CRITERIA SUPPORT DOCUMENT

Site-Specific Standard for Total Dissolved Solids

Blue Creek Reservoir and Blue Creek, Box Elder County, Utah

Utah Division of Water Quality

September 3, 2015 Final

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 4,900 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 6,300 mg/l and an average criterion of 4,700 mg/l TDS are recommended.

For water quality assessment purposes of the maximum criteria, the criteria were derived assuming that up to 10% of the assessment samples may exceed the site-specific TDS criteria (R317-2-7). For water quality assessment for the average criteria, the data and methods used should be consistent with the methods used to derive the criteria. Specifically, the assessment methods should consider the variability and uncertainty of the data supporting the criteria as well as the assessment data. As an example, the mean of 10 summer assessment samples could be compared to 4,100 mg/l, the 95% upper prediction limit of the mean assuming k=10 future samples. For the winter, the 95% upper prediction limit for k=10 future samples is 5,300 mg/l. **Assessment sample means should not be directly compared to the average criteria.**

Applying the same methodologies for deriving the maximum criteria to Blue Creek Reservoir, a maximum criterion of 2,100 mg/ is recommended.

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)		Blue Creek Reservoir
Maximum	Average	Maximum	Average	Maximum
4,900	3,800	6,300	4,700	2,100

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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. Concerns during the comment period that the maximum criteria proposed in the March 3, 2015 draft would be prone to not identifying impairments when the 10% exceedance allowed by R317-2-7 was applied.

This document is an update of the *Proposed Site-Specific Standard for Total Dissolved Solid, Blue Creek, Box Elder County, Utah,* September 24, 2013 and March 3, 2015 Drafts. The methodology was revised for both Blue Creek and Blue Creek Reservoir resulting in different recommendations for the criteria as presented herein.

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) and *March 3, 2015 Draft* (DWQ, 2015).

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. Water quality 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. An appropriate statistical test (e.g., t-test or prediction limits) that controls for these potential decision errors is recommended.

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 this parameter only considers 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. USEPA (2009) recommends that a minimum of 8 samples be used to construct prediction limits. This requirement is one of the limitations of this approach because the resulting comparison value is sensitive to the number of samples. For these reasons, specific comparison values for assessing compliance with the average are not specified although examples are provided.

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 (along with the frequency and duration) 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 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.

Previous derivations of the maximum TDS criteria for Blue Creek were based on 95th or 99th percentile estimates. USEPA Region 8 questioned whether these percentiles were appropriate because when assessing water quality, Utah's water quality standards allow for up 10% of the sample results to exceed the TDS criterion and the water quality would be concluded to meet the criterion. As a compromise to reduce the potential for disapproval of the standard by USEPA Region 8, the 90% upper tolerance limit was selected for the maximum criteria. The 90th percentile has a higher probability of resulting in false positives during assessment but is more protective than the higher percentiles.

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.

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.

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					

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 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.

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				

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).

When assessing water quality for meeting the average criterion, **the mean of the assessment samples cannot be directly compared to average criterion.** Instead, a statistical method that is consistent with the derivation of the average criteria should be used. Table 5 summarizes example comparison values (CVs) to assess if TDS concentrations are meeting the average criteria. As discussed in Section 1.2.3., the UPL is generally preferred and at least 10 samples are recommended based on the results of hypothetical water quality assessments using the existing TDS data.

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 4,900 to 7,200 mg/l. For Blue Creek in the summer season, the 95% UTL with 90% coverage of 4,100 mg/l is selected for the maximum criterion. The 90th percentile of the summer TDS dataset is 4,800 suggesting that false positive water quality impairments may occur but if they are false positives, they should be able to be resolved with additional sample results.

Figure 7 shows a histogram of the summer season TDS data with both the proposed average and the maximum criteria.

