EXHIBIT B
FINAL UAA REPORT

FTN Associates Ltd.
water resources / environmental consultants

DEVELOPMENT OF AND TECHNICAL SUPPORT FOR SITE-SPECIFIC CRITERIA FOR TOTAL DISSOLVED SOLIDS AND SULFATE IN BRUSHY CREEK AND SULFATE IN STENNITT CREEK LAWRENCE COUNTY, ARKANSAS

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EXECUTIVE SUMMARY

Overview

For 10 years, Vulcan Construction Materials, LLC (Vulcan) and the Arkansas Department of Environmental Quality (ADEQ), with input from the US Environmental Protection Agency (EPA), have been working together to develop a Use Attainability Analysis (UAA). The UAA supports (a) a change in the total dissolved solids (TDS) and sulfate water quality criteria for an unnamed tributary (UT) from Vulcan's Outfall 001 to its confluence with Brushy Creek and for a segment of Brushy Creek from its confluence with the UT to its confluence with Stennitt Creek; (b) a removal of the designated, but not existing, domestic water supply (DWS) use designation from those same stream segments; and (c) a change in the sulfate water quality criterion for a segment of Stennitt Creek from its confluence with Brushy Creek to its confluence with Spring River.

Vulcan's Outfall 001 discharges groundwater and stormwater pumped from the quarry pit of its facility in Black Rock, Arkansas, under National Pollutant Discharge Elimination System (NPDES) Permit No. AR0046922. Sulfate and TDS concentrations from Outfall 001 add to the sulfate and TDS concentrations which exceed regulatory levels set forth in Arkansas Pollution Control and Ecology (APCEC) Regulation No. 2 (APCEC 2017) in the UT, Brushy Creek, and Stennitt Creek. The ionic composition of the water discharged through Outfall 001 is the result of the natural geology of the region and quarry activities that expose pyritic rock. The source of the TDS and sulfate is water that is exposed to pyritic rock on the walls of the quarry pit.

This UAA evaluates the feasibility of alternative discharge locations as well as several treatment options (wetlands, distillation, reverse osmosis [RO], etc.) as means to meet the current TDS and sulfate water quality criteria in the UT, Brushy Creek and Stennitt Creek. The evaluation demonstrates that none of these alternatives is technically or economically feasible. Beginning in 2008, Vulcan commissioned FTN Associates Ltd. (FTN) to evaluate the feasibility of developing site-specific TDS and sulfate criteria for the receiving streams in accordance with §2.308 and §2.306 of APCEC Regulation No. 2 and Title 40 Code of Federal Regulations (CFR), Part 131.11. These regulations allow the development of site-specific criteria using scientifically defensible methods that fully protect and maintain existing uses. This UAA establishes that the TDS and sulfate concentrations resulting from the Vulcan discharge support the existing and attainable designated uses in the affected stream segments. Therefore, the site-specific criteria proposed herein based on water quality that results from the current Vulcan discharge are justified.

Attainment of Designated Uses

Primary and Secondary Contact Recreation, Industrial Water Supply, and Agricultural Water Supply

Sections 11.2 through 11.6 of this report document that the existing TDS and sulfate concentrations resulting from the Outfall 001 discharge support attainment of primary and secondary contact recreation, industrial water supply, and agricultural water supply designated uses in Brushy Creek, Stennitt Creek and the UT.

Domestic Water Supply

Mass balance water quality modeling of potential downstream TDS and sulfate concentrations based on 7Q10 flows[1] indicated potential exceedance of the secondary drinking water values for TDS (500 mg/L), but not for sulfate (250 mg/L), in both Brushy Creek and Stennitt Creek. However, the DWS use was removed from Stennitt Creek for the reach of Stennitt Creek downstream of the mouth of Brushy Creek in 1999 as part of a previously approved UAA and Third-Party Rulemaking. (APCEC 2017). Removal of the DWS use in Brushy Creek would require mass balance computations based on harmonic mean flows[2]. Additionally, mass balance computations based on harmonic mean flows is required for Stennitt Creek below Brushy Creek since DWS use was previously removed.

In 2010, Vulcan conducted an analysis of the attainability of the DWS designated use in the UT and Brushy Creek. This evaluation (Section 11.6) concluded that due to the lack of sufficient flow, it is unlikely that the DWS designated use is attainable, even with the added

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[1] ADEQ policy requires the use of 7Q10 flows for the evaluation of domestic water supply use attainment.

[2] ADEQ policy requires the use of harmonic mean flows for the development of site-specific dissolved minerals criteria.

Vulcan flow. Furthermore, DWS is not an existing use in either the UT or Brushy Creek: neither stream segment is currently used as a domestic water supply; and the Arkansas Department of Health (ADH) does not list either waterbody as a current or planned drinking water source. Accordingly, per 40 CFR 131.10(g)(2)[3] removal of the DWS designated use is appropriate for the UT and for the reach of Brushy Creek from its confluence with the UT inflow to its confluence with Stennitt Creek.

Aquatic Life

Attainment of the aquatic life designated use of biological integrity was determined per Section 5 of ADEQ (2018) and attainment of designated uses per APCEC (2017). The assessment also included modified field sampling protocols and field experiments designed in close cooperation with ADEQ to control for potential confounding between water quality and habitat quality.

Sections 4 through 9 of this UAA provide the results of that assessment, which demonstrate the following:

1. The aquatic life use is supported for both communities in Brushy Creek downstream of the inflow from the UT and in Stennitt Creek downstream of the mouth of Brushy Creek.
2. Evaluation of key and indicator fish species documents support of aquatic life designated uses per §2.302(F)(3) of APCEC (2017).

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[3] States may remove a designated use that is *not* an existing use if the State conducts a use attainability analysis that demonstrates attaining the use is not feasible because. "Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions can be compensated for by the discharge of sufficient volume of effluent discharges..." 40 CFR 131.10(g)(2)

3. Aquatic life use support is also documented for those segments of Brushy and Stennitt Creeks which are not influenced by the Vulcan discharge or other point sources. This conclusion of aquatic life use support for Brushy Creek (i.e., based on the results of the instream evaluation) is consistent with ADEQ assessment procedures from analysis of instream data (ADEQ 2018) and reflects the integrated response of the benthic macroinvertebrate community to long-term exposure to the Vulcan discharge. Experiments using artificial substrates conducted in Brushy Creek showed some upstream to downstream differences in macroinvertebrate communities that colonized the artificial substrates, however the artificial substrate results only reflect a deployment period that occurred during the low-flow season when upstream to downstream differences in TDS/sulfate due to the discharge are expected to be greatest, i.e., a short-term effect.

The results of this analysis demonstrate that the Vulcan discharge supports all existing and attainable uses.

Criteria Development

Domestic Water Supply

ADEQ policy requires the use of 7Q10 flows when evaluating mineral concentrations for DWS protection. Accordingly, mass balance computations were initially carried out for 7Q10 flow conditions to calculate proposed TDS and sulfate criteria for the protection of aquatic life using TDS and sulfate concentrations of Outfall 001 (95th percentile) and upstream concentrations from recent monitoring. However, these calculations indicated potential exceedance of the secondary drinking water standard for TDS (500 mg/L) in Brushy Creek and the UT. DWS is not an existing or attainable use in Brushy Creek or the UT. Therefore, this proposal includes removal of the DWS as allowed by 40 CFR 131.10(g)(2) and supported in Section 11.6. In the absence of the DWS use, site-specific dissolved minerals criteria are developed from mass balance computations based on harmonic mean flows rather than 7Q10 flows. Additional mass balance computations were carried out for harmonic mean flow conditions to develop proposed TDS and sulfate criteria for protection on aquatic life.

Aquatic Life

Most prior studies for site-specific mineral criteria in Arkansas have utilized a set percentile of observed or predicted (based on mass balance modeling) instream concentrations, usually the 95th percentile, for a 5-year period. This approach has been questioned on the grounds that the resulting value is not derived directly from evidence that the aquatic life use is supported. Additionally, justifying proposed criteria on the basis of the 95th percentile potentially varies significantly depending on the period of record chosen. In light of these questions, Vulcan explored five methods for criteria development (discussed in detail in Section 10.2):

1. Criteria based on development of a "tolerance benchmark" for specific conductance (conductivity) for the existing benthic communities using XC95 values of macroinvertebrate taxa present in the reference location and selection of appropriate TDS/sulfate to conductivity ratios based on Hem (1985);
2. Criteria based on development of a "tolerance benchmark" for conductivity for the existing benthic communities using XC95 values of macroinvertebrate taxa present in the reference location and use of established relationships of Ozark Highlands ecoregion TDS/sulfate to conductivity (EPA 2016);
3. Criteria based on the background-to-criterion (B-C) model (Cormier et al. 2018) using conductivity measured in Clear Creek during the fall 2016 sampling as the background conductivity model input;
4. Criteria based on the background-to-criterion (B-C) model (Cormier et al. 2018) using Ozark Highlands ecoregion background conductivity (EPA 2016) as the model input; and
5. Criteria based on EPA's (2016) development of a "tolerance benchmark" for conductivity using XC95 values of macroinvertebrate taxa collected in the region during selected studies and use of established relationships of Ozark Highlands ecoregion conductivity and TDS.

An initial review of method 5 determined that the method was unfavorable for criteria development. This method was dismissed from further evaluation because the EPA (2016) determined that the sample size was too small with respect to the number of locations with paired water chemistry and biology (193) and the number of total taxa with XC95 values (27). The approach was considered a screening estimate and would have provided greater confidence in the tolerance benchmark if sample sizes were 400-500 for the study region or if there were 90 or more genera with XC95 values.

Analyses of methods 1-4 identified method 1 as the preferred method; therefore, this study proposes criteria for Brushy Creek based on method 1: development of a “tolerance benchmark” for conductivity for the existing benthic communities using XC95 values of macroinvertebrate taxa present in the reference location (Clear Creek) and the use of empirically derived translators (conductivity to TDS and conductivity to sulfate ratios) based on Hem (1985). For purposes of this analysis, a “tolerance benchmark” is a conductivity value that protects 95% of the existing taxa. Site-specific TDS and sulfate criteria for Brushy Creek were derived from the tolerance benchmark by converting conductivity to TDS and sulfate concentrations using the conductivity to TDS and sulfate ratios. Mass balance computations using the Brushy Creek criteria, background TDS and sulfate concentrations, and critical flows (harmonic mean) were then used to derive: (1) TDS and sulfate concentrations from Outfall 001 that support the TDS and sulfate criteria in the UT and Brushy Creek; and (2) a sulfate criterion in Stennitt Creek consistent with the sulfate criterion in Brushy Creek. Note that this mass balance computation (harmonic mean) differs from that used for the DWS evaluation (7Q10) in the following ways:

1. The Brushy Creek TDS and sulfate concentrations are the criteria values based on the tolerance benchmark analysis as opposed to the 95th percentile values from the outfall;
2. Criteria for the UT are based on outfall concentrations that support the tolerance benchmark-based criteria in Brushy Creek, and
3. Mass balance computations to estimate TDS and sulfate concentrations in Stennitt Creek and Spring River are based on harmonic mean flows in Brushy Creek, Stennitt Creek, and Spring River and the tolerance benchmark-based criteria in Brushy Creek.

The proposed site-specific sulfate and TDS criteria for the protection of aquatic life are provided in Table 10.10, which is reproduced as Table ES.1 below.

Table ES.1. Summary of existing and proposed criteria for waterbodies downstream of Vulcan Outfall 001.

Stream Segment	Existing (mg/L)			Proposed (mg/L)		
	Sulfate	TDS	Chloride	Sulfate	TDS	Chloride
Unnamed tributary from Outfall 001 to confluence with Brushy Creek	22.7	240	17.3	260	725	No change
Brushy Creek from confluence with unnamed tributary to confluence with Stennitt Creek	22.7	240	17.3	126	549	No change
Stennitt Creek from confluence with Brushy Creek to confluence with Spring River	22.7	456*	17.3	43.3	No change	No change
Spring River downstream of confluence with Stennitt Creek	30	290	20	No change	No change	No change

*Site-specific values based on previous (1999) UAA and rulemaking, which included removal of the domestic water supply designated use.

Conclusions and Recommendations

The conclusions and recommendations of studies conducted from 2008 through 2016 are as follows:

1. Most treatment alternatives for reducing TDS and sulfate concentrations in Outfall 001 to ecoregion values (e.g. distillation, wetlands) are technically infeasible;
2. Although RO treatment is technically feasible, its implementation is cost prohibitive and would result in the quarry operation becoming not economically viable. In addition, RO treatment would involve waste disposal issues with associated environmental impacts which further increases costs.
3. Building a pipeline to another stream with greater assimilative capacity (e.g. Spring River), is technically feasible, like RO treatment, but is not an economically feasible option for permit compliance for the quarry operation;
4. The existing discharge supports industrial and agricultural water supply uses as well as primary and secondary contact recreation;
5. The DWS use for the UT and Brushy Creek is not an existing or attainable use nor does the ADH have current or future plans for using either as a public water supply. Accordingly, this study recommends removal of this use due to the levels of the dissolved minerals proposed;
6. Water quality in Bushy Creek and Stennitt Creek supports aquatic life uses based on ADEQ’s 2018 assessment methodology;

7. TDS and sulfate recommended criteria are (a) 725 and 260 mg/L, respectively for the unnamed tributary from Outfall 001 to the confluence with Brushy creek and (b) 549 and 126 mg/L, respectively for Brushy Creek from the confluence with the unnamed tributary to the confluence with Stennitt Creek.
8. The sulfate recommended criterion is 43.3 for Stennitt Creek from the confluence with Brushy Creek to the confluence with the Spring River.
9. The recommended criteria (Table ES.1) are based on the preferred methodology, i.e., based on the Clear Creek (reference) macroinvertebrate community tolerance values from published field studies using EPA methodology and a conservative assumption regarding the relationship between conductivity and dissolved minerals in the receiving streams.
10. The recommended TDS criterion is an intermediate value in the range of values calculated by the methods considered in this study and all methods are considered appropriate for criteria development to support the aquatic life use.
11. The recommended criteria are consistent with existing effluent and instream concentrations which “support” fish and benthic macroinvertebrate communities.

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1.0 INTRODUCTION

1.1 History

In 1996, Vulcan Construction Materials, LLC (Vulcan) purchased the Black Rock limestone quarry facility in Lawrence County, Arkansas (Figure 1.1). In 1998, the Arkansas Department of Pollution Control & Ecology (now named the Arkansas Department of Environmental Quality [ADEQ]) issued a renewal National Pollutant Discharge Elimination System (NPDES) permit for the facility with limits for chemical oxygen demand (COD), total suspended solids (TSS), pH, turbidity, and oil & grease (O&G). The renewal permit also included a monitor and report requirement for total dissolved solids (TDS). TDS is commonly found in drainage from quarries located in carbonate (dolomite) formations such as that found at the Black Rock facility.

The 2004 NPDES renewal permit included 500 mg/L monthly average and 750 mg/L daily maximum TDS limits with a 3-year compliance schedule. When it became clear that Vulcan could not consistently meet the TDS monthly average permit limit, Vulcan began working with ADEQ to find a solution. It was jointly decided that Vulcan would enter into a Consent Administrative Order (CAO)[4] with ADEQ that called for Vulcan to perform a use attainability analysis (UAA) and then file a third-party rulemaking with the Arkansas Pollution Control & Ecology Commission (APCEC) to change the TDS water quality values for Brushy Creek and remove the designated, but not existing, domestic water supply (DWS) use designation from Brushy Creek and the unnamed tributary (UT). The CAO provided a 750 mg/L monthly average TDS limit until such time as the third-party rulemaking was final and effective.

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[4] In the Matter of Vulcan Construction Materials, LLC, Black Rock Quarry, LIS -08-109 (2008).

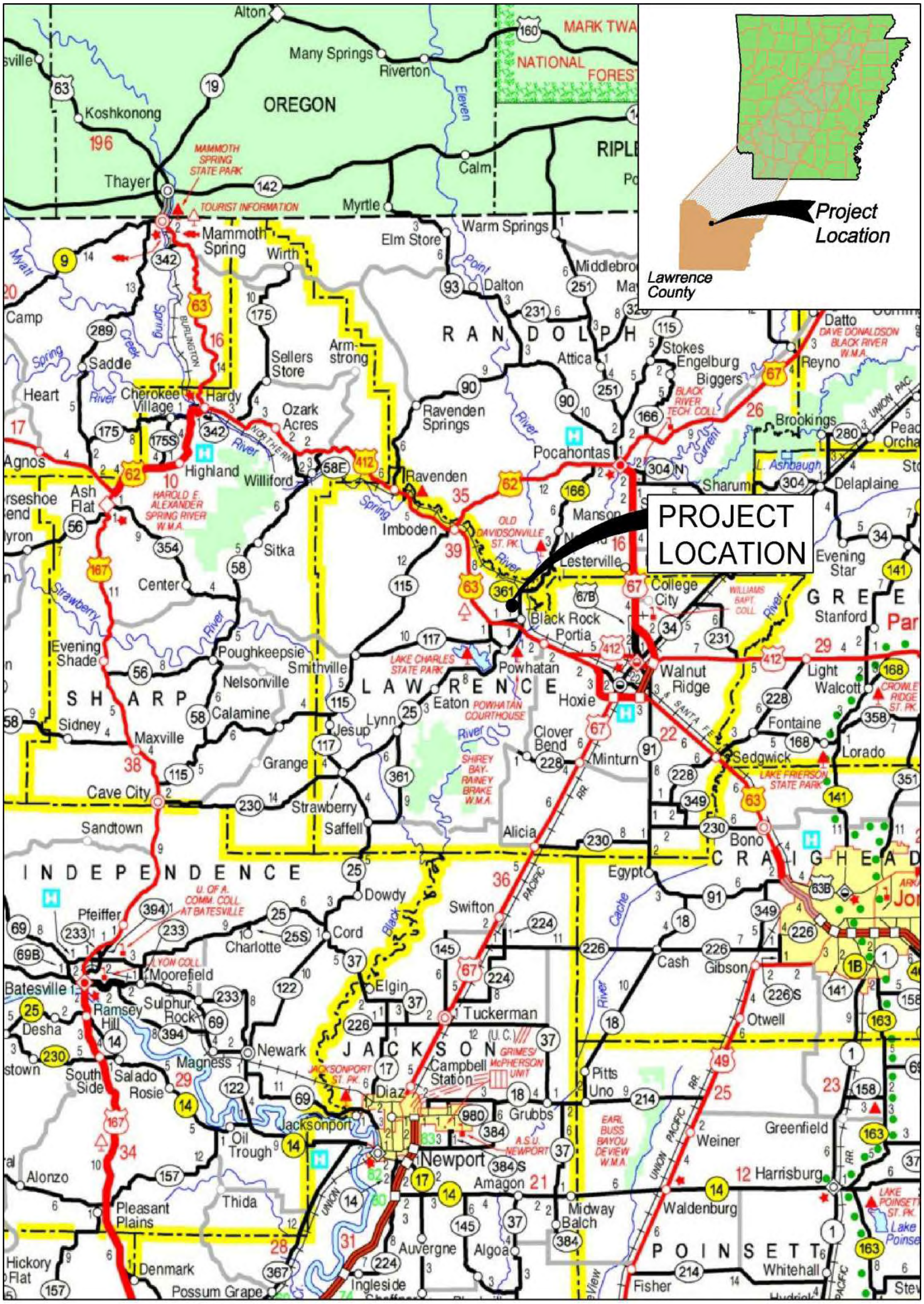

Figure 1.1. Project location map.

FTN Associates, Ltd. (FTN) prepared the UAA Study Plan in 2008. Following comment by ADEQ and revision and resubmittal of the study plan to include dry weather seasonal aquatic toxicity sampling, FTN conducted the study and submitted a draft UAA to ADEQ in June 2009 and a revised draft UAA in July incorporating the changes requested by ADEQ. In August 2009, the US Environmental Protection Agency (EPA) provided technical comments on the revised draft UAA in which EPA requested additional data and additional alternatives analyses. A meeting with EPA, ADEQ, Vulcan, and FTN in late October 2009 resulted in the submittal in November 2009 of an agreed-upon outline of proposed additional work to include upstream and downstream diversity testing in the fall of 2009 and the summer of 2010 as well as the gathering of sulfate data from the effluent and development of a site-specific sulfate value.

In September 2011, FTN submitted a revised UAA report (hereinafter referred to as “The Original UAA Report) to ADEQ. At ADEQ’s request, Vulcan then submitted to ADEQ a summary of the alternatives reviewed in the UAA and an analysis of five other alternatives (land application, chemical treatment, dilution of effluent, cessation of discharge, and conditional/restricted discharge), concluding that none were technically or economically viable options for the facility. In January 2013, ADEQ notified Vulcan that it could not support modification of the TDS and sulfate water quality standards and removal of the DWS use designation because it believed that more information was needed as to the confounding effects of upstream and downstream habitat differences and the analysis of any available alternatives.

In June 2015 Vulcan and ADEQ agreed to an amended CAO[5] under which (a) Vulcan would supplement The Original UAA Report to support site-specific TDS and sulfate criteria development followed by a third-party rulemaking; and (b) the 750 mg/L monthly average TDS limit would remain in effect until April 1, 2020, unless APCEC or EPA disapproved the third-party rulemaking or ADEQ determined that Vulcan was not diligently pursuing the site-specific criteria development. During the summer and fall of 2015, Vulcan and FTN conducted a supplemental study (First Supplemental Study), which was designed in cooperation with ADEQ. That study is described more fully in Section 1.5.2. A Second Supplemental Study, designed in

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[5] In the Matter of Vulcan Construction Materials, LLC, Black Rock Quarry, LIS -08-109-001 (2015).

cooperation with ADEQ and EPA Region VI staff, was conducted in the fall of 2016. The Second Supplemental Study is described more fully in Section 1.5.3.

1.2 Facility Description

The Black Rock facility discharges from Outfall 001 to a farm stock pond (at the request of the landowner), thence by an overflow weir to a drainage ditch (the UT), thence to Brushy Creek, thence to Stennitt Creek (Figure 1.2). Stennitt Creek flows into the Spring River, which APCEC has designated as a trout stream, an Extraordinary Resource Water, and an Ecologically Sensitive Waterbody (APCEC 2017). The project area is located within the Ozark Highlands ecoregion (APCEC 2017).

1.3 Regulatory Background

When Vulcan acquired the Black Rock limestone quarry facility in 1996, a Phase I environmental site assessment (ESA) revealed that the previous owner had an NPDES permit under which elevated levels of TDS were reported in the discharge monitoring reports (DMRs). The ESA concluded that the discharged TDS levels were considered common for a quarry in a carbonate (dolomite) formation.

The current NPDES permit issued to Vulcan (effective March 31, 2015) contains discharge limitations for chemical oxygen demand (COD), total suspended solids (TSS), TDS[6], O&G, and pH (Table 1.1). Currently there is no discharge limitation for sulfate. However, the facility is subject to the requirements of §2.511(B) of APCEC Regulation No. 2 regarding ecoregion reference values for dissolved minerals. Per §2.511(B), instream concentrations of sulfate exceeding 22.7 mg/L in the Ozark Highlands ecoregion represent a "significant modification" of water quality as compared to the value for sulfate[7] (APCEC 2017). Sulfate concentrations measured as part of a study in 2010 indicate that downstream sulfate concentrations exceed 22.7 mg/L and are therefore a "significant modification value". See Table 1.2.

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[6] The 750 mg/L monthly average TDS limit is a part of the terms and conditions of the 2015 CAO.

[7] Per §2.511(B), the "significant modification" value for sulfate (22.7 mg/L) is calculated by multiplying the ecoregion reference value for sulfate (17 mg/L) by one-third and adding the product to the ecoregion reference value for sulfate.

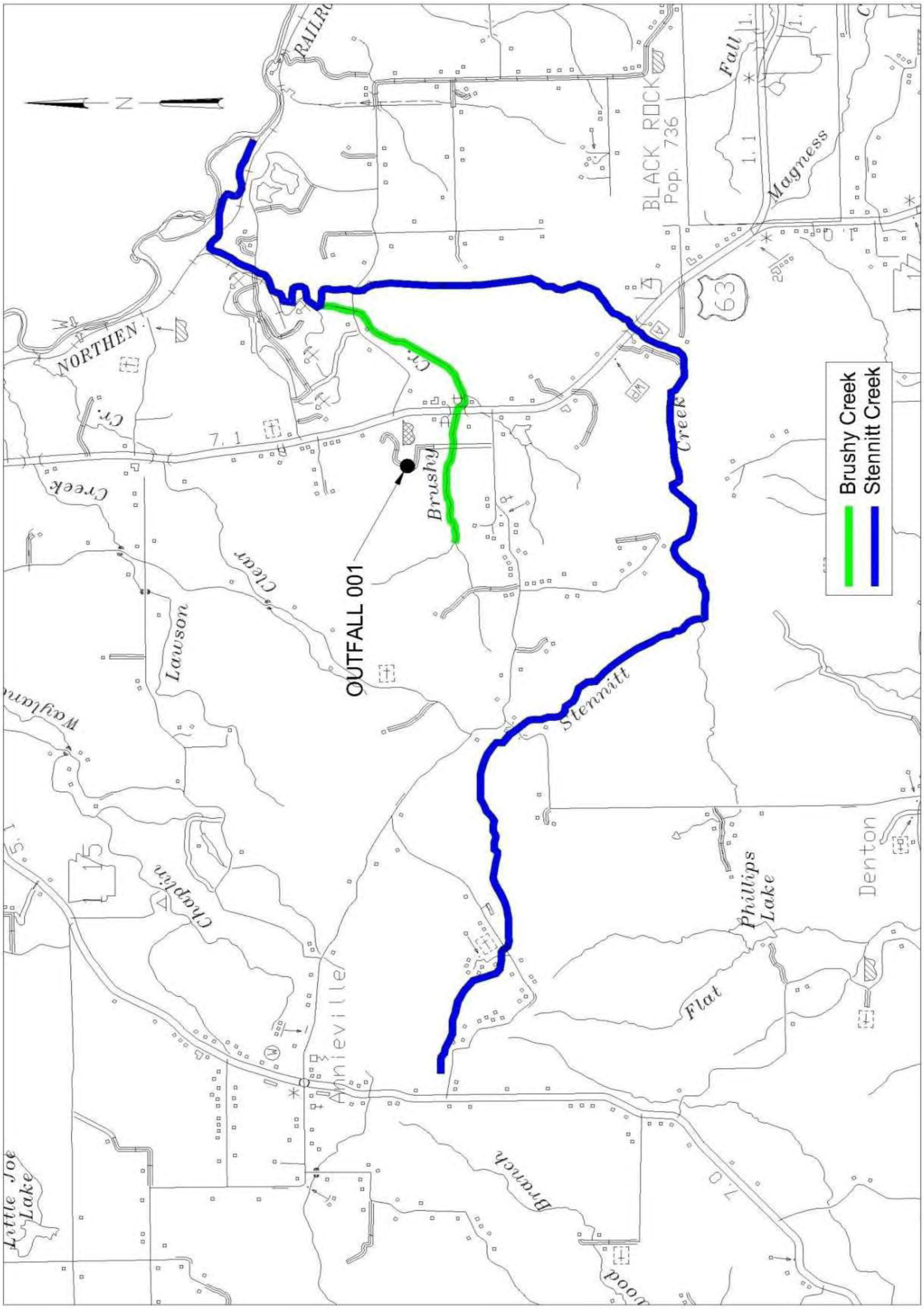

Figure 1.2. Project vicinity map.

Table 1.1 Current NPDES permit discharge limits for Outfall 001.

Effluent Parameter	Discharge Limitations				Sampling Frequency
	Mass (lbs/day)		Concentration (mg/L)		
	Monthly Average	Daily Maximum	Monthly Average	Daily Maximum	
COD	320.3	480.4	50	75	Once per month
TSS	128.1	192.2	20	30	Once per month
TDS	3,202.6	4,803.8	500	750	Once per month
O&G	64.1	96.1	10	15	Once per month
pH	N/A	N/A	Min 6 su	Max 9 su	Once per month

Table 1.2. Applicable Arkansas water quality standards, minerals values, and designated uses for the Vulcan receiving streams.

.	Ecoregion Reference Values & Applicable Criteria for Dissolved Minerals			Designated Uses
	Chloride (mg/L)	Sulfate (mg/L)	TDS (mg/L)	
Unnamed tributary	13 (a) 250 (b)	17 (a) 250 (b)	240 (a) 500 (b)	Primary and secondary contact recreation; domestic, industrial, and agricultural water supply; seasonal Ozark Highlands fishery
Brushy Creek	13 (a) 250 (b)	17 (a) 250 (b)	240 (a) 500 (b)	Primary and secondary contact recreation; domestic, industrial, and agricultural water supply; seasonal Ozark Highlands fishery
Stennitt Creek above Brushy Creek	13 (a) 250 (b)	17 (a) 250 (b)	240 (a) 500 (b)	Primary and secondary contact recreation; domestic, industrial, and agricultural water supply; perennial Ozark Highlands fishery
Stennitt Creek below Brushy Creek	13 (a)	17 (a)	456 (c)	Primary and secondary contact recreation; industrial and agricultural water supply; perennial Ozark Highlands fishery
Spring River below Stennitt Creek	20 (d)	30 (d)	290 (d)	Primary and secondary contact recreation; industrial and agricultural water supply; perennial Ozark Highlands fishery
Clear Creek	13 (a) 250 (b)	17 (a) 250 (b)	240 (a) 500 (b)	Primary and secondary contact recreation; domestic, industrial, and agricultural water supply; seasonal Ozark Highlands fishery
Significant modification of naturally occurring level(d)	17.3	22.7	255	NA

Notes:
(a) Ecoregion value per §2.511.
(b) Secondary drinking water standard based on domestic water supply designated use.
(c) Site-specific values based on previous UAA (1999) and third-party rulemaking, which included removal of domestic water supply designated use.
(d) Site-specific criteria per §2.511(A) of Regulation No. 2 (APCEC 2017).

1.4 Purpose of This UAA

40 CFR 131.11 provides for the establishment of numeric water quality criteria based on Section 304(a) guidance modified to reflect site-specific conditions or other scientifically defensible methods. This UAA provides the results, analyses, and conclusions of the First Supplemental Study and the Second Supplemental Study conducted in 2015 and 2016 and the appropriate results from The Original UAA Study demonstrating that the TDS and sulfate concentrations in the receiving streams resulting from the Vulcan discharge support attainment of the aquatic life use for the receiving waters. Accordingly, this UAA proposes site-specific criteria for TDS and sulfate in the UT and Brushy Creek and a site-specific sulfate criterion in Stennitt Creek that protects all existing and attainable designated uses including aquatic life. This UAA also demonstrates that the DWS designated use is not an existing or an attainable use in the UT and Brushy Creek. The evaluation of other alternatives for permit compliance establishes that the available alternatives are either not technically feasible or not economically feasible for the quarry.

1.4.1 Original UAA Report

On September 12, 2011, Vulcan submitted to ADEQ a UAA study on Brushy Creek (FTN 2011) that was conducted during 2010. That report (provided in Appendix A) concluded that the existing water quality (in particular TDS and sulfate) downstream of Vulcan supported the aquatic life designated use set forth in the applicable APCEC Regulation No. 2. This conclusion was the basis for proposed site-specific criteria for TDS and sulfate that reflected the existing conditions supporting the designated use. However, in its review, ADEQ noted that the potential effects of water quality on the benthic macroinvertebrate community were confounded with habitat differences between upstream and downstream locations and requested additional supporting data.

1.5 Biological and Water Quality Studies

1.5.1 First Supplemental Study

During the summer and fall of 2015, Vulcan and FTN conducted a supplemental study to address ADEQ's concerns regarding confounded results from the original study. The study was designed in cooperation with ADEQ staff with the following parameters to minimize confounding the effects of habitat and water quality on biological assessments:

1. Subdivision of upstream and downstream fish sampling reaches to include similar habitat types,
2. Performance of a detailed analysis of habitat, particularly substrate, and
3. Deployment of artificial substrates for benthic macroinvertebrate colonization in riffle habitats.

The study also included instream sampling of the benthic macroinvertebrate community per ADEQ sampling protocol (see Section 2).

1.5.2 Second Supplemental Study

A second supplemental study, designed in cooperation with ADEQ and EPA Region VI staff, was conducted in the fall of 2016 to update biological habitat and water quality data in the reference location (Clear Creek) and Stennitt Creek.

1.5.2.1 Reference Location (Clear Creek)

Based on discussions with ADEQ staff, it was agreed that the results from the fish and instream benthic macroinvertebrate sampling of Brushy Creek from the First Supplemental Study (conducted in the summer and fall of 2015) could be directly compared to the results from the fish and instream benthic macroinvertebrate sampling of the reference stream (Clear Creek) from the Second Supplemental Study (conducted in the fall of 2016).

Fish and macroinvertebrate communities at the reference location were sampled in the same way as for Brushy Creek in the First Supplemental Study, i.e., through subdividing upstream and downstream fish sampling reaches to include similar habitat types, completing a detailed analysis of habitat (particularly substrate), and instream sampling of the benthic macroinvertebrate community per ADEQ sampling protocol. No artificial substrates were deployed at the reference location during the Second Supplemental Study.

Sampling methods and data analysis are described in more detail in Section 2 of this UAA.

1.5.2.2 Stennitt Creek

Sampling in Stennitt Creek was undertaken to address potential changes in aquatic life communities from TDS and sulfate entering from Brushy Creek. The Original UAA Study included biological sample collection in Stennitt Creek upstream of the mouth of Brushy Creek. However, due to lack of access, the reach downstream of the mouth of Brushy Creek was not sampled. One purpose of the Second Supplemental Study was to obtain biological data upstream and downstream of the Brushy Creek inflow. Site reconnaissance indicated that only very limited portions of the habitat in the upstream and downstream reaches of Stennitt Creek were amenable to fish sampling. Dense emergent vegetation, which cannot be sampled efficiently with either seines or backpack electro-fishing gear, dominated both reaches. The only portions of the reaches that could be sampled efficiently were small, shallow, silt-bottomed pools, which would be expected to hold limited numbers and diversity of fish. This information was communicated to staff at EPA Region VI and the ADEQ Planning Division, who agreed that representative fish samples probably could not be obtained in the relevant reaches of Stennitt Creek. Accordingly, ADEQ, EPA Region VI staff, FTN and Vulcan agreed that sampling the benthic macroinvertebrate community using a targeted habitat approach and artificial substrates would provide adequate information for assessing the aquatic life designated use. A sampling approach was developed with agency input, which, in lieu of fish sampling, involved macroinvertebrate sampling of selected major habitats (emergent vegetation, silt/sand-bottom pools) and deployment of artificial substrates (Hester-Dendy) in reaches of Stennitt Creek upstream and downstream of the mouth of Brushy Creek.

1.6 Background Information

1.6.1 Vulcan Discharge

Effluent from Vulcan originates from groundwater and stormwater pumped from the quarry pit. Figure 1.3 shows the drainage route from the outfall to Brushy Creek. The quarry sump collects stormwater and groundwater, which are pumped through a pipe that runs up the quarry wall. The pipe splits via a valve to either discharge off the property or add makeup water to the wash ponds (Figure 1.3). The makeup water and wash ponds system is a closed-loop system. The quarry sump pump has a capacity of 800 gallons per minute (gpm) and is sometimes turned on and off manually, but it normally operates by a level float. The pump typically operates approximately 8 hours per day, or more during wet weather, with minimal or no discharge during dry conditions. Water from the wash ponds does not discharge off the property.

Once the water leaves Outfall 001, it flows to a downstream landowner's stock watering pond (at the landowner's request). Water exits the pond though an overflow and travels down a natural pasture drainage feature (the UT) across the farm property to Brushy Creek. The permitted Vulcan property boundary is indicated in Figure 1.3.

1.6.2 Watersheds and Receiving Streams

The receiving waters are listed in the NPDES permit as "an unnamed tributary of Brushy Creek, thence to Brushy Creek, thence to Stennitt Creek, thence to the Spring River, thence to the Black River, thence to the White River in Segment 4H of the White River Basin." Both Brushy Creek and Stennitt Creek are within the Ozark Highlands ecoregion (Plate OH-4, APCEC 2017). Applicable Arkansas water quality standards and dissolved minerals ecoregion values (APCEC 2017) are provided in Table 1.2. Brushy Creek originates immediately west of the Black Rock Quarry (Lawrence County, Arkansas) and flows east and northeast for approximately 1.8 miles to its confluence with Stennitt Creek (Figure 1.2). The total watershed for Brushy Creek is 3.79 square miles (USGS 2012). Stennitt Creek originates west of the Black Rock Quarry and has a watershed area of 10.1 square miles at its confluence with Brushy Creek (USGS 2012) and 15.8 square miles at the Spring River.

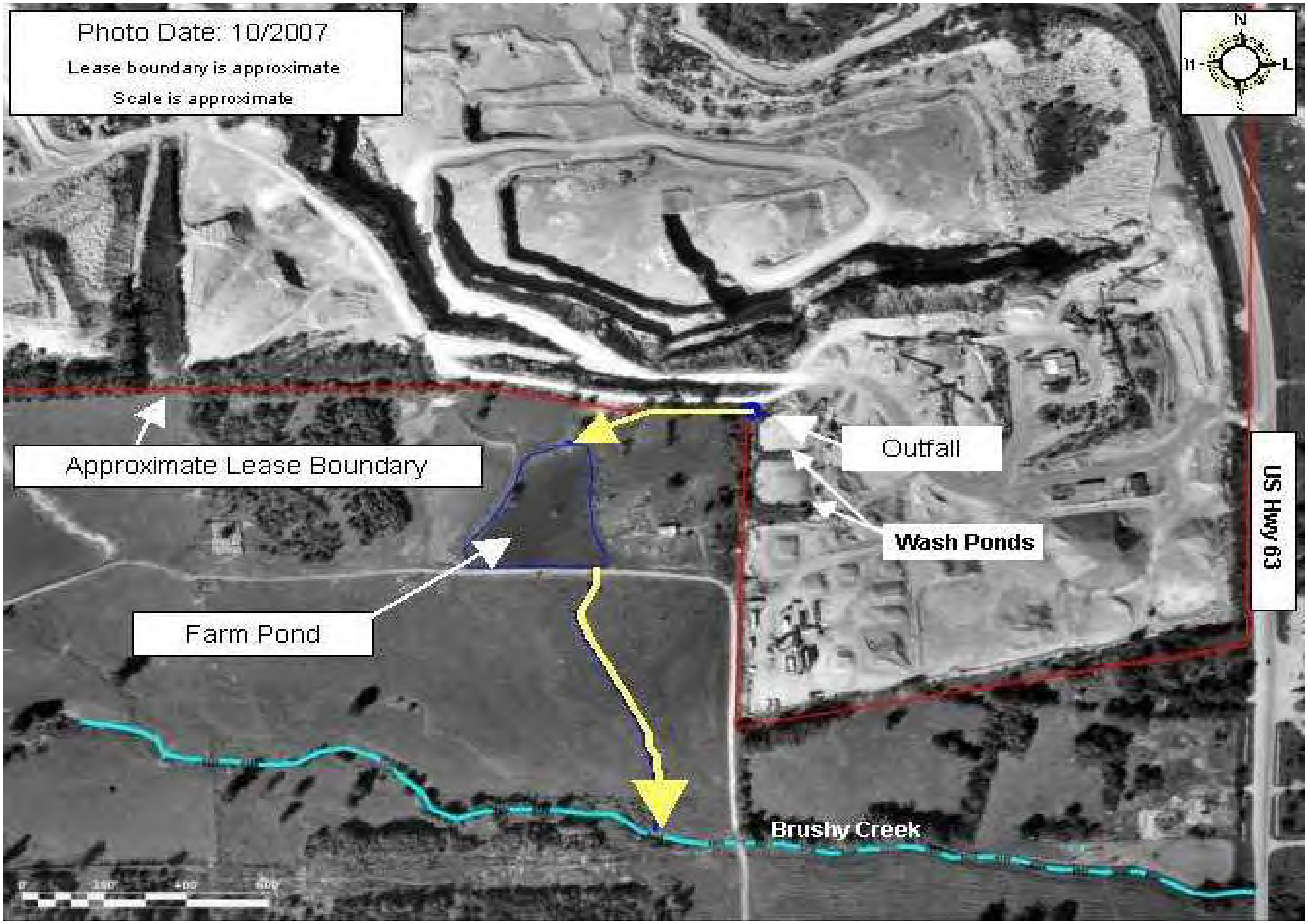

Figure 1.3. Aerial photograph of Vulcan site showing route of discharge route from Outfall 001 to Brushy Creek.

1.6.3 Ionic Composition of the Discharge and Receiving Streams

Calcium, magnesium and bicarbonate are the dominant ions in Outfall 001and Brushy Creek upstream of the influence of Outfall 001 with additional sulfate in Outfall 001 (Table 1.3). Table 1.3 also includes monitoring data from October 14, 2015, through December 7, 2016, which shows that recent TDS, chloride, sulfate, and hardness concentrations are similar to the levels observed during previous monitoring. Therefore, the ionic makeup of the outfall and receiving stream has changed little if any since the original study.

These monitoring data from Outfall 001 encompass three complete years and include periods of unusually wet (spring of 2009) and dry (summer and fall of 2010) weather and are therefore representative of the range of TDS and sulfate concentrations likely to occur at Outfall 001 and Brushy Creek.

Table 1.3. Comparison of ionic strength and composition between Outfall 001 and Brushy Creek upstream of the unnamed tributary.

Sampling Period	Parameter	Outfall 001				Brushy Creek Upstream (BC-0)			
		Min	Mean	Max	N	Min	Mean	Max	N
February 29, 2009 through March 21, 2011	Total Alkalinity*	150	199	240	10	220	260	290	4
	Bicarbonate*	180	239	288	10	264	312	348	4
	Calcium	62	73.3	85	10	55	61	66	4
	Magnesium	40	47.3	54	10	30	35	38	4
	Potassium	1.7	2.75	4.6	10	1.4	1.5	1.7	4
	Sodium	2.8	3.87	5.9	10	1.8	2.4	2.8	4
	TDS	327	482	618	23	240	305	340	4
	Chloride	5.4	8.58	13	10	3.8	5.8	9.9	4
	Sulfate	72.4	135	200	22	7.9	13.0	17	4
	Hardness*	320	378	432	10	261	297	321	4
October 14, 2015 through December 7, 2016	TDS	361	470	594	7	288	319	374	7
	Chloride	0.1	9.2	20	7	0.1	3.6	10	7
	Sulfate	98.1	117	131	7	5.0	5.4	6.9	7
	Hardness	260	304	384	7	288	319	374	7

Notes: All units mg/L unless otherwise noted. HCO_3^- values calculated per SM 4500-CO2 D (APHA 1998).
* mg/L as $CaCO_3$

1.6.4 Sources of TDS and Sulfate

Data presented in Table 1.3 indicate that TDS in Brushy Creek upstream of the inflow from Outfall 001 is typically higher than the ecoregion TDS value of 240 mg/L and that TDS in the outfall is the result of the added sulfate and calcium. A comparison of groundwater monitoring data and Outfall 001 presented in Table 1.4 shows that the ionic makeup of the Outfall 001 discharge is virtually identical to the groundwater except for elevated sulfate (and resulting elevated TDS) in the discharge. The dominance of calcium, magnesium and bicarbonate in groundwater and the Vulcan discharge (Table 1.4) is consistent with the location of the quarry in the Powell Dolomite formation.

A striking feature of the groundwater data summarized in Table 1.4 is that all of the TDS data exceed the ecoregion TDS value of 240 mg/L. Therefore, background TDS concentrations in the study area can be expected to exceed the ecoregion TDS value depending on local surface and groundwater hydrology.

Table 1.4. Summary of major ion concentrations at Outfall 001 and 14 monitoring wells in Randolph and Lawrence counties.

Parameter	**Outfall 001**				**Monitoring Wells***			
	Minimum	**Mean**	**Maximum**	**N**	**Minimum**	**Mean**	**Maximum**	**N**
Total Alkalinity	150	199	240	10	287	428	560	14
TDS	327	482	618	23	324	394	532	14
Calcium	62	73.3	85	10	34	82	101	14
Magnesium	40	47.3	54	10	30	40	59	14
Potassium	1.7	2.75	4.6	10	0.9	2.2	3.4	14
Sodium	2.8	3.87	5.9	10	1.3	7.0	32	14
Chloride	5.4	8.58	13	10	1.4	9.4	26	14
Sulfate	72.4	135	200	22	1.0	14	5.6	14

Notes: Discharge data based on routine DMR sampling for TDS, additional sampling for sulfate, and field surveys conducted between February 29, 2009, and March 21, 2011.
*Depth range 75 to 300 ft; average depth of 151 ft; see Table 7 in *Water Resources of Randolph and Lawrence Counties, Arkansas* (USGS 1879-B).

The source of the added sulfate is exposed pyritic rock on the walls of the quarry pit. Pyrite can be found as finely disseminated particles in the shales common in this formation, as secondary precipitated minerals along fractures within the rock, or as secondary precipitates within karst features. Pyrite is a well-known source of sulfate in surface water and is a likely source of sulfate in the outfall. The high concentrations of bicarbonate characteristic of the discharge, receiving waters, and groundwater prevent the acidification resulting from oxidation of pyrite in water that would likely happen in poorly buffered systems.

This information indicates that the ionic composition of the water discharged through Outfall 001 is the result of the combination of the natural geology of the region and the exposed pyritic rock. There are no process activities that Vulcan can change or modify to meet ecoregion values and current water quality criteria.

1.7 Alternatives Evaluation

UAA guidance and the Arkansas Continuing Planning Process (CPP; page IX-7, items 3a and 3c) require that a petition to increase dissolved minerals concentrations above existing conditions include an evaluation of alternatives to the direct discharge of the water. These alternatives are evaluated for technical and economic considerations. Wastewater technologies, such as conventional precipitation, can efficiently remove the heavy metals from wastewater to meet the effluent requirements. However, these systems do not remove dissolved compounds like sulfate and TDS. The alternatives for management of effluents with elevated dissolved minerals are limited. Four alternatives that have been reviewed for other UAAs include the following:

1. Distillation treatment,
2. Reducing sulfate concentrations using a constructed wetland,
3. Relocating the discharge point to a larger river that holds the potential for dilution of the minerals, and
4. Membrane treatment (reverse osmosis or Nanofiltration) to remove or reduce all dissolved minerals.,

FTN has completed an evaluation of alternatives based on previous experience, information from published literature, and from data provided by the facility.

1.7.1 Distillation

Based on preliminary screening of these four options, the use of reverse osmosis for feedwater with an initial concentration of 30,000 mg/L or less is generally preferable to the use of distillation processes. In any case, there are no significant economic benefits with the distillation technology compared to the reverse osmosis process. Therefore, reverse osmosis will be evaluated for this application.

1.7.2 Constructed Wetlands

Constructed wetlands can be dismissed as an option for this facility. Constructed wetlands can only be used to reduce sulfate, which results in the production of bicarbonate in place of sulfate (Hedin et al. 1989). Although a constructed wetland could, in principle, reduce sulfate in the discharge from this facility, the resulting TDS concentration would not be decreased (due to the replacement of the sulfate ions with bicarbonate ions) and no net benefit would be obtained.

1.7.3 Relocating the Discharge Point

Given the location of the Vulcan plant, there are no streams in the vicinity that could feasibly be used as dilution to completely avoid a change in the water quality standards. Stennitt Creek currently receives the Vulcan discharge indirectly in a diluted form and still exceeds ecoregion sulfate values due to the discharge. A direct discharge to the Spring River would be problematic given its designation as an Ecologically Sensitive Water Body and an Extraordinary Resource Water.

1.7.4 Membrane Treatment (Reverse Osmosis and Nanofiltration)

Membrane filtration systems, such as reverse osmosis (RO) and nanofiltration (NF), represent a class of advanced water/wastewater treatment processes capable of removing dissolved contaminants including TDS and sulfate. The contaminants are removed as highly pressurized feed water flows across a membrane, with a portion of the flow, identified as "permeate," going through the membrane. The rest of the feed is called "concentrate" or "reject" because it carries off the concentrated contaminants rejected by the membrane. The concentrate volume depends on many factors and varies between 10% to 40% of the feed. Depending on the size of the pores in the membrane, the process results in different classes of separation. For the removal of dissolved solids composed of sodium and chloride, a membrane capable of rejecting elemental-sized particles must be utilized. For this reason, RO is the standard treatment for applications involving seawater.

NF is capable of removing a high fraction of sulfate and other large molecules, but cannot reject smaller ions. Thus, the actual removal efficiency of TDS depends on the compositional matrix. For RO, removal rates could be as high as 95% for both TDS and sulfate. Removal rates for NF is likely to be around 50% for TDS, again depending on the specific matrix. In either case, membrane systems are the only filtration-type system that can reduce dissolved solids.

Based on the information available from the literature and from equipment manufacturers, membrane systems are a possible alternative treatment for effluent to meet restricted limits for TDS and sulfate in this application.

The cost of installing a membrane system, as well as the cost of operation (i.e., electricity, membrane cleaning, etc.) is high. The costs of operation primarily result from pumping to achieve the high necessary pressure. The most common maintenance problem involves the tendency for membranes to foul when applied to concentrated waste streams. Most wastewater sources require rigorous pretreatment and may still result in frequent cleaning or replacement of the membranes.

For both RO and NF, a single-stage membrane is capable of achieving the necessary effluent limitations. Since Brushy Creek does not offer any upstream dilution for TDS, the effluent limitation for TDS would be the water quality standard (i.e. 240 mg/L). Some dilution relative to sulfate is available. The comparable limitation for sulfate, and the value to be used in this analysis, is 30 mg/L.

A membrane system could be installed to treat a portion of the flow with some blending to achieve the 240 mg/L value for TDS and 30 mg/L for sulfate. Since the rejection of certain molecules is different between RO and NF, an analysis has been performed to calculate the design flow, blending percentages and production of waste brine requiring disposal for both circumstances. A spreadsheet analysis has been developed to assess these factors. Results from the spreadsheet calculations are given in Appendix B.

Despite the comparatively high initial, operation and maintenance costs of membrane systems, the disposal of the concentrated brine generated by this process can be a more significant issue. Unless there is a convenient location for the disposal of brine (e.g., the ocean), this factor alone often discourages the selection of membranes (or distillation processes) for applications involving pollution control. Membrane systems separate the dissolved parameters from the water but do not chemically alter their state to other non-polluting compounds. Thus, the concentrate, or brine, requires disposal by other methods.

A review of the options available for disposal of the brine solution is a critical part of the overall economic analysis. Based on past experience, the options for disposal include the following:

1. Solidification and disposal onsite,
2. Transport offsite for stabilization prior to landfilling,
3. Transport offsite to a municipal or industrial wastewater treatment system with a large river or seawater outfall, and
4. Transport offsite to a deep-well injection facility.

1.7.4.1 Stabilization/Landfill

The concentrate could be stabilized and solidified onsite, using a cementitious material such as Portland cement or fly ash. This would require the construction of a mixing facility, purchase of the cementitious agent, crews, and equipment to mix the waste solution, regulatory authority to dispose of the waste onsite, and engineering support for selection and operation of a disposal area. The critical costs for this option are the mixing ratio for the waste solution/stabilization agent, and any required environmental protection controls for the disposal area. The mixing ratio determines the tonnage necessary for purchase of the stabilizing agent. Final disposal could be achieved with an existing local landfill or the permitting and installation of a landfill by the facility. A landfill of this type would require liners and caps, and would be subject to stringent regulatory oversight.

Some commercial landfill operations currently offer dewatering capability through a solidification process, similar to that described above. There is a minimum amount of regulatory approval required by the generator when the waste is removed to a commercial offsite facility.

1.7.4.2 Offsite Treatment/Discharge

The resulting brine could be transported offsite by truck to an industrial or municipal wastewater treatment facility, if such a facility can be identified. As with the review of alternative disposal for the entire flow, the treatment facility would need to be located at a site with capabilities for discharging to a large waterbody. The critical cost component would be the cost of transportation and the cost per disposal on a per-gallon basis.

Most municipalities in Arkansas, even those located on larger rivers, are reluctant to accept sources of wastewater from outside their service area. This uncertainty makes this option untenable for long term consideration.

1.7.4.3 Deep-Well Disposal

Most of the saltwater brine generated in Arkansas, whether from the brine industry in south Arkansas or water from the gas- and/or oil-drilling operations, is disposed in deep-well injection sites. There are commercial operations operating in the state for this purpose, although most are specifically intended for disposal of fluids associated with oil/gas operations or brine from a chemical plant. The use of deep well disposal in Arkansas for brines that are similar to this application offers ample evidence that this method is the most economical alternative. For purposes of an economic evaluation, the cost of hauling and disposal at a commercial deep-well disposal site is considered to be comparable (or favorable) to solidification or hauling to an offsite treatment plant.

1.7.4.4 Economic Considerations of a Membrane System

Based on the above evaluation, it is determined that a membrane system would likely provide similar, or favorable, economics, compared to other treatment alternatives. With this option, the disposal of the resulting brine will be evaluated based on the most common disposal method used in Arkansas for similar brines (i.e., deep well disposal).

The evaluation of costs for this treatment option involves establishing a set of criteria for treatment and flow rates. The initial wastewater analysis and the design flow requirements are primary considerations in the sizing and cost of the equipment.

The analysis in Appendix B compares RO to NF and develops costs for the complete system. In each case, cost information is based upon a single-pass membrane for water treatment followed by additional RO treatment for concentrating the reject water to about 1/100 of its original volume. The concentrate would be stored in an onsite holding tank for subsequent transportation to a disposal well.

The capital cost associated with installing a RO treatment system has been estimated in previous studies available in the literature. The US Corps of Engineers (USACE) (1998) estimated this cost from $1.44 to $2.13 per gallon per day for a single-stage RO unit. The costs were developed by USACE for a typical brackish water application in Florida. These published values are widely cited in the literature, and although dated, are still considered adequate for a comparison of alternatives. Over this time period (since the mid-1990s), the cost of RO membranes has been reduced. However, the cost of ancillary equipment (i.e., equipment housing, pumping, and piping) has increased. USACE further estimated the operating costs of a RO system (less the costs of brine disposal) at about $0.001 per gallon for a large-scale treatment system (USACE 1998). The overall estimated costs are considered valid for a RO membrane system, but does not include pretreatment or treatment of residual solids.

As additional support for these costs, a study by the Texas Water Development Board (TWDB) was reviewed. This study also estimated the costs of capital and operating costs (Arroyo and Shirazi 2012) based on a review of various utilities and consultants. The TWDB examined six brackish groundwater desalination plants completed in the period from 2002 to 2012 and arrived at the following conclusions:

- Capital cost range from $2.03 to $3.91 per gallon per day of installed capacity; and
- Operation and maintenance costs range from $0.53 to $1.16 per 1,000 gallons of water ($0.00053 to $0.00116 per gallon).

The costs from the TWDB study are similar in value with the numbers based on the USACE study.

These estimates were based on the treatment of brackish groundwater with low suspended solids. For a surface water application, additional pretreatment will be needed along with raw water storage to equalize flows. Also, there will need to be special equipment for handling the concentrated solids.

The installation and operating cost of NF systems has not been as widely reported in the literature. For purposes of this study, the cost of the NF membrane equipment is estimated to be 80 percent of the cost of RO. The costs of pretreatment and residual concentration are the same for both systems based on unit flow rates.

The capital costs estimates developed in Appendix B provide a method for comparison between the different membrane alternatives that are available. Each system is based on a design that provides compliance with TDS and sulfate reduction.

As stated above, the cost of disposal of the concentrate is a major factor with each option. The cost of brine disposal in a commercial deep well, not including transportation to the site, is estimated to vary between $0.10 and $0.15 per gallon. Some of the closest commercial disposal wells, known to be available to accept brine of this type, are located in south Arkansas or in northwest Oklahoma. This location would represent a hauling distance of at least 500 miles round trip. Given this distance, the transport cost per 5,000-gallon tanker to load, haul, and unload is estimated at $600, or $0.12 per gallon. A total cost of $0.25 per gallon (haul plus disposal fee) will be used for disposal of brine in the economic evaluation in Appendix B.

The basic assumptions used in the analysis of costs are shown below. Additional calculations used to develop this information are included in Appendix B:

1. An initial average flow rate of approximately 0.384 million gallons per day (mgd).
2. The initial concentration of TDS and sulfate is taken as the 50th percentile value from the measured values (i.e., 394 and 101.1 mg/L, respectively).
3. The target concentration for the discharged water to meet water quality standards would be 240 mg/L for TDS and 30 mg/L for sulfate.
4. To reduce the amount of brine requiring disposal, the system will include two RO units in series following the initial membrane treatment. Each pass will have a reject rate of 30%.
5. The resulting brine solution will require disposal in a commercial deep well.
6. The treated effluent will be discharged to Brushy Creek through the existing outfall.

A summary of the analysis in Appendix B indicates the following:

1. For both types of membrane systems, the treatment for sulfate controls the design flow rate (the percentage of water that must be treated). Both TDS and SO4 limitations must be met.
2. The rejection of sulfate is considered the same for both types of systems. Thus, the design flow rate is the same.
3. While the design flow is the same, the overall capital cost of NF is slightly less based on the cost of membranes.
4. The overall rejection for sodium, chloride and other smaller ions is less for NF compared to RO. This provides a reduced cost for the disposal of reject water.
5. Appendix B estimates the capital cost of NF to be $5.6 million and the annual operating cost to be $456,000 per year.

The design life of the system is expected to be 20 years at which point a new system would likely need to be installed. The need for, and costs associated with, treatment in perpetuity, has not been evaluated. The present worth of the annual operating costs, assuming a 4% interest factor and 20-year term is $6.2 million. Thus, the overall present worth cost of a membrane treatment system to meet the effluent standards could be considered to be $11.8 million.

1.7.5 Direct Discharge with Site-Specific Criteria

Any capital and operating costs associated with the direct discharge option (e.g., effluent monitoring) would also be required in the other options, and therefore were not added to the cost estimates.

The implementation of the direct discharge option is estimated to be less than $400,000; this estimate accounts for the cost of the UAA study as well as consulting and legal expenses to support the rule-making process to modify the criteria in the Brushy Creek and Stennitt Creek and to remove the DWS use in Brushy Creek.

1.7.6 Summary of Costs

Table 1.5 summarizes the estimated costs with each option for this facility.

Table 1.5. Summary of costs for various options to attain compliance with permit limits.

Option Description	Estimated Capital Cost	Estimated Annual Operating Cost*	Present Worth Cost
Membrane Treatment; Discharge to Brushy Creek; disposal of residuals by deep well	$5.6 million	$0.46 million	$11.8 million
Direct Discharge to Brushy Creek (site-specific TDS criterion)	<$400,000	NA	<$400,000

*Does not include the cost of disposal

1.8 Proposed Approach to Meeting Water Quality Criteria

The information provided above indicates the following:

1. Sulfate concentrations in the Vulcan discharge are not the result of a process that Vulcan can control or modify to meet ecoregion values or water quality criteria,
2. There is no feasible alternative discharge location, and
3. Treatment alternatives are either technically infeasible and/or economically infeasible for the quarry.

Accordingly, the development of site-specific criteria for TDS and sulfate was evaluated as a means to meet water quality criteria. This proposal is in accordance with §2.308 and §2.306 of Regulation No. 2 (APCEC 2017) and 40 CFR 131.11, which allow the development of site-specific criteria using scientifically defensible methods that fully protect and maintain existing uses and meet the requirements for public participation per the CPP.

The approach to this study was to evaluate whether the water quality in Brushy Creek and Stennitt Creek resulting from the existing Vulcan discharge supports existing and attainable designated uses with emphasis on the aquatic life use in Brushy Creek and Stennitt Creek.

2.0 METHODS

The sampling methodology described herein was developed in close cooperation with staff from the ADEQ Planning Section. Figure 2.1 provides a schematic representation of the relationships among Outfall 001 and the receiving streams. The First Supplemental Study, conducted from July 21 through November 24, 2015, focused on fish, benthic macroinvertebrates, habitat, and water quality in the reaches of Brushy Creek upstream and downstream of the inflow from the UT. This study included water quality sampling in Stennitt Creek and deployment of artificial substrates in riffles of Brushy Creek upstream and downstream of the UT inflow. The Second Supplemental Study focused on fish, benthic macroinvertebrates, habitat, and water quality in a reference location (Clear Creek) near Brushy Creek and benthic macroinvertebrates, habitat, and water quality in the reaches of Stennitt Creek upstream and downstream of the Brushy Creek inflow. This study included deployment of artificial substrates in Stennitt Creek upstream and downstream of the inflow from Brushy Creek. The spatial relationships of the sampling reaches are shown in Figure 2.2.

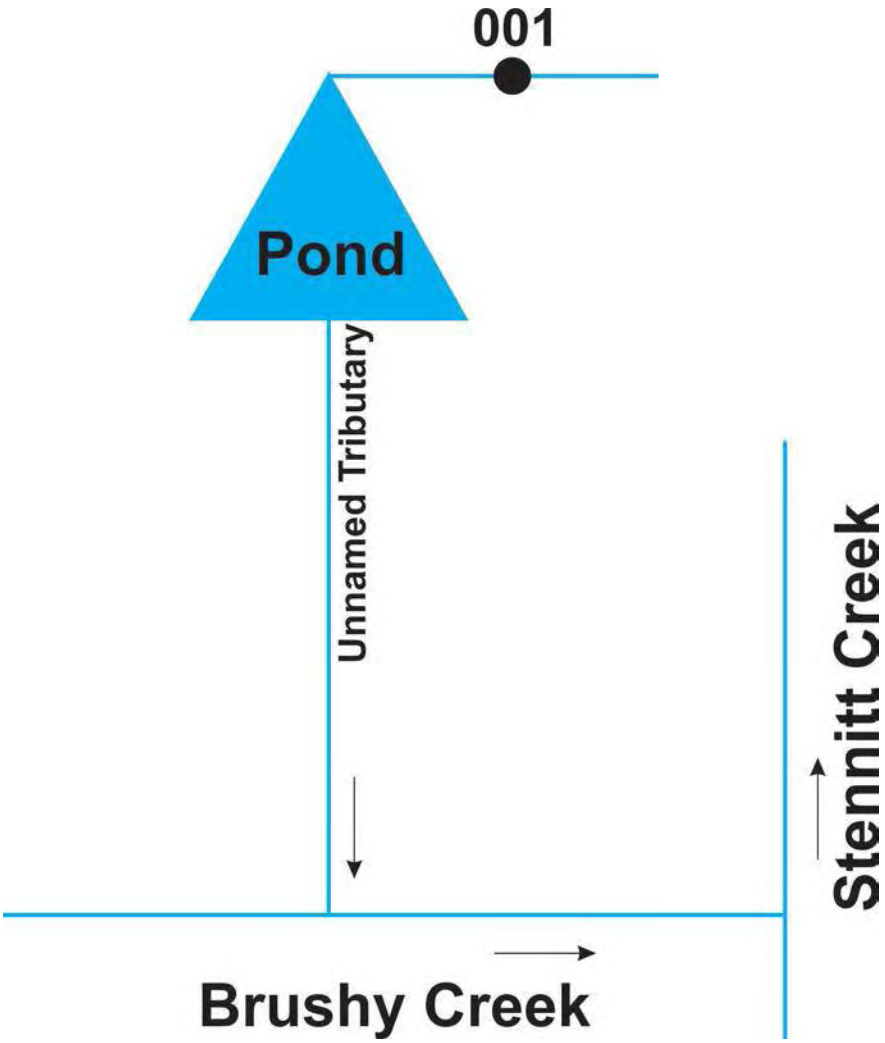

Figure 2.1. Schematic representation of the relationships among Outfall 001 and the receiving streams.

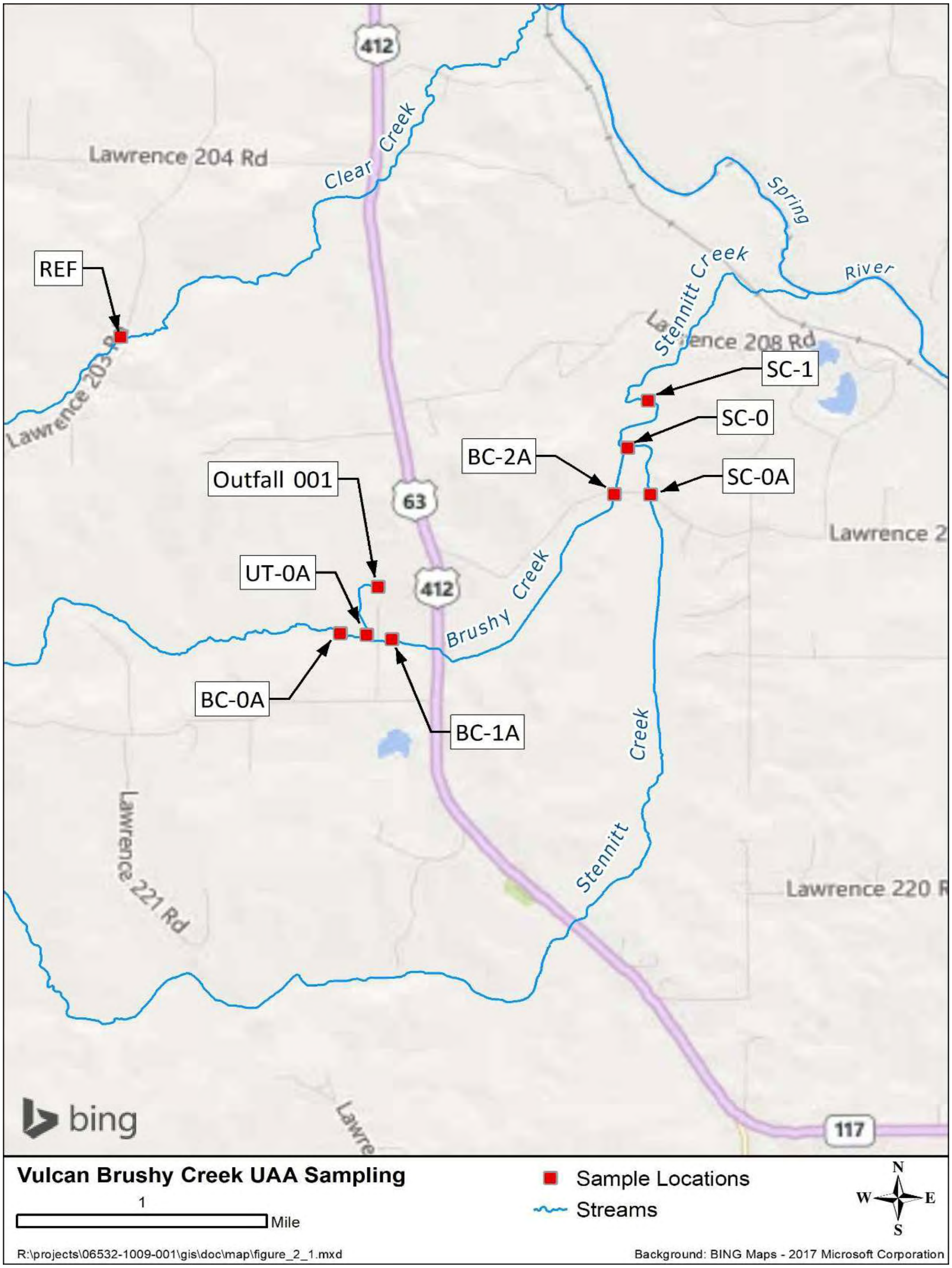

Figure 2.2. Spatial relationships of the Brushy Creek, Stennitt Creek, and Clear Creek sampling locations.

2.1 Sampling Locations and Schedule

Sampling locations for the supplemental studies are described in Table 2.1; sampling dates/periods are provided in Table 2.2. For purposes of comparison, sampling dates/periods for the original study conducted in 2010 are provided in Table 2.3.

Table 2.1. Sampling station descriptions and locations.

Station ID	Latitude	Longitude	Description: Water Quality	Description: Biological
Outfall 001	36.1420	-91.1623	NPDES compliance point	NA
UT-0A*	36.1390	-91.1632	35 meters upstream of confluence with Brushy Creek	NA
BC-0A*	36.1391	-91.1651	Brushy Creek upstream of confluence with UT; downstream point of biological sampling reach	Stream reach extending approximately 180 m upstream
BC-1A*	36.1387	-91.1614	Brushy Creek downstream of confluence with UT; upstream point of biological sampling reach	Stream reach extending approximately 130 m downstream
BC-2A*	36.1476	-91.1454	Brushy Creek. Culvert on Lawrence Road downstream of confluence with UT, upstream of Brushy Creek confluence with Stennitt Creek	NA
SC-0A*	36.1475	-91.1428	Stennitt Creek culvert on Lawrence Road upstream of confluence with Brushy Creek	NA
SC-0	36.1504	-91.1444	Stennitt Creek upstream of confluence with Brushy Creek	Stream reach extending from approximately 30 m upstream to approximately 30 m downstream
SC-1*	36-1533	-91.1429	Stennitt Creek downstream of confluence with Brushy Creek	Stream reach extending from approximately 50 m upstream to approximately 60 m downstream
REF*	36.1574	-91.1807	Clear Creek reference stream upstream point of biological sampling reach	Stream reach extending 300 m downstream

*Supplemental studies

Table 2.2. Sampling dates and periods for water quality, habitat, fish, and benthic macroinvertebrates during the first (2015) and second (2016) supplemental studies.

			Biological		
				Macroinvertebrates	
Station ID	Water Quality	Habitat	Fish	Instream	Artificial Substrate
Outfall 001	7/31/2015 - 11/24/2015; 10/25/2016 and 12/7/2016	NA	NA	NA	NA
UT-0A*	7/31/2015 - 11/24/2015; 10/25/2016 and 12/7/2016	NA	NA	NA	NA
BC-0A*	7/31/2015 - 11/24/2015; 10/25/2016 and 12/7/2016	11/24/2015	8/13/2015	11/24/2015	10/13/2015 through 11/23/2015
BC-1A*	7/31/2015 - 11/24/2015; 10/25/2016 and 12/7/2016	11/24/2015	8/13/2015	11/24/2015	10/13/2015 through 11/23/2015
BC-2A*	7/31/2015 - 11/24/2015; 10/25/2016 and 12/7/2016	NA	NA	NA	NA
SC-0A*	7/31/2015 - 11/24/2015; 10/25/2016 and 12/7/2016	NA	NA	NA	NA
SC-0	10/25/2016 and 12/7/2016	10/26/2016	NA	10/26/2016	10/26/2016 through 12/7/2016
SC-1*	10/25/2016 and 12/7/2016	10/26/2016	NA	10/26/2016	10/26/2016 through 12/7/2016
REF*	10/25/2016 and 12/7/2016	10/25/2016	10/25/2016	10/25/2016	NA

*Supplemental studies

Table 2.3. Description of sampling locations and information collected during original UAA study conducted in 2010.

Station ID	Description	GPS Coordinates		Water Quality	Fish, Benthos, Habitat
		Latitude	Longitude		
001	Outfall 001	36.14203	-91.1622	6/14/2010 9/29/2010	
UT-0	Unnamed tributary to Brushy Creek	36.13952	-91.1632	6/14/2010 9/29/2010	6/14/2010 9/29/2010
BC-0	Brushy Creek upstream of mouth of unnamed tributary	36.1392	-91.1652	6/14/2010 9/29/2010	6/14/2010 9/29/2010
BC-1	Brushy Creek downstream of mouth of unnamed tributary	36.13865	-91.1625	6/14/2010 9/29/2010	6/14/2010 9/29/2010
BC-2	Brushy Creek upstream of confluence with Stennitt Creek	36.1482	-91.1453	6/14/2010 9/29/2010	6/14/2010 9/29/2010
SC-0	Stennitt Creek upstream of mouth of Brushy Creek	36.15046	-91.1441	6/14/2010 9/29/2010	6/14/2010 9/29/2010
SR-0	Spring River at Hwy 62 upstream of mouth of Stennitt Creek	36.20385	-91.1697	6/14/2010 9/29/2010	
SR-1	Spring River at Hwy 361 downstream of mouth of Stennitt Creek	36.20383	-91.1697	6/14/2010 9/29/2010	
REF	Reference stream – Clear Creek at Lawrence County Road 203	36.15738	-91.1803	6/14/2010 9/29/2010	6/14/2010 9/29/2010

2.1.1 First Supplemental Study (7/21/2015-11/24/2015)

The Brushy Creek sampling locations sampled as part of the First Supplemental Study were selected based on reconnaissance conducted by FTN and ADEQ and differed from the locations used in the 2010 study (FTN 2011). The Brushy Creek locations immediately upstream and downstream of the confluence with the UT (BC-0 and BC-1, respectively, in the original study) were moved to the BC-0A and BC-1A locations for the First Supplemental Study to include habitat that was more comparable between the upstream and downstream stations. The BC-0A and BC-1A locations were further upstream and further downstream, respectively, than the previous BC-0 and BC-1 locations. The previous BC-2 and SC-0 stations were moved upstream to BC-2A and SC-0A, respectively, to allow for more accessible locations for routine water quality sampling. Brushy Creek sampling locations are shown in Figure 2.3. Points on the map indicate the locations of water quality sampling; highlighted sections of the creek indicate reaches for biological sampling and artificial substrate placement.

2.1.2 Second Supplemental Study (10/24/2016-12/15/2016)

Sampling locations on Stennitt Creek and Clear Creek are shown in Figures 2.4 and 2.5, respectively. Points on the map indicate the locations of water quality sampling; highlighted sections of the creeks indicate reaches for biological sampling and, in the case of Stennitt Creek, artificial substrate placement.

2.2 Water Chemistry

2.2.1 First Supplemental Study

2.2.1.1 Grab Samples and Flows

Water chemistry samples were collected from six locations (Table 2.2) at approximately 2- to 4-week intervals, starting prior to fish assemblage sampling and continuing through completion of fall macroinvertebrate sampling (7/31/2015 through 11/24/2015). All samples downstream of Outfall 001 were collected while water was being actively pumped from the quarry pit. Samples were analyzed for the parameters listed in Table 2.4 using the indicated analytical methods. Stream flow and in situ temperature (° C), dissolved oxygen (DO; mg/L), pH (standard units), and specific conductance (conductivity; µS/cm) were measured at the time of sample collection. Stream flow was measured at the downstream end of the upstream reach (BC-0A) and the upstream end of the downstream reach (BC-1A). Flows were measured by measuring stream width, depth, and current velocity per USGS (1982) protocols using a calibrated wading rod and a Marsh-McBirney (Flow Mate Model 2000) flow meter. All flow measurements were made concurrently with grab sample collection.

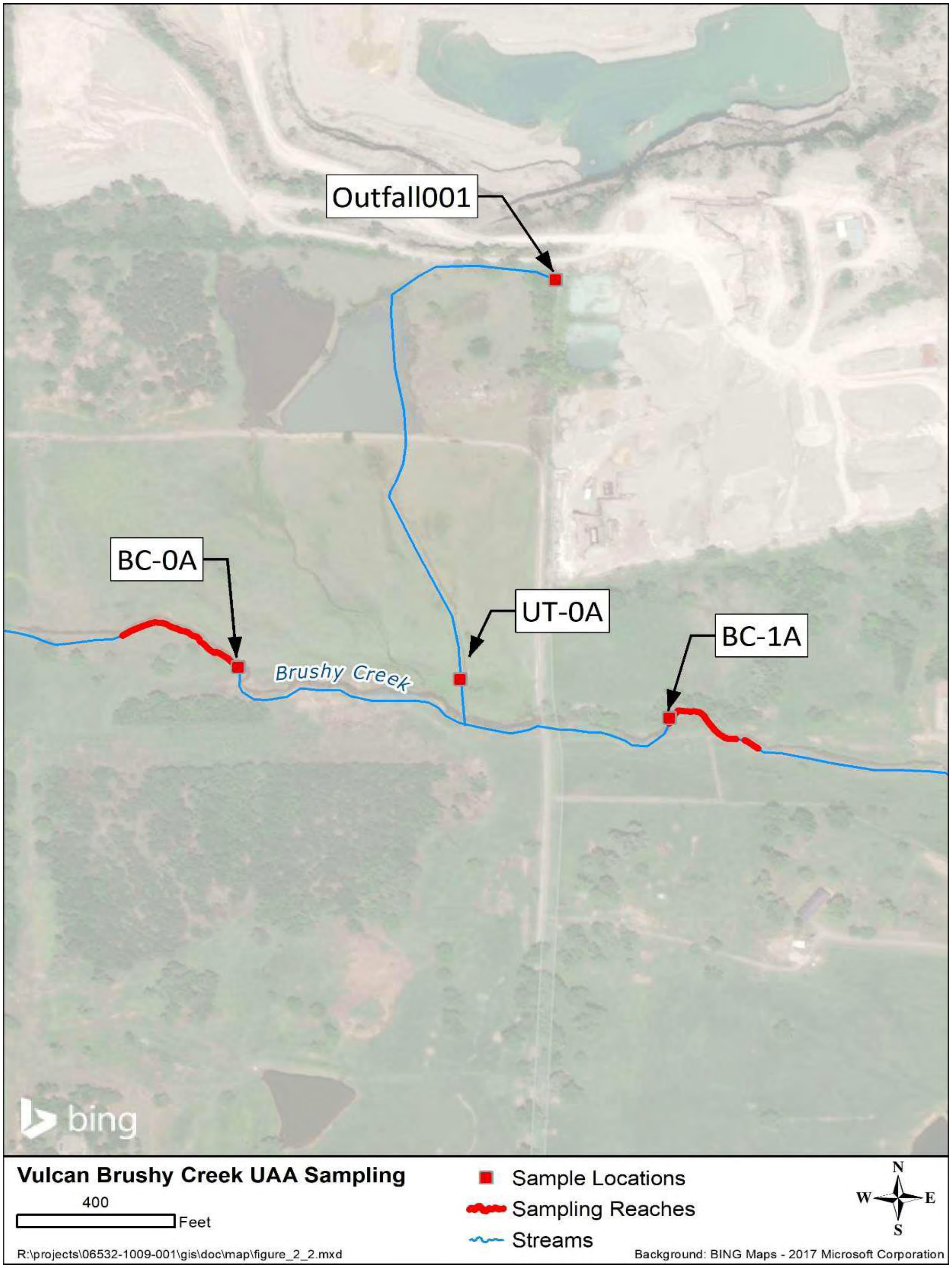

Figure 2.3. Sampling reaches on Brushy Creek, unnamed tributary, and Outfall 001 used for the First Supplemental Study.

