. Gamma UTL with 95% Coverage	285.6		

APPENDIX G SUPPLEMENTARY INFORMATION ON CALCULATING UPPER PERCENTILE VALUES FROM USEPA (2013)