Table 5. Example 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 UPL = upper prediction limit	

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
Lognormal 95% UTL with 90% Coverage	**4,900**

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). As with the summer season average criterion, **the mean of the assessment samples cannot be directly compared to average criterion.** Instead, a statistical method that is consistent with the derivation of the average criteria should be used. Table 7 summarizes example comparison values (CVs) to assess if TDS concentrations are meeting the average criteria. As discussed in Section 1.2.3., the UPL is generally preferred and at least 10 samples are recommended based on the results of hypothetical water quality assessments using the existing TDS data.

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 90th, 95th and 99th percentiles and the 95% USL range from 6,300 to 8,100 mg/l (Table 8). The 6,300 mg/l 95% upper tolerance limit with 90% coverage is selected as the maximum criterion. The 90th percentile of the winter TDS dataset is 6,000 suggesting a lower potential for false positive water quality impairments than when assessing the summer season maximum. False positive water quality impairment decisions should be able to be resolved with additional sample results if they occur. Figure 7 shows a histogram of the winter season TDS data with both the proposed average and maximum 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.

1.3.3.4. Trends

The criteria were based on the TDS spanning a 24 year period. When this data is graphed, the slope of the trend line is positive and significantly significant. The trend observed over this time period suggests that TDS concentrations may have increased on average by over 700 mg/l over the 24 year period. If this trend continues, the site-specific standards will have to be recalculated in the future.

Table 7. Example 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**

1.3.4. Site-Specific Criteria for Blue Creek Reservoir

For the reservoir, a single maximum criterion of 2,100 mg/l TDS based on a 95% UTL with 90% coverage is recommended. TDS concentrations showed little variation in the reservoir, and the other upper-percentile estimates were all similar. For instance, 2,100 mg/l based on the 90th percentile and 95% UTL with 90% coverage were the lowest upper bound estimates.

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
95% UTL with 90% Coverage	**6,300**
Notes: UPL = Upper Prediction Limit UTL = Upper Tolerance Limit USL = Upper Simultaneous Limit	