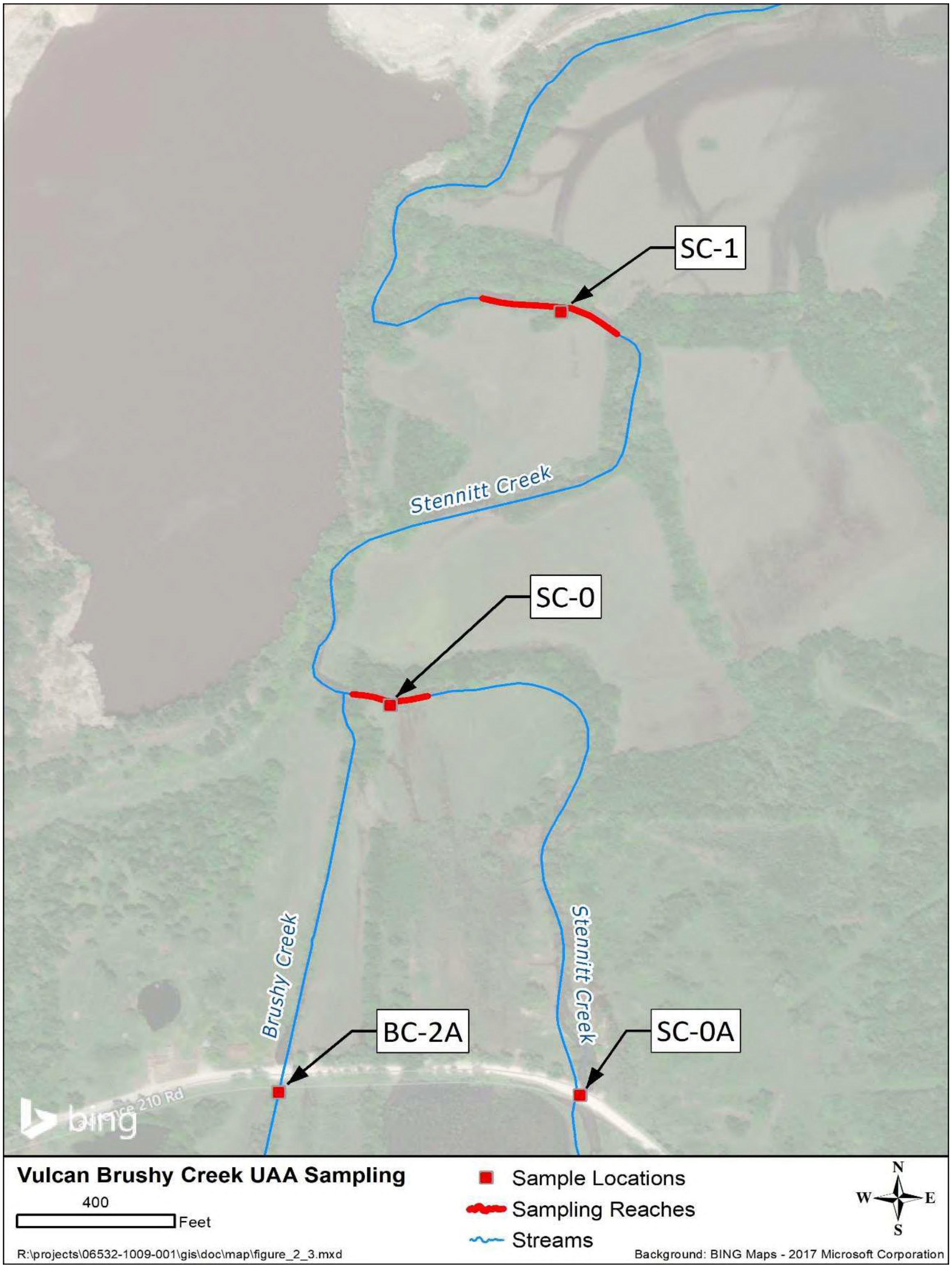

Figure 2.4. Sampling locations on Brushy Creek and Stennitt Creek used for the Second Supplemental Study.

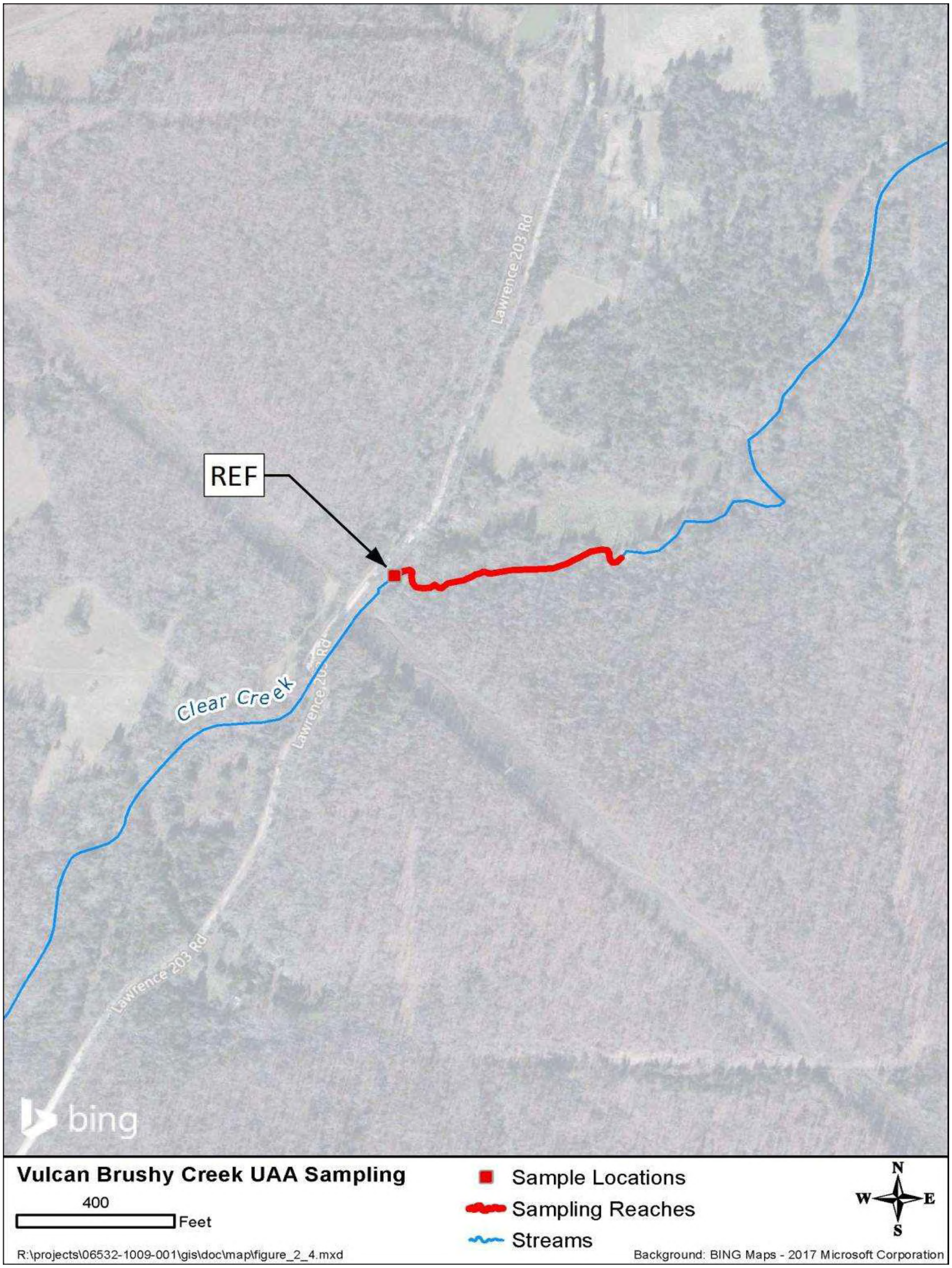

Figure 2.5. Sampling locations on Clear Creek used for the Second Supplemental Study.

Table 2.4. Analytes and analytical methods for water quality sampling.

Analyte	Method (or equivalent)
Chloride	US Environmental Protection Agency (EPA) Method 300.0
Sulfate	EPA Method 300.0
TDS	EPA Method 160.1
Hardness	EPA Method 200.7
TSS	EPA Method 160.2
Temperature	Measured in situ at time of sample collection using Hydrolab mini-sonde field meter
DO	
pH	
Conductivity	

In situ measurements were taken using Hydrolab mini-sonde multi-probe water quality monitors. Instruments were calibrated on the day of use or deployment. Calibration of the DO function on all instruments was performed using air calibration. Calibration of pH and conductivity functions was performed using standard buffers (pH) and calibration standards (conductivity). Calibration was checked upon completion of each day's measurements by comparing instrument readings with readings in standard buffers, calibration standards, or saturated air, as appropriate. All calibration information was documented and retained as part of the project records. Discrete in situ measurements were taken in mid-current at mid-depth concurrently with grab water samples.

2.2.1.2 In Situ Semi-Continuous Monitoring

Semi-continuous recording monitors were deployed at stations BC-0A and BC-1A to record temperature, DO, pH, and conductivity at 15-minute intervals for approximately 96 hours during August 10 through 14, 2015. Instruments were calibrated at the beginning of the deployment period and calibration was checked at the end of the of the deployment period as described in Section 2.2.1.1.

2.2.2 Second Supplemental Study

Water chemistry samples were collected from nine locations (Table 2.2) on October 25and December 7, 2016. These dates correspond to the deployment and retrieval, respectively, of the artificial substrate samplers that were placed in Stennitt Creek. All samples downstream of Outfall 001 were collected while water was being actively pumped from the quarry pit. Samples were analyzed for the parameters listed in Table 2.4 using the indicated analytical methods. Stream flow and in situ temperature (°C), DO (mg/L), pH (standard units), and conductivity (µS/cm) were measured at the time of sample collection. Stream flow was measured at the upstream end of reach. Flows were determined by measuring stream width, depth, and current velocity per USGS (1982) protocols using a calibrated wading rod and a Marsh-McBirney (Flow Mate Model 2000) flow meter. All flow measurements were made concurrently with grab sample collection.

2.3 Habitat Assessments

2.3.1 First Supplemental Study

The objective of the habitat assessments carried out in conjunction with benthic macroinvertebrate sampling was to obtain greater resolution in habitat differences that were previously reported as embeddedness. The assessment focused primarily on quantitatively characterizing the substrate size and composition through the use of Wolman pebble counts in each reach sampled. Wolman pebble counts were conducted in each riffle and each pool of the three separate pool-riffle complexes for a total of 12 sets of pebble counts (three pools and three riffles in both the BC-0A and BC-1A reaches). In addition, habitat evaluation in Brushy Creek used the “high gradient” RBA procedure found in Barbour et al. (1999).

2.3.2 Second Supplemental Study

2.3.2.1 Stennitt Creek

Habitat evaluation in Stennitt Creek used the “low gradient” RBA procedure found in Barbour et al. (1999). No Wolman pebble counts were performed in Stennitt Creek because the substrate was exclusively sand and silt.

2.3.2.2 Clear Creek

Habitat evaluation in Clear Creek matched that performed in Brushy Creek in the First Supplemental Study.

2.3.3 Habitat Data Analysis

Frequency distributions of habitat categories and substrate size categories were evaluated among and/or between locations using Pearson's Chi Square (X^2) test. A non-significant X^2 value ($P > 0.05$) indicates that the distribution of habitat scores or substrate size categories is independent of sampling location.

2.4 Fish Community Evaluation

2.4.1 First Supplemental Study

The fish sampling design was intended to assess upstream/downstream assemblage differences at the reach and habitat scale. Three separate pool-riffle complexes were sampled using a backpack electo-fisher in Brushy Creek upstream (BC-0A) and downstream (BC-1A) of the mouth of the UT (Figure 2.3). Pool and riffle habitats were sampled separately using block nets and a three-pass depletion effort. Accordingly, the final data set was comprised of three separate pool collections and three separate riffle collections from both of the two reaches. Fish were identified to species and counted, with living fish returned to the stream. A sub-sample of up to 25 fish of each species (as allowed by the numbers caught) was measured (total length to the nearest millimeter) and weighed (to nearest 0.1 gram) at both BC-0A and BC-1A.

2.4.2 Second Supplemental Study

The fish sampling protocol for Clear Creek (Figure 2.5) matched that used for Brushy Creek in the First Supplemental Study. As discussed in Section 1.5.3.2, no fish sampling was conducted in Stennitt Creek.

2.4.3 Fish Data Analysis

As noted previously in Section 1.5.3.1, based on discussions with ADEQ staff it was agreed that the results from the fish sampling of Brushy Creek from the First Supplemental Study (conducted in the summer of 2015) could be directly compared to the results from the fish sampling of the reference stream (Clear Creek) from the Second Supplemental Study (conducted in the fall of 2016).

Analysis of fish data focused on comparisons of BC-0A and Clear Creek (REF) versus BC-1A with respect to ADEQ's Community Structure Index (CSI) (ADEQ 2018) species composition, relative abundance, community structure, and population size. Length-specific weight and average weight was evaluated for species having 20 or more paired length-weight measurements.

2.4.3.1 Species Composition and Relative Abundance

The evaluation of species composition and relative abundance focused on a comparison of species present and their relative abundance (percent composition) in Brushy and Clear Creek reaches and the presence of Ozark Highlands ecoregion key and indicator species per APCEC (2017).

2.4.3.2 Community Structure Index

Evaluations of community composition used ADEQ's CSI (ADEQ 2018) to compare BC-0A and REF versus BC-1A and REF versus BC-0A. The CSI uses selected metrics to compute a CSI score that provides a measure of the similarity of the community to an ecoregion-specific least-disturbed community. CSI values were computed for three levels of data aggregation:

1. **<u>CSI values computed for each replicate in each pool and riffle habitat</u>**: This allowed separate statistical comparisons of CSI values among and between BC-0A, BC-1A and REF for riffles and pools. Data were evaluated for variance, homogeneity and normality using Levene's and Shapiro-Wilk tests, respectively, and were transformed (log10) as necessary to achieve equal variance and normality. Analysis of variance (ANOVA) was conducted on the original or transformed data, as appropriate, and the statistical significance of all possible pairs of locations was evaluated using Tukey's Honestly Significant Difference (HSD) test only if the F-test from the ANOVA comparing all locations was statistically significant ($P \leq 0.05$). All statistical computations were performed using Systat 12.
2. **<u>CSI values computed for all replicates combined within riffles and pools</u>**: No statistical comparison is possible using this level of consolidation, nor is it equivalent to averaging the CSI values among replicates of pools or riffles at a sampling reach. It provides a more complete description of overall community

structure (based on CSI metrics) because it combines information from three different riffles or pools within each sampling reach.

3. **<u>CSI values computed for pools and riffles combined in upstream and downstream reaches</u>**: As in item 2 above, this level of data consolidation does not allow a statistical comparison among and between BC-0A, BC-1A and REF nor is it equivalent to averaging the CSI values. However, it provides the most complete CSI values because it consolidates data from all replicates at both pools and riffles and reflects the total community composition at each sampling reach. CSI values from this level of aggregation were used per ADEQ's comparison methodology (ADEQ 2018) to assess aquatic life use support.

2.4.3.3 Population Size

Although the sampling methodology allowed estimates of population size using the "removal method," a preliminary evaluation of population estimates indicated that catch-per-unit-effort (CPUE) data expressed as numbers per minute of pedal-down time (PDT) captured the same differences and trends.

CPUE values were computed for two levels of data aggregation:

1. **<u>CPUE values computed for each replicate in each pool and riffle habitat</u>**: This allowed separate statistical comparisons of CPUE among and between BC-0A, BC-1A, and REF for riffles and pools using the same statistical approach used for CSI values.
2. **<u>CPUE values computed for pools and riffles combined in upstream and downstream reaches</u>**: This level of data aggregation is equivalent to comparing weighted averages (weighted by PDT) and does not permit statistical comparison among and between locations.

2.4.3.4 Fish Size

Average fish weight for species having 20 or more paired length-weight measurements was compared among BC-0A, BC-1A and REF using an ANOVA or Kruskal-Wallis test, depending on validation of equal variance and normality, for those species collected at all three locations, and a Wilcoxon-Mann-Whitney test for those species collected at only two locations. Average weights for each species for each pairwise combination of locations were evaluated for statistical significance using Tukey's HSD test if the F-test for the ANOVA was significant. All statistical computations were performed using Systat 12.

2.4.3.5 Condition Factor

Condition factor as indicated by length-specific weight (i.e., weight at a comparable length) at BC-0A, BC-1A and REF for species having 20 or more paired length-weight measurements was evaluated using an analysis of covariance (ANCOVA). The ANCOVA analysis was performed using log10-transfomed length and weight measurements. Adjusted weights for each species for each pairwise combination of locations were evaluated for statistical significance using Tukey's HSD test if the F-test for the ANCOVA was significant. All statistical computations were performed using Systat 12.

2.5 Benthic Macroinvertebrate Community Evaluation

2.5.1 Instream Sampling

2.5.1.1 First Supplemental Study

Instream samples of benthic macroinvertebrates were collected using the five-minute traveling kick method per ADEQ (2010) using a D-frame kick net with 0.5-mm mesh net. Two riffles within each reach were sampled for a combined time of five minutes. Sampling started at a downstream corner of each riffle, which was "kicked" along a diagonal path upstream through the riffle for 2.5 minutes. After removal and washing of large debris, the entire content of the net was washed into wide-mouth plastic jars and immediately preserved with 70% ethanol. The two riffle samples from each reach were combined into one composite sample to produce a single sample each for BC-0A and BC-1A.

2.5.1.2 Second Supplemental Study

Instream samples of benthic macroinvertebrates were collected from Stennitt Creek (Figure 2.4) using a modified multi- habitat approach based on Barbour et al. (1999). A total of seven "jabs" were executed in each of three habitat types: emergent vegetation, silt bottom, and undercut bank/woody debris for a total of 21 jabs at each Stennitt Creek location. All 21 jabs were composited to produce a single sample each for SC-1A and SC-0A.

Instream macroinvertebrate samples from the reference location (Clear Creek) were collected using the five-minute travel kick method per ADEQ (2016) using a D-frame kick net with 0.5-mm mesh net. Two riffles (REF-2 and REF-3) within Clear Creek were sampled for a time of five minutes. Sampling started at a downstream corner of each riffle, which was “kicked” along a diagonal path upstream through the riffle for 5 minutes. After removal and washing of large debris, the entire content of the net was washed into wide-mouth plastic jars and immediately preserved with 70% ethanol. The two riffle samples from Clear Creek were kept independent to produce two samples for Clear Creek.

2.5.2 Artificial Substrates

Two types of artificial substrates were deployed as part of this study: rock bags (RBs) were deployed in Brushy Creek as part of the First Supplemental Study and Hester-Dendy (HD) samplers were deployed in Stennitt Creek as part of the Second Supplemental Study.

2.5.2.1 First Supplemental Study

Triplicate RB samplers were deployed in suitable flow and depth in each of three riffles within the BC-0A and BC-1A reaches from October 13 through November 23, 2015 (Table 2.1). The RB samplers consisted of an elliptical bag made of 0.75-inch mesh nylon netting filled with a 2-gallon volume of a homogenized mixture of river stones ranging in size from 26 mm to 64 mm (Figure 2.6).

Upon retrieval (41 days after deployment), the substrate material was removed from the RB sampler and washed and agitated to remove attached organisms. The organisms and fine substrate material/detritus was preserved with 70% ethanol in high-density polyethylene (HDPE) jars in preparation for taxonomic identification. Each RB sampler was analyzed independently which resulted in a total of 18 RB data sets (3 RBs in each of three riffles in both the BC-0A and BC-1A reaches).

Figure 2.6. Photograph of newly deployed rock bag sampler.

2.5.2.2 Second Supplemental Study

Triplicate HD samplers were deployed over sand/silt substrate in approximately 0.6 m of water in measurable flow (> 10 cm/sec) in Stennitt Creek upstream (SC-0A) and downstream (SC-1A) of the mouth of Brushy Creek (Table 2.1) from October 25 through December 7, 2016. Each sampler was deployed approximately 0.1 m above the channel bottom by affixing the sampler to a metal stake driven into the substrate. Samplers consisted of 14 round, 75-mm-diameter, 3-mm-thick plates separated by various widths (ranging from 2.5 to 14 mm) with nylon spacers and held together with an eyebolt and wingnut. The total surface area of each sampler was approximately 0.4 m^2.

At the end of the 41-day deployment period the samplers were retrieved by gently lifting each sampler out of the water, enclosing it in a plastic bag, and immediately preserving it with 70% ethanol. Each sampler was cleaned in the laboratory by placing the sampler and the contents of the plastic bag into a sorting tray. The sampler was disassembled and all obvious invertebrates were removed. The surfaces of all sampler parts were then gently scrubbed with a plastic bristle scrub brush in the sorting tray. The organisms and fine substrate material/detritus were preserved with 70% ethanol in HDPE jars in preparation for taxonomic identification. Each HD sampler was analyzed independently which resulted in a total of 6 HD data sets (3 HDs in both the SC-0 and SC-1 reaches).

2.5.3 Macroinvertebrate Sample Processing

Sample sorting and taxonomic identification were conducted by EcoAnalysts, Inc.[8] Each sample was sorted to obtain a 300-organism subsample. In general, the laboratory carried out taxonomic identifications to genus (including Chironomidae), except for bivalve mollusks, gastropods, and decapod shrimp, which were identified to family.

2.5.4 Macroinvertebrate Data Analysis

As noted in Section 1.5.3.1, based on discussions with ADEQ staff, it was agreed that the results from the instream benthic macroinvertebrate sampling of Brushy Creek from the First Supplemental Study (conducted in the fall of 2015) could be directly compared to the results from the instream benthic macroinvertebrate sampling of the reference stream (Clear Creek) from the Second Supplemental Study (conducted in the fall of 2016).

This study generated two different types of macroinvertebrate data: data collected using the instream sampling protocol and data generated using artificial substrates (RB and HD). Benthic macroinvertebrate communities sampled using the instream sampling protocol were evaluated using the multi-metric Index of Biotic Integrity (IBI) approach used by ADEQ for assessing instream impairment (ADEQ 2018).

The data analysis applied to the instream samples was not appropriate for the experimental design for the RB or HD deployments. The RB deployment involved two reaches, each with three replicates (riffles) and three subsamples (RB), for a total of 18 RB units (RBUs). The HD deployment involved two reaches, each with three replicate HD samplers, for a total of six HD units (HDUs). The data from each unit is comprised of large number of potential variables in the form of biological metrics.

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[8] EcoAnalysts, Inc., 1420 South Blaine Street, Suite 14, Moscow, ID 83843.

Cluster analysis was applied using Systat 12 to explore relationships and differences in colonization between the upstream and downstream RB or HD units. The procedure represents a way of analyzing structure within data sets. Cluster analysis identifies groups of similar objects (RBUs from the First Supplemental Study and HDUs from the Second Supplemental Study) based on their overall similarity (in terms of metric values) and displays the results as a tree diagram. It is useful for detecting and visualizing groups and sub-groups in hierarchically organized data (e.g., replicates within riffles, riffles within locations).

Macroinvertebrate data were also analyzed based on the results of field studies directed towards the response of macroinvertebrate communities to dissolved minerals. EPA (2011) describes a methodology for obtaining field-based threshold values for ionic strength based on conductivity. The study developed extirpation concentration (XC95) values that represent the level of exposure (based on conductivity) above which a genus is effectively absent from water bodies of region. XC95 values developed in the EPA (2011) study were obtained from EPA's National Center for Environmental Assessment (Office of Research and Development, Cincinnati, OH). The data analysis in EPA (2011) is best applied to situations, such as found in Brushy Creek and Stennitt Creek, in which calcium, magnesium, sulfate, and HCO_3^- dominate the ionic composition of the streams (Table 1.3). Macroinvertebrate genera contained in the Brushy Creek and Stennitt Creek samples were assigned XC95 values based on the EPA data set. XC95 values were then analyzed statistically as described in Section 2.5.5 to evaluate differences in the distribution and mean XC95 values between upstream and downstream locations in Brushy Creek and Stennitt Creek.

2.5.4.1 Instream Samples

All pairwise comparisons of BC-0A, BC-1A and REF were computed per (ADEQ 2018). Scoring criteria were summed for selected metrics (Table 2.5) to derive the IBI score for the "study sites." All scores for the "reference" sites were given a value of 6, except for the "percent contribution of dominant taxa" metric, which is scored based on the actual score. The percent comparability for all pairwise comparisons of BC-0A, BC-1A and REF was calculated from the ratio of the respective total scores. The attainment status of any location relative to any other based on percent comparability was evaluated based on Table 2.6.

Table 2.5. Biological metric scoring rubric.

Metric	Scoring Criteria			
	6	4	2	0
Taxa Richness [a]	≥80%	<80-60%	<60-40%	<40%
Hilsenhoff Biotic Index [b]	≥85%	<85-70%	<70-50%	<50%
Ratio of EPT to Chironomid Abundances [a]	≥75%	<75-50%	<50-25%	<25%
Percent Contribution of Dominant Taxa [c]	<20%	20-<30%	30-<40%	≥40%
EPT Index [a] (percent of EPT individuals)	≥90%	<90-80%	<80-70%	<70%
Community Loss Index [d]	<0.5	0.5-<1.5	1.5-<4.0	≥4.0
Ratio of Scrapers to Filter-Collectors [a]	≥50%	<50-35%	<35-20%	<20%

Notes:

a. Score is a ratio of study site to reference site, multiplied by 100.
b. Score is a ratio of reference site to study site, multiplied by 100.
c. Scoring criteria evaluate actual percent contribution, not percent comparability to reference site.
d. Range of values obtained. A comparison to the reference site is incorporated in these indices.

Table 2.6. IBI attainment status scoring rubric.

	Biological Condition Category	% Comparable Estimate	Attribute
Support	Comparable to reference	≥83%	Comparable to the best situation in an ecoregion.
	Supporting	54-79%	Community structure less than reference site. Taxa richness lower and tolerant forms are more prevalent.
Non-support	Partially supporting	21-50%	Obvious decline in community structure with loss of intolerant forms. EPT index reduced.
	Non-supporting	<20%	Community dominated by 1 or 2 taxa, few taxa present.

2.5.4.2 Artificial Substrates: First Supplemental Study

The cluster analysis was performed on the standardized transformed data set (see below) using Euclidian distances with the following hierarchical clustering algorithms: single linkage, complete linkage, average linkage, centroid linkage, median linkage, Ward minimum variance, and weighed average linkage methods as follows:

1. Metric selection: As part of its reporting package EcoAnalysts, Inc. provides values for 105 metrics describing abundance, dominance, richness, community composition, functional groups (composition and richness), and diversity. The data set was examined to identify and eliminate metrics that were invariant (i.e., did not show variability across sites) or inappropriate (e.g., more applicable to lentic environments). The list of the remaining 22 metrics, which was used in the cluster analysis for Brushy Creek, is provided in Table 2.7.

2. Data transformation/standardization:
   a. All metrics expressed as percentages were transformed as $y = \text{arcsine}(p)^{0.5}$ where p = the percentage expressed as a proportion.
   b. All metrics, including arcsine-transformed metrics, were standardized as follows:

   $$y_i = (\bar{x} - x_i)/\text{Stdev}(x),$$

   where:

   y_i = standardized variate
   x_i = original variate
   $\bar{x}$ = the arithmetic average of the original variates,
   Stdev(x) = standard deviation of the original variates.

   The resulting standardized variables will have a mean equal to zero and standard deviation equal to one. Standardization prevents variables with inherently large values (e.g., total counts) from dominating the distance matrix.

2.5.4.3 Artificial Substrates: Second Supplemental Study

The procedure for analyzing HD data from the Stennitt Creek locations was the same as used for the RB data from the Brushy Creek locations except as follows:

1. The list of metrics selected for Stennitt Creek differed from the list of metrics selected for Brushy Creek due to variability between sites in more metrics (32 instead of 22 metrics) (Table 2.8), and

2. $\text{Log}_{10}(x+1)$ transformation was used because some of the selected metrics had “zero” values.

Table 2.7. Biological metrics used for the cluster analysis of RB samples.

Selected Metrics	
Total Abundance (Corrected)	Percent Chironomidae
Percent Composition of the Most Dominant Taxon	Percent Filterers
Total Taxa Richness	Percent Gatherers
EPT Richness	Percent Predators
Ephemeroptera Richness	Percent Scrapers
Trichoptera Richness	Filterer Richness
Chironomidae Richness	Gatherer Richness
Non-Chironomid, Non-Oligochaete Richness	Predator Richness
Percent Ephemeroptera	Scraper Richness
Percent Trichoptera	Shredder Richness
Percent EPT	Hilsenhoff Biotic Index

Table 2.8. Biological metrics used for the cluster analysis of HD samples.

Selected Metrics	
Total Abundance (Corrected)	Percent Odonata
EPT Abundance	Percent Filterers
Dominant Abundance	Percent Gatherers
Species Richness	Percent Predators
EPT Richness	Percent Scrapers
Ephemeroptera Richness	Percent Shredders
Trichoptera Richness	Percent Piercer-Herbivores
Chironomidae Richness	Filterer Richness
Oligochaete Richness	Gatherer Richness
Non-Chironomid, Non-Oligochaete Richness	Predator Richness
Percent Ephemeroptera	Shredder Richness
Percent Trichoptera	Shannon-Weaver H’ (log 10)
Percent EPT	Margalef’s Richness
Percent Coleoptera	Hilsenhoff Biotic Index
Percent Diptera	% Tolerant Individuals
Percent Chironomidae	% Tolerant Taxa

2.5.5 Analysis of XC95 Values

To compare XC95 values between locations an "XC95 Index[9]" was computed as the average XC95 value among taxa weighed by the numerical abundance of each taxon as follows:

$$\text{XC 95 index} = \frac{(\sum_{i=1}^{j} \text{XC95i} \times \text{Ni})}{\sum_{i=1}^{j} \text{Ni}}$$

Where

XC95i = XC95 value of the i^{th} taxon, and

Ni = numerical abundance of the i^{th} taxon

For Brushy Creek RB samples, an XC95 index was computed for each riffle (replicates combined), and the three resulting XC95 index values for BC-0A and BC-1A were compared using a t-test. For Stennitt Creek HD samples, an XC95 index was computed for each of the three HD samples at each location, and the resulting values for SC-0 and SC-1 were compared using a t-test.

For instream samples, the XC95 indices for the upstream and downstream locations were compared using a t-test based on the variance of the weighed mean. The variance (s^2) of the weighted mean was calculated as follows:

$$s^2(\text{XC95 index}) = s^2_0 \sum_{i=1}^{j} (N_i / N_t)^2$$

where:

s^2_0 = variance of the XC95 values,

N_i = numerical abundance of the i^{th} taxon, and

N_t = total numerical abundance of all taxa.

All statistical computations were performed using Systat 12.

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[9] XC95 index values were developed to identify tolerance levels in each stream that could be compared across and within streams and not used to propose a site-specific TDS criterion.

3.0 RESULTS: WATER CHEMISTRY

3.1 Routine Outfall 001 Monitoring

TDS and sulfate concentrations in samples from Outfall 001 vary significantly from month to month as well as year to year. Time-series plots (Figure 3.1) of the historical Outfall 001 TDS and sulfate data demonstrate this variability and a lack of consistent trends (see the recent TDS data versus previous years). The outfall data variability is not explained by any single factor but rather appears related to complex and unpredictable interactions involving multiple factors including, but not limited to, precipitation, surface and subsurface hydrology, quarry water management, etc., which results in varying exposures of the water to quarry materials. Vulcan representatives most familiar with on-site mining practices have concluded that the recent downward trend is likely a result of where active mining is occurring and the resulting geologic formation that water in the pit is exposed to. Accurate predictions regarding future decreases or increases in mineral concentrations in the outfall are not possible.

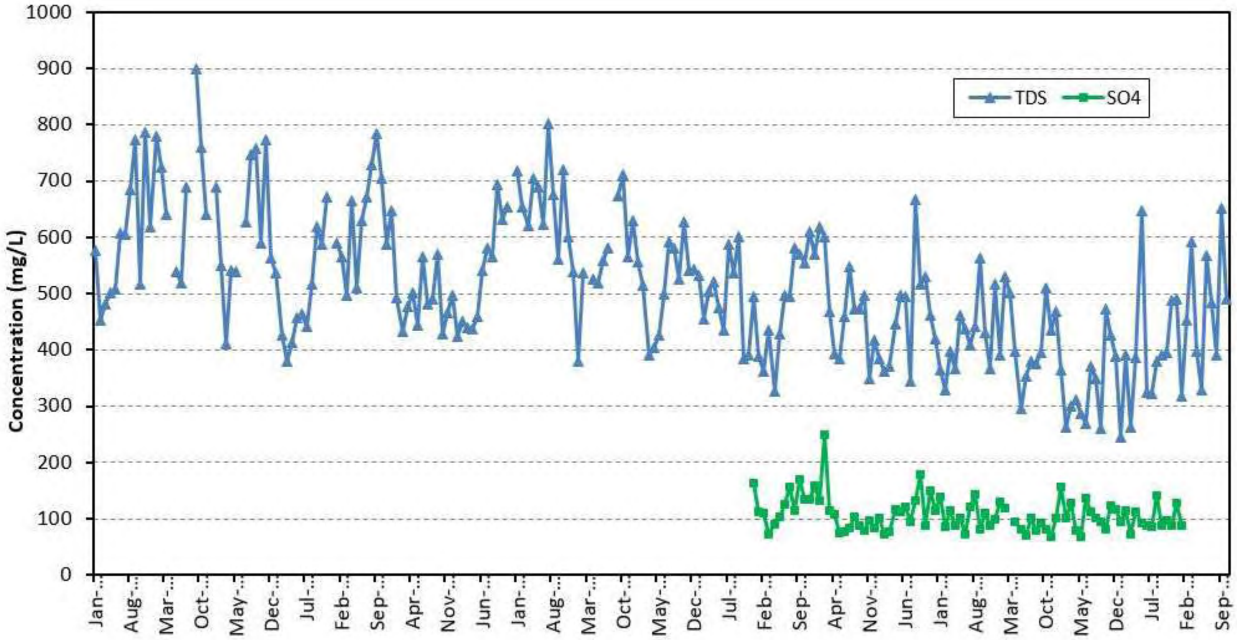

Figure 3.1. TDS and sulfate at Outfall 001 from January 1999 to October 2017.

3.2 Brushy Creek

3.2.1 Grab Samples

Water chemistry data (Table 3.1) indicate an average 30 mg/L increase in TDS in Brushy Creek (391 versus 421 mg/L at BC-0A and BC-1A, respectively) and an average 81 mg/L increase in sulfate (5.4 versus 86.6 mg/L at BC-0A and BC-1A, respectively) downstream of the mouth of the UT. TDS was higher in the Brushy Creek location upstream of the mouth of the UT on July 31 and August 14, 2015; on the five remaining sampling dates, TDS was higher downstream of the mouth of the UT. Chloride concentrations were uniformly low at all locations.

Tables 3.1 and 3.2 and time-series plots (2015) of TDS and sulfate at BC-0A, BC-1A, and UT-0A presented in Figure 3.2 show the following:

1. Sulfate concentrations at locations not influenced by Outfall 001 (i.e., BC-0A, SC-0A, and REF) were generally near or below detection limits but were distinctly higher in locations influenced by Outfall 001 (i.e., UT-0A, BC-1A, and BC-2A);
2. Sulfate concentrations at BC-1A and BC-2A always exceeded the "significant modification" value of 22.7 mg/L;
3. TDS concentrations were generally higher at BC-1A than BC-0A due to input from UT-0A;
4. TDS concentrations at locations not influenced by Outfall 001 (i.e., BC-0A, SC--A, and REF) always exceeded the ecoregion value of 240 mg/L and the "significant modification" value of 255 mg/L at all locations with the exception of one sample collected at REF on 12/7/2016 where the TDS concentration was 240 mg/L (ecoregion value).
5. Conductivity in Brushy Creek was consistently higher upstream of the mouth of the UT (BC-0A) than downstream of the UT (BC-1A) during 2015.

In situ measurements (Table 3.2) indicate generally uniform levels of pH and temperature across locations on each sampling date. DO was slightly more variable across locations. Flow measurements (Table 3.2) indicated the following:

1. Flows at the UT location were mainly due to inflows from Outfall 001, but additional inputs due to springs within the pond are likely (Charles Milgrin, landowner personal communication),
2. Flow from the UT dominated flow in Brushy Creek downstream of the mouth of the UT, and
3. Brushy Creek acquires additional flow which dilutes sulfate and TDS between the mouth of the UT and the Brushy Creek confluence with Stennitt Creek.

Table 3.1. Water quality and flow data collected from Outfall 001 and receiving streams during 2015 and 2016.

Parameter	Sample Collection Date	Outfall 001	UT-0A	BC-0A	BC-1A	BC-2A	SC-0A	SC-1	REF
Chloride (mg/L)	7/31/2015	<0.1	5	<0.1	5	<0.1	<0.1	NM	NM
	8/14/2015	20	10	10	10	10	10	NM	NM
	9/15/2015	5	< 0.1	<0.1	5	<0.1	5	NM	NM
	10/14/2015	10	10	10	10	30	10	NM	NM
	11/24/2015	10	< 0.1	5	< 0.1	5	10	NM	NM
	10/26/2016	NM	5	<0.1	<0.1	<0.1	5	<0.1	<0.1
	12/7/2016	<10	5	<0.1	<0.1	<0.1	10	<0.1	<0.1
	Average	9.2	5.0	3.6	4.3	6.5	7.2	<0.1	<0.1
Sulfate (mg/L)	7/31/2015	98.1	85	<5	57.1	30	<5	NM	NM
	8/14/2015	101	94.2	5.97	79.4	69.7	<5	NM	NM
	9/15/2015	117	105	5.06	93.8	76.7	<5	NM	NM
	10/14/2015	128	118	6.9	92	90	<5	NM	NM
	11/24/2015	131	128	33.8*	113	90.9	5.8	NM	NM
	10/26/2016	NM	89.6	<5	85.3	26.7	<5	6.5	<5
	12/7/2016	124	100.7	5.2	85.7	76.4	<5	5.4	<5
	Average	116.5	102.9	5.5	86.6	65.8	5.1	5.9	<5
Hardness (mg/L as $CaCO_3$)	7/31/2015	260	260	312	272	248	284	NM	NM
	8/14/2015	260	268	312	268	260	272	NM	NM
	9/15/2015	312	260	288	232	244	248	NM	NM
	10/14/2015	384	312	332	312	312	304	NM	NM
	11/24/2015	312	288	374	312	304	276	NM	NM
	10/26/2016	NM	316	324	316	276	300	300	308
	12/7/2016	296	264	292	216	240	272	260	296
	Average	304	281	319	275	269	279	280	302
TDS (mg/L)	7/31/2015	361	368	330	266	334	310	NM	NM
	8/14/2015	594	606	664	614	598	538	NM	NM
	9/15/2015	493	448	322	438	400	636	NM	NM
	10/14/2015	440	360	288	352	342	280	NM	NM
	11/24/2015	424	412	372	406	368	314	NM	NM
	10/26/2016	NM	358	290	360	280	282	292	276
	12/7/2016	510	420	470	510	470	580	260*	240
	Average	470	425	391	421	399	420	--	258
TSS (mg/L)	7/31/2015	4	25	10	21	17	10	NM	NM
	8/14/2015	<1	9	5	9	10	<1	NM	NM
	9/15/2015	2	33	5	13	3	6	NM	NM
	10/14/2015	14	21	3	5	24	4	NM	NM
	11/24/2015	7	<1	5	6	3	4	NM	NM
	10/26/2016	NM	14	<1	2	3	3	2	<1
	12/7/2016	4	56	3	10	20	3	2	6
	Average	5.3	22.7	4.6	9.4	11.4	4.4	2	3.5

*Outlier not included in analyses, NM-Not measured

Table 3.2. In situ and flow data collected from Outfall 001 and receiving streams during 2015 and 2016.

Parameter	Sample Collection Date	Outfall 001	UT-0A	BC-0A	BC-1A	BC-2A	SC-0A	SC-1	REF
Conductivity (µS/cm)	7/31/2015	520	503	584	513	483	524	NM	NM
	8/14/2015	520	523	575	529	510	527	NM	NM
	9/15/2015	654	554	581	547	536	522	NM	NM
	10/14/2015	702	595	598	580	557	545	NM	NM
	11/24/2015	552	527	552	534	491	4878	NM	NM
	10/26/2016	NM	568	566	575	494	539	539	519
	12/7/2016	644	605	541	596	487	505	499	506
	Average	599	554	571	553	508	521	519	513
pH (su)	7/31/2015	8.3	7.9	7.7	7.9	8	8.1	NM	NM
	8/14/2015	8.2	7.9	7.6	7.6	7.9	7.9	NM	NM
	9/15/2015	7.3	8	7.7	8.1	7.5	7.8	NM	NM
	10/14/2015	7.6	8.2	7.7	7.4	7.8	7.7	NM	NM
	11/24/2015	7.8	8.1	7.6	7.9	7.7	7.7	NM	NM
	10/26/2016	NM	7.9	7.2	7.2	7.4	7.3	7.6	7.4
	12/7/2016	8.1	8.6	7.9	8.3	8	7.7	7.7	8.3
	Average	7.9	8.1	7.6	7.8	7.8	7.7	7.7	7.9
DO (mg/L)	7/31/2015	8.74	6.28	9.18	10.18	6.38	11.46	NM	NM
	8/14/2015	8.85	6.83	7.59	6.54	6.71	8.81	NM	NM
	9/15/2015	5.94	8.06	10.92	8.66	7.76	9.41	NM	NM
	10/14/2015	6.9	8.68	9.76	6.61	6.74	5.85	NM	NM
	11/24/2015	12.96	13.39	12.25	13.21	12.93	11.75	NM	NM
	10/26/2016	NM	9.16	7.97	8.23	7.03	5.79	5.98	9.63
	12/7/2016	12.95	12.33	11.68	12.47	9.59	8.75	10.62	10.84
	Average	9.39	9.25	9.91	9.41	8.16	8.83	8.30	10.24
Temp (°C)	7/31/2015	30.6	32.6	33.3	31.9	29.6	30.6	NM	NM
	8/14/2015	28.1	27.7	22.3	26.3	27.5	26.1	NM	NM
	9/15/2015	20.9	22.7	21.2	22.8	21.8	21.9	NM	NM
	10/14/2015	16.2	17.3	15.6	15.7	17.1	16	NM	NM
	11/24/2015	8.5	8.8	7.9	8.1	8.5	8.6	NM	NM
	10/26/2016	NM	17.1	14.5	15.5	14.6	15.9	14.8	16.7
	12/7/2016	8.6	8.1	9.8	8.3	7.3	8.1	6.9	9.7
	Average	18.8	19.1	17.8	18.4	18.1	18.2	10.8	13.2
Flow (cfs)	7/31/2015	0.59	0.33	0.06	0.39	0.59	1.36	NM	NM
	8/14/2015	0.45	1.1	0.1	1.5	1.42	0.93	NM	NM
	9/15/2015	NM	NM	NM	NM	NM	NM	NM	NM
	10/14/2015	0.45	0.88	0.02	0.03	0	0	NM	NM
	11/24/2015	0.59	1.56	0.28	1.52	2.78	3.37	NM	NM
	10/26/2016	NM	0.41	0.08	0.27	0.28	0.41	0.5	0.59
	12/7/2016	NM	2.1	0.13	0.85	NM	0.43	3.5	0.58
	Average	0.52	1.07	0.11	0.76	1.01	1.08	2.03	0.59

NM = not measured.

In contrast to the 2015 patterns shown by TDS, conductivity in Brushy Creek was consistently higher upstream of the mouth of the UT (BC-0A) than downstream of the UT (BC-1A) (Figure 3.2).

Average values for selected water chemistry and in situ parameters are summarized in Figure 3.2 to illustrate general spatial trends among stations from the 2015 sampling, which did not include samples from SC-1, and in Figure 3.3 from sampling in 2016, which included samples from SC-1.

3.2.2 Semi-Continuous In Situ Monitoring

Semi-continuous monitoring of temperature, DO, pH, and conductivity performed August 10 through 14, 2015, is compared for BC-0A and BC-1A in Figures 3.4 and 3.5. The figures illustrate differences in diel patterns for all four parameters. Daily maxima and minima were seen at BC-0A for temperature and DO (expressed as percent saturation; Figure 3.4). Maximum pH levels were similar at both locations but minimum levels were lower at BC-1A.

Conductivity was consistently 40 to 80 µS/cm higher at the location upstream of the mouth of the UT (BC-0A; Figure 3.5). This pattern was consistent with monthly in situ measurements at those locations (Table 3.2 and Figure 3.2). The lower chart in Figure 3.5 shows the same conductivity data as the upper chart except that the ordinate scale has been magnified to illustrate the difference in diel patterns between BC-0A and BC-1A. Figure 3.5 shows that diel maxima at one location correspond to minima of the other location.

3.3 Stennitt Creek

Water quality in Stennitt Creek in relation to Brushy Creek and Outfall 001 is best evaluated using the 2016 data because that data set, unlike the 2015 data set, included measurements in Stennitt Creek both upstream and downstream of the mouth of Brushy Creek. Table 3.3 and Figure 3.3 indicate that on October 26 there was littleincrease in TDS and conductivity and that on October 26 and December 7 there was a modest increase in sulfate in Stennitt Creek downstream of the mouth of Brushy Creek. The TDS concentration reported at SC-1 on December 7, 2018, was verified by the lab but, given the upstream concentrations at (BC-2A and SC-0A), was considered an outlier and not included in the analyses.

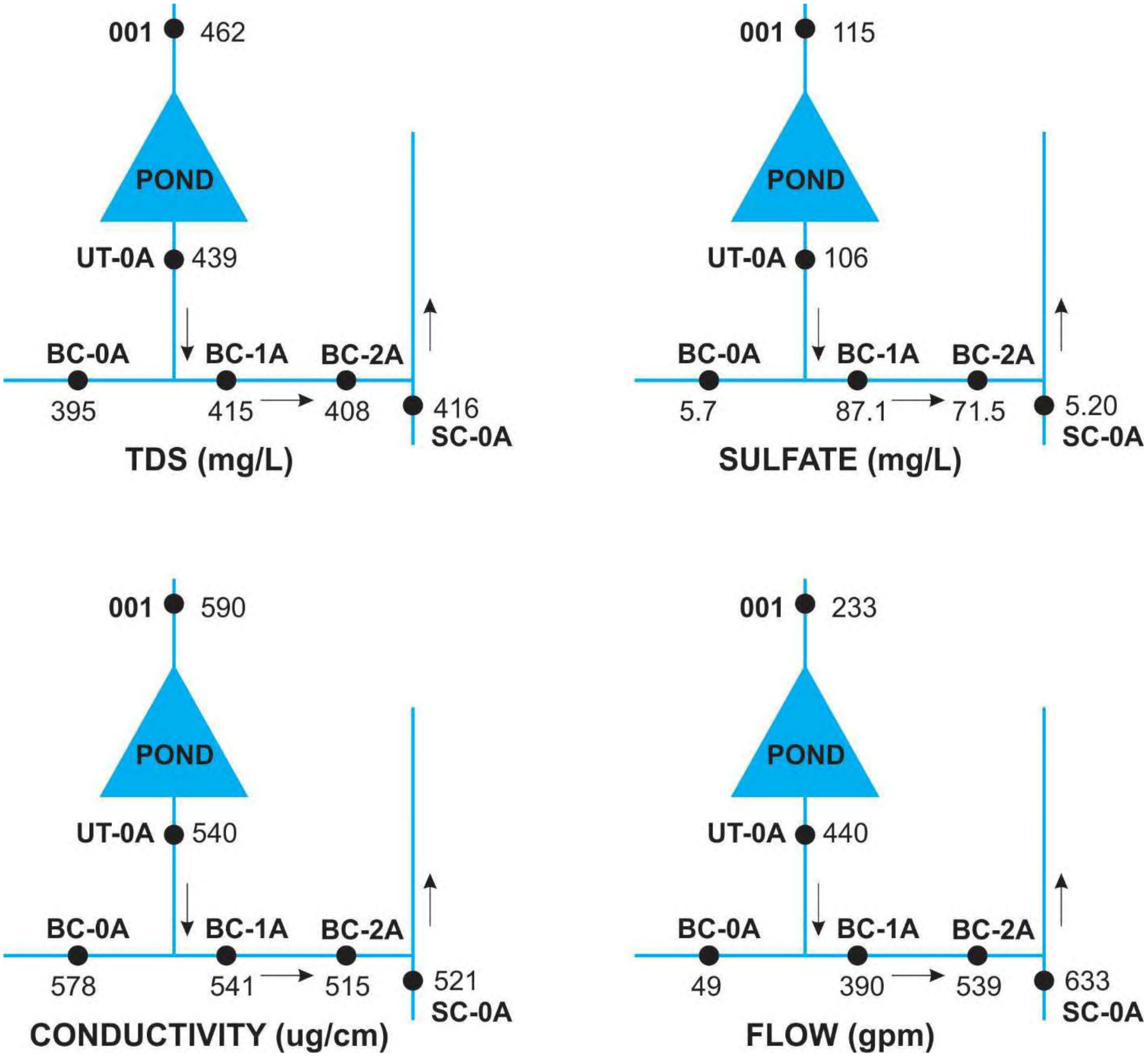

Figure 3.2. Schematic representation indicating general spatial trends in the average values of selected water chemistry parameters from sampling conducted in 2015.

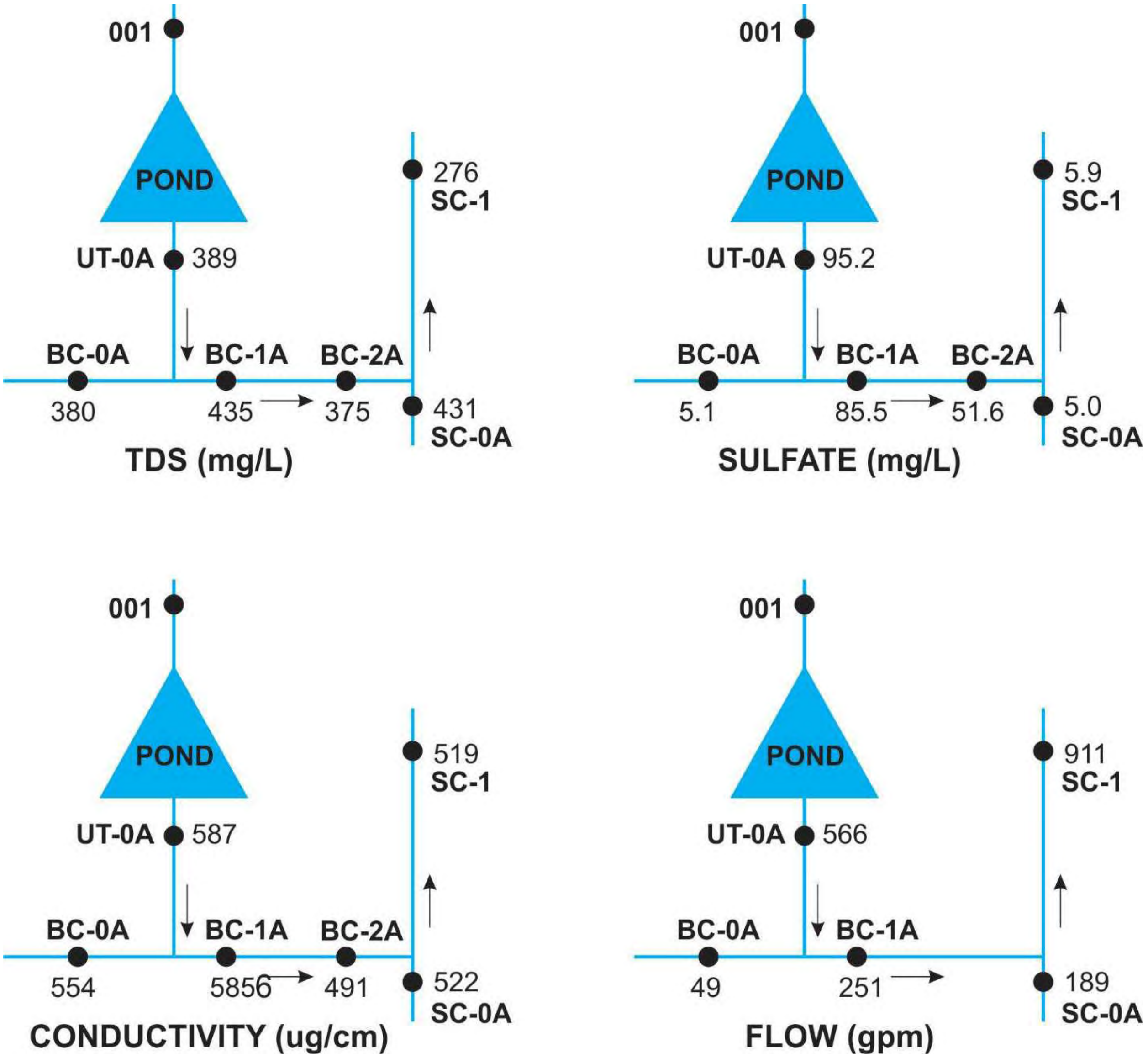

Figure 3.3. Schematic representation indicating general spatial trends in the average values of selected water chemistry parameters from sampling conducted in 2016.

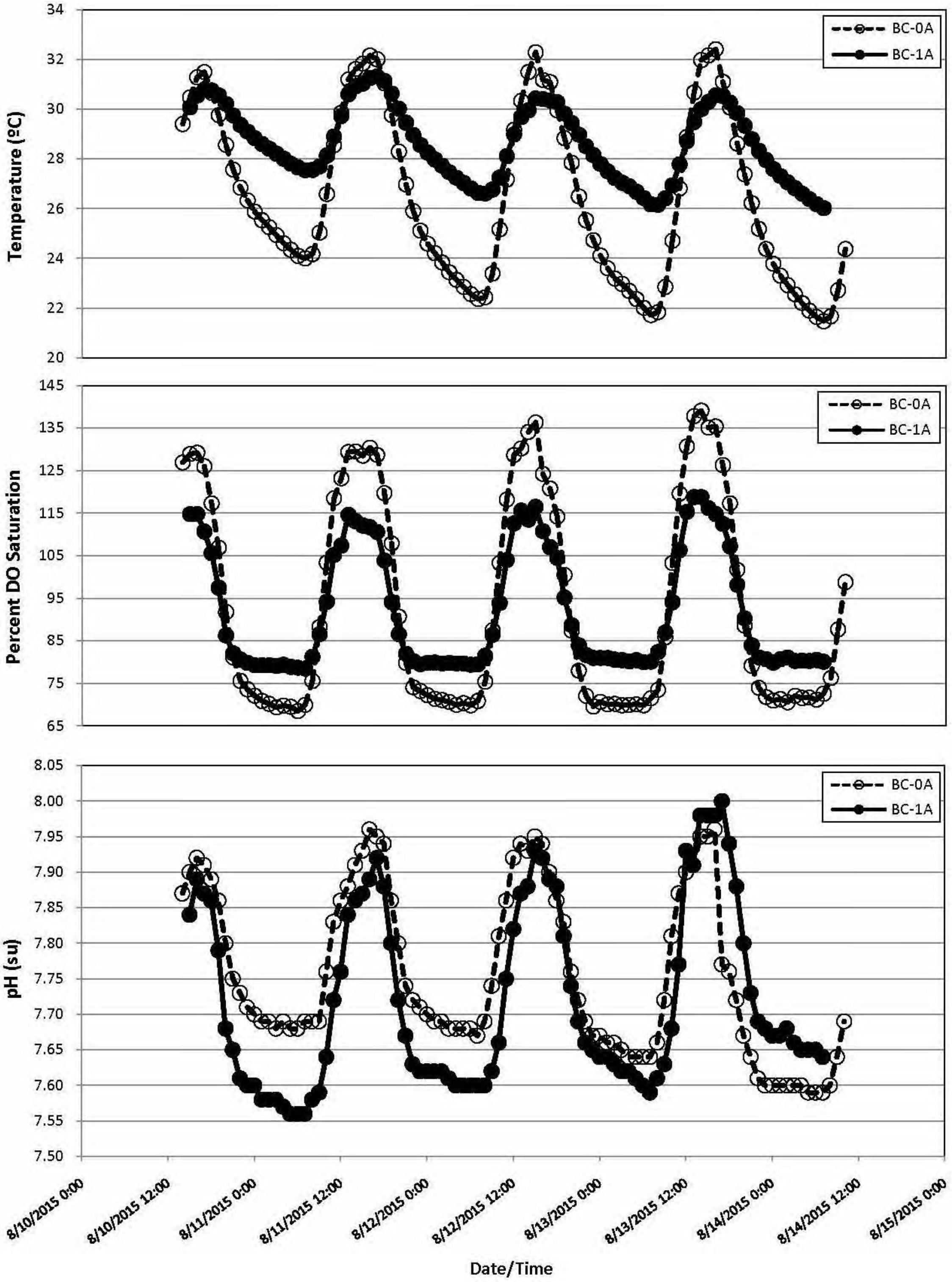

Figure 3.4. Semi-continuous measurements of temperature, DO (percent saturation), and pH at BC-0A and BC-1A, August 10 through 14, 2015.

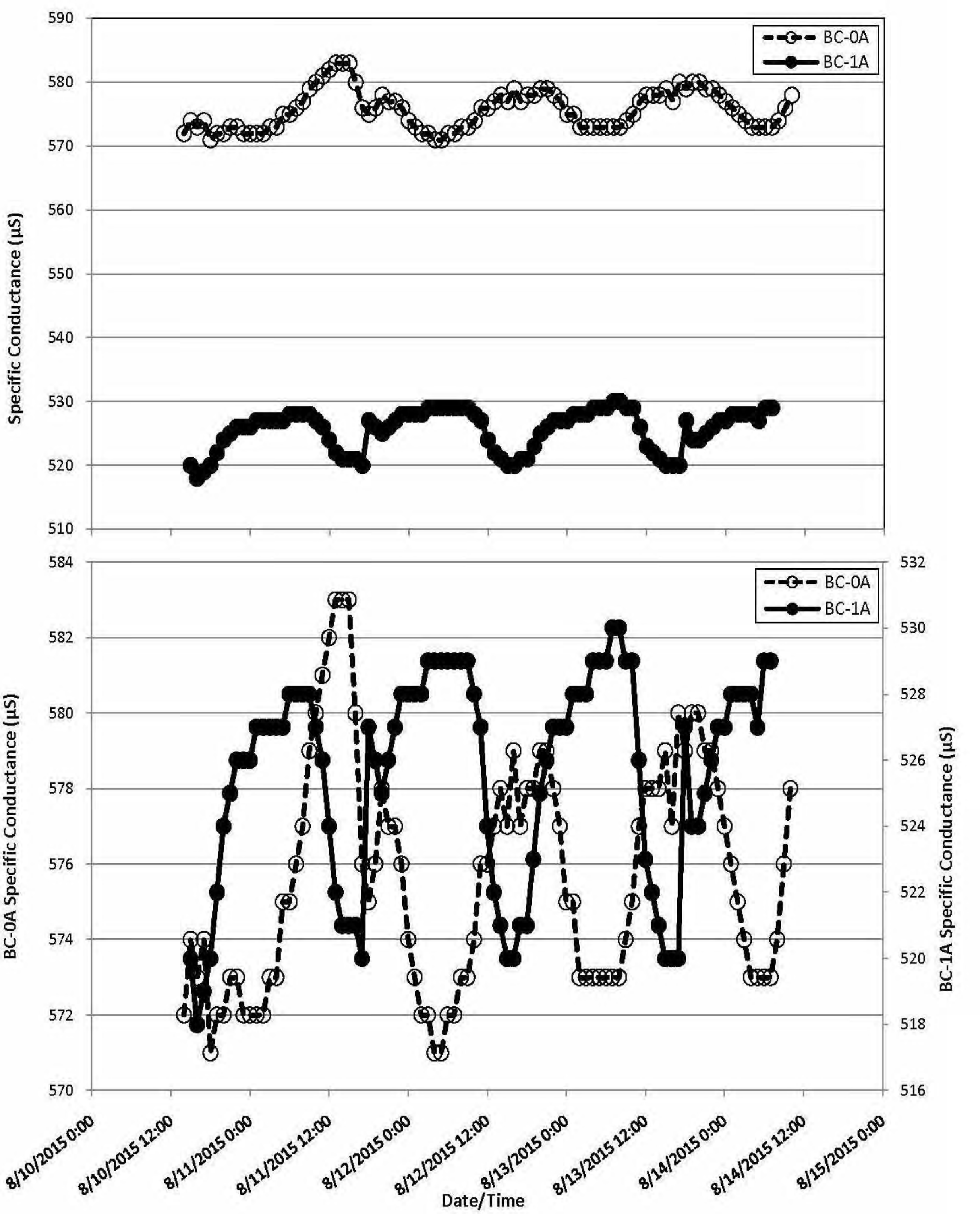

Figure 3.5. Semi-continuous measurements of conductivity at BC-0A and BC-1A, August 10 through 14, 2015.

3.4 Reference Stream (Clear Creek) versus Brushy and Stennitt Creeks

Water quality parameters measured during the 2016 sampling at Clear Creek, Brushy Creek and Stennitt Creek are provided in Table 3.3. Sulfate concentrations at locations not influenced by Outfall 001 were generally near or below detection limits but were higher in locations influenced by Outfall 001. TDS and conductivity were lowest at the reference (Clear Creek) location. TDS exceeded the ecoregion value of 240 mg/L and the "significant modification" value of 255 mg/L at all locations including the upstream Brushy and Stennitt Creek and the REF location with the exception of the sample collected at REF on December 7, 2016 where the TDS concentration was 240 mg/L (ecoregion value).

3.5 Relationships among Conductivity, TDS, and Sulfate

Bivariate scatter plots of conductivity vs. TDS and TDS vs. sulfate are provided in Figure 3.6. The conductivity vs. TDS plot uses data from Tables 3.1 and 3.2 which is primarily data from the receiving streams and the reference stream. Two TDS vs. sulfate plots are provided: One using only data from Tables 3.1 and 3.2 and another using only data from routine monthly monitoring of Outfall 001 collected from January 2012 through January 2017. Both conductivity and sulfate appear to be independent of TDS.

Table 3.3. Summary of water quality parameters measured during the 2016 sampling at Clear Creek, Brushy Creek, and Stennitt Creek.

Parameter	Sample Collection Date	Influenced by Outfall 001					Not Influenced by Outfall 001		
		Outfall 001	UT-0A	BC-1A	BC-2A	SC-1	BC-0A	SC-0A	REF
Chloride (mg/L)	10/26/2016	NM	5	< 0.1	< 0.1	< 0.1	< 0.1	5	< 0.1
	12/7/2016	< 10	5	< 0.1	< 0.1	< 0.1	< 0.1	10	< 0.1
	Average	10.0	5.0	0.1	0.1	0.1	0.1	7.5	0.1
Sulfate (mg/L)	10/26/2016	89.2	89.6	85.3	26.7	6.5	< 5	< 5	< 5
	12/7/2016	124.0	100	85.7	76.4	5.4	5.2	< 5	< 5
	Average	107.0	95.2	85.5	51.6	5.9	5.1	5.0	5.0
Hardness (mg/L as $CaCO_3$)	10/26/2016	530	316	316	276	300	324	300	308
	12/7/2016	296	264	216	240	260	292	272	296
	Average	413	290	266	258	280	308	286	302
TDS	10/26/2016	510	358	360	280	292	290	282	276

Table 3.3. Summary of water quality parameters measured during the 2016 sampling at Clear Creek, Brushy Creek, and Stennitt Creek (continued).

Parameter	Sample Collection Date	Influenced by Outfall 001					Not Influenced by Outfall 001		
		Outfall 001	UT-0A	BC-1A	BC-2A	SC-1	BC-0A	SC-0A	REF
(mg/L)	12/7/2016	490	420	510	470	260*	470	580	240
	Average	500	389	435	375	--	380	431	258
Conductivity (µS/cm)	10/26/2016	NM	568	575	494	539	566	539	519
	12/7/2016	NM	604	596	487	499	541	505	506
	Average	NM	586	586	491	519	553	522	512
pH (su)	10/26/2016	NM	7.9	7.2	7.4	7.6	7.2	7.3	7.4
	12/7/2016	NM	8.6	8.3	8.0	7.8	7.9	7.7	8.3
	Average	NM	8.3	7.8	7.7	7.7	7.5	7.5	7.9
Flow (gpm)	10/26/2016	224	184	121	124	224	35	184	264
	12/7/2016	224	942	381	NM	1593	58	193	260
	Average	224	563	251	--	909	47	188	263

*Outlier not included in analyses, NM=Not Measured

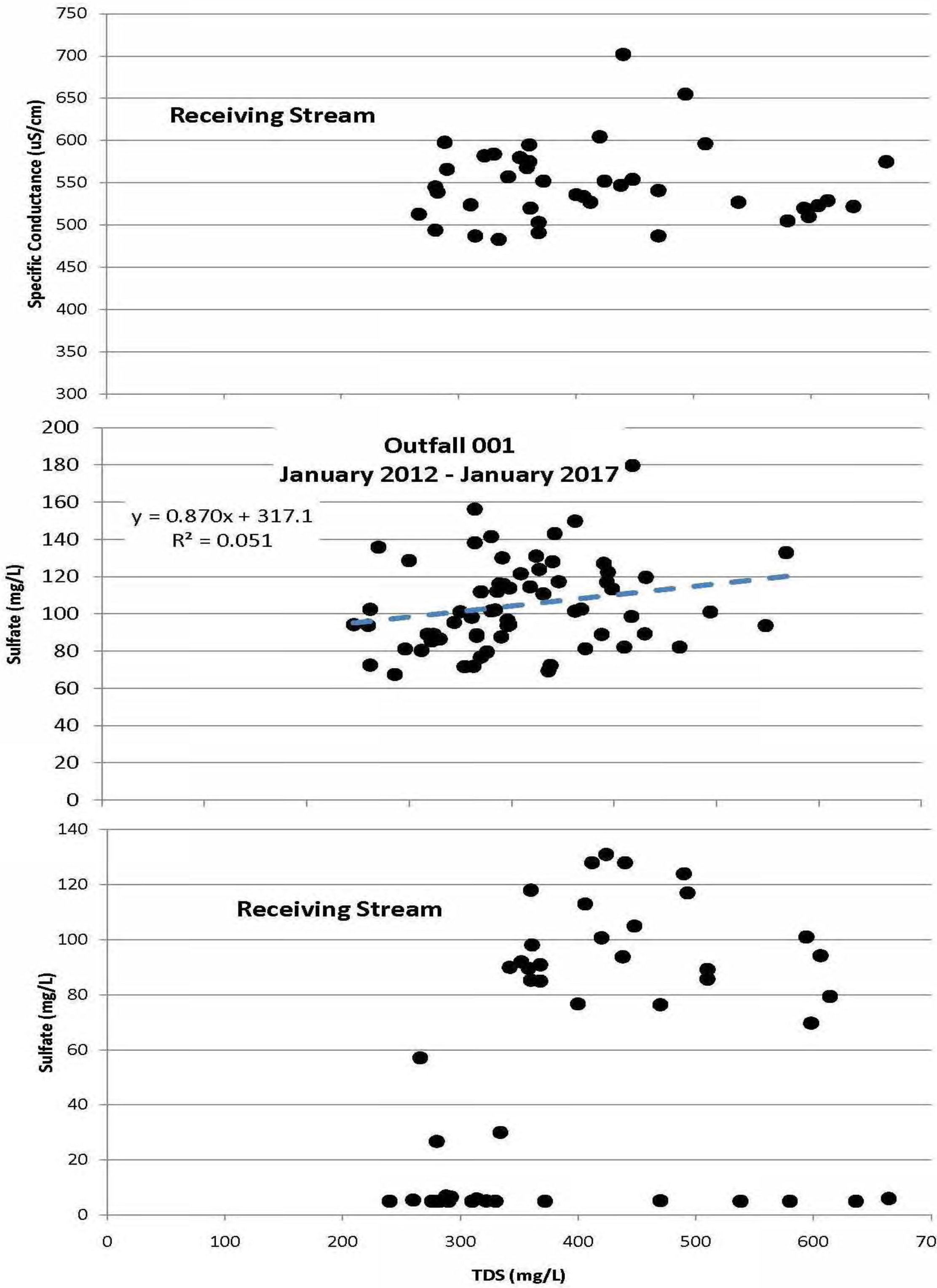

Figure 3.6. Scatter plots of the relationships between TDS versus sulfate and TDS versus conductivity.

4.0 RESULTS: HABITAT

4.1 Brushy Creek and Clear Creek

4.1.1 Rapid Bioassessment Physical Characteristics

Results of the assessment of physical characteristics in Brushy Creek and Clear Creek (reference) (Table 4.1) indicate primarily cobble/gravel substrates with bedrock present at all locations. Pool and riffle habitat dominated all locations with little or no “run” habitat present. Clear Creek sampling reaches were somewhat larger than Brushy Creek reaches with respect to depth, width and flows. There were no oils, sheens or odors at any locations. The immediate surrounding watershed was forest and inactive pasture (no livestock or signs of livestock present) at Clear Creek and active pasture (livestock and/or signs of livestock present) at both Brushy Creek locations.

4.1.2 Rapid Bioassessment Habitat Categories

Table 4.2 presents RBA habitat scores and the results of the statistical comparison among sampling locations. The non-significant X^2 value ($P = 0.97$) indicates that the distribution of habitat scores is independent of sampling location. Total habitat scores at BC-0A and BC-1A were nearly identical. The higher total score at REF (180) compared to BC-0A and BC-1A (144 and 145, respectively) is a reflection of higher scores in almost all categories and higher overall habitat quality at REF. The greatest differences between REF and the Brushy Creek locations were in epifaunal substrate/available cover, vegetative protection, and riparian vegetative zone width.

Table 4.1. Physical habitat characterization of Brushy Creek and Clear Creek sampling reaches.

Category		**BC-0A (11/24/2015)**	**BC-1A (11/24/2015)**	**REF (10/26/2016)**
Canopy cover		None	Partly shaded	Shaded
Inorganic substrate (percent coverage)	Bedrock	2	20	5
	Boulder	1	5	5
	Cobble	30	25	20
	Gravel	60	35	60
	Sand	7	15	10
	Silt	0	0	0
	Clay	0	< 1	0
Organic substrate (percent composition)	CPOM	0	0	30
	FPOM	0	0	0
	Shell	0	< 5	0
Dominant aquatic vegetation		Rooted emergent (watercress)	Rooted emergent (watercress)	0
Percent of reach with aquatic vegetation		1	15	0
Large woody debris		0 m^2	1 m^2	0 m^2
Pool/riffle/run ratio		60/40/0	65/35/0	70/30/0
Channelized?		No	No	No
Dam present?		Riprap/road between BC-0 and BC-1	Riprap/road between BC-0 and BC-1	Road and low water crossing upstream
Average stream depth		10 cm	20 cm	20 cm
Average stream width		1 m	1 m	1 m
Average current velocity		< 10 cm/sec	< 10 cm/sec	10-20 cm/sec
Water odors		Normal/none	Normal/none	Normal/none
Water surface oils		None	None	None
Turbidity		Clear	Clear	Clear
Substrate odors		Normal	Normal	Normal
Substrate oils		Absent	Absent	Absent
Substrate deposits		None	Silt	None
Embedded stones black on underside?		No	Yes	No
Dominant riparian vegetation		Grasses (heath aster, ragweed)	Trees, shrubs	Trees, shrubs
Watershed features	Land use	Pasture	Pasture	Forest, abandoned pasture
	Pollution sources	Active quarry	Active quarry	None
	Erosion	Moderate	Moderate	Slight
Weather		40% cloud cover; rain during previous week	40% cloud cover; rain during previous week	80% cloud cover; no rain during previous week

Table 4.2. Rapid bioassessment habitat category scores (high gradient) from Brushy Creek and Clear Creek sampling reaches.

Category	**BC-0A (11/24/2015)**	**BC-1A (11/24/2015)**	**REF (10/26/2016)**
Epifaunal Substrate/Available Cover	13	15	19
Embeddedness	16	17	18
Velocity/Depth Regime	15	15	15
Sediment Deposition	15	10	18
Channel Flow Status	15	15	18
Channel Alteration	20	20	20
Frequency of Riffles (or bends)	18	18	20
Bank Stability	14	13	14
Vegetative Protection	12	14	20
Riparian Vegetative Zone Width	6	8	18
Total Habitat Score	144	145	180
X^2	8.46		
P	0.97		
df	18		

4.1.3 Wolman Pebble Counts

Table 4.3 presents a summary of Wolman pebble counts and results of the statistical comparison among sampling locations. The highly significant X^2 values ($P < 0.001$) indicate significant differences in the distribution of substrate size categories among all three sampling locations as well as between Brushy Creek reaches. Riffle substrates had similar gravel + cobble composition among locations, higher percentages of sand + silt/clay at BC-0A and higher median substrate size (D50) at REF. Pools in BC-1A showed the smallest D50, lowest percentage of gravel + cobble, and highest percent sand + silt/clay. Silt/clay abundance was highest at the BC-0A and lowest at REF. Cobble abundance was highest at REF and lowest at BC-0A.

4.2 Stennitt Creek

Table 4.4 provides RBA habitat scores for Stennitt Creek at the sampling reaches upstream (SC-0) and downstream (SC-1) of the mouth of Brushy Creek. Total habitat as well as individual scores were similar in the two reaches and not statistically different (P = 0.98).

Table 4.3. Summary and analysis of Wolman pebble counts from Brushy Creek and Clear Creek sampling reaches.

Category		All Riffles			All Pools		
		BC-0A	**BC-1A**	**REF**	**BC-0A**	**BC-1A**	**REF**
D50 (mm)		32	32	64	64	11	64
Substrate Category Frequency (N = 300)	Silt/clay	27	10	0	32	69	0
	Sand	24	14	20	37	36	21
	Gravel	181	191	171	165	116	149
	Cobble	52	57	94	52	32	73
	Boulder	0	2	2	0	2	5
	Bedrock	16	26	13	14	45	52
All sites	X^2	56.553			128.271		
	P	< 0.001			<0.001		
	df	10			10		
BC-0 vs. BC-1	X^2	15.322			45.163		
	P	0.009			<0.001		
	df	5			5		

Table 4.4. RBA habitat category scores (low gradient) from Stennitt Creek sampling reaches.

Category	SC-0 (10/26/2016)	SC-1 (10/26/2016)
Epifaunal Substrate/Available Cover	13	9
Pool Substrate	15	14
Pool variability	11	13
Sediment Deposition	14	17
Channel Flow Status	17	12
Channel Alteration	20	20
Channel sinuosity	6	7
Bank Stability	16	17
Vegetative Protection	16	16
Riparian Vegetative Zone Width	9	11
Total Habitat Score	137	136
X^2	2.38	
P	0.98	
df	9	

Physical characteristics of the Stennitt Creek locations (Table 4.5) were similar with respect to substrate and immediate watershed characteristics. Both reaches at the time of sampling had similar width and depth. However, SC-1 contained pool, riffle and run habitat whereas SC-0 contained only pool and run habitat.

Table 4.5. Physical characterization of Stennitt Creek sampling reaches.

Category		**SC-0**	**SC-1**
Canopy cover		partly open	partly open
Inorganic substrate (percent coverage)	Bedrock	0	0
	Boulder	0	0
	Cobble	0	0
	Gravel	0	0
	Sand	90	90
	Silt	10	10
	Clay	0	0
Organic substrate (percent composition)	CPOM	50	60
	FPOM	0	0
	Shell	0	0
Dominant aquatic vegetation		Rooted emergent; water willow	Rooted emergent; water willow
Percent of reach with aquatic vegetation		20	30
Large woody debris		5 m^2	5 m^2
Pool/riffle/run ratio		90/0/10	60/25/15
Channelized?		No	No
Dam present?		Beaver dam upstream of SC-1	No
Average stream depth		30 cm	30 cm
Average stream width		3 m	2 m
Average current velocity		< 10 cm/sec	< 10 cm/sec
Water odors		Normal/none	Normal/none
Water surface oils		None	None
Turbidity		Clear	Clear
Substrate odors		Normal	Normal
Substrate oils		Absent	Absent
Substrate deposits		Sand	Sand
Embedded stones black on underside?		No	No
Dominant riparian vegetation		Trees, shrubs	Trees, shrubs
Watershed features	Land use	Pasture	Pasture
	Pollution sources	Roads, pasture	Roads, pasture, active quarry
	Erosion	Moderate	Moderate
Weather		40%; no rain during previous week	40%; no rain during previous week

5.0 RESULTS: FISH

As noted in Section 2.4.3, for purposes of analysis and comparison, fish community data collected at BC-0A and BC-1A as part of the First Supplemental Study were compared with data collected at REF as part of the Second Supplemental Study. As noted in Section 1.5.3.2, staff at EPA Region VI and the ADEQ planning division agreed that representative fish samples probably could not be obtained in the relevant reaches of Stennitt Creek due to dense emergent vegetation; therefore, fish sampling was not conducted in Stennitt Creek.

5.1 Species Composition and Relative Abundance

The complete fish collection data set is provided in Appendix C. Table 5.1 summarizes numbers and percent relative abundance of fish species captured in the reaches of Brushy Creek upstream (BC-0A) and downstream (BC-1A) of the mouth of UT and Clear Creek (REF). Sixteen, 17, and 15 species were collected at BC-0A, BC-1A, and REF respectively.

Species composition at the Brushy Creek locations differed only in the absence of the striped shiner (*Luxilus chrysocephalus*) and northern studfish (*Fundulus catenatus*) at BC-0A and the absence of mosquitofish (*Gambusia affinis*) at BC-1A

REF differed from both Brushy Creek locations with the presence of southern redbelly dace (*Chrosomus erythrogaster*; 15.8%), Mississippi silvery minnow (*Hybognathus nuchalis*; 0.4%), Ozark madtom (*Noturus albater*; 7.6%) and pirate perch (*Aphredoderus sayanus*; 1.1%) and the absence of redear sunfish (*Lepomis microlophus*), largemouth bass (*Micropterus salmoides*), and greenside darter (*Etheostoma blennioides*).

The three most abundant species at BC-0A were the central stoneroller (*Campostoma anomalum*), longear sunfish (*Lepomis megalotis*), and current darter (*E. uniporum*), accounting for 45.5%, 13.2%, and 21.0% of the total species composition, respectively. *C. anomalum* and *L. megalotis* dominated BC-1A (43.0% and 23.8%, respectively). The three most abundant species at REF were *C. anomalum* (22.0%), creek chub (*Semotilus atromaculatus*; 14.2%), and *E. uniporum* (8.4%).

Table 5.1. Summary of fish species abundance in Brushy Creek and Clear Creek.

			Total Collected			Percent Relative Abundance		
Family	**Scientific Name**	**Common Name**	**BC-0A**	**BC-1A**	**REF**	**BC-0A**	**BC-1A**	**REF**
Cyprinidae	*Campostoma anomalum*	central stoneroller	715	368	99	45.5	43	22
	Chrosomus erythrogaster[2,3]	Southern redbelly dace	0	0	71	0	0	15.8
	Hybognathus nuchalis	Mississippi silvery minnow	0	0	2	0	0	0.4
	Luxilus chrysocephalus	striped shiner	0	26	0	0	3	0
	Luxilus zonatus[1,3]	bleeding shiner	5	45	3	0.3	5.3	0.7
	Notropis boops[3]	bigeye shiner	0	0	1	0	0	0.2
	Pimephales notatus	bluntnose minnow	50	32	0	3.2	3.7	0
	Semotilus atromaculatus	creek chub	22	1	64	1.4	0.1	14.2
Catostomidae	*Erimyzon oblongus*	creek chubsucker	27	10	10	1.7	1.2	2.2
Ictaluridae	*Ameiurus natalis*	yellow bullhead	4	2	0	0.3	0.2	0
	Noturus albater[2,3]	Ozark madtom	0	0	34	0	0	7.6
Aphredoderidae	*Aphredoderus sayanus*	pirate perch	0	0	5	0	0	1.1
Fundulidae	*Fundulus catenatus*[3]	northern studfish	0	1	0	0	0.1	0
	Fundulus olivaceus	blackspotted topminnow	152	52	29	9.7	6.1	6.4
Poeciliidae	*Gambusia affinis*	mosquitofish	10	0	0	0.6	0	0
Centrarchidae	*Lepomis cyanellus*	green sunfish	34	22	25	2.2	2.6	5.6
	Lepomis macrochirus	bluegill	8	7	3	0.5	0.8	0.7
	Lepomis megalotis	longear sunfish	207	204	32	13.2	23.8	7.1
	Lepomis microlophus	redear sunfish	1	3	0	0.1	0.4	0
	Micropterus salmoides	largemouth bass	2	5	0	0.1	0.6	0
Percidae	*Etheostoma blennioides*[3]	greenside darter	1	12	0	0.1	1.4	0
	Etheostoma flabellare[3]	fantail darter	4	18	34	0.3	2.1	7.6
	Etheostoma uniporum [1,4]	current darter	330	48	38	21	5.6	8.4

Notes:

1. Ozark Highlands ecoregion key species.
2. Ozark Highlands ecoregion indicator species,
3. Sensitive species.
4. Formally known as a subspecies of the orangethroat darter (*E. spectabile*) and retains key species status for this evaluation.

5.2 Key and Indicator Species

Abundance of Ozark Highlands ecoregion key species, Ozark Highlands ecoregion indicator species, and sensitive species is summarized in Table 5.2. Two ecoregion key species (bleeding shiner, *Luxilus zonatus*) and *E. uniporum*[10] were collected at all three locations. No indicator species were collected in the Brushy Creek reaches. The REF location contained two ecoregion indicator species *C. erythrogaster*, and *N. albater*. Table 5.2 suggests that relative abundance of *L. zonatus* was similar in REF and BC-0A locations but greater at BC-1A downstream of the UT inflow while relative abundance of *E. uniporum* was highest at BC-0A but similar at the REF and BC-1A locations. Regarding sensitive species: all three locations contained fantail darter (*E. flabellare*) with the greatest relative abundance observed at REF followed by BC-1A, both Brushy Creek locations contained greenside darter (*E. blennioides*) with a greater relative abundance at BC-1A (only 1 individual collected at BC-0A vs. 12 at BC-1A), and 1 northern studfish (*Fundulus catenatus*) and 1 bigeye shiner (*Notropis boops*) was collected at BC-1A and REF, respectively (Table 5.2).

Table 5.2. Summary of Ozark Highlands ecoregion key species, Ozark Highlands ecoregion indicator species, and sensitive species collected at the Brushy Creek and Clear Creek locations.

Scientific Name	**Common name**	**Total Collected**			**Percent Relative Abundance**		
		BC-0A	**BC-1A**	**REF**	**BC-0A**	**BC-1A**	**REF**
Chrosomus erythrogaster[b,c]	Southern redbelly dace	0	0	71	0	0	15.8
Luxilus zonatus[a,c]	bleeding shiner	5	45	3	0.3	5.3	0.7
Notropis boops[c]	bigeye shiner	0	0	1	0	0	0.2
Noturus albater[b,c]	Ozark madtom	0	0	34	0	0	7.6
Fundulus catenatus[c]	northern studfish	0	1	0	0	0.1	0
Etheostoma blennioides[c]	greenside darter	1	12	0	0.1	1.4	0
Etheostoma flabellare[c]	fantail darter	4	18	34	0.3	2.1	7.6
Etheostoma uniporum[a]	current darter	330	48	38	21.0	5.6	8.4

[a] Ozark Highlands ecoregion key species; [b] Ozark Highlands ecoregion indicator species; [c] sensitive species

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[10] *E. uniporum* was formerly known as a subspecies of the orangethroat darter (*E. spectabile*). APCEC Regulation No. 2 (2017) does not identify *E. uniporum* as a Ozark Highlands ecoregion key species; however, for the purposes of this evaluation, the key species status of *E. spectabile* was maintained for *E. uniporum.*

5.3 Community Structure Index

Metric values and scores using ADEQ's CSI are provided for pool and riffle and aggregates in Appendix D. CSI scores from reaches in Brushy Creek and Clear Creek (reference) are summarized in Table 5.3. CSI data met assumptions of equal variance and normality (Table 5.4). Results of the ANOVA comparing mean CSI values (untransformed data) between habitats (pool versus riffle) and among locations (Table 5.4) indicated statistically significant differences in CSI values among locations but not between habitats. Results of multiple comparisons (Tukey's HSD) and mean CSI values among locations are presented in Table 5.5. Mean CSI values at BC-0A and BC-1A were not statistically different ($P > 0.05$); CSI values at BC-0A and BC-1A were both statistically different from REF ($P \leq 0.05$).

Table 5.3. Summary of CSI scores at the Brushy Creek and Clear Creek locations.

Metric	BC-0A		BC-1A		REF	
	Pools	**Riffles**	**Pools**	**Riffles**	**Pools**	**Riffles**
Replicate Values	16	26	19	24	27	19
	16	22	12	18	25	25
	19	19	17	26	31	33
Average Within Habitats	17.0	22.3	16.0	22.7	27.7	25.7
Average Among Habitats Combined[1]	19.7[a]		19.3[a]		26.7[b]	

[1] - Values with the same super script are not statistically different ($P > 0.05$)

Table 5.4. ANOVA results comparing mean CSI values (untransformed data) between habitats (pool versus riffle) and among locations.

Levene's test of variance homogeneity	P = 0.433				
Shapiro-Wilk's test of normality	P = 0.969				
Analysis of Variance					
Source	**SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
Location	205.778	2	102.889	5.917	0.016
Habitat	50.000	1	50.000	2.875	0.116
Location X Habitat	65.333	2	32.667	1.879	0.195
Error	208.667	12	17.389		

Table 5.5. Results of multiple comparisons (Tukey's HSD) of mean CSI values among locations.

Comparison	Difference	P-value	95.0% Confidence Interval	
			Lower	Upper
BC-0A vs. BC-1A	0.333	0.990	-6.090	6.757
BC-0A vs. REF	-7.000	0.033	-13.423	-0.577
BC-1A vs. REF	-7.333	0.026	-13.757	-0.910

Table 5.6 summarizes CSI values among replicates combined within habitats and habitats combined. These values are not the equivalent of arithmetic averages among replicates and within habitats. CSI scores among replicates at BC-1A ranged from 19 to 26; score for combined habitats was 21, which ADEQ (2018) classifies as "generally similar" to reference conditions. CSI values increased as the level of aggregation increased (i.e., CSI values for combined replicates within habitats were higher than individual replicate values; values for combined habitats within reaches were higher than values for individual habitats).

Table 5.6. CSI scores for replicates combined within habitats and habitats combined.

Metric	BC-0A		BC-1A		REF	
	Pools	Riffles	Pools	Riffles	Pools	Riffles
CSI scores for replicates combined within habitats	19	22	19	26	29	29
CSI scores for habitats combined	23		21		35	

The overall CSI scores for BC-0A and BC-1A (i.e., scores for habitats combined) were similar (23 and 21, respectively), while the overall score at REF (35) was substantially higher. ADEQ (2018) classifies the CSI scores of 23 and 21 for BC-0A and BC-1A, respectively, for Ozark Highlands fish communities as "generally similar"[11] to reference conditions; the score of 35 from REF is classified as "mostly similar"[12].

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[11] ADEQ 2018 describes the "Generally Similar" classification as follows: "Community structure less than expected. Taxa richness lower than expected. Some intolerant taxa loss. Percent contribution of tolerant forms may increase."

[12] ADEQ 2018 describes the "mostly similar" classification as follows: "Comparable to the best situation to be expected. Balanced trophic structure and optimum community structure present."

5.4 Population Size

Comparisons of CPUE at Brushy Creek and Clear Creek (reference) are summarized in Table 5.7. Log (10)-transformed CPUE data met assumptions of equal variance and normality (Table 5.8). CPUE was statistically different ($P \leq 0.05$) between habitats (pool versus riffle) and among locations (Table 5.8). Multiple comparisons among locations (Table 5.9) indicated that all possible pairwise comparisons were statistically significant. CPUE was highest at BC-0A, lowest at REF and intermediate at BC-1A.

Table 5.7. Summary of CPUE* at the Brushy Creek and Clear Creek locations.

Metric	BC-0A		BC-1A		REF	
	Pools	**Riffles**	**Pools**	**Riffles**	**Pools**	**Riffles**
Replicate Values	12.9	15.2	9.4	4.7	7.5	2.5
	18.2	14.5	12.5	8.7	5.4	2.9
	18.8	8.5	13.4	8.6	5.2	2.9
Average Within Habitats	16.59	12.72	11.76	7.34	6.01	2.75
Average Among Habitats Combined	14.7		9.6		4.4	

* Catch per unit effort (number of fish per minute of pedal-down time)

Table 5.8. ANOVA results comparing mean CPUE values [log(10)-transformed] between habitats (pool versus riffle) and among locations.

Levene's test of variance homogeneity	P = 0.105				
Shapiro-Wilk's test of normality	P = 0.053				
Analysis of Variance					
Source	**SS**	**df**	**Mean Squares**	**F-ratio**	**p-value**
Location	0.922	2	0.461	41.110	0.000
Habitat	0.228	1	0.228	20.301	0.001
Location X Habitat	0.034	2	0.017	1.505	0.261
Error	0.135	12	0.011		

Table 5.9. Results of multiple comparisons (Tukey's HSD) of mean CPUE values between habitats and among locations.

Comparison	Difference	P-value	95.0% Confidence Interval	
			Lower	**Upper**
Pools vs. Riffles	0.225	0.001	0.116	0.334
BC-0A vs. BC-1A	0.195	0.020	0.031	0.358
BC-0A vs. REF	0.547	0.000	0.384	0.710
BC-1A vs. REF	0.352	0.000	0.189	0.515

5.5 Fish Size

This analysis focused on six fish species (*C. anomalum, P. notatus, F. olivaceus, L. cyanellus, L. megalotis, E. uniporum*) that had sample sizes of 20 to 25 fish. Table 5.10 summarizes mean weight for each location[13] and the results of the statistical analyses comparing mean weights among locations. All but one data set (*F. olivaceus*) required log (10) transformation to achieve normality and equal variance. All species except *L. megalotis* showed statistically significant differences in size (as measured by mean weight) among locations[14]. Tukey's HSD was used as a post hoc test to ANOVA to assess statistical significance for all possible pairs of means. Post hoc tests were not necessary for *P. notatus* due to its presence at only two locations or *L. megalotis* due to no statistical difference in mean weight between locations. Mean weights of all six species at BC-1A were higher than, similar to or intermediate between weights at BC-0A and REF locations. In the one instance (*L. megalotis*) in which mean weight was lowest at BC-1A, the differences among locations were not statistically significant.

Table 5.10. Summary of mean weight and the results of the statistical analyses comparing mean weights among locations.

	Mean Weight (g)[1]			P Value		
Species	**BC-0A**	**BC-1A**	**REF**	**Normality (Shapiro Wilk's)**	**Variance Homogeneity (Levene's)**	**Significance Test**
Campostoma anomalum	1.8^{a}	8.8^{b}	5.3^{c}	0.124	0.051	< 0.001[2]
Pimephales notatus	1.6^{a}	2.7^{b}	NA	0.715	0.030	< 0.001[3]
Fundulus olivaceus	1.6^{a}	2.1^{a}	4.1^{b}	0.233	0.412	< 0.001[2]
Lepomis cyanellus	18.5^{ab}	21.5^{b}	13.6^{a}	0.504	0.423	0.002[2]
Lepomis megalotis	8.9^{a}	7.9^{a}	11.2^{a}	< 0.001	0.111	0.527[4]
Etheostoma uniporum	0.4^{a}	0.8^{b}	1.2^{c}	0.081	0.291	< 0.001[2]

Notes:

1. Values with the same letter superscripts are not statistically different (P > 0.05).
2. ANOVA performed using log (10)-transformed data.
3. Analysis performed using Wilcoxon-Mann-Whitney test.
4. Analysis performed using Kruskal-Wallis test.

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[13] *P. notatus* was not collected at REF.

[14] Although the log (10)-transformed data were not normally distributed, differences among locations can be considered to be non-significant because of the high P-value (0.527).

5.6 Condition Factor

This analysis focused on six fish species (*C. anomalum, P. notatus, F. olivaceus, L. cyanellus, L. megalotis, E. uniporum*) having at least 20 paired length and weight measurements. Length-adjusted weight for these six species is summarized in Table 5.11. There were no statistically significant ($P < 0.05$) differences in length-specific weight among locations except for *L. megalotis* and *E. uniporum*. For *L. megalotis*, adjusted weight was similar between BC-0A and BC-1A and lowest at REF. The significant differences among locations for *E. uniporum* are extremely small (less than 0.1 g difference among location) and are likely an artifact of heterogeneous slopes (Table 5.11).

Table 5.11. Results of ANCOVA of length-specific weight for selected fish species among locations.

	Adjusted Weight (g)[1]			P-values[2]			
				Normality (Shapiro-Wilk's)	Equal Variance (Levene's)	Among Locations (H_o: BC-0A=BC-1A=REF)	
Species	**BC-0A**	**BC-1A**	**REF**			**Slope**	**Adjusted Weight**
C. anomalum	4.2^{a}	4.4^{a}	3.8^{a}	0.738	0.224	0.406	0.353
P. notatus	1.7^{a}	1.8^{a}	NA	0.734	0.005	0.422	0.475
F. olivaceus	1.6^{a}	1.7^{a}	1.7^{a}	< 0.001	0.264	0.540	0.546
L. cyanellus	13.0^{a}	12.5^{a}	11.7^{a}	0.005	0.271	0.307	0.429
L. megalotis	7.0^{a}	7.2^{a}	6.6^{b}	0.638	0.878	0.065	0.039
E. uniporum	0.7^{a}	0.7^{b}	0.6^{a}	0.090	0.013	0.037	0.034

Notes:

1. Values with the same letter superscripts are not statistically different ($P > 0.05$).
2. All analyses performed using log (10)-transformed data.

6.0 RESULTS: BENTHIC MACROINVERTEBRATES

The complete benthic macroinvertebrate collection data set is provided in Appendix E. General summary tables for benthic macroinvertebrate sampling from 2015 and 2016 are provided in Appendix F. This information includes summaries of the 10 most abundant taxa and values for selected metrics from instream and artificial substrate data sets.

6.1 Instream Samples: Brushy Creek and Clear Creek

6.1.1 Metric Comparisons

Values of the metrics used as part of the ADEQ comparison methodology are presented in Table 6.1. Results of all pairwise comparisons using ADEQ comparison methodology are presented in Table 6.2. The row in Table 6.2 corresponding to BC-1A as the study site indicates values of 95%, 95%, and 86% comparability compared to the respective reference sites BC-0A, REF-2, and REF-3. These values indicate a “biological condition category” of “comparable to reference” per Table 6 of ADEQ (2018) (reproduced as Table 2.6 in Section 2.5.4.1) and indicates “support” of the aquatic life use.

Table 6.1. Values of the metrics used as part of the ADEQ comparison methodology for comparing benthic macroinvertebrate communities between Brushy Creek and Clear Creek.

Metric	Brushy Creek		Clear Creek	
	BC-0A	**BC-1A**	**REF-2**	**REF-3**
Total organisms (adjusted)	1,475	2,243	1,083	850
Total unique taxa	43	49	43	44
HBI	6.65	5.78	4.94	4.85
Ratio of EPT to chironomid abundances	14.25	6.79	3.00	3.65
Percent contribution of dominant taxon	36.7	21.1	23.4	18.6
Proportion as EPT	0.51	0.50	0.55	0.56
Number EPT taxa	11	11	14	11
Percent Chironomidae	3.6	7.3	18.4	15.3
Ratio of Scrapers to Filter-Collectors	1.50	1.05	0.43	1.07

Table 6.2. Results of all pairwise comparisons between sampling locations in Brushy Creek and Clear Creek using ADEQ comparison methodology for comparing benthic macroinvertebrate communities between a study site and a reference site.

Percent Comparability				
	Reference Site			
Study Site	**BC-0A**	**BC-1A**	**REF-2**	**REF-3**
BC-0A	----	90	85	81
BC-1A	95	----	95	86
REF-2	74	80	----	90
REF-3	95	95	105	----
Assessment Result*				
	Reference Site			
Study Site	**BC-0A**	**BC-1A**	**REF-2**	**REF-3**
BC-0A	----	CTR	CTR	Sup-CTR
BC-1A	CTR	----	CTR	CTR
REF-2	Sup	Sup-CTR	----	CTR
REF-3	CTR	CTR	CTR	----

*CTR: comparable to reference; Sup: supporting; Sup-CTR: supporting to comparable to reference.

6.1.2 XC95 Analysis: Brushy Creek and Clear Creek Instream Samples

Results of the analysis of XC95 values, which included a comparison of the XC95 index values among BC-0A, BC-1A, REF-2, and REF-3, are summarized in Tables 6.3 and 6.4. XC95 values were available for 50% to 70% of the genera and 63% to 84% of individuals in the data set (Table 6.3). There were no statistical differences in XC95 index values between BC-1A and BC-0A or REF-3 (Table 6.4). The difference between BC-1A and REF-2 was statistically significant (Table 6.4) but the index value at REF-2 was higher than the value at BC-1A (Table 6.3).

Table 6.3. Summary of analysis of XC95 index values from instream sampling at the Brushy Creek and Clear Creek locations.

Location	Total Taxa	Percent of Genera with XC95 Value	Total Individuals	Percent of Individuals with XC95 Value	XC95 Index (µS/cm)	Estimated Variance of XC95 Index	N
BC-0A	43	51	1,475	78	3,729	3,848,785	22
BC-1A	49	50	2,243	63	3,967	2,770,971	24
REF-2	43	63	1,083	84	4,957	1,698,040	27
REF-3	44	70	850	81	3,727	1,081,289	31

N - Number of XC95 values associated with the estimated variance of the XC95 index.

Table 6.4. Results of the statistical comparisons of XC95 index values from instream sampling among Brushy Creek and Clear Creek locations.

Comparison	Difference (µS/cm)	Standard Error of the Difference	Calculated t	df	P (2-tailed)
BC-1A vs. BC-0A	237.63	538.8895	0.440967	44	> 0.5
BC-1A vs. REF-2	-990.58	422.3121	-2.34561	49	< 0.05
BC-1A vs. REF-3	239.89	387.7337	0.618701	53	> 0.5

6.2 Instream Samples: Stennitt Creek

6.2.1 Metric Comparisons

Values of the metrics used as part of the ADEQ comparison methodology are presented in Table 6.5. Results of all pairwise comparisons using ADEQ comparison methodology are presented in Table 6.6. SC-1 was 95% comparable compared to the SC-0 reference site. This value indicates a “biological condition category” of “comparable to reference” per Table 6 of ADEQ (2018) and indicates “support” of the aquatic life use.

Table 6.5. Values of the metrics used as part of the ADEQ comparison methodology for comparing benthic macroinvertebrate communities between a study site and a reference site (Stennitt Creek).

Metric	SC-0	SC-1
Total organisms (adjusted)	5,856	19,392
Total unique taxa	55	52
HBI	6.78	6.55
Ratio of EPT to Chironomid abundances	0.40	0.60
Percent contribution of dominant taxon	17.7	18.5
Proportion as EPT	0.11	0.22
Number EPT taxa	4	6
Percent Chironomidae	27.2	37.3
Ratio of Scrapers to Filter-Collectors	0.24	0.50

Table 6.6. Results of comparisons between sampling locations in Stennitt Creek using ADEQ comparison methodology for comparing benthic macroinvertebrate communities between a study site and a reference site.

Percent Comparability		
	Reference Site	
Study Site	**SC-0**	**SC-1**
SC-0	----	71
SC-1	95	----
Assessment Result*		
	Reference Site	
Study Site	**SC-0**	**SC-1**
SC-0	----	Sup
SC-1	CTR	----

*CTR: comparable to reference; Sup: supporting.

6.2.2 XC95 Analysis: Stennitt Creek Instream Samples

Results of the analysis of XC95 values, which included a comparison of the XC95 index values between SC-0 and SC-1, are summarized in Tables 6.7 and 6.8. XC95 values were available for 42% to 46% of the genera and 50% to 76% of the individuals in the SC-0 and SC-1 data sets, respectively (Table 6.7). There was no statistical difference (P>0.2) in XC95 index values between SC-1 and SC-0 (Table 6.8).

Table 6.7. Summary of analysis of XC95 index values from instream sampling at the Stennitt Creek locations.

Location	Total Taxa	Percent Genera with XC95 Value	Total Individuals	Percent Individuals with XC95 Value	XC95 Index (µS/cm)	Estimated Variance of XC95 Index	N
SC-0	55	42	5,856	50	5,439	1,770,638	23
SC-1	52	46	19,392	76	5,004	1,564,318	24

N - Number of XC95 values associated with the estimated variance of the XC95 index.

Table 6.8. Results of the statistical comparison of XC95 index values from instream sampling between Stennitt Creek locations.

Comparison	Difference (µS/cm)	SE	Calculated t	df	P (2-tailed)
SC-1 vs. SC-0	-435.2	377.0466	-1.15	45	> 0.2

6.3 Artificial Substrates: Brushy Creek

6.3.1 Cluster Analysis

The dendrogram resulting from the hierarchical cluster analysis using the Ward minimum variance method (selected for visual clarity) is provided in Figure 6.1. The dendrogram shows two somewhat distinct clusters: one comprised exclusively of RBUs from BC-0 and the second comprised mainly of RBUs from BC-1 (9 out of 11 RBUs). Additional dendrograms resulting from hierarchical cluster analysis using single linkage, complete linkage, average linkage, centroid linkage, median linkage, and weighted average linkage methods similarly show two distinct clusters: one comprised exclusively of RBUs from BC-0 and the second comprised mainly of RBUs from BC-1 (9 out of 10 or 11 RBUs). The additional dendrograms are provided in Appendix G.

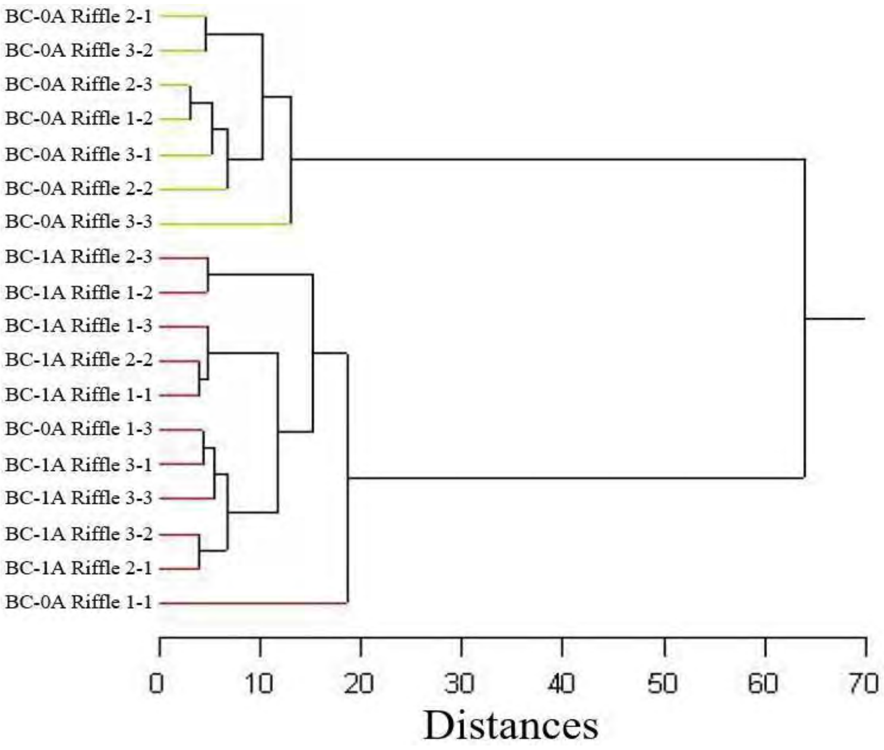

Figure 6.1. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates using Ward minimum variance method with Euclidean distances.

6.3.2 XC95 Analysis: Brushy Creek Artificial Substrates

Results of the analysis of XC95 values, which included a comparison of the XC95 index values between BC-0A and BC-1A, are summarized in Tables 6.9 and 6.10. XC95 values were available for 51% to 57% of the genera and 70% to 83% of the individuals in the data set (Table 6.9). The comparison of XC95 index values from RBs between locations was based on the XC95 index values obtained from pooling all replicates within each riffle. Table 6.10 provides the results of the comparison of average XC95 index values averaged among riffles between locations. The average XC95 index value at the BC-1A (5,938 µS/cm) was 18.7% higher than the value from the BC-0A (5,003 µS/cm). This difference was statistically significant (P = 0.022).

Table 6.9. Summary of analysis of XC95 values from rock bag artificial samplers at the Brushy Creek locations.

Location	Total Taxa	Percent of Taxa with XC95 Value	Total Individuals	Percent of Individuals with XC95 Value
BC-0A	97	57	4,969	70
BC-1A	82	51	27,091	83

Table 6.10. Results of the statistical comparisons of XC95 index values from rock bag artificial samplers at the Brushy Creek locations.

Summary Statistic	BC-0A	BC-1A
XC95 Index Value (µS/cm) (number of XC95 values comprising each index value)	4,953 (82)	5,926 (64)
	4,596 (75)	6,044 (60)
	5,459 (84)	5,843 (66)
Mean	5,003	5,938
Standard deviation	433.6927	100.9079
F-test for equal variance	F = 18.47; P > 0.05	
Shapiro-Wilk test for normality	W = 0.98; P = 0.95	
Difference	934.5	
Standard Error	257.0808	
t-calc (df=4)	3.64	
P(2-tailed)	0.022	

Values in parentheses indicate number of XC95 values that comprise each XC95 index.

6.4 Artificial Substrates: Stennitt Creek

6.4.1 Cluster Analysis

The dendrograms resulting from hierarchical cluster analysis using single linkage, complete linkage, average linkage, centroid linkage, median linkage, Ward minimum variance, and weighted average linkage methods show that there is separation between the SC-0 and SC-1 locations (though no predominant clusters were identified); however, all dendrograms show overlap with the two most similar HDUs belonging to SC-0 and SC-1. The dendrogram resulting from the hierarchical cluster analysis using the Ward minimum variance method (selected for visual clarity) is provided in Figure 6.2. The additional dendrograms are provided in Appendix G.

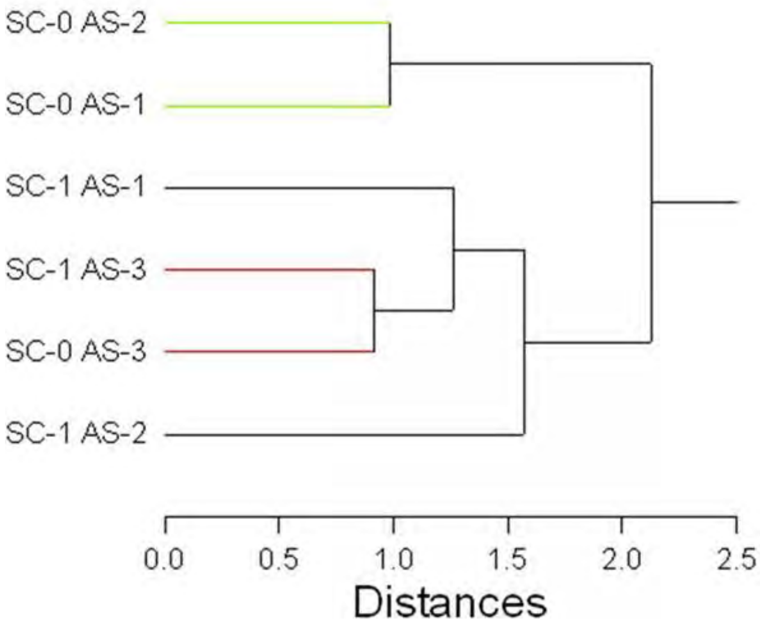

Figure 6.2. Dendrogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from Hester-Dendy artificial substrates using Ward minimum variance method with Euclidean distances.

6.4.2 XC95 Analysis: Stennitt Creek Artificial Substrates

XC95 values were available for 52% to 71% of the genera and 83% to 87% of the individuals in the data set (Table 6.11). The comparison of XC95 index values from HDs between locations was based on the XC95 index values obtained from each replicate within each location. Table 6.12 provides the results of the comparison of average XC95 index values between locations. The average XC95 index value at SC-1 (8,599 µS/cm) was not statistically different (P = 0.20) from SC-0 (9,327 µS/cm).

Table 6.11. Summary of analysis of XC95 values from Hester-Dendy artificial samplers at the Stennitt Creek locations.

Location	Total Taxa	Percent of Taxa with XC95 Value	Total Individuals	Percent of Individuals with XC95 Value
SC-0	50	52	643.8	83
SC-1	21	71	93.0	87

Table 6.12. Results of the statistical comparisons of XC95 index values from Hester-Dendy artificial samplers between Stennitt Creek locations.

Summary Statistic	SC0	SC-1
XC95 Index Value (µS/cm) (number of XC95 values comprising each index value)	10,075 (13)	8,150 (8)
	9,042 (24)	9,159 (6)
	8,865 (13)	8,488 (13)
Mean	9,327	8,599
Standard deviation	653.619	513.757
F-test for equal variance	F = 1.62; P > 0.25	
Shapiro-Wilk test for normality	W = 0.84; P = 0.13	
Difference	728.0	
Standard Error	479.9874	
t-calc (df=4)	1.52	
P(2-tailed)	0.20	

7.0 DISCUSSION: WATER QUALITY AND HABITAT

The primary purposes and objectives of the following discussion of water quality and habitat are as follows:

1. Document, quantify, and compare differences in water quality, primarily TDS and sulfate, in the receiving streams in relation to the outfall; and
2. Document, quantify, and compare differences in habitat and assess habitat differences that might cause differences in aquatic life.

Towards this end, the following questions will be addressed:

1. What are the spatial patterns in water quality upstream versus downstream of the influence of the Vulcan discharge?
2. Are there temporal trends in water quality in the discharge?
3. What are background TDS and sulfate concentrations?
4. How does the outfall impact water quality and flows in Brushy Creek downstream of the UT?
5. Are there discernible or statistically significant differences in habitat among locations that might confound comparison of biological communities among locations?

7.1 Water Quality

7.1.1 Outfall 001

As shown in Figure 3.1 and discussed in Section 3.1, TDS and sulfate concentrations in samples from Outfall 001 vary significantly from month to month as well as year to year. Vulcan representatives most familiar with on-site mining practices have concluded that the recent downward trend is likely a result of where active mining is occurring and the resulting geologic formation that water in the pit is exposed to. Accurate predictions regarding future decreases or increases in mineral concentrations in the outfall are not possible. Accordingly, the evaluation of water quality impacts of Outfall 001 to the receiving streams was based on recent sampling (conducted during 2015 and 2016).

7.1.2 Brushy Creek, Stennitt Creek, and Clear Creek (Reference)

Sampling conducted during 2015 and 2016 indicated the following:

1. Sulfate concentrations at locations not influenced by Outfall 001 (i.e., BC-0A, SC-0A, and REF) were generally near or below detection limits but were distinctly higher in locations influenced by Outfall 001 (i.e., UT-0A, BC-1A, and BC-2A);
2. TDS concentrations were generally higher at BC-1A than BC-0A due to input from UT-0A;
3. TDS concentrations at locations not influenced by Outfall 001 (i.e., BC-0A, SC-0A, and REF) always exceeded the ecoregion value of 240 mg/L the “significant modification” value of 255 mg/L at all locations with the exception of one sample collected at REF on 12/7/2016 where the TDS concentration was 240 mg/L (ecoregion value) (APCEC 2017);
4. Sulfate concentrations at BC-1A and BC-2A always exceed the “significant modification” value of 22.7 mg/L (APCEC 2017);
5. The sulfate concentration at SC-1 did not exceed the “significant modification” value of 22.7 mg/L;
6. The TDS concentration at SC-1 did not exceed the site-specific criterion of 456 mg/L and the TDS concentration at SC-1 represented little or no increase over upstream concentrations;
7. Conductivity in Brushy Creek was consistently higher upstream of the mouth of the UT (BC-0A) than downstream of the UT (BC-1A) during 2015;
8. Flows at the UT location are mainly due to inflows from Outfall 001, but additional inputs due to springs within the pond are likely (FTN observations, communication with Charles Milgrim, landowner);
9. Flow from the UT dominated flow in Brushy Creek downstream of the mouth of the UT; and
10. Brushy Creek acquires additional flow, which dilutes sulfate and TDS between the mouth of the UT and the Brushy Creek confluence with Stennitt Creek.

Table 7.1. TDS data from recent sampling (see Table 3.2) and from FTN (2011).

Sampling Date	BC-0/0A	SC-0/0A	REF
9/28/2010	340	290	280
6/16/2011	240	280	280
11/24/2015	372	314	NM
10/14/2015	288	280	NM
9/15/2015	322	636	NM
8/14/2015	664	538	NM
7/31/2015	330	310	NM
10/26/2016	290	282	276
12/7/2016	470	580	240
Average	368	390	269

Other than the unexpected spatial and temporal patterns in conductivity, water quality monitoring confirmed expected differences in TDS and sulfate; namely, the UT inflow increases TDS and sulfate concentrations in Brushy Creek, which exceed Ozark Highlands ecoregion water quality criteria.

It is important to note that the increase in sulfate concentrations in Stennitt Creek downstream of the mouth of Brushy Creek did not result in a “significant modification” of the naturally occurring concentration per §2.511(B) of Regulation No. 2 (APCEC 2017) nor did the TDS concentration exceed the site-specific criterion or appreciably increase TDS concentrations. However, these results are based on only 2 samples and 1 sample for sulfate and TDS, respectively, so that the potential for downstream exceedances of “significant modification” concentrations for sulfate or the site-specific criterion for TDS and the corresponding appropriateness of any change in existing criteria must be evaluated through mass-balance modeling (see Section 10).

Continuous in situ monitoring in Brushy Creek upstream and downstream showed that conductivity was consistently 40 to 80 µS/cm higher at the location upstream of the mouth of the UT (BC-0A; Figure 3.5). This pattern could not be attributed to instrumentation because post-deployment calibration checks did not indicate significant differences between instruments and it was consistent with monthly in situ measurements at those locations taken simultaneously with a third instrument. The pattern contrasted with measured TDS, which was typically higher at BC-1A than BC-0A. Although the physical-chemical explanation for these results is not evident, they are part of a larger general pattern that shows a poor correlation between TDS vs. conductivity and TDS vs. sulfate (see below).

There was little, if any, increase in TDS and conductivity and a modest (0.9 mg/L) increase in sulfate in Stennitt Creek downstream of the mouth of Brushy Creek on the 2 days sampled. Long-term frequent monitoring of Stennitt Creek upstream and downstream of the mouth of Brushy Creek is not feasible due to unreliable access to the downstream location so that only limited field data from SC-1 are available. The need to consider criteria changes in the downstream reach of Stennitt Creek was based primarily on mass balance modeling indicating potential exceedances of the sulfate and TDS criteria due to the inflow from Brushy Creek. Additional evaluation of the impact of the Brushy Creek inflow on the potential to exceed TDS and sulfate criteria in Stennitt Creek based on mass balance modeling is provided in Section 10.

The monitoring revealed that TDS concentrations at BC-0A, SC-0A, and REF consistently exceed ecoregion values. Additional data collected during 2010 and 2011 at BC-0, SC-0 and REF are presented in Table 7.1 along with TDS data collected at BC-0A, SC-0A, and REF in 2015 and 2016. The data clearly show that these concentrations are comparable to the groundwater values presented in Table 1.4. REF concentrations are typically lower than both BC-0/0A and SC-0/0A concentrations, which is likely due to different geochemical factors. There are no known point sources of TDS to these streams so these values should be considered background and provide a partial justification for site-specific TDS criteria.

7.1.3 Relationships Among Conductivity, TDS, and Sulfate

Information presented in Section 3.5 demonstrates that neither conductivity nor sulfate are correlated with TDS. This finding means that a regression-based approach cannot be used to estimate TDS or sulfate from conductivity. The approach used to translate conductivity to TDS and sulfate is provided in Section 10.

7.2 Summary of Water Quality Findings

Water quality monitoring and analyses provided the following findings:

1. The UT inflow causes elevated TDS and sulfate concentrations in Brushy Creek, which exceed Ozark Highlands ecoregion criteria,
2. TDS concentrations at BC-0A, SC-0A, and REF routinely exceed ecoregion values, are comparable to concentrations found in groundwater and should be considered to represent background concentrations,
3. Differences between concentrations at REF versus BC-0A and SC-0A are likely due to geochemical factors as there are no point sources in the study area,
4. Conductivity cannot be used to estimate TDS or sulfate using a regression-based approach,
5. Flow from the UT dominates flow in Brushy Creek downstream of the mouth of the UT, and
6. Brushy Creek acquires additional flow, which dilutes sulfate and TDS between the mouth of the UT and the Brushy Creek confluence with Stennitt Creek.

The general ranking of water quality with respect to TDS and sulfate concentrations for purposes of interpreting aquatic life in Brushy Creek, Stennitt Creek, and Clear Creek (REF) is as follows:

Brushy Creek and Clear Creek (REF):
    Water Quality (TDS): REF > BC-0A > BC-1A[15]
    Water Quality (Sulfate): REF = BC-0A > BC-1A
Stennitt Creek:
    Water Quality (TDS): SC-0 = SC-1
    Water Quality (Sulfate): SC-0 > SC-1

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[15] For water quality comparisons ">" and "=" should be interpreted as "of higher water quality (i.e., lower TDS and/or sulfate concentrations) than" and "of similar quality to," respectively.

7.3 Habitat

7.3.1 Brushy Creek and Clear Creek

The physical habitat characterization indicated mainly cobble-gravel substrates with little or no "run" habitat at BC-0A, BC-1A, and REF. The riparian zone of REF was mainly forested while that of the Brushy Creek locations was mainly pasture (Table 4.1). The total habitat score was greatest at REF (Table 4.2) and was primarily due to higher scores for the vegetative protection, riparian vegetative zone width, and epifaunal substrate/available cover categories. Although there was no statistically significant association between the distribution of RBA habitat categories and sampling reach, the differences in vegetative protection, riparian vegetative zone width, and epifaunal substrate/available cover categories probably represent ecologically significant differences with respect to habitat quality for aquatic life support, especially for fish communities.

The distribution of substrate size categories (Table 4.3) was strongly associated with sampling location and reflects less silt/clay and more cobble in both pools and riffles at REF[16]. These results indicate higher quality habitat at REF compared to either Brushy Creek location. Based on habitat differences, a higher level of aquatic life use attainment would be expected in Clear Creek compared to either Brushy Creek reach.

RBA habitat scores and the Brushy Creek locations upstream (BC-0A) and downstream (BC-1A) of the UT inflow were similar among all categories, which is reflected in nearly identical total habitat scores (144 and 145 for BC-0A and BC-1A, respectively; Table 4.2). The significantly different distribution of substrate categories at BC-0A versus BC-1A (Table 4.3) reflects more bedrock and less silt/clay and gravel in the BC-1A riffles while D50 was the same (Table 4.3). The BC-1A pools had less gravel and cobble, more silt/clay and smaller D50 (Table 4.3): however, cobble and gravel dominated both habitat types at both locations. Although these differences result in statistically significant differences between upstream and downstream reaches, the biological significance and expected overall effect on the level of aquatic life use attainment is not clear. Based on professional judgment, these differences appear to be somewhat

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[16] The apparent contradiction of higher frequency of silt/clay at the Brushy Creek location as shown in the Wolman data versus similar levels of embeddedness among locations shown in the RBA assessment is the result of the focus on riffles/run habitat in the RBA assessment of embeddedness in FTN's RBA protocol.

modest in terms of biological significance. Given the minimal differences in RBA scores and the similar dominance by gravel and cobble substrate, overall habitat at BC-0A and BC-1A appears to be similar and should support similar levels of aquatic life use attainment.

Therefore, the general ranking of habitat quality for purposes of interpreting aquatic life for both fish and benthic macroinvertebrates in Brushy Creek and Clear Creek (REF) is:

REF > BC-0A = BC-1A[17]

7.3.2 Stennitt Creek

The SC-0 and SC-1 sampling reaches were similar and generally comparable in terms of RBA habitat categories (Table 4.4), substrate, immediate watershed characteristics and size (depth, width); however, comparisons of the benthic macroinvertebrate communities between SC-1 and SC-0 should consider the higher incidence of riffle/run habitat at SC-1, which was sampled as part of the benthic macroinvertebrate assessment.

Therefore, the general ranking of habitat quality for purposes of interpreting aquatic life for benthic macroinvertebrates in Stennitt Creek is:

SC-1 > SC-0

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[17] For habitat comparisons “> “and “= “should be interpreted as “of higher quality than” and “of similar quality to”, respectively.

8.0 DISCUSSION: FISH COMMUNITIES

The primary purpose and objective of the following discussion of fish communities is to determine if current TDS and sulfate concentrations in Brushy Creek downstream of the influence of Vulcan's Outfall 001 (i.e., downstream of the inflow from the UT) support the aquatic life designated use with respect to fish communities. Towards this end the following questions will be addressed:

1. Does the fish community at BC-1A indicate attainment per Regulation No. 2 (APCEC 2017) and ADEQ assessment methodology (ADEQ 2018)?
2. Are there statistically or ecologically significant differences among fish communities?
3. Can statistically or ecologically significant differences that are observed among fish communities be attributed to elevated TDS and/or sulfate concentrations at BC-1A as opposed to other factors such as habitat?

As noted in Section 7, the following general patterns of habitat and water quality differences are present among BC-0A, BC-1A, and REF:

1. Water Quality (TDS): REF > BC-0A > BC-1A
2. Water Quality (Sulfate): REF = BC-0A > BC-1A
3. Habitat quality: REF > BC-0A = BC-1A

8.1 Aquatic Life Attainment at BC-1 Based on Fish Community

8.1.1 Attainment Based on Regulation No. 2

Section 2.302 of APCEC (2017) uses the presence of "key" and "indicator"[18] fish species as one factor to assess attainment of ecoregion designated uses. Ozark Highlands ecoregion key

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[18] Per APCEC (2017), key species are fishes which are normally the dominant species (except for some ubiquitous species) within important groups such as fish families or trophic feeding levels. All specified key species need not be present to establish a normal or representative fishery. Indicator species are species of fish which may not be abundant within a species group and may not be limited to one area of the state, but which, because of their presence, are readily associated with a specific ecoregion. All indicator species need not be present to establish a normal or representative fishery.

and indicator species are listed in Table 8.1. As described in Section 5 and summarized in Table 5.2, two ecoregion key species (*E. uniporum*[19] and *L. zonatus*) were collected at all three locations. REF contained two ecoregion indicator species, *C. erythrogaster*, and *N. albater* (Table 5.2), while no indicator species were collected in the Brushy Creek reaches.

Table 8.1 Key and indicator species for the Ozark Highlands ecoregion.

Key Species		**Indicator species**	
“Rock” basses	*Ambloplites* spp.	Southern redbelly dace	*Chrosomus erythrogaster*
Rainbow darter	*Etheostoma caeruleum*		
Orangethroat darter	*Etheostoma spectabile*	Banded sculpin	*Cottus carolinae*
Northern hogsucker	*Hypentelium nigricans*		
Cardinal shiner	*Luxilus cardinalis*	Whitetail shiner	*Cyprinella galactura*
Duskystripe shiner	*Luxilus pilsbryi*	Ozark madtom	*Noturus albater*
Bleeding shiner	*Luxilus zonatus*		
Smallmouth bass	*Micropterus dolomieu*	Ozark minnow	*Notropis nubilus*
Slender madtom	*Noturus exilis*		

Although the relative abundance of *E. uniporum* (key species) at BC-0A was more than three times higher (Table 5.2) than at BC-1A (21% vs. 5.6%) where TDS and sulfate concentrations are the highest, the relative abundance of *E. uniporum* at BC-1A and REF, where TDS and sulfate are lowest, was similar (8.4% versus 5.6% at REF and BC-1A, respectively). This result indicates that the relative abundance of *E. uniporum* is not associated with TDS and sulfate concentrations and that the elevated concentrations of TDS and sulfate at BC-1A support a population of *E. uniporum* similar to REF. Also, the highest abundance of *L. zonatus*, another key species, was at BC-1A where sulfate and TDS are the highest (Table 5.2)[20].

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[19] *E. uniporum* was formerly known as a subspecies of the orangethroat darter (*E. spectabile*). APCEC Regulation No. 2 (2017) does not identify *E. uniporum* as a Ozark Highlands ecoregion key species; however, for the purposes of this evaluation, the key species status of *E. spectabile* was maintained for *E. uniporum.*

[20] There was no statistical evaluation of relationships between key species relative abundance and specific minerals. A cursory review indicated that dissolved minerals were not a limiting factor to key species.

It should also be noted that BC-1A supported populations of three darter species: *E. flabellare*, *E. blennioides*, and *E. uniporum*, while REF lsupported two (*E. flabellare and E. uniporum*) (Table 5.1).

The absence of indicator species in Brushy Creek cannot be definitively explained, although it is conceivable that it is due to the higher background TDS and/or lower quality habitat present in Brushy Creek (Table 3.2).

These findings demonstrate that the elevated TDS and sulfate concentrations at BC-1A support the Ozark Highlands designated use (key species) per Section 2.302 of Regulation No. 2 (APCEC 2017). They also demonstrate that TDS concentrations higher than the ecoregion value of 240 mg/L will support, in this instance, the Ozark Highlands ecoregion aquatic life designated use per Regulation No. 2 (APCEC 2017).

8.1.2 Attainment Based on ADEQ Methodology

Section 5 of ADEQ's assessment methodology (ADEQ 2018) uses the CSI to assess attainment of aquatic life with respect to fish communities and interprets CSI scores based on Table 7 of the methodology, which is reproduced, in part, in Table 8.2. Per Table 7 (ADEQ 2018), CSI scores that are classified as "mostly similar" or "generally similar" indicate support of the aquatic life designated use.

Table 8.2. Interpretation of CSI scores for Ozark Highlands ecoregion (adapted from Table 7 of ADEQ's assessment methodology; ADEQ 2018).

CSI Score	Category: Degree of Similarity to Expected or Reference Condition	Attribute
25-32	Mostly similar	Comparable to the best situation to be expected. Balanced trophic structure and optimum community structure present.
24-17	Generally similar	Community structure less than expected. Taxa richness lower than expected. Some intolerant taxa loss. Percent contribution of tolerant forms may increase.
16-9	Somewhat similar	Obvious decline in taxa richness due to the loss of tolerant forms. Loss of Key and Indicator taxa.
0-8	Not similar	Few taxa present and normally dominated by one (1) or two (2) taxa.

The CSI scores from fish sampling in Brushy Creek and Clear Creek were analyzed in Section 5.3 and summarized in Table 5.6. CSI scores were 23, 21, and 35 for BC-0A, BC-1A, and REF, respectively, and indicate that the fish communities in all three stream reaches support the aquatic life designated use per Table 7 of ADEQ (2018).

The analysis of CSI scores also indicated a statistically non-significant difference between the CSI scores of BC-0A versus BC-1A. Since habitat is similar at the 2 locations, this result indicates that not only are the two fish communities attaining the designated use, but that there is no discernible incremental impairment of the fish community at BC-1A due to the elevated TDS and sulfate at the location. It should be noted that although physical habitat at BC-0A and BC-1A were similar (Section 7.3), the BC-1A reach is a larger stream with higher flows. This difference might be sufficient cause to expect more diversity in the absence of elevated minerals but the effect might also be simply to support larger fish (as was observed). However, regardless of any effect of greater size and flows in the BC-1A reach, these findings demonstrate that the elevated TDS and sulfate concentrations at BC-1A support the Ozark Highlands aquatic life designated use per Section 5 in ADEQ (2018).

This result also demonstrates that TDS values in excess of the 240 mg/L Ozark Highlands ecoregion value will support a fish community that is “generally similar” to “mostly similar” to the expected condition and attains the aquatic life designated use.

8.2 Evaluation of Statistically or Ecologically Significant Differences Among Fish Communities

8.2.1 CSI Scores

The analysis of CSI scores indicated a significant difference between the CSI scores of REF and both BC-0A and BC-1A (Table 5.3). Water quality data summarized in Table 3.1 shows a difference in TDS concentration between REF and BC-0A of 133 mg/L (258 versus 391 mg/L at REF and BC-0A, respectively) that is larger than the increase of 30 mg/L between BC-0A and BC-1A (391 versus 421 mg/L for BC-0A and BC-1A, respectively). This difference is accompanied by a difference in both riparian habitat quality and substrate size. Therefore, the difference in CSI scores between REF versus BC-0A and BC-1A could be due to either better habitat at REF or higher background TDS at BC-0A. In either case, the difference represents variation in aquatic life due to background habitat differences resulting from variation in land use (e.g., pasture vs. mainly forested) and/or water quality due to geochemistry as opposed to mineral inputs from Outfall 001.

8.2.2 Population Size (CPUE)

Comparisons of CPUE between the Brushy Creek reaches and Clear Creek (Tables 5.7 and 5.9) indicated that all possible pairwise comparisons were statistically significant. CPUE was highest at BC-0A, lowest at REF and intermediate at BC-1A. This result indicates that the differences in the carrying capacity among locations are not related to variation in TDS or sulfate.

8.2.3 Fish Weight

The analysis of *C. anomalum, P. notatus, F. olivaceus, L. cyanellus, L. megalotis,* and *E. uniporum* showed that all species except *L. megalotis* showed statistically significant differences in weight (as measured by mean weight) among locations (Table 5.10). However, there was no general pattern in the differences; species at BC-1A showed generally higher or intermediate weights compared to BC-0A and REF. In the one instance (*L. megalotis*) where mean weight was lowest at BC-1A, the differences among locations were not statistically significant. This result indicates that differences in the fish weight among locations are not related to variation in TDS or sulfate.

8.2.4 Fish Condition Factor (Length-Specific Weight)

The analysis of *C. anomalum, P. notatus, F. olivaceus, L. cyanellus, L. megalotis,* and *E. uniporum* indicated no statistically significant ($P < 0.05$) differences in growth rates (as indicated by length-specific weight) among locations except for *L. megalotis* and *E. uniporum* (Table 5.11). For *L. megalotis*, adjusted weight was similar between BC-0A and BC-1A and lowest at REF. The significant differences among locations for *E. uniporum* are extremely small (less than 0.1 g difference among locations) and are likely an artifact of heterogeneous slopes.

This result indicates that differences in condition factors among locations are generally non-significant and, in any case, not related to variation in TDS or sulfate.

8.3 Summary of Comparisons among Fish Communities

This evaluation assessed attainment of aquatic life for fish communities with respect to designated uses [key and indicator species per APCEC (2017)] and CSI scores [per ADEQ (2018)] as well more subtle effects such as population size, fish size, and condition factor. The results of the comparison of fish communities among locations are summarized with general patterns of water quality and habitat in Table 8.3. If Outfall 001 were having an adverse impact on the fish community at BC-1A, the expected pattern of biological metrics would be REF ≥ BC-0A > BC-1A. None of the biological metrics examined showed this pattern, which indicates that the few statistically significant differences among locations that do occur are not ecologically significant from the standpoint of effects due to the Vulcan discharge.

Table 8.3. Summary of comparisons of biological metrics of fish communities among locations and general patterns of water quality and habitat.

Parameter Type	Parameter	Location Rank
Fish Community	Key and Indicator Species	REF > BC-0A = BC-1A
	CSI	REF > BC-0A = BC-1A
	CPUE	BC-0A > BC-1A > REF
	Fish Size	No pattern
	Growth Rates	No pattern
	Expected pattern for adverse effects due to Outfall 001	REF ≥ BC-0A > BC-1A
Water Quality (concentrations)	TDS	REF > BC-0A = BC-1A
	Sulfate	REF > BC-0A > BC-1A
Habitat	Habitat	REF > BC-0A = BC-1A

This analysis demonstrates that statistically or ecologically significant differences that are observed among fish communities cannot be attributed to elevated TDS and/or sulfate concentrations at BC-1A as opposed to other factors such as habitat or background TDS concentrations.

8.4 Aquatic Life Use Attainment

This analysis demonstrates that water quality and habitat at the Brushy Creek reaches support the Ozark Highlands aquatic life designated use per Regulation No. 2 (APCEC 2017) and ADEQ assessment methodology (ADEQ 2018) with respect to fish communities.

9.0 DISCUSSION: BENTHIC MACROINVERTEBRATE COMMUNITIES

The primary purpose and objective of the following discussion of benthic macroinvertebrate communities is to determine if current TDS and sulfate concentrations in Brushy Creek downstream of the influence of Vulcan's Outfall 001 (i.e., location BC-1A downstream of the inflow from the UT) and Stennitt Creek downstream of the mouth of Brushy Creek (location SC-1) support the aquatic life designated use with respect to macroinvertebrate communities. Towards this end the following questions will be addressed:

1. Do the macroinvertebrate communities at BC-1A and SC-1 indicate attainment per ADEQ assessment methodology (ADEQ 2018)?
2. Are there other discernible or statistically significant differences between the upstream and downstream benthic macroinvertebrate communities?
3. Can discernible or ecologically significant differences that are observed among benthic macroinvertebrate communities be attributed to elevated TDS and/or sulfate concentrations at BC-1A or SC-1 as opposed to other factors such as habitat?

As noted in Section 7, the following general patterns of habitat and water quality are present among BC-0A, BC-1A, and REF:

1. Water Quality (TDS): REF > BC-0A > BC-1A,
2. Water Quality (sulfate): REF = BC-0A > BC-1A, and
3. Habitat quality: REF > BC-0A = BC-1A.

General patterns of habitat and water quality differences between SC-0A and SC-1 are as follows:

1. Water Quality (TDS): SC-1= SC-0A,
2. Water Quality (sulfate): SC-0A > SC-1, and
3. Habitat quality: SC-1 > SC-0A.

9.1 Aquatic Life Attainment at BC-1A and SC-1 Based on ADEQ Methodology

ADEQ (2018) assessment of biological integrity is based on Plafkin et al. (1989), which was applied to the data collected using the instream sampling methodology described in Section 2.5.

9.1.1 Brushy Creek: Instream Samples

Percent comparability for BC-1A versus BC-0A, REF-2, and REF-3 were 95%, 95% and 86%, respectively (Table 6.2). These values indicate a “biological condition category” of “comparable to reference” per Table 6 of ADEQ (2018) and indicates “support” of the aquatic life use. They also demonstrate that TDS concentrations higher than the ecoregion value of 240 mg/L will support the aquatic life use for this ecoregion.

9.1.2 Stennitt Creek: Instream Samples

Percent comparability for SC-1 versus SC-0 was 95%, which corresponds to a ”biological condition category” of “comparable to reference” per Table 6 of ADEQ (2018) and indicates “support” of the aquatic life use (Table 6.6).

Percent comparability as low as 54% indicates “supporting” per Table 6 in ADEQ (2018). Because the percent comparability (95%) between the two locations was at the high end of the range indicating support, the level of confounding between habitat and water quality in this comparison would probably not be sufficient to result in a determination of impairment at SC-1 if the habitat factor could somehow be removed. Therefore, based on ADEQ methodology for assessing attainment, these results indicate that the water quality in Stennitt Creek downstream of the mouth of Brushy Creek supports the aquatic life use with respect to benthic macroinvertebrates.

9.2 Evaluation of Discernible or Statistically Significant Differences Between Upstream and Downstream Communities

This section presents an evaluation of the macroinvertebrate communities that colonized artificial substrates during studies performed in Brushy Creek and Stennitt Creek. These experiments offered a sensitive means to detect and evaluate potential effects on the benthic community in relation to water quality changes due to Outfall 001. Important factors such as substrate quality and availability of insect colonists are essentially the same in the upstream versus downstream substrates; however, differences in flows due to the presence of the discharge (in the case of Brushy Creek) or the presence of Brushy Creek (in the case of Stennitt Creek) remained as one potential confounding factor that could not be controlled.

This section also evaluates the potential effects of elevated TDS and sulfate based on EPA (2011) methodology for obtaining field-based threshold values for ionic strength based on conductivity. The EPA study developed extirpation concentration (XC95) values that represent the level of exposure (based on conductivity) above which a genus is effectively absent from waterbodies of a region. XC95 values from the EPA (2011) study were obtained from EPA's National Center for Environmental Assessment (Office of Research and Development, Cincinnati, OH). The data analysis in EPA (2011) is best applied to situations, such as found in Brushy Creek and Stennitt Creek, in which calcium, magnesium, sulfate, and bicarbonate dominate the ionic composition of the streams. The data from EPA (2011) provide XC95 values for only a subset (42% to 71%) of the taxa present in the study streams. Therefore, this analysis cannot be used by itself to develop site-specific criteria such as described in Cormier and Suter (2013). However, this analysis provides another line of evidence to consider in evaluating current water quality impacts due to the discharge, and using the methodology described in Cormier and Suter (2013), identifies a "tolerance benchmark" for the existing benthic communities (see Section 10). For purposes of this analysis a "tolerance benchmark" is a TDS or sulfate concentration that protects 95% of the existing taxa and provides an upper bounds to proposed site-specific criteria as developed herein.

9.2.1 Representativeness of the EPA (2011) XC95 Data Set

As noted in the previous section and in Sections 6.1.2, 6.2.2, 6.3.2, and 6.4.2, XC95 values from EPA (2011) were available for 42% to 71% of the taxa (genera) and 50% to 87% of the individuals for the benthic communities (instream and artificial substrates) in this study. A valid application of the EPA (2011) data to the Brushy/Stennitt/Clear Creek data must assume that the subset of taxa for which XC95 values are available is representative of the entire set of taxa at the Brushy/Stennitt/Clear Creek sites. To evaluate this assumption, the frequency (i.e., number of individuals) of EPT, Ephemeroptera, Coleoptera, and Diptera of the subset of each data set having XC95 values was compared to the frequency of those taxa from the entire data set for the following data sets individually:

1. Brushy Creek and Clear Creek instream samples,
2. Stennitt Creek instream samples,
3. Brushy Creek artificial substrates, and
4. Stennitt Creek artificial substrates.

This analysis focused on EPT, Ephemeroptera, Coleoptera, and Diptera because of the importance of these metrics in differentiating upstream and downstream locations (especially EPT and Ephemeroptera) and their general preponderance in the samples[21]. The frequencies were evaluated statistically using Pearson's Chi Square (X^2) test of association. All statistical computations were performed using Systat 12. This analysis did not consider lower taxonomic levels (e.g., families, genera) because the resulting low frequencies in cells of the RxC matrix could cause spurious results (Section 17.4 in Sokal and Rohlf 1995). Results of the comparisons (Table 9.1) indicate no difference in the frequencies of EPT, Ephemeroptera, Coleoptera, and Diptera for the subset of data having XC95 values versus the entire data set for each data set listed above. Therefore, the subset of taxa having XC95 values is representative of the taxa in the whole data set for each analysis (instream samples for Brushy/Clear Creek and Stennitt Creek; artificial substrates for Brushy Creek and Stennitt Creek).

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[21] Organisms from these groups generally dominated the top 10 taxa from each data set (Appendix F).

Table 9.1. Comparison of the frequency among selected metrics and taxa (number of individuals) for the subset of data having XC95 values versus the entire data set.

	Instream Samples				Artificial Substrates			
	Brushy and Clear Creeks		Stennitt Creek		Brushy and Clear Creeks		Stennitt Creek	
Taxon	All data	Data with XC95 Values	All data	Data with XC95 Values	All data	Data with XC95 Values	All data	Data with XC95 Values
EPT	18	11	7	4	19	12	10	6
Ephemeroptera	8	7	3	3	6	5	4	4
Coleoptera	12	7	6	3	7	6	5	2
Diptera	32	24	34	22	48	35	25	18
Pearson’s X^2	0.53		0.46		0.28		0.81	
P	0.91		0.93		0.96		0.85	

9.2.2 Brushy Creek: Artificial Substrates

The cluster analysis (Figure 6.1) identified two somewhat distinct clusters: one comprised exclusively of RBUs from the upstream location and the second comprised mainly of RBUs from the downstream location (9 out of 11 RBUs). This result indicates differences in the communities that colonized the RB substrates at BC-0A vs. BC-1A.

9.2.3 Stennitt Creek: Artificial Substrates

The cluster analysis (Figure 6.3) identified two clusters: one containing two HDUs from the upstream location and the second having three out of four HDUs from the downstream location. Although the dendrogram showed separation between SC-0 and SC-1, the two most similar HDUs belonged to SC-0 and SC-1.

9.2.4 Brushy Creek: Analysis of XC95 Values

9.2.4.1 Instream Samples

There was no statistically significant difference (P > 0.5) in XC95 index values in Brushy Creek downstream versus upstream of the influence of the discharge (i.e., BC-1A versus BC-0A, respectively; Tables 6.3 and 6.4). Differences between BC-1A and the REF locations were significant in one case (BC-1A versus REF-2). In that case, however, the XC95 value for REF-2 was higher than the BC-1A value, which indicates a more tolerant community in the reference location. These results indicate that the benthic macroinvertebrate community downstream of the influence of the outfall is not more tolerant to TDS (as indicated by conductivity) than the upstream community or the reference location.

9.2.4.2 Artificial Substrates

Average XC95 index values (Table 6.10) were higher at BC-1A than at BC-0A (5,938 versus 5,003 µS/cm, respectively). This difference was statistically significant ($P = 0.022$) and indicates that the benthic macroinvertebrate communities that colonized the RB substrates at BC-1A can tolerate higher TDS concentration (as indicated by conductivity) than the upstream communities.

9.2.5 Stennitt Creek: Analysis of XC95 Values

9.2.5.1 Instream Samples

Average XC95 index values at SC-0 and SC-1 (Table 6.7 and 6.8) were not significantly different ($P > 0.2$) indicating that the benthic macroinvertebrate community at SC-1 is not more tolerant of TDS (as indicated by conductivity) than the upstream communities.

9.2.5.2 Artificial Substrates

There was no statistically significant difference ($P > 0.25$) in XC95 index values of the macroinvertebrate communities that colonized HD substrates in Stennitt Creek downstream versus upstream of the influence of the discharge (i.e., SC-1 versus SC-0, respectively; Tables 6.11 and 6.12). This result indicates that the benthic macroinvertebrate community that colonized HD substrates downstream of the influence of the outfall was not more tolerant to TDS (as indicated by conductivity) than the upstream community.

9.2.6 Summary of Discernible or Statistically Significant Differences Between Upstream and Downstream Communities

9.2.6.1 Brushy Creek

The RB experiment revealed subtle differences in TDS tolerance (as indicated by conductivity) in the benthic macroinvertebrate communities at BC-0A and BC-1A that were not observed with the instream samples. Experiments using the RB substrates revealed differences that were not evident in the instream samples possibly due to the following factors:

1. The deployment period for the RB substrates occurred during the low-flow season when upstream to downstream differences in TDS/sulfate due to the discharge are expected to be greatest. All colonization of the RB substrates occurred during low flow conditions when the impacts of the discharge on water quality at BC-1A are greatest. The resulting data reflect this relatively short-term effect. In contrast, the data from the instream sampling reflect how benthic communities integrate the longer-term effects of varying TDS/sulfate conditions over several seasons. It is interesting to note that the average XC95 index values for the RB communities were higher than the values from the instream sampling (3,729 versus 5,003 µS/cm at BC-0 and 3,976 versus 5,937 µS/cm at BC-1).
2. The experimental protocol used for the RB samples probably resulted in greater efficiency of capture and higher total sample volume with the RB samplers. With the RB samples the entire contents from nine different substrates were collected into containers so that virtually all individuals present became part of the sample. In contrast, instream sampling involves a certain degree of selectivity and only a small portion of the entire riffle substrate is actually sampled. These differences could account for the differences in the upstream to downstream comparisons with RB samples versus instream sampling. It probably also accounts, at least in part, for the two-fold difference in taxa numbers in the RB data set (average = 90) versus the instream samples (average = 46).

The difference between the results of the comparisons using RB versus instream data could reflect actual biological differences in the communities that are a function of factors such as differences related to the age of the communities; opportunity for colonization; magnitude, duration, and frequency of elevated sulfate and TDS; and flow variation. Alternatively, the apparent sensitivity of the RB experiment could be due to greater efficiency in organism capture and larger total sample volumes associated with the RB experiment. It is likely that both biological and sampling factors are at play.

Instream sample data were utilized for assessing aquatic life use attainment following ADEQ (2018) and reflects the integrated response of the benthic macroinvertebrate community to long-term exposure to the Vulcan discharge. The RB experiment, although it represents a more sensitive assessment procedure when compared to the instream sample data (See Section 9.3), did not reflect a long-term, representative sampling interval for accurate attainment assessment.

9.2.6.2 Stennitt Creek

There were no statistically significant differences and few discernible differences between upstream and downstream communities:

1. Upstream versus downstream differences in HD communities that were apparent did not indicate lower levels of aquatic life use attainment in the HD substrates deployed downstream of the influence of the Vulcan discharge,
2. There was no indication of more tolerant communities downstream of the influence of the Vulcan discharge (i.e., downstream of the mouth of Brushy Creek), and
3. Analysis of the instream data set demonstrated support of the aquatic life use for benthic macroinvertebrates per ADEQ (2018).

It is interesting to note that, as in Brushy Creek, the average XC95 index values for the HD communities were higher than the values from the instream sampling (5,439 versus 9,327 µS/cm at SC-0 and 5,004 versus 8,599 µS/cm at SC-1). Also, the XC95 index values from Brushy Creek (3,852 and 5,420 µS/cm for the instream and RB samples, respectively) were lower than the values from Stennitt Creek (5,221 and 8,963 µS/cm for the instream and HD samples, respectively). This result indicates that the benthic macroinvertebrate communities in Stennitt Creek are more tolerant to TDS than Brushy Creek communities and that any site-specific value that supports aquatic life in Brushy Creek will also support aquatic life in Stennitt Creek.

9.3 Aquatic Life Use Attainment: Benthic Macroinvertebrates

The upstream to downstream differences in the macrobenthic communities that colonized the RB substrates in Brushy Creek are most likely due to increased TDS and sulfate due to the discharge rather than other factors. This result represents a somewhat short-term effect (i.e., colonization during a 6-week period during low flows) and suggests that elevated TDS and sulfate might, at times, limit aquatic life in Brushy Creek downstream of the influence of the outfall. The results of the instream sampling, which show little if any difference between upstream and downstream locations, suggest that the magnitude, frequency and duration of the conditions that might lead to differences between upstream and downstream reaches (such as shown by the RB substrate deployment) are not sufficient to impair the aquatic life use as determined per ADEQ (2018). This conclusion assumes that differences in sampling efficiency and sample volume are not a major factor in the differences between the results from the RB and instream data sets. In any case, the determination of aquatic life use attainment should rely on instream sampling because this is the methodology that ADEQ uses for determining aquatic life use attainment (ADEQ 2018). That data set shows no impairment at BC-1A and documents that existing TDS and sulfate conditions support the aquatic life designated use with respect to benthic macroinvertebrates.

Stennitt Creek macroinvertebrate communities are more tolerant of TDS (higher XC95 index values), experience less upstream to downstream change in TDS or sulfate and show no impairment per ADEQ (2018). Therefore, the TDS/sulfate regimes in Brushy Creek and Stennitt Creek imposed by the Outfall 001 discharge support and do not impair the aquatic life uses of Brushy Creek and Stennitt Creek with respect to the benthic macroinvertebrate communities. Accordingly, site-specific criteria for TDS and sulfate based on existing conditions will support aquatic life uses. These results also demonstrate that TDS concentrations higher than the ecoregion value of 240 mg/L will support aquatic life uses.

10.0 CRITERIA DEVELOPMENT

Mass balance computations based on harmonic mean flows were carried out to develop site-specific dissolved minerals criteria for the UT from Vulcan's Outfall 001 to its confluence with Brushy Creek, a segment of Brushy Creek from its confluence with the UT to its confluence with Stennitt Creek, and a segment of Stennitt Creek from its confluence with Brushy Creek to its confluence with Spring River (see Section 10.3).

Because the DWS designated use applies to the UT and Brushy Creek, initial mass balance water computations using 7Q10 flows were carried out to calculate proposed dissolved minerals criteria for the protection of aquatic life using TDS and sulfate concentrations of Outfall 001 (95th percentile) and upstream concentrations from recent monitoring. However, these calculations indicated potential exceedance of the secondary drinking water standard for TDS (500 mg/L) in Brushy Creek and the UT. The DWS designated use, but not existing use, is proposed to be removed from the UT and from Brushy Creek downstream of the UT (see Section 11) based on the mass balance results for 7Q10 conditions. In the absence of the DWS use in Brushy Creek, site-specific dissolved minerals criteria would be developed from mass balance computations based on harmonic mean flows rather than 7Q10 flows. Additionally, mass balance computations based on harmonic mean flows is required for Stennitt Creek below Brushy Creek since DWS use was removed in 1999 as part of a previously approved UAA and Third-Party Rulemaking. (APCEC 2017).

10.1 Domestic Water Supply

In the Arkansas water quality standards (APCEC 2017), critical flow for site-specific dissolved minerals criteria is harmonic mean flow, and critical flow for DWS minerals criteria is 7Q10 (also referred to as "Q7-10"). If the designated uses of a waterbody include DWS, then the waterbody must meet the DWS criteria (250 mg/L chloride, 250 mg/L sulfate, and 500 mg/L TDS) at 7Q10 flow conditions.

The DWS designated use was previously removed for Stennitt Creek below Brushy Creek, but it still applies for Brushy Creek and the UT. Therefore, the mass balance computations were initially carried out for 7Q10 flow conditions.

10.1.1 Mass Balance Computations for 7Q10 Flow Conditions

10.1.1.1 Ambient Flows for 7Q10 Conditions

The 7Q10 flow for Stennitt Creek upstream of the mouth of Brushy Creek was estimated using StreamStats version 3 (USGS 2012), which recommends a minimum drainage area of 12.1 square miles for using regression equations that StreamStats uses to estimate 7Q10 flows for ungaged streams in this area. The watershed area for Stennitt Creek at the mouth of Brushy Creek is 10.1 square miles (Table 10.1), which is close to the minimum recommended value and was considered to provide a reasonable basis for the 7Q10 flow estimate for Stennitt Creek upstream of the mouth of Brushy Creek. However, the watershed areas for Brushy Creek upstream and downstream of the mouth of the UT obtained using StreamStats are 1.19 and 2.60 square miles, respectively (Table 10.1), both of which are well below the minimum recommended drainage area of 12.1 square miles. Accordingly, 7Q10 flows for both the UT and for the area draining to Brushy Creek downstream of the UT were calculated using the 7Q10 flow per square mile for the Stennitt Creek watershed upstream of the mouth of Brushy Creek.

Table 10.1. Summary of mass balance inputs for 7Q10 flow conditions.

Source of Inflow	Drainage Area (mi^2)	7Q10 Flow (cfs)	Sulfate (mg/L)	TDS (mg/L)
Outfall 001	0	0.5941	142.8	556
Brushy Creek upstream of the mouth of the UT	1.19	0.0109	5.5	391
Brushy Creek between the mouth of the UT and the confluence with Stennitt Creek	2.60	0.0239[a]	5.5[b]	391[c]
Stennitt Creek upstream of the mouth of Brushy Creek	10.1	0.0929	5.1	420
Spring River upstream of the mouth of Stennitt Creek	---	287	3.8	219

Notes:
a. Inflow to Brushy Creek from watershed between the UT and Stennitt creek
b. Sulfate concentration (background) in waters entering Brushy Creek from watershed between the UT and Stennitt Creek
c. TDS concentration (background) in waters entering Brushy Creek from watershed between the UT and Stennitt Creek

The 7Q10 flow for the Spring River was obtained from Funkhouser et al. (2008) and is based on the USGS gage on the Spring River at Imboden, AR (gage 07069500), which is located approximately 4.5 stream miles upstream of the mouth of Stennitt Creek.

10.1.2 Background TDS and Sulfate Concentrations

Background TDS and sulfate concentrations for inflow to Brushy Creek both upstream and downstream of the UT were set to averages of the concentrations measured at BC-0A during the 2015 and 2016 sampling (Section 3, Table 3.1). As noted in Table 3.1, the sulfate value of 33.8 mg/L obtained November 24, 2015, at BC-0A was considered an outlier and was excluded from the calculation of the average sulfate value. The average values used as background concentrations for Brushy Creek were 5.5 mg/L sulfate and 391 mg/L TDS.

For Stennitt Creek upstream of Brushy Creek, the background concentrations of sulfate and TDS were set to averages of the concentrations measured at SC-0A during the 2015 and 2016 sampling (5.1 mg/L sulfate and 420 mg/L TDS). For the Spring River upstream of Stennitt Creek, the background concentrations were set to 3.8 mg/L for sulfate and 219 mg/L for TDS; these are averages of monthly and bimonthly measurements collected from January 1, 1960, through September 27, 1970, at the USGS gage at Imboden (Table 10.2).

Table 10.2. TDS and sulfate statistics for the Spring River (January 1960 – September 1970).

Summary Statistic		**TDS (mg/L)**	**Sulfate (mg/L)**
Percentile	25th	203	3.0
	50th	219	3.6
	75th	237	4.2
	95th	259	5.2
Minimum		135	2.0
Average		219	3.8
Maximum		280	11.0
Number of Values		93	92

Vulcan typically operates the quarry pit sump pump at 800 gpm for 8 hours per day. This flow rate corresponds to an average discharge of 267 gpm (0.5941 cubic feet per second [cfs]) over a 24-hour period. It is appropriate to consider this flow as continuous, because the intervening pond between the discharge and the UT can be expected to equalize the intermittent discharge from Outfall 001. The TDS and sulfate concentrations used for the 7Q10-based computations used the 95th percentile outfall concentrations during January 2012 through January 2017.

10.1.3 Mass Balance Results for 7Q10 Conditions

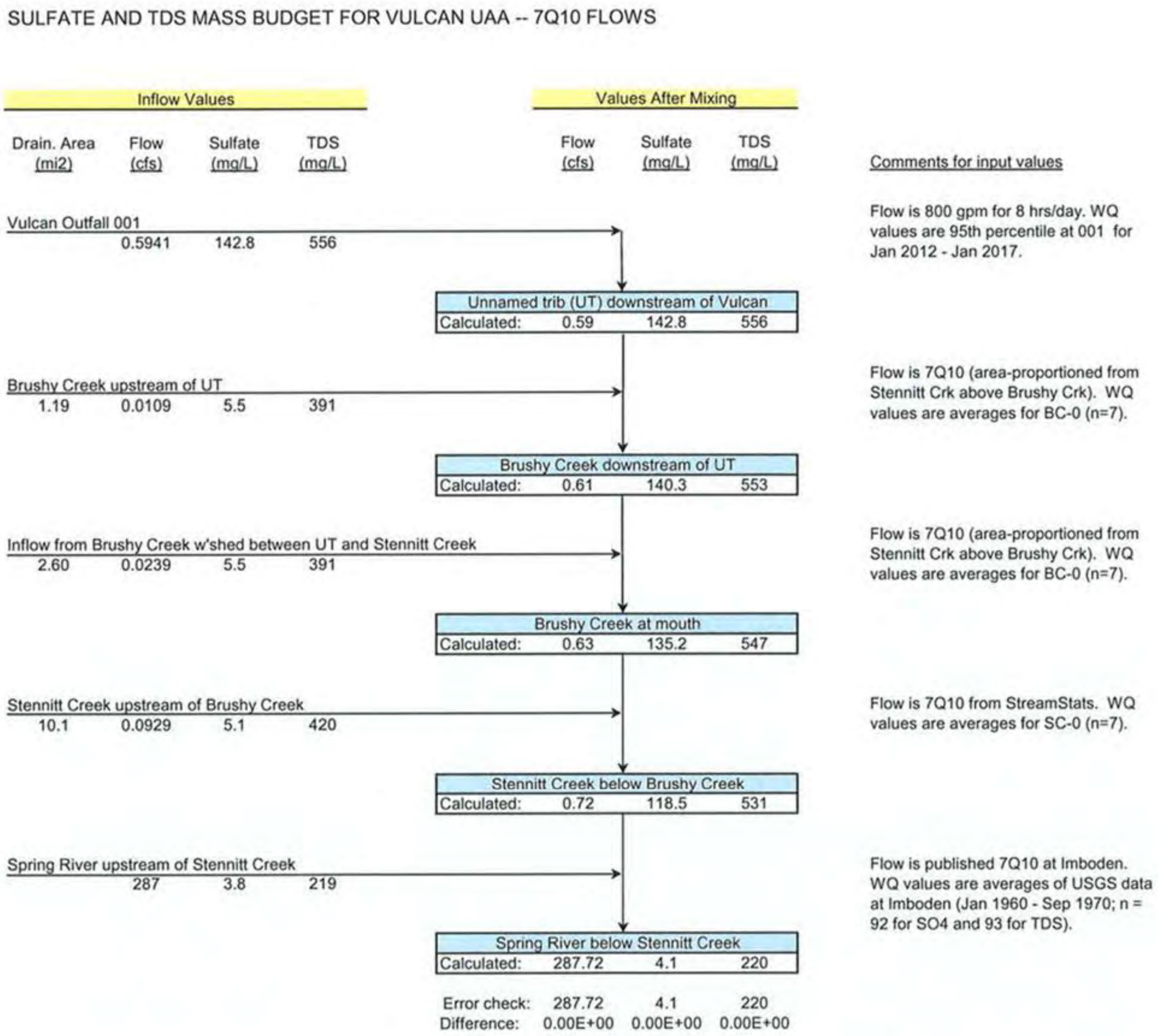
Input values for mass balance computations for 7Q10 conditions are summarized in Table 10.1. Results of the mass balance computations for 7Q10 conditions are summarized in Table 10.3 and a schematic diagram is shown in Figure 10.1. These results indicate that loading from Outfall 001 under 7Q10 critical conditions will cause downstream TDS concentrations in the UT and in Brushy Creek to exceed the DWS values. Based on these results, this document proposes to remove the DWS designated use from the UT and from Brushy Creek downstream of the UT. As noted earlier, the designated use of DWS was previously removed for Stennitt Creek downstream of Brushy Creek.

Table 10.3. Predicted concentrations for 7Q10 flow conditions.

Stream Reach	**Sulfate (mg/L)**	**TDS (mg/L)**
UT from Outfall 001 to Brushy Creek	142.8	556*
Brushy Creek below the mouth of the UT	140.3	553*
Stennitt Creek downstream of the mouth of Brushy Creek	118.5	531
Spring River downstream of the mouth of Stennitt Creek	4.1	220

*Exceeds value for domestic water supply

These results show that discharges from Outfall 001 have minimal impact on TDS and sulfate concentrations in the Spring River. Discharges from Outfall 001 will not cause exceedances of DWS criteria in the Spring River for 7Q10 conditions.



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	Inflow Values				Values After Mixing			
	Drain. Area (mi2)	Flow (cfs)	Sulfate (mg/L)	TDS (mg/L)	Flow (cfs)	Sulfate (mg/L)	TDS (mg/L)	Comments for input values
Vulcan Outfall 001		0.5941	142.8	556				Flow is 800 gpm for 8 hrs/day. WQ values are 95th percentile at 001 for Jan 2012 - Jan 2017.
Unnamed trib (UT) downstream of Vulcan — Calculated:					0.59	142.8	556	
Brushy Creek upstream of UT	1.19	0.0109	5.5	391				Flow is 7Q10 (area-proportioned from Stennitt Crk above Brushy Crk). WQ values are averages for BC-0 (n=7).
Brushy Creek downstream of UT — Calculated:					0.61	140.3	553	
Inflow from Brushy Creek w'shed between UT and Stennitt Creek	2.60	0.0239	5.5	391				Flow is 7Q10 (area-proportioned from Stennitt Crk above Brushy Crk). WQ values are averages for BC-0 (n=7).
Brushy Creek at mouth — Calculated:					0.63	135.2	547	
Stennitt Creek upstream of Brushy Creek	10.1	0.0929	5.1	420				Flow is 7Q10 from StreamStats. WQ values are averages for SC-0 (n=7).
Stennitt Creek below Brushy Creek — Calculated:					0.72	118.5	531	
Spring River upstream of Stennitt Creek		287	3.8	219				Flow is published 7Q10 at Imboden. WQ values are averages of USGS data at Imboden (Jan 1960 - Sep 1970; n = 92 for SO4 and 93 for TDS).
Spring River below Stennitt Creek — Calculated:					287.72	4.1	220	
Error check:					287.72	4.1	220	
Difference:					0.00E+00	0.00E+00	0.00E+00	

Figure 10.1. Schematic diagram of mass balance computations for 7Q10 conditions.