REFERENCES

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

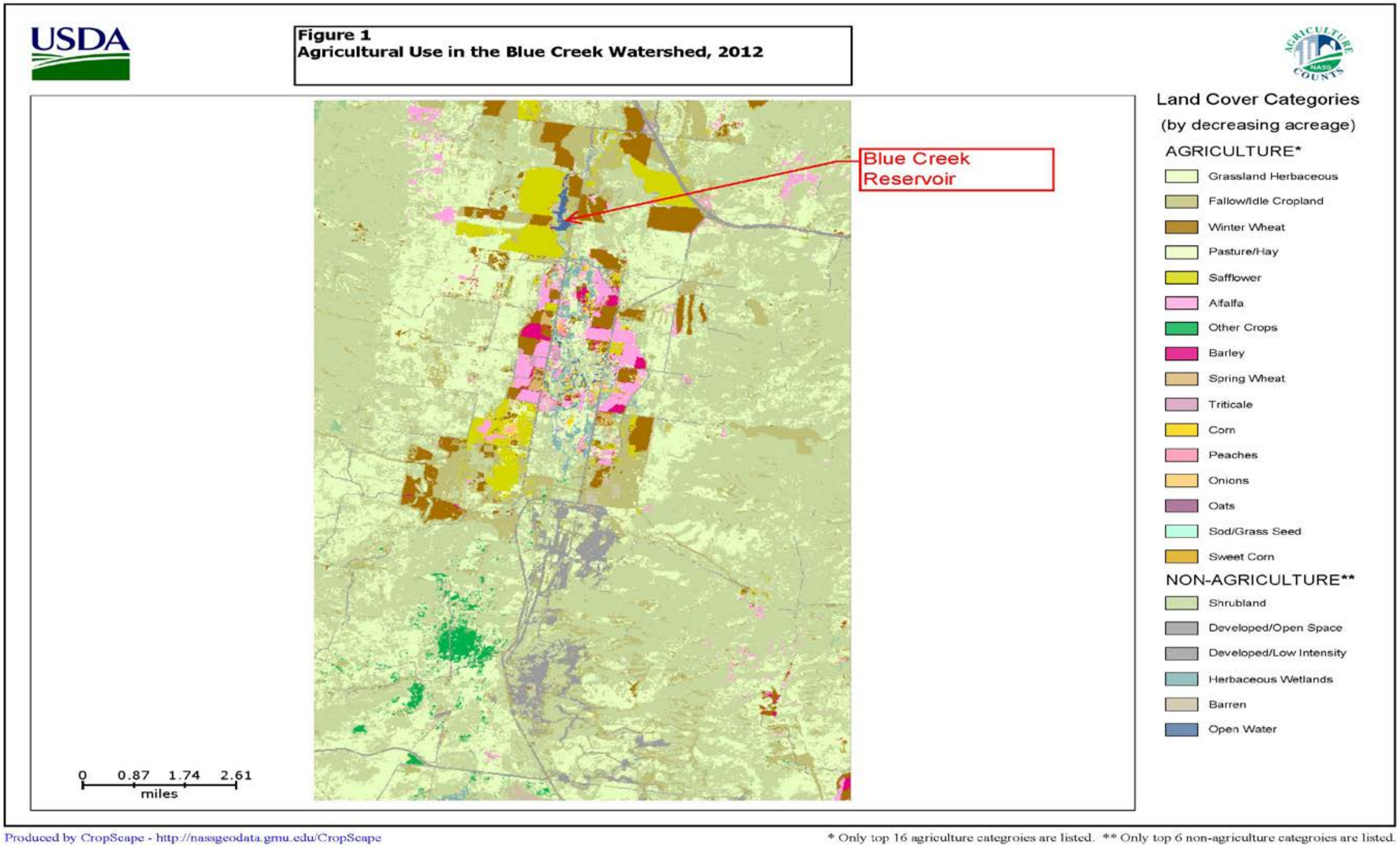

Figure 1. Agricultural Use in the Blue Creek Watershed