10.2 Aquatic Life Protection

Most prior studies for site-specific mineral criteria in Arkansas have utilized a set percentile of observed or predicted (based on mass balance modeling) instream concentrations, usually the 95th percentile for a 5-year period. This approach has been questioned on the grounds that the resulting value is not derived directly from evidence that the aquatic life use is supported. Additionally, justifying proposed criteria on the basis of the 95th percentile potentially varies significantly depending on the period of record chosen. In light of these questions, Vulcan explored five methods for criteria development:

1. Criteria based on development of a "tolerance benchmark" for specific conductance (conductivity) for the existing benthic communities using XC95 values of macroinvertebrate taxa present in the reference location and selection of appropriate TDS/sulfate to conductivity ratios based on Hem (1985);
2. Criteria based on development of a "tolerance benchmark" for conductivity for the existing benthic communities using XC95 values of macroinvertebrate taxa present in the reference location and use of established relationships of Ozark Highlands ecoregion TDS/sulfate to conductivity (EPA 2016);
3. Criteria based on the background-to-criterion (B-C) model (Cormier et al. 2018) using conductivity measured in Clear Creek during the fall 2016 sampling as the background conductivity model input;
4. Criteria based on the background-to-criterion (B-C) model (Cormier et al. 2018) using Ozark Highlands ecoregion background conductivity (EPA 2016) as the model input; and
5. Criteria based on EPA's (2016) development of a "tolerance benchmark" for conductivity using XC95 values of macroinvertebrate taxa collected in the region during selected studies and use of established relationships of Ozark Highlands ecoregion conductivity and TDS.

An initial review of method 5 determined that the method was unfavorable for criteria development. This method was dismissed from further evaluation because the EPA (2016) determined that the sample size was too small with respect to the number of locations with paired water chemistry and biology (193) and the number of total taxa with XC95 values (27). The approach was considered a screening estimate and would have provided greater confidence in the tolerance benchmark if sample sizes were 400-500 for the study region or if there were 90 or more genera with XC95 values.

10.2.1 Method 1

Proposed criteria for Brushy Creek for aquatic life protection were based on development of a “tolerance benchmark” for conductivity for the existing benthic communities using XC95 values of macroinvertebrate taxa present in the reference location (Clear Creek). For purposes of this analysis, a “tolerance benchmark” is a conductivity value that protects 95% of the existing taxa and provides the basis for proposed site-specific TDS and sulfate criteria for Brushy Creek. TDS and sulfate criteria for Brushy Creek were derived from the tolerance benchmark using empirically derived translators. Mass balance computations using the Brushy Creek criteria, background TDS and sulfate concentrations, and estimated critical flows (harmonic mean) were then used to derive: (1) TDS and sulfate concentrations from Outfall 001 that support the TDS and sulfate criteria in Brushy Creek; (2) TDS and sulfate criteria in the UT consistent with the Brushy Creek criteria; and (3) TDS and sulfate criteria in Stennitt Creek consistent with the Brushy Creek criteria. Note that this mass balance computation differs from that used for the DWS evaluation in the following ways:

1. The Brushy Creek TDS and sulfate concentrations are the criteria values based on the tolerance benchmark analysis (see below) as opposed to the 95th percentile values from the outfall,
2. Criteria for the UT are based on outfall concentrations that support the tolerance benchmark-based criteria in Brushy Creek, and
3. Concentrations in Stennitt Creek and Spring River are based on harmonic mean flows in Brushy Creek, Stennitt Creek, and Spring River and the tolerance benchmark-based criteria in Brushy Creek.

Sections 8 and 9 of this of this document demonstrate that the existing TDS and sulfate concentrations in Brushy Creek and Stennitt Creek resulting from the Outfall 001 discharge support the aquatic life designated use. Accordingly, it is appropriate for site-specific criteria to reflect that support (i.e., existing TDS and sulfate conditions should attain criteria).

10.2.1.1 Tolerance Benchmark and Corresponding Mineral Criteria for Existing Benthic Communities in Brushy Creek

This section develops tolerance benchmarks for the existing benthic communities. For purposes of this analysis, a tolerance benchmark is a conductivity value that protects 95% of the existing taxa and provides a basis for proposed site-specific criteria[22]. The approach is based on Cormier and Suter (2013) and uses a species sensitivity distribution (SSD) to derive a protective XC95 value based on conductivity. Protective TDS and sulfate values were then derived from the tolerance benchmark using appropriate translators. The SSD was developed using the taxa found in Clear Creek (REF-2 and REF-3) from the 2016 sampling that have XC95 values obtained from EPA (2011). Using the EPA (2011) data set requires that calcium, magnesium, bicarbonate, and sulfate dominate the ionic composition of the waterbodies in question. Although there is no direct measurement of these ions available for Clear Creek, other water quality parameters measured in Clear Creek (TDS, hardness) and the ionic composition of the outfall (Section 3) and ecoregion groundwater (Section 1) strongly support that these ions (with the exception of sulfate) also dominate Clear Creek. Furthermore, benthic macroinvertebrate data from Clear Creek are ideal for this purpose for the following reasons:

1. Clear Creek sulfate and TDS concentrations are lower than Brushy and Stennitt Creek,
2. Clear Creek does not experience elevated TDS or sulfate concentrations due to a point source,
3. Clear Creek TDS concentrations are higher than the ecoregion value, and
4. Clear Creek provides high-quality habitat.

10.2.1.2 SSD Development

Table 10.4 provides the list of the 34 taxa from Clear Creek having XC95 values. XC95 values were available for 63% and 70% of the taxa and 84% and 81% of the individuals at REF-2 and REF-3, respectively (Table 6.3). The frequency distribution of taxa having XC95 values was not statistically different from the distribution of all taxa present (Table 10.5). These

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[22] The “tolerance threshold” used herein is conceptually and computationally the same as the “HC05” in EPA (2011).

results demonstrate that XC95 values were available for the majority of taxa and individuals from the Clear Creek samples and that the subset of taxa having XC95 values is representative of all taxa present.

To develop the SSD, the taxa having XC95 values were ranked from lowest to highest XC95 value. The cumulative probability for each genus (P) was calculated as P = R/(N+1), where R is the rank of the genus and N is the number of genera (EPA 2011). The tolerance benchmark of 900 µS/cm was obtained using a two-point interpolation between the XC95 values bracketing P = 0.05[23] and rounded to two significant figures per Section 3.3 in EPA (2011). This procedure is illustrated graphically in Figure 10.2.

10.2.1.3 Translating Tolerance Threshold to TDS and Sulfate Concentrations

As noted in Sections 3.5 and 7.2, conductivity is not well correlated with TDS or sulfate and cannot be used to estimate TDS or sulfate concentrations in the waterbodies of this study using a regression-based approach. As an alternative to regression-based translators, the ratios of TDS and sulfate to conductivity were calculated from the data presented in Tables 3.1 and 3.2. A summary of these ratios is presented in Table 10.6, which omits values from BC-0A, SC-0A, and REF, because sulfate concentrations at these locations were generally near or below detection limits and do not contribute appreciably to TDS or conductivity.

Selection of an appropriate ratio of TDS to conductivity was based on Hem (1985) who reported a range of 0.54 to 0.96 (most values falling between 0.55 and 0.75) for the ratio of TDS to conductivity from a variety of natural waters. Hem (1985) also reported that higher ratios are generally associated with elevated sulfate concentrations. Accordingly, the 25th percentile values of 0.61 and 0.14 for TDS and sulfate, respectively (Table 10.6), were chosen to derive estimates of TDS and sulfate based on conductivity. These ratios are conservatively low (note that the lower the ratio selected, the lower the resulting value) because 75% of the values from the study were higher and because waters with elevated sulfate are expected to show higher rather lower ratios

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[23] P and XC95 values bracketing P = 0.05: P = 0.0278 and 0.0556; XC95 = 782 µS/cm and 927 µS/cm.

Table 10.4. List of Clear Creek (REF-2, REF-3) taxa having XC95 values.

Class	Order	Family	Genus	XC95
Malacostraca	Amphipoda	Gammaridae	*Gammarus*	4,713
Insecta	Coleoptera	Dryopidae	*Helichus*	11,646
Insecta	Coleoptera	Elmidae	*Dubiraphia*	7,370
Insecta	Coleoptera	Elmidae	*Macronychus*	1,890
Insecta	Coleoptera	Elmidae	*Microcylloepus*	3,341
Insecta	Coleoptera	Elmidae	*Optioservus*	9,790
Insecta	Coleoptera	Psephenidae	*Ectopria*	1,380
Insecta	Diptera	Ceratopogonidae	*Atrichopogon*	2,257
Insecta	Diptera	Chironomidae	*Brillia*	2,005
Insecta	Diptera	Chironomidae	*Corynoneura*	2,006
Insecta	Diptera	Chironomidae	*Microtendipes*	3,489
Insecta	Diptera	Chironomidae	*Parametriocnemus*	4,713
Insecta	Diptera	Chironomidae	*Paratanytarsus*	3,489
Insecta	Diptera	Chironomidae	*Polypedilum*	4,884
Insecta	Diptera	Chironomidae	*Rheotanytarsus*	3,489
Insecta	Diptera	Chironomidae	*Stempellinella*	927
Insecta	Diptera	Chironomidae	*Tanytarsus*	9,180
Insecta	Diptera	Chironomidae	*Thienemanniella*	9,790
Insecta	Diptera	Chironomidae	*Tvetenia*	2,613
Insecta	Diptera	Empididae	*Hemerodromia*	9,790
Insecta	Diptera	Simuliidae	*Simulium*	6,468
Insecta	Diptera	Tipulidae	*Tipula*	1,979
Insecta	Ephemeroptera	Baetidae	*Baetis*	1,395
Insecta	Ephemeroptera	Caenidae	*Caenis*	3,923
Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*	1,035
Insecta	Ephemeroptera	Heptageniidae	*Stenacron*	782
Insecta	Ephemeroptera	Isonychiidae	*Isonychia*	1,180
Insecta	Megaloptera	Corydalidae	*Corydalus*	11,227
Insecta	Megaloptera	Corydalidae	*Nigronia*	9,790
Insecta	Odonata	Gomphidae	*Stylogomphus*	6,468
Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*	9,180
Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*	7,010
Insecta	Trichoptera	Philopotamidae	*Chimarra*	3,972
Insecta	Trichoptera	Polycentropodidae	*Polycentropus*	4,713

Table 10.5. Comparison of the frequency among selected metrics and taxa (number of individuals) for the subset of data having XC95 values versus the entire data set for Clear Creek.

Taxon	Data with XC95 Values	All Data
EPT	17	25
Ephemeroptera	4	8
Coleoptera	9	9
Diptera	25	32
Pearson's X^2	0.94	
df	3	
P	0.8161	

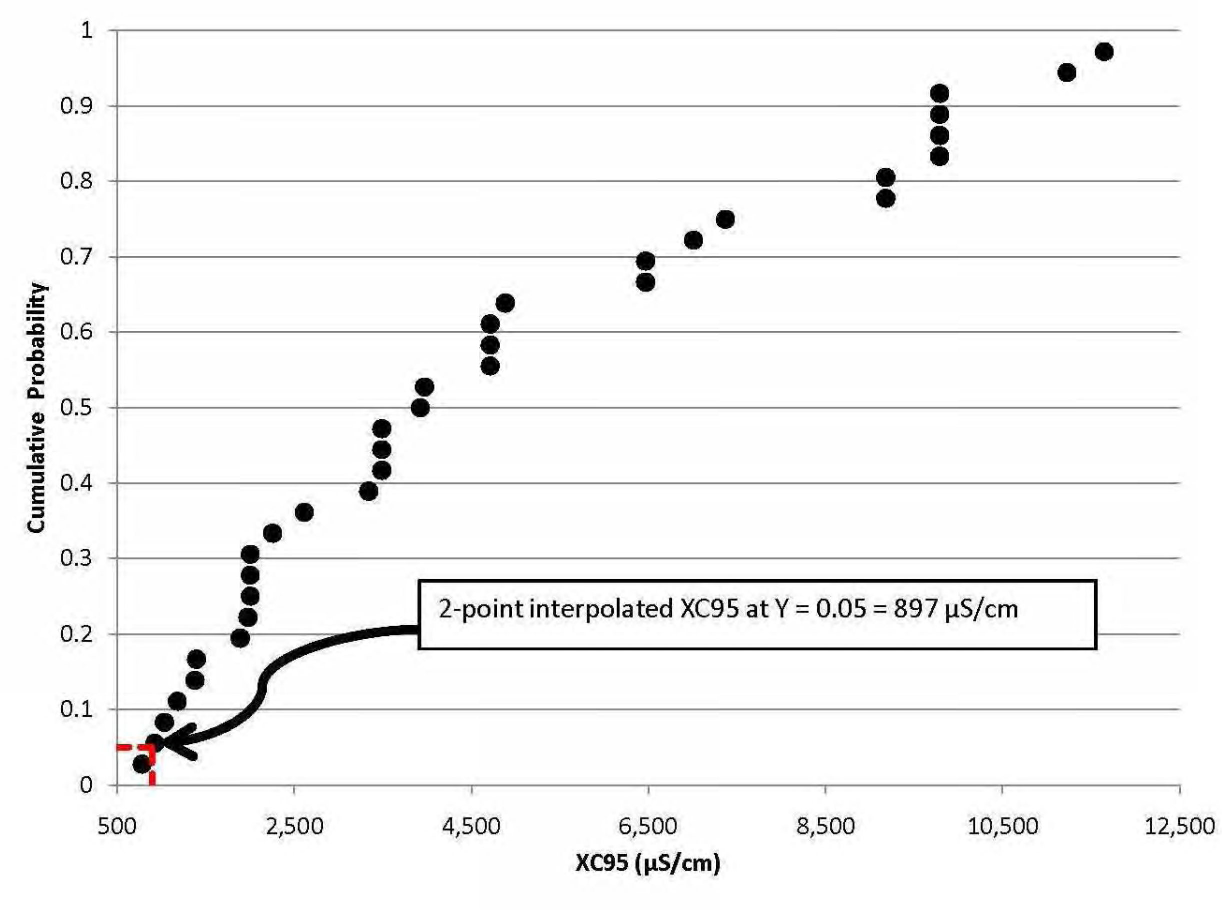

Figure 10.2. Species sensitivity distribution of XC95 values for genera from Clear Creek.

Table 10.6. Summary of ratios of TDS and sulfate to conductivity from receiving stream monitoring in 2015 and 2016 (Data obtained from Tables 3.1 and 3.2.).

Summary Statistic		TDS/Conductivity	Sulfate/Conductivity
Percentile	5	0.51	0.03
	10	0.53	0.06
	25	0.61	0.14
	50	0.71	0.17
	75	0.84	0.19
	95	1.16	0.23
Minimum		0.48	0.01
Mean		0.76	0.16
Maximum		1.22	0.24
N		42	29

Accordingly, TDS and sulfate concentrations that correspond to the tolerance threshold are calculated as follows:

1. 900 µS/cm x 0.61 mg/L TDS x $(\mu S/cm)^{-1}$ = 549 mg/L TDS, and
2. 900 µS/cm x 0.14 mg/L sulfate x $(\mu S/cm)^{-1}$ = 126 mg/L sulfate.

These values represent concentrations of TDS and sulfate that will protect aquatic life in Brushy Creek and Stennitt Creek and provide a basis for protective site-specific criteria.

10.2.2 Method 2

A second method explored for criteria development for Brushy Creek was based on development of a “tolerance benchmark” for conductivity for the existing benthic communities using XC95 values of macroinvertebrate taxa present in the reference location (Clear Creek) as was done for method 1. The derived tolerance benchmark 900 µS/cm (see Section 10.2.1.2). This method differed from method 1 in that TDS and sulfate criteria were derived from the tolerance benchmark using established relationships (ratios) of Ozark Highlands ecoregion TDS and sulfate to conductivity (EPA 2016) as translators.

10.2.2.1 Translating Tolerance Threshold to TDS and Sulfate Concentrations

The ratio of TDS to conductivity was obtained from EPA (2016) and was based on an ecoregion specific regression model developed to convert TDS to conductivity. The correlations between TDS and conductivity were analyzed for samples from the Ozark Highlands ecoregion where TDS concentrations were ≤500 mg/L in order to reduce biases introduced by highly impacted stations that are not representative of the waters of the ecoregion as a whole. A value of 0.75 was used to derive TDS based on specific conductance.

The ratio of sulfate to conductivity was not provided by EPA (2016). An estimated ratio of sulfate to conductivity was calculated from the EPA (2016) dataset by first calculating the background conductivity from the background TDS using the established relationship (0.75) and then dividing the ecoregion background sulfate by the calculated ecoregion background conductivity. The 75th percentile of the frequency distribution of minerals values measured in reference streams is conventionally used by EPA to estimate background concentrations (EPA 2000). The 75th percentile of the frequency distribution of TDS and sulfate values measured in Ozark Highlands ecoregion reference streams were 233.5 and 5.341 mg/L, respectively (EPA 2016).

The ratio of sulfate to conductivity was calculated as follows:

1. Background conductivity = 233.5 mg/L TDS / 0.75 = 311 μS/cm.
2. Sulfate/conductivity ratio = 5.341 mg/L / 311 μS/cm = 0.02

TDS and sulfate concentrations that correspond to the tolerance threshold are calculated as follows:

1. 900 μS/cm x 0.75 mg/L TDS x $(\mu S/cm)^{-1}$ = 675 mg/L TDS, and
2. 900 μS/cm x 0.02 mg/L sulfate x $(\mu S/cm)^{-1}$ = 18 mg/L sulfate.

These values represent concentrations of TDS and sulfate that will protect aquatic life in Brushy Creek and Stennitt Creek and provide a basis for protective site-specific criteria.

10.2.3 Method 3

A third method explored for criteria development for Brushy Creek was based on the B-C model (Cormier et al. 2018) using mean conductivity from measured concentrations in Clear Creek during the fall 2016 sampling as the background conductivity model input. The B-C model was developed as a model-based approach for predicting the extirpation concentration (XC95) for benthic invertebrates exposed to dissolved salts using only specific conductivity as the independent variable. The model is based on three assumptions:

1. A genus will rarely occur where background concentrations exceed its upper physiological limitations,
2. The lowest tolerance limit of a genus is defined by natural background concentrations, and
3. As a result, there is an association between background specific conductivity and the specific conductivity at which salt intolerant genera are present.

10.2.3.1 Background to Criterion (B-C) Model

The B-C model is as follows:

$$y = 0.658x + 1.071$$

where:

x = the log10 of the background SC (µS/cm), and

y = the log10 of the predicted XCD05[24] (µS/cm)

50% prediction limits (PL) provide the upper and lower PLs of the mean predicted log10 of the predicted XCD05 and identify the 75% probability range of an XCD95 (XC95) value derived by the field XCD method (EPA 2011) for a new ecoregion. The upper and lower 50% prediction limits are calculated as follows:

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[24] The "tolerance threshold" used herein is conceptually and computationally the same as the "HC05" in EPA (2011).

$$\hat{y} \pm t_{\propto/2,\ n-2} S_y \sqrt{1 + \frac{1}{n} + \frac{\left(X_0 - \bar{X}\right)^2}{SS}} = PL$$

Where:

PL = upper and lower prediction limits

$\hat{y}$ = Log10 of mean predicted XCD_{05}

n = number of samples in model

α = Alpha error rate for prediction interval (α = 0.5)

t_{n-2} = t-value at specific level (α) and degrees of freedom (n-2)

S_y = residual standard error of prediction (standard deviation)

SS = Sum of square of x deviation from their mean,

$$\sum_{i=1}^{n} (x_i - \bar{x}^2)$$

$\bar{x}$ = mean of x values used in the B-C model generation

x_0 = x value of new prediction interval

10.2.3.2 Translating Tolerance Threshold to TDS and Sulfate Concentrations

Using the mean conductivity in Clear Creek during 2016 sampling (513 µS/cm, Table 3.2), the B-C model calculated the log10 of the predicted XCD05 as 2.85 with upper and lower 50% PLs at 2.93 and 2.77, respectively. The inverse of the log10 of the predicted XCD05 and the 50% PLs was calculated to identify the conductivity tolerance threshold. The conductivity tolerance threshold was 715 µS/cm with upper and lower PLs of 859 and 595 µS/cm, respectively. The ratios of TDS and sulfate to conductivity for the Ozark Highlands ecoregion were obtained from EPA (2016) (see Section 10.2.2.1).

TDS concentrations and PLs that correspond to the tolerance threshold are calculated as follows:

1. 715 µS/cm x 0.75 mg/L TDS x $(\mu S/cm)^{-1}$ = 536 mg/L TDS,
2. 859 µS/cm x 0.75 mg/L TDS x $(\mu S/cm)^{-1}$ = 644 mg/L TDS (upper 50% PL), and
3. 595 µS/cm x 0.75 mg/L TDS x $(\mu S/cm)^{-1}$ = 446 mg/L TDS (lower 50% PL).

Sulfate concentrations that correspond to the tolerance threshold are calculated as follows:

1. 715 µS/cm x 0.02 mg/L sulfate x $(\mu S/cm)^{-1}$ = 14 mg/L sulfate,
2. 859 µS/cm x 0.02 mg/L sulfate x $(\mu S/cm)^{-1}$ = 17 mg/L sulfate (upper 50% PL), and
3. 595 µS/cm x 0.02 mg/L sulfate x $(\mu S/cm)^{-1}$ = 12 mg/L sulfate (lower 50% PL).

These values represent concentrations of TDS and sulfate that will protect aquatic life in Brushy Creek and Stennitt Creek and provide a basis for protective site-specific criteria.

10.2.4 Method 4

A fourth method explored for criteria development for Brushy Creek was based on the B-C model (Cormier et al. 2018) using ecoregion background conductivity (EPA 2016).

10.2.4.1 Translating Tolerance Threshold to TDS and Sulfate Concentrations

Using the EPA (2016) Ozark Highlands ecoregion background conductivity (311, See Section 10.2.2.1), the B-C model calculated the log10 of the predicted XCD05 as 2.71 with upper and lower 50% PLs at 2.79 and 2.63, respectively. The inverse of the log10 of the predicted XCD05 and the 50% PLs was calculated to identify the conductivity tolerance threshold. The conductivity tolerance threshold was 514 µS/cm with upper and lower PLs of 616 and 429 µS/cm, respectively. The ratios of TDS and sulfate to conductivity for the Ozark Highlands ecoregion were obtained from EPA (2016) (see Section 10.2.2.1).

TDS concentrations and PLs that correspond to the tolerance threshold are calculated as follows:

1. 514 µS/cm x 0.75 mg/L TDS x $(\mu S/cm)^{-1}$ = 386 mg/L TDS,
2. 616 µS/cm x 0.75 mg/L TDS x $(\mu S/cm)^{-1}$ = 462 mg/L TDS (upper 50% PL), and
3. 429 µS/cm x 0.75 mg/L TDS x $(\mu S/cm)^{-1}$ = 322 mg/L TDS (lower 50% PL).

Sulfate concentrations that correspond to the tolerance threshold are calculated as follows:

1. 514 µS/cm x 0.02 mg/L sulfate x $(\mu S/cm)^{-1}$ = 10 mg/L sulfate,
2. 616 µS/cm x 0.02 mg/L sulfate x $(\mu S/cm)^{-1}$ = 12 mg/L sulfate (upper 50% PL), and
3. 429 µS/cm x 0.02 mg/L sulfate x $(\mu S/cm)^{-1}$ = 19 mg/L sulfate (lower 50% PL).

These values represent concentrations of TDS and sulfate that will protect aquatic life in Brushy Creek and Stennitt Creek and provide a basis for protective site-specific criteria.

10.2.5 Criteria Development Method Selection

Table 10.7 summarizes the Brushy Creek criteria calculation results from the analysis of methods 1-4. The criteria calculated for each of the four methods are considered protective of the aquatic life in Brushy Creek downstream of Outfall 001. While all four methods are protective, method 1 was selected as the preferred method for criteria development.

Table 10.7. Summary of Brushy Creek criteria calculations from the analysis of four methods.

	Brushy Creek Criteria Calculation Results (mg/L)					
	TDS			**Sulfate**		
Method	**Criterion**	**Lower 50% PL***	**Upper 50% PL***	**Criterion**	**Lower 50% PL***	**Upper 50% PL***
Method 1 - Tolerance benchmark developed from reference taxa and empirically derived translators based on Hem (1985)	549	--	--	126	--	--
Method 2 - Tolerance benchmark developed from reference taxa and ratios of ecoregion TDS and S04 to conductivity (EPA 2016)	675	--	--	18	--	--
Method 3 - B-C model (Cormier et al. 2018) using 2016 measured Clear Creek conductivity as the background conductivity	536	446	644	14	12	17
Method 4 - B-C model (Cormier et al. 2018) using ecoregion background conductivity (EPA 2016)	386	322	462	10	9	12

* Prediction Limit

The most conservative TDS criterion (386 mg/L) was calculated using the B-C model (Cormier et al. 2018) and Ozark Highlands ecoregion background conductivity (EPA 2016) as the model input (method 4). The mean background TDS concentration in Brushy Creek upstream of the Outfall 001 influence (391 mg/L) was higher than the calculated TDS criterion using method 4. Because there is a higher mean background TDS concentration in the upstream reach of Brushy Creek outside of the influence of Outfall 001, and that reach of Brushy Creek supports the aquatic life use per ADEQ (2018), the calculated TDS criterion for Brushy Creek downstream of Outfall 001 using method 4 should be dismissed as a candidate criterion.

The highest TDS criterion (675 mg/L) was calculated by developing a tolerance benchmark for conductivity for the existing benthic communities in Clear Creek and converting that conductivity benchmark to TDS using the EPA (2016) ratio of Ozark Highlands ecoregion conductivity to TDS (method 2). The EPA (2016) relationships calculated from streams throughout the entire ecoregion would be expected to calculate estimates of a criterion that supports the aquatic life use in Brushy Creek.

The intermediate TDS criterion derived from methods 1 and 3 were 536 and 549 mg/L, respectively; an approximately 2.5 percent difference. While method 1 was based on a tolerance benchmark from the Clear Creek macroinvertebrate community and method 3 was based on the B-C model, both models used data from the study streams rather than EPA (2016) data derived from streams throughout the Ozark Highlands ecoregion. These calculated values also reflect a TDS criterion that supports the aquatic life use. The method 1 criterion of 549 mg/L relies entirely on scientifically defensible data collected from the study streams.

The calculated sulfate criterion was derived either from EPA (2016) calculated Ozark Highlands ecoregion background sulfate concentration (5.3 mg/L, method 2) or the mean background sulfate concentration measured at Clear Creek during the fall 2016 field study (5.5 mg/L, methods 3 and 4). Elevated sulfate levels are present in Outfall 001 and concentrations measured in Brushy Creek downstream of the Outfall 001 influence represent a “significant modification” of water quality as compared to the ecoregion reference value for sulfate and the concentrations in Brushy Creek upstream of the influence (ADEQ 2017). However, in the presence of elevated sulfate levels, the reach of Brushy Creek influenced by

Outfall 001 supports the aquatic life use per ADEQ (2018). Method 1 calculates a sulfate criterion (126 mg/L) based on receiving stream concentrations that have been demonstrated to support the aquatic life use. A sulfate criterion for Brushy Creek downstream of Outfall 001 based on methods 2, 3, or 4 does not consider sulfate contributions from Outfall 001 that have been demonstrated to support the aquatic life use and therefore are dismissed in this study as candidates for the sulfate criterion.

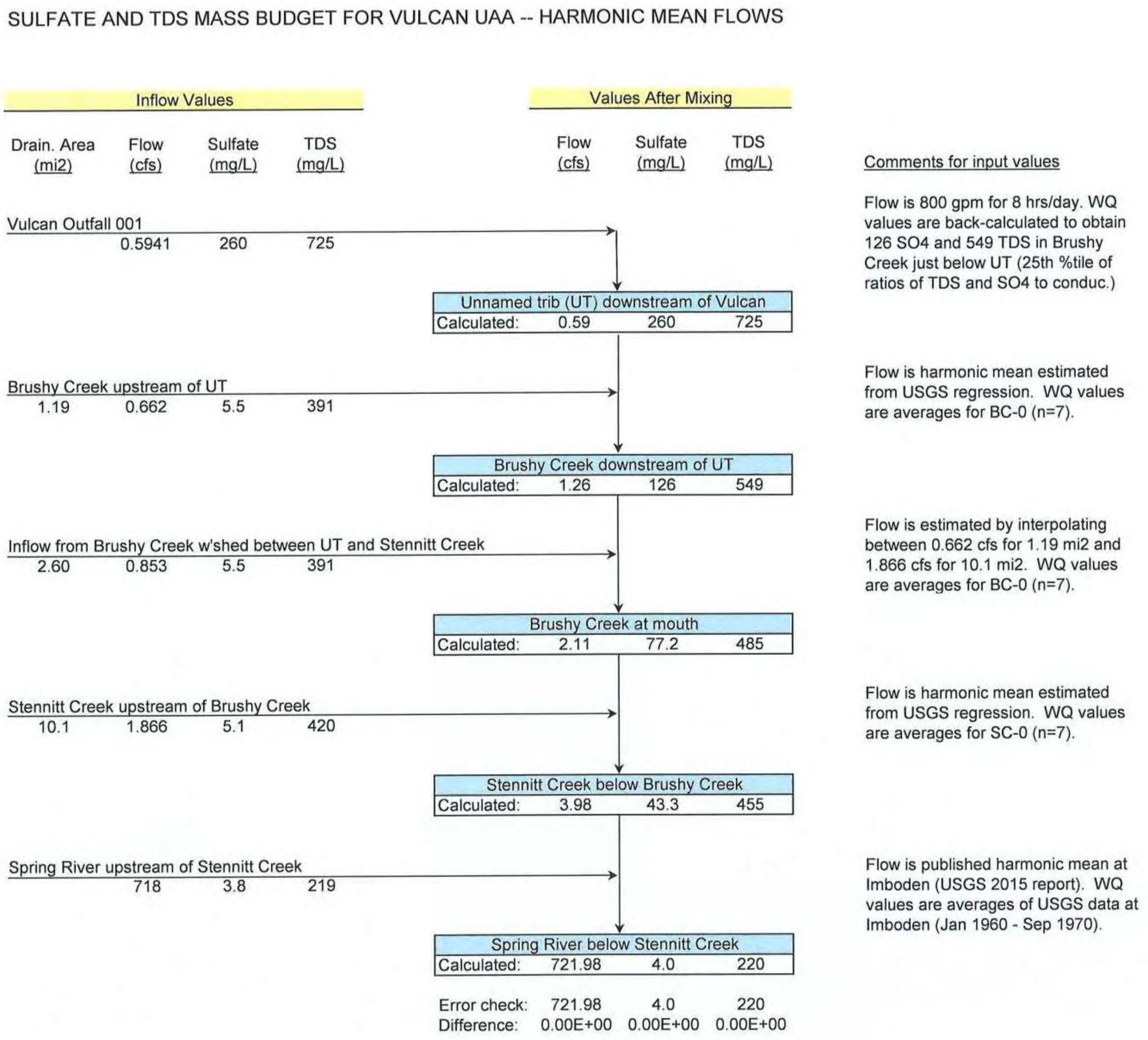
Although not used for criteria development due to the proposed removal of the DWS use, the mass balance computations initially carried out for 7Q10 flow conditions used the 95th percentile of TDS and sulfate concentrations measured at Outfall 001 during a recent 5-year period of record (January 2012 through January 2017) to calculate TDS and sulfate criteria in Brushy Creek that would limit non-compliance status under the NPDES permit. The values for TDS and sulfate were 553 and 140 mg/L respectively. These calculations are consistent with the criteria calculations from method 1 to support the aquatic life use and to achieve permit compliance at Outfall 001.

10.3 Mass Balance Computations for Harmonic Mean Flow Conditions

A second set of mass balance computations were developed for harmonic mean flow conditions for aquatic life protection. Flow rate and concentrations for the effluent and the ambient inflow concentrations were the same as in the 7Q10 mass balance (Table 10.1). The ambient inflow rates were the only inputs that were different between 7Q10 conditions and harmonic mean flow conditions. The harmonic mean flows for Brushy Creek upstream of the UT and Stennitt Creek upstream of Brushy Creek were estimated using a regional regression equation developed by USGS (Table 3 in Beaker 2015). For the inflow to Brushy Creek downstream of the UT, the harmonic mean flow was interpolated by drainage area using the results from the regression equation for Brushy Creek upstream of the UT and Stennitt Creek upstream of Brushy Creek. The harmonic mean flow for the Spring River upstream of Stennitt Creek was the published value for the USGS gage at Imboden (Table 3-1 in Beaker 2015). These flows and the other inputs for the mass balance computations for harmonic mean flow conditions are listed in Table 10.8. A schematic diagram of the harmonic mean mass balance computations is shown in Figure 10.3 and the results are summarized in Table 10.9.

10.4 Proposed Site-Specific Criteria for TDS and Sulfate

The proposed site-specific criteria are based on the results of the mass balance computations for harmonic mean flow conditions. These proposed criteria are listed in Table 10.10. As noted in Section 11, the DWS designated use is proposed to be removed from the UT and from Brushy Creek downstream of the UT (see Section 11) based on the mass balance results for 7Q10 conditions.



Flow is 800 gpm for 8 hrs/day. WQ values are back-calculated to obtain 126 SO4 and 549 TDS in Brushy Creek just below UT (25th %tile of ratios of TDS and SO4 to conduc.)

Flow is harmonic mean estimated from USGS regression. WQ values are averages for BC-0 (n=7).

Flow is estimated by interpolating between 0.662 cfs for 1.19 mi2 and 1.866 cfs for 10.1 mi2. WQ values are averages for BC-0 (n=7).

Flow is harmonic mean estimated from USGS regression. WQ values are averages for SC-0 (n=7).

Flow is published harmonic mean at Imboden (USGS 2015 report). WQ values are averages of USGS data at Imboden (Jan 1960 - Sep 1970).

Figure 10.3. Schematic diagram of mass balance computations based on harmonic mean flow.

Table 10.8. Summary of mass balance inputs for harmonic mean flow conditions.

Source of Inflow	Drainage Area (mi^2)	Harmonic Mean Flow (cfs)	Sulfate (mg/L)	TDS (mg/L)
Outfall 001	0	0.5941	260	725
Brushy Creek upstream of the mouth of the UT	1.19	0.662	5.5	391
Brushy Creek between the mouth of the UT and the confluence with Stennitt Creek	2.60	0.853	5.5	391
Stennitt Creek upstream of the mouth of Brushy Creek	10.1	1.866	5.1	420
Spring River upstream of the mouth of Stennitt Creek	---	718	3.8	219

Table 10.9. Receiving stream concentrations corresponding to harmonic mean flow conditions.

Stream Reach	Sulfate (mg/L)	TDS (mg/L)
UT from Outfall 001 to Brushy Creek	260	725
Brushy Creek below the mouth of the UT	126*	549*
Stennitt Creek downstream of the mouth of Brushy Creek	43.3	455
Spring River downstream of the mouth of Stennitt Creek	4.0	220

*Concentrations based on tolerance benchmark analysis.

Table 10.10. Summary of existing and proposed criteria for receiving streams.

Stream Segment	Existing Criteria (mg/L)			Proposed Criteria (mg/L)		
	Sulfate	TDS	Chloride	Sulfate	TDS	Chloride
Unnamed tributary from Outfall 001 to confluence with Brushy Creek	22.7	250	17.3	260	725	No change
Brushy Creek from confluence with unnamed tributary to confluence with Stennitt Creek	22.7	250	17.3	126	549	No change
Stennitt Creek from confluence with Brushy Creek to confluence with Spring River	22.7	456*	17.3	43.3	No change	No change
Spring River downstream of confluence with Stennitt Creek	30	290	20	No change	No change	No change

*Site-specific values based on previous 1999 UAA and rulemaking, which included removal of the domestic water supply designated use.

11.0 ATTAINABLE AND NON-ATTAINABLE USES

This section evaluates attainable and non-attainable uses in Brushy Creek and the UT in the presence of the Vulcan discharge. In evaluating attainable uses for Brushy Creek and the UT, the following assumptions were made with regard to the Vulcan discharge:

- The discharge occurs an average of 8 hours per day;
- The current discharge supports most, if not all, of the dry season flow in both Brushy Creek and the UT; and
- The Vulcan discharge exceeds ecoregion TDS and sulfate values, but does not exceed the chloride value (17.3 mg/L).

11.1 Aquatic Life

Attainability of aquatic life uses is addressed in Sections 2 through 9 of this document. That analysis demonstrates that the TDS and sulfate regimes in Brushy Creek and Stennitt Creek, which are due to the Vulcan Outfall 001 discharge, support designated uses per ADEQ (2018) and APCEC (2017).

11.2 Primary and Secondary Contact Recreation

DMR data indicate that the Vulcan discharge routinely meets current limits for TSS (monthly average/daily maximum = 20/30 mg/L) and turbidity [monthly average report only, Nephelometric turbidity units (NTUs)]. The Vulcan discharge flows directly into a private pond at the pond owner’s request. The pond owner currently uses the pond, in part, for recreation. Therefore, current concentrations of TDS and sulfate should not affect the attainability of this use for the UT or Brushy Creek.

11.3 Industrial Water Supply

Although the industrial water supply use is not an existing use, current concentrations of TDS and sulfate do not affect the attainability of this use.

11.4 Agricultural Water Supply: Crops

11.4.1 Flows

According to information provided by the University of Arkansas, Division of Agriculture, Cooperative Extension Service[25], a water supply suitable for irrigation should provide minimum flows of 5, 10, or 15 gpm per acre for center pivot, furrow, and levee irrigation, respectively, of soybeans (Tacker and Vories 2004). The maximum flow from the facility is an intermittent flow of 800 gpm, which could, theoretically, provide irrigation for 40 to 129 acres of soybeans. This information indicates that the current discharge flows from the plant will support a marginally attainable agricultural use.

11.4.2 TDS

The most commonly used guideline for salinity tolerance of crops is Ayers and Westcot (1985). In this document, yield potentials for a number of crops are associated with soil and water salinity values measured as electrical conductance. Salinity values associated with yield potentials for cotton, soybeans, and rice are summarized in Table 11.1. The water salinity (ECw) values reported in Ayers and Westcot (1985) have been calculated from the soil salinity (ECe) values reported (ECw = ECe/1.5). TDS values shown in Table 11.1 were calculated from the conductivity values (TDS = 650*conductivity). The maximum effluent TDS concentration (802 mg/L; see Table 4.2) is well below the calculated irrigation water TDS values summarized in Table 11.1, thus indicating that effluent TDS would not be expected to negatively affect crop productivity. The US Salinity Laboratory (US Department of Agriculture, Agricultural Research Services) has calculated linear regressions of irrigation water salinity (measured as the conductivity) to relative rice yield measurements based on experiments conducted in the late 1990s (Zeng and Shannon 2000). These relationships are based on the response of rice to sodium chloride (NaCl) solutions of various strengths that were used for irrigation in the experiments. Table 11.2 shows irrigation water conductivities for relative yields of grain weight per panicle and grain weight per plant that correspond to the yield potentials that are shown in Table 11.1. These values were calculated using Zeng and Shannon's (2000) linear regression equations. TDS

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[25] http://www.uaex.edu/Other_Areas/publications/HTML/MP-197.asp

values in Table 11.2 are calculated using the same equation as Table 11.1 values. The linear regression relationships developed by the US Salinity Laboratory indicate that a TDS concentration (due primarily to NaCl) of 1,000 mg/L could reduce rice productivity by about 10%. Tacker et al. (2001) also report that irrigation water with conductivity greater than 1.2 dS/m (approximately 780 mg/L TDS) is borderline for use on rice. The U of A Cooperative Extension Service reports that TDS levels greater than 770 ppm in irrigation water for rice are cause for concern[26].

Table 11.1 Influence of soil salinity (ECe) and irrigation water salinity (ECw) on crop tolerance and yield potential of selected crops (Ayers and Westcot 1985).

	Parameter	**100% yield**		**90% yield**		**75% yield**		**50% yield**		**0% yield**	
Crop		**ECe**	**ECw**	**ECe**	**ECw**	**ECe**	**ECw**	**ECe**	**ECw**	**ECe**	**ECw**
Cotton	Cond, dS/m	7.7	5.1	9.6	6.4	13	8.4	17	12	27	18
	TDS, mg/L	0	3,315	0	4,160	0	5,460	0	7,800	0	11,700
Rice	Cond, dS/m	3	2	3.8	2.6	5.1	3.4	7.2	4.8	11	7.6
	TDS, mg/L	0	1,300	0	1,690	0	2,210	0	3,120	0	4,940
Soybean	Cond, dS/m	5	3.3	5.5	3.7	6.3	4.2	7.5	5	10	6.7
	TDS, mg/L	0	2,145	0	2,405	0	2,730	0	3,250	0	4,355

Table 11.2 Irrigation water salinity for selected relative rice yield measurements calculated using US Salinity Laboratory linear regression equations (Zeng and Shannon 2000).

	Parameter	**Percent Yield**				
Yield Measurement		**100**	**90**	**75**	**50**	**0**
Grain weight per panicle	Cond, dS/m	0.49	1.71	3.54	6.59	12.68
	TDS, mg/L	317	1,110	2,299	4,280	8,244
Grain weight per plant	Cond, dS/m	0.46	1.52	3.12	5.78	11.10
	TDS, mg/L	297	989	2,026	3,755	7,212

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[26] http://www.aragriculture.org/soil_water/irrigation/crop/Rice/quality.htm

This information indicates that the Vulcan discharge may only be marginally suitable for rice irrigation. However, the topography of the Brushy Creek watershed and its rocky soils are not conducive to rice cultivation. Therefore, the TDS concentrations in the Vulcan discharge will not affect the attainability of the agricultural water supply use with respect to rice cultivation.

11.4.3 Sulfate

Sulfate in irrigation water is generally considered to be beneficial to crops rather than harmful (Tracy and Hefner 1993, Bauder et al. 2004, Glover 2001, Baser and Gilmour 1982). James et al. (1982) classify irrigation water with sulfate concentrations of 673 mg/L to 1,153 mg/L, and TDS concentrations of 488 mg/L to 1,300 mg/L, as useable for crop irrigation. These thresholds are well above any sulfate concentrations observed in effluent monitoring data. Therefore, sulfate concentrations are expected to remain well below concentrations that are harmful to crops.

11.4.4 Chloride

Monitoring data (Table 4.4) indicate that the Vulcan discharge will meet the ecoregion chloride value of 17.3 mg/L.

11.5 Agricultural Water Supply: Livestock

The Vulcan discharge flows directly into a private pond at the pond owner’s request. The pond owner uses the pond, in part, for livestock watering. Field observations indicate that the land adjacent to Brushy Creek and the UT is used extensively as cattle pasture.

An evaluation of the suitability of the Vulcan discharge for pasture irrigation revealed that pasture irrigation is not a common practice in Lawrence County, and there are no published guidelines for salinity/TDS in pasture irrigation water (personal communication, Bryce Baldridge, University of Arkansas Extension Agent, Lawrence County, University of Arkansas Extension Service, Walnut Ridge Arkansas). This information indicates that these aspects of the agricultural water supply use are currently attained in the presence of the Vulcan discharge.

11.6 Domestic Water Supply

There are three residences located on Brushy Creek downstream of its confluence with the UT. During 2010, Vulcan's Robert Ball contacted these residences and spoke with Charles Milgrim, Jeanette Smith, and Carolyn Webster about present and past use of Brushy Creek as a drinking water source. All three landowners stated that they have never used Brushy Creek as a drinking water source. Brushy Creek passes through areas of livestock use and flows in Brushy Creek either cease or become very low during the summer months. These factors preclude its use as a reliable and safe domestic water supply. Recent sampling and reconnaissance in the Brushy Creek watershed indicate no new residences and no change in land use since the 2010 survey. Due to the lack of sufficient flow, it is unlikely that the DWS use is attainable, even with the added Vulcan flow. The UT runs through active pasture and is not a feasible drinking water source, nor has it previously been used for the purpose.

The Arkansas Department of Health (ADH) has confirmed that there are no present or future plans for using Brushy Creek as water supply (ADH letter to Vulcan, March 24, 2009; Appendix H). Accordingly, removal of the DWS designated use is appropriate for the UT and the reach of Brushy Creek from its confluence with Stennitt Creek to the UT inflow.

12.0 CONCLUSIONS

The conclusions and recommendations of studies conducted from 2008 through 2016 are as follows:

1. Most treatment alternatives for reducing TDS and sulfate concentrations in Outfall 001 to ecoregion values (e.g. distillation, wetlands) are technically infeasible;
2. Although RO treatment is technically feasible, its implementation is cost prohibitive and would result in the quarry operation becoming economically not viable, and more importantly, it results in waste disposal issues that have additional environmental impacts and additional costs;
3. Building a pipeline to another stream with greater assimilative capacity (e.g., Spring River) is not a feasible option for permit compliance;
4. The existing discharge supports industrial and agricultural water supply uses as well as primary and secondary contact recreation;
5. The DWS use for the UT and Brushy Creek is not an existing or attainable use nor does the ADH have current or future plans for using them as a public water supply. Accordingly, this study recommends removal of this use due to the levels of the dissolved minerals proposed;
6. Water quality in Bushy Creek and Stennitt Creek supports aquatic life uses based on ADEQ's assessment methodology (ADEQ 2018);
7. TDS and sulfate recommended criteria are (a) 725 and 260 mg/L, respectively for the unnamed tributary from Outfall 001 to the confluence with Brushy creek and (b) 549 and 126 mg/L, respectively for Brushy Creek from the confluence with the unnamed tributary to the confluence with Stennitt Creek.
8. The sulfate recommended criterion is 43.3 for Stennitt Creek from the confluence with Brushy Creek to the confluence with the Spring River.
9. The recommended criteria (Table 10.9) are based on the preferred methodology, i.e., based on the Clear Creek (reference) macroinvertebrate community tolerance values from published field studies using EPA (2011) methodology and using a conservative assumption regarding the relationship between conductivity and dissolved minerals in the receiving streams.
10. The recommended TDS criterion is an intermediate value in the range of values calculated by the methods considered in this study and all methods are considered appropriate for criteria development to support the aquatic life use.
11. The recommended criteria are consistent with existing effluent and instream concentrations which "support" fish and benthic macroinvertebrate communities.

13.0 REFERENCES

ADEQ. 2010. *Standard Operating Procedure for Macroinvertebrate Sampling Methodology for Wadeable Streams*. Little Rock, AR; Arkansas Department of Environmental Quality.

ADEQ. 2012. *2012 Integrated Water Quality Monitoring and Assessment Report*. Little Rock, AR: Arkansas Department of Environmental Quality, Water Division, Planning Branch.

ADEQ. 2016. *DRAFT Standard Operating Procedure for Sampling Macroinvertebrates in Wadeable Streams and Rivers*. Little Rock, AR; Arkansas Department of Environmental Quality. February 2016.

ADEQ. 2018. *Assessment Methodology for the Preparation of the 2018 Integrated Water Quality Monitoring and Assessment Report*. Little Rock, AR: Arkansas Department of Environmental Quality.

Ames, K.A., S.A. Ebelhar, K.L. Barber, and W.L. Pendersen. 2000. Soybean and wheat responses to chloride in potassium chloride fertilizers for suppression of disease. Illinois Fertilizer Conference Proceedings, January 24-26, 2000. Illinois.

APCEC. 2017. *Regulation No. 2, Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas*. Little Rock, AR: Arkansas Pollution Control & Ecology Commission.

Arroyo, J., and S. Shirazi. 2012. *Cost of Brackish Groundwater Desalination in Texas* [White Paper]. Austin, TX: Innovative Water Technologies, Texas Water Development Board.

Ayers, R.S., and D.W. Westcot. 1985. Water quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev.1. Food and Agriculture Organization of the United Nations. Rome.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, second edition* [EPA 841-B-99-002]. US Environmental Protection Agency, Office of Water. Washington, DC.

Baser, R.E., and J.T. Gilmour. 1982. Tolerance of rice seedlings to potassium salts. Bulletin 860. U of A Agricultural Experiment Station.

Bauder, T.A., R.M. Waskom, and J.G. Davis. 2004. Irrigation Water Quality Criteria. Crop Series No. 506. Colorado State Cooperative Extension.

Cormier, S.M., and G.W. Suter. 2011. A method for deriving water-quality benchmarks using field data. *Environ. Toxicol. Chem.* 32:255-276.

Cormier, S.M., L. Zheng, and C.M. Flaherty. 2018. A field-based model of the relationship between extirpation of salt-intolerant benthic invertebrates and background conductivity. *Sci. Total Environ.* 633:1629-1636.

EPA. 1991. Technical support document for water quality-based toxics control. United States Environmental Protection Agency, Office of Water, EPA/505/2-90-001, March 1991.

EPA. 2000. Nutrient criteria technical guidance manual: rivers and streams. United States Environmental Protection Agency, Office of Water, EPA-822-B-00-002, July 2000.

EPA. 2011. A field-based aquatic life benchmark for conductivity in central Appalachian streams. United States Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington DC. EPA/600/R-10/023F. March 2011.

EPA. 2016. EPA technical support: evaluation of several approaches to develop mineral criteria in Arkansas. Final Report. United States Environmental Protection Agency. February 2016.

FTN. 2011. *Use Attainability Analysis Report for Brushy Creek, Vulcan Construction Materials, LP, Black Rock Quarry, Lawrence County, Arkansas.* Prepared for Vulcan Materials Company. Little Rock, AR: FTN Associates, Ltd. September 12, 2011.

Funkhouser, J.E., K. Eng, and M.W. Moix. 2008. *Low-flow characteristics and regionalization of low-flow characteristics for selected streams in Arkansas* [Scientific Investigations Report 2008-5065]. Reston, VA: US Geological Survey. 161 pp.

Gilmour, J.T. 2001. Water Quality in Rice Production. In R.J. Norman and J.F. Meullenet (eds). B.R. Wells Rice Research Studies, Research Series 485. University of Arkansas, Agricultural Experiment Station. Pp.171-177.

Glover, C.R. 2001. Irrigation water classification systems. Guide A-116. New Mexico State University Cooperative Extension. Online at: http://cahe.nmsu.edu/pubs/_a/a-116.html.

Hedin, R.S., R. Hammack, and D. Hyman. 1989. "Potential Importance of Sulfate Reduction Processes in Wetlands Constructed to Treat Mine Drainage." Chapter 38b in *Constructed Wetlands for Wastewater Treatment*. Edited by Donald A. Hammer. Lewis Publishers, Inc. pp. 508-514.

Hem, J.D. 1985. Study and Interpretation of the Chemical Characteristics of Water. U.S. Geological Survey Water Supply Paper 2254. Third Ed. Library of Congress Cat. # 85-600603.

James, D.W., R.J. Hanks, and J.H. Jurinak. 1982. *Modern Irrigated Soils.* John Wiley and Sons. New York, NY.

Lamonds, A.G., M.S. Hines, and R.O. Plebuch. 1969. *Water Resources of Randolph and Lawrence Counties, Arkansas* [USGS Water Supply Paper 1879-B]. Washington, DC: US Government Printing Office. 45 pp.

Meador, M.R., and D.M. Carlisle. 2007. Quantifying tolerance indicator values for common fish species of the United States. *Ecological Indicators* 7:329-338.

Page, L.M. 1983. *Handbook of Darters.* Illinois Natural History Survey, Champaign, IL, TFH Pub. Inc. 271pp.

Plafkin, J.L. M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes. 1989. *Rapid bioassessment protocols for use in streams and rivers: Benthic macroinvertebrates and fish* [EPA 440-4-89-001]. Washington, DC: US Environmental Protection Agency, Office of Water Regulations and Standards.

Rupe, J.C., J.D. Widick, W.E. Sabbe, R.T. Robbins, and C.B. Becton. 2000. Effect of chloride and soybean cultivar on yield and the development of sudden death syndrome, soybean

Systat Software Inc. 2007. SYSTAT 12 (version 12.02.00). San Jose, CA: Systat Software, Inc.

Tacker, P., and E. Vories. 2004. "Irrigation." Chapter 8 in *Arkansas Soybean Handbook* (MP 197-10M-4-00RV). Developed by Soybean Commodity Committee of the University of Arkansas, Division of Agriculture, Cooperative Extension Service. Available online at http://www.uaex.edu/other_areas/publications/HTML/MP-197.asp.

Tacker, P., E. Vories, C. Wilson, and N. Slaton. 2001. "Water management." Chapter 9 in *Rice Production Handbook* (MP 192), edited by Nathan Slaton. University of Arkansas, Division of Agriculture, Cooperative Extension Service. Available online at http://www.uaex.edu/Other_Areas/publications/PDF/MP192/MP-192.asp.

Tanji, K.K. (ed). 1990. Crop Salt Tolerance, Agricultural Salinity Assessment and Management Manual. ASCE. New York.

Tracy, P., and S.G. Hefner. 1993. *Calculating crop nutrient value from irrigation water inputs: a survey of southeast Missouri irrigation* [WQ278]. University of Missouri Cooperative Extension. Online at http://muextension.missouri.edu/explore/envqual/wq0278.htm.

Timpano, A.J., S.H. Schoenholtz, C.E. Zipper, and D.J. Soucek. 2010. "Isolating effects of total dissolved solids on aquatic life in central Appalachian coalfield streams." In *Proceedings of the 2010 National Meeting of the American Society of Mining and Reclamation*, Bridging Reclamation, Science, and the Community, 1284-1302. Pittsburgh, PA: American Society of Mining and Reclamation.

Plants in Florida. Chapter 2, Water Quality Improvement Technologies, Section 2.1, Desalination by Reverse Osmosis. *In* United Nations Environment Programme. 1998. S*ource Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean.* Osaka: UNEP International Environmental Technology Centre.

USGS. 2012. *The StreamStats program for Arkansas*. US Geological Survey in cooperation with the Arkansas State Highway and Transportation Department, the Arkansas Natural Resources Commission, the Natural Resources Conservation Service, the US Forest Service, and the US Army Corps of Engineers – Little Rock District. Online at http://water.usgs.gov/osw/streamstats/arkansas.html.

Zeng, L., and M.C. Shannon. 2000. Salinity effects on seedling growth and yield components of rice. *Crop Sci.* 40:996-1003.

APPENDIX A

UAA for Brushy Creek

Associates Ltd.
water resources / environmental consultants

USE ATTAINABILITY ANALYSIS REPORT FOR BRUSHY CREEK

VULCAN CONSTRUCTION MATERIALS, LP
BLACK ROCK QUARRY
LAWRENCE COUNTY, ARKANSAS

SEPTEMBER 12, 2011

USE ATTAINABILITY ANALYSIS REPORT
FOR BRUSHY CREEK
VULCAN CONSTRUCTION MATERIALS, LP
BLACK ROCK QUARRY
LAWRENCE COUNTY, ARKANSAS

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September 12, 2011

EXECUTIVE SUMMARY AND CONCLUSIONS

ES.1 Summary

A Use Attainability Analysis (UAA) was completed to determine if current designated uses of Brushy Creek (Lawrence County, Arkansas) are existing and attainable. The UAA also evaluated alternatives for permit compliance for the Vulcan Construction Materials, LP (VCM) Black Rock Quarry facility, including modified Arkansas water quality standards (ARWQS) for the Domestic Water Supply (DWS) use designation and criteria for total dissolved solids (TDS) and sulfate (SO_4^{-2}) in Brushy Creek and the unnamed tributary to Brushy Creek, into which VCM discharges. VCM operates a limestone quarry facility near Black Rock, Lawrence County, Arkansas, and discharges through Outfall 001 as authorized by National Pollutant Discharge Elimination System (NPDES) Permit No. AR0046922, issued by the Arkansas Department of Environmental Quality (ADEQ).

UAA activities followed the Final UAA Work Plan prepared by FTN Associates, Ltd. (FTN), which was reviewed by ADEQ prior to beginning the field work. The UAA included field studies, toxicity testing, engineering analysis of alternatives for discharge, and an analysis of designated uses and water quality criteria associated with downstream waterbodies.

The recommended modified ARWQS were developed and evaluated according to requirements in Arkansas Pollution Control & Ecology Commission (APCEC) Regulation No. 2, §2.306 (APCEC 2010); the Administrative Guidance Document (AGD) (ADEQ 2000); and the State of Arkansas Continuing Planning Process (CPP) (ADEQ 2000).

Per the AGD, letter communications from the Arkansas Natural Resources Commission (ANRC), the Arkansas Game and Fish Commission (AGFC), and the Arkansas Department of Health (ADH) indicate that:

1. There are no current registered domestic water users on Brushy Creek,
2. There are no current plans to use Brushy Creek as a DWS, and
3. The proposed use removal will not conflict with the protection of fish and wildlife in the area.

The official letter responses from state agencies are provided in Appendix A.

Evaluation of the TDS and SO_4^{-2} in the VCM discharge indicates that:

1. The ionic composition of the water discharged through Outfall 001 is the result of the combination of the natural geology of the region and quarry activities that expose pyritic rock;
2. Based on published information and testing conducted as part of this project, dissolved minerals will not reach concentrations that will cause acute or chronic toxicity; and
3. Based on sampling of biological communities, the existing levels of dissolved minerals will not impair existing or attainable designated uses, including aquatic life.

ES.2 Alternative Evaluations

1. Reverse osmosis (RO) represents the most effective treatment option available for removing TDS from the VCM discharge to meet ARWQS; however, RO is prohibitively expensive, produces a concentrated brine reject that is environmentally difficult to dispose, and would not provide additional environmental benefits.
2. Constructing a 1.2-mile pipeline to convey the discharge to Stennitt Creek would meet ARWQS in Stennitt Creek due to upstream dilution. However, construction costs of the pipeline would be approximately $254,000, with $40,000 in annual operating costs, and would not provide additional environmental benefits.
3. Constructed wetlands designed to chemically reduce sulfate are seasonally variable in their effectiveness and produce a TDS mixture that has greater potential toxicity to aquatic life than the original TDS mixture.

ES.3 Use Analysis

Results of the analysis of designated uses (per Title 40 Code of Federal Regulations [CFR] Part 131.3) in the receiving waterbodies are summarized in Table ES.1. The analysis indicates that the DWS uses on Brushy Creek and the unnamed tributary are neither existing nor attainable uses due to natural, ephemeral, intermittent, or low-flow conditions or water levels that prevent the attainment of the use. These conditions are not compensated for by the discharge of sufficient volume of effluent discharges (see 40 CFR 131.10). In addition, the DWS designated use on the segment of Stennitt Creek downstream of the Brushy Creek confluence was removed by a previous UAA (APCEC 2010). Therefore, the DWS designated use removal on Brushy Creek and the unnamed tributary to Brushy Creek does not conflict with, and is consistent with, the DWS designated use removal on Stennitt Creek.

Table ES.1. Summary of designated use analysis for waterbodies downstream of the VCM discharge.

Waterbody	Designated Use	Existing?	Attainable With Discharge?
Unnamed tributary from Outfall 001 to confluence with Brushy Creek	Aquatic Life	Yes	Yes
	Agricultural Water Supply	Yes	Yes
	Industrial Water Supply	No	Yes
	Domestic Water Supply	No	No
	Primary/Secondary Contact Recreation	Yes	Yes
Brushy Creek from confluence with unnamed tributary to confluence with Stennitt Creek	Aquatic Life	Yes	Yes
	Agricultural Water Supply	Yes	Yes
	Industrial Water Supply	No	Yes
	Domestic Water Supply	No	No
	Primary/Secondary Contact Recreation	Yes	Yes
Stennitt Creek from confluence with Brushy Creek to confluence with Spring River	Aquatic Life	Yes	Yes
	Agricultural Water Supply	Yes	Yes
	Industrial Water Supply	Yes	Yes
	Domestic Water Supply*	No	No
	Primary/Secondary Contact Recreation	Yes	Yes
Spring River downstream of confluence with Stennitt Creek	Aquatic Life	Yes	Yes
	Agricultural Water Supply	Yes	Yes
	Industrial Water Supply	Yes	Yes
	Domestic Water Supply	Yes	Yes
	Primary/Secondary Contact Recreation	Yes	Yes
	Agricultural Water Supply	Yes	Yes

*Removed per a previous UAA (see Section ES.3).

Results of this analysis also concluded that water quality in Brushy Creek, the unnamed tributary to Brushy Creek, and Stennitt Creek will support an Ozark Highlands ecoregion fishery with the existing VCM discharge.

ES.4 Recommendations

In accordance with APCEC Regulation No. 2 (§2.306), 40 CFR 131.10 and the CPP, the study recommends:

- Remove the Domestic Water Supply use designation from the unnamed tributary and from Brushy Creek downstream of the mouth of the unnamed tributary, and
- Adopt site-specific mineral criteria for downstream waterbodies as summarized in Table ES.2.

This UAA report demonstrates that these proposed modifications protect the existing and attainable uses of Brushy Creek and also allow VCM to discharge from Outfall 001.

Table ES.2. Summary of existing and proposed criteria for waterbodies downstream of VCM Outfall 001.

	Existing (mg/L)			**Proposed (mg/L)**		
Stream Segment	**SO_4^{-2}**	**TDS**	**Cl^-**	**SO_4^{-2}**	**TDS**	**Cl^-**
Unnamed tributary from Outfall 001 to confluence with Brushy Creek*	22.7	250	17.3	197.5	713.5	No change
Brushy Creek from confluence with unnamed tributary to confluence with Stennitt Creek*	22.7	250	17.3	179.0	676	No change
Stennitt Creek from confluence with Brushy Creek to confluence with Spring River	22.7	465	17.3	87.8	No change	No change
Spring River downstream of confluence with Stennitt Creek	22.7	250	17.3	No change	No change	No change

*Removal of Domestic Water Supply designated use.

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1.0 INTRODUCTION

1.1 Background

Vulcan Construction Materials, LP (VCM) operates a limestone quarry facility near Black Rock in Lawrence County, Arkansas (Figure 1.1). The facility discharges groundwater and stormwater pumped from the quarry pit via Outfall 001 to an unnamed tributary, thence to Brushy Creek, thence to Stennitt Creek. Stennitt Creek flows into the Spring River, which the Arkansas Pollution Control & Ecology Commission (APCEC) has designated as a trout stream, an Extraordinary Resource Water, and an Ecologically Sensitive Waterbody (APCEC 2010). VCM acquired the facility in 1996. A Phase I Environmental Site Assessment (ESA) revealed that the previous owner had a National Pollutant Discharge Elimination System (NPDES) permit and elevated levels of total dissolved solids (TDS), which were reported on the facility's Discharge Monitoring Reports (DMRs). The ESA indicated that the discharged TDS levels were considered common for a quarry in a carbonate (dolomite) formation.

The previous NPDES permit (No. AR0046922) issued to VCM by the Arkansas Department of Environmental Quality (ADEQ) on January 31, 2004, contained discharge limitations for chemical oxygen demand (COD), total suspended solids (TSS), pH, turbidity, and oil and grease. TDS was present in the permit as a "report only" parameter for the first 3 years of the permit. The permit included a compliance schedule that specified compliance with TDS limits within 3 years after the effective date of the permit. The current NPDES permit, effective on July 1, 2009, contained the limitations summarized in Table 1.1. The VCM discharge has routinely met all present discharge limitations, with the exception of the TDS monthly average.

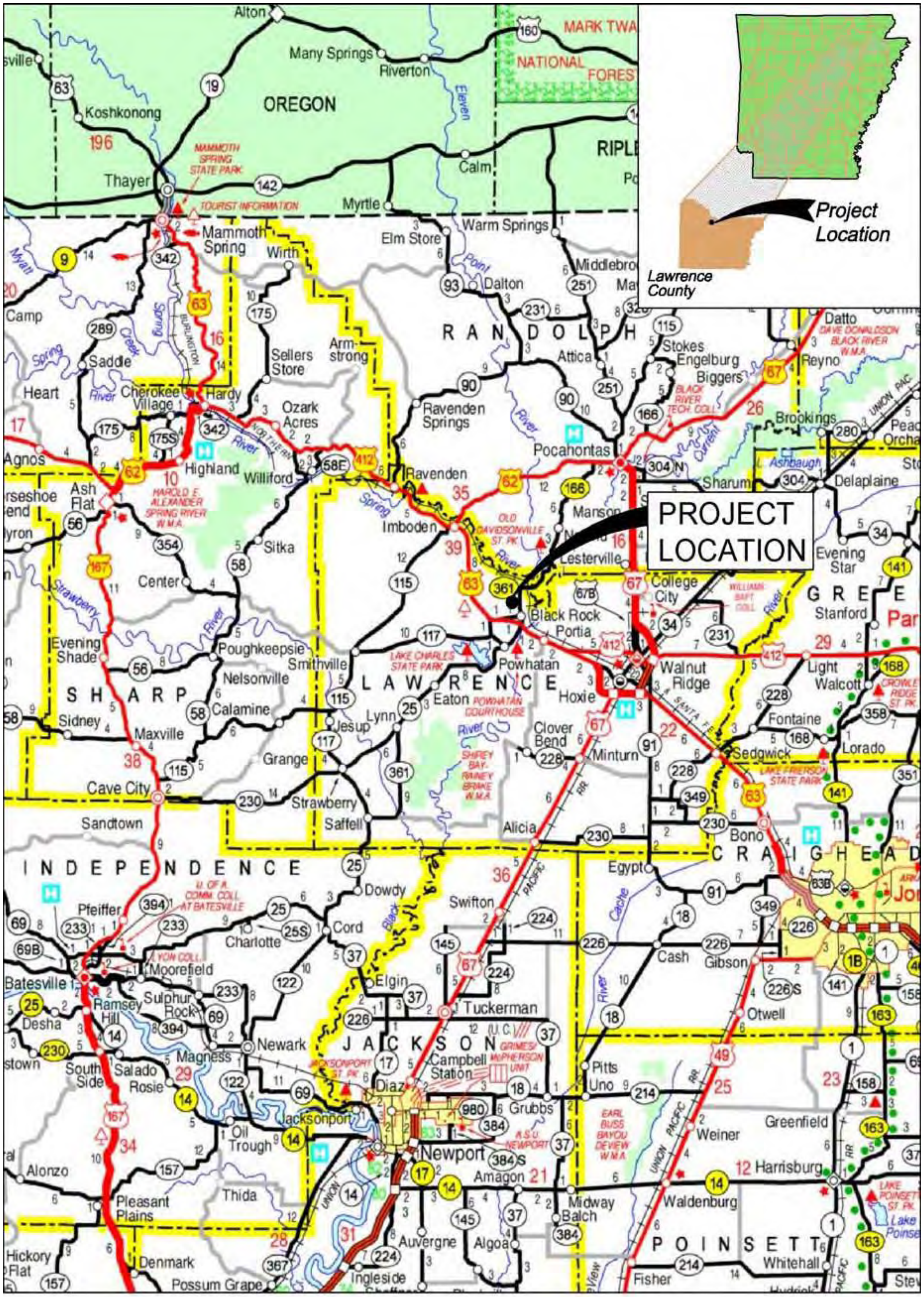

Figure 1.1. Project location map.

Figure 1. Vicinity map based on Arkansas Highway map.

Table 1.1 Current NPDES permit discharge limits for Outfall 001.

	Discharge Limitations				
	Mass (lbs/day)		**Concentration (mg/L)**		
Effluent Characteristic	**Monthly Average**	**Daily Maximum**	**Monthly Average**	**Daily Maximum**	**Sampling Frequency**
COD	133.4	200.2	50	75	Once per month
TSS	53.4	80.1	20	30	Once per month
TDS	1,334.4	2,001.6	500	750	Once per month
Oil and Grease	26.7	40.0	10	15	Once per month
pH	N/A	N/A	Min 6 su	Max 9 su	Once per month

Per Arkansas' current mineral permitting strategy (Appendix D of ADEQ 2000), "If the IWC[1] at Q7-10 flow exceeds 230 *[sic]*/250/500[2], actions must be taken to remove the drinking water designation from the receiving waterbody if it is designated as a domestic drinking water supply; additionally, chronic toxicity testing must be conducted no less than every other month for one year to demonstrate that no toxicity exist *[sic]*." In the case of the VCM discharge, the removal of the Domestic Water Supply (DWS) designated use would cause the VCM permit limits to be based on ecoregion mineral criteria of 17.3/22.7/250 (chloride/sulfate/TDS, respectively, as mg/L).

An analysis of discharge TDS concentration revealed that VCM discharge could meet TDS limits based on the ecoregion TDS criterion by applying the upstream dilution of 4 cubic feet per second (cfs) that is allowed per Arkansas' current mineral permitting strategy (Appendix D of ADEQ 2000). Accordingly, VCM undertook a Use Attainability Analysis (UAA) to evaluate the removal of the DWS use designation for Brushy Creek, which was the original focus of the UAA study reported herein. However, effluent data obtained as part of the original UAA study indicated that, while the discharge could comply with the sulfate (SO_4^{-2}) criterion of 250 mg/L under the DWS criteria, it would not comply with a SO_4^{-2} limit based on the ecoregion criterion of 22.7 mg/L, even with the allowable 4 cfs upstream dilution. Accordingly, VCM expanded the focus of the original UAA to include options for compliance with an eventual SO_4^{-2} limit. This expanded focus included evaluation of treatment options,

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[1] Instream waste concentration

[2] Refers to ***250***/250/500 as chloride/sulfate/TDS, respectively (in mg/L).

alternative discharge locations, and site-specific modifications of water quality standards and criteria.

To allow time to conduct and submit the UAA study, ADEQ and VCM entered into a consent administrative order (CAO) that provided an interim TDS permit limit of 750 mg/L.

1.2 UAA Objectives

The UAA study reported herein was conducted to:

1. Determine existing and attainable uses in waterbodies downstream of the VCM discharge (Brushy Creek, Stennitt Creek, Spring River);
2. Determine if the existing direct discharge from VCM negatively affects existing or attainable uses in downstream waterbodies; and
3. Evaluate options for permit compliance, including treatment, alternative discharge locations, designated use removal (Domestic Water Supply) and site-specific minerals criteria.

1.3 UAA Approach

Preliminary evaluation of site-specific TDS and SO_4^{-2} criteria indicated that:

- A TDS criterion consistent with the existing discharge would exceed the 500 mg/L criterion associated with the DWS designated use, and
- A SO_4^{-2} criterion consistent with the existing discharge would exceed the ecoregion criterion of 22.7 mg/L, even with the 4 cfs upstream dilution that is allowed for permitting purposes.

Therefore, in addition to the evaluation of treatment and alternative discharge locations, this UAA includes an evaluation of site-specific TDS and SO_4^{-2} criteria *and* removal of the DWS designated use.

1.3.1 Designated Use Removal

This proposal to justify designated use removal is in accordance with §2.306 of Regulation No. 2, *Procedures for Removal of Any Designated Use Except Fishable/Swimmable, Extraordinary Resource Water, Ecologically Sensitive Waterbody, or Natural and Scenic*

*Waterway, and Modification of Water Quality Criteria not Related to Fishable/Swimmable Uses (*APCEC 2010), which requires documentation that addresses, at a minimum:

1. Technological or economic limits of treatability,
2. Economic analysis of the impact on the local area,
3. Documentation that the use being removed is not an existing use and that all other designated uses will be protected.

This proposal for changes to APCEC Regulation No. 2 is also in accordance with the applicable sections of Title 40 Code of Federal Regulations (CFR) Part 131.10, including:

1. 40 CFR 131.10(b): In designating uses of a waterbody and the appropriate criteria for those uses, the State shall take into consideration the water quality standards of downstream waters and shall ensure that its water quality standards provide for the attainment and maintenance of the water quality standards of downstream waters.
2. 40 CFR 131.10(e): Prior to adding or removing any use, or establishing sub-categories of a use, the State shall provide notice and an opportunity for a public hearing under Sec. 131.20(b) of this regulation.
3. 40 CFR 131.10(g): States may remove a designated use which is *not* an existing use, as defined in Sec. 131.3, or establish sub-categories of a use if the State can demonstrate that attaining the designated use is not feasible because:
    a. Naturally occurring pollutant concentrations prevent the attainment of the use;
    b. *Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met;*
    c. Human-caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place;
    d. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the waterbody to its original condition or to operate such modification in a way that would result in the attainment of the use;

e. Physical conditions related to the natural features of the waterbody, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or

f. Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

(Note: Italics indicate 40 CFR131.10(g) criteria applicable to this case).

1.3.2 Site-Specific Criteria

This proposal is also in accordance with §2.308 and §2.306 of Regulation No. 2 (APCEC 2010), which allow the development of site-specific criteria using scientifically defensible methods that fully protect and maintain existing uses and meet the requirements for public participation per the Continuing Planning Process (CPP).

The following were components of the approach to address these issues:

1. A waterbody survey to document current water quality and biological conditions in waterbodies receiving the discharge and on other area creeks;
2. Analysis of the toxicity of the effluent discharge;
3. An evaluation of the technical, environmental, and economic feasibility of treatment to reduce TDS and SO_4^{-2}; and
4. An evaluation of the technical, environmental, and economic feasibility of moving the discharge to an alternate location.

Development of the UAA approach followed applicable guidance in:

1. The US Environmental Protection Agency (EPA) *Water Quality Standards Handbook: Second Edition* (EPA 1994);
2. The EPA Technical Support Document for Waterbody Surveys and Assessments for Conducting UAAs (EPA 1983);
3. The Water Environment Research Foundation's (WERF) reports "Suggested Framework for Conducting UAAs and Interpreting Results" (WERF 1997a) and "A Comprehensive UAA Technical Reference" (WERF 1997b);
4. The State of Arkansas Continuing Planning Process document (ADEQ 2000);

5. APCEC Regulation No. 2, including §2.306 (2010); and
6. 40 CFR 131.10(a) through (k).

The UAA process included development of a UAA Study Plan to document the various strategies and planned tasks for ADEQ and EPA review. The revised plan (February 3, 2009) incorporated comments from ADEQ. As part of this process, ADEQ indicated conceptual agreement with the proposed UAA approach.

1.4 Anticipated Outcome of the UAA

It was anticipated that the UAA study would reveal that the DWS designated use in Brushy Creek and the unnamed tributary are neither existing (regulation-defined) nor attainable due to intermittent low flows. Such a finding would support the removal of the DWS designated use in Brushy Creek and the unnamed tributary. This finding would allow development of site-specific criteria for TDS and SO_4^{-2} that protect existing and attainable uses while allowing VCM to meet permit limits *based on actual hydrological conditions governing flow and dilution without the default 4 cfs upstream dilution allowed by ADEQ's present mineral permitting policy.*

1.5 Facility Process Description

Effluent from VCM Black Rock Quarry originates from groundwater and stormwater that are pumped from the quarry pit. Stormwater and groundwater collect in the quarry sump and water is pumped through a pipe that runs up the quarry wall (Figure 1.2). The pipe splits via a valve to either (1) add makeup water to the wash ponds located south of the quarry, which are part of a closed-loop system; or (2) discharge off the property. The 800-gallon-per-minute (gpm) pump (600 gpm at Outfall 001)is sometimes operated manually, but it normally operates by a level float. The pump typically operates approximately 8 hours per day or more during wet weather, with less discharge during dry conditions. Water from the wash ponds (closed-loop system) does not discharge off the property. Water that is not needed for the wash ponds is discharged through Outfall 001. Once the water leaves Outfall 001 (Figure 1.3), it flows to a downstream landowner's stock watering pond at the landowner's request (Figure 1.4). The pond overflows via pipe (Figure 1.5) through the pond dam and travels through a natural drainage feature across the farm property, referred to herein as the unnamed tributary (Figure 1.6), thence to Brushy Creek (Figure 1.7). The drainage route from the outfall to Brushy Creek is shown on Figure 1.8, as is the permitted facility's property boundary.

1.6 Economic Impact on Local Area

VCM employs 13 people with an average annual salary of $32,000. In addition, VCM indirectly impacts employment for the local ready-mix concrete, asphalt paving, and trucking businesses that use the VCM product. State and local taxes paid annually total $331,000, and are summarized in Table 1.2. The quarry is a sponsor and contributor to Sloan-Hendrix School through the Adopt-a-School program and also sponsors and supports local athletic teams and other regional events on a regular basis.

Table 1.2. Summary of annual state and local taxes paid by VCM.

Tax Type	Amount Paid Annually
Property	$33,000
State severance	$21,000
State sales	$215,000
County sales	$54,000
City sales	$6,000
State consumer use	$26,000
County consumer use	$9,000
Total	**$331,000**

Figure 1.2. Photograph of quarry sump pump and pipe.

Figure 1.3. Outfall 001, located behind trees.

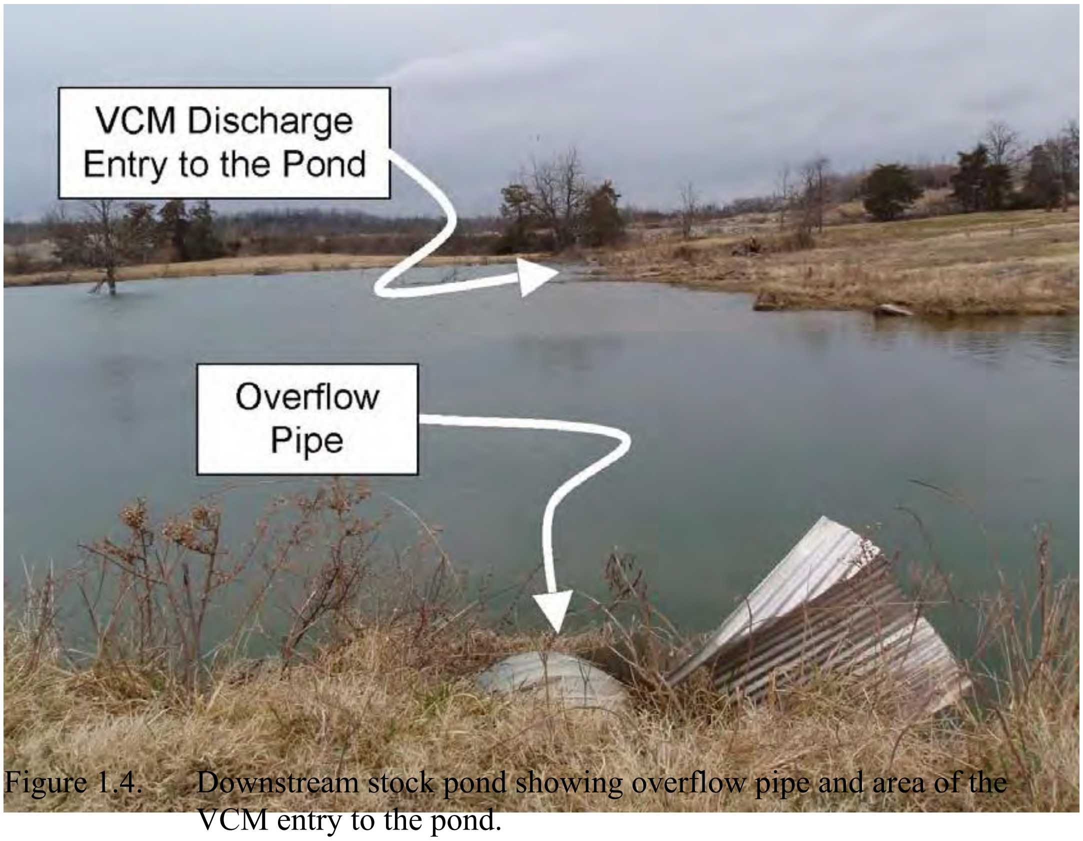

Figure 1.4. Downstream stock pond showing overflow pipe and area of the VCM entry to the pond.

Figure 1.5. Pond outlet.

Figure 2.7: Pond outlet.

Figure 1.6. Unnamed tributary drainage across pasture.

Figure 2.8. Unnamed tributary drainage across pasture.

Figure 1.7. Brushy Creek looking upstream towards mouth of unnamed tributary.

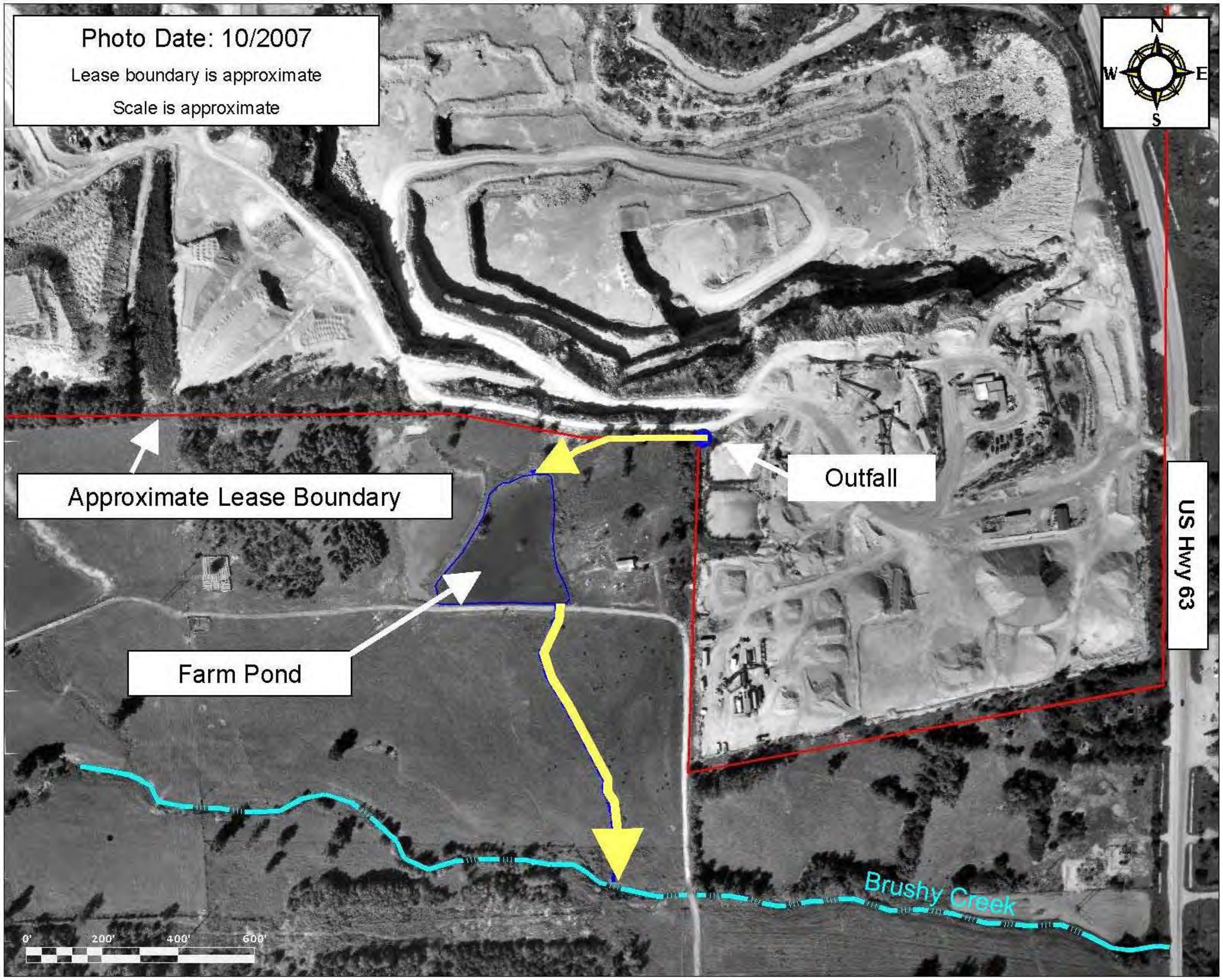

Figure 1.8. Aerial photograph of VCM site showing route of discharge water from Outfall 001 to Brushy Creek.

2.0 WATERBODY DESCRIPTIONS AND APPLICABLE ARKANSAS WATER QUALITY STANDARDS (APCEC REGULATION NO. 2)

Potentially affected waterbodies (unnamed tributary to Brushy Creek, Brushy Creek, Stennitt Creek, and Spring River) are located in the Ozark Highlands ecoregion. Table 2.1 summarizes default designated uses and mineral criteria applicable to waterbodies downstream of the VCM discharge. Stream locations, watershed boundaries and watershed areas are provided on Figure 2.1. Note that although the Brushy Creek watershed area is less than 10 square miles, this investigation assumes that it supports a perennial fishery because of the presence of enduring pools observed during low-flow conditions.

Table 2.1 Summary of default designated uses and mineral criteria applicable to waterbodies downstream of the VCM discharge.

Waterbody	**Designated Use**	**Ecoregion Mineral Criteria (mg/L)**		
		Cl^-	**SO_4^{-2}**	**TDS**
Unnamed tributary from Outfall 001 to confluence with Brushy Creek	Seasonal Ozark Highlands Fishery Agricultural Water Supply Industrial Water Supply Domestic Water Supply Primary/Secondary Contact Recreation	17.3	22.7	250
Brushy Creek from confluence with unnamed tributary to confluence with Stennitt Creek	Perennial Ozark Highlands Fishery[3] Agricultural Water Supply Industrial Water Supply Domestic Water Supply Primary/Secondary Contact Recreation	17.3	22.7	250
Stennitt Creek from confluence with Brushy Creek to confluence with Spring River	Perennial Ozark Highlands Fishery Agricultural Water Supply Industrial Water Supply Domestic Water Supply **(removed*)** Primary/Secondary Contact Recreation	17.3	22.7	465*
Spring River downstream of confluence with Stennitt Creek	Perennial Ozark Highlands Fishery Agricultural Water Supply Industrial Water Supply Domestic Water Supply Primary/Secondary Contact Recreation Agricultural Water Supply	17.3	22.7	250

*Domestic Water Supply designation removed and site-specific TDS criterion adopted per 1998 UAA for Stennitt Creek.

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[3] A perennial fishery is assumed because of the enduring pools present during low flows based on field observations.

The reader should note the site-specific TDS criterion of 465 mg/L and the removal of the DWS designated use for Stennitt Creek from the mouth of Brushy Creek to its confluence with the Spring River (Table 2.1). The UAA study supporting the Stennitt Creek use and criterion changes was conducted in 1998 and is provided in its entirety in Appendix B. The Stennitt Creek UAA did not address SO_4^{-2} concentrations in Stennitt Creek. DMR data collected from the VCM Outfall 001 (Table 2.2) document that the VCM discharge was contributing elevated TDS to downstream waterbodies at the time of the Stennitt Creek UAA study and that the results and conclusions of the 1998 UAA study incorporate the effects of the present VCM discharge. Therefore, existing water quality in Brushy Creek is consistent with current water quality criteria and uses in Stennitt Creek downstream of the mouth of Brushy Creek. Accordingly, use and criteria changes to Brushy Creek based on the existing VCM discharge, as proposed herein, do not represent a change from historical conditions in Brushy Creek or other downstream waterbodies.

Table 2.2. TDS monitoring data collected at VCM Outfall 001 during 1998 and 1999.

Sampling Date	TDS Concentration (mg/L)
March 31, 1998	559
June 30, 1998	275
September 30, 1998	514
December 31, 1998	1,100
January 31, 1999	577
February 28, 1999	453
March 31, 1999	482
April 30, 1999	502
May 31, 1999	508
June 30, 1999	607
July 31, 1999	605
August 31, 1999	685
September 31, 1999	774
October 31, 1999	517
November 30, 1999	787
December 31, 1999	619

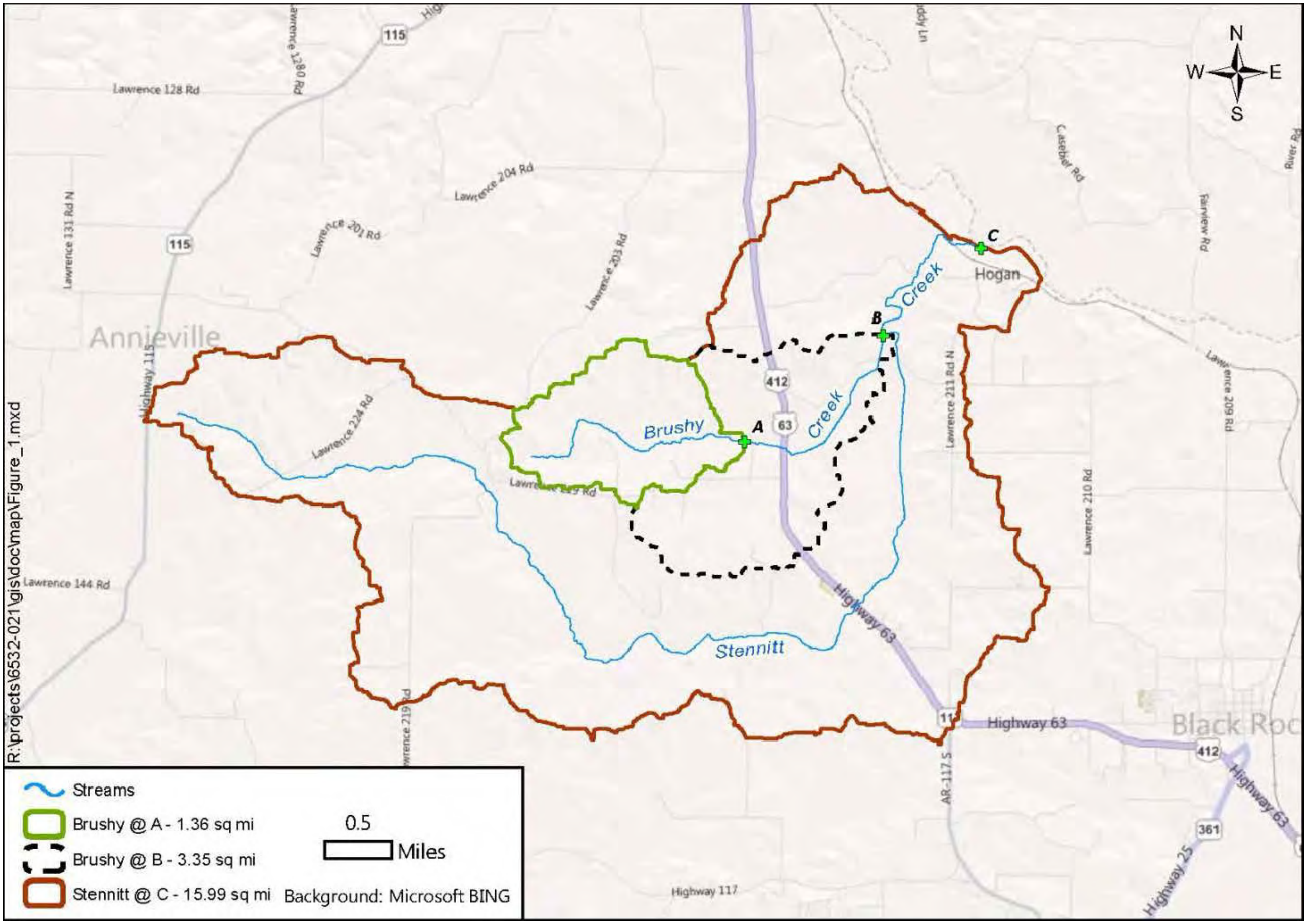

Figure 2.1. Map of study area showing location and size of watersheds.

3.0 EVALUATION OF EXISTING USES

The following sections provide an evaluation of existing uses (i.e., those uses that were attained on or after November 28, 1975) in Stennitt Creek downstream of its confluence with Brushy Creek; in Brushy Creek downstream of its confluence with the unnamed tributary; and in the unnamed tributary, all as indicated by the results of field observations, interviews with landowners (primarily on Brushy Creek downstream of the unnamed tributary), and aerial imagery available via Google Earth. All uses listed below can assumed to be existing for the Spring River downstream of its confluence with Stennitt Creek.

3.1 Primary and Secondary Contact Recreation

These uses were assigned by default to Stennitt Creek, Brushy Creek and the unnamed tributary. They can be assumed to be existing uses because, theoretically, people can come in contact with water from these waterbodies (e.g., swimming).

3.2 Industrial Water Supply

Neither Stennitt Creek downstream Brushy Creek nor the unnamed tributary are presently used as a source of water for industry, and no evidence of such use was discovered during the field observations or from aerial imagery. This use is not an existing use.

3.3 Agricultural Water Supply

The Arkansas Natural Resources Commission requires registration of irrigation (or other) water withdrawals. No ANRC-registered water withdrawals exist for Stennitt Creek, Brushy Creek, or the unnamed tributary. Field observations indicate that the land surrounding Brushy Creek and the unnamed tributary are presently used as pasture to support cattle. Therefore, this use is assumed to be an existing use.

3.4 Domestic Water Supply

There are three residences located on Brushy Creek downstream of its confluence with the unnamed tributary. VCM's Robert Ball contacted these residences and spoke with Charles Milgrim, Jeanette Smith, and Carolyn Webster about present and past use of Brushy Creek as a drinking water source. All three landowners said that they have never used Brushy Creek as a drinking water source, and that flows in Brushy Creek either cease or become very low during the summer months. Since VCM was not in operation during November 1975 when ADEQ originally assigned the DWS use designation to waters of the Ozark Highlands ecoregion, there would have been even less flow in Brushy Creek due to the absence of the VCM discharge. Therefore, the DWS use is not an existing use due to the lack of sufficient flow.

As noted in Section 2.0, the DWS use was removed from Stennitt Creek downstream of its confluence with Brushy Creek.

3.5 Aquatic Life

3.5.1 Seasonal Ozark Highlands Fishery

The watershed of the unnamed tributary to Brushy Creek is less than 10 square miles. Since VCM was not in operation during November 1975, it is questionable whether the unnamed tributary supported a seasonal fishery as defined in Regulation No. 2 (APCEC 2010). However, for purposes of this evaluation, this use will be assumed to be an existing use for the unnamed tributary.

3.5.2 Perennial Ozark Highlands Fishery

Although flows in Brushy Creek may cease or decrease to very low levels at times, field observations indicate that there are likely enduring isolated pools during low flows. Therefore, the aquatic life use is assumed to be an existing perennial use in Brushy Creek and all downstream waterbodies.

3.6 Conclusions: Existing Uses

The evaluation of existing uses of Brushy Creek and the unnamed tributary indicates the following:

- Existing uses include Primary and Secondary Contact Recreation, Agricultural Water Supply, and Aquatic Life; and
- Industrial Water Supply and Domestic Water Supply uses are not existing uses.

4.0 DISCHARGE CHARACTERISTICS

Discharge characteristics were evaluated based on routine DMR sampling for TDS; additional sampling for SO_4^{-2}; and field surveys conducted between February 29, 2009, and March 21, 2011. Additional information on the mineral content of groundwater in the Black Rock area is available from 14 monitoring wells ranging in depth from 75 to 300 ft (with an average depth of 151 ft), available as part of water resources surveys conducted by the United States Geological Survey (USGS 1969). These data are summarized in Table 4.1.

Table 4.1. Summary of major ion concentrations at Outfall 001 and 14 monitoring wells in Randolph and Lawrence counties.

	Outfall 001				**Monitoring Wells***			
Parameter	**Minimum**	**Mean**	**Maximum**	**N**	**Minimum**	**Mean**	**Maximum**	**N**
Total Alkalinity	150	199	240	10	287	428	560	14
TDS	327	482	618	23	324	394	532	14
Ca^{+2}	62	73.3	85	10	34	82	101	14
Mg^{+2}	40	47.3	54	10	30	40	59	14
K^{+}	1.7	2.75	4.6	10	0.9	2.2	3.4	14
Na^{-}	2.8	3.87	5.9	10	1.3	7.0	32	14
Cl	5.4	8.58	13	10	1.4	9.4	26	14
SO_4^{-2}	72.4	135	200	22	1.0	14	5.6	14

Notes: Discharge data based on routine DMR sampling for TDS, additional sampling for SO_4^{-2}, and field surveys conducted between February 29, 2009, and March 21, 2011.
*Depth range 75 to 300 ft; average depth of 151 ft; see Table 7 in *Water Resources of Randolf and Lawrence Counties, Arkansas* (USGS 1879-B).

4.1 Ionic Composition

Analysis of cations and anions indicate calcium (Ca^{+2}) and magnesium (Mg^{+2}) and bicarbonate (HCO_3^-) as dominant ions in groundwater, with additional SO_4^{-2} in Outfall 001. Ionic makeup of the Outfall 001 discharge is virtually identical to the groundwater except for elevated SO_4^{-2} (and resulting elevated TDS) in the discharge (Table 4.1). The quarry is located in the Powell Dolomite formation. Dolomite is composed of $(CaMg)(CO_3)_2$, which is consistent with the dominance of Ca^{+2}, Mg^{+2} and HCO_3^- in groundwater and the VCM discharge (Table 4.1).

These monitoring data from Outfall 001 encompass two complete years and include periods of unusually wet (spring of 2009) and dry (summer and fall of 2010) weather and are therefore representative of the range of TDS and SO_4^{-2} concentrations likely to occur at Outfall 001. A striking feature of the groundwater data summarized in Table 4.1 is that *all of the TDS data exceed the ecoregion TDS criterion of 250 mg/L*. Therefore, background TDS concentrations in the study area can be expected to exceed ecoregion criteria depending on local surface and groundwater hydrology. A plot of SO_4^{-2} versus TDS from the outfall (Figure 4.1) shows a significant correlation (Spearman $R^2 = 0.56$, $p = 0.004$) between TDS and SO_4^{-2}, which indicates that SO_4^{-2} from the outfall contributes to the relatively high background TDS.

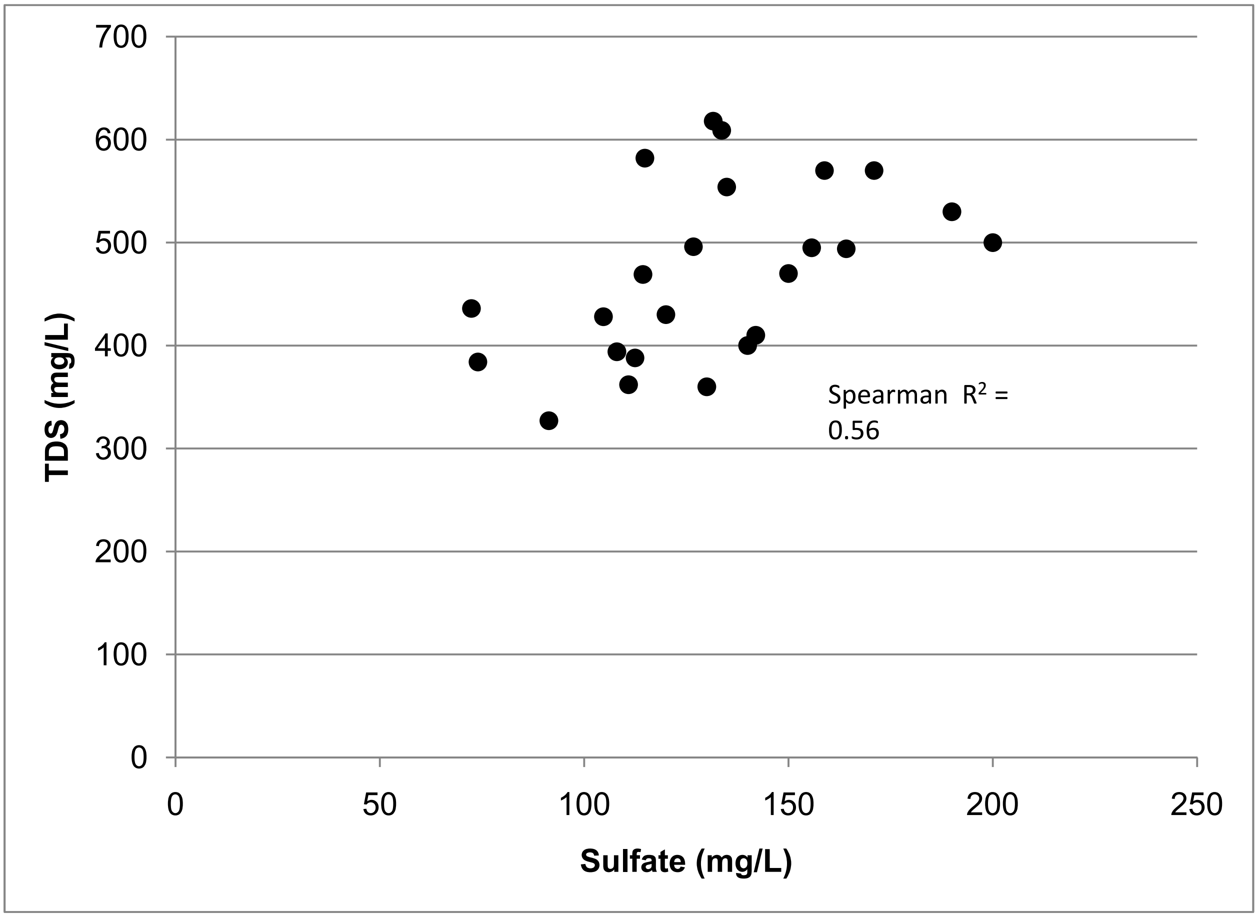

Figure 4.1. Plot of TDS versus SO_4^{-2} from Outfall 001. (Data collected February 24, 2009, to June 22, 2011.)

A photograph taken near the bottom of the quarry (Figure 4.2) shows the presence of green-colored shale strata, as well as yellowish staining of the quarry wall, which is due to either oxidized pyrite or iron oxide precipitated from the leaching groundwater. Pyrite can be found as finely disseminated particles in the shales common in this formation, as secondary precipitated minerals along fractures within the rock, or as secondary precipitates within karst features. Pyrite is a well-known source of SO_4^{-2} in surface water and is a likely source of SO_4^{-2} in the outfall. The high concentrations of HCO_3^- characteristic of the discharge, receiving waters, and groundwater prevent the acidification that would likely happen in poorly buffered systems.

This information indicates that the ionic composition of the water discharged through Outfall 001 is the result of the combination of the natural geology of the region and quarry activities that expose pyritic rock.

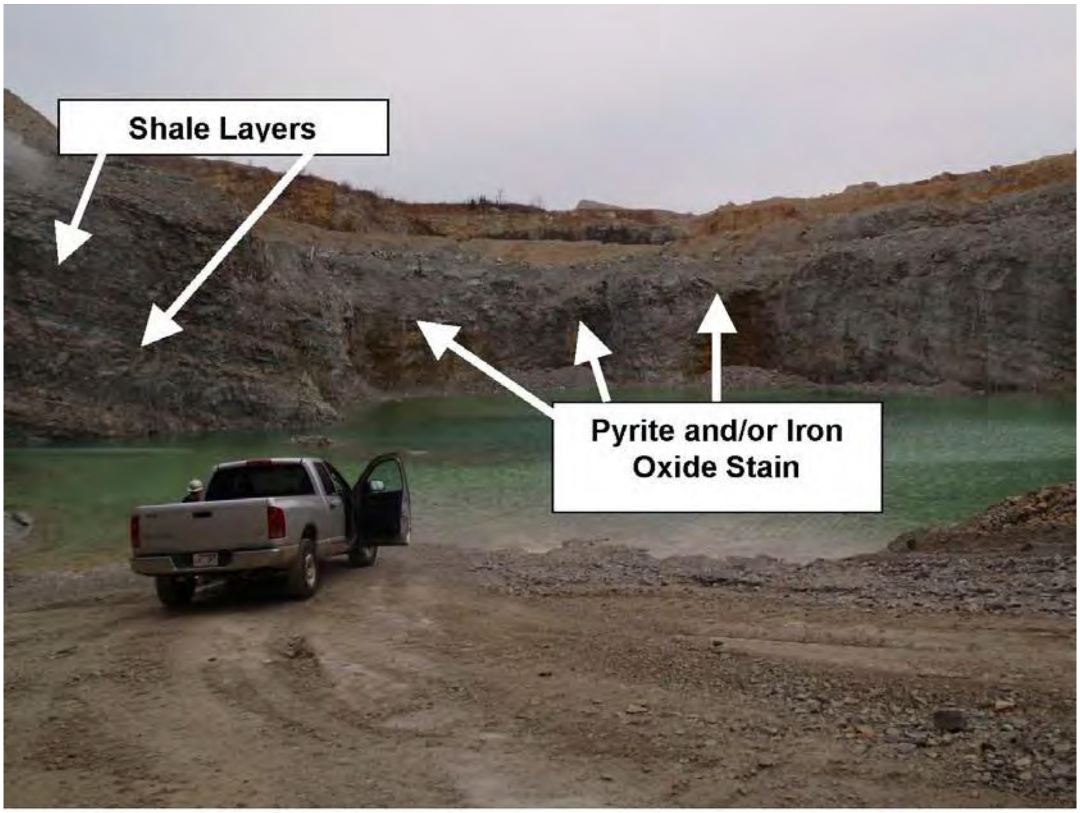

Figure 4.2. Photograph taken near the bottom of the quarry showing shale layers and iron staining (pyrite or iron oxide).

4.2 Toxicity Testing

TDS and ionic composition are the primary concern regarding potential toxic effects of the VCM discharge. Chronic survival, reproduction, and growth toxicity tests (EPA 2002) performed on a sample collected on February 24, 2009[4], indicated no lethal or sub-lethal toxicity to either *Ceriodaphnia dubia* or *Pimephales promelas*. This result justified further effort to develop the UAA, which included experiments to manipulate effluent sample concentrations of Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, Cl^{-}, SO_4^{-2} and HCO_3^{-} ions by adding inorganic salts to the effluent sample. These ions (primarily Ca^{+2}, Mg^{+2}, SO_4^{-2}, and HCO_3^{-}) account for virtually 100% of the TDS in effluent samples collected during the study (Table 4.2). The spiked effluent solutions were tested for lethal and sub-lethal effects to *C. dubia* in toxicity tests (Method 1000.2; EPA 2002) to evaluate potential toxic effects of TDS and SO_4^{-2} at “worse case” concentrations. This evaluation focused on *C. dubia*, which is known to be more sensitive to TDS-related toxicity than other standard freshwater test organisms such as *P. promelas* and *Daphnia pulex* (Goodfellow et al. 2000; Mount et al. 1997).

Toxicity test data provided in this section were generated by Huther and Associates, Inc.[5] (HAI). Initial efforts to conduct spiked effluent tests performed by American Interplex Corporation Laboratories (AIC) produced results that indicated the presence of sub-lethal toxicity in the VCM discharge that was due to the ionic strength/composition of the samples. However, these results were at considerable variance from published information on ion toxicity, particularly regarding expected dose responses and toxic levels of SO_4^{-2} and HCO_3^{-} in the presence of Ca^{+2}. In addition, split sample testing between HAI and AIC indicated consistent differences between laboratories, with HAI consistently showing no lethal or sub-lethal toxicity and AIC consistently showing sub-lethal toxicity in undiluted effluent (Table 4.3). After agency consultation, results generated by AIC were considered aberrant and the results from HAI were used to support this evaluation. A detailed discussion and documentation of the reasoning for this decision is provided in Appendix C.

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[4] Test performed by American Interplex Corporation Laboratories, 8600 Kanis Road, Little Rock, AR 72204.

[5] Huther and Associates, Inc., 1156 North Bonnie Brae, Denton,TX 76201.

Table 4.2. Summary of ionic makeup of Outfall 001 samples.

	Concentration (mg/L)					Proportion of Measured TDS				
Parameter	Min (mg/L)	Mean (mg/L)	Max (mg/L)	SD (a)	N	Min (%)	Mean (%)	Max (%)	SD	N
Total Alkalinity	150	199	240	27.67	10	NA (b)	NA	NA	NA	NA
HCO_3^- (c)	90.4	119.44	146	16.95	10	0.20	0.28	0.37	0.0550	10
TDS	327	482	618	86.46	23	NA	NA	NA	NA	NA
TDS (d)	327	542	802	103.45	96	NA	NA	NA	NA	NA
Ca^{+2}	62	73.3	85	8.001	10	0.14	0.17	0.19	0.0156	10
Mg^{+2}	40	47.3	54	5.100	10	0.10	0.11	0.13	0.0112	10
K^+	1.7	2.75	4.6	0.8223	10	0.00	0.01	0.01	0.0014	10
Na^+	2.8	3.87	5.9	0.8367	10	0.01	0.01	0.01	0.0014	10
Cl^-	5.4	8.58	13	2.215	10	0.01	0.02	0.03	0.0046	10
SO_4^{-2}	72.4	135	200	30.61	22	0.28	0.34	0.40	0.0360	22
SO_4^{-2}/Cl^-	14.0	18.1	24.1	3.1648	10	NA	NA	NA	NA	NA
Hardness	320	378	432	39.95	10	NA	NA	NA	NA	NA
TDS as measured ions	360	405	476	38.60	10	0.87	0.93	1.08	0.0783	10
TDS as SO_4^{-2}, HCO_3^-, Ca^{+2}, Mg^{+2}	344	390	456	36.35	10	0.83	0.90	1.04	0.0761	10

Notes: Discharge data based on routine DMR sampling for TDS, additional sampling for SO_4^{-2}, and field surveys conducted between February 29, 2009, and March 21, 2011.

(a) Standard deviation.

(b) Not applicable.

(c) HCO_3^- values calculated per SM 4500-CO2 D (APHA 1998).

(d) From DMR monitoring January 29, 2003, through June 22, 2011.

Table 4.3. Results of inter-laboratory comparison: Outfall 001 chronic screening tests using *Ceriodaphnia dubia*.

Sample Collection Date	Laboratory	Test Parameter			
		% Survival (n=10)		Average Number of Young	
		Control	Effluent	Control	Effluent
February 24, 2009	AIC	100	100	27.9	27.1
March 17, 2010	AIC	100	100	16.2	11.9 *
	AIC (Retest)	100	70	20.1	7.4 *
May 18, 2010	AIC	100	100	15.6	11.5 *
	HAI	100	100	25.4	24.8
August 18, 2010	AIC	100	100	19.7	15.6 *
	AIC (Retest)	100	90	19.2	8.4 *
September 28, 2010	AIC	100	100	18.4	14.4 *
November 15, 2010	AIC	100	90	19.9	16.2 *
	HAI	100	100	22.7	24.5
March 16, 2011	AIC	100	90	17.6	13.7 *
	HAI	100	100	24.4	27.7

*Statistically less than the control ($P < 0.05$).

4.2.1 Spiked Effluent Toxicity Testing

An experiment using spiked effluent tests was designed to evaluate the possibility that (1) toxicity was due to an unknown toxicant in the effluent, and/or (2) toxicity was related to an interaction between SO_4^{-2} and elevated hardness due to the presence of both Mg^{+2} and Ca^{+2}. The possibility of this interaction was suggested by:

1. A toxicity result in Ephlick et al. (2011) indicated an increase in SO_4^{-2} toxicity at hardness levels comparable to those found the VCM discharge (300 to 400 mg/L), and
2. Mg^{+2}, which accounts for approximately 50% of the effluent hardness, is a significant parameter in the STR model developed by Mount et al. (1997).

4.2.2 Spiked Effluent Toxicity Testing: Approach and Test Design

The approach to the spiking experiment was to increase SO_4^{-2} as $MgSO_4$ and $CaSO_4$ such that hardness and SO_4^{-2} increased simultaneously while (1) retaining the original proportion of Ca^{+2} to Mg^{+2} (approximately 2:1 by weight), and (2) increasing the Ca^{+2}:Mg^{+2} ratio to approximately 3:1. Tests were conducted using both Outfall 001 and the sample collected from Brushy Creek immediately upstream of its confluence with the unnamed tributary. The ionic makeup of Brushy Creek is very similar to that of the VCM discharge minus the elevated SO_4^{-2} (Table 4.4). The purpose of including this sample (spiked to mimic outfall SO_4^{-2} ionic composition) was to evaluate the possibility of an unknown toxicant in the VCM discharge. If the outfall sample were to show toxicity while the Brushy Creek sample (after adjustment) did not, it would suggest an unknown toxicant in the outfall not attributable to its ionic strength/composition. This experiment was performed by HAI on samples collected on November 15, 2010, as follows.

Upon arrival to the laboratory aliquots of sample were collected and analyzed for the analytes indicated in Table 4.5. Six treatments were then prepared per Table 4.6 by adding reagent-grade inorganic salts to the samples from Outfall 001 and Brushy Creek upstream of the unnamed tributary (BC0) and aerating for 24 hours. Aliquots of Treatments 2, 3, 5, and 6 were collected and analyzed for SO_4^{-2} and Ca^{+2}. Each treatment in Table 4.6 was then used as a test exposure against a common control in a 3-brood chronic toxicity test using *C. dubia.*

Table 4.4. Comparison of ionic strength and composition between Outfall 001 and Brushy Creek upstream of the unnamed tributary.

Parameter	Outfall 001				Brushy Creek Upstream (BC0)			
	Min	Mean	Max	N	Min	Mean	Max	N
Total Alkalinity	150	199	240	10	220	260	290	4
HCO_3^-	90.4	119.44	146	10	133	157	176	4
TDS	327	482	618	23	240	305	340	4
Ca^{+2}	62	73.3	85	10	55	61	66	4
Mg^{+2}	40	47.3	54	10	30	35	38	4
K^+	1.7	2.75	4.6	10	1.4	1.5	1.7	4
Na^-	2.8	3.87	5.9	10	1.8	2.4	2.8	4
Cl^-	5.4	8.58	13	10	3.8	5.8	9.9	4
SO_4^{-2}	72.4	135	200	22	7.9	13.0	17	4
Hardness	320	378	432	10	261	297	321	4

Notes: Discharge data based on routine DMR sampling for TDS, additional sampling for SO_4^{-2}, and field surveys conducted between February 29, 2009, and March 21, 2011. All units for minimum, mean, and maximum concentrations are mg/L unless otherwise noted. HCO_3^- values calculated per SM 4500-CO2 D (APHA 1998).

Table 4.5. Analytes and analytical methods for spiked effluent testing and other water quality evaluations.

Analyte	Method (or equivalent)
Cl^-	EPA 300.0
SO_4^{-2}	EPA 300.0
Ca^{+2}	EPA 200.7
Mg^{+2}	EPA 200.7
Na^+	EPA 200.7
K^+	EPA 200.7
Total Alkalinity	SM 2320B
Hardness	EPA 200.7
TDS	SM 2540C
pH	Electrode
Specific Conductance	Electrode

Table 4.6. Summary of spiking experiment setup.

Trt	Description	Expected Increase in Concentration (mg/L)				
		TDS	Ca^{+2}	Mg^{+2}	SO_4^{-2}	Hardness
1	Outfall 001	None	None	None	None	None
2	Outfall 001 + 130 mg/L $CaSO_4(2H_2O)$ + 100 mg/L $MgSO_4$	202	30	20	153	157
3	Outfall 001 + 130 mg/L $CaSO_4(2H_2O)$ + 100 mg/L $MgSO_4$ + 138 mg/L $CaCl_2$	340	80	20	153	281
4	BC0	None	None	None	None	None
5	BC0 + 260 mg/L $CaSO_4(2H_2O)$ + 200 mg/L $MgSO_4$	405	60	40	306	314
6	BC0 + 260 mg/L $CaSO_4(2H_2O)$ + 200 mg/L $MgSO_4$ + 138 mg/L $CaCl_2$	543	110	40	306	438
7	Lab Water Control	None	None	None	None	None

4.2.3 Spiked Effluent Toxicity Testing: Results

Results of the spiking experiment are presented in Table 4.7. Laboratory control survival and reproduction for Outfall 001 were 100% and 24.5 neonates, respectively. Measured versus expected SO_4^{-2} concentrations showed close agreement, while measured Ca^{+2} concentrations were consistently lower than expected. This result indicates that some precipitation of Ca^{+2} likely occurred during sample preparation and equilibration.

There were no statistically significant differences between the control and test treatments or among test treatments ($P > 0.05$). The TDS, SO_4^{-2}, and hardness concentrations of the non-toxic unspiked Outfall 001 sample were 410, 142, and 418 mg/L, respectively. Spiked samples containing approximately 300 mg/L SO_4^{-2} (average measured concentration of 294 mg/L), which is approximately 50% higher than the highest effluent concentration (Table 4.4), showed no lethal or sub-lethal toxicity. Similarly, spiked samples having up to 833 mg/L TDS (estimated), which exceeds the maximum Outfall 001 concentrations (Table 4.4), showed no lethal or sub-lethal toxicity. There was no difference in the toxicity response of the Outfall 001 versus the Brushy Creek samples, indicating no unknown toxicants in the VCM effluent. Finally, there was no evidence of increased SO_4^{-2} toxicity at elevated hardness as seen in the data reported in Elphick et al. (2011).

Table 4.7. Results of spiking experiment.

	Outfall 001					BC0				
	Treatment 1	Treatment 2		Treatment 3		Treatment 4	Treatment 5		Treatment 6	
	Unspiked	$CaSO_4 + MgSO_4$		$CaSO_4 + MgSO_4 + CaCl_2$		Unspiked	$CaSO_4 + MgSO_4$		$CaSO_4 + MgSO_4 + CaCl_2$	
Analyte	Measured	Measured	Expected	Measured	Expected	Measured	Measured	Expected	Measured	Expected
Total Alkalinity	240	--	--	--	--	302	--	--	--	--
HCO_3^-	140	--	--	--	--	171	--	--	--	--
TDS	410	--	612*	--	750*	290	--	695*	--	833*
Ca^{+2}	78.5	85.6	109	118	159	65.6	94.5	126	116	176
Mg^{+2}	54.0	--	74.0	--	74.0	38.6	--	78.6	--	78.6
K^+	2.93	--	--	--	--	1.09	--	--	--	--
Na^+	4.18	--	--	--	--	2.09	--	--	--	--
Cl^-	10.1	--	--	--	--	3.83	--	--	--	--
SO_4^{-2}	142	293	295	301	295	6.9	296	313	286	313
pH (su)	8.7	8.7	--	8.6	--	8.9	8.8	--	8.7	--
Hardness	418	--	575	--	699	322	--	636	--	760
Conductivity (µS)	695	920	--	1,122	--	510	991	--	1,216	--
% Survival	100	100		100		100	100		100	
Reproduction	24.5	22.8		21.1		21.9	21.6		21.4	

Notes: All units are mg/L unless otherwise noted.
*Estimate based on measured value in unspiked sample plus added amounts of Ca^{+2} and Mg^{+2} salts.

4.2.4 Spiked Effluent Toxicity Testing: Conclusions

Testing of spiked samples of effluent and receiving stream indicate that:

1. Mineral concentrations in the VCM discharge are not toxic to aquatic life. No chronic toxicity should be expected at SO_4^{-2} and TDS concentrations well in excess of maximum concentrations;
2. No additional toxicants in the VCM discharge are evident; and
3. No unusual interactions or non-additive responses are expected due to the ionic makeup of the discharge and receiving streams.

5.0 WATER QUALITY AND FLOWS IN RECEIVING STREAMS

To evaluate the attainability of aquatic life uses (Perennial Ozark Highlands Fishery) water quality and biological surveys were conducted during the late spring (June 14 to 16) and early fall (September 28 to 30) of 2010. The purpose of the field surveys was to:

1. Establish the range of chemical, physical, habitat and biological conditions present in Brushy Creek, Stennitt Creek, and other stream environments near the site; and
2. Evaluate factors (habitat, pollutants) that limit aquatic life in stream reaches affected by the VCM discharge.

5.1.1 Sampling Stations

Sampling stations were chosen to characterize representative reaches of Brushy Creek and Stennitt Creek upstream and downstream of the discharge. Accessibility was a major factor in selecting sampling locations due to landowner permission and dense riparian vegetation. Consequently no sampling was possible in Stennitt Creek downstream of the mouth of Brushy Creek. The locations of the sampling stations are indicated on Figure 5.1, illustrated schematically on Figure 5.2, and described in Table 5.1. A reference stream location on nearby Clear Creek (REF) was identified based a reconnaissance of streams with watersheds similar in size to Brushy Creek near its confluence with the unnamed tributary. The watershed of the reference stream location was almost entirely forested and contained no identifiable point sources of pollution other than the road crossing upstream of the sampling reach. Little if any sedimentation or substrate impairment was apparent due to the road crossing. Photographs of selected locations from the fall sampling are provided in Appendix D.

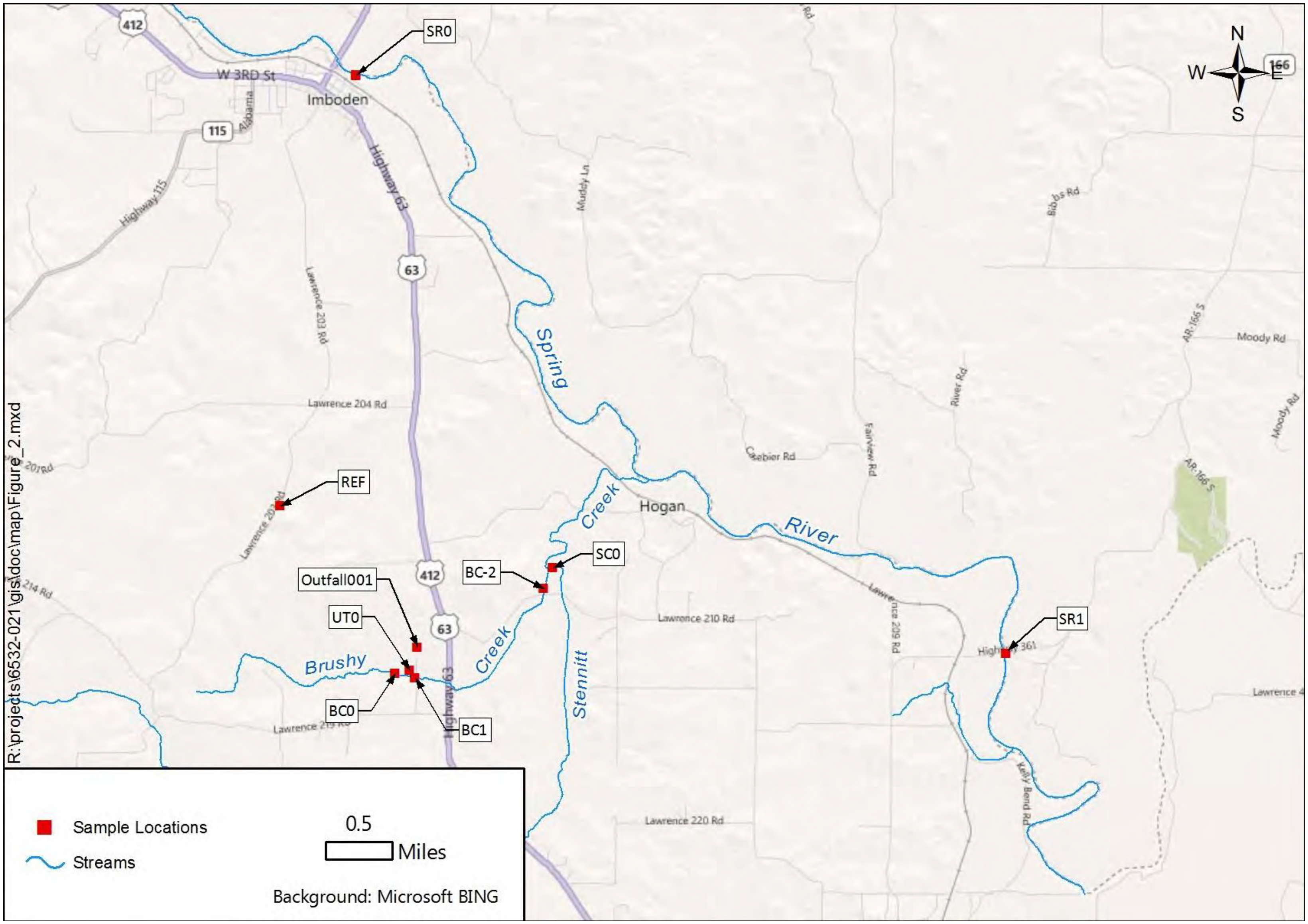

Figure 5.1. Map of waterbodies sampled during the study a locations of sampling stations.

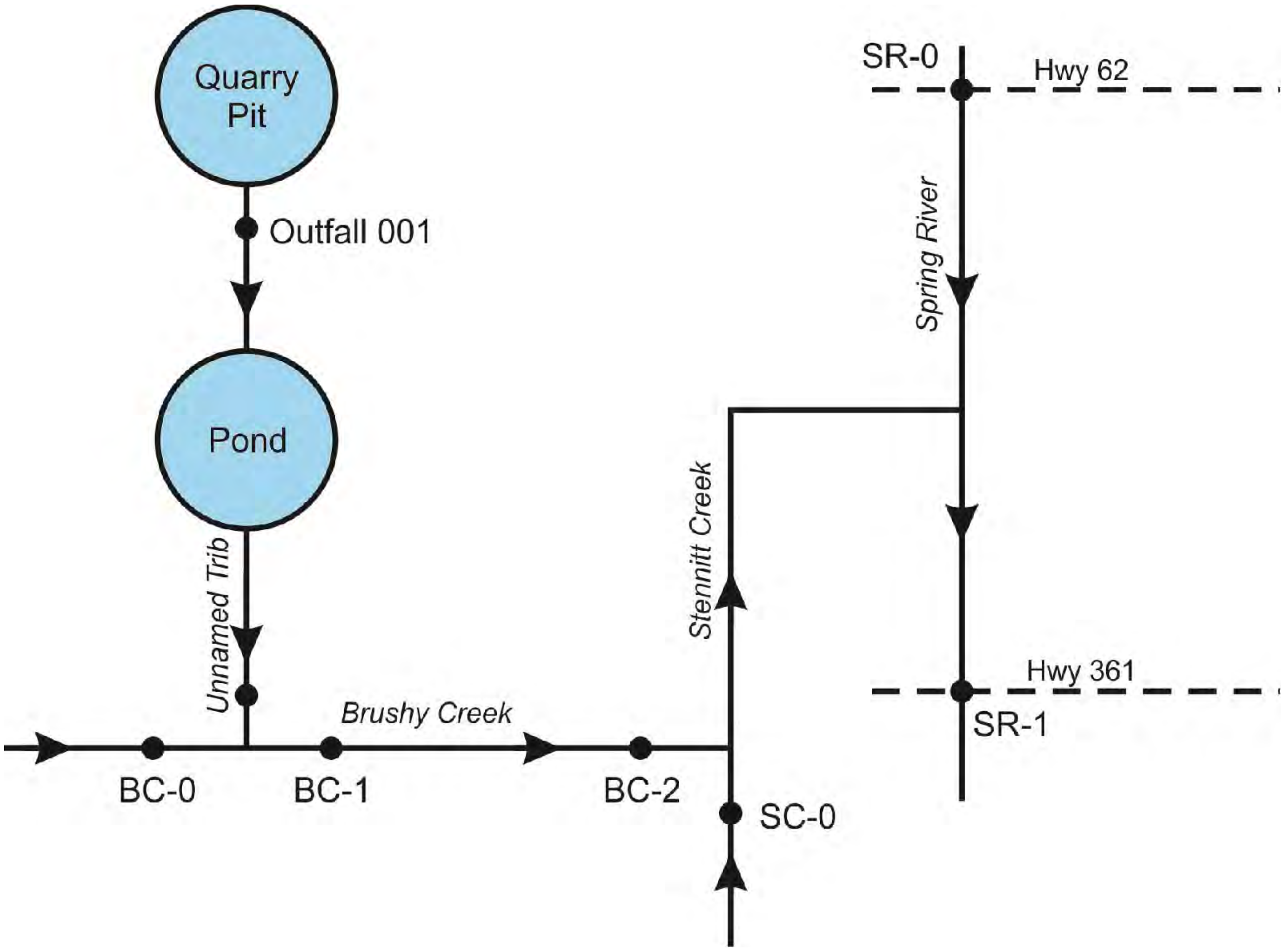

Figure 5.2. Schematic diagram of discharge source and receiving streams.

Table 5.1. Description of sampling locations and information collected during spring and fall field surveys.

Station ID	Description	GPS Coordinates		Water Quality	Flow	Fish, Benthos, Habitat
		Latitude	Longitude			
001	Outfall 001	36.14203	-91.1622	X	X	▨
UT0	Unnamed tributary to Brushy Creek	36.13952	-91.1632	X	X	X
BC0	Brushy Creek upstream of mouth of unnamed tributary	36.1392	-91.1652	X	X	X
BC1	Brushy Creek downstream of mouth of unnamed tributary	36.13865	-91.1625	X	X	X
BC2	Brushy Creek upstream of confluence with Stennitt Creek	36.1482	-91.1453	X	X	X
SC0	Stennitt Creek upstream of mouth of Brushy Creek	36.15046	-91.1441	X	X	X
SR0	Spring River at Hwy 62 upstream of mouth of Stennitt Creek	36.20385	-91.1697	X	▨	▨
SR1	Spring River at Hwy 361 downstream of mouth of Stennitt Creek	36.20383	-91.1697	X	▨	▨
REF	Reference stream – Clear Creek at County Road	36.15738	-91.1803	X	X	X

5.1.2 Water Quality and Flow

Grab samples were collected at all sample locations according to FTN sampling protocols. Samples were taken from mid-surface from flowing portions of the stream using a clean plastic bucket. The sample was then split into aliquots and placed into sample containers containing preservative appropriate for the selected analyses. Samples were placed on ice immediately upon collection and delivered to AIC, which is certified by ADEQ for the selected analyses. Samples were analyzed for the list of analytes using the methods listed in Table 4.5.

Stream flow was measured at the upstream end of each sampling reach indicated. Flows were measured by measuring stream width, depth and current velocity per USGS (1982) protocols using a calibrated wading rod and a Marsh-McBirney (Flow Mate Model 2000) flow meter. All flow measurements were made concurrently with grab sample collection.

In situ measurements of temperature (°C), dissolved oxygen (DO; mg/L), pH (standard units), and specific conductance (conductivity; µS) were taken using Hydrolab Minisonde Multiprobe water quality monitors. Instruments were calibrated on the day of use or deployment.

Calibration of the DO function on all instruments was performed using air calibration. Calibration of conductivity and pH functions was performed using standard buffers (pH) and calibration standards (conductivity). Calibration was checked upon completion of each day's measurements by comparing instrument readings with readings in standard buffers, calibration standards or saturated air, as appropriate. All calibration information was documented and retained as part of the project records. Discreet in situ measurements were taken in mid-current at mid-depth concurrently with grab water samples.

5.1.2.1 Water Quality and Flow Measurement Results and Discussion

Results of flow and chemical measurements are presented in Tables 5.2 and 5.3 for the June and September 2010 sampling, respectively. Samples collected in June 2010 showed TDS in excess of the ecoregion criterion of 250 mg/L in all waterbodies except the Spring River, where TDS concentrations were near ecoregion criteria. Sulfate concentrations at the unnamed tributary (UT0), Outfall 001, and Brushy Creek downstream of the unnamed tributary and upstream of Stennitt Creek (BC2) exceeded ecoregion criteria (Table 5.2).

Similarly, samples collected in September 2010 (Table 5.3) showed TDS in excess of ecoregion criteria in all waterbodies with one duplicate sample from the Spring River exceeding the TDS criterion. Sulfate concentrations at the unnamed tributary (UT0), Outfall 001, and both downstream Brushy Creek stations (BC1 and BC2) exceeded ecoregion criteria.

There was not strong seasonality in parameters related to dissolved minerals.

The combination of hard substrate and low flows prevented flow measurement at BC0 (upstream of the mouth of the unnamed tributary). Flow at this point was estimated based on the measured flow at BC1 minus measured flow at UT0.

Sampling results from locations unaffected by the VCM discharge (BC0, SC0, SR0, REF) showed that background TDS concentrations commonly exceed or are near (as with the Spring River concentrations) ecoregion TDS criteria. Brushy Creek stations downstream of the unnamed tributary generally exceeded ecoregion TDS and SO_4^{-2} criteria (except for SO_4^{-2} in the June sample) and reflected the additional loading of these parameters from the VCM discharge.

Table 5.2. Summary of results of flow, water chemistry analyses of grab samples and in situ measurements taken June 14 through 16, 2010.

Parameter	Station								
	UT0	**BC0**	**BC1**	**BC2** [(a)]	**SC0**	**REF**	**001**	**SR0**	**SR1**
Date [(b)]	6/15	6/14	6/14	6/15	6/15	6/16	6/15	6/15	6/15
Time [(b)] (24 h)	1550	1745	1515	1100	1310	0740	1015	0713	1908
Flow (gpm)	2	220	182	223	1,435	494	NM	$4.54x10^5$ [(c)]	$4.54x10^5$ [(c)]
Temperature (ºC)	NM	24.32	NM	31.42	26.77	19.50	26.3	26.98	NM
DO (mg/L)	NM	6.98	NM	7.44	6.07	7.91	5.8	6.72	NM
pH (su)	NM	7.68	7.7	7.81	7.57	7.90	7.3	7.81	NM
Specific Conductance (μS)	704	596	NM	562	537	211	696	454/440	NM
TDS (mg/L)	**400**	**340**	**310**	**360/340**	**280**	**280**	**430**	240	240
Alkalinity as $CaCO_3$ (mg/L)	150	260	270	220/170	300	270	210	220	200
Chloride (mg/L)	7.3	3.8	4.0	5.2/5.0	3.2	4.3	6.5	3.5	3.3
Sodium (mg/L)	4.6	2.6	2.7	3.2/3.3	2.5	2.2	3.6	2.0	1.8
Potassium (mg/L)	2.9	1.4	1.3	2.5/2.4	1.3	<1	3.0	1.6	1.6
Calcium (mg/L)	4.6	66	68	61/60	69	62	76	54	47
Magnesium (mg/L)	44	38	39	38/38	32	33	47	30	26
Sulfate (mg/L)	**91**	7.9	10	**44/44**	3.7	3.4	**120**	3.1	2.9

Notes: Bold entries indicate values not meeting ecoregion water quality criteria; NM = not measured.

(a) Duplicate samples collected.

(b) Date and time of sample collection and in situ measurements.

(c) Spring River flows obtained from USGS gage at Imboden (http://waterdata.usgs.gov/ar/nwis/uv?site_no=07069500)

Table 5.3 Summary of results of flow, water chemistry analyses of grab samples and in situ measurements taken September 28 to 30, 2010.

Parameter	**Station**								
	UT0	**BC0**	**BC1**	**BC2**	**SC0**	**REF**	**001**	**SR0**	**SR1(a)**
Date (b)	9/29	9/29	9/29	9/30	9/29	9/30	9/28	9/30	9/30
Time (24 h) (b)	1300	1350	0900	0900	1600	1100	1640	1440	0740
Flow (gpm)	2	22 (c)	24	68	244	97	NM	1.95x10^5	1.95x10^5
Temperature (ºC)	26.19	29.75	18.2	16.55	21.67	16.66	20.76	21.75	19.02
DO (mg/L)	8.77	7.42	5.64	5.96	5.6	6.24	5.17	6.49	6.61
pH (su)	8.21	7.49	6.36	7.50	7.33	7.71	6.67	7.97	7.78
Specific Conductance (µS)	690	565	619	567	513	518	785	398	463
TDS (mg/L)	**590**	**340**	**450**	**390**	**290**	**280**	**530**	160	220/**280**
Alkalinity as $CaCO_3$ (mg/L)	140	290	220	200	270	270	210	200	230/270
Chloride (mg/L)	9.9	4.5	6.9	8.4	4.0	5.2	10	3.3	3.8/5.2
Sodium (mg/L)	5.1	2.8	4.0	4.0	2.8	2.6	5.9	2.0	2.4/2.6
Potassium (mg/L)	4.2	1.4	2.9	4.0	2.1	1.0	4.6	1.6	1.7/1.0
Calcium (mg/L)	65	64	62	58	65	63	85	46	49/63
Magnesium (mg/L)	52	38	44	39	31	34	54	27	30/34
Sulfate (mg/L)	**210**	11	**100**	**95**	4.8	4.3	**190**	3.2	3.8/4.3

Notes: Bold entries indicate values not meeting ecoregion water quality criteria. NM = not measured.

(a) Duplicate samples collected.

(b) Date and time of day of sample collection and in situ measurements.

(c) Estimated (see text).

(d) Spring River flows obtained from USGS gage at Imboden (http://waterdata.usgs.gov/ar/nwis/uv?site_no=07069500)

A comparison of June versus September ion concentrations at sampling locations receiving no VCM discharge (BC0, SC0, REF, SR0) did not show strong seasonality, even though there was strong seasonality in flows. In many geophysical areas, ion concentrations act as conservative parameters with concentrations inversely related to flow, resulting in distinct seasonal fluxes in ion concentrations. Ion concentrations in the streams in this study area are apparently controlled by factors operating at larger spatial and/or temporal scales such that seasonal variation is negligible. In contrast, stronger seasonality in ion concentrations was apparent at Outfall 001 and UT0 (Tables 5.2 and 5.3). The stronger seasonality at these stations might be due to greater levels of summertime evaporation in the sump area of the quarry pit and in the pond through which the discharge passes before passing to the unnamed tributary. This can be expected to result in slightly greater seasonality in ion concentrations in Brushy Creek due to the VCM discharge.

The Spring River station downstream of the mouth of Stennitt Creek showed a consistent increase in all mineral-related parameters during the September sampling. To evaluate the potential effect that the VCM discharge has on mineral concentrations in the Spring River, a conservatively high estimate of the TDS and SO_4^{-2} loading to the Spring River from Brushy Creek can be computed as follows:

The average flow at the USGS stream gage on the Spring River at Imboden, AR (Station No. 07069500[6]), which is approximately 6 miles upstream of the mouth of Stennitt Creek, was 436 cfs during September 28 to 30, 2010. During the same time, the measured TDS and SO_4^{-2} at Outfall 001 were 530 and 190 mg/L, respectively. Using the measured flow at BC2 of 68 gpm or 0.152 cfs (note that the actual flow from the unnamed tributary at this time was only 2 gpm, or 0.004 cfs), the dilution of Brushy Creek into the Spring River can be estimated. Using these highly conservative flow-weighting values (i.e., outfall parameter concentrations + downstream flow values), the dilution of Outfall 001 into the Spring River during the September study can be calculated as:

$$0.152 \text{ cfs} \div 436 \text{ cfs} = 3.49 \times 10^{-4}$$

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[6] http://waterdata.usgs.gov/ar/nwis/uv?site_no=07069500

Therefore the increase in TDS in the Spring River due to the Outfall 001 discharge can be calculated as 3.49 x 10^{-4} x 530 mg/L = 0.18 mg/L, and the increase in SO_4^{-2} in the Spring River due to the Outfall 001 discharge can be calculated as 3.49 x 10^{-4} x 190 mg/L = 0.07 mg/L. These changes represent negligible increases in the Spring River even under these unrealistically conservative conditions.

As will be discussed later in this document, the September flow and concentration measurements were taken under moderate to severe drought conditions and provided a close approximation of critical flow conditions.

5.1.2.2 Water Quality and Flow Measurement Conclusions

The primary findings of the water quality survey were:

- Background concentrations of TDS routinely exceed ecoregion criteria;
- The VCM discharge causes TDS and SO_4^{-2} concentrations to exceed ecoregion criteria in Brushy Creek downstream of the unnamed tributary;
- Stream segments that receive no VCM discharge show little of the flow-related seasonality in ion concentrations often seen in streams. Therefore an additional effect of the VCM discharge on downstream waterbodies would be to increase seasonal variation in ion concentrations;
- The slight increase in Spring River TDS and SO_4^{-2} concentrations downstream of the VCM discharge cannot be attributed to the VCM discharge even under unrealistically conservative flow-weighting assumptions (i.e., Outfall 001 concentrations at downstream Brushy Creek flows).

6.0 ATTAINABLE USES

This section evaluates attainable uses in Brushy Creek and the unnamed tributary in the presence of the VCM discharge. In evaluating attainable uses for Brushy Creek and the unnamed tributary, it is assumed that the VCM discharge:

- Occurs an average of 8 hours per day;
- The current discharge supports most, if not all, of the dry season flow in both Brushy Creek and the unnamed tributary; and
- The VCM discharge exceeds ecoregion TDS and SO_4^{-2} criteria, but does not exceed chloride criteria (17.3 mg/L).

6.1 Primary and Secondary Contact Recreation

DMR data indicate that the VCM discharge routinely meets current limits for TSS (monthly average/daily maximum = 20/30 mg/L) and turbidity (monthly average report only, Nephelometric turbidity units [NTU]). The VCM discharge flows directly into a private pond at the pond owner's request. The pond owner currently uses the pond, in part, for recreation. Therefore, current concentrations of TDS and sulfate should not affect the attainability of this use for the unnamed tributary or Brushy Creek.

6.2 Industrial Water Supply

Although the Industrial Water Supply Use is not an existing use, current concentrations of TDS and sulfate do not affect the attainability of this use.

6.3 Agricultural Water Supply: Crops

6.3.1 Flows

According to information provided by the University of Arkansas, Division of Agriculture, Cooperative Extension Service[7], a water supply suitable for irrigation should provide minimum flows of 5, 10, or 15 gpm per acre for center pivot, furrow, and levee

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[7] http://www.uaex.edu/Other_Areas/publications/HTML/MP-197.asp

irrigation, respectively, of soybeans (Tacker and Vories 2004). The maximum flow from the facility is an intermittent flow of 600 gpm, which could, theoretically, provide irrigation for 40 to 129 acres of soybeans. This information indicates that the current discharge flows from the plant will support a marginally attainable agricultural use.

6.3.2 TDS

The most commonly used guideline for salinity tolerance of crops is Ayers and Westcot (1985). In this document, yield potentials for a number of crops are associated with soil and water salinity values measured as electrical conductance. Salinity values associated with yield potentials for cotton, soybeans, and rice are summarized in Table 6.1. The water salinity (ECw) values reported in Ayers and Westcot (1985) have been calculated from the soil salinity (ECe) values reported (ECw = ECe/1.5). TDS values shown in Table 6.1 were calculated from the conductivity values (TDS = 650*conductivity). The maximum effluent TDS concentration (802 mg/L; see Table 4.2) is well below the calculated irrigation water TDS values summarized in Table 6.1, thus indicating that effluent TDS would not be expected to negatively affect crop productivity. The US Salinity Laboratory (US Department of Agriculture, Agricultural Research Services) has calculated linear regressions of irrigation water salinity (measured as the conductivity) to relative rice yield measurements based on experiments conducted in the late 1990s (Zeng and Shannon 2000). These relationships are based on the response of rice to sodium chloride (NaCl) solutions of various strengths that were used for irrigation in the experiments. Table 6.2 shows irrigation water conductivities for relative yields of grain weight per panicle and grain weight per plant that correspond to the yield potentials that are shown in Table 6.1. These values were calculated using Zeng and Shannon’s (2000) linear regression equations. TDS values in Table 6.2 are calculated using the same equation as Table 6.1 values. The linear regression relationships developed by the US Salinity Laboratory indicate that a TDS concentration (due primarily to NaCl) of 1,000 mg/L could reduce rice productivity by about 10%. Tacker et al. (2001) also report that irrigation water with conductivity greater than 1.2 dS/m (approximately 780 mg/L TDS) is borderline for use on rice. The U of A Cooperative

Extension Service reports that TDS levels greater than 770 ppm in irrigation water for rice are cause for concern[8].

Table 6.1 Influence of soil salinity (ECe) and irrigation water salinity (ECw) on crop tolerance and yield potential of selected crops (Ayers and Westcot 1985).

Crop	Parameter	100% yield		90% yield		75% yield		50% yield		0% yield	
		ECe	**ECw**	**ECe**	**ECw**	**ECe**	**ECw**	**ECe**	**ECw**	**ECe**	**ECw**
Cotton	Cond, dS/m	7.7	5.1	9.6	6.4	13	8.4	17	12	27	18
	TDS, mg/L	--	3,315	--	4,160	--	5,460	--	7,800	--	11,700
Rice	Cond, dS/m	3	2	3.8	2.6	5.1	3.4	7.2	4.8	11	7.6
	TDS, mg/L	--	1,300	--	1,690	--	2,210	--	3,120	--	4,940
Soybean	Cond, dS/m	5	3.3	5.5	3.7	6.3	4.2	7.5	5	10.	6.7
	TDS, mg/L	--	2,145	--	2,405	--	2,730	--	3,250	--	4,355

Table 6.2 Irrigation water salinity for selected relative rice yield measurements calculated using US Salinity Laboratory linear regression equations (Zeng and Shannon 2000).

Yield Measurement	Parameter	Percent Yield				
		100	**90**	**75**	**50**	**0**
Grain weight per panicle (1)	Cond, dS/m	0.49	1.71	3.54	6.59	12.68
	TDS, mg/L	317	1,110	2,299	4,280	8,244
Grain weight per plant (2)	Cond, dS/m	0.46	1.52	3.12	5.78	11.10
	TDS, mg/L	297	989	2,026	3,755	7,212

Notes:

1. ECw = (1.040 – relative yield)/0.082, r^2=0.87
2. ECw = (1.043 – relative yield)/0.094, r^2=0.83

This information indicates that the VCM discharge may only be marginally suitable for rice irrigation. However, the topography of the Brushy Creek watershed and its rocky soils are not conducive to rice cultivation. Therefore, the TDS concentrations in the VCM discharge will not affect the attainability of the Agricultural Water Supply use with respect to rice cultivation.

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[8] http://www.aragriculture.org/soil_water/irrigation/crop/Rice/quality.htm

6.3.3 Sulfate

Sulfate in irrigation water is generally considered to be beneficial to crops rather than harmful (Tracy and Hefner 1993, Bauder et al. 2004, Glover 2001, Baser and Gilmour 1982). James et al. (1982) classify irrigation water with sulfate concentrations of 673 mg/L to 1,153 mg/L, and TDS concentrations of 488 mg/L to 1,300 mg/L, as useable for crop irrigation. These thresholds are well above any SO_4^{-2} concentrations observed in effluent monitoring data. Therefore, sulfate concentrations are expected to remain well below concentrations that are harmful to crops.

6.3.4 Chloride

Monitoring data (Table 4.4) indicate that the VCM discharge will meet the ecoregion chloride criterion of 17.3 mg/L.

6.4 Agricultural Water Supply: Livestock

The VCM discharge flows directly into a private pond at the pond owner’s request. The pond owner uses the pond, in part, for livestock watering. Field observations indicate that the land adjacent to Brushy Creek and the unnamed tributary is used extensively as cattle pasture.

An evaluation of the suitability of the VCM discharge for pasture irrigation revealed that pasture irrigation is not a common practice in Lawrence County, and there are no published guidelines for salinity/TDS in pasture irrigation water (personal communication, Bryce Baldridge, University of Arkansas Extension Agent, Lawrence County, University of Arkansas Extension Service, Walnut Ridge Arkansas). This information indicates that these aspects of the Agricultural Water Supply Use are currently attained in the presence of the VCM discharge.

6.5 Domestic Water Supply

There are three residences located on Brushy Creek downstream of its confluence with the unnamed tributary. VCM’s Robert Ball contacted these residences and spoke with Charles Milgrim, Jeanette Smith, and Carolyn Webster about present and past use of Brushy Creek as a drinking water source. All three landowners said that they have never used Brushy Creek as a drinking water source because flows in Brushy Creek either cease or become very low during the summer months. Therefore, due to the lack of sufficient flow, it is unlikely that the DWS use is attainable, even with the added VCM flow.

6.6 Aquatic Life

Attainability of the aquatic life use is addressed in Section 7.0 of this document.

7.0 AQUATIC LIFE ATTAINMENT EVALUATION

The evaluation of attainable aquatic life uses included a field survey of benthic macroinvertebrates, fish and habitat during wet season (June) and dry season (September) flow conditions. Although seasonal changes in ion concentrations are likely to be relatively small (see Section 4.0), low-flow conditions of late summer and early fall will still represent the highest concentrations of TDS and SO_4^{-2} and the lowest amount of available habitat. Therefore, this period of the year is likely to represent limiting conditions for adult and juvenile fish and middle instar invertebrates.

The comparisons of primary interest were:

1. BC0 versus BC1 to assess effects on Brushy Creek due to the VCM discharge after it enters Brushy Creek via the unnamed tributary,
2. BC1 versus BC2 to assess downstream recovery from effects shown at BC1, and
3. BC2 versus SC0 to assess potential effects on Stennitt Creek due to the VCM-influenced inflow from Brushy Creek[9].

All comparisons require that habitat is at least roughly equivalent between comparison locations or that the confounding effects of habitat can be resolved based on habitat preferences of the biota.

7.1 Habitat Evaluation

Habitat characterization followed high-gradient stream habitat assessment procedures per Barbour et al. (1999). The characterization included visual evaluation of physical habitat and a scoring methodology that allowed a rough comparison of habitat quality among sites. Field forms used for the habitat assessment were taken directly from Barbour et al. In contrast to the evaluation of physical variables, physical and habitat characteristics evaluated for the habitat characterization (per Barbour et al.) were based on the entire length of each sampling reach.

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[9] Although this comparison does not represent an “upstream” versus “downstream” comparison, the SC0 and BC2 locations were in close proximity in the same floodplain area and represent streams with and without input from the VCM discharge.

Physical variables assessed included:

1. Canopy cover,
2. Substrate type,
3. Sediment characteristics,
4. Dominant aquatic vegetation,
5. Proportion of reach with aquatic vegetation,
6. Pool/riffle ratio,
7. Average depth, width, current velocity,
8. Dominant riparian vegetation, and
9. Watershed features.

Scored habitat variables included:

1. Epifaunal substrate/available cover,
2. Embeddedness,
3. Velocity/depth regime,
4. Sediment deposition,
5. Channel flow status,
6. Channel alteration,
7. Frequency of riffles or bends,
8. Bank stability,
9. Vegetative protection, and
10. Riparian vegetative zone width.

Assessment of physical and habitat characteristics was performed at each site during both the June and September sampling to account for habitat differences due to flow.

7.1.1 Physical Habitat Characteristics: Results and Discussion

Results of the assessment of physical characteristics and habitat variables of each site are presented in Tables 7.1 through 7.4. Complete habitat forms are provided in Appendix E. Local land use was primarily pasture and forest. Trees and grasses dominated all riparian zones. Nonpoint runoff from roads and/or pastures potentially affected all locations. None of the stream reaches, except possibly the unnamed tributary, was channelized.

The unnamed tributary, which is an intermittent stream, is not comparable to the other streams in the study. Therefore, habitat comparisons among sampling sites are best restricted to the sites on Brushy Creek, Stennitt Creek, and the reference stream. Brushy Creek habitat was comprised of pools, riffles, and runs, with coarse substrate generally comprised of cobble and gravel. Stennitt Creek habitat was also mainly pools and riffles, with finer substrate generally comprised of gravel, sand, and silt. Stennitt Creek had much more woody debris and coarse particulate organic matter (leaves, sticks, twigs). The reference stream habitat was primarily riffles and runs, with relatively little pool habitat, and coarse substrate comprised of bedrock, boulders, and cobble.

Scored habitat variables (Tables 7.3 and 7.4) can be used to evaluate relative habitat quality. Although they are somewhat subjective and subject to investigator bias, they are useful for evaluating general tends and relationships and for detecting large differences in habitat. A given difference in total habitat scores can be due to small consistent differences among most or all parameters, or large differences among a few. In general, differences in total habitat scores of approximately 20 points or more can be considered to indicate an actual difference in habitat quality. By this criterion, the scoring showed generally better habitat in Brushy Creek, Stennitt Creek, and the reference stream during the spring survey. For the spring survey, the scored habitat of the sampling sites per Table 7.3 can be ranked in descending order as follows, where locations connected by underscoring indicate locations with roughly similar habitat:

REF BC1 BC0 SC0

For the fall survey they can be ranked per Table 7.4 as

REF BC0 SC0 BC1 BC2

Table 7.1. Summary of physical and habitat characteristics evaluation performed during June 14 through 16, 2010.

Category		UT0	BC0	BC1	SC0	REF
Canopy Cover		Open	Partly shaded	Partly shaded	Partly shaded	Shaded
Inorganic Substrate (% coverage)	Bedrock	0	0	15	0	50
	Boulder	0	< 1	5	0	5
	Cobble	5	20	20	10	25
	Gravel	5	50	40	20	15
	Sand	25	20	20	60	5
	Silt	65	10	0	10	0
	Clay	0	0	0	0	0
Organic Substrate (% composition)	CPOM	0	< 2	5	5	2
	FPOM	0	0	0	0	0
	Shell	0	0	0	0	0
Dominant Aquatic Vegetation		None	None	None	Water willow	None
Percent of reach with aquatic vegetation		0	0	0	< 5	0
Pool/Riffle Ratio		NA	4:1	2:1	3:1	2:1
Average Stream Depth (m)		0.1	0.2	0.1	0.5	0.2
Average Stream Width (m)		0.5	4	3	4	3
Average Current Velocity (m/s)		< 0.1	0.3	0.2	0.2	0.2
Substrate odors		Normal	Normal	Normal	Normal	Normal
Substrate oils		None	None	None	None	None
Substrate deposits		None	None	None	None	None
Embedded stones black on underside?		No	No	No	No	No
Dominant Riparian Vegetation		Grasses	Grasses/shrubs	Grasses/shrubs	Trees/shrubs	Trees/shrubs
Watershed Features	Land use	Field/pasture/quarry	Field/pasture/quarry	Field/pasture/quarry	Field/pasture	Forest
	Pollution sources	Yes	Yes	Yes	No	No
	Erosion	Moderate	Moderate	Moderate	Moderate	Minimal
Weather		Partly cloudy	Partly cloudy	Partly cloudy	Partly cloudy	Partly cloudy

Table 7.2. Summary of physical and habitat characteristics evaluation performed during September 28 through 30, 2010.

Category		UT0	BC0	BC1	BC2	SC0	REF
Canopy Cover		Open	Partly shaded	Partly open	Partly shaded	Partly shaded	Partly shaded
Inorganic Substrate (% coverage)	Bedrock	0	0	0	0	0	0
	Boulder	0	5	0	0	0	0
	Cobble	0	35	10	5	0	50
	Gravel	35	40	25	25	0	45
	Sand	5	10	0	25	0	5
	Silt	60	10	65	45	100	0
	Clay	0	0	0	0	0	0
Organic Substrate (% composition)	CPOM	NR	0	0	NR	NR	NR
	FPOM	35	0	100	5	20	NR
	Shell	NR	0	0	NR	20	NR
Dominant Aquatic Vegetation		Rooted/ Floating	Rooted/ Emergent	Rooted/ Floating	Rooted/ Emergent	Rooted/ Emergent	Rooted/ Emergent
Percent of reach with aquatic vegetation		NR	75	NR	NR	NR	NR
Pool/Riffle Ratio		0	NR	NR	NR	3:1	NR
Average Stream Depth (m)		NR	0.3	NR	NR	NR	NR
Average Stream Width (m)		NR	1	NR	NR	5	NR
Average Current Velocity (m/s)		NR	NR	NR	NR	NR	NR
Substrate odors		Normal	Normal	Normal	Normal	Sulfide	Normal
Substrate oils		None	None	None	None	None	None
Substrate deposits		None	None	None	None	None	None
Embedded stones black on underside?		No	No	No	No	No	No
Dominant Riparian Vegetation		Grasses	Grasses	Grasses	Trees/grasses	Trees/grasses	Trees
Watershed Features	Land use	Field/pasture	Agriculture	Field/pasture	Field/pasture	Field/pasture	Forest
	Pollution sources	Yes	No	Yes	Yes	No	No
	Erosion	Moderate	Moderate	Moderate	Moderate	Moderate	Minimal
Weather		Clear	Clear	Clear	Clear	Clear	Clear

NR = not recorded

Table 7.3. Summary of habitat evaluation performed June 14 through 16, 2010.

Category	**UT0**	**BC0**	**BC1**	**SC0**	**REF**	**Range Among BC and SC Locations**
Epifaunal Substrate/Available Cover	5	13	18	18	18	5
Embeddedness	5	4	16	3	18	13
Velocity/depth regime	1	10	15	8	18	7
Sediment Deposition	3	11	15	7	18	8
Channel Flow Status	3	15	15	13	18	2
Channel Alteration	18	20	20	18	20	2
Frequency of riffles	2	8	17	2	18	15
Bank Stability	8/8	8/8	8/6	8/8	10/10	2
Vegetative Protection	8/8	10/10	9/9	9/9	10/10	2
Riparian Vegetative Zone Width	4/4	10/10	9/9	9/9	10/10	2
Total Habitat Score	77	137	166	121	188	45

Table 7.4. Summary of habitat evaluation performed September 28 through 30, 2010.

Category	**UT0**	**BC0**	**BC1**	**BC2**	**SC0**	**REF**	**Range Among BC and SC Locations**
Epifaunal Substrate/Available Cover	12	13	10	10	11	14	3
Embeddedness	8	15	5	8	1	18	14
Velocity/depth regime	4	9	7	8	8	15	2
Sediment Deposition	7	14	8	9	17	15	9
Channel Flow Status	7	9	5	5	13	18	8
Channel Alteration	16	17	14	17	17	18	3
Frequency of riffles	2	8	8	7	2	17	6
Bank Stability	7/7	7/7	8/8	7/7	7/7	9/9	2
Vegetative Protection	7/7	7/7	9/9	7/7	8/8	9/9	4
Riparian Vegetative Zone Width	7/7	5/5	9/6	5/5	8/8	9/9	6
Total Habitat Score	98	123	106	102	115	169	21

The far right column in Tables 7.3 and 7.4 indicates the range of score values among the Brushy Creek and Stennitt Creek locations. In general the ranges are greatest for instream parameters such as embeddedness, sediment deposition, and frequency of riffles rather than riparian parameters such as vegetative protection. Therefore, instream parameters capture most of the differences in habitat quality among locations.

7.1.2 Habitat Characteristics: Conclusions

Habitat assessments indicated waterbodies with generally coarse substrates and land use dominated by forest and pasture. The habitat rankings given above can be used to interpret differences in biological communities among sampling locations. These habitat rankings are primarily a function of instream characteristics related to substrate. Substrate characteristics are a key factor in using habitat to interpret differences in benthic communities among locations. It should be noted that, although the BC0 and SC0 locations scored similarly on both surveys per Tables 7.3 and 7.4, they are in fact very different habitats due to differences in substrate (Tables 7.1 and 7.2). The SC0 substrate was much finer and contained far greater amount of woody debris and coarse organic particulate matter (CPOM) such as leaves, sticks and twigs.

For the purpose of interpreting differences in benthic communities based on habitat quality, the abundance and diversity of benthic macroinvertebrates and fish is expected to follow the same general pattern as habitat quality. Large deviations from this expectation indicate other limiting factors such as water quality.

7.2 Biological Communities

7.2.1 Benthic Macroinvertebrate Methods

Prior to sampling each stream reach, the upper and lower ends of the reach were cordoned off using block nets. Invertebrate sampling was conducted before fish sampling. Invertebrates were sampled using D-frame kick nets with 0.5-mm mesh net. A total of 15 individual samples (“jabs”) were collected from all available habitat, including woody debris, emergent vegetation, snags, undercut banks, open substrate, and riffles. The sampling effort was distributed among habitat types in proportion to the availability of habitats, as assessed by visual inspection. After removal and washing of large debris, the entire content of the net was washed into wide-mouth glass jars and immediately preserved with 70% ethanol.

Samples were sorted in the laboratory by dispensing the entire sample onto a Caton grid. All organisms were sorted from randomly selected grids until a minimum of 160 organisms were collected. If the whole sample was sorted and the number of organisms fell short of 160, then the whole sample was used. Sorted organisms were transferred to 70% ethanol in glass vials. To assure thorough removal of specimens from the sample, the sorted residue was retained and examined by a second biological technician. If the second sorting produced fewer than 10% of the number of organisms found in the initial sorting, the sorting of that sample was considered complete. If the second sorting produced more than 10% of the number of organisms found in the initial sorting, the sample was resorted until the 10% goal was reached.