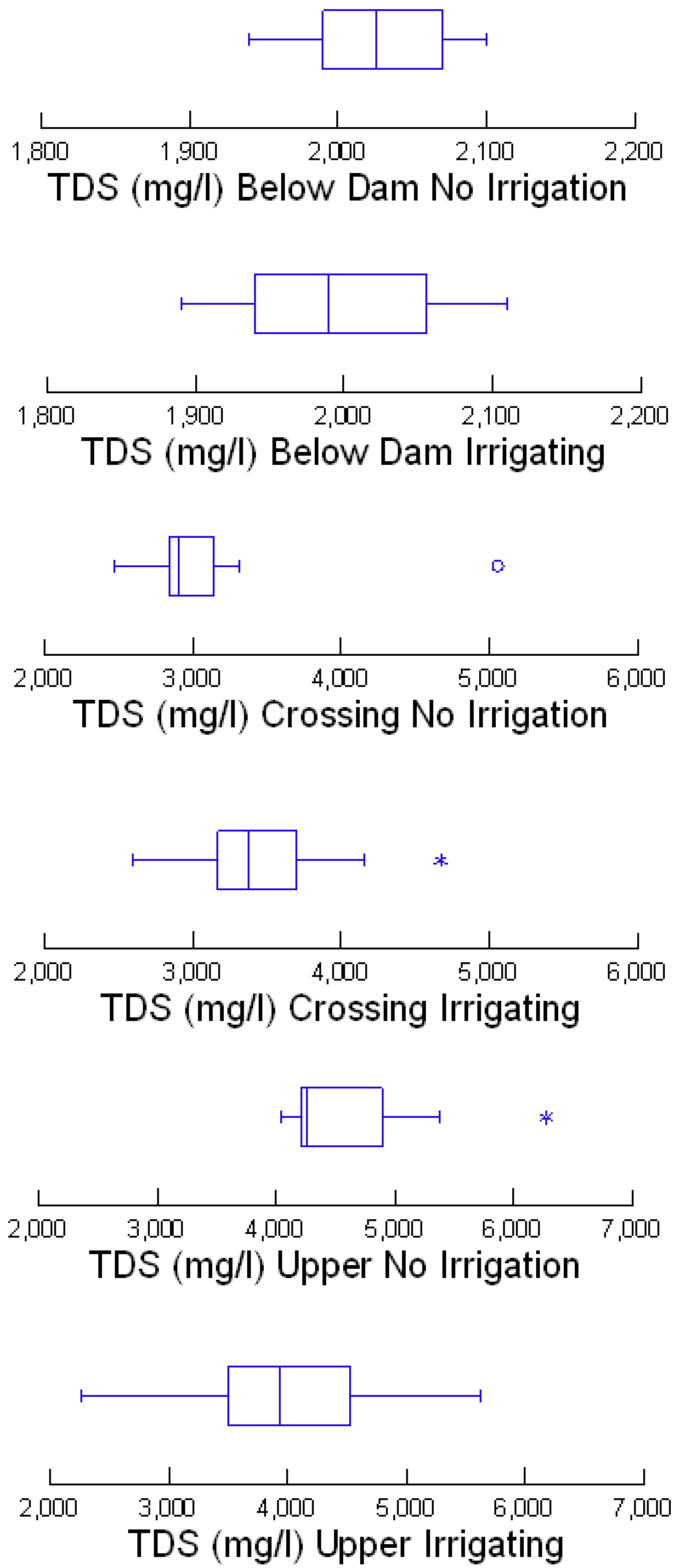

Figure 2. Box Plots for Total Dissolved Solids, Blue Creek, Box Elder County, Utah