Taxonomic identifications were carried out to the lowest practical taxon according to Merritt and Cummins (1996), Thorp and Covich (2001) and Houston (1980). In general, macroinvertebrates were identified to genus except for bivalve mollusks, gastropods, dipteran larvae, and decapod shrimp, which were identified to family. A voucher collection of invertebrate taxa collected at the sites was retained for further reference. Taxonomic identifications in the voucher collection were verified by a second taxonomist and identification discrepancies were resolved. All invertebrate taxa were classified into functional feeding groups (Predator, Shredder, Omnivore, Gatherer/Collector, Scraper, and Filterer/Collector) per Barbour et al. (1999).

Benthic invertebrate data were evaluated by visually examining changes and/or differences in taxa richness and relative abundance of functional feeding groups relative to habitat.

7.2.2 Fish Sampling Methods

Fish sampling was conducted using a Smith-Root LR-24 DC current backpack electroshocker. Sampling of each reach was conducted by probing all available habitat beginning at the downstream end of the reach, and proceeding upstream. Two sampling passes were performed on each reach. Stunned fish were collected in a plastic bucket and maintained with aeration until processed. Each individual captured was identified in the field to species according to Robison and Buchanan (1984). Individuals not positively identified in the field were killed, preserved in formalin and identified in the laboratory. Up to 25 individuals of each species were weighed to the nearest 0.1 gram and measured (total length) to the nearest millimeter. After processing, all living fish were returned to the sampling reach.

Fish data were evaluated by visually examining differences in total species richness, and species richness, and relative abundance of minnow, darter, sunfish and predator species among locations in relation to habitat. Length-weight relationships were compared among locations for those species captured in sufficiently large numbers.

7.3 Biological Characteristics Results and Discussion

7.3.1 Benthic Macroinvertebrates

Benthic invertebrate taxa and relative abundance from the June and September sampling are presented in their entirety in Appendix F. Functional feeding group composition and other metrics are summarized in Tables 7.5 and 7.6 for the spring and fall sampling, respectively.

Table 7.5. Summary of benthic macroinvertebrate sampling results from June 2010.

Metric		Sampling Location				
		UT0	BC0	BC1	SC0	REF
Functional Feeding Group (% of individuals)	Gatherer	82	46	53	51	27
	Predator	2	1	6	4	4
	Filterer	9	47	34	29	52
	Scraper	2	6	7	12	16
	Shredder	5	2	0	0	1
	Omnivore	0	0	0	1	0
	Parasite	0	0	0	0	0
	NA	0	0	0	3	0
Taxa Richness		16	12	17	19	15
% EPT*		15	64	53	17	60
% Diptera		28	30	34	25	2

* Individuals of Ephemeroptera, Plecoptera, Trichoptera

Table 7.6. Summary of benthic macroinvertebrate sampling results from September 2010.

Metric		Sampling Location					
		UT0	BC0	BC1	BC2	SC0	REF
Functional Feeding Group (% of individuals)	Gatherer	55	19	28	79	57	20
	Predator	6	19	23	8	12	3
	Filterer	10	13	37	4	5	22
	Scraper	29	48	11	7	24	54
	Shredder	0	1.6	0	0	0	0
	Omnivore	0	0	0	0	3	0
	Parasite	0	0	0	0	0	0
	NA	0	0	0	0	0	0
Taxa Richness		13	23	20	16	18	16
% EPT*		2	50	7	15	6	49
% Diptera		16	6	24	55	36	5

* Individuals of Ephemeroptera, Plecoptera, Trichoptera

7.3.1.1 June Sampling

The highest taxa richness (19 taxa) was seen at SC0 (Table 7.5). Diversity and distribution of feeding groups was similar among all sites except for UT0, which consisted primarily of gatherers (82%). Gatherers and filterers were the dominant feeding groups at BC0 (93%) and BC1 (87%), while gatherers, filterers, and scrapers dominated the benthic taxa of SC0 (92%) and REF (95%). BC0 and REF had the highest percentages of Ephemeroptera/Plecoptera/ Trichoptera (EPT) (64% and 60%, respectively). BC1 located downstream of the confluence of UT0 also had a high percentage of EPT (53%). Percent diptera was highest at BC1 (34% of individuals) and lowest at REF (2% of individuals).

BC0 Versus BC1

A comparison of BC0 versus BC1 for the spring survey (Table 7.5) indicates strong similarity between benthic invertebrate communities. Gatherers and filterers dominated the functional feeding groups of both habitats and the percent composition of EPT and dipteran individuals was similar. There was a slight increase in taxa richness at BC1. This difference is consistent with habitat differences (i.e., higher habitat score at BC1). Benthic communities at both locations were similar to the REF location with respect to functional group makeup and EPT composition but contained greater proportions of dipteran individuals.

UT0

The unnamed tributary supported a macrobenthos community with similar taxa richness but a different distribution of functional feeding groups than downstream locations.

7.3.1.2 September Sampling

The highest taxa richness was seen at BC0 (23 taxa) and BC1 (20 taxa) (Table 7.6). Gatherers and scrapers were generally the most numerous feeding groups at all locations. Gatherers, predators, and scrapers were the dominant feeding groups at BC0 (86%) while gatherers, predators, and filterers dominated the benthic taxa of BC1 (88%). Gatherers and scrapers dominated the UT0 community (84%). Percent EPT was highest at the upstream location (BC0) and the reference location. Percent diptera was highest at BC2 (55% of individuals) and SC0 (36% of individuals).

BC0 Versus BC1 and BC2

A comparison of BC0 versus BC1 for the fall survey (Table 7.6) indicates decreased taxa richness and EPT at BC1, increased dipterans and a shift in functional feeding group makeup. The BC2 location shows a further decrease in taxa richness, an increase in EPT and dipterans, and a further shift in functional feeding group composition. These changes indicate a slight overall degradation in the benthic community proceeding from BC0 to BC2. This trend is consistent with the habitat score trend per Table 7.4 and Section 7.1.1, which showed decreasing habitat scores from BC0 to BC2. The physical habitat characterization (Table 7.2) indicates more silt and sand in the substrate of BC2, which is also consistent with the biological community.

BC2 Versus SC0

A comparison of BC2 and SC0 for the fall survey (Table 7.6) indicates slightly more total taxa at SC0, lower percent EPT, slightly more uniform functional feeding group composition, and a relatively large portion (36%) of dipteran individuals. These data do not indicate a clear difference between the locations at this level of community analysis, which is consistent with the relatively small difference noted in the habitat scores (Table 7.4). In addition, the preponderance of a sandy, silty substrate at SC0 is consistent with a lower proportion of EPT individuals and a preponderance of dipterans.

UT0

The unnamed tributary supported a macrobenthos community with similar taxa richness but a different distribution of functional feeding groups than downstream locations.

7.3.2 Fish

Relative species abundance and other sampling information is presented for the June, September and combined collections in Tables 7.7 through 7.9. Family composition for the June, September, and combined collections is summarized in Tables 7.10 through 7.12, respectively.

7.3.2.1 June Sampling

Cyprinids and centrarchids dominated fish communities in terms of species composition and numbers of individuals at all Brushy Creek and Stennitt Creek locations. Cyprinids and centrarchids also dominated the species composition of the fish community at the reference stream location, although relatively fewer numbers of centrarchid individuals were present (Table 7.10). Fish sampling was not conducted at the unnamed tributary. *Etheostoma spectabile* was the most common darter at all locations, *Lepomis megalotis* was the most common sunfish, and *Campostoma oligolepis* was the most common minnow.

BC0 Versus BC1

The fish communities at BC0 and BC1 were very similar with respect to the percentages of both total taxa and total individuals within each family (Table 7.10). Centrarchids and cyprinids dominated the species composition and numbers at both locations. Darters (Percidae: *Etheostoma spectabil*e), top minnows (Fundulidae: *Fundulus olivaceus*), and stonerollers (Cyprinidae: *Campostoma oligolepis*) were common at all locations. Both locations were also similar to the reference stream location with respect to the percentages of total taxa within each family. CPUE was similar among both Brushy Creek locations and the reference stream.

Table 7.7. Summary of fish collections (as percent relative abundance) conducted June 14 through 16, 2010.

Species	Sampling Location			
	BC0	**BC1**	**SC0**	**REF**
Ameiurus natalis	1.2	1.0	1.1	0.0
Aphredoderus sayanus	0.0	0.0	0.4	0.8
Campostoma oligolepis	39.7	16.0	32.1	37.9
Campostoma sp.	0.0	0.2	0.0	0.0
Erimyzon oblongus	7.9	3.9	7.3	1.3
Etheostoma blennioides	0.0	0.0	0.8	0.0
Etheostoma flaballare	0.0	0.0	0.0	7.5
Etheostoma spectabile(1)	13.8	5.0	3.4	15.6
Fundulus olivaceus	6.9	6.0	1.1	3.4
Gambusia affinis	0.1	0.2	1.5	0.0
Lepomis cyanellus	3.7	2.3	6.1	4.1
Lepomis macrochirus	1.2	1.0	1.5	0.3
Lepomis megalotis	14.2	30.8	21.8	2.2
Lepomis microlophus	0.0	0.0	0.4	0.0
Luxilus chrysocephalus	0.0	0.0	1.1	0.0
Luxilus zonatus(1)	0.0	0.0	5.3	0.0
Lythrurus umbratilis	1.1	4.0	0.4	0.0
Micropterus salmoides	1.0	0.4	0.8	0.0
Micropterus sp.	0.0	0.6	0.0	0.0
Notropis amblops	0.0	0.0	1.1	0.0
Notropis boops	0.1	0.4	8.0	0.0
Notropis sp.	0.0	0.2	0.0	0.0
Noturus exilis(1)	0.0	0.0	0.0	0.9
Phoxinus erythrogaster(2)	0.0	0.0	0.0	18.8
Pimephales notatus	6.3	27.7	4.2	0.0
Semotilis atromaculatus	2.8	0.4	1.5	7.2
Total Taxa	**14**	**17**	**20**	**12**
Total Number	**812**	**519**	**262**	**639**

Notes:
(1) Ozark Highlands ecoregion key species
(2) Ozark Highlands ecoregion indicator species

Table 7.8. Summary of fish collections (as percent relative abundance) conducted September 28 through 30, 2010.

Species	**Sampling Location**					
	UT0	**BC0**	**BC1**	**BC2**	**SC0**	**REF**
Ameiurus natalis	0.0	0.0	0.8	0.0	0.9	0.0
Aphredoderus sayanus	0.0	0.0	0.0	0.6	1.8	0.0
Campostoma oligolepis	0.0	15.5	0.8	5.8	0.9	33.3
Cyprinella venusta	0.0	0.0	0.0	2.3	0.9	0.0
Cyprinella whipplei	0.0	0.0	0.0	9.8	0.0	0.0
Erimyzon oblongus	0.0	0.0	4.3	0.6	4.5	2.5
Etheostoma flabellare	0.0	0.0	0.0	0.0	0.0	0.9
Etheostoma spectabile(1)	20.0	26.4	5.1	4.0	2.7	17.6
Fundulus olivaceus	20.0	14.7	18.2	1.2	2.7	2.5
Gambusia affinis	0.0	0.0	4.3	31.8	1.8	0.0
Labidesthes sicculus	0.0	0.0	0.0	2.9	0.0	0.3
Lepomis cyanellus	20.0	3.1	1.2	5.8	8.0	0.0
Lepomis macrochirus	0.0	5.4	6.3	4.0	9.8	1.3
Lepomis megalotis	0.0	31.0	51.8	18.5	57.1	0.0
Lepomis microlophus	0.0	0.0	0.8	0.0	1.8	0.0
Luxilus chrysocephalus	0.0	0.0	0.4	0.6	0.0	0.0
Luxilus zonatus(1)	0.0	0.0	0.0	0.6	0.0	0.0
Lythrurus umbratilis	0.0	0.0	0.8	0.0	0.0	0.0
Micropterus salmoides	20.0	0.0	0.0	0.6	0.0	0.0
Moxostoma duquesnei	0.0	0.0	0.0	0.0	0.9	0.0
Notropis boops	0.0	0.0	0.0	4.6	2.7	0.0
Notropis exilis(1)	0.0	0.0	0.0	0.0	0.0	2.8
Phoxinus erythrogaster(2)	0.0	0.0	0.0	0.0	0.0	35.5
Pimephales notatus	20.0	0.0	5.1	6.4	2.7	0.0
Semotilis atromaculatus	0.0	3.9	0.0	0.0	0.9	3.1
Total Taxa	**5**	**7**	**13**	**17**	**16**	**10**
Total Number	**5**	**129**	**253**	**173**	**112**	**318**

Notes:

(1) Ozark Highlands ecoregion key species

(2) Ozark Highlands ecoregion indicator species

Table 7.9. Summary of fish collections (as percent relative abundance) conducted June and September 2010.

Species	**Sampling Location**					
	UT0	**BC0**	**BC1**	**BC2**	**SC0**	**REF**
Ameiurus natalis	0.0	1.1	0.9	0.0	1.1	0.0
Aphredoderus sayanus	0.0	0.0	0.0	0.6	0.8	0.5
Campostoma oligolepis	0.0	36.3	11.0	5.8	22.7	36.4
Campostoma spp.	0.0	0.0	0.1	0.0	0.0	0.0
Cyprinella venusta	0.0	0.0	0.0	2.3	0.3	0.0
Cyprinella whipplei	0.0	0.0	0.0	9.8	0.0	0.0
Erimyzon oblongus	0.0	6.8	4.0	0.6	6.4	1.7
Etheostoma blennioides	0.0	0.0	0.0	0.0	0.5	0.0
Etheostoma flaballare	0.0	0.0	0.0	0.0	0.0	5.3
Etheostoma spectabile(1)	20.0	15.5	5.1	4.0	3.2	16.3
Fundulus olivaceus	20.0	8.0	10.0	1.2	1.6	3.1
Gambusia affinis	0.0	0.1	1.6	31.8	1.6	0.0
Labidesthes sicculus	0.0	0.0	0.0	2.9	0.0	0.0
Lepomis cyanellus	20.0	3.6	1.9	5.8	6.7	2.8
Lepomis macrochirus	0.0	1.8	2.7	4.0	4.0	0.2
Lepomis megalotis	0.0	16.5	37.7	18.5	32.4	1.9
Lepomis microlophus	0.0	0.0	0.3	0.0	0.8	0.0
Luxilus chrysocephalus	0.0	0.0	0.1	0.6	0.8	0.0
Luxilus zonatus(1)	0.0	0.0	0.0	0.6	3.7	0.0
Lythrurus umbratilis	0.0	1.0	3.0	0.0	0.3	0.0
Micropterus salmoides	20.0	0.9	0.3	0.6	0.5	0.0
Micropterus spp.	0.0	0.0	0.4	0.0	0.0	0.0
Moxostoma duquesnei	0.0	0.0	0.0	0.0	0.3	0.0
Notropis amblops	0.0	0.0	0.0	0.0	0.8	0.0
Notropis boops	0.0	0.1	0.3	4.6	6.4	0.0
Notropis spp.	0.0	0.0	0.1	0.0	0.0	0.0
Noturus exilis(1)	0.0	0.0	0.0	0.0	0.0	1.6
Phoxinus erythrogaster(2)	0.0	0.0	0.0	0.0	0.0	24.3
Pimephales notatus	20.0	5.4	20.3	6.4	3.7	0.0
Semotilis atromaculatus	0.0	3.0	0.3	0.0	1.3	5.9
Total Taxa	**5**	**14**	**19**	**17**	**22**	**12**
Total Number	**5**	**941**	**772**	**173**	**374**	**957**

Notes:
(1) Ozark Highlands ecoregion key species
(2) Ozark Highlands ecoregion indicator species

Table 7.10. Summary of fish sampling conducted June 14 through 16, 2010.

Family	UT0	BC0		BC1		BC2	SC0		REF	
		% Taxa	% Ind.	% Taxa	% Ind.		% Taxa	% Ind.	% Taxa	% Ind.
Catostomidae	NS	7.1	1.2	5.9	1.0	NS	5.0	1.1	0.0	0.0
Centrarchidae	NS	28.6	20.1	23.5	34.5	NS	25.0	30.6	25.0	6.6
Cyprinidae	NS	35.7	50.0	29.4	48.5	NS	40.0	53.7	33.3	64.8
Cyprinodontidae	NS	7.1	7.9	5.9	3.9	NS	5.0	7.3	8.3	1.3
Fundulidae	NS	7.1	6.9	5.9	6.0	NS	5.0	1.1	8.3	3.4
Percidae	NS	7.1	13.8	5.9	5.0	NS	10.0	4.2	1.7	23.1
Total Taxa	NS	**14**		**17**		NS	**20**		**12**	
Total Individuals	NS	**812**		**519**		NS	**262**		**639**	
CPUE	NS	**95.3**		**73.3**		NS	**37.8**		**86.2**	

Notes: % Ind. = percent of individuals; NS = not sampled; CPUE = catch per until effort (number of fish per 10 minutes of pedal-down time).

Table 7.11. Summary of fish sampling conducted September 28 through 30, 2010.

Family	UT0		BC0		BC1		BC2		SC0		REF	
	% Taxa	% Ind.	% Taxa	% Ind.	% Taxa	% Ind.	% Taxa	% Ind.	% Taxa	% Ind.	% Taxa	% Ind.
Catostomidae	0.0	0.0	0.0	0.0	7.7	0.8	0.0	0.0	6.3	0.9	0.0	0.0
Centrarchidae	40.0	40.0	42.9	39.5	30.1	60.1	23.5	28.9	25.0	76.7	10.0	1.3
Cyprinidae	20.0	20.0	28.6	19.4	30.8	7.1	47.1	33.6	31.3	8.1	50.0	75.0
Cyprinodontidae	0.0	0.0	0.0	0.0	7.7	4.3	6.0	6.0	12.5	2.7	10.0	2.5
Fundulidae	20.0	20.0	14.3	14.7	7.7	18.2	6.0	1.2	6.3	5.4	10.0	2.5
Percidae	20.0	20.0	14.3	26.4	7.7	5.1	6.0	4.0	6.3	2.7	20.0	18.5
Total Taxa	**5**		**7**		**13**		**17**		**16**		**10**	
Total Individuals	**5**		**129**		**253**		**173**		**112**		**318**	
CPUE	**0.8**		**19.4**		**38.0**		**26.0**		**16.8**		**47.4**	

Notes: % Ind. = percent of individuals; CPUE = catch per until effort (number of fish per 10 minutes of pedal-down time).

Table 7.12. Summary of fish sampling for June and September combined.

Family	UT0		BC0		BC1		BC2		SC0		REF	
	% Taxa	**% Ind.**	**% Taxa**	**% Ind.**	**% Taxa**	**% Ind.**	**% Taxa**	**% Ind.**	**% Taxa**	**% Ind.**	**% Taxa**	**% Ind.**
Catostomidae	NA	NA	7.1	1.1	5.3	0.9	NA	NA	4.5	1.1	0.0	0.0
Centrarchidae	NA	NA	28.6	22.8	26.3	42.9	NA	NA	22.7	44.4	25.0	4.9
Cyprinidae	NA	NA	35.7	45.8	31.6	35.3	NA	NA	40.9	40.0	33.3	68.2
Cyprinodontidae	NA	NA	7.1	6.8	5.3	4.0	NA	NA	9.1	6.7	8.3	1.7
Fundulidae	NA	NA	7.1	8.0	5.3	10.0	NA	NA	4.5	1.6	8.3	3.1
Percidae	NA	NA	7.1	15.5	5.3	5.1	NA	NA	9.1	3.7	16.7	21.6
Total Taxa	NA		**14**		**19**		NA		**22**		**12**	
Total Individuals	NA		**941**		**772**		NA		**374**		**957**	
Average CPUE	**NA**		**57.4**		**55.7**		NA		**27.3**		**66.8**	

Notes: % Ind = percent of individuals; CPUE = catch per until effort (number of fish per 10 minutes of pedal-down time). “NA” indicates “not applicable” because only one season was sampled.

7.3.2.2 September Sampling

CPUE in the fall survey was approximately 50% that of the spring survey at all locations including the reference stream, with the exception of the catch rate at BC0, which was approximately 20% of the CPUE observed in the spring survey (Table 7.11). CPUE was highest at REF (47.4) and BC1 (38.0) and lowest at SC0 (16.8) and BC0 (19.4). Community composition in terms of the percentage of total taxa in each family was similar to the spring survey across all locations. The percentage of individuals as cyprinids decreased at BC0, BC1, and SC0.

BC0 Versus BC1 and BC2

Although the fish communities at BC0 and BC1 were similar in terms of percentage of total taxa in each family, there was a dramatic shift in dominance of individuals in favor of sunfish. Total taxa and CPUE at BC1 were approximately twice the values at BC0. These observations indicate greater abundance and diversity of fish in the location downstream of the input of VCM discharge. The reason for the differences in the fish communities of the BC0 versus BC1 locations is not apparent as both flows (22 gpm at BC0 and 24 gpm at BC1) and habitat were similar (Table 7.4, Section 7.1.1). The BC2 location showed similar community makeup to BC0 but with higher total taxa (17 total taxa at BC2 versus 7 total taxa at BC0) and 34% greater CPUE. The cause of these differences between BC0 and BC2 are also not apparent. However, these comparisons do not indicate a decrease in biomass or diversity of fishes downstream of the input from the VCM discharge.

BC2 Versus SC0

Total number of taxa and the percentages of total taxa in each family were similar between locations while CPUE was greater at BC2. These similarities are consistent with the similar habitat at both locations (Table 7.4 and Section 7.1.1). These comparisons do not indicate a decrease in biomass or diversity of fishes due to the input from the VCM discharge.

UT0

The fall survey indicated that the unnamed tributary supports macrobenthos and fish, including an ecoregion Key Species (*Etheostoma spectabile*).

7.4 Aquatic Life Use Attainability

The June survey results showed very close similarity between the upstream BC0 location and the downstream BC1 location in both benthic macroinvertebrate and fish communities. Biological communities in both locations were similar to the reference stream location. The September survey results showed either downstream increases in biomass and diversity (fish community) or changes that were consistent with differences in habitat (benthic macroinvertebrate community). In addition, the unnamed tributary supports both benthic macroinvertebrates and fish.

These comparisons indicate little, if any, negative impact of the VCM discharge on the aquatic life of downstream waterbodies. Therefore, downstream waterbodies support aquatic life uses in the presence of the existing VCM discharge. It is unlikely that the aquatic life use would benefit from the removal of the VCM discharge or treatment of the discharge to meet ecoregion criteria for SO_4^{-2} and TDS.

8.0 SITE-SPECIFIC CRITERIA BASED ON EXISTING DISCHARGE CONDITIONS

The analysis presented in Section 7.0 demonstrates that the Aquatic Life (Ozark Highlands ecoregion fishery) designated use in Brushy Creek, Stennitt Creek, and the unnamed tributary is attainable in the presence of the VCM discharge. This analysis justifies site-specific TDS and SO_4^{-2} criteria for downstream waterbodies based on the flow conditions and mineral concentrations of the discharge and low-flow conditions (and corresponding mineral concentrations) in the receiving streams.

8.1 Current Outfall 001 Discharge Conditions

Table 8.1 summarizes paired SO_4^{-2} measurements from Outfall 001 taken approximately monthly from February 24, 2009, through June 22, 2011, and monthly TDS measurements from routine DMR monitoring from January 29, 2003, through June 11, 2011. The entire data set for this table is provided in Appendix G. Table 8.1 indicates that the 95th percentile TDS concentration among all discharge data for the January 29, 2003, through June 11, 2011, period of record is 713.5 mg/L; and the 95th percentile SO_4^{-2} concentration for the February 24, 2009, through June 22, 2011, period of record is 197.5 mg/L. These concentrations are well below the No Observed Effect Concentration (NOEC) for sulfate-dominated TDS toxicity presented in Section 4.2, and represent appropriate criteria values for the unnamed tributary under conservative low-flow conditions in which there is no dilution from the unnamed tributary's watershed. Accordingly, site-specific SO_4^{-2} and TDS criteria of 197.5 mg/L and 713.5 mg/L, respectively, are proposed for the unnamed tributary from Outfall 001 to its mouth at Brushy Creek.

8.2 Flows and Mineral Concentrations in Receiving Streams

Evaluation of appropriate TDS and SO_4^{-2} criteria in Brushy Creek and Stennitt Creek requires identifying appropriate low-flow discharge volume and mineral concentrations. Sampling for the fall survey was conducted during September 28 to 30, 2010. During the week preceding the sampling, the northeast portion of Arkansas was experiencing a moderate to severe drought (Figure 8.1) according to the weekly archives of the US Drought Monitor web site[10]. Therefore, flows and mineral concentrations measured in Brushy Creek and Stennitt Creek during the fall survey provide a valid representation of low-flow conditions and are an appropriate basis for developing downstream site-specific TDS and SO_4^{-2} criteria. These low-flow and background mineral concentrations and associated mass balance calculation results are provided in Table 8.2. The VCM discharge also causes elevated SO_4^{-2} in Stennitt Creek downstream of the mouth of Brushy Creek. Therefore, the proposed site-specific criteria for the receiving streams include the reach of Stennitt Creek downstream of Brushy Creek. Proposed site-specific TDS and SO_4^{-2} criteria based on the results of the mass balance analysis are provided in Table 8.3.

Table 8.1. Summary of TDS and SO_4^{-2} concentrations from Outfall 001.

Summary Statistic		**TDS* (mg/L)**	**SO_4^{-2}** (mg/L)**
Percentile	10th	407	84.7
	25th	464	111
	50th	542	131
	75th	612	154
	90th	683	180
	95th	713.5	197.5
Minimum		327	72
Mean		542	134
Maximum		802	249
Number of Samples		96	26

Notes:
* January 29, 2003, to June 11, 2011
** February 24, 2009, to June 22, 2011

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[10] The Drought Monitor, National Drought Mitigation Center, P.O. Box 830988, Lincoln, NE 68583-0988, http://www.drought.unl.edu/dm/archive.html

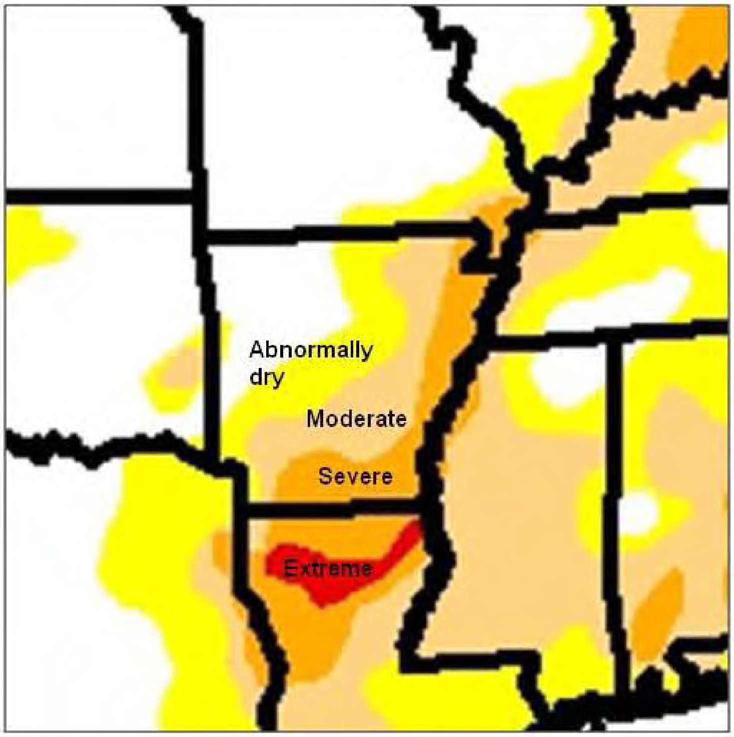

Figure 8.1. Illustration of drought conditions in the study area during the week preceding the fall survey (from US Drought Monitor).

Table 8.2. Calculated instream TDS and SO_4^{-2} concentrations of receiving streams.

Sampling Location	Critical Flow			Background (mg/L)		Segment	Calculated Low-Flow Concentration (mg/L)	
	gpm	cfs	L/sec	SO_4^{-2}	TDS		SO_4^{-2}	TDS
001	200	0.45	12.62	**197.5**	**713.5**	NA	NA	NA
BC0	22	0.05	1.39	11	**340**	NA	NA	NA
BC1	24	0.05	1.51	**100**	**450**	BC1 to BC2	**179.0**	**676**
BC2	68	0.15	4.29	**95**	**390**	BC2 to mouth of Brushy Creek	**63.2**	244.9
SC0	244	0.54	15.39	4.8	290	Stennitt Creek from mouth of Brushy Creek to confluence with Spring River*	**87.8**	**474**

Notes: Bold entries indicate values exceeding ecoregion minerals criteria.
*Based on input at BC1

Table 8.3. Summary of existing and proposed criteria for waterbodies downstream of VCM Outfall 001.

	Existing (mg/L)			Proposed (mg/L)		
Stream Segment	**SO_4^{-2}**	**TDS**	**Cl^-**	**SO_4^{-2}**	**TDS**	**Cl^-**
Unnamed tributary from Outfall 001 to confluence with Brushy Creek	22.7	250	17.3	197.5	713.5	No change
Brushy Creek from confluence with unnamed tributary to confluence with Stennitt Creek	22.7	250	17.3	179.0	676	No change
Stennitt Creek from confluence with Brushy Creek to confluence with Spring River	22.7	465	17.3	87.8	No change	No change
Spring River downstream of confluence with Stennitt Creek	22.7	250	17.3	No change	No change	No change

9.0 EVALUATION OF ALTERNATIVES

The VCM discharge contains elevated concentrations of dissolved minerals, primarily Ca^{+2}, Mg^{+2}, SO_4^{-2} and HCO_3^-, due in part to the natural geological conditions that affect groundwater characteristics. The direct discharge of this wastewater would be the most economical method for managing this wastewater. However, the TDS concentrations downstream from the discharge exceed the DWS criterion of 500 mg/L. Removal of the DWS designated use would result in permit limits based on the Ozark Highlands ecoregion criterion of 250 mg/L. Permit compliance based on the ecoregion criterion could be accomplished by assuming 4 cfs of upstream flow per ADEQ's present minerals permitting policy. However, mass balance calculations indicate that the existing discharge would not comply with an ecoregion-based SO_4^{-2} permit limit even with the assumed 4-cfs upstream flow. A direct discharge would, therefore, require modified ARWQS and removal of the default DWS designation for Brushy Creek and the unnamed tributary as well as site-specific criteria for both TDS and SO_4^{-2}. UAA guidance requires an evaluation of alternatives to propose direct discharge.

Based on a number of similar evaluations in previous UAAs, the alternatives for management of effluents with elevated dissolved minerals are limited. Two alternatives to meet ARWQS are (1) reverse osmosis (RO) treatment of the wastewater, and (2) pumping the wastewater to a larger stream that has the capacity to dilute the minerals. Accordingly, the following sections evaluate four alternatives for an environmentally safe discharge of the plant effluent, namely:

- RO treatment to remove or reduce dissolved minerals,
- Pumping the wastewater to a larger stream that has the capacity to dilute the minerals,
- Constructed wetland to chemically reduce SO_4^{-2}, and
- Site-specific criteria for SO_4^{-2} and TDS and removal of the default DWS use designation.

The evaluation of these alternatives is documented in the following discussion.

9.1 TDS Treatment through Reverse Osmosis

Wastewater technologies, such as conventional precipitation, can efficiently remove the heavy metals from wastewater to meet the effluent requirements. However, these systems do not remove the dissolved compounds like SO_4^{-2} and TDS. As a result, the effluent flow from the treatment plant is limited by the dilution of the flow in the receiving stream to reduce these constituents to acceptable concentrations.

RO is an advanced water/wastewater treatment process capable of removing dissolved contaminants such as TDS and SO_4^{-2}. It is essentially an extension of a filtration process in which highly pressurized feed water flows across a membrane with a portion of the flow, identified as “permeate,” going through the membrane. The rest of the feed is called “concentrate” because it carries off the concentrated contaminants rejected by the membrane. The concentrated amount depends on many factors and can vary between 10% to 30% of the feed. Depending on the size of the pores in the membrane, the process results in different classes of separation. For the removal of dissolved solids, a membrane capable of rejecting elemental particles must be utilized.

9.1.1 Technical Considerations

Based on the preliminary information available from equipment manufacturers, RO is a possible alternative treatment for the discharge to meet the limits for TDS and SO_4^{-2}. The RO permeate would be of high quality and meet downstream ARWQS in this process.

The most common problems with RO involve the tendency for fouling problems when applied to concentrated waste streams and the cost of operation (i.e., electricity, membrane cleaning, etc.).

The disposal of the concentrated brine generated by this process is another problem if a direct discharge option is not available. The issue of disposal of the RO byproduct generally becomes the controlling factor in the selection of RO for many applications. RO separates the contaminants from water, but it does not chemically change them to other non-polluting compounds. The concentrate would require disposal by other methods.

9.1.2 Concentrate Disposal Options

The brine solution may be solidified and disposed onsite, transported offsite for stabilization prior to landfilling, or transported offsite to a municipal or industrial wastewater treatment system. The waste brine solution is not a hazardous waste in Arkansas, but disposal in neighboring states may be restricted to industrial or hazardous waste facilities. Transportation will be a critical factor for two of the three options.

9.1.2.1 Onsite Stabilization

The concentrate could be stabilized onsite, using a cementitious element, such as Portland cement or fly ash. This would require the construction of a mixing facility, purchase of the cementitious agent, crews and equipment to mix the waste solution, regulatory authority to dispose of the waste onsite, and engineering support for selection and operation of a disposal area. The critical and unknown costs for this option are the mixing ratio for the waste solution/stabilization agent, and any required environmental protection controls for the disposal area. The mixing ratio determines the tonnage necessary for purchase of the stabilizing agent, and the environmental protection controls could range from open disposal on land adjacent to the facility or the installation of a landfill with liners and caps.

9.1.2.2 Offsite Treatment

The concentrate wastewater could be transported offsite by truck to an industrial or municipal wastewater treatment facility. It would be necessary to provide waste profile information to each facility to obtain cost information. For treatment and discharge, the treatment facility would need to be located at a site with capabilities for discharging to a large waterbody. The critical cost component would be the cost of transportation and the cost per disposal on a per-gallon basis.

9.1.2.3 Offsite Stabilization

The wastewater could be transported to an industrial or municipal landfill for stabilization and disposal. Offsite disposal offers several advantages. The site earthwork balance does not have to account for onsite disposal, and there is a minimum of regulatory approval required when the waste is removed to an offsite facility. For local landfills, the costs may be lower than for landfills dedicated to industrial or hazardous waste, but the environmental control can differ from cell to cell, requiring more oversight of disposal operations.

9.1.3 Economic Considerations

The water analysis and the design flow requirements are primary considerations in the sizing and cost of the equipment. Pumps and piping that are associated with the RO process would be required along with controls, building, utilities, etc.

The basic assumptions used in the analysis of costs for RO treatment are shown below:

1. A retention basin would be built so that the water treatment could be spread out over a given day to approximately 150 gpm;
2. An average of approximately 150 gpm of water will be treated in the RO system;
3. Approximately 0.63 million gallons per year will be generated as brine solution reject from the RO treatment system and will require disposal;
4. The system will consist of a minimum of three RO units in series, and a holding tank to facilitate disposal of the concentrate;
5. The treated effluent will be discharged to waters of the US;
6. The waste brine solution will be 20% solids and 80% water; and
7. For the pipeline option, the pipe will be sized for the maximum expected flow rate.

The following cost information is based upon a three-stage RO system, able to sequentially concentrate the sump water approximately 100 times. The concentrate could then be stored in an onsite holding tank.

The capital costs of installing a single-stage RO treatment system have been estimated by the US Army Corps of Engineers (USACE) to range from $1.44 to $2.13 per gallon, per day. For a three-stage RO unit, the costs would be approximately 1.5 times higher. For purposes of this discussion, the costs for installing a RO system are estimated at $3 per gallon, per day. This provides an estimated capital cost of the treatment system of approximately $650,000. USACE further estimated the operating costs of a RO system (less the costs of brine disposal) at about

$0.001 per gallon for a large-scale treatment system. This cost would translate to an annual operating cost of about $63,000.

For both the capital and operating costs, the factors provided by USACE may be low due to the relative size of this application. However, the cost estimates should provide a method for comparison. Also, as stated above, the costs of disposal of the concentrate actually becomes the controlling factor with this application.

For the disposal of the concentrate, the critical cost components for offsite treatment or disposal are the cost of transportation and the per ton disposal fee for the waste. Safety-Kleen Corporation provided a preliminary cost quote for a similar project of $1.00 per gallon for transport and disposal at an Oklahoma facility. The use of a local landfill, if acceptance of the waste can be obtained, may lower that cost to about $0.60 per gallon. Even at this lower cost, the annual costs associated with disposal would be about $378,000.

Therefore, based on these preliminary calculations, RO treatment would have a capital cost of about $650,000, and an annual operating cost of about $441,000.

9.2 Pipeline to Stennitt Creek

This alternative would require that all of the VCM discharge be pumped a minimum of 1.2 miles to Stennitt Creek. This would require the construction of a 10-inch-diameter force main and a pump station with adequate capacity for the operation, and would involve obtaining a right-of-way from at least three private landowners.

For this size pipeline, a polyethylene line could be routed underground. The estimated costs for this project would be about $100,000 for the pump station and about $25 per linear foot for the installed pipe. Based on these preliminary estimates, the capital costs associated with the pipeline alternative would be about $254,000.

The primary operating costs for this option would result from the electrical costs associated with pumping and the maintenance of the pumping station and pipeline. This is estimated at about $40,000 annually.

9.3 TDS Treatment Using Wetlands

Constructed wetlands have been used for wastewater treatment, particularly for acid mine drainage where conditions involving low pH and the presence of heavy metals are encountered. Despite the success in these applications, constructed wetlands are not considered applicable for the treatment of TDS or SO_4^{-2} (Hedin et al. 1989).

By definition, dissolved, or soluble compounds cannot be filtered from the water except with the use of an extremely tight membrane such as reverse osmosis. Converting the soluble compounds to a form that is insoluble is necessary for filtration. For iron and certain heavy metals, such as copper and lead, this conversion can be routinely accomplished in a treatment system or even in a lake or other natural waterbody. However, nearly all forms of the common minerals, involving SO_4^{-2}, chloride, and sodium, are soluble at concentrations below 1,000 mg/L. For this reason, in water matrices where the primary constituents are these minerals, the conversion to an insoluble form has proven to be a difficult technical problem (Hedin et al. 1989).

Sulfate reduction is possible through a different process termed dissimilatory sulfate reduction (DSR), that, under optimum conditions, is functional in most wetland systems. DSR is dependent on anaerobic bacteria that, in the absence of oxygen, decompose organic matter using sulfate as the electron acceptor. Sulfate is reduced to hydrogen sulfide (which exists in gaseous form and can be volatilized from the water) according to the following formula:

$$SO_4^{-2} + 2CH_2O \rightarrow H_2S + 2HCO_3^-$$

From this formula, it can be seen that sulfate and organic matter, in the presence of bacteria, are converted to hydrogen sulfide and bicarbonate. The organic matter must be supplied either through introduction of an organic substrate such as chicken litter, or, for a mature wetland system, through the decomposition of sufficient plant and animal growth. In this process, two moles of carbonate alkalinity are generated for each mole of sulfate reduced. The production of carbon dioxide, either as carbonate or bicarbonate, effectively represents a tradeoff in terms of TDS. For instance, with sodium as the primary cation, the process will convert sodium sulfate to sodium bicarbonate. This conversion actually represents an increase in the TDS concentration by about 18%. By this analysis, a natural biological system, such as applied in a constructed wetland system, cannot be effective for the reduction of TDS (Hedin et al. 1989).

It should also be noted that Mount et al. (1997), in a study that examined the aquatic toxicity of mixtures of common ions, report that ion toxicity can be ranked as $K^+ > HCO_3^- > Mg^{+2} > Cl^- > SO_4^{-2}$. Therefore, at neutral pH, the DSR system replaces sulfate with a more toxic anion (HCO_3^-), thereby producing a TDS mixture with greater toxicity potential to aquatic life.

The operating experience with these systems has been inconsistent. The treatment effectiveness, as with most treatment systems that depend on the activity of microorganisms, is particularly affected by cold temperatures. Very low rates of sulfate reduction have been measured for wetlands and other natural systems in the winter months. Other technical issues associated with the application of DSR as a treatment method for sulfates exist with the re-oxidation of sulfide back to sulfate and the generation of excessive sulfide in the liquid matrix which can prove toxic to the microorganisms, if not quickly removed (Hedin et al. 1989).

Without a method for mitigating the seasonal impacts, such as water storage during the winter months, or acceptance of seasonal variations in treatment effectiveness, the use of constructed wetlands for the reduction of sulfate is not practical. The use of these systems for the reduction of TDS is not feasible under this situation nor would it reduce the potential impacts to aquatic life.

9.4 Site-Specific Criteria and DWS Use Removal

This evaluation indicates that the removal of the DWS designated use and site-specific TDS and SO_4^{-2} criteria based on the existing discharge concentrations would result in permit compliance for VCM.

9.5 Summary of Costs

There are three technically feasible options available for the management of TDS and SO_4^{-2} in the discharge from the facility:

1. Installation of an RO treatment system,
2. Installation of a pipeline to Stennitt Creek, and
3. Direct discharge to the adjacent unnamed tributary (removing DWS use designation and adopting site-specific minerals criteria).

Table 9.1 provides a summary of the estimated costs with each option. Any capital and operating costs associated with the direct discharge option (e.g., effluent monitoring) would also be required in the other options and, therefore, were not added to the cost estimates. The implementation costs refer to costs for the UAA study and consulting and legal costs to support the rule-making process for change in ARWQS and/or criteria.

Table 9.1. Summary of capital, operating, and implementation costs for engineering alternatives.

Option Description	Estimated Capital Cost	Estimated Annual Operating Cost	Implementation Cost	Total
RO treatment	$650,000	$441,000	--	$1,091,000
Pipeline to Stennitt Creek	$254,000	$40,000	--	$294,000
Discharge to unnamed tributary*	--	--	$100,000	$100,000

*Requires site-specific minerals criteria and removal of the DWS designated use in the unnamed tributary and in Brushy Creek below the mouth of the unnamed tributary.

9.6 Conclusions

The information presented herein indicates that the most cost-effective option for VCM is a direct discharge to the unnamed tributary. Implementing this option will require ARWQS modification for the unnamed tributary and Brushy Creek downstream of the mouth of the unnamed tributary. With the removal of the DWS designated use in these segments, the Ozark Highlands ecoregion minerals criteria (Section 2.0) will become the applicable criteria for NPDES permitting purposes. Application of current permitting policies for minerals (APCEC 2010) will allow VCM to meet permit limitations for TDS. However, this study revealed elevated SO_4^{-2} concentrations in the VCM discharge that would not meet permit limitations (if they were in place) based on ecoregion minerals criteria per Regulation No. 2 (APCEC 2010). Therefore, direct discharge to the unnamed tributary will also require a site-specific modification of the Ozark Highlands ecoregion TDS and SO_4^{-2} criteria in the unnamed tributary to Brushy Creek, in Brushy Creek downstream of the mouth of the unnamed tributary, and in Stennitt Creek downstream of the mouth of Brushy Creek (see Table 8.3). Analysis of designated uses in the receiving streams indicates that all existing and attainable uses are supported in the waterbodies receiving the VCM discharge. Accordingly, this UAA report recommends the following changes to the ARWQS:

1. Removal of the Domestic Water Supply designated use for the unnamed tributary and Brushy Creek downstream of the mouth of the unnamed tributary,
2. Site-specific modification of the Ozark Highlands ecoregion TDS and SO_4^{-2} criteria as summarized in Table 8.3.

10.0 REFERENCES

ADEQ. 2000. State of Arkansas Continuing Planning Process: Update and revisions, January 2000. Arkansas Department of Environmental Quality, Water Division. Little Rock, AR.

Arkansas Department of Pollution Control & Ecology. 1987. Physical chemical and biological characteristics of least-disturbed reference streams in Arkansas ecoregions. Arkansas Department of Pollution Control & Ecology, June 1987.

APCEC. 2010. *Regulation No. 2: Regulation establishing water quality standards for surface water of the State of Arkansas.* Arkansas Pollution Control and Ecology Commission. December 3, 2010.

APHA. 1998. *Standard Methods for the Examination of Water and Wastewater, 20th ed.* American Public Health Association, Washington, DC.

Ames, K.A., S.A. Ebelhar, K.L. Barber, and W.L. Pendersen. 2000. Soybean and wheat responses to chloride in potassium chloride fertilizers for suppression of disease. Illinois Fertilizer Conference Proceedings, January 24-26, 2000. Illinois.

Arkansas Soil and Water Conservation Commission. 1992. *Flow Duration and Low-Flow Characteristics of Selected Arkansas Streams* [Water-Resources Investigations Report 92-4026]. US Geological Survey.

Ayers, R.S., and D.W. Westcot. 1985. Water quality for Agriculture. FAO Irrigation and Drainage Paper 29 Rev.1. Food and Agriculture Organization of the United Nations. Rome.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. *Rapid bioassessment protocols for use in streams and wadeable rivers: Periphyton, benthic macroinvertebrates and fish, second edition* [EPA 841-B-99-002]. US Environmental Protection Agency, Office of Water. Washington, DC.

Baser, R.E., and J.T. Gilmour. 1982. Tolerance of rice seedlings to potassium salts. Bulletin 860. U of A Agricultural Experiment Station.

Bauder, T.A., R.M. Waskom, and J.G. Davis. 2004. Irrigation Water Quality Criteria. Crop Series No. 506. Colorado State Cooperative Extension.

Elphick J.R., M. Davies, G. Gilron, E.C. Canaria, B. Lo, and H.C. Bailey. 2011. An aquatic toxicological evaluation of sulfate: the case for considering hardness as a modifying factor in setting water quality guidelines. *Environ. Toxicol. Chem.* 30(1):247-253.

Environmental Consulting & Technology, Inc. November 2001. *Mixing Zone And 7Q10 Low-Flow Analysis, TPS Dell Power Station* (ECT No. 001063-0100). Gainesville, FL.

EPA. 1983. *Technical support document for waterbody surveys and assessments for conducting use attainability analysis.* US Environmental Protection Agency, Office of Water Regulation and Standards, Washington, DC.

EPA. 1991. *Methods for measuring the acute toxicity of effluents and receiving waters to freshwater and marine organisms, fourth edition* [EPA-600-4-90-027]. US Environmental Protection Agency, Office of Research and Development. Washington, DC.

EPA. 1994. *Water Quality Standards Handbook, second edition* [EPA-823-B-94-006]. Update #1. US Environmental Protection Agency, Office of Water, Washington, DC.

EPA. 2002. *Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms, fourth edition* [EPA-821-R-02-013]. US Environmental Protection Agency, Office of Water. Washington, DC.

Freiwald, D.A. 1984. *Average annual precipitation and runoff for Arkansas, 1951-80* [Water-Resources Investigation Report 84-4363]. U.S. Geological Survey.

FTN. 1990. *UAA for Hurricane Creek near Bryant, Arkansas.* Prepared for Aluminum Company of America, Arkansas Operations and Reynolds Metals Company, Hurricane Creek Plant; Submitted to ADPCE on July 19, 1990.

FTN. 2005. *UAA Study Plan: Dell Power Plant Discharge to Ditch No. 27 near Dell, Arkansas.* Prepared for Associated Electric Cooperative Inc. FINAL REVISED, April 28, 2005.

Gilmour, J.T. 2001. Water Quality in Rice Production. In R.J. Norman and J.F. Meullenet (eds). B.R. Wells Rice Research Studies, Research Series 485. University of Arkansas, Agricultural Experiment Station. Pp.171-177.

Glover, C.R. 2001. Irrigation water classification systems. Guide A-116. New Mexico State University Cooperative Extension. Online at: http://cahe.nmsu.edu/pubs/_a/a-116.html.

Goodfellow, W.L., L.W. Ausley, D.T. Burton, D.L. Denton, P.B. Dorn, D.R. Grothe, M.A. Heber, T.J. Norberg-King, and J.H. Rodgers. 2000. Major ion toxicity in effluent: A review with permitting recommendations. *Environ. Toxicol. Chem.* 19:175-182.

Hedin, R.S., R. Hammack, and D. Hyman. 1989. "Potential Importance of Sulfate Reduction Processes in Wetlands Constructed to Treat Mine Drainage." Chapter 38b in *Constructed Wetlands for Wastewater Treatment*. Edited by Donald A. Hammer. Lewis Publishers, Inc. pp. 508-514.

Houston, J. 1980. Checklist of the Damselflies (Odonata: Zygoptera) of Arkansas. Arkansas Academy of Science, Arkansas Biota Survey Checklist No. 25. 1 p.

James, D.W., R.J. Hanks, and J.H. Jurinak. 1982. *Modern Irrigated Soils.* John Wiley and Sons. New York, NY.

Merritt, R.W., and K.W. Cummins. 1996. *An Introduction to the Aquatic Insects of North America*. Kendall/Hunt Publishing Company. Dubuque, IA.

Mount, D.R., D.D. Gulley, J.R. Hockett, T.D. Garrison, and J.M. Evans. 1997. Statistical models to predict the toxicity of major ions to *Ceriodaphnia dubia, Daphnia magna* and *Pimephales promelas* (fathead minnows). *Environ. Toxicol. Chem.* 16:2009-2019.

NCDC (National Climatic Data Center). 2005. Daily meteorological data from the Cooperative National Weather Service network. Web site maintained by the National Climatic Data Center in Asheville, NC. Available online at http://www.ncdc.noaa.gov/oa/climate/climatedata.html

Robison, H.W., and T.M. Buchanan. 1988. *Fishes of Arkansas.* University of Arkansas Press. Fayetteville, AR. 536 p.

Rupe, J.C., J.D. Widick, W.E. Sabbe, R.T. Robbins, and C.B. Becton. 2000. Effect of chloride and soybean cultivar on yield and the development of sudden death syndrome, soybean cyst nematode, and southern blight. *Plant Dis.* 84:669-674.

Sherrard, J.H., D.R. Moore, and T.A. Dillaha. 1987. TDS: determinations, sources, effects, and removal. *Journal of Environmental Education* 18(2):19-24.

Tacker, P., and E. Vories. 2004. "Irrigation." Chapter 8 in *Arkansas Soybean Handbook* (MP 197-10M-4-00RV). Developed by Soybean Commodity Committee of the University of Arkansas, Division of Agriculture, Cooperative Extension Service. Available online at http://www.uaex.edu/other_areas/publications/HTML/MP-197.asp.

Tacker, P., E. Vories, C. Wilson, and N. Slaton. 2001. "Water management." Chapter 9 in *Rice Production Handbook* (MP 192), edited by Nathan Slaton. University of Arkansas, Division of Agriculture, Cooperative Extension Service. Available online at http://www.uaex.edu/Other_Areas/publications/PDF/MP192/MP-192.asp.

Tanji, K.K. (ed). 1990. Crop Salt Tolerance, Agricultural Salinity Assessment and Management Manual. ASCE. New York.

Thorpe, J.H.. and A.P. Covich (eds). 2001. *Ecology and Classification of North American Freshwater Invertebrates*. Second Ed. Academic Press, 1056 p.

Tracy, P., and S.G. Hefner. 1993. *Calculating crop nutrient value from irrigation water inputs: a survey of southeast Missouri irrigation* [WQ278]. University of Missouri Cooperative Extension. Online at http://muextension.missouri.edu/explore/envqual/wq0278.htm.

USGS. 1982. *Measurement and Computation of Streamflow: Volume 1. Measurement of stage and discharge*. United States Geological Survey Water-Supply Paper 2175.

WERF. 1997a. A comprehensive UAA technical reference. Final Report, Project 91-NPS-1, 1997. Water and Environment Research Foundation.

WERF. 1997b. A suggested framework for conducting UAAs and interpreting results. Final Report, Project 91-NPS-1, 1997. Water and Environment Research Foundation.

Zeng, L., and M.C. Shannon. 2000. Salinity effects on seedling growth and yield components of rice. *Crop Sci.* 40:996-1003.

APPENDIX A

Agency Communication

Arkansas Department of Health

4815 West Markham Street • Little Rock, Arkansas 72205-3867 • Telephone (501) 661-2000
Governor Mike Beebe
Paul K. Halverson, DrPH, FACHE, Director and State Health Officer

Engineering Section, Slot 37 Ph 501-661-2623 Fax 501-661-2032
www.HealthyArkansas.com/eng/ After Hours Emergency 501-661-2136

March 24, 2009

Stacy Whittington, Environmental Specialist
Vulcan Construction Material, LP
1200 Urban Center Drive
Birmingham, AL 35242

RE: FTN's UAA Letter dated March 18, 2009
Black Rock, Lawrence County
09-70941

Dear Mr. Whittington:

In response to FTN's letter dated March 18, 2009, there are no present or future plans for using the Brushy Creek as a Public Water Supply. However, there is a proposed surface water intake that will be located approximately five (5) miles downstream on the Spring River (e.g., below its confluence with the Eleven Point River).

When submitting correspondence pertaining to this project, please include our plan identification number 09-70941.

Sincerely,

Jeff A. Stone, P.E.
Chief Engineer
Engineering Section

JAS:GAG:SGB:sgb

cc: Pat Downey, FTN Associates (3 Innwood Circle, Suite 220; Little Rock, AR 7221)
Marcy Taylor, Mitchell Williams (425 W. Capitol AVE, Suite 1800; Little Rock 72201-3525)

RECEIVED

MAR 27 2009

Keeping the Natural State natural.

Arkansas Game and Fish Commission

Scott Henderson
Director

April 16, 2009

Ms. Stacy Whittington
Environmental Specialist
Vulcan Construction Materials, LP
1200 Urban Center Drive
Birmingham, AL 35242

Re: Vulcan Materials Company Discharge to Brushy Creek via
Unnamed Tributary Black Rock, Lawrence County, Arkansas
FNT No. 6532-020

Dear Ms. Whittington:

This is in response to a letter dated March 24, 2009, from Mr. Pat Downey of FTN Associates, LTD concerned with the above referenced project and the proposed removal of the Domestic Water Supply designated use for Brushy Creek.

It is our determination that the proposed use removal will not conflict with the protection of fish and wildlife in the area.

Thank you for giving us the opportunity to comment on this proposal.

Sincerely,

Mike Armstrong
Chief of Fisheries

cc: Mr. Pat Downey
Ms. Marcy Taylor

RECEIVED
APR 30 2009

2 Natural Resources Drive • Little Rock, AR 72205 • www.agfc.com
Phone (800) 364-4263 • (501) 223-6300 • Fax (501) 223-6448

Arkansas Natural Resources Commission

J. Randy Young, PE
Executive Director

101 East Capitol, Suite 350
Little Rock, Arkansas 72201
http://www.anrc.arkansas.gov/

Phone: (501) 682-1611
Fax: (501) 682-3991
E-mail: anrc@arkansas.gov

Mike Beebe
Governor

July 16, 2009

Ms. Stacy Whittington
Environmental Specialist
Vulcan Construction Materials, LP
1200 Urban Center Drive
Birmingham, AL 35242

Dear Ms. Whittington:

My staff has reviewed the following request for evaluation, and determined that removal of the Designated Domestic Water Supply Use from the below listed stream segment does not conflict with the Arkansas Water Plan at this time:

Lawrence County: Brushy Creek extending up stream from its confluence with Stennitt Creek

Sincerely,

J. Randy Young, P.E.
Executive Director

JRY/KB/atd

cc: Mr. Pat Downey FTN Associates, Ltd 3 Innwood Circle, Suite 220 Little Rock, AR 72211

Ms. Marcy Taylor Mitchell Williams 425 West Capitol Ave., Suite 1800 Little Rock, AR 72201

RECEIVED

JUL 17 2009

APPENDIX B

Justification Report Supporting Use Removal and Site-Specific TDS Criterion in Stennitt Creek

Stennitt Creek 4g Report

Prepared for:

Meridian Aggregates
Black Rock Quarry
PO Box 260
Black Rock, AR 72415

Prepared by:

GBM^c & Associates
219 Brown Lane
Bryant, AR 72022

May 13, 1999

CONTENTS

CONTENTS (cont.)

FIGURES AND TABLES

CONTENTS (cont.)

ATTACHMENTS

1.0 INTRODUCTION

This report presents the documentation required by Section 2.306 (formerly Section 4g) of the Arkansas Water Quality Standards (WQS), to support modifications of designated but non-existing and unattainable uses and associated water quality criteria. This report addresses the requirements of the 1994 Administrative Guidance Document of the ADEQ which clarifies the Section 2.306 documentation process.

In addition, this report provides documentation regarding the attainability of the domestic water supply use of Stennitt Creek from the perspective of the 40 CFR 131.10(g) rationale for use removal. The requirement for providing 40 CFR 131.10(g) documentation is to fulfill the recent US EPA Region 6 requests for inclusion of use attainability information in the 4g process.

This report provides recommendations (Section 2.0), a summary of the site's background (Section 3.0), the physical, chemical, and biological characteristics of Stennitt Creek which receives an NPDES permitted discharge from Meridian Aggregates (Meridian) (Section 4.0), and mass balance modeling results (Section 5.0). A review of alternatives for removal of dissolved minerals to meet ecoregion criterion is provided in Section 6.0. Attainability of the domestic water supply use of Stennitt Creek is discussed in Section 6.0. Section 7.0 provides the citation for documents referenced in this report.

Meridian operates a limestone quarry in Lawrence County just north of Black Rock, Arkansas. The quarry discharges from a settling pond into Stennitt Creek. Stennitt Creek is a second order tributary of the Spring River in northeast Arkansas. This discharge contains concentrations of total dissolved solids (TDS), in the form of calcium carbonate, in excess of the ecoregion based permit limits as provided by Meridian's National Pollutant Discharge Elimination System (NPDES) Permit No. AR0047198.

2.0 RECOMMENDATIONS

Based on the documentation presented herein, it is recommended that the designated domestic water supply use for Stennitt Creek be removed. In addition, an increase in the water quality criteria for total dissolved solids (TDS) for Stennitt Creek is recommended. Table 1 summarizes the recommended changes for Stennitt Creek:

Table 1. Summary of Proposed WQS Modifications.

Stennitt Creek (from the confluence with Brush Creek downstream to the confluence with the Spring River)
Remove the designated Domestic Water Supply Use.
Amend dissolved minerals criteria: TDS from 240 mg/L to 456 mg/L.

3.0 BACKGROUND

3.1 Introduction

Meridian operates a limestone quarry in Lawrence County just north of Black Rock, Arkansas. The quarry discharges from a settling pond into Stennitt Creek. Stennitt Creek is a second order tributary of the Spring River in northeast Arkansas. This discharge contains concentrations of total dissolved solids (TDS), in the form of calcium carbonate, in excess of the ecoregion based permit limits as provided by Meridian's National Pollutant Discharge Elimination System (NPDES) permit.

The Arkansas Water Quality Standards - Regulation No. 2 (Reg. 2) allows for modification of water quality standards under various conditions. Specifically, Section 2.306 of Reg. 2 (1998) allows for the removal of a designated use other than a fishable or swimmable use, and for establishment of less stringent water quality criteria without affecting fishable or swimmable uses. Reg. 2 allows for the removal of the designated but non-existing domestic water supply use of Stennitt Creek and modification of the TDS water quality criteria provided certain conditions are met. This project report documents the findings necessary to develop the information required to amend Reg. 2 through third party rulemaking. The study area, including the Stennitt Creek site locations, is shown in Figure 1.

The Meridian treatment system consists of two settling lagoons. The primary lagoon is approximately 25 feet by 75 feet by 8 feet deep in size. The second lagoon is approximately two-surface acres by 40-feet deep in size. The water to be discharged from Outfall 001 is pumped from the second lagoon. The sources of water entering the settling basin are storm water, process water used for crushed rock washing, and ground water that leaches into the quarry. Discharge from Outfall 001 is intermittent, predicated primarily on the volume of storm water reaching the second lagoon and the need to retain lagoon capacity.

The receiving stream for the discharge, Stennitt Creek has a watershed size of approximately 16 square miles (mi^2) at its mouth (Figure 2).

3.2 Designated Uses

The designated uses for Stennitt Creek are those listed in the WQS for Ozark Highlands streams with watersheds greater than 10 mi^2. They are as follows:

- Primary Contact Recreation,
- Secondary Contact Recreation,
- Perennial Ozark Highlands Fishery,
- Domestic Water Supply,
- Industrial Water Supply, and
- Agricultural Water Supply.

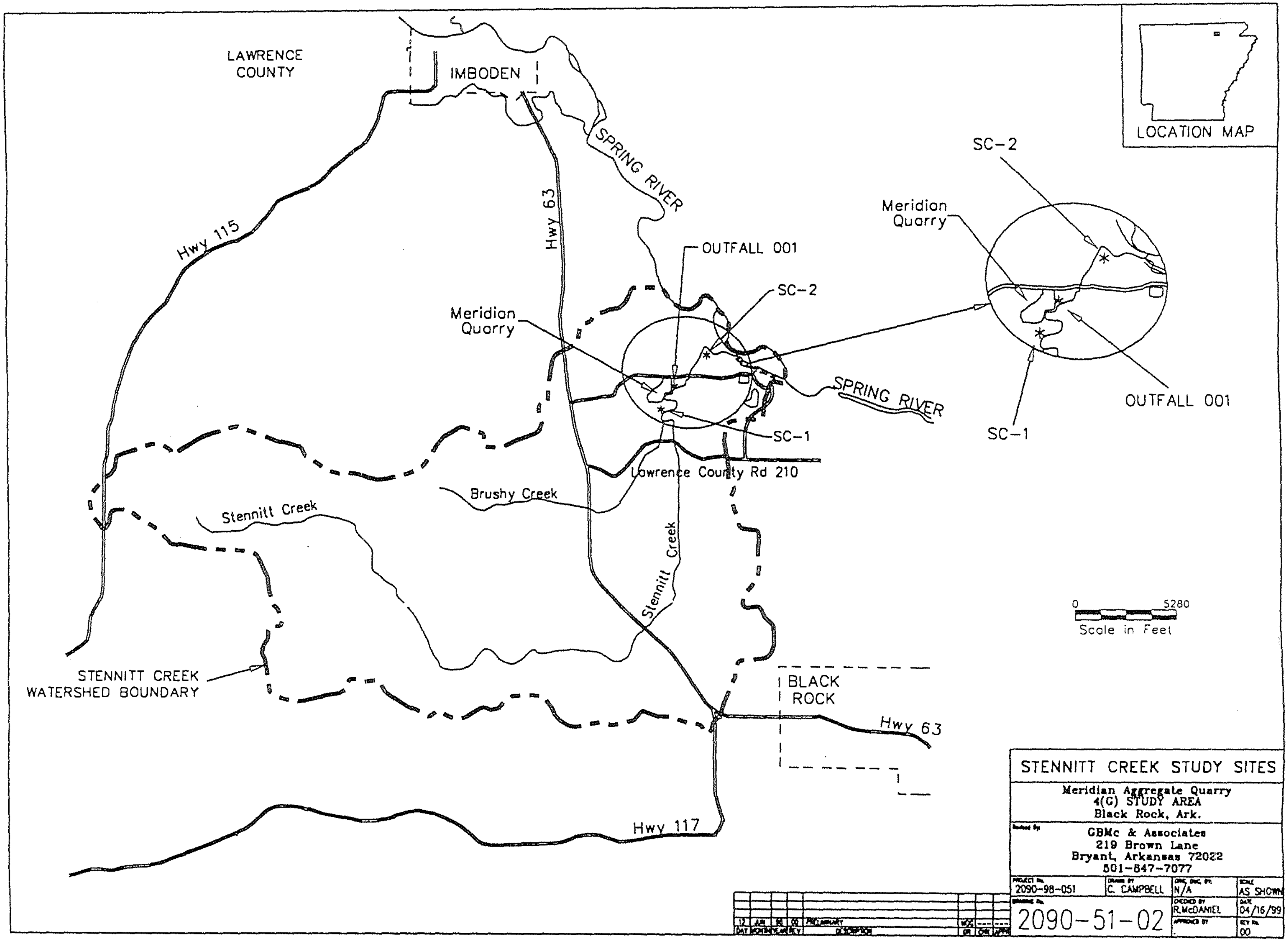

Figure 1. Stennitt Creek study area.

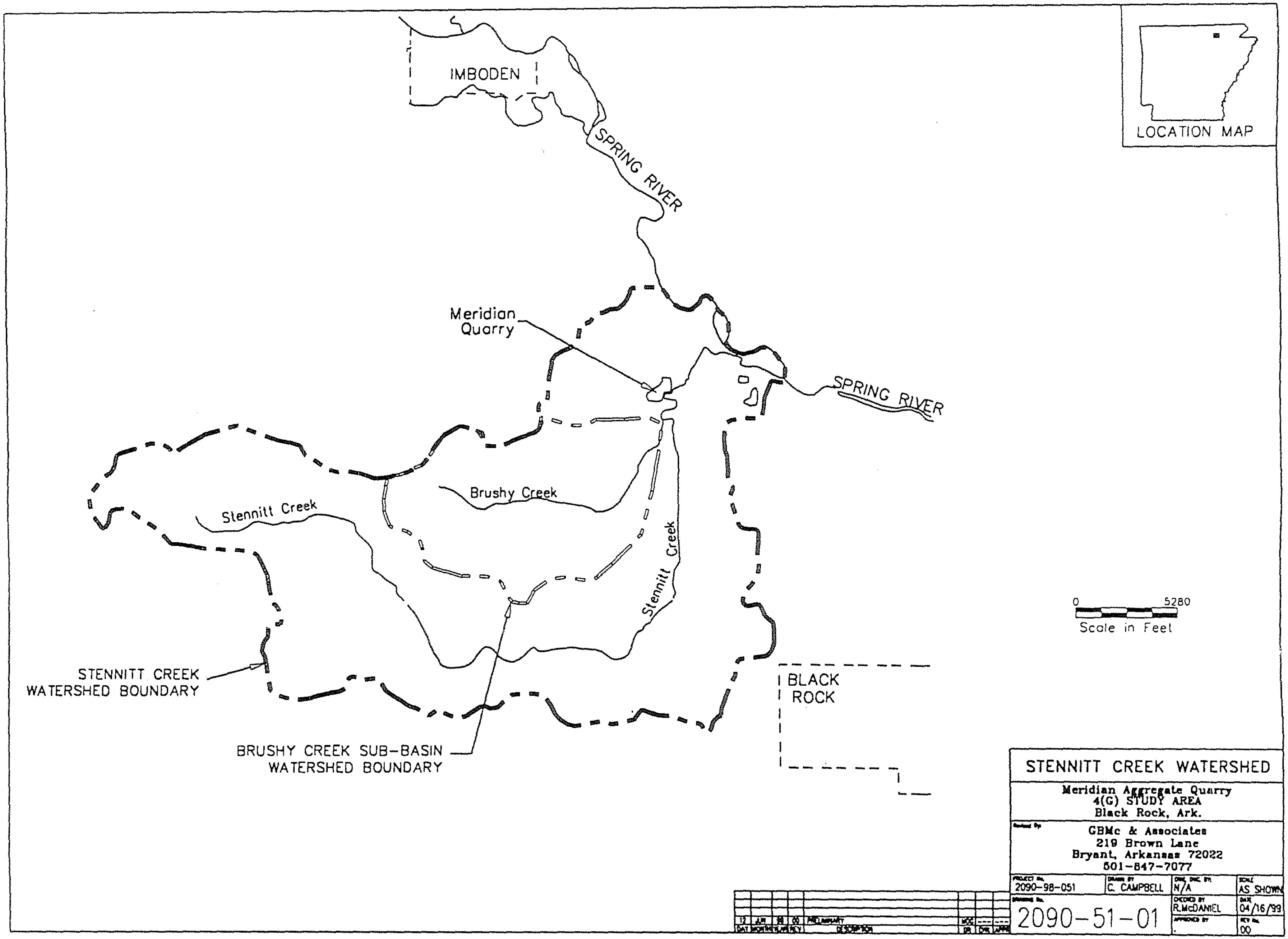

Figure 2. Stennitt Creek and Brushy Creek watersheds.

3.3 Domestic Water Supply Use

Based upon documentation provided by the Arkansas Department of Health (ADH), Stennitt Creek is neither an existing or planned public water supply source. In addition, the Arkansas Soil and Water Conservation Commission (ASWCC) has documented that the removal of the designated domestic water supply use from Stennitt Creek does not conflict with the Arkansas Water Plan. The letters from the ADH and ASWCC are provided in Attachment A.

3.4 Effluent Characteristics

Table 2 presents the effluent characteristics of Outfall 001. This data represents the results of monthly grab samples from October 1995 to December 1998. Documentation for the 99th percentile value is presented in Section 5.0. The percentile concentration values represent statistically calculated values based on methodologies outlined in *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987) which will be discussed in detail in Section 5.2.2.

Table 2. Outfall 001 Discharge Statistics December 1995 through December 1998.

Statistic	TDS (mg/L)
Data Characterization (Daily Maximum Concentrations from Monthly Summaries)	
Maximum	698
Minimum	320
Average	437
99th percentile	698
95th percentile	666

3.5 Description of Existing and Proposed Pollution Prevention Practices

Meridian has installed pollution prevention practices at the Black Rock Quarry designed to reduce the potential of solids moving to the stream system during storm water runoff events. Locations near the rock washing operation and adjacent material stockpile areas are potential sources of sediments that could be picked up and discharged with storm water. To address this situation Meridian has erected straw bales along the entire perimeter of the washing operation area and the material stockpiles. Sediment berms have been installed along these areas as well. The sediment berms function as a second layer of defense to trap transported solids and also to ensure long term straw bale placement and stability.

In addition to specific targeting of the material stockpiles, a line of straw bales has been set and a sediment berm has been constructed immediately adjacent to Stennitt Creek to catch solids in runoff from general quarry operations. Straw bales have also been placed as a sediment barrier adjacent to a facility bridge over Stennitt Creek at the plant water pump station.

3.6 Current NPDES Permit Status

3.6.1 NPDES Permit Compliance

Meridian's current NPDES permit (Permit No. AR0047198) became effective on November 1, 1994. The permit remains in effect until October 31, 1999.

3.6.1.1 Discharge and Monitoring Requirements

The effluent limitations of concern are based on the Ozark Highlands ecoregion criteria for totals dissolved solids in Reg. No. 2. Outfall 001 final discharge limitations and monitoring requirements are summarized in Table 3. For TDS, the monthly average limit is 346 mg/L while the daily maximum limit is 519 mg/L. Monitoring requirements consist of once per month grab samples when discharging.

Table 3. Final Discharge Limitations for Meridian Outfall 001.

Effluent Characteristic	**Monthly Average**	**Daily Maximum**	**Frequency of Analysis**
Flow (MGD)	N/A	NA	Daily**
Chemical Oxygen Demand	50 mg/L	75 mg/L	Once per month**
Total Dissolved Solids, mg/L	346 mg/L	519 mg/L	Once per month**
Turbidity (as NTU)	10 NTU	Report	Once per quarter**
Oil and Grease	10 mg/L	15 mg/L	Once per quarter**
pH (SU)	*	*	Once per month**
*pH shall not be less than 6.0 standard units nor greater that 9.0 standard units **when discharging			

3.6.1.2 Dissolved Minerals

Data from discharge monitoring reports at Outfall 001 (DMR values from October, 1995 to December, 1998) were summarized and are presented in Table 4.

Since only once per month sampling was required, the monthly average and daily maximum TDS values are the same each month that a discharge occurred. The overall mean value of the data set was 437 mg/L while the highest value measured was 698 mg/L. The DMR data for TDS is shown in Figure 3.

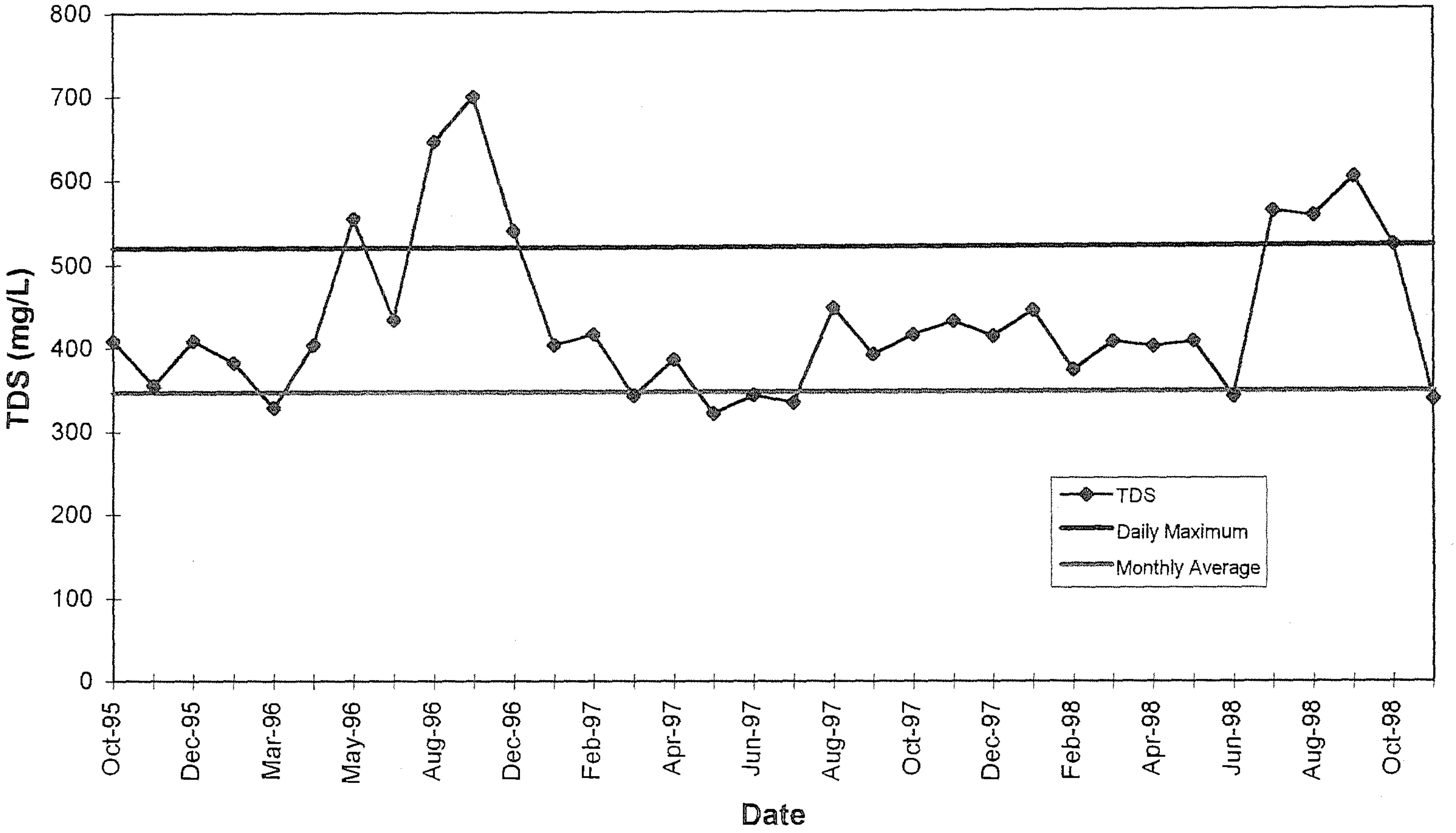

Figure 3. TDS data from Outfall 001 at the Meridian Black Rock Quarry, daily maximum and monthly average TDS NPDES permit limits also shown.

Table 4. Outfall 001 Discharge Monitoring Report Values from October 1995 through December 1998.

Sample Date	pH	TDS	COD	O & G	Turbidity
Oct-95	7.00	408	7.00	2.50	1.00
Nov-95	6.90	354	10.0	-	-
Dec-95	7.00	408	7.00	-	-
Jan-96	6.90	382	8.00	2.50	1.00
Feb-96	ND	ND	ND	-	-
Mar-96	7.20	327	5.00	-	-
Apr-96	7.60	403	5.00	2.50	1.00
May-96	7.00	554	2.50	-	-
Jun-96	7.30	433	2.50	-	-
Jul-96	ND	ND	ND	2.50	1.00
Aug-96	7.70	645	7.00	-	-
Sep-96	7.80	698	2.50	-	-
Oct-96	ND	ND	ND	2.50	1.00
Nov-96	ND	ND	ND	-	-
Dec-96	7.70	539	2.50	-	-
Jan-97	7.10	402	2.50	2.50	1.00
Feb-97	7.40	415	2.50	-	-
Mar-97	7.40	341	2.50	-	-
Apr-97	7.90	385	2.50	2.50	1.00
May-97	7.60	320	2.50	-	-
Jun-97	7.00	342	2.50	-	-
Jul-97	7.30	333	7.00	2.50	1.00
Aug-97	7.80	446	2.50	-	-
Sep-97	7.20	390	2.50	-	-
Oct-97	7.50	414	2.50	2.50	1.00
Nov-97	7.00	430	11.0	-	-
Dec-97	7.20	412	2.50	-	-
Jan-98	7.40	443	2.50	2.50	1.00
Feb-98	7.40	371	2.50	-	-
Mar-98	7.00	405	2.50	-	-
Apr-98	7.30	399	2.50	2.50	5.90
May-98	7.20	405	2.50	-	-
Jun-98	7.40	340	2.50	-	-
Jul-98	7.70	560	6.00	2.50	1.00
Aug-98	7.40	554	2.50	-	-
Sep-98	7.60	600	2.50	-	-
Oct-98	7.40	520	2.50	2.50	23.0
Nov-98	ND	ND	ND	-	-
Dec-98	7.20	336	5.00	-	-

ND indicates months where no discharge occurred.

3.6.2 Toxicity Testing

Meridian is not required to conduct toxicity testing as a provision of their NPDES permit. Therefore, toxicity testing has not been completed on Meridian's effluent. As previously noted, the effluent TDS is in the form of calcium carbonate ($CaCO_3$). The maximum TDS value recorded to date has been 698 mg/L. This value is far below the toxicity of $CaCO_3$ reported in the literature.

Calcium is considered to represent the least toxic of the cations. Also, the carbonate anion is generally considered to represent the least toxic of the "ate" anions (sulfate, nitrate, etc.).

Published information regarding the toxicity of $CaCO_3$ is limited due primarily to the lack of toxicity except at extremely high concentrations. Mortality values have been reported to be greater than 56,000 mg/L for freshwater fish, (essentially up to the solubility of $CaCO_3$). In Arkansas, toxicity testing has been completed on effluent from a facility that quarries $CaSO_4$. The TDS values from this facility exceeds 1000 mg/L without any indication of toxicity at 100% effluent in 7 day chronic toxicity tests. Also several studies have been completed in Arkansas that demonstrate that TDS concentrations in excess of 1000 mg/L maintains in-stream biological integrity.

Since the TDS produced in the limestone quarry is $CaCO_3$, and the maximum concentrations are well below 1000 mg/L, there is little potential for toxicity from the TDS of the discharge.

4.0 AQUATIC LIFE FIELD STUDY

4.1 Introduction

The objective of the aquatic life field study was to document whether the designated and existing aquatic life use was being maintained by the existing discharge conditions. To accomplish this objective, the aquatic life field study included evaluations of the habitat conditions, water quality, aquatic macroinvertebrate community, and fish community assemblages. The results of this evaluation are provided in this section.

4.2 Habitat Characterization

4.2.1 Introduction

The objectives of the habitat characterization were to:

1) assess the availability and quality of habitat for the development and maintenance of benthic invertebrate and fish communities, and
2) evaluate habitat limitations which may prevent attainment of designated uses and limit biological integrity.

4.2.2 Methods

The physical habitat was characterized from measurements and observations of stream attributes made along three transects at each of the study stations. The physical habitat was characterized during the mid summer, during the peak of vegetative growth.
Two habitat evaluation reaches were established in Stennitt Creek:

1) SC-1 (Stennitt Creek upstream of the Outfall 001 discharge from Meridian downstream from the mouth of Brushy Creek), and
2) SC-2 (Stennitt Creek downstream from the Outfall 001 discharge from Meridian).

The physical characteristics along three transects were evaluated within each reach. Characteristics of the following six attributes were recorded from each transect:

1) flow
2) channel width
3) stream width
4) velocity
5) depth, and
6) substrate

An additional eight attributes that were qualitatively estimated for the entire reach included:

1) percent pool,
2) percent riffle,
3) percent bank habitat,
4) percent instream habitat,
5) bank slope,
6) bank stability,
7) riparian cover, and
8) percent canopy cover.

All distance measurements were made using a 0.1 ft incremental tape. Velocity measurements were read directly from a Marsh-McBirney velocity meter. Drainage areas and stream gradients were calculated from USGS 7.5 minute topographic maps and field verified as possible.

A qualitative habitat assessment was also completed at each reach using the method modified from EPA's rapid bioassessment procedures. This assessment rated habitat potential by scoring habitat parameters on an qualitative scale from 1 to 20. The following parameters were used for the evaluation:

1) instream cover,
2) epifaunal substrate,
3) pool substrate characterization,
4) pool variability,
5) channel alteration,
6) sediment deposition,
7) channel sinuosity,
8) channel flow status,
9) condition of banks,
10) bank vegetative protection,
11) disruptive pressure, and
12) riparian vegetative zone width.

Each reach was evaluated by three experienced field biologists who ranked each attribute independently and summed them for a total score. The scores were then averaged to produce the overall ranking. Calculated scores placed the reach into a habitat category of optimal (181-240), suboptimal (121-180), marginal (61-120), or poor (1-60).

4.2.3 Results and Discussion

4.2.3.1 Habitat Quality

A summary of the physical attributes of all stations where physical data was collected is presented in Table 5. Field sheets and the raw habitat data are provided in Attachment B.

4.2.3.2 Reach SC-1

The upstream station, SC-1, was composed mostly of pools with riffle/run areas accounting for only 20% of the reach. The average stream width was 20.0 ft and the average stream depth was 1.0 ft. The average velocity and flow recorded at this station during the low flow period were 0.2 fps and 0.7 cfs, respectively. An average channel width as measured bank to bank was 41.0 ft. (Figure 4).

Instream habitat was composed of depressions within shallow pools and areas of logs and debris habitat that occurred in the deeper pools (Figure 5). The stream substrate was composed of

Figure 4. Typical section of Stennitt Creek at Site SC-1, upstream of the Meridian discharge location, July 1998.

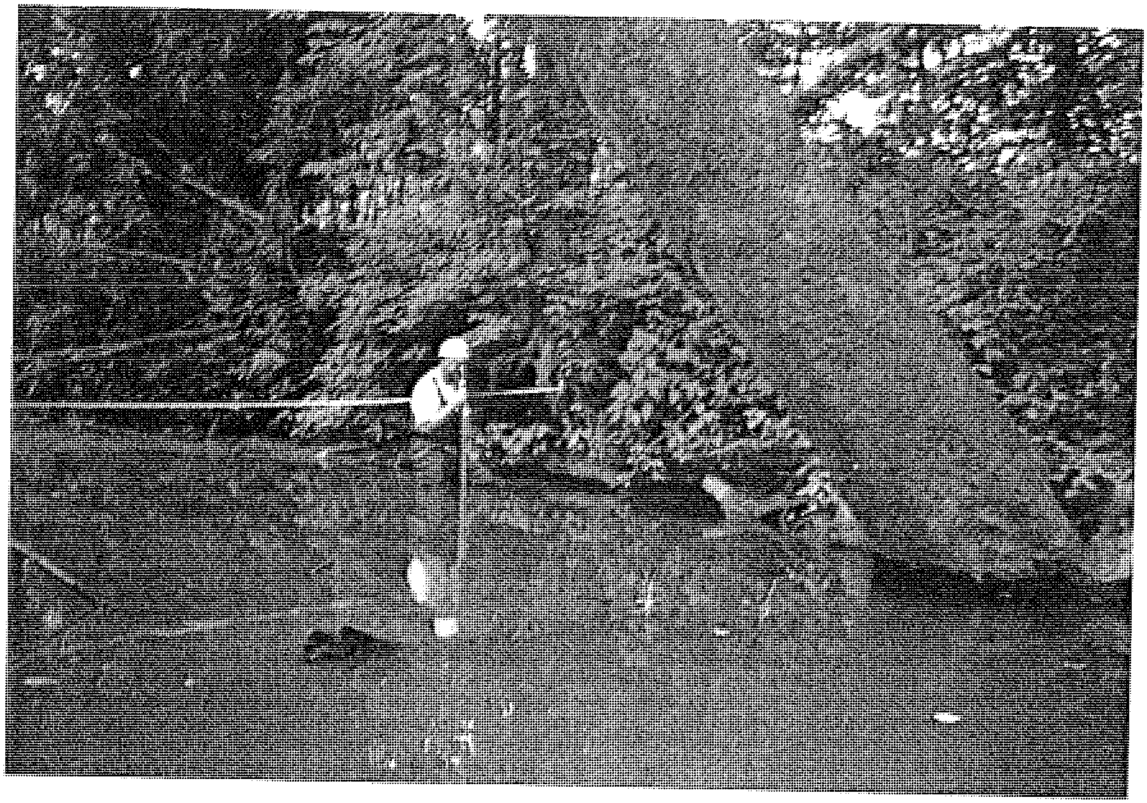

Figure 5. Pooled area with woody structure at Stennitt Creek, Site SC-1, July 1998

sand and mud with a liberal littering of detritus in most of the pooled areas. The substrate composition appeared to lend itself to macrophyte growth and several sections of Stennitt Creek at SC-1 contained abundant macrophyte (Figure 6). The riffle/run areas were primarily composed of gravel, heavily embedded in sand and silt. The bank habitat was composed of roots, vegetation, and undercut banks, with several areas being nearly bare. The bank slope was steep (>30°) to moderately steep (9°-30°) with the soils being moderately stable to unstable from an erosion perspective. A number of the pools in this reach were maintained by beaver activity.

Table 5. Physical Habitat Evaluation at Stennitt Creek near Black Rock, July 1998.

	SC-1 (Upstream)				SC-2 (Downstream)			
Observation	**T-1**	**T-2**	**T-3**	**Average**	**T-1**	**T-2**	**T-3**	**Average**
Date	7/15/98	7/15/98	7/15/98		7/15/98	7/15/98	7/15/98	
Time	1115	1140	1205		1645	1715	1730	
Stream Width (ft)	25	27	8	20.0	16	22	5	14.3
Velocity (fps)				0.2				0.9
Flow (cfs)				0.7				0.5
Channel Width (ft)	38	40	45	41.0	35	38	50	41.0
Average Depth (ft)	0.8	1.7	0.39	1.0	0.68	1.5	0.17	0.8
Area (sq. ft.)	19.9	45.8	3.3	23.0	11.6	35.5	0.65	15.9
Bank Habitat: (%)								
Roots	25	33.3	0	19.4	66	33.3	0	33.1
Vegetation	0	33.3	50	27.8	33	33.3	100	55.4
Undercut	25	33.3	0	19.4	0	33.3	0	11.1
Devoid	50	0	50	33.3	0	0	0	0.0
Right Bank Slope: (%)								
Flat	0	0	25	8.3	0	25	10	11.7
Mod	10	10	50	23.3	20	25	75	40.0
Steep	90	90	25	68.3	80	50	15	48.3
Left Bank Slope: (%)								
Flat	0	0	25	8.3	0	15	10	8.3
Mod	20	25	50	31.7	10	15	40	21.7
Steep	80	75	25	60.0	90	70	50	70.0
Right Bank Stability: (%)								
Stable	0	0	50	16.7	35	20	50	35.0
Mod. Stable	50	50	25	41.7	50	50	25	41.7
Unstable	50	50	25	41.7	15	30	25	23.3
Left Bank Stability: (%)								
Stable	0	0	50	16.7	25	10	75	36.7
Mod. Stable	50	30	25	35.0	40	30	10	26.7
Unstable	50	50	25	41.7	35	60	15	36.7
Right Bank Riparian Cover: (%)								
Ground Cover	75	90	100	88.3	80	90	100	90.0
Canopy Cover	15	80	0	31.7	50	90	60	66.7
Left Bank Riparian Cover: (%)								
Ground Cover	75	90	100	88.3	80	80	100	86.7
Canopy Cover	15	20	10	15.0	50	75	45	56.7
% Pool				80.0				70.0
% Riffle/Run				20.0				30.0
Stream Habitat: (%)								

Table 5. Physical Habitat Evaluation at Stennitt Creek near Black Rock, July 1998. (cont.)

	SC-1 (Upstream)				SC-2 (Downstream)			
Observation	T-1	T-2	T-3	Average	T-1	T-2	T-3	Average
Logs/Debris	15	100	0	38.3	0	0	0	0.0
Depressions	85	0	100	61.7	0	0	0	0.0
Vegetation	0	0	0	0	0	0	100	33.3
Devoid	0	0	0	0	100	100	0	66.7
Substrate: (%)								
Mud	68	40	0	36.0	33.3	23	0	18.8
Sand	32	44	100	58.7	33.3	18	0	17.1
Gravel	0	16	0	5.3	33.3	38	0	23.8
Cobble	0	0	0	0.0	0	21	100	40.3
%CPOM on Substrate	92	36	0	42.7	0	0	0	0.0
Canopy Cover (%)	85	100	22	69.0	100	67	0	55.7

4.2.3.3 Reach SC-2

The downstream station, SC-2, was composed mostly of pooled areas with runs and riffles comprising approximately 30% of the reach. Although the average stream width was 14.3 ft which was 30% less than the upstream station, the average depth was 0.8 ft. An average flow of 0.5 cfs was measured with an average velocity of 0.9 fps. The average channel width as measured bank to bank was 41.0 ft which was similar to the upstream reach indicating bank full flows varied little from the two reaches (Figure 7).

The existing instream habitat was composed entirely of vegetation with much of the reach being devoid. A cobble and gravel substrate dominated the stream bed in this reach (Figure 8). A unique feature of this reach is the bedrock outcropping which comprised a portion of the reach but was not included as substrate since most of it was exposed due to low flow conditions. The bank habitat was composed of vegetation, roots, and undercut banks. The bank slope was generally steep to moderately steep. The soils on the bank varied greatly from stable to unstable.

Differences between SC-1 and SC-2 included the vegetation and the amount of instream structure (logs and woody debris) that was present at SC-1 when compared to SC-2, where logs and debris were sparse (Figure 9). Additionally, there were some differences in substrate at SC-2 relative to SC-1. The downstream station was dominated by cobble and gravel substrate, while the upstream station was sand and mud bottomed with very little gravel and cobble. These differences are reflected in habitat potential.

4.3 Habitat Potential

A qualitative assessment of the habitat placed SC-1 in the suboptimal category and SC-2 in the marginal category with mean scores of 12.3 and 9.7, respectively (Table 6). The scores represent a habitat similarity of 79% between the two reaches. The differences in the scores were demonstrated most significantly by differences in instream cover and epifaunal substrate between the two sites. For the category of instream cover SC-2 was 10 points lower than SC-1 and for epifaunal cover SC-2 was 5.7 points below the score for SC-1. The large difference in instream cover rankings is largely due to the scarcity of logs and debris habitat in the SC-2 reach. The scores also reflect sedimentation which increased at SC-2 relative to SC-1.

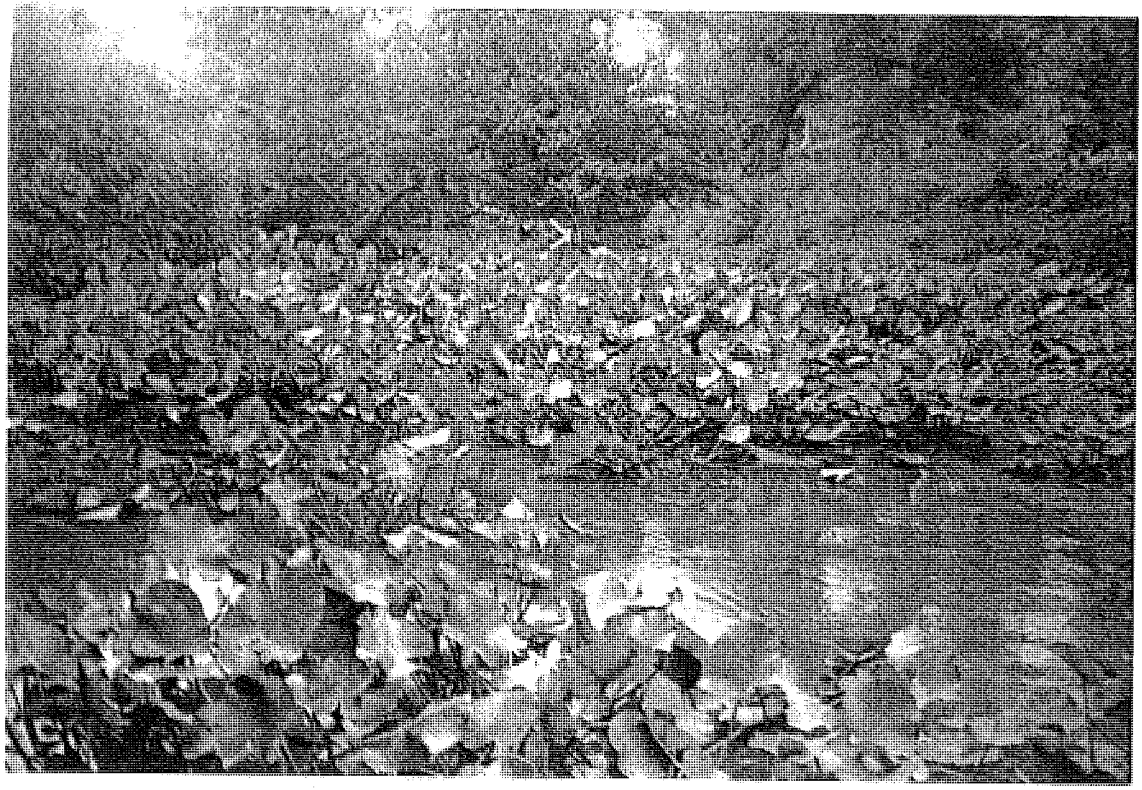

Figure 6. Macrophyte growth in Stennitt Creek at SC-1, July 1998.

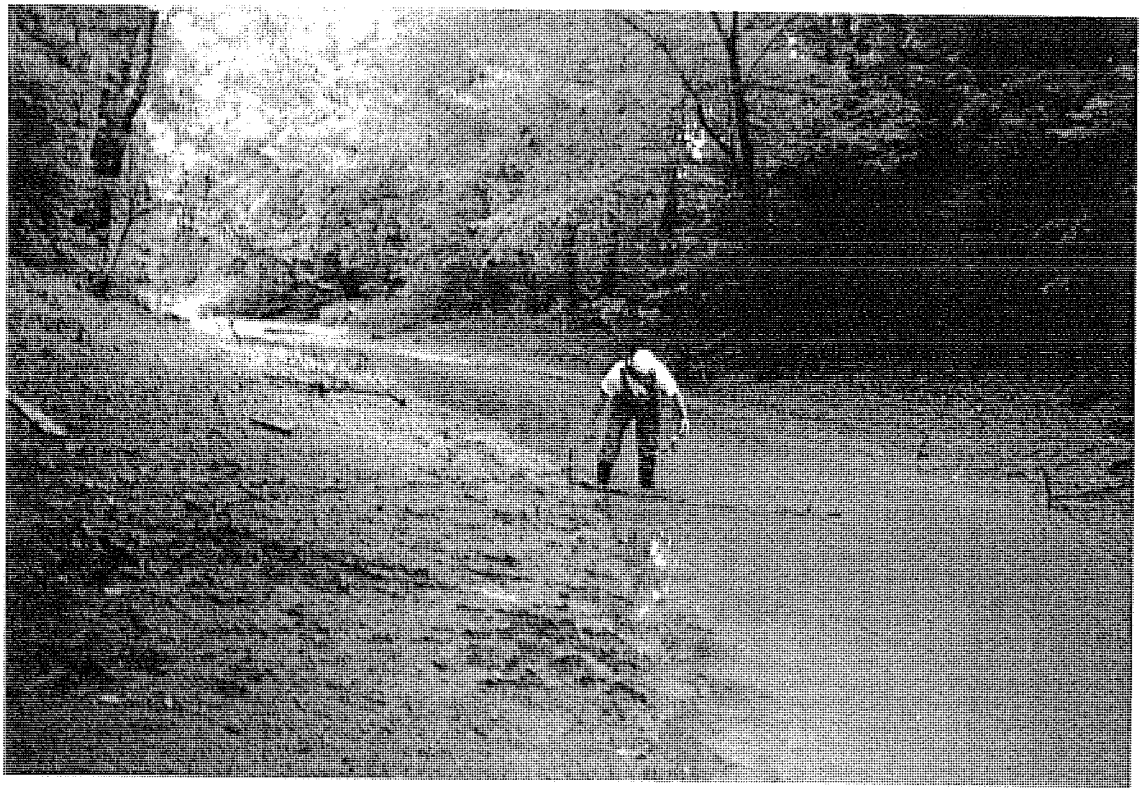

Figure 7. Typical section of Stennitt Creek at the downstream station, SC-2, July 1998.

Figure 8. Cobble riffle area at SC-2 in Stennitt Creek, July 1998.

Figure 9. Stennitt Creek at Station SC-2, showing typical reach of stream with limited in-stream structure, July 1998.

The results of the qualitative habitat assessment indicate the presence of more available habitat for fish at SC-1 (upstream) than at SC-2 (downstream).

The assessment also ranked the macroinvertebrate habitat at SC-1 higher than that at SC-2, making the upstream site more conducive to colonization.

4.4 Habitat Conclusions

The habitat evaluation indicated that:

1) The habitat at SC-1 is sufficient for the maintenance and development of a benthic macroinvertebrate and a fish community representative of a typical Ozark Highlands stream.
2) The habitat at SC-2, though less variable than that at SC-1, is sufficient to maintain the macroinvertebrate and fish communities typical for the ecoregion and watershed size.
3) With the exception of instream cover and eplifaunal substrate the differences in overall habitat were minimal upstream and downstream of the Meridian Aggregates discharge.

Table 6. Summary of Qualitative Habitat Assessment, Stennitt Creek near Black Rock, July 1998.

Parameters	SC-1	SC-2
Instream Cover	16.3	6.3
Epifaunal Substrate	14.7	9.0
Pool Substrate Characteristics	13.7	9.7
Pool Variability	14.0	9.7
Channel Alteration	15.3	16.3
Sediment Composition	10.7	7.7
Channel Sinuosity	12.0	7.7
Channel Flow Status	13.7	8.3
Bank Condition	8.7	8.0
Bank Vegetative Condition	9.7	8.0
Disruptive Pressure	9.7	13.3
Riparian Vegetative Zone Width	9.3	12.7
Score Total	147.7	116.7
Score Average	12.3	9.7
Ranking	S	M

Ranking:	Range:
Optimal (O)	16-20
Sub-optimal (S)	11-15
Marginal (M)	6-10
Poor (P)	1-5

4.5 Water Quality

4.5.1 Chemical Characteristics

This section presents the methods and results of the low flow analyses used to characterize the in situ water quality and TDS of Stennitt Creek. The analytical methods used followed procedures outlined in Standard Methods for the Examination of Water and Wastewater and appropriate EPA published methods.

4.5.2 Methods

The intensive survey was conducted on July 15 and 16, 1998 to reflect summer low flow conditions. Water quality parameters were measured at Sites SC-1 and SC-2 in Stennitt Creek (Figure 1). Water quality sampling included both in situ measurements and grab samples for laboratory analysis of TDS (Table 7). In situ measurements included water temperature (°C), dissolved oxygen (DO mg/L), pH (su), and specific conductance (µS). Grab samples were collected, packed on ice and transported to a contract laboratory for analyses.

Table 7. In situ water quality of Stennitt Creek during low flow conditions, July 1998.

Station	SC-1	SC-2
Temperature, C°	28.2	26.9
Dissolved Oxygen, mg/L	5.4	7.3
Conductivity, µS	347	634
pH, su	7.5	7.7
TDS, mg/L	180	410

4.5.3 Results

The temperature ranged from 26.9 °C to 28.2 °C. The DO increased from upstream to downstream with measurements of 5.4 mg/L and 7.3 mg/L, respectively. Specific conductance ranged from 347 µS to 634 µS. The pH varied only slightly between the stations ranging from 7.5 su to 7.7 su.

The concentration of total dissolved solids at the downstream station increased over that of the upstream station, 410 mg/L versus 180 mg/L, respectively. The downstream TDS measurement was higher than the 240 mg/L TDS standard in the Ozark Highlands Ecoregion. It should be noted that the flow in Stennitt Creek was less than the 4.0 cfs at which the ecoregion standard applies.

4.5.4 Conclusions

Based on the in situ water quality parameters measured during the field survey, the biological integrity of Stennitt Creek should not be adversely impacted and the existing attainable uses should be maintained by the existing condition in Stennitt Creek, including the existing discharge from Meridian. The TDS levels, though elevated in the downstream reach relative to the

Ozark Highlands Ecoregion standard, are well below those levels found in other Arkansas streams in which biological integrity and aquatic life uses are maintained.

4.6 Benthic Macroinvertebrate Community

4.6.1 Introduction

The benthic invertebrate community reflects the effects of habitat availability, and the long term exposure to physical and chemical properties of the water in which they develop and live. The diversity and the presence of an expected level of benthic community reflects the maintenance of a systems biological integrity.

4.6.2 Methods

A biological assessment of the benthic macroinvertebrate community was performed using rapid bioassessment (RBA) techniques as detailed in ADEQ, 1988. The methods were modified to sample in pool habitats and limited to habitats present at both sites evaluated. Stream reaches upstream of the effluent discharge (SC-1) and downstream of the effluent discharge (SC-2) were chosen for evaluation. Macroinvertebrates were sampled using a Turtox Indestructible® dip net. Each station was sampled for three minutes according to the RBA protocol. Each sample was condensed, placed in a labeled one-liter jar, and preserved in 70% ethanol for subsequent processing in the lab.

In the lab, the samples were removed from their respective jars, placed on a white sorting tray, and thoroughly mixed to prevent potential bias. A 100 organism sub-sample was then randomly picked (according to the RBA procedures) from the tray and identified. The 100 organism sub-samples were preserved in 70% ethanol as a voucher to be used if more detailed analysis becomes necessary. The remainder of the original sample was retained as a voucher for the sub-sampling techniques used. These voucher samples will be held at GBM^c for a period of 24 months, from the conclusion of the third party rulemaking at which time the samples may be submitted to an academic zoological collection.

The macroinvertebrate assemblages from each station were analyzed according to several benthic community biometrics. These include richness (number of different taxa), EPT richness (number of different taxa represented in the orders Ephemeroptera, Plecoptera, and Trichoptera), and species diversity as determined by the Shannon-Wiener diversity Index. The analysis also included the seven biometrics used by the State of Arkansas (ADEQ, 1988) in their RBA scoring system. This scoring system places a value (1 to 4, 1=excessive differences, 4=no differences) on each of the seven biometrics to achieve a final mean score.

4.6.3 Results and Discussion

The mean result of the biometric scoring was a 2.6 which indicates minimal differences between the upstream and downstream macroinvertebrate communities. The ADEQ RBA document indicating a 2.6 minimal impairment score. This suggests that there is full support of the designated aquatic life use and should be considered as compliant with no increased monitoring recommended (ADEQ, 1988). Closer examination of the community assemblages suggests that this difference reflects improvements in the macroinvertebrate community in the downstream reach, rather than an impairment. A list of the macroinvertebrates collected at SC-1 and SC-2 is presented in Table 8.

Table 8. Macroinvertebrates Collected from Stennitt Creek near Black Rock, July 1998.

Taxa/Station Data	**Upstream SC-1**	**Downstream SC-2**
ANNELIDA		
Hirudinea	1	1
Oligochaeta	–	2
GASTROPODA		
Physa	–	3
NEMATODA		
Nematoda	1	–
PELECYPODA		
Corbicula	1	–
Sphaerium	1	–
CRUSTACEA		
Cambarinae	3	10
Isopoda	1	–
Palaemonetes	–	5
EPHEMEROPTERA		
Caenis	45	18
Callibaetis	10	2
Stenacron	1	1
Stenonema	–	12
ODONATA		
Argia	–	2
Boyeria vinosa	–	1
Dromogomphus	5	1
Hagenius brevistylus	1	–
Ischnura	1	3
Macromia	2	–
TRICHOPTERA		
Cheumatopsyche	–	8
Hydropsyche	–	7
Hydroptilidae	–	1
Polycentropus	–	1
COLEOPTERA		
Berosus	–	1
Dineutus	–	2
Peltodytes	2	4
Peltodytes larvae	4	–
Stenelmis	–	1
Uvarus	2	1
MEGALOPTERA		
Chauloides	1	–
Cornutus	–	3
Sialis	7	1

Table 8. Macroinvertebrates Collected from Stennitt Creek near Black Rock, July 1998. (cont.)

Taxa/Station Data	Upstream SC-1	Downstream SC-2
DIPTERA		
Chironomidae	7	9
Tabanidae	3	--
Tipulidae	1	--
Sum of Percentages	100	100
Total Abundance:	100	100
Species Richness:	21	25
Shannon-Wiener Diversity Index	3.10	3.99

The macroinvertebrate community at SC-2 had a higher species diversity than that at SC-1, 3.99 versus 3.10, respectively. The species richness at SC-2 was also higher than that found at SC-1 (Table 9). The most noticeable change in the community structure was represented by the change in EPT (richness which included 3 taxa upstream and 8 taxa downstream of the discharge. This marked increase in EPT taxa at SC-2 was due mostly to the addition of four taxa of Trichopterans which were not present in the upstream sample. The downstream station also exhibited a shift in the trophic structure where the scrapers became the second most abundant feeding group, accounting for 18% of the assemblage, compared to 1% at SC-1. Also, the downstream assemblage demonstrated a more even distribution among the functional groups indicating a more balanced community.

The differences in the macroinvertebrate communities upstream and downstream was likely due to habitat availability, not to water quality. Though the downstream reach of Stennitt Creek was observed to have less total sustainable habitat than the upstream reach, the existing habitat included vegetated cobblestone riffles. Riffles provide good habitat and increased oxygen levels accommodating the establishment of EPT assemblages. The increased diversity of EPT species resulted in the majority of the change in the downstream community structure noted. In addition to substrate changes downstream, the increased flow resulting from the discharge likely provided a larger wetted substrate for EPT colonization during periods of normally low flow. Although colonization in lotic systems are generally considered to occur from upstream to downstream through "drift" the proximity and direct connection to the Spring River may have also influenced the benthic community at SC-2.

Table 9. Macroinvertebrate community analysis for Stennitt Creek at Black Rock, AR.

Parameter	Upstream SC-1	Downstream SC-2
COMMUNITY MEASURES		
Total number of Taxa (Richness)	21	25
EPT Richness	3	8
Diversity Indices (Shannon-Wiener)	3.10	3.99
Total % of 5 Dominant Taxa	74	57
RANK OF ORDINAL GROUPS*		
Ephemeroptera	1	1
Trichoptera	--	2

Table 9. Macroinvertebrate community analysis for Stennitt Creek at Black Rock, AR. (cont.)

Parameter	Upstream SC-1	Downstream SC-2
Odonata	3	–
Coleoptera	4	4
Diptera	2	4
Other (Amphipoda/Decapoda)		3
FUNCTIONAL FEEDING ASSEMBLAGES %		
Shredders	10	14
Scrapers	1	18
Collectors	66	52
Predators	22	15
BIOMETRIC SCORE	**2.6**	

*Numerically ranked from most (1) to least dominant (4)

4.6.4 Conclusions

The benthic macroinvertebrate communities at each station were somewhat similar allowing for the following conclusions:

1) The benthic macroinvertebrate community, as represented by collections from both sites, in Stennitt Creek is being maintained and is similar to that expected in other Ozark Highland Ecoregion streams.
2) The discharge from Meridian Aggregates does not prevent the development of a stable macroinvertebrate community. In fact, the community structure downstream of the discharge appears to be enhanced over that found upstream.
3) Only minimal differences in the benthic community at SC-1 and SC-2 were exhibited. This suggests that the aquatic life uses of Stennitt Creek are being maintained both upstream and downstream of the discharge.

4.7 Fish Community

4.7.1 Introduction

Stennitt Creek is designated as a Perennial Ozark Highlands fishery in Reg. No. 2. Accordingly, the fish community of Stennitt Creek was evaluated to determine its status, relative to that designation, and any impact caused by the TDS discharged from Meridian on the fishery.

4.7.2 Methods

An assessment of the fish community upstream (SC-1) and downstream (SC-2) of the effluent discharge was performed. Each station was sampled using a Smith-Root backpack electroshocker. The shocker includes a counter which records the amount of time that electricity is actually being applied, or "pedal down time" (PDT). The PDT at SC-1 was 52.9 minutes while the PDT at SC-2 was 39.2 minutes. Shocked fish were captured with hand held dip nets and held in buckets while the sampling continued. The fish were field identified and some larger specimens returned to the stream.

At the end of each sampling effort fish from both stations were preserved in formalin for verification of any field identifications made. Fish identifications were made according to the Fishes of Arkansas (Robison, 1988) and (Pflieger, 1975) to the species level where possible. The fish assemblages at each station were compared according to several biometrics including: species richness, species diversity, abundance, dominant groups, and key indicators as indicated in Reg. No.2.

4.7.3 Results and Discussion

The fish assemblages from the upstream and downstream reaches of Stennitt Creek exhibited minimal differences in composition and structure. The fish community at SC-1 upstream of the discharge, and from SC-2 downstream of the discharge were each similar to those expected in streams of the Ozark Highlands Ecoregion of equal size.

Collections from both stations suggested a fish community dominated by minnows and sunfish. Station SC-1 was characterized by 54% sunfishes, 25% minnows, 7% mosquitofish, and 6% darters. Station SC-2 was characterized by 51% minnows, 18% sunfishes, 9% bullhead catfishes, 8% mosquitofish, and 6% suckers. A complete list of the fish collected in Stennitt Creek is provided in Table 10.

The Station SC-1 fish sample contained 18% of the Ecoregion key and indicator species as listed in Reg. No. 2. In the SC-2 fish sample, 27% of the Ecoregion key and indicator fish species were present.

Both taxa richness and species diversity were higher at the downstream station than at the upstream station, 26 species and 3.65 versus 22 species and 3.60, respectively. However, the abundance of fish upstream was greater than downstream (Table 11). This difference was likely due to the available instream habitat that was reduced in the downstream reach, particularly in regards to the woody structure preferred by sunfish species. When compared to the upstream reach, a noticeable shift in the dominant ordinal group, from sunfish to minnows, occurred downstream. This was likely also a result of habitat availability. The downstream reach contained more emergent vegetation and riffle/runs conducive to minnow colonization while the upstream reach contained more woody debris and pools conducive to sunfish habitation.

Table 10. Fish collected from Stennitt Creek near Black Rock, AR.

Scientific Name	Common Name	Upstream SC-1	Downstream SC-2
CYPRINIDAE			
Campostoma oligolepis	largescale stoneroller	16	42
Hybognathus nuchalis	Mississippi silvery minnow	3	30
Hybopsis amblops	bigeye chub	1	--
Notropis boops	bigeye shiner	--	4
*Notropis nubilus****	ozark minnow	18	--
Notropis telescopus	telescope shiner	1	--
Notropis sp.1	minnow	--	1
Notropis sp.2	minnow	--	1
Pimephales notatus	bluntnose minnow	6	--
Pimephales tenallus	slim minnow	35	10

Table 10. Fish collected from Stennitt Creek near Black Rock, AR. (cont.)

Scientific Name	**Common Name**	**Upstream**	**Downstream**
		SC-1	**SC-2**
CATOSTOMIDAE			
Erimyzon oblongus	creek chubsucker	17	2
*Hypentelium nigricans***	northern hogsucker	–	2
Moxostoma sp.	redhorse sp.	–	6
ICTALURIDAE			
Ameiurus natalis	yellow bullhead	3	15
APHREDODERIDAE			
Aphredoderus sayanus	pirate perch	1	5
FUNDULIDAE			
Fundulus olivaceus	blackspotted topminnow	3	1
Fundulus catenatus	northern studfish	–	1
POECILIIDAE			
Gambusia affinis	Mosquitofish	22	14
ATHERINIDAE			
Labidesthes sicculus	brook silverside	–	1
CENTRARCHIDAE			
Lepomis cyanellus	green sunfish	2	5
Lepomis gulosus	warmouth	1	1
Lepomis megalotis	longear sunfish	58	14
Lepomis microlophus	redear sunfish	3	–
Lepomis punctatus	spotted sunfish	33	1
Lepomis macrochirus	bluegill sunfish	56	6
Lepomis (juvenile)	juvenile sunfish	4	1
*Micropterus dolomieui***	smallmouth bass	–	1
Micropterus punctulatus	spotted bass	12	1
Micropterus salmoides	large mouth bass	–	1
PERCIDAE			
*Etheostoma Caeruleum***	rainbow darter	3	5
Etheostoma chlorosomum	bluntnose darter	16	–
Etheostoma flabellare	fantail darter	–	1
Total No. Taxa Collected		22	26
Total Fish Collected		314	172
Level of Effort (Minutes) PDT*		52.9	39.2
Catch per Minute, PDT		5.9	4.4
Shannon-Wiener Diversity Index		3.60	3.65

* Pedal Down Time

** Key Ecoregion species

*** Indicator Ecoregion species

4.7.4 Conclusions

Based on the results of the fish collections, the following conclusions are provided:

1) The fish community in Stennitt Creek is being maintained as is the designated Perennial Ozark Highlands fishery use.
2) Fish assemblages found in the SC-2 reach are similar to those expected in a typical Ozark Highlands Ecoregion stream for that size watershed.
3) The fish community downstream of the Meridian Aggregates discharge is moderately different to the community upstream of the discharge. This difference is manifested by increased diversity and richness of species, downstream of Meridian, which more closely reflects the expected community of a typical Ozark Highlands stream of that size watershed.

Table 11. Fish community structural analysis for Stennitt Creek near Black Rock, AR.

Parameter	Upstream SC-1	Downstream SC-2
COMMUNITY MEASURES		
Total number of Taxa (Richness)	22	26
Abundance, fish collected/minute	5.9	4.4
Diversity Indices (Shannon-Wiener)	3.60	3.65
Total % of 5 Dominant Taxa	65	67
PERCENT OF 5 DOMINANT ORDINAL GROUPS		
Centrarchidae	54	18
Cyprinidae	25	51
Poeciliidae	7	8
Percidae	6	--
Catostomidae	5	6
Ictaluridae	--	9

5.0 EXISTING LOADINGS OF DISSOLVED MINERALS

5.1 TDS Water Quality Criteria

The existing ecoregion based TDS water quality criteria for Stennitt Creek is 240 mg/L. Utilizing the appropriate flows and background concentrations provided in the WQS and the Continuous Planning Process (CPP) as used in preparation of the existing permit, the discharge to Stennitt Creek will not maintain the existing ecoregion dissolved minerals criteria. The existing Meridian permit limits were based on maintaining the ecoregion criteria.

In addition to ecoregion water quality criteria, the domestic water supply use designation for Stennitt Creek results in a numeric criterion of 500 mg/L for TDS. As discussed in Sections 3.2 and 3.3, the drinking water use is a designated, but not an existing use for Stennitt Creek. Additionally, there are no plans to utilize either stream as a domestic water supply use. Review of the Meridian

DMR data indicates that attaining the instream criterion of 500 mg/L can not be assured under low flow conditions in Stennitt Creek.

In order to determine an appropriate TDS criteria for Stennitt Creek, a mass balance was developed as described in the following sections.

5.2 Mass Balance

The following mass balance equation was used to calculate instream waste concentrations (IWC) for TDS:

$$IWC = [(Qb \times Cb) + (Qe \times Ce)] / (Qb + Qe)$$

Where:

Qb = The background flow of the receiving stream
Cb = The background concentration of TDS in the receiving stream
Qe = The discharge flow of the effluent
Ce = The effluent concentration of TDS

5.2.1 Methods

The procedure for evaluating instream concentrations and developing permit limits for minerals can be found in *ADEQ Discharge Permit, Toxic Control Implementation Procedure* in Arkansas' 1995 Continuing Planning Process (CPP). The value used for the background concentration of TDS (143 mg/L) was the mean concentration for the Ozark Highland Ecoregion. The background value is listed in the CPP in Attachment XII, *Mineral Permitting Strategy*, for streams in the Ozark Highlands with a Q7-10 of less than 100 cfs. A background flow of 4 cfs was used, as allowed for determining instream mineral concentrations in the WQS. Effluent concentrations for TDS were derived from historical maximum monthly concentrations from December 1995 through December 1998. Instream concentrations were calculated for Stennitt Creek .

5.2.2 Computations for Stennitt Creek

The Ozark Highland Ecoregion background concentration for TDS is 143 mg/L. Meridian's reported highest monthly average flow for a period from January 14, 1999 through March 5, 1999 was 3.34 mgd (5.17 cfs). This specific time period was used because data prior to the date listed is not accurate. During December 1998 a new and calibrated flow totalizer was installed for Outfall 001. Flow data from January, 1999 through the present time has been field verified and is accurate. The flow data set used to calculate the highest monthly average from the abbreviated time period, included 19 flow values. The flow value used in the computations as the discharge flow at Outfall 001 was selected as directed by Section D of *ADEQ Discharge Permit, Toxic Control Implementation Procedure* in the CPP. A concentration of 698 mg/L was used as the effluent concentration. This value is the 99th percentile of the data set calculated according to nonparametric (the data set was neither normally distributed or lognormally distributed) statistical methodologies as outlined in *Statistical Methods for Environmental Pollution Monitoring* (Gilbert, 1987). The TDS data was analyzed for normality using the W-test developed by Shapiro and Wilks. This test determined that the data was not normally distributed. The data was then lognormally transformed and reanalyzed with the W-test. The data was not found to be lognormally distributed. Therefore, the 99th percentile for the TDS data was calculated using a nonparametric technique (Gilbert, 1987) presented below:

$$k = p(n=1)$$

where: k = the ranked order number from the TDS data set (values of k that are not integers are interpolated for using the two values that k falls between).
p = desired percentile
n = number of data points

This method returns a $k = 31.68$. The TDS data set has an $n = 31$, therefore, the highest value in the data set ranked as "31" (698 mg/L) is equal to the 99th percentile. Utilizing all the aforementioned data the IWC is calculated below. The summary of the mass balance data inputs are provided in Table 12.

IWC_{TDS} =
[(4.0 cfs x143 mg/L) + (5.17 cfs x 698 mg/L)] / (4.0 cfs + 5.17 cfs) = 456 mg/L

Table 12. Mass Balance Calculation for Stennitt Creek.

Stennitt Creek: Factors Used in the Criteria Calculations	TDS
Ce, mg/L (projected 99th%tile)	698
Cb, mg/L	143
Qe, cfs	5.17
Qb, cfs	4.0
Projected Standard at Discharge(Stennitt Cr.), mg/L	456

6.0 ALTERNATIVE ANALYSES

This section summarizes the analyses of alternatives for Meridian to maintain the WQS for Stennitt Creek. As described in Section 5.0, the effluent discharge from Meridian cannot be assured to maintain the protective criterion for TDS related to the designated (but not existing) Domestic Water Supply use. In addition, the discharged concentrations of TDS are projected to cause instream exceedence of the ecoregion criteria at 4.0 cfs upstream flow.

Five alternatives were identified to address designated uses and the protective criteria for TDS. They are as follows:

1) No action,
2) No discharge,
3) Treatment,
4) Source reduction, and
5) Water Quality Standards modification.

6.1 No Action

This alternative would maintain the current discharge situation. TDS effluent concentrations would continue to exceed the monthly average permit limit (and occasionally the daily maximum permit limit) established to maintain the ecoregion based criteria. In addition, it is projected that instream exceedences of TDS criteria based on the designated Domestic Water Supply use will occur under critical conditions. For these reasons, this alternative is not considered to be feasible.

6.2 No Discharge

The no discharge alternative is not economically feasible. An inability to discharge would result in an inability to continue operations of the quarry.

The Meridian Black Rock Quarry employs approximately 50 full time employees (plus an additional 10 - 15 full time on site contractors) with an annual payroll estimated at approximately $1.5 million dollars. Meridian is a significant employer in Lawrence County and is the largest utility user in the county. This alternative could require the cessation of operations at the Black Rock Quarry which would greatly affect the local economy.

This alternative is considered infeasible due to the socio-economic effects to the local area should the Black Rock Quarry close.

6.3 Pollution Prevention Activities

As discussed in Section 3.5, pollution prevention activities have been installed and will continue to reduce the potential for contaminated runoff leaving the Quarry site. Installation of the pollution prevention activities will not effect the concentration of TDS discharged through the permitted outfall.

6.4 Treatment

EPA has no Best Available Technology (BAT) for TDS removal from waste streams. While ion exchange (anion) and reverse osmosis treatment technologies exist, these methods currently are not cost effective on a large scale and are not recommended. Also, the extremely concentrated reject streams generated from such processes must be disposed of at a great expense and with much greater potential environmental risk than the wastewater which was initially treated.

The technical limitations and uncertain environmental effects of concentrated wastestreams generated from ion exchange and reverse osmosis treatment make the treatment alternative infeasible.

6.5 WQS Modifications

Discussions concerning the WQS Modification alternative are contained in the following sections.

6.5.1 Designated Uses

As discussed in Section 3.2, the following designated uses have been assigned to Stennitt Creek in the AWQS.

- Primary Contact Recreation,
- Secondary Contact Recreation,
- Perennial Ozark Highlands Fishery,
- Domestic Water Supply,
- Industrial Water Supply, and
- Agricultural Water Supply.

6.5.2 Existing Uses

The documented existing fishery use in Stennitt Creek is a Perennial Ozark Highlands Fishery.

The primary contact recreation use was not documented as an existing use. The uses of agricultural and industrial water supply were also not documented as existing and may be limited due to water volume, but are not precluded due to water quality.

6.5.3 Attainability of the Domestic Water Supply Use

As previously noted based on the documentation provided by ADH, Stennitt Creek is not an existing or planned public water supply source. In addition, the ASWCC has documented that the removal of the designated domestic water supply use from Stennitt Creek does not conflict with the Arkansas Water Plan.

In addition to an evaluation of the existing and planned use of Stennitt Creek as a domestic water supply, the USEPA Region 6 has requested that information concerning the attainability of the domestic water supply use on the basis of the regulatory criteria contained at 40 CFR 131.10(g) be included in use removal request documentation. Review of the project documentation considering the 40 CFR 131.10(g) criteria demonstrates that removing the designated, but not existing domestic water supply use is appropriate because the use is not attainable based on two of the 40 CFR 131.10(g) criteria. The first of these is criterion No. 2, which states:

> "Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met."

The Stennitt Creek watershed is approximately 16 mi^2 in size, the stream is intermittent in nature and does not have consistent base flows required to supply the volume of water necessary for the development and operation of a domestic water supply. In addition, because of the intermittent nature of the discharge from Meridian the increased flow supplied sporadically through effluent discharge is not sufficient to compensate for the small watershed size of Stennitt Creek. Neither the stream system or the discharge provide the consistent flow volume required for feasible attainment of a domestic water supply use.

The second applicable 40 CFR 131.10 (g) criterion is No. 5, which states:

> "Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses"

As can be seen in the documentation, the physical characteristics of Stennitt Creek, which primarily consist of shallow pools and riffle/run areas, will not support intake and storage areas necessary for the development of a domestic water supply system. As such, the extensive physical modifications required to develop intake and storage areas would result in the removal of riparian habitat and modification of Ozark Highland fisheries habitats. Such modifications would impact the existing aquatic life use.

Based upon the previous analyses, the following modifications to the WQS are recommended:

Table 13. Summary of Proposed WQS Modifications.

Stennitt Creek (from the confluence with Brush Creek downstream to the confluence with the Spring River)
Remove the designated Domestic Water Supply Use.
Amend dissolved minerals criteria: TDS from 240 mg/L to 456 mg/L.

These proposed modifications are supported by the documentation which meets the requirements of AWQS Section 2.306 as clarified by the Administrative Guidance Document.

7.0 REFERENCES

ADEQ, 1998. Regulation No. 2, As Amended: Regulation Establishing Water Quality Standards for Surface Waters of the State of Arkansas, January 1998 (Regulation No. 2).

ADEQ, 1995. State of Arkansas Continuing Planning Process, Update and Revisions, January 1995. ADEQ Water Division.

EPA, 1991. Technical Support Document for Water Quality Based Toxics Control. EPA/505/2-90-001. March 1991.

Robison, H. W. and T. M. Buchanan, 1988. Fishes of Arkansas. University of Arkansas Press. 536 pp.

ADEQ, 1987. Rapid Bioassessment of Lotic Macroinvertebrate Communities: Biocriteria Development. 45 pp.

Pflieger, W. L., 1975. The Fishes of Missouri. Missouri Department of Conservation. 343 pp.

Attachment A

ADH and ASWCC Letters

Arkansas
Soil and Water
Conservation Commission

J. Randy Young, P.E.
Executive Director

101 EAST CAPITOL
SUITE 350
LITTLE ROCK, ARKANSAS 72201

PHONE 501-682-1611
FAX 501-682-3991

March 17, 1999

Mr. Vince Blubaugh, Principal
GBMc and Associates
219 Brown Lane
Bryant, Arkansas 72022

Dear Mr. Blubaugh:

My staff has reviewed the following request for evaluation, and determined that removal of the Designated Domestic Water Supply Use from the below listed stream segment does not conflict with the Arkansas Water plan at this time:

> Lawrence County: Stennitt Creek extending approximately one mile upstream from its confluence with Spring River.

Sincerely,

Earl T. Smith, P.E.
Chief, Water Resource Management Division

ETS/sl/ddavis

cc: Ken Brazil, Supervisor, Water Management

Arkansas Department of Health

4815 West Markham Street • Little Rock, Arkansas 72205-3867 • Telephone (501) 661-2000
Sandra B. Nichols, M.D., Director • Mike Huckabee, Governor

September 28, 1998

Mr. Vince Blubaugh
GBM^c & Associates
22461 Interstate 30 East
Landers Corporate Plaza Suite 402
Bryant, Arkansas 72022

RE: Designated Domestic Water Supply Use
GBM^c No.: 2099-98-070

Dear Mr. Blubaugh:

In reference to your letter of September 28, 1998, concerning existing or planned public water systems in the referenced segment of Stennitt Creek prior to Spring River north of Black Rock, we have the following comments:

1. The Imboden water system has a well 3.3 miles north of Brushy Creek and US Hwy 63. There also is a well in the Black Rock system in that town.

2. There is not public water available throughout the area east of US Hwy 63 between Brushy Creek and Clear Creek to Spring River and west to near Annieville.

3. There are no public water systems downstream in the vicinity. But, area residents could be utilizing Stennitt Creek or the Spring River near Stennitt Creek as a private source of domestic water.

If you have any questions concerning this matter, please contact this office.

Sincerely,

Robert Hart

Robert Hart, P.E.
Chief Engineer
Division of Engineering

RH:CSC:LD:ld

cc: ADPC&E

Keeping Your Hometown Healthy

"An Equal Opportunity Employer"

Attachment B

Field Data Sheets

GBM^c & Associates
Strategic Environmental Services

PHYSICAL CHARACTERIZATION FIELD FORM

Location: around 100' downstream of the beaver dam

Date/Time: 7/15/98 1115 hrs	Stream: Stennett Creek
Observer(s): SRS RPM	Transect No: #1 upstream
Project No:	Picture No: SC1

Distance from ([✓ LB]/RB)	Width (ft)	Depth (ft)	Area (ft²)	Bank Habitat	Stream Habitat	Sub.	Canopy Cover (Y/N)
1. Edge 0.5	Edge (0)		0	U, R			yes
2. 1.5	1'	0.6'	0.9		L	M + org mat.	yes
3. 2.0	3'	0.9'	1.8		D	M + org mat	yes
4. 2.0	5'	1.0'	2.0		D	org, M	yes
5. 2.0	7'	0.6'	1.2		D	org, m	yes
6. 2.0	9'	0.6'	1.2		D	org, m	NO
7. 2.0	11'	0.7'	1.4		D	S, m, org	NO
8. 2.0	13'	0.8'	1.6		D	S, m, org	NO
9. 2.0	15'	0.9'	1.8		D	S, m, org	yes
10. 2.0	17'	1.0'	2.0		D	S, m, org	yes
11. 2.0	19'	1.0'	2.0		D	S, m, org	yes
12. 2.0	21'	1.0	2.0		D	S, m, org	yes
13. 2.0	23'	0.8	1.6		D	S, m, org	yes
14. Edge 1.0	25'	0.4	0.4	Devoid (eroded bank)	D	Mud	yes
15.	25.0'	$\bar{x}$ = 0.80	19.9'				
16.							
17.							
18.							
19.							
20.							
Calculations							

these measurements ≅ 60/40 ratio sand to mud

Bank Habitat R = Roots U = Undercut Bank V = Vegetation X = Devoid	**Stream Habitat** D = Depressions L = Logs, Debris V = Vegetation X = Devoid

org mat. = organic material (sticks, leaves)

Substrate

M = Mud <.04 mm	B = Boulders 25-45 cm
S = Sand .06-6 mm	R = Rubble 6-25 cm
G = Gravel 6-60 mm	L = Lithified

PHYSICAL CHARACTERIZATION FIELD FORM
Continued

Dissolved Oxygen, mg/l	Stream Width, ft 25.0'
Temperature, °C	Channel Width, ft ~35'-40'
Conductivity, uhmos	Pool Length, ft
pH, su	Riffle/Run Length, ft

Riparian Ground Cover			**Riparian Canopy Cover**		
Left	Right		Left	Right	
75%	75%	% Vegetated	15%	15%	% Canopy Cover
25%	25%	% Soil/Sand			
0	0	% Rock			
Bank Slope			**Bank Stability**		
Left	Right		Left	Right	
		Flat (<8°)			Stable
20%	10%	Mod (9-30°)	50%	50%	Moderately Stable
80%	90%	Steep (>30°)	50%	50%	Unstable
Bank Height (ft)			**Percent Embedded**		
Left	Right		____Sands	____Gravel	
6'	6-8'				(No cobbles)

COMMENTS:

Comments take in to account some of the general vicinity around the transect.

Transect area was typically more shallow than the many of the areas shocked. Lots of emmergent vegetation - large macrophyte beds in this general area also woody structure abundant.

GBMc & Associates
Strategic Environmental Services

PHYSICAL CHARACTERIZATION FIELD FORM

Date/Time: 7/15/98 1140
Stream: Stennett Creek upstream Site SC-1
Observer(s): [illegible]
Transect No: # 2
Project No:
Picture No:

Location is further upstream relative to transect #1.

Distance from ([✓ LB]/RB)	Width (ft)	Depth (ft)	Area (ft²)	Bank Habitat	Stream Habitat	Sub.	Canopy Cover (Y/N)
1. Edge 0.50	0		0	R, U, V			
2. 1.5	1′	0.2′	0.3		L, Stump	Org m	yes
3. 2.0	3′	0.3′	0.6		L,	M, S 50/50	
4. 2.0	5′	0.5′	1.0		L	m, S 50/50	
5. 2.0	7′	0.9′	1.8		L	m, S	
6. 2.0	9′	1.1′	2.2		L,	m, S, Gravel	
7. 2.0	11′	1.2′	2.4		L,	m, S Gravel	
8. 2.0	13′	1.7′	3.4		L,	m, S	
9. 2.0	15′	2.3′	4.6		L,	m, S, org	
10. 2.0	17′	3.0	6.0		L,	S, G	
11. 2.0	19′	3.2′	6.4		L,	S, G	
12. 2.0	21′	3.2′	6.4		L	S, G	
13. 2.0	23′	3.0	6.0		L	M, S	
14. 2.0	25′	2.0	4.0		L	m, S,	
15. Edge 1.0	27′	0.7	0.7	R U V		m, S	yes
16.	27.0	$\bar{X}$ = 1.7′	45.8				
17.							
18.							
19.							
20.							
Calculations							

Mud/sand in 50/50 mix w/ some organic

100% canopy

Bank Habitat
R = Roots
U = Undercut Bank
V = Vegetation
X = Devoid

Stream Habitat
D = Depressions
L = Logs, Debris
V = Vegetation
X = Devoid

Substrate
M = Mud <.04 mm
S = Sand .06-6 mm
G = Gravel 6-60 mm
B = Boulders 25-45 cm
R = Rubble 6-25 cm
L = Lithified

PHYSICAL CHARACTERIZATION FIELD FORM
Continued

Dissolved Oxygen, mg/l
Temperature, °C
Conductivity, uhmos
pH, su

Stream Width, ft 27.0'
Channel Width, ft ~ 40'
Pool ______ Length, ft ______
Riffle/Run ______ Length, ft ______

Riparian Ground Cover

Left	Right	
90	90	% Vegetated
100%	100%	% Soil/Sand
		% Rock

Riparian Canopy Cover

Left	Right	
20%	80%	% Canopy Cover

Bank Slope

Left	Right	
		Flat (<8°)
25%	10%	Mod (9-30°)
75%	90%	Steep (>30°)

Bank Stability

Left	Right	
		Stable
50%	50%	Moderately Stable
50%	50%	Unstable

Bank Height (ft)

Left	Right	
6'	10'	

Percent Embedded

____Sands		____Gravel
		Cobble

COMMENTS:

Nice gravel bar near transect.
Lots of woody structure - two areas too deep to wade
through with shoulder ≥ 4' deep. Lots of
beaver activity

V1.0 1096

GBM^c & Associates
Strategic Environmental Services

PHYSICAL CHARACTERIZATION FIELD FORM

Date/Time: 7/15/98 1205	Stream: Stennett Creek upstream
Observer(s): SRS RBM	Transect No: #3 ~ 150' u/s from #2
Project No:	Picture No:

Distance from ([✓ LB]/RB)	Width (ft)	Depth (ft)	Area (ft^2)	Bank Habitat	Stream Habitat	Sub.	Canopy Cover (Y/N)
1. Edge 0.5	0	0.2	0.1	Devoid	D	Sand	yes
2. 1.0	1.0	0.2	0.2	–	D	Sand	yes
3. 1.0	2.0	0.3	0.3			Sand	NO
4. 1.0	3	0.4	0.4			Sand	NO
5. 1.0	4	0.5	0.5			Sand	NO
6. 1.0	5	0.7	0.7			Sand	NO
7. 1.0	6	0.5	0.5				
8. 1.0	7'	0.5	0.5		↓		
9. Edge 0.5	8	0.2	0.1	V - Heavy		↓	↓ NO.
10.	8.0'	x̄=0.39	3.3				
11.							
12.							
13.							
14.							
15.							
16.							
17.							
18.							
19.							
20.							
Calculations							

in shallow sandy habitat.

Bank Habitat	**Stream Habitat**
R = Roots	D = Depressions
U = Undercut Bank	L = Logs, Debris
V = Vegetation	V = Vegetation
X = Devoid	X = Devoid

Substrate

M = Mud <.04 mm	B = Boulders 25-45 cm
S = Sand .06-6 mm	R = Rubble 6-25 cm
G = Gravel 6-60 mm	L = Lithified

V1.0 1096

PHYSICAL CHARACTERIZATION FIELD FORM
Continued

Dissolved Oxygen, mg/l	Stream Width, ft 8.0'
Temperature, °C	Channel Width, ft ~ 30'-40'
Conductivity, uhmos	Pool ____ Length, ft ____
pH, su	Riffle/Run ____ Length, ft ____

Riparian Ground Cover			**Riparian Canopy Cover**		
Left	Right		Left	Right	
100	100	% Vegetated	10%	0	% Canopy Cover
100	100	% Soil/Sand			
		% Rock			
Bank Slope			**Bank Stability**		
Left	Right		Left	Right	
15	15	Flat (<8°)	50	50	Stable
50	50	Mod (9-30°)	25	25	Moderately Stable
15	15	Steep (>30°)	25	25	Unstable
Bank Height (ft)			**Percent Embedded**		
Left	Right		____Sands		____Gravel
5'	3'				

COMMENTS:

Most of the minnows were collected in this area — several darters as well.

V1.0 1096

GBM^c & Associates
Strategic Environmental Service

15 July 1998
Stennitt Co. SC-1
REM

Habitat Assessment Field Data Sheet

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
1. Instream Cover	Greater than 50% mix of snags, submerged logs, undercut banks, or other stable habitat; rubble, gravel may be present.	30-50% mix of stable habitat; adequate habitat for maintenance of population.	10-30% mix of stable habitat; habitat availability less than desirable.	Less than 10% stable habitat; lack of habitat obvious.
SCORE 18	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
2. Epifaunal Substrate	Preferred benthic substrate (to be sampled) abundant throughout stream site and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	Substrate common but not prevalent or well suited for full colonization potential	Substrate frequently distrubed or removed.	Substrate unstable lacking.
SCORE 15	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1
3. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mid, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay to sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root or vegetation.
SCORE 15	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1
4. Pool Variability	Even mix of large-shallow, large-deep small-shallow, small deep pools present.	Majority of pools large deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or absent.
SCORE 16	20 19 18 17 [✓ 16]	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Alteration	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e dredging, (greater than past 20 yrs.) may be present, but recent channelization is not present.	New embankments present on both banks; channelization may be extensive, usually in urban areas or drainage areas of agriculture lands; and >80% of steam reach channelized and disrupted.	Extensive channelization; shored with gabion cement; heavily urbanized areas; in steam habitat greatly altered or removed entirely.
SCORE 15	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1
6. Sediment Disposition	Less than 20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars.	20-50% affected; moderate accumulation; substantial sediment movement only during major storm even; some new increase in bar formation.	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events.	Channelized; movement and/or sand in bank or nonbraided channels; pools absent due to deposition.
SCORE 11	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1

90

Habitat Parameter	CATEGORY			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than it if was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a distance.
SCORE 11	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1
8. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or < 25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1
9. Condition of Banks	Banks stable; no evidence of erosion or bank failure.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along stable sections and bend side slopes 60-100% has erosion scars.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1
10. Bank Vegetative Protection	More than 90% of the streambank surfaces covered by vegetation.	70-90% of the streambank surfaces covered by vegetation.	50-70% of the streambank surfaces covered by vegetation.	Less than 50% of streambank surfaces covered by vegetation.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1
11. Grazing or Other Disruptive Pressure	Vegetation disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Disruption of stream bank vegetation very high; vegetation has been removed; 2 inches or less average stubble height.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1
12. Riparian Vegetative Zone Width (Least Buffered Side)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clearcuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impactaed zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted a great deal.	Width of riparian zone <6 meters; little riparian vegetation to human activities.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1

TOTAL SCORE 161

$\bar{X}$ = 13.4 avg.

13.4
12)161
12
41
36
50

Barbour and Stribling: An evaluation of a visual-based technique for assessing stream habitat structure.

GBMc & Associates
Strategic Environmental Serv.

SC-1
u/s Stewart Cr
7/15/98
1221 RBM

Habitat Assessment Field Data Sheet

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
1 Instream Cover	Greater than 50% mix of snags, submerged logs, undercut banks, or other stable habitat; rubble, gravel may be present.	30-50% mix of stable habitat; adequate habitat for maintenance of population.	10-30% mix of stable habitat; habitat availability less than desirable.	Less than 10% stable habitat; lack of habitat obvious.
SCORE 18	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
2. Epifaunal Substrate	Preferred benthic substrate (to be sampled) abundant throughout stream site and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	Substrate common but not prevalent or well suited for full colonization potential	Substrate frequently distrubed or removed	Substrate unstable lacking.
SCORE 19	20 [✓ 19] 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
3. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mid, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay to sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root or vegetation.
SCORE 15	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1
4. Pool Variability	Even mix of large-shallow, large-deep small-shallow, small deep pools present.	Majority of pools large deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or absent.
SCORE 16	20 19 18 17 [✓ 16]	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Alteration	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e dredging, (greater than past 20 yrs.) may be present, but recent channelization is not present.	New embankments present on both banks; channelization may be extensive, usually in urban areas or drainage areas of agriculture lands; and >80% of steam reach channelized and disrupted.	Extensive channelization; shored with gabion cement; heavily urbanized areas; in steam habitat greatly altered or removed entirely.
SCORE 17	20 19 18 [✓ 17] 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
6. Sediment Disposition	Less than 20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars.	20-50% affected; moderate accumulation; substantial sediment movement only during major storm even; some new increase in bar formation.	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events.	Channelized; movement and/or sand in bank or nonbraided channels; pools absent due to deposition.
SCORE 15	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
7 Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than it if was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a distance.
SCORE 11	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1
8. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or < 25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 14	20 19 18 17 16	15 [✓ 14] 13 12 11	10 9 8 7 6	5 4 3 2 1
9. Condition of Banks	Banks stable; no evidence of erosion or bank failure.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along stable sections and bend side slopes 60-100% has erosion scars.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
10. Bank Vegetative Protection	More than 90% of the streambank surfaces covered by vegetation.	70-90% of the streambank surfaces covered by vegetation.	50-70% of the streambank surfaces covered by vegetation.	Less than 50% of streambank surfaces covered by vegetation.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
11 Grazing or Other Disruptive Pressure	Vegetation disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Disruption of stream bank vegetation very high; vegetation has been removed; 2 inches or less average stubble height.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
12. Riparian Vegetative Zone Width (Least Buffered Side)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clearcuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impactaed zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted a great deal.	Width of riparian zone <6 meters; little riparian vegetation to human activities.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2·1

TOTAL SCORE ~~137~~ 157

$\bar{X} = 13.1$

Barbour and Stribling: An evaluation of a visual-based technique for assessing stream habitat structure.

GBMc & Associates
Strategic Environmental Servic

Stennett Creek
Upstream Site
7/15/98 SRS

Habitat Assessment Field Data Sheet

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
1. Instream Cover	Greater than 50% mix of snags, submerged logs, undercut banks, or other stable habitat; rubble, gravel may be present.	30-50% mix of stable habitat; adequate habitat for maintenance of population.	10-30% mix of stable habitat; habitat availability less than desirable.	Less than 10% stable habitat; lack of habitat obvious.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1
2. Epifaunal Substrate	Preferred benthic substrate (to be sampled) abundant throughout stream site and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	Substrate common but not prevalent or well suited for full colonization potential	Substrate frequently distrubed or removed.	Substrate unstable lacking.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
3. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mid, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay to sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root or vegetation.
SCORE 11	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1
4. Pool Variability	Even mix of large-shallow, large-deep small-shallow, small deep pools present.	Majority of pools large deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or absent.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
5. Channel Alteration	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e dredging, (greater than past 20 yrs.) may be present, but recent channelization is not present.	New embankments present on both banks; channelization may be extensive, usually in urban areas or drainage areas of agriculture lands; and >80% of steam reach channelized and disrupted.	Extensive channelization; shored with gabion cement; heavily urbanized areas; in steam habitat greatly altered or removed entirely.
SCORE 14	20 19 18 17 16	15 [✓ 14] 13 12 11	10 9 8 7 6	5 4 3 2 1
6. Sediment Disposition	Less than 20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars.	20-50% affected; moderate accumulation; substantial sediment movement only during major storm even; some new increase in bar formation.	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events.	Channelized; movement and/or sand in bank or nonbraided channels; pools absent due to deposition.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1

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Habitat Parameter	CATEGORY			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than it if was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a distance.
SCORE 14	20 19 18 17 16	15 [✓ 14] 13 12 11	10 9 8 7 6	5 4 3 2 1
8. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or < 25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 14	20 19 18 17 16	15 [✓ 14] 13 12 11	10 9 8 7 6	5 4 3 2 1
9. Condition of Banks	Banks stable; no evidence of erosion or bank failure.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along stable sections and bend side slopes 60-100% has erosion scars.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1
10. Bank Vegetative Protection	More than 90% of the streambank surfaces covered by vegetation.	70-90% of the streambank surfaces covered by vegetation.	50-70% of the streambank surfaces covered by vegetation.	Less than 50% of streambank surfaces covered by vegetation.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
11. Grazing or Other Disruptive Pressure (cattle access etc)	Vegetation disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Disruption of stream bank vegetation very high; vegetation has been removed; 2 inches or less average stubble height.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
12. Riparian Vegetative Zone Width (Least Buffered Side)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clearcuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impactaed zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted a great deal.	Width of riparian zone <6 meters; little riparian vegetation to human activities.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1

TOTAL SCORE ~~135~~ 125

$\bar{X} \simeq 10.4$

11
12)135
12
1

Barbour and Stribling: An evaluation of a visual-based technique for assessing stream habitat structure.

GBMc & Associates
Strategic Environmental Services

PHYSICAL CHARACTERIZATION FIELD FORM

Down from Meridian

Date/Time: 7-15-98 1645	Stream: Stennett Creek at SC2
Observer(s): SRS RBM	Transect No: #1
Project No:	Picture No:

Distance from (LB/[✓ RB])	Width (ft)	Depth (ft)	Area (ft²)	Bank~~s~~ Habitat	Stream Habitat	Sub.	Canopy Cover (Y/N)
1. Edge 0'	1.0	0.3	0.3	R, V (both sparse)		MSG**	100%
2. 2'	2.0	0.3	0.6		X	MSG*	
3. 4'	2.0	0.8	1.6		X	MSG	
4. 6'	2.0	0.8	1.6		X	MSG	
5. 8'	2.0	1.0	2.0		X	MSG	
6. 10'	2.0	1.0	2.0		X	MSG	
7. 12	2.0	0.8	1.6		X	MSG	
8. 14	2.0	0.8	1.6		X	MSG	
9. Lw Edge 16	1.0	0.3	0.3	R	None	MSG	
10.	16.0	$\bar{x}$=0.68	11.6				
11.							
12.							
13.							
14.							
15.							
16.							
17.							
18.							
19.							
20.							
Calculations							

** lime sludge also - base layer is a fairly even mix of gravel & sand

Bank Habitat	**Stream Habitat**
R = Roots	D = Depressions
U = Undercut Bank	L = Logs, Debris
V = Vegetation	V = Vegetation
X = Devoid	X = Devoid

Substrate

M = Mud <.04 mm	B = Boulders 25-45 cm
S = Sand .06-6 mm	R = Rubble 6-25 cm
G = Gravel 6-60 mm	L = Lithified

* Bank habitat reflects available habitat at bank flow. At low flow their is no water edge habitat from this point downstream -

This location is 200-250 yds from the Spring R confluence

V1.0 1096

PHYSICAL CHARACTERIZATION FIELD FORM
Continued

Stennett Cr Downstream
SC2

Dissolved Oxygen, mg/l
Temperature, °C
Conductivity, uhmos
pH, su

Stream Width, ft 16.0'
Channel Width, ft ~35'
Pool ______ Length, ft ______
Riffle/Run ______ Length, ft ______

Riparian Ground Cover		
Left	Right	
80%	80%	% Vegetated
100	100	% Soil/Sand
		% Rock
Bank Slope		
Left	Right	
		Flat (<8°)
10	20	Mod (9-30°)
90	80	Steep (>30°)
Bank Height (ft)		
Left	Right	
35'	15'	

Riparian Canopy Cover		
Left	Right	
50+	50+	% Canopy Cover
Bank Stability		
Left	Right	
25	35	Stable
40	50	Moderately Stable
35	15	Unstable
Percent Embedded		
_____Sands 50% Gravel / embedded		
		w/ fine material

7-15-98

COMMENTS:

From this point downstream habitat is poor. Stream is a continuous flat run, typically 1-2' deep and somewhat deeper near the confluence. Very little woody structure no under cuts – Channel is only 25-50% full the bank edge is very poor habitat.

PHYSICAL CHARACTERIZATION FIELD FORM

Date/Time: 7-15-98 1715hrs	Stream: Stennett Creek
Observer(s): [illegible] RBM	Transect No: #2 - upstream 150 yds from #1
Project No:	Picture No:

ool habitat

Distance from (LB/[✓ RB])	Width (ft)	Depth (ft)	Area (ft²)	Bank Habitat	Stream Habitat	Sub.	Canopy Cover (Y/N)
1. Edge 0 1.0	0'	0.2'	0.2	sparce V (poor)		Sand	y
2. 2 2.0	2'	0.4	0.8		X	Mud Sand	y
3. 2.0	4'	0.5'	1.0		X	S, M 70/30	N
4. 2.0	6'	1.0'	2.0		X	gravel	N
5. 2.0	8'	1.8'	3.6		x	gravel	N
6. 2.0	10'	2.4'	4.8		X	g, cobble	N
7. 2.0	12'	2.7'	5.4		x	cobble	y
8. 2.0	14'	2.6'	5.2		X	cobble	y
9. 2.0	16'	2.5	5.0		X	gravel	y
10. 2.0	18'	2.1	4.2		x	gravel	y
11. 2.0	20'	1.5	3.0		X	mud	y
12. LEW 1.0	22'	0.3	0.3	RU	x	Mud	y
13.	22.0'	$\bar{x}$=1.5	35.5	poor and out of the water.			
14.							
15.							
16.							
17.							
18.							
19.							
20.							
Calculations							

→ This pool about 22 x 50' – poor habitat roots and undercuts out of the water

Bank Habitat
R = Roots
U = Undercut Bank
V = Vegetation
X = Devoid

Stream Habitat
D = Depressions
L = Logs, Debris
V = Vegetation
X = Devoid

Substrate
M = Mud <.04 mm
S = Sand .06-6 mm
G = Gravel 6-60 mm
B = Boulders 25-45 cm
R = Rubble 6-25 cm
L = Lithified

PHYSICAL CHARACTERIZATION FIELD FORM
Continued

Dissolved Oxygen, mg/l	Stream Width, ft 22.0'
Temperature, °C	Channel Width, ft ~35-40'
Conductivity, uhmos	Pool Length, ft
pH, su	Riffle/Run Length, ft

Riparian Ground Cover			**Riparian Canopy Cover**		
Left	Right		Left	Right	
80	90	% Vegetated	75	90	% Canopy Cover
100	100	% Soil/Sand			
—	—	% Rock			
Bank Slope			**Bank Stability**		
Left	Right		Left	Right	
15	25	Flat (<8°)	10	20	Stable
15	25	Mod (9-30°)	30	50	Moderately Stable
70	50	Steep (>30°)	60	30	Unstable
Bank Height (ft)			**Percent Embedded**		
Left 30 Right 60'			75% Sands 50% Gravel		

COMMENTS:

better substrate material ~~[illegible]~~ (parent material) downstream compared to upstream but much poorer overall habitat. continued sparce woody structure.

V1.0 1096

GBMc & Associates
Strategic Environmental Services

PHYSICAL CHARACTERIZATION FIELD FORM

Date/Time: 7-15-98 1730	Stream: Stennett Creek Dwn SC-2
Observer(s): SRS RBM	Transect No: #3 - ≅ 50 from furthest shocked at SC2
Project No:	Picture No: upstream view

Distance from (LB/RB)	Width (ft)	Depth (ft)	Area (ft²)	Bank Habitat	Stream Habitat	Sub.	Canopy Cover (Y/N)
1. Edge 0.5	0'	0.1	0.05	Veg		Cobble	N
2. 1.0	1'	0.2	0.2		Veg *	Cobble	N
3. 1.0	2'	0.2	0.2		Veg	Cobble	N
4. 1.0	3'	0.1	0.1		Veg	Cobble	N
5. 1.0	4'	0.1	0.1		Veg	Cobble	
6. Edge 0.5	5'	0	0	Veg			
7.	5.0'	x̄=0.17'	0.65	Veg			
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
16.							
17.							
18.							
19.							
20.							
Calculations							

(direct sun at mid day)

iffle Area

w flow riffle - veg would be flooded at higher flows

* Veg + higher velocity (1.5 to 2.0'/sec)

Bank Habitat
R = Roots
U = Undercut Bank
V = Vegetation
X = Devoid

Stream Habitat
D = Depressions
L = Logs, Debris
V = Vegetation
X = Devoid

Substrate
M = Mud <.04 mm
S = Sand .06-6 mm
G = Gravel 6-60 mm
B = Boulders 25-45 cm
R = Rubble 6-25 cm
L = Lithified

V1.0 1096

PHYSICAL CHARACTERIZATION FIELD FORM
Continued

Dissolved Oxygen, mg/l	Stream Width, ft 5.0′
Temperature, °C	Channel Width, ft ~ 50′
Conductivity, uhmos	Pool Length, ft
pH, su	Riffle/Run Length, ft

Riparian Ground Cover			**Riparian Canopy Cover**		
Left	Right		Left	Right	
100	100	% Vegetated	45	60	% Canopy Cover
100	100	% Soil/Sand			
		% Rock			
Bank Slope			**Bank Stability**		
Left	Right		Left	Right	
10	10	Flat (<8°)	75	50	Stable
40	75	Mod (9-30°)	10	25	Moderately Stable
50	15	Steep (>30°)	15	25	Unstable
Bank Height (ft)			**Percent Embedded**		
Left	Right		50 Sands	25 Gravel	25 cobble
40	20				

COMMENTS:

Typicall small riffle Better riffles downstream then upstream.

GBM^{c} & Associates
Strategic Environmental Servic

SRS 7-15-98
Sterritt Cr
SC-2

Habitat Assessment Field Data Sheet

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
1. Instream Cover	Greater than 50% mix of snags, submerged logs, undercut banks, or other stable habitat; rubble, gravel may be present.	30-50% mix of stable habitat; adequate habitat for maintenance of population.	10-30% mix of stable habitat; habitat availability less than desirable.	Less than 10% stable habitat; lack of habitat obvious.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1
2. Epifaunal Substrate	Preferred benthic substrate (to be sampled) abundant throughout stream site and at stage to allow full [✓ colonization] potential (i.e. cobble logs/snags that are <u>not</u> new fall and <u>not</u> transient).	Substrate common but not prevalent or well suited for full colonization potential	Substrate frequently distrubed or removed.	Substrate unstable lacking.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
3. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, [✓ mud] or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay to sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root or vegetation.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1
4. Pool Variability	Even mix of large-shallow, large-deep small-shallow, small deep pools present.	Majority of pools large deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or absent.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
5. Channel Alteration	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e dredging, (greater than past 20 yrs.) may be present, but recent channelization is not present.	New embankments present on both banks; channelization may be extensive, usually in urban areas or drainage areas of agriculture lands; and >80% of steam reach channelized and disrupted.	Extensive channelization; . shored with gabion cement; heavily urbanized areas; in steam habitat greatly altered or removed entirely.
SCORE 16	20 19 18 17 [✓ 16]	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
6. Sediment ~~Disposition~~ Deposition	Less than 20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars.	20-50% affected; moderate accumulation; substantial sediment movement only during major storm even; some new increase in bar formation.	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events.	Channelized; movement and/or sand in bank or nonbraided channels; pools absent due to deposition.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than it if was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a distance.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1
8. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or < 25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1
9. Condition of Banks	Banks stable; no evidence of erosion or bank failure.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along stable sections and bend side slopes 60-100% has erosion scars.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1
10. Bank Vegetative Protection	More than 90% of the streambank surfaces covered by vegetation.	70-90% of the streambank surfaces covered by vegetation.	50-70% of the streambank surfaces covered by vegetation.	Less than 50% of streambank surfaces covered by vegetation.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
11. Grazing or Other Disruptive Pressure	Vegetation disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Disruption of stream bank vegetation very high; vegetation has been removed; 2 inches or less average stubble height.
SCORE 16	20 19 18 17 [✓ 16]	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
12. Riparian Vegetative Zone Width (Least Buffered Side)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clearcuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impactaed zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted a great deal.	Width of riparian zone <6 meters; little riparian vegetation to human activities.
SCORE 16	20 19 18 17 [✓ 16]	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1

TOTAL SCORE ~~133~~ 123

$\bar{X} = 10.3$

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Barbour and Stribling: An evaluation of a visual-based technique for assessing stream habitat structure.

GBM^{c} & Associates
Strategic Environmental Service

SC-2
7-15-98
KBM
D/S Station

Habitat Assessment Field Data Sheet

Habitat Parameter	CATEGORY			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Instream Cover	Greater than 50% mix of snags, submerged logs, undercut banks, or other stable habitat; rubble, gravel may be present.	30-50% mix of stable habitat; adequate habitat for maintenance of population.	10-30% mix of stable habitat; habitat availability less than desirable.	Less than 10% stable habitat; lack of habitat obvious.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
2. Epifaunal Substrate	Preferred benthic substrate (to be sampled) abundant throughout stream site and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	Substrate common but not prevalent or well suited for full colonization potential	Substrate frequently distrubed or removed.	Substrate unstable lacking.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
3. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mid, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay to sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root or vegetation.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
4. Pool Variability	Even mix of large-shallow, large-deep small-shallow, small deep pools present.	Majority of pools large deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or absent.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1
5. Channel Alteration	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e dredging, (greater than past 20 yrs.) may be present, but recent channelization is not present.	New embankments present on both banks; channelization may be extensive, usually in urban areas or drainage areas of agriculture lands; and >80% of steam reach channelized and disrupted.	Extensive channelization; shored with gabion cement; heavily urbanized areas; in steam habitat greatly altered or removed entirely.
SCORE 18	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1
6. Sediment Disposition	Less than 20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars.	20-50% affected; moderate accumulation; substantial sediment movement only during major storm even; some new increase in bar formation.	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events.	Channelized; movement and/or sand in bank or nonbraided channels; pools absent due to deposition.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1

63

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than it if was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a distance.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
8. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or < 25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 12	20 19 18 17 16	15 14 13 [✓ 12] 11	10 9 8 7 6	5 4 3 2 1
9. Condition of Banks	Banks stable; no evidence of erosion or bank failure.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along stable sections and bend side slopes 60-100% has erosion scars.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
10. Bank Vegetative Protection	More than 90% of the streambank surfaces covered by vegetation.	70-90% of the streambank surfaces covered by vegetation.	50-70% of the streambank surfaces covered by vegetation.	Less than 50% of streambank surfaces covered by vegetation.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1
11. Grazing or Other Disruptive Pressure	Vegetation disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Disruption of stream bank vegetation very high; vegetation has been removed; 2 inches or less average stubble height.
SCORE 13	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1
12. Riparian Vegetative Zone Width (Least Buffered Side)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clearcuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impactaed zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted a great deal.	Width of riparian zone <6 meters; little riparian vegetation to human activities.
SCORE 12	20 19 18 17 16	15 14 13 [✓ 12] 11	10 9 8 7 6	5 4 3 2 1

TOTAL SCORE 126

$\bar{X} = 10.5$

63
63
126

GBM & Associates
Strategic Environmental Servi

15 July 1778
SC-2 d/s meridian
REW

Habitat Assessment Field Data Sheet

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
1. Instream Cover	Greater than 50% mix of snags, submerged logs, undercut banks, or other stable habitat; rubble, gravel may be present.	30-50% mix of stable habitat; adequate habitat for maintenance of population.	10-30% mix of stable habitat; habitat availability less than desirable.	Less than 10% stable habitat; lack of habitat obvious.
SCORE 5	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	[✓ 5] 4 3 2 1
2. Epifaunal Substrate	Preferred benthic substrate (to be sampled) abundant throughout stream site and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	Substrate common but not prevalent or well suited for full colonization potential	Substrate frequently distrubed or removed.	Substrate unstable lacking.
SCORE 11	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1
3. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mid, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay to sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root or vegetation.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
4. Pool Variability	Even mix of large-shallow, large-deep small-shallow, small deep pools present.	Majority of pools large deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or absent.
SCORE 6	20 19 18 17 16	15 14 13 12 11	REW 10 9 [✓ 8] 7 ~~6~~	5 4 3 2 1
5. Channel Alteration	No channelization or dredging present.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e dredging, (greater than past 20 yrs.) may be present, but recent channelization is not present.	New embankments present on both banks; channelization may be extensive, usually in urban areas or drainage areas of agriculture lands; and >80% of steam reach channelized and disrupted.	Extensive channelization; shored with gabion cement; heavily urbanized areas; in steam habitat greatly altered or removed entirely.
SCORE 15	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1
6. Sediment Disposition	Less than 20% of bottom affected; minor accumulation of fine and coarse material at snags and submerged vegetation; little or no enlargement of islands or point bars.	20-50% affected; moderate accumulation; substantial sediment movement only during major storm even; some new increase in bar formation.	50-80% affected; major deposition; pools shallow, heavily silted; embankments may be present on both banks; frequent and substantial sediment movement during storm events.	Channelized; movement and/or sand in bank or nonbraided channels; pools absent due to deposition.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1

49

Habitat Parameter	CATEGORY			
	Optimal	Suboptimal	Marginal	Poor
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than it if was in a straight line.	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 2 to 1 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a distance.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
8. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or < 25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 [✓ 6]	5 4 3 2 1
9. Condition of Banks	Banks stable; no evidence of erosion or bank failure.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach areas of erosion.	Unstable; many eroded areas; "raw" areas frequent along stable sections and bend side slopes 60-100% has erosion scars.
SCORE 11	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1
10. Bank Vegetative Protection	More than 90% of the streambank surfaces covered by vegetation.	70-90% of the streambank surfaces covered by vegetation.	50-70% of the streambank surfaces covered by vegetation.	Less than 50% of streambank surfaces covered by vegetation.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1
11. Grazing or Other Disruptive Pressure	Vegetation disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption minimal or not evident; almost all plants allowed to grow naturally.	Disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Disruption of stream bank vegetation very high; vegetation has been removed; 2 inches or less average stubble height.
SCORE 11	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1
12. Riparian Vegetative Zone Width (Least Buffered Side)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clearcuts, lawns or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impactaed zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted a great deal.	Width of riparian zone <6 meters; little riparian vegetation to human activities.
SCORE 10	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1

TOTAL SCORE 101

Avg 8.4

8.4.
12)101
96
50
48

2
49
101

Barbour and Stribling: An evaluation of a visual-based technique for assessing stream habitat structure.