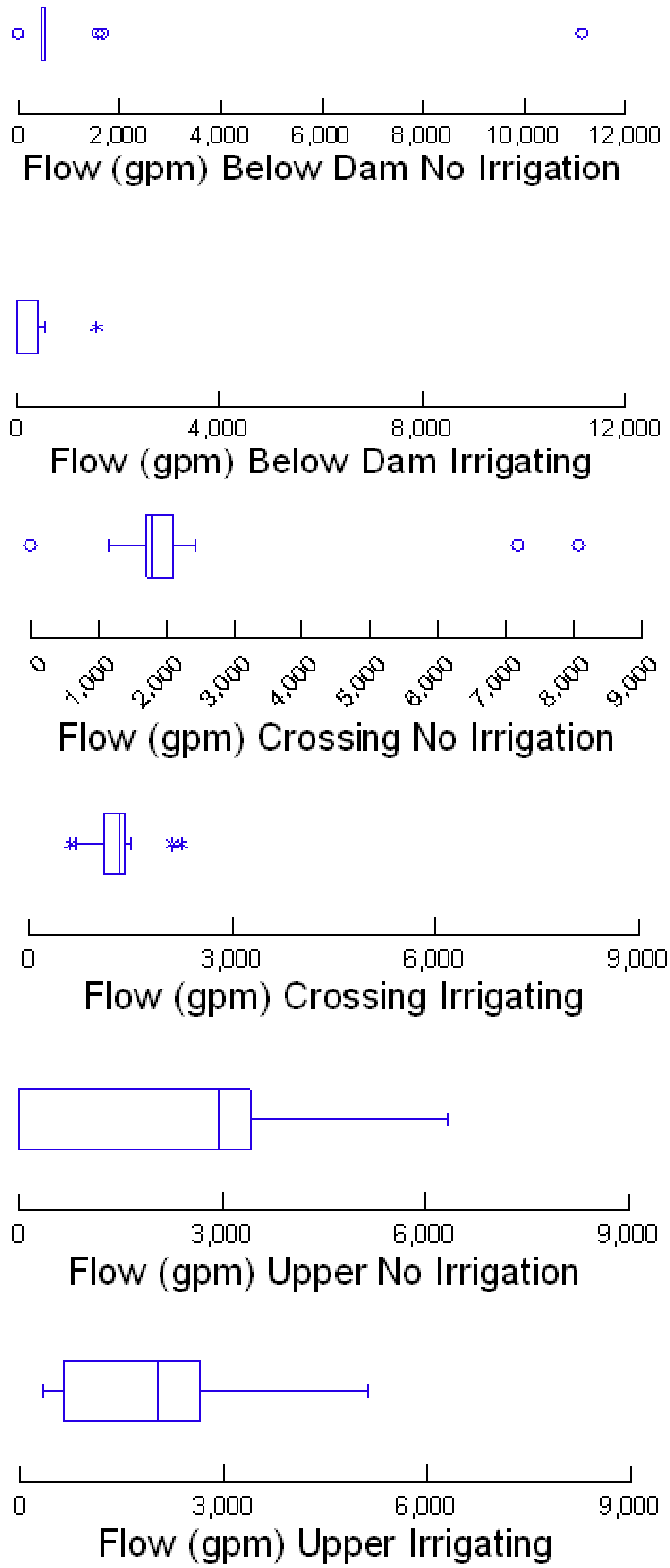

Figure 3. Box Plots for Flow, Blue Creek, Box Elder County, Utah

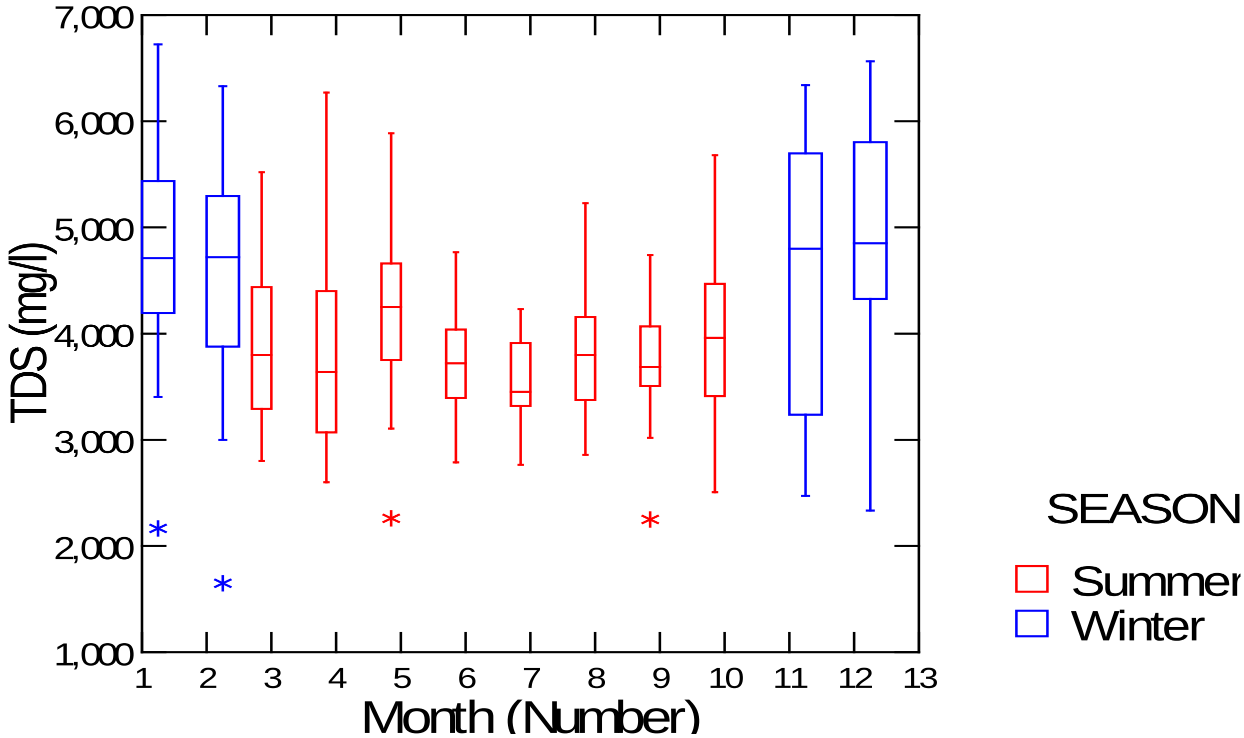

Figure 4. Box Plots of total dissolved solids (TDS) at the Blue Creek Upper Site by Month and Season

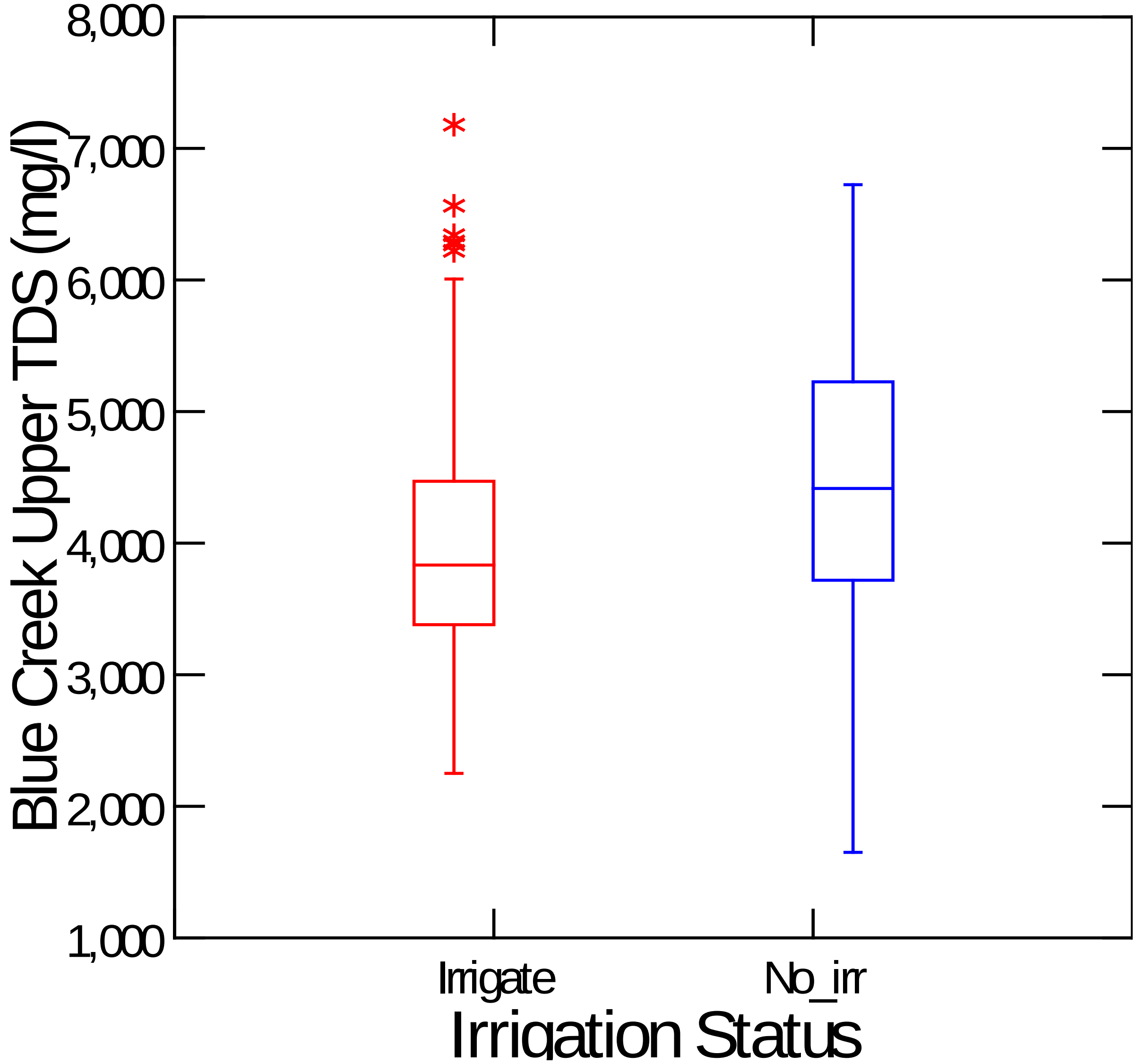

Figure 5. Box Plots of total dissolved solids (TDS) at the Blue Creek Upper Site by Irrigation Season

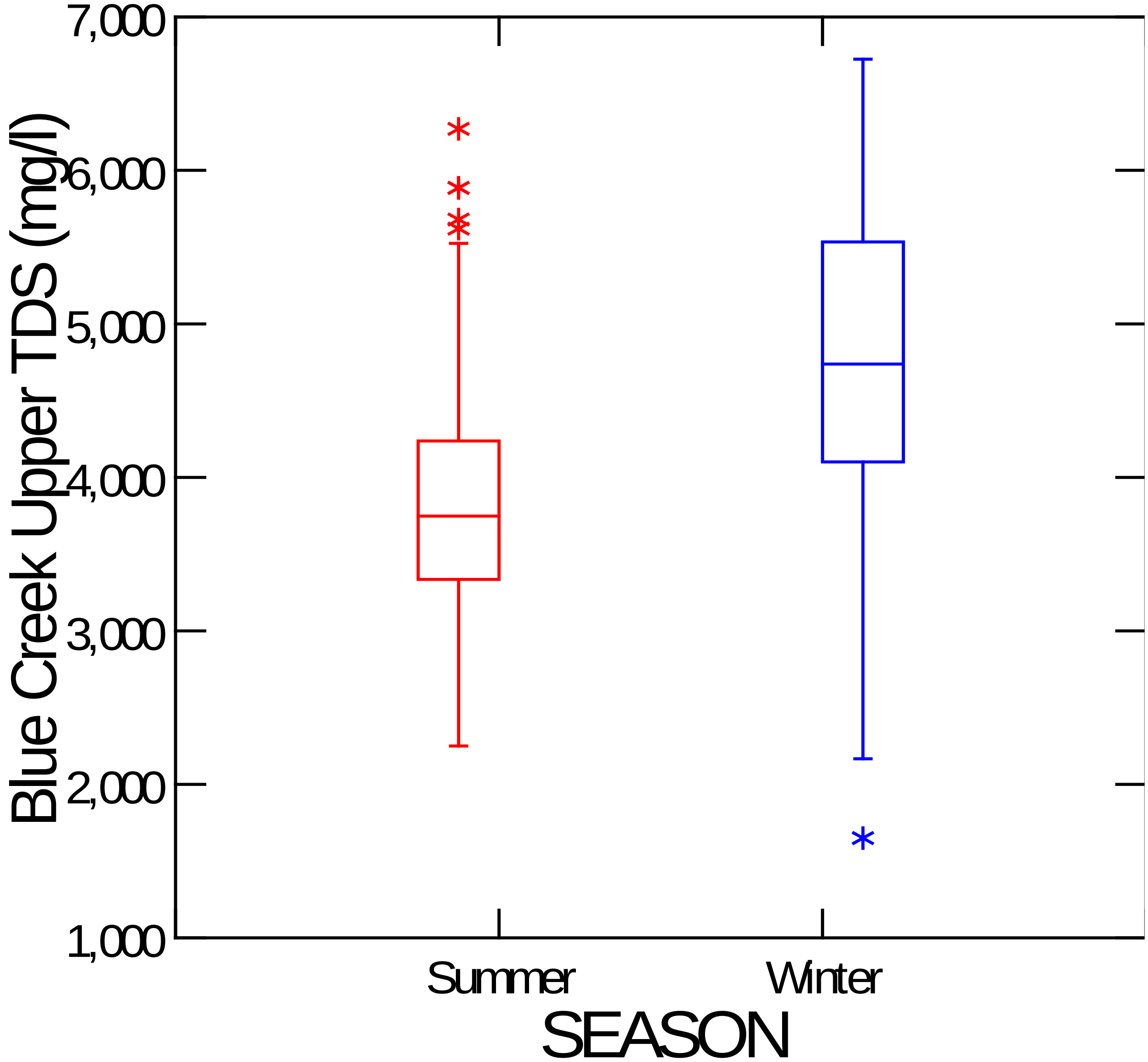

Figure 6. Box Plots of total dissolved solids (mg/l) at the Blue Creek Upper Site by Season

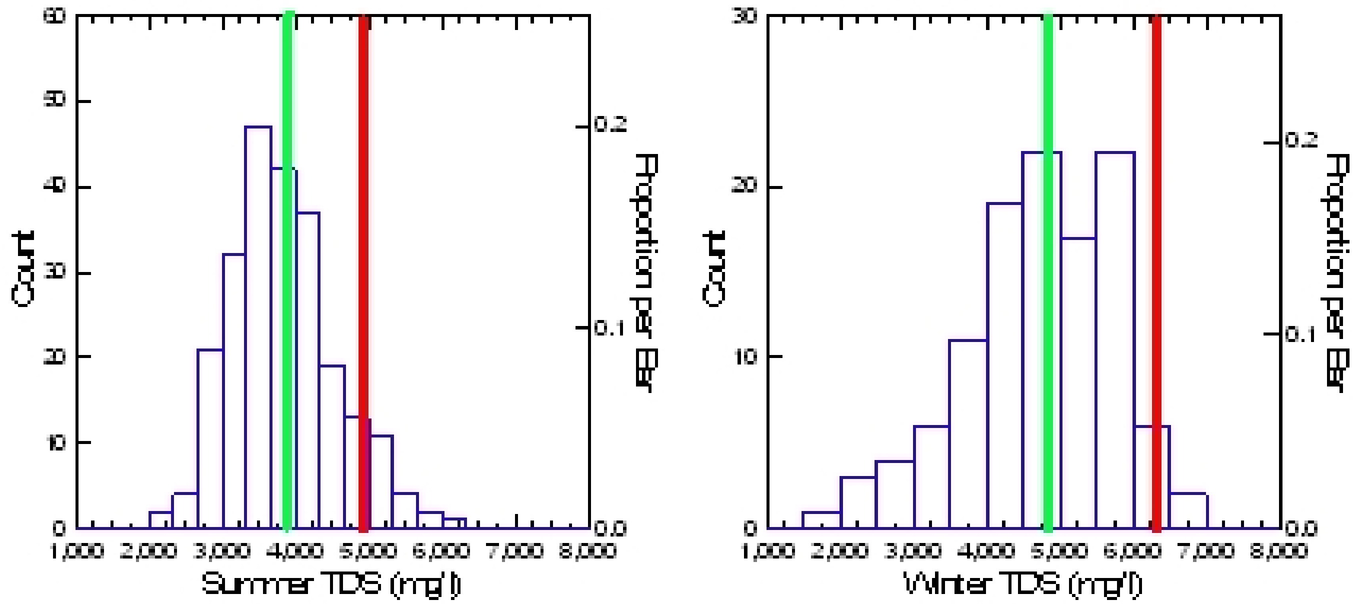

Figure 7. Histograms of Blue Creek summer and winter seasons total dissolved solids concentrations with proposed average (green lines) and maximum (red lines) criteria

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

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

APPENDIX E HYPOTHESIS TESTING RESULTS AND PROUCL OUTPUTS

- Blue Creek Upper TDS Concentration ANOVA with season and irrigation status as Factors
- Blue Creek Upper TDS Concentrations in Winter versus Summer SeasonsProUCL output for Background Threshold Values for Blue Creek
- ProUCL output for Background Threshold Values for Blue Creek Reservoir

APPENDIX F UTAH WATER RIGHTS DATABASE FOR BLUE CREEK

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