APPENDIX C

Additional Information on Toxicity Testing of VCM Outfall 001

Laboratory Testing of Spiked Effluent Samples

This appendix has been prepared to provide information to augment the evaluation of effluent toxicity potential in the main text of the report titled “Use Attainability Analysis Report: Brushy Creek, Lawrence County, Arkansas,” herein referred to as the UAA Report. Permit compliance based on existing Outfall 001 discharge concentrations of sulfate (SO_4^{-2}) and total dissolved solids (TDS) will require site-specific criteria. Accordingly, toxicity evaluations were designed and conducted to assess toxic thresholds relative to existing discharge concentrations.

The experimental approach was to manipulate effluent sample concentrations of Ca^{+2}, Mg^{+2}, Na^{+}, K^{+}, Cl^{-}, SO_4^{-2} and HCO_3^{-} ions by adding inorganic salts to effluent sample. These ions (primarily Ca^{+2}, Mg^{+2}, SO_4^{-2} and HCO_3^{-}) account for virtually 100% of the TDS in effluent samples collected during the study (Table C.1). The resulting spiked effluent solutions were then tested for lethal and sub-lethal effects to *Ceriodaphnia dubia* in toxicity tests based on EPA Method 1000.2 (EPA 2002). This evaluation focused on *C. dubia* which is known to be more sensitive to TDS-related toxicity than other standard freshwater test organisms such as *Pimephales promelas* and *Daphnia pulex* (Goodfellow et al. 2000; Mount et al. 1997). A previous chronic screening test on sample collected on February 24, 2009, showed no lethal or sublethal toxicity to *C. dubia*, indicating that existing ion concentrations were not toxic.

Spiked Effluent Toxicity Evaluation: Series 1

The spiked effluent tests were conducted on an Outfall 001 grab sample collected on March 16, 2010. Upon arrival to the laboratory, the sample was analyzed per methods listed in Table C.2. Based on these initial analytical results, inorganic salts [$CaSO_4(2H_2O)$, $MgSO_4$, $MgCl(6H_2O)$, KCl, $NaHCO_3$ and NaCl] were added to the effluent in quantities calculated to produce a solution eight times more concentrated than the unspiked sample in all ions except HCO_3^{-}. The 8x-concentrated effluent solution was then diluted with laboratory deionized water by factors of 0.5, 0.375 and 0.25 to produce solutions corresponding to 8x, 4x, 3x, 2x and 1x (unspiked effluent) concentrations of the ions in the unspiked effluent. These solutions were then used as test exposures in a 3-brood *C. dubia* toxicity test. The test included a laboratory control. Since some precipitation of salts was noted in the 8x solution, two sets of exposures were prepared. The first set was used for test setup and two subsequent renewals and the second was used for the final three test renewals. Each test exposure was analyzed for Ca^{+2}, Mg^{+2}, Na^+, K^+, Cl^-, and SO_4^{-2}.

Table C.1. Summary of ionic makeup of Outfall 001 samples.

Parameter	Concentration (mg/L)					Proportion of Measured TDS				
	Min (mg/L)	Mean (mg/L)	Max (mg/L)	SD[a]	N	Min	Mean	Max	SD	N
Total Alkalinity	150	199	240	27.67	10	NA[b]	NA	NA	NA	NA
HCO_3^- [c]	90.4	119.44	146	16.95	10	0.20	0.28	0.37	0.0550	10
TDS	327	482	618	86.46	23	NA	NA	NA	NA	NA
TDS [d]	327	542	802	103.45	96	NA	NA	NA	NA	NA
Ca^{+2}	62	73.3	85	8.001	10	0.14	0.17	0.19	0.0156	10
Mg^{+2}	40	47.3	54	5.100	10	0.10	0.11	0.13	0.0112	10
K^+	1.7	2.75	4.6	0.8223	10	0.00	0.01	0.01	0.0014	10
Na^+	2.8	3.87	5.9	0.8367	10	0.01	0.01	0.01	0.0014	10
Cl^-	5.4	8.58	13	2.215	10	0.01	0.02	0.03	0.0046	10
SO_4^{-2}	72.4	135	200	30.61	22	0.28	0.34	0.40	0.0360	22
SO_4^{-2}/Cl^-	14.0	18.1	24.1	3.1648	10	NA	NA	NA	NA	NA
Hardness	320	378	432	39.95	10	NA	NA	NA	NA	NA
TDS as measured ions	360	405	476	38.60	10	0.87	0.93	1.08	0.0783	10
TDS as SO_4^{-2}, HCO_3^-, Ca^{+2}, Mg^{+2}	344	390	456	36.35	10	0.83	0.90	1.04	0.0761	10

Notes: Discharge data based on routine DMR sampling for TDS, additional sampling for SO_4^{-2}, and field surveys conducted between February 29, 2009, and March 21, 2011.

(a) Standard deviation.

(b) Not applicable.

(c) HCO_3^- values calculated per SM 4500-CO2 D (APHA 1998).

(d) From DMR monitoring January 29, 2003, through June 22, 2011.

Table C.2. Analytes and analytical methods for spiked effluent testing.

Analyte	Method (or equivalent)
Cl^-	EPA 300.0
SO_4^{-2}	EPA 300.0
Ca^{+2}	EPA 200.7
Mg^{+2}	EPA 200.7
Na^+	EPA 200.7
K^+	EPA 200.7
Total Alkalinity	SM 2320B
Hardness	EPA 200.7
TDS	SM 2540C
pH	Electrode
Specific Conductance	Electrode

Measured ion concentrations and toxicity test results (Table C.3) show close agreement between target and measured values. Unspiked effluent was sub-lethally toxic to *C. dubia* with reproduction (mean number of young per female) monotonically decreasing with increasing ionic strength of the test exposure. This result suggests that the sub-lethal toxicity observed in the unspiked effluent might be due to its ionic strength. Additional chronic screening tests on several samples (Table C.4) indicated consistent sub-lethal toxicity to *C. dubia* among samples showing similar ionic makeup. The observed toxicity in the spiked effluent test seemed inconsistent with published information on ion toxicity (Davies and Hall 2007; Elphick et al. 2011; Lasier and Hardin 2010; Mount et al. 1997; Soucek and Kennedy 2007; Soucek 2007, Soucek et al. 2011, van Dam et al. 2010) that suggested ion toxicity not should occur at the concentrations measured in Outfall 001 sample. The following discussion addresses laboratory testing and literature information to evaluate sublethal toxicity observed in effluent testing.

Table C.3. Results of toxicity tests and analytical measurements on spiked effluent sample collected on March 16, 2010.

			First Exposure Prep						**Second Exposure Prep**					
Exposure	**%S**	**Rep**	**Cl^-**	**SO_4^{-2}**	**K^+**	**Ca^{+2}**	**Mg^{+2}**	**Na^+**	**Cl^-**	**SO_4^{-2}**	**K^+**	**Ca^{+2}**	**Mg^{+2}**	**Na^+**
Control	100	16.2	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
1x	100	11.6 *	5.8	130	2.5	84	54	4.3	5.8	130	2.6	79	50	4.1
2x	90	5.0*	10	290	5.2	120	89	10	6.5	240	4.6	120	55	36
3x	90	2.0*	16	440	6.3	190	120	12	8.9	400	7.0	220	100	42
4x	100	0.7*	20	640	9	270	150	14	17	620	6.5	330	150	46
8x	0*	-	42	1300	14	570	290	26	42	1300	19	840	350	66

%S = percent survival (n=10); Rep = average number of young produced; * = Statistically less than the control ($P < 0.05$)

Expected Ion Toxicity Based on Published Literature

Mount et al. (1997) showed that the toxicity of ionic mixtures depends on the specific types of ions present. For example, solutions with higher concentrations of K^+ and/or HCO_3^- were shown to be more toxic than solutions of similar ionic strength (TDS) dominated by Ca^{+2} or SO_4^{-2}. The VCM Outfall 001 samples have very little K^+ but up to 146 mg/L (37% of TDS by weight; Table C.1) of HCO_3^-. Mount et al. reported a 48-hour LC50 for $NaHCO_3$ with *C. dubia* of 1,020 mg/L (from Table 2 in Mount et al. 1997, reproduced in its entirety on Figure C.1), which is equivalent to 742 mg/L as HCO_3^-. Therefore, toxicity due to HCO_3^- in the samples described in Table C.3 would imply an acute to chronic ratio (ACR) for HCO_3^- ranging from 5.1 (742 mg/L ÷ 146 mg/L = 5.1) to 7.7 (742 mg/L ÷ 96.1 mg/L = 7.7). These ACR values are substantially higher than the ACR of 2.7 for HCO_3^- in moderately hard water (where hardness is approximately 100 mg/L) reported by Lasier and Hardin (2010). Similarly, SO_4^{-2} accounts for up to 40% of the measured TDS by weight. Mount et al. (1997) reported a 48-hour LC50 for $CaSO_4$ + $MgSO_4$ with *C. dubia* of greater than 5,610 mg/L (Figure C.1), which is equivalent to 4,206 mg/L as SO_4^{-2}. Therefore, toxicity that is due to SO_4^{-2} in these samples would imply ACRs for SO_4^{-2} ranging from 21 (4,206 mg/L ÷ 200 mg/L = 21) to 32 (4,206 mg/L ÷ 130 mg/L = 32), which are an order of magnitude higher than the ACR of 2.3 for SO_4^{-2} in moderately hard water (where hardness is approximately 100 mg/L) reported by Lasier and Hardin (2010).

Table C.4. Toxicity test and analytical results from chronic screening tests on Outfall 001 using *C. dubia.*

	Sampling Date								
		03/17/10			**08/18/10**				
Parameter	**02/24/09**	**Original Test**	**Retest**	**05/18/10**	**Original Test**	**Retest**	**09/28/10**	**11/15/10**	**03/16/11**
Total Alkalinity	170	160	200	170	220	NM	210	240	130
HCO_3^-	102	96.1	120	102	133	NM	127	146	NM
TDS	500	400	440	400	470	NM	530	410	NM
Ca^{+2}	71	84	76	62	85	NM	85	78	NM
Mg^{+2}	48	54	48	40	53	NM	54	54	NM
K^+	2.5	2.5	1.7	2.7	3.3	NM	4.6	2.9	NM
Na^+	4	4.3	3..2	4	4	NM	5.9	4.2	NM
Cl^-	13	5.8	5.4	10	7.5	NM	10	10	NM
SO_4^{-2}	200	130	130	140	150	NM	190	142	NM
Conductivity	760	640	640	600	690	560	848	720	560
Hardness	375	432	387	320	430	390	432	417	390
pH	8.1	8.2	8.2	7.9	7.8	8.1	8.0	7.7	8.1
Control % Survival	100	100	100	100	100	90	100	90	90
Effluent % Survival	100	100	70	100	100	100	100	100	100
Control % Reproduction	27.9	16.2	20.1	15.6	19.7	19.2	18.4	19.9	17.6
Effluent % Reproduction	27.1	11.9*	7.4*	11.5*	15.6*	8.4*	14.4*	16.2*	13.7 *

*Statistically less than the control ($P < 0.05$)

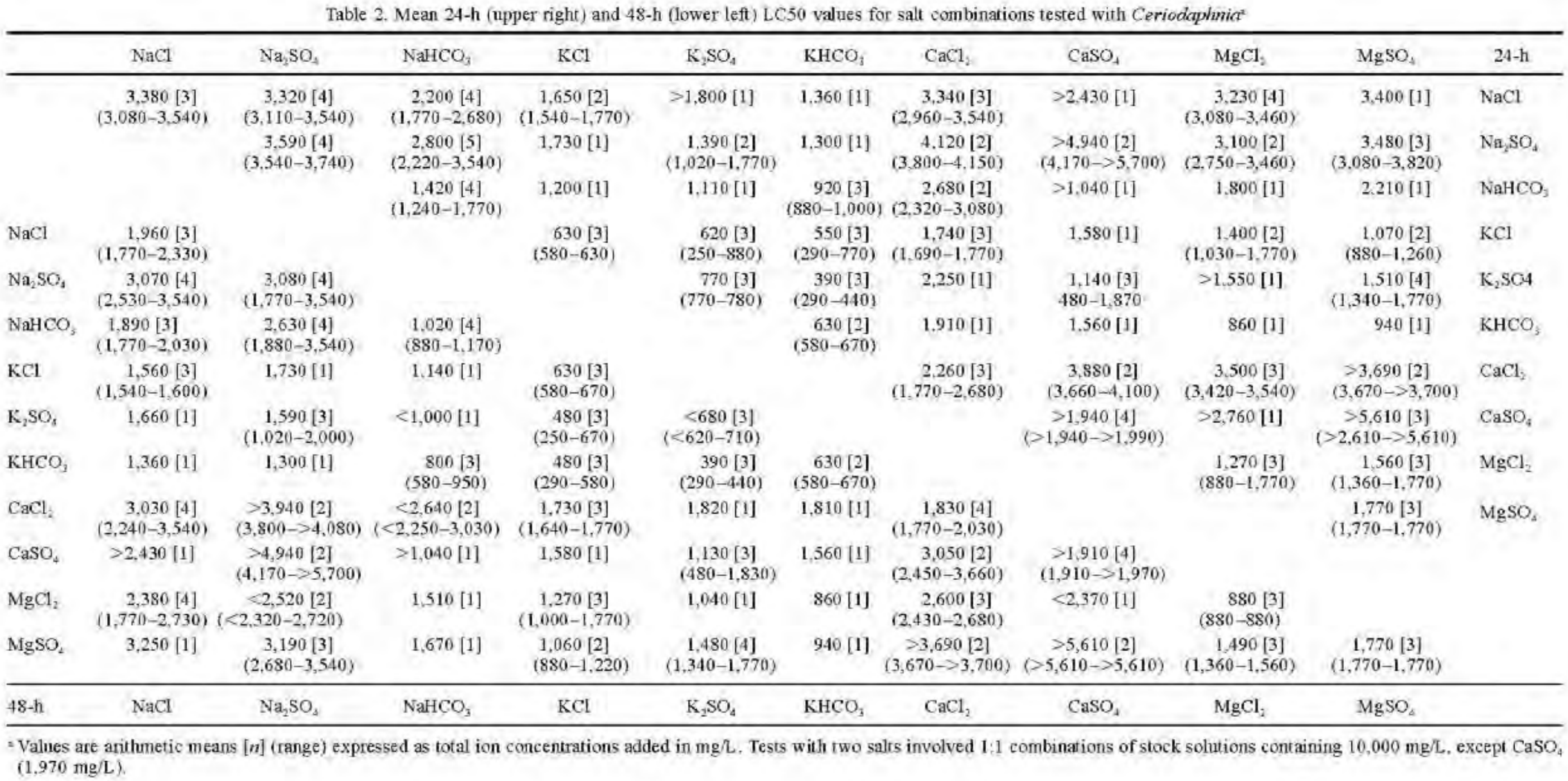


Table 2. Mean 24-h (upper right) and 48-h (lower left) LC50 values for salt combinations tested with *Ceriodaphnia*[a]

	NaCl	Na_2SO_4	$NaHCO_3$	KCl	K_2SO_4	$KHCO_3$	$CaCl_2$	$CaSO_4$	$MgCl_2$	$MgSO_4$	24-h
	3,380 [3] (3,080–3,540)	3,320 [4] (3,110–3,540)	2,200 [4] (1,770–2,680)	1,650 [2] (1,540–1,770)	>1,800 [1]	1,360 [1]	3,340 [3] (2,960–3,540)	>2,430 [1]	3,230 [4] (3,080–3,460)	3,400 [1]	NaCl
		3,590 [4] (3,540–3,740)	2,800 [5] (2,220–3,540)	1,730 [1]	1,390 [2] (1,020–1,770)	1,300 [1]	4,120 [2] (3,800–4,150)	>4,940 [2] (4,170–>5,700)	3,100 [2] (2,750–3,460)	3,480 [3] (3,080–3,820)	Na_2SO_4
			1,420 [4] (1,240–1,770)	1,200 [1]	1,110 [1]	920 [3] (880–1,000)	2,680 [2] (2,320–3,080)	>1,040 [1]	1,800 [1]	2,210 [1]	$NaHCO_3$
NaCl	1,960 [3] (1,770–2,330)			630 [3] (580–630)	620 [3] (250–880)	550 [3] (290–770)	1,740 [3] (1,690–1,770)	1,580 [1]	1,400 [2] (1,030–1,770)	1,070 [2] (880–1,260)	KCl
Na_2SO_4	3,070 [4] (2,530–3,540)	3,080 [4] (1,770–3,540)			770 [3] (770–780)	390 [3] (290–440)	2,250 [1]	1,140 [3] 480–1,870	>1,550 [1]	1,510 [4] (1,340–1,770)	K_2SO4
$NaHCO_3$	1,890 [3] (1,770–2,030)	2,630 [4] (1,880–3,540)	1,020 [4] (880–1,170)			630 [2] (580–670)	1,910 [1]	1,560 [1]	860 [1]	940 [1]	$KHCO_3$
KCl	1,560 [3] (1,540–1,600)	1,730 [1]	1,140 [1]	630 [3] (580–670)			2,260 [3] (1,770–2,680)	3,880 [2] (3,660–4,100)	3,500 [3] (3,420–3,540)	>3,690 [2] (3,670–>3,700)	$CaCl_2$
K_2SO_4	1,660 [1]	1,590 [3] (1,020–2,000)	<1,000 [1]	480 [3] (250–670)	<680 [3] (<620–710)			>1,940 [4] (>1,940–>1,990)	>2,760 [1]	>5,610 [3] (>2,610–>5,610)	$CaSO_4$
$KHCO_3$	1,360 [1]	1,300 [1]	800 [3] (580–950)	480 [3] (290–580)	390 [3] (290–440)	630 [2] (580–670)			1,270 [3] (880–1,770)	1,560 [3] (1,360–1,770)	$MgCl_2$
$CaCl_2$	3,030 [4] (2,240–3,540)	>3,940 [2] (3,800–>4,080)	<2,640 [2] (<2,250–3,030)	1,730 [3] (1,640–1,770)	1,820 [1]	1,810 [1]	1,830 [4] (1,770–2,030)			1,770 [3] (1,770–1,770)	$MgSO_4$
$CaSO_4$	>2,430 [1]	>4,940 [2] (4,170–>5,700)	>1,040 [1]	1,580 [1]	1,130 [3] (480–1,830)	1,560 [1]	3,050 [2] (2,450–3,660)	>1,910 [4] (1,910–>1,970)			
$MgCl_2$	2,380 [4] (1,770–2,730)	<2,520 [2] (<2,320–2,720)	1,510 [1]	1,270 [3] (1,000–1,770)	1,040 [1]	860 [1]	2,600 [3] (2,430–2,680)	<2,370 [1]	880 [3] (880–880)		
$MgSO_4$	3,250 [1]	3,190 [3] (2,680–3,540)	1,670 [1]	1,060 [2] (880–1,220)	1,480 [4] (1,340–1,770)	940 [1]	>3,690 [2] (3,670–>3,700)	>5,610 [2] (>5,610–>5,610)	1,490 [3] (1,360–1,560)	1,770 [3] (1,770–1,770)	
48-h	NaCl	Na_2SO_4	$NaHCO_3$	KCl	K_2SO_4	$KHCO_3$	$CaCl_2$	$CaSO_4$	$MgCl_2$	$MgSO_4$	

[a] Values are arithmetic means [*n*] (range) expressed as total ion concentrations added in mg/L. Tests with two salts involved 1:1 combinations of stock solutions containing 10,000 mg/L, except $CaSO_4$ (1,970 mg/L).

Figure C.1. Table 2 of Mount et al. 1997.

Lasier and Hardin (2010) developed predictive models to estimate chronic toxicity to *C. dubia* in waters dominated by Cl^-, SO_4^{-2} and HCO_3^-. Although they developed their models with hardness ranges lower than those found in this UAA study (40 to 80 mg/L versus 300 to 400 mg/L), the model predictions can be used to assess expected levels of toxicity by assuming that HCO_3^- toxicity is either independent of, or negatively correlated with, hardness. Lasier and Hardin's finding that HCO_3^- toxicity was not affected by hardness over the range of 40 to 80 mg/L and the findings of others (Davies and Hall 2007; Soucek and Kennedy 2007; Soucek 2007; Soucek et al. 2011; van Dam et al. 2010) that the toxicity of other ions (e.g., SO_4^{-2} and Cl^-) show negative correlations with hardness support this assumption. The linear multiple regression model developed by Lasier and Hardin (2010) was used to predict chronic toxicity to *C. dubia* under the following seven scenarios based on mean and maximum Cl^-, SO_4^{-2}, and HCO_3^- concentrations from Table C.1:

1. Mean ion concentration,
2. Maximum ion concentration,
3. Maximum ion concentration + SO_4^{-2} at criterion,
4. Maximum ion concentration + 1.5x maximum [SO_4^{-2}],
5. Maximum ion concentration + 2x maximum [SO_4^{-2}],
6. Maximum ion concentration + 3x maximum [SO_4^{-2}], and
7. Maximum ion concentration x 2.

The model does not predict significant toxicity in the ion mixture until SO_4^{-2} concentrations reach 1.5 times the maximum observed SO_4^{-2} concentration (Table C.5).

Lasier and Hardin (2010) also reported toxicity relationships in terms of TDS. Figure C.2, taken directly from Lasier and Hardin (2010), provides plots of *C. dubia* reproduction (% of test controls) against TDS of anion mixtures. Although the authors fitted a straight line to the scatter plot, the data (developed in test waters with hardness = 80 mg/L) appear to show a distinct threshold response between 1,000 and 1,500 mg/L. This threshold is approximately two times higher than the highest TDS concentrations from effluent monitoring (802 mg/L; Table C.1).

Table C.5. Predicted chronic toxicity (number of neonates produced as percent of control) of Outfall 001 concentrations of Cl^-, SO_4^{-2}, and HCO_3^- based on a linear multiple regression model developed by Lasier and Hardin (2010).

Model Parameters		**Model Scenario Input**						
Variable	**Coefficient**	**Mean [Ion]**	**Max [Ion]**	**Max [Ion]**				
Intercept	**111.516**			**+ SO_4^{-2} at Criterion**	**+ 1.5x Max [SO_4^{-2}]**	**+2x Max [SO_4^{-2}]**	**+3x Max [SO_4^{-2}]**	**x2**
SO_4^{-2}	-0.079	135	200	185	300	400	600	400
Cl^-	-0.049	8.6	13	13	13	13	13	26
HCO_3^-	-0.105	119	146	146	146	146	146	292
SO_4^{-2}/Cl^-	0.11	18	24	14	36	48	72	48
Predicted Reproduction as Percent of Control		90	82	82	76	69	56	53
Standard Error	2.8763							
$t_{(192, 0.05)}$	1.96							
95% CI	11							

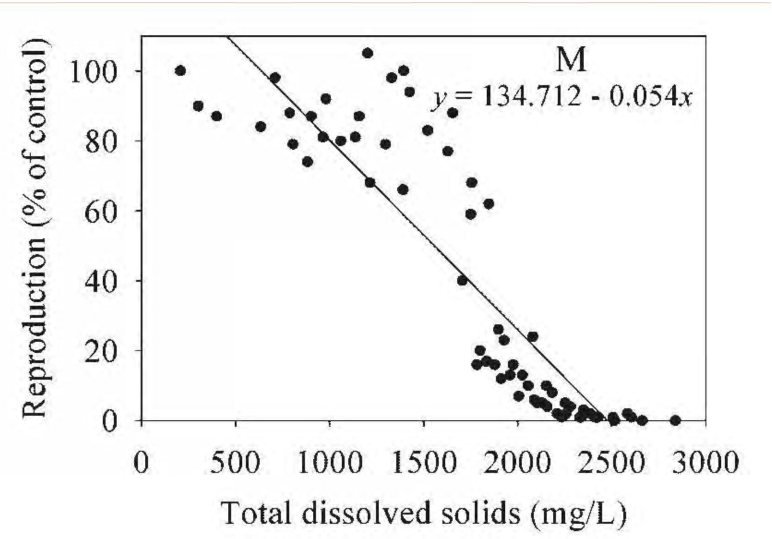


Figure C.2. Figure 2 (in part) from Lasier and Hardin, 2010.

Potential chronic toxicity of SO_4^{-2} concentrations in effluent can be evaluated based on data sets developed by Elphick et al. (2011) who developed hardness-based toxicity relationships for Na_2SO_4. Included in their data set are IC25 SO_4^{-2} concentrations for *C. dubia* of 246 mg/L, 855 mg/L, 1,212 mg/L, and 512 mg/L at hardness concentrations of 40 mg/L, 80 mg/L, 160 mg/L, and 320 mg/L (as $CaCO_3$), respectively. The IC25 value of 512 mg/L SO_4^{-2} for hardness equal to 320 mg/L indicates that SO_4^{-2} concentrations up to 200 mg/L at Outfall 001 are well below toxic thresholds for *C. dubia*. However, these data also indicate a possible non-linear response of SO_4^{-2} toxicity to hardness at higher hardness levels such as those found in the VCM discharge. This possibility will be addressed in following sections of this appendix. Elphick et al. (2011) also used their data set to develop hardness-dependent toxicity thresholds based on the species sensitivity distribution similar to the approach of Stephan et al. (1985). The authors proposed thresholds of 129 mg/L SO_4^{-2} for soft water (hardness = 10 to 40 mg/L); 644 mg/L SO_4^{-2} for moderately hard water (hardness = 80 to 100 mg/L); and 725 mg/L SO_4^{-2} for hard water (hardness = 160 to 250 mg/L). Measured SO_4^{-2} concentrations in the VCM effluent were well below these threshold values for hard and moderately hard waters.

Summary and Conclusions Based on Published Literature

The analysis presented above indicates that results of chronic screening and the Series 1 effluent spiking tests are inconsistent with toxicity caused by SO_4^{-2}, HCO_3^-, ionic strength, or ion composition for the following reasons:

1. SO_4^{-2} and HCO_3^- together account for approximately 75% of the ionic makeup of Outfall 001. Sub-lethal toxicity due to these ions would imply ACRs of up to 7.7 and 32 for HCO_3^- and SO_4^{-2}, respectively, compared to literature values of 2.7 and 2.3, respectively. Although synergistic processes can, in principle, result in large ACRs, studies that have evaluated ion mixtures (Lasier and Hardin 2010; Mount et al. 1997; Soucek et al. 2011; Soucek and Kennedy 2005; van Dam et al. 2010) have reported that ion toxicity is generally additive and that interactions (except for the ameliorating effects of calcium) are typically weak or absent.
2. Empirical models (Lasier and Hardin 2010) do not predict toxicity at the highest observed ion concentrations for Outfall 001.
3. Toxicity of SO_4^{-2} and HCO_3^- mixtures expressed as TDS indicate a toxic threshold between 1,000 and 1,500 mg/L (Lasier and Hardin 2010), which is approximately two times the highest effluent TDS concentration.
4. Toxic thresholds for SO_4^{-2} using criteria development methodology (Elphick et al. 2011) indicate thresholds two to three times above the highest effluent SO_4^{-2} concentrations.

Inter-Laboratory Comparison of Effluent Toxicity

As part of the evaluation of sub-lethal toxicity observed at Outfall 001, an inter-laboratory comparison was conducted by splitting samples between the laboratory typically used for toxicity testing, American Interplex Corporation Laboratories[1] (AIC) and Huther and Associates, Inc.[2] (HAI). Results of the split sample testing (Table C.6) indicate that tests conducted by HAI were consistently non-toxic in contrast to the consistent toxicity observed in the AIC tests. These results were the determining factor in the decision to not employ chronic toxicity identification evaluation (TIE) procedures (EPA 1991) to evaluate causes of toxicity because they indicated that the sub-lethal toxicity at Outfall 001 is not a repeatable property of the effluent. Accordingly, a second series of spiked effluent tests were designed and conducted as described below.

Table C.6. Results of inter-laboratory comparison: Outfall 001 chronic screening tests using *C. dubia*.

Sample Collection Date	Laboratory	Test Parameter			
		% Survival (n=10)		Average Number of Young	
		Control	Effluent	Control	Effluent
February 24, 2009	AIC	100	100	27.9	27.1
March 17, 2010	AIC	100	100	16.2	11.9 *
	AIC (Retest)	100	70	20.1	7.4 *
May 18, 2010	AIC	100	100	15.6	11.5 *
	HAI	100	100	25.4	24.8
August 18, 2010	AIC	100	100	19.7	15.6 *
	AIC (Retest)	100	90	19.2	8.4 *
September 28, 2010	AIC	100	100	18.4	14.4 *
November 15, 2010	AIC	100	90	19.9	16.2 *
	HAI	100	100	22.7	24.5
March 16, 2011	AIC	100	90	17.6	13.7 *
	HAI	100	100	24.4	27.7

*Statistically less than the control ($P < 0.05$).

---

[1] 8600 Kanis Road, Little Rock, AR 72204
[2] 1156 North Bonnie Brae, Denton, TX 76201

Spiked Effluent Toxicity Evaluation: Series 2

A second series of spiked effluent tests was designed to evaluate the possibility that (1) toxicity was due to an unknown toxicant in the effluent, and/or (2) toxicity was related to an interaction between SO_4^{-2} and elevated hardness due to the presence of both Mg^{+2} and Ca^{+2}. The possibility of this interaction was suggested by:

1. A toxicity result in Elphick et al. (2011) indicating an increase in SO_4^{-2} toxicity at hardness levels comparable to those found the VCM discharge (300 to 400 mg/L), and
2. Mg^{+2} accounts for on average, approximately 50% of the effluent hardness and is a significant parameter in the STR model developed by Mount et al. (1997).

The approach to the spiking experiment was to increase SO_4^{-2} as $MgSO_4$ and $CaSO_4$ such that hardness and SO_4^{-2} increased simultaneously while (1) retaining the original proportion of Ca^{+2} to Mg^{+2} (approximately 2:1 by weight) and (2) increasing the ratio of Ca^{+2} to Mg^{+2} to approximately 3:1. Tests were conducted using both Outfall 001 and sample collected from the receiving stream (Brushy Creek) immediately upstream of its confluence with the unnamed tributary that conveys the VCM discharge to Brushy Creek (see text of UAA Report). The ionic makeup of Brushy Creek (BC0) is very similar to that of the VCM discharge minus the elevated SO_4^{-2}. The purpose of including this sample (spiked to mimic outfall SO_4^{-2} concentrations) was to evaluate the possibility of an unknown toxicant in the VCM discharge. If the outfall sample were to show toxicity while the Brushy Creek sample (after adjustment to have similar ionic composition, including SO_4^{-2}) did not, it would suggest an unknown toxicant in the outfall not attributable to its ionic strength/composition.

This experiment was originally performed by AIC on samples collected on September 28, 2010. Those results were not interpretable due to non-monotonic dose responses (i.e., higher effects at lower ion concentrations) and are not included herein. Based on these results and the consistent difference in lab results described above, the experiment was repeated using laboratory services provided by HAI on samples collected on November 15, 2010. The experiment was prepared and conducted as follows:

Upon arrival to the laboratory aliquots of sample were collected and analyzed for the analytes indicated in Table C.2. Six treatments were then prepared per Table C.7 by adding reagent-grade inorganic salts to the Outfall 001 and Brushy Creek (BC0) samples and aerating for 24 hours. Aliquots of Treatments 2, 3, 5, and 6 were collected and analyzed for SO_4^{-2} and Ca^{+2}. Each treatment in Table C.7 was then used as a test exposure against a common control in a 3-brood chronic toxicity test using *C. dubia.*

Table C.7. Summary of Series 2 spiking experiment setup.

Trt	**Description**	**Expected Increase in Concentration (mg/L)**				
		TDS	**Ca^{+2}**	**Mg^{+2}**	**SO_4^{-2}**	**Hardness**
1	Outfall 001	None	None	None	None	None
2	Outfall 001 + 130 mg/L $CaSO_4(2H_2O)$ + 100 mg/L $MgSO_4$	202	30	20	153	157
3	Outfall 001 + 130 mg/L $CaSO_4(2H_2O)$ + 100 mg/L $MgSO_4$ + 138 mg/L $CaCl_2$	340	80	20	153	281
4	BC-0	None	None	None	None	None
5	BC-0 + 260 mg/L $CaSO_4(2H_2O)$ + 200 mg/L $MgSO_4$	405	60	40	306	314
6	BC-0 + 260 mg/L $CaSO_4(2H_2O)$ + 200 mg/L $MgSO_4$ + 138 mg/L $CaCl_2$	543	110	40	306	438
7	Lab Water control	None	None	None	None	None

Results of the Series 2 spiking experiments are presented in Table C.8. Laboratory control survival and reproduction was 100% and 24.5 neonates, respectively. Measured versus expected SO_4^{-2} concentrations showed close agreement, while measured Ca^{+2} concentrations were consistently lower than expected concentrations. This result indicates that some precipitation of Ca^{+2} likely occurred during sample preparation and equilibration.

Table C.8. Results of the Series 2 spiking experiments.

	Outfall 001					BC0				
	Treatment 1	Treatment 2		Treatment 3		Treatment 4	Treatment 5		Treatment 6	
	Unspiked	$CaSO_4 + MgSO_4$		$CaSO_4 + MgSO_4 + CaCl_2$		Unspiked	$CaSO_4 + MgSO_4$		$CaSO_4 + MgSO_4 + CaCl_2$	
Analyte	Measured	Measured	Expected	Measured	Expected	Measured	Measured	Expected	Measured	Expected
Total Alkalinity	240	--	--	--	--	302	--	--	--	--
HCO_3^-	140	--	--	--	--	171	--	--	--	--
TDS	410	--	612*	--	750*	290	--	695*	--	833*
Ca^{+2}	78.5	85.6	109	118	159	65.6	94.5	126	116	176
Mg^{+2}	54.0	--	74.0	--	74.0	38.6	--	78.6	--	78.6
K^+	2.93	--	--	--	--	1.09	--	--	--	--
Na^+	4.18	--	--	--	--	2.09	--	--	--	--
Cl^-	10.1	--	--	--	--	3.83	--	--	--	--
SO_4^{-2}	142	293	295	301	295	6.9	296	313	286	313
pH (su)	8.7	8.7	--	8.6	--	8.9	8.8	--	8.7	--
Hardness	418	--	575	--	699	322	--	636	--	760
Conductivity (µS)	695	920	--	1,122	--	510	991	--	1,216	--
% Survival	100	100		100		100	100		100	
Reproduction	24.5	22.8		21.1		21.9	21.6		21.4	

Notes: All units are mg/L unless otherwise noted.
*Estimate based on measured value in unspiked sample plus added amounts of Ca^{+2} and Mg^{+2} salts.

There were no statistically significant differences between the control and test treatments or among test treatments ($P > 0.05$). The TDS, SO_4^{-2}, and hardness concentrations of the non-toxic unspiked Outfall 001 sample were 410, 142 and 418 mg/L, respectively, which is within the range of concentrations in all samples reported as toxic by AIC (Table C.4). Spiked samples containing approximately 300 mg/L SO_4^{-2} (average measured concentration of 294 mg/L), which is over 50% higher than the proposed SO_4^{-2} criteria, showed no lethal or sub-lethal toxicity. Similarly, spiked samples having up to 833 mg/L TDS, which substantially exceeds the highest effluent concentration, showed no lethal or sub-lethal toxicity. There was no difference in the toxicity response of the Outfall 001 versus the spiked BC0 samples, indicating no added unknown toxicants in the VCM effluent. Finally, there was no evidence of increased toxicity at elevated hardness as seen in the data reported in Elphick et al. (2011).

Summary and Conclusions Based on Toxicity Testing

Although toxicity screening tests conducted by AIC showed consistent sub-lethal toxicity, inter-laboratory comparison testing showed that this is not a repeatable property of the VCM discharge. Furthermore, the results of split sample testing and spiked samples tests conducted by HA agreed with expected results based on published literature. Therefore, for purposes of this support document, the results generated by AIC will be discarded in favor of those produced by HA.

Literature Cited

Davies, T.D., and K.J. Hall. 2007. Importance of calcium in modifying the acute toxicity of sodium sulfate to *Hyalella azteca* and *Daphnia magna*. *Environ. Toxicol. Chem.* 26: 1243-1247.

Elphick, J.R., M. Davies, G. Gilron, E.C. Canaria, B. Lo, and H.C. Bailey. 2011. An aquatic toxicological evaluation of sulfate: the case for considering hardness as a modifying factor in setting water quality guidelines. *Environ. Toxicol Chem.* 30: 247-253.

EPA. 1991. *Toxicity identification: Characterization of Chronically Toxic Effluents, Phase I* [EPA-600/6-91/005]. Edited by T.J. Norberg-King, D.I. Mount, J. Amato, D.A. Jensen, and J.A. Thompson. US Environmental Protection Agency. June 1991.

EPA. 2002. *Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms, fourth edition* [EPA-821-R-02-013]. US Environmental Protection Agency, Office of Water. Washington, DC.

Goodfellow, W.L., L.W. Ausley, D.T. Burton, D.L. Denton, P.B. Dorn, D.R. Grothe, M.A. Heber, T.J. Norberg-King, and J.H. Rodgers. 2000. Major ion toxicity in effluent: a review with permitting recommendations. *Environ. Toxicol. Chem.* 19:175-182.

Lasier, P.J., and I.R. Hardin. 2010. Observed and predicted reproduction of *Ceriodaphnia dubia* exposed to chloride, sulfate, and bicarbonate. *Environ. Toxicol. Chem.* 29: 347-358.

Mount, D.R., D.D. Gulley, J.R. Hockett, T.D. Garrison, and J.M. Evans. 1997. Statistical models to predict the toxicity of major ions to *Ceriodaphnia dubia, Daphnia magna* and *Pimephales promelas* (fathead minnows). *Environ. Toxicol. Chem.* 16:2009-2019.

Soucek, D.J. 2007. Comparison of hardness and chloride regulated acute effects of sodium sulfate on two freshwater crustaceans. *Environ. Toxicol. Chem.* 26: 773-253.

Soucek, D.J., and A.J. Kennedy. 2005. Effects of hardness, chloride, and acclimation on the acute toxicity of sulfate to freshwater invertebrates. *Environ. Toxicol. Chem.* 24:1204-1210.

Soucek, D.J., T.K. Linton, C.D. Tarr, A. Dickinson, N. Wickramanayake, C.G. Delos, and L.A. Cruz. 2011. Influence of water hardness and sulfate on the acute toxicity of chloride to sensitive freshwater invertebrates. *Environ. Toxicol. Chem.* 30: 930-938.

Van Dam, R.A., A.C. Hogan, C.D. McCullough, M.A. Houston, C.L. Humphrey, and A.J. Harford. 2010. Aquatic toxicity of magnesium sulfate and the influence of calcium in very low ionic concentration water. *Environ. Toxicol. Chem.* 29: 410-421.

APPENDIX D

Sampling Location Photographs from Fall Survey (September 28 to 30, 2010)

Figure D.1. Unnamed tributary near Brushy Creek.

Figure D.2. Brushy Creek at BC0.

Figure D.3. Brushy Creek at BC1. Photograph taken after sampling activities.

Figure D.4. Brushy Creek at BC2.

Figure D.5. Stennitt Creek at SC0.

Figure D.6. Clear Creek at Ref0.

APPENDIX E

Field Forms for Spring and Fall Surveys

R:\projects\6532-021\tech\Spring 2010 sampling\Vulcan Field Sampling Week of 5_10_2010.docx

Vulcan Field Sampling Week of 6/14-18/2010

Plant contact: **David Smith 870-878-6245 (cell: 870-809-0016)**

To quarry: On S side of road, 5 mi east of the Black River bridge (at Black Rock) on Hwy 63.

Mon:

Drive up there on Monday PM– suggest collecting grab samples from Spring R at that time.

Call Sharon Anderson **(870-878-1817)** who's property you will access on Tues to sample Stennitt and the mouth of Brushy. You need to call her Monday PM to coordinate when and where to meet on Tues AM so he can open the gate.

Tues,

Call David Smith to let him know you are in the area and sampling.

Sample Stennitt and mouth of Brushy

On Wed;

Call David Smith to coordinate sampling of Outfall.

Sample the mouth Brushy and the UT on the **Sexton's** property. He is expecting you, but you should go by the house anyway.

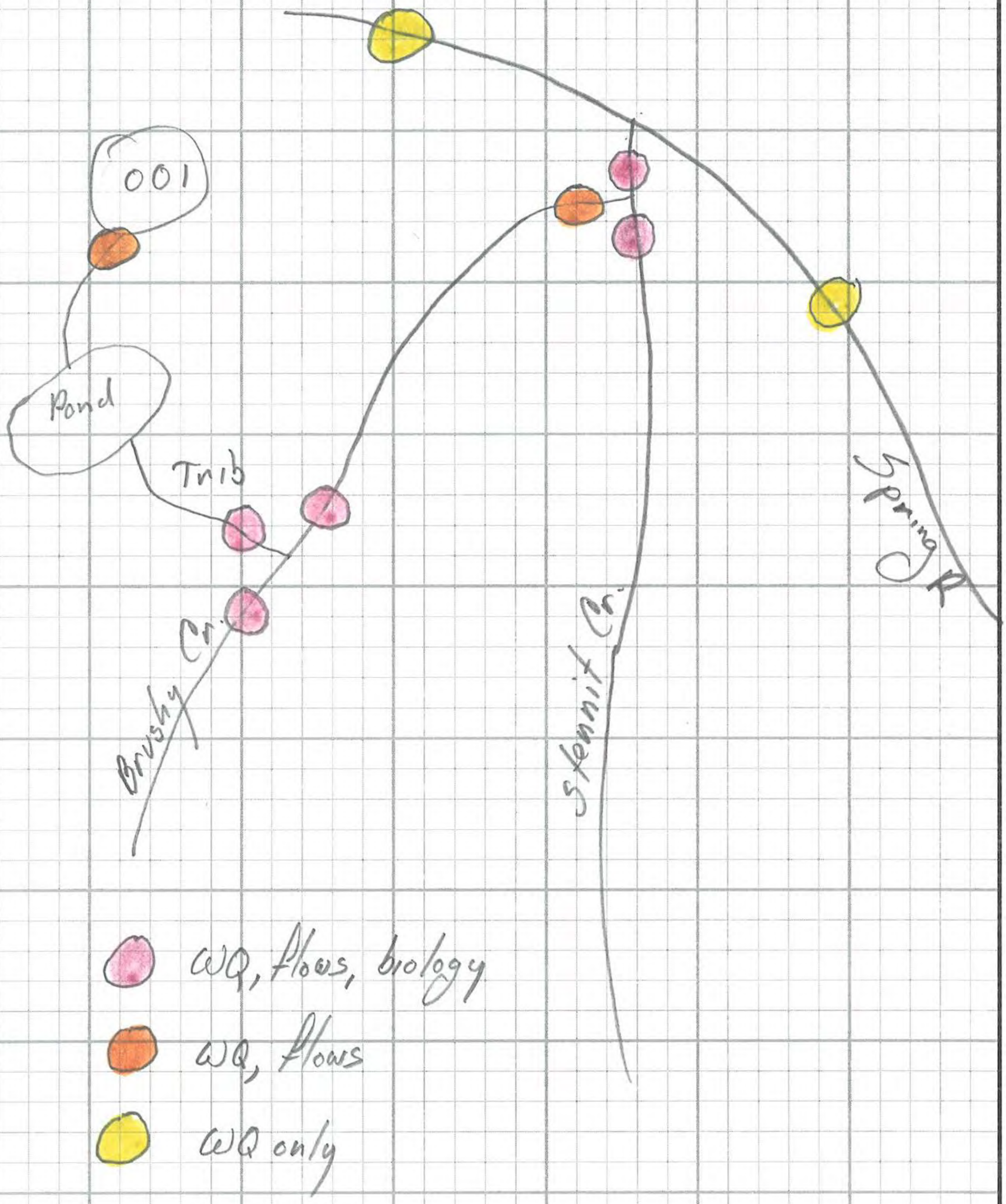
See sampling summary below

ftn Associates Ltd.
water resources / environmental consultants

3 Innwood Circle, Suite 220
Little Rock, AR 72211
(501) 225-7779
Fax (501) 225-6738

Sheet No.____ of____
Date________
By________
Chkd____ Date____
Job No.________

Subject ________________



Vulcan Field Sampling Week of 5/10-14/2010

Sampling summary:

Station ID	Location	WQ	Flow	Biol/Hab	GPS	Photo
001	Outfall 001	X	Get flow from Plant	▨	X	X
UT-0	Unnamed trib to Brushy	X	X	X	X	X
BC-0	Brush Cr. u/s of UT	X	X	X	X	X
BC-1	Brushy Cr. d/s of UT	X	X	X	X	X
BC-2	Mouth of Brushy Cr.	X	X	X	X	X
SC-0	Stennitt Cr. u/s of Brushy	X	X	X	X	X
SC-1	Stennitt Cr. d/s of Brushy	X	X	X	X	X
SR-~~0~~ 1	Spring R. d/s of Stennitt at Hwy 361	X	▨	▨	X	X
SR-~~1~~ 0	Spring R. u/s of Stennitt at Hwy 62	X	▨	▨	X	X
Dup	Any station	X	▨	▨	▨	▨

All WQ samples are grab samples and need to include in situ.

Sampling notes:

The BC-0 vs BC-1 biological sampling needs to be from comparable habitats to the extent possible b/c we are looking as us v ds effects of the UT.

The same goes for SC-0 vs SC-1 biological sampling.

For the UT-0 and BC-2 stations we need to sample a variety of habitats (as available) b/c we are more focused on aq life support at those sites.

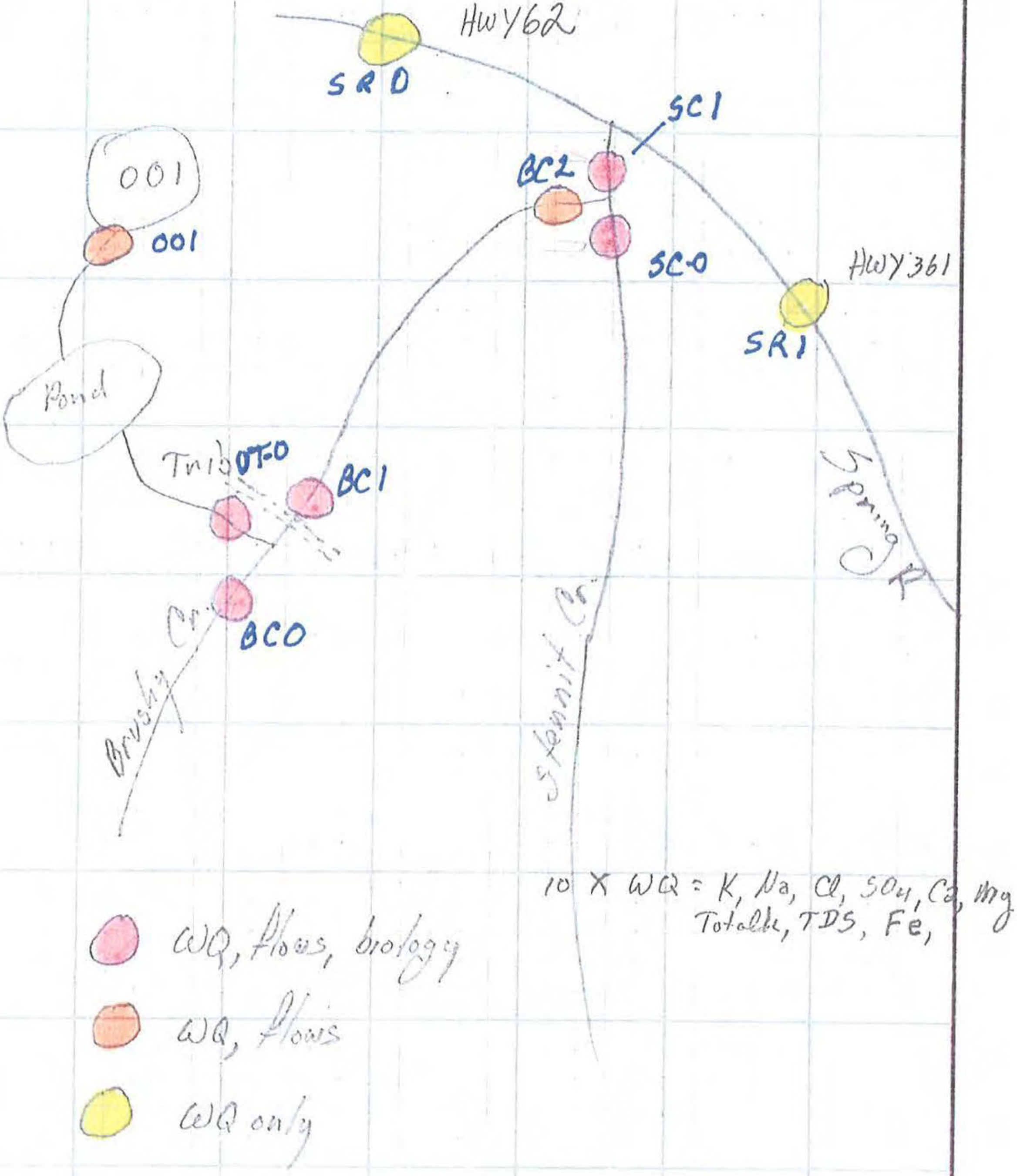
Note the duplicate water sample.

ftn Associates Ltd.
water resources / environmental consultants

3 Innwood Circle, Suite 220
Little Rock, AR 72211
(501) 225-7779
Fax (501) 225-6738

Subject

Sheet No. of
Date
By
Chkd Date
Job No.



10 X WQ = K, Na, Cl, SO_4, Ca, Mg
Total alk, TDS, Fe,

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Unnamed Trib	LOCATION UT-O
STATION #______ RIVERMILE ______	STREAM CLASS
MAP DATUM:______ Zone:______	RIVER BASIN
UTM: Easting ______ Northing ______	AGENCY
INVESTIGATORS	
FORM COMPLETED BY PDD	DATE 6/15/10 TIME 1100 AM PM
REASON FOR SURVEY	

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
___% ☐	%cloud cover	☐ 0-50 %
☒	clear/sunny	☐

Has there been a heavy rain in the last 7 days? ☐ Yes ☒ No

Air Temperature ____ °C

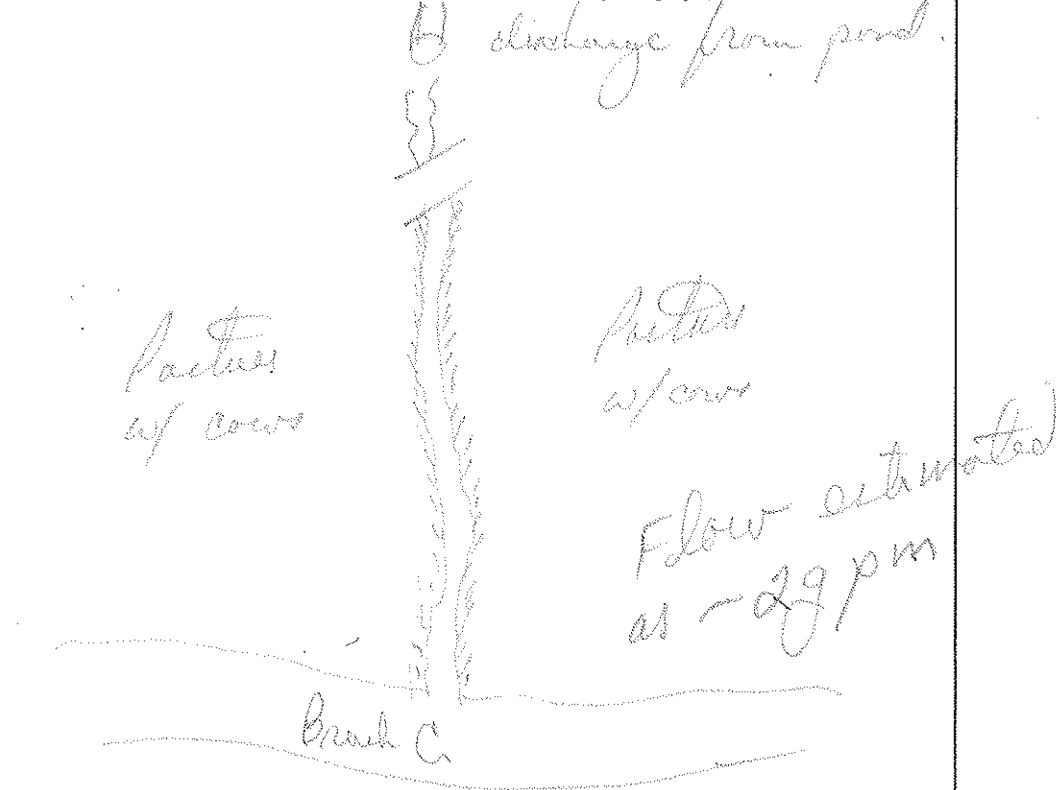
Other__________

SITE LOCATION/MAP

Flow:

Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Velocity (f/s)

Draw a map of the site and indicate the areas sampled (or attach a photograph)



Flow estimated as ~2gpm

STREAM CHARACTERIZATION

Stream Subsystem
☐ Perennial ☒ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☐ Other From Pond

Catchment Area______km²

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

UT-0

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☐ Agricultural ☐ Other ______
☐ Residential

Local Watershed
☐ No evidence ☐ Some potential sources
☒ Obvious sources

Local Watershed Erosion
☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☐ Trees ☐ Shrubs ☒ Grasses ☐ Herbaceous
dominant species present ______

INSTREAM FEATURES

Estimated Reach Length ____m 50 ft
Estimated Stream Width ____m 1.5 ft
Sampling Reach Area ____m^2
Area in km² (m²x1000) ____km^2
Estimated Stream Depth ____m 0.05 ft
Surface Velocity (at thalweg) ____m/sec <0.5 ft/sec

Canopy Cover None
☐ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark____m None
Proportion of Reach Represented by Stream Morphology Types NA small trickle
☐ Riffle____% ☐ Run____%
☐ Pool____%
Channelized ☐ Yes ☒ No
Dam Present ☒ Yes ☐ No

LARGE WOODY DEBRIS

LWD 0 m^2
Density of LWD 0 m^2/km^2 **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☐ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae
Dominant species present None
Portion of the reach with aquatic vegetation 0 %

WATER QUALITY

See notebook

Temperature____°C
Specific Conductance ______
Dissolved Oxygen ______
pH ______
Turbidity ______
WQ Instrument Used ______

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other ______

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ______

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other______

SEDIMENT/ SUBSTRATE

Odors
☐ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☒ None
☐ Other ______

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other None

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)

Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		
Boulder	> 256 mm (10")	
Cobble	64-256 mm (2.5" – 10")	5
Gravel	2-64 mm (0.1" – 2.5")	5
Sand	0.06 – 2mm (gritty)	25
Silt	0.004-0.06 mm	65
Clay	<0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	Sticks, wood, coarse plant materials (CPOM)	0
Muck-Mud	Black, very fine organic (FPOM)	0
Marl	Grey, shell fragments	0

UT-0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME UT-0	LOCATION UT-0
STATION #________ RIVERMILE________	STREAM CLASS
LAT ________ LONG ________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE 5/15/10 TIME 1100 AM PM
REASON FOR SURVEY	

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	[✓ 5] 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	[✓ 5] 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 [✓ 1] 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 [✓ 3] 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 [✓ 3] 2 1 0

UT-0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

	Habitat Parameter	Condition Category			
		Optimal	Suboptimal	Marginal	Poor
Parameters to be evaluated broader than sampling reach	**6. Channel Alteration**	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
	SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 [✓ 2] 1 0
	8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
	SCORE ___ (LB)	Left Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
	9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
	SCORE ___ (LB)	Left Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
	10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
	SCORE ___ (LB)	Left Bank 10 9	8 7 6	5 [✓ 4] 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 [✓ 4] 3	2 1 0

Total Score __________

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Brushy Cr	LOCATION Upper BC D
STATION # BC-10 RIVERMILE ______	STREAM CLASS
MAP DATUM:__________ Zone:__________	RIVER BASIN
UTM: Easting ________ Northing ________	AGENCY
INVESTIGATORS	
FORM COMPLETED BY POD	DATE 6/19/10 TIME 1530 AM PM

REASON FOR SURVEY UAA

WEATHER CONDITIONS Clear

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
10-50% ☐	%cloud cover	☐ 10-50%
☐	clear/sunny	☐

Has there been a heavy rain in the last 7 days?
☐ Yes ☐ No

Air Temperature ~33 °C

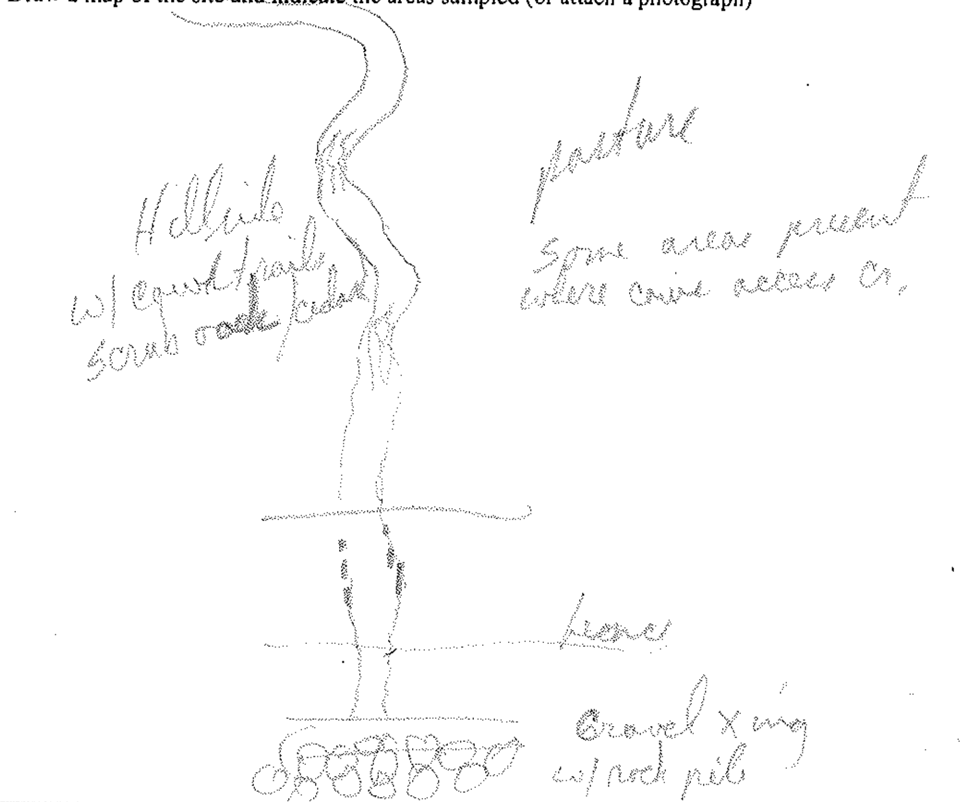
Other________________

SITE LOCATION/MAP

Flow:

Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Velocity (f/s)
5.5	0		0
5.8	0.1		0
6.1	0.26		0.17
6.4	0.32		0.38
6.7	.30		0.37
7.0	0.40		0.47
7.3	.30		0.88
7.6	0.31		0.81
7.9	0.36		0.78
8.2	0.38		0.59
8.5	0.30		0.33
8.8	0.2		0.27
9.1	0.21		0.18
9.4	0.1		0
9.7	0.1		0
10.0	0.1		0
10.3	0.1		0

Draw a map of the site and indicate the areas sampled (or attach a photograph)



STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☐ Other Ground / runoff

Catchment Area__________km²

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BC-0

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest
☒ Field/Pasture
☐ Agricultural
☐ Residential
☐ Commercial
☒ Industrial Quarry
☐ Other ___________

Local Watershed
☐ No evidence ☐ Some potential sources
☒ Obvious sources

Local Watershed Erosion
☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☐ Trees ☒ Shrubs ☐ Grasses ☐ Herbaceous

dominant species present ______________________________

INSTREAM FEATURES

Estimated Reach Length _____m 500 ft

Estimated Stream Width _____m 12

Sampling Reach Area _____m^2

Area in km^2 (m^2x1000) _____km^2

Estimated Stream Depth _____m

Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☐ Partly open ☒ Partly shaded ☐ Shaded

High Water Mark _______m

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle ~~[illegible]~~ % 15 ☐ Run ~~25~~ % 100
☐ Pool 60 %
6/14/10

Channelized ☒ Yes ☒ No

Dam Present ☐ Yes ☐ No

LARGE WOODY DEBRIS

LWD _________m^2

Density of LWD _________m^2/km^2 **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☐ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae

Dominant species present None

Portion of the reach with aquatic vegetation 0 %

WATER QUALITY

Temperature _______°C

Specific Conductance ________

Dissolved Oxygen ________

pH ___________

Turbidity ______________

WQ Instrument Used __________

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other __________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ______________

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other_______

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ____________________

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other None

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)

Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		
Boulder	> 256 mm (10")	<1
Cobble	64-256 mm (2.5" – 10")	20
Gravel	2-64 mm (0.1" – 2.5")	50
Sand	0.06 – 2mm (gritty)	~~[illegible]~~ 10
Silt	0.004-0.06 mm	10
Clay	<0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	Sticks, wood, coarse plant materials (CPOM)	<2
Muck-Mud	Black, very fine organic (FPOM)	0
Marl	Grey, shell fragments	0

BC-O

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Brushy	LOCATION BC-O
STATION #________ RIVERMILE________	STREAM CLASS
LAT __________ LONG __________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY BPJD	DATE 6/14 TIME 1553 AM PM REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 [✓ 4] 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

BC-D

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	[✓ 20] 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0

Total Score __________

BC-01

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☐ Agricultural ☐ Other ________
☐ Residential

Local Watershed
☐ No evidence ☒ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☐ Trees ☒ Shrubs ☒ Grasses ☐ Herbaceous
dominant species present ________

INSTREAM FEATURES

Estimated Reach Length ____m 600 ft
Estimated Stream Width ____m 10 ft
Sampling Reach Area ____m²
Area in km² (m²x1000) ____km² 0.34
Estimated Stream Depth ____m $\bar{X}$ = [illegible]
Surface Velocity (at thalweg) ____m/sec $\bar{X}$ = .5 ft/sec

Canopy Cover open
☐ Partly open ☐ Partly shaded ☐ Shaded
High Water Mark 1 m

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle [illegible] % ☐ Run 10 %
☐ Pool [illegible] % 60
[illegible] = 60/30/10

Channelized ☐ Yes ☒ No
Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD ________m²
Density of LWD ________m²/km² **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☐ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae

Dominant species present None

Portion of the reach with aquatic vegetation ________%

WATER QUALITY

Temperature ____°C
Specific Conductance ________
Dissolved Oxygen ________
pH ________
Turbidity ________
WQ Instrument Used ________

All in [illegible]

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other ________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ________

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other ________

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ________

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other ________

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)

Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		15
Boulder	> 256 mm (10")	5
Cobble	64-256 mm (2.5" – 10")	20
Gravel	2-64 mm (0.1" – 2.5")	[illegible]
Sand	0.06 – 2mm (gritty)	20
Silt	0.004-0.06 mm	
Clay	<0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	Sticks, wood, coarse plant materials (CPOM)	5
Muck-Mud	Black, very fine organic (FPOM)	0
Marl	Grey, shell fragments	0

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Brushy
LOCATION BC 01
STATION #________ RIVERMILE ______
STREAM CLASS
MAP DATUM:________ Zone:________
RIVER BASIN
UTM: Easting ________ Northing ________
AGENCY
INVESTIGATORS
FORM COMPLETED BY PJD
DATE 6/15/10
TIME 0820 AM PM
REASON FOR SURVEY

WEATHER CONDITIONS

Clear, calm
warm

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
____% ☐	%cloud cover	☐ 0-50 %
☒	clear/sunny	☐

Has there been a heavy rain in the last 7 days? ☐ Yes ☒ No

Air Temperature ____ °C 85°F

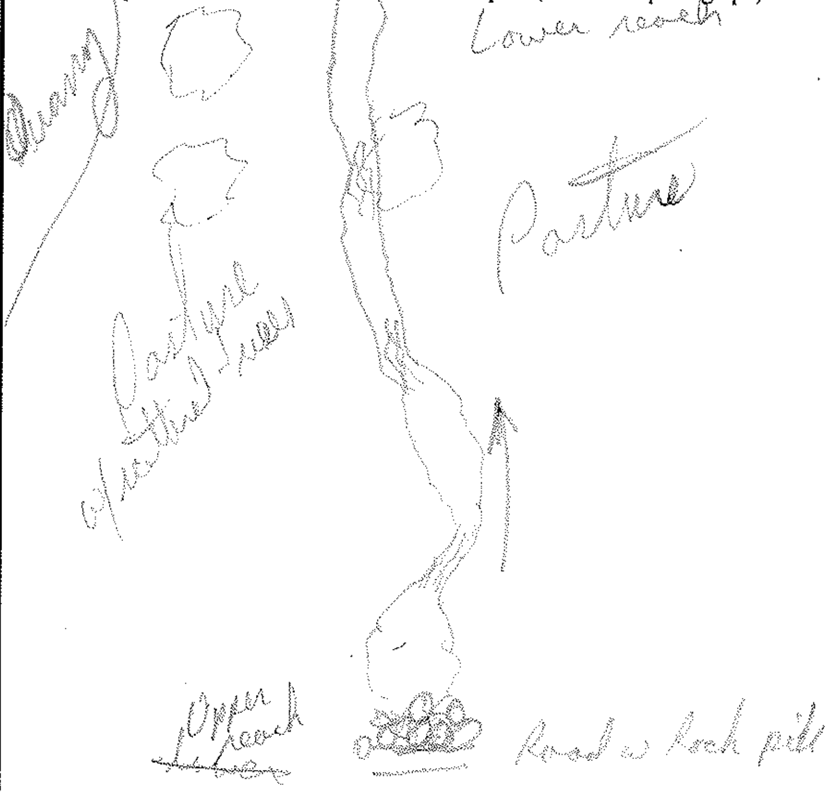
Other________________

SITE LOCATION/MAP

Flow:

Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Velocity (f/s)

Draw a map of the site and indicate the areas sampled (or attach a photograph)



STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☒ Spring-fed
☐ Non-glacial montane ☒ Mixture of origins
☐ Swamp and bog ☐ Other________

Catchment Area________km²

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HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Brush	LOCATION BC-87
STATION #_________ RIVERMILE_________	STREAM CLASS
LAT _____________ LONG _____________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY PGD	DATE 6/15/10 TIME 0840 AM PM
	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 [✓ 16]	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 ~~17~~ 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

BC0 1

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	**Condition Category**			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	[✓ 20] 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distanee between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 [✓ 17] 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 [✓ 6]	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities(i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0

Pasture

Total Score __________

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 6/14/10
Observer JWB / JMR
Project No. Vulcan

Stream ~~BC-0~~ BC-1
Transect No. ~~BC-0~~ BC-1
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L
Temperature, C
Conductivity, uhmos
pH, su
ORP, mv

III. Physical Characterization

Stream Width, ft ~~5.4~~ 4.8
Channel Width, ft
Pool ______ Length, ft
Riffle/Run ______ Length, ft
Tape Down (ft)
GPS

Transect Reading	Tape Reading from ~~LB~~/[✓ RB]	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow (cfs)	Comments
1	5.0	0.0			0		
2	5.2	0.01			0		
3	5.4	0.01			0		
4	5.6	0.2			0		
5	5.8	0.5			0		
6	6.0	0.5			0		
7	6.2	0.1			0		
8	6.4	0.1			0.2		
9	6.6	0.1			0.27		
10	6.8	0.1			0.54		
11	7.0	0.15			0.87		
12	7.2	0.2			1.53		
13	7.4	0.25			1.46		
14	7.6	0.25			0.97		
15	7.8	0.25			0.80		
16	8.0	0.25			0.82		
17	8.2	0.25			0.38		
18	8.4	0.20			0.89		
19	8.6	0.2			0.65		
20	8.8	0.2			0.33		
21	9.0	0.2			0.04		
22	9.2	0.15			0.0		
23	9.4	0.05			0.0		
24	9.6	0.025			0.0		
25	9.8	0.0			0.0		
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

-O Insitu

5/10 1400

Temp 26.77

DO 5.07

pH 7.57

Cond 537

BC O Pass 1 3206

BC O Pass 2 Shelby Twn

→ 1908

SC-O Stock Tank 2113 Pass 1

" " 2050 Pass 2

Wpy pts 6 SC-O u/s
7 SC-O d/s
8 BC-2 WQ/flow

BC-2 Insitu

Temp 31.42

pH 7.51

Cond 562

DO 7.44

BC-2 flow

Mark	Depth	V	Mark	Depth	V
1.5	0	0	12.0	0.2	0.47
2.0	0.025	0	12.5	0.15	0.0
2.5	0.05	0	13.0	0.1	0.0
3.0	0.025	0	13.5	0.05	0.0
3.5	0.1	0.30	14.0	0.05	0.09
4.0	0.15	0.09	14.5	0.1	0.0
4.5	0.15	0.21	15.0	0.0	0.0
5.0	0.2	0.16			
5.5	0.15	0.30			
6.0	0.15	0.07			
6.5	0.15	0.07			
7.0	0.2	0.12			
7.5	0.2	0.50			
8.0	0.2	0.43			
8.5	0.15	0.56			
9.0	0.2	0.59			
9.5	0.2	0.31			
10.0	0.05 ~~0.025~~	0.27			
10.5	0.2	0.27			
11.0	0.2	0.29			
11.5	0.2	0.61			

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Stennett
LOCATION 50-0
STATION #______ RIVERMILE ______
STREAM CLASS
MAP DATUM:______ Zone:______
RIVER BASIN
UTM: Easting ______ Northing ______
AGENCY
INVESTIGATORS
FORM COMPLETED BY POD
DATE 6/15/10
TIME 1416 AM PM
REASON FOR SURVEY

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
30 % ☐	%cloud cover	☐ 0-50 %
☐	clear/sunny	☐ 0-5

Has there been a heavy rain in the last 7 days?
☐ Yes ☒ No

Air Temperature 90 °F °C

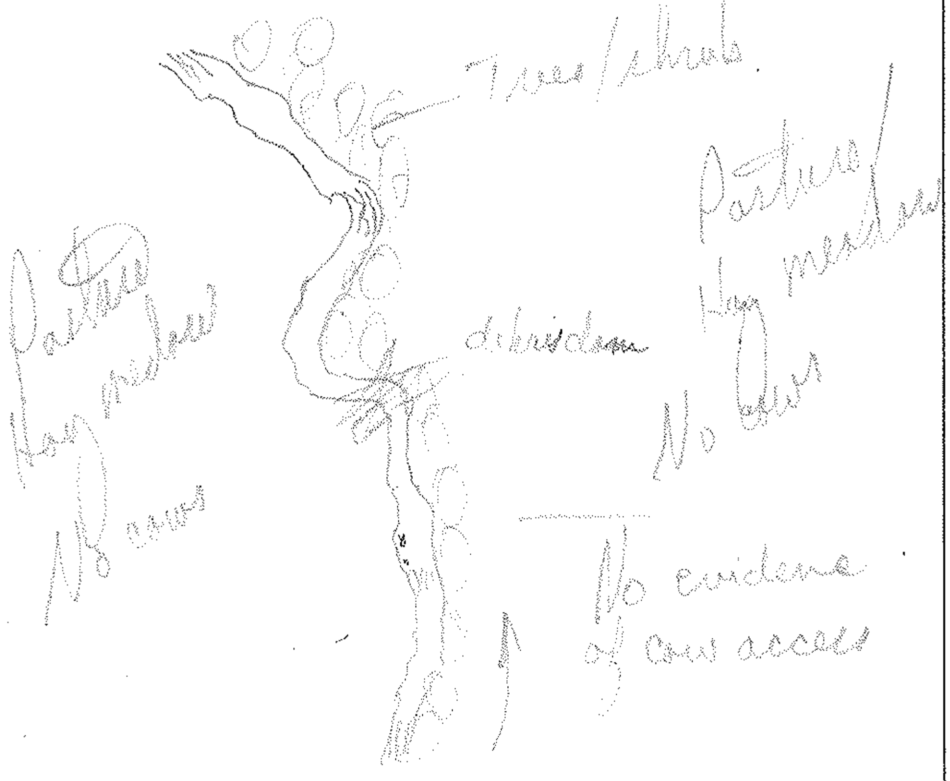
Other______

SITE LOCATION/MAP

Flow:

Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Velocity (f/s)

Draw a map of the site and indicate the areas sampled (or attach a photograph)



STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☐ Other Ground/runoff

Catchment Area______km²

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

5C-0

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☐ Agricultural ☐ Other ____
☐ Residential

Local Watershed
☒ No evidence ☐ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☒ None ☐ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☒ Trees ☒ Shrubs ☐ Grasses ☐ Herbaceous
dominant species present ____

INSTREAM FEATURES

Estimated Reach Length ____m 600 ft
Estimated Stream Width ____m 10-12 ft
Sampling Reach Area ____m^2
Area in km^2 (m^2x1000) ____km^2
Estimated Stream Depth ____m
Surface Velocity (at thalweg) ____m/sec

Canopy Cover
☐ Partly open ☒ Partly shaded ☐ Shaded

High Water Mark 1 m

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle 10 % ☐ Run 60 %
☐ Pool ~~[illegible]~~ 30 % POB 6/15/10

Channelized ☐ Yes ☒ No
Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD 10 m^2
Density of LWD ____m^2/km^2 **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☒ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae
Dominant species present Water willow
Portion of the reach with aquatic vegetation 45 %

WATER QUALITY

Temperature____°C
Specific Conductance ____
Dissolved Oxygen ____
pH____
Turbidity ____
WQ Instrument Used ____

no meter

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other ____

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ____

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other____

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ____

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other None

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)		
Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		
Boulder	> 256 mm (10")	0
Cobble	64-256 mm (2.5" – 10")	10
Gravel	2-64 mm (0.1" – 2.5")	POB 6/15/10 ~~[illegible]~~ 20
Sand	0.06 – 2mm (gritty)	~~70~~ 60
Silt	0.004-0.06 mm	10
Clay	<0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	Sticks, wood, coarse plant materials (CPOM)	5
Muck-Mud	Black, very fine organic (FPOM)	0
Marl	Grey, shell fragments	0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Stennett	LOCATION 5C - 0	
STATION #________ RIVERMILE________	STREAM CLASS	
LAT __________ LONG __________	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS		
FORM COMPLETED BY POD	DATE 6/15/10 TIME 1442 1420 AM PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 [✓ 3] 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep). POD 6/15/10
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 ~~3~~ 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1 0

SC-0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 [✓ 2] 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining. 6/5/10	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 [✓ 9]	~~8~~ 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0

Total Score ________

③⑥

/15
R-0 collected @ 16FC
@ 11WY62

-O Intake @ 0723
Temp 26.98
DO 6.72
pH 7.81
Cond 454

001 1030 6/15 1200
Temp 26.78
DO 5.77
pH 7.32
Cond 696

Benthics collected 6/15/16
1115
O Benthics " 6/15/10 1130

Flows estimated @ 2 gpm

③⑦

SC-0 Flows

Mark	depth	V
4.0	0.4	0
4.5	0.5	0
5.0	0.3	0
5.5	0.5	0.3
6.0	0.35	0.8
6.5	0.36	0.0
7.0	0.25	0
7.5	0.26	0
8.0	0.19	0
8.5	0.29	-0.04
9.0	0.32	0.02
9.5	0.10	0.17
10	0.30	0.38
10.5	0.20	0.26
11	0.81	0.15
11.5	0.90	0.21
12.0	0.90	0.22
12.5	0.96	0.31
13.0	0.97	0.36
13.5	1.00	0.39
14.0	1.08	0.49
14.5	1.08	0.46
16.0	1.00	0.57
15.5	0.98	0.32
16.0	0.90	0.48
16.5	0.80	0.38
17.0	0.80	0.53
17.5	0.70	0.53
18.0	0.52	0.26
18.5	0.45	0.36
19.0	0.34	0.31
19.5	0.31	0.12
20	0.1	-0.09
20.5	0.10	0.02
21	0.1	0.11
21.5	0.1	0.10
22	0	0

Ref 1

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☒ Forest
☐ Field/Pasture
☐ Agricultural
☐ Residential
☐ Commercial
☐ Industrial
☐ Other ___________

Local Watershed
☐ No evidence ☒ Some potential sources Ag
☐ Obvious sources

Local Watershed Erosion minimal
☒ None ☐ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☐ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous
dominant species present ___________

INSTREAM FEATURES

Estimated Reach Length _____m 400 ft
Estimated Stream Width _____m 10 ft
Sampling Reach Area _____m^2
Area in km^2 (m^2x1000) _____km^2
Estimated Stream Depth _____m $\bar{x}$ = 0.3 ft
Surface Velocity (at thalweg) _____m/sec $\bar{x}$ = 2 ft/sec

Canopy Cover
☐ Partly open ☐ Partly shaded ☒ Shaded

High Water Mark 0.5 m

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle 25 % ☐ Run 25 %
☐ Pool 50 %

Channelized ☐ Yes ☒ No

Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD _________m^2
Density of LWD _________m^2/km^2 **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☐ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae
Dominant species present None
Portion of the reach with aquatic vegetation _________%

WATER QUALITY

Temperature ______°C
Specific Conductance ________
Dissolved Oxygen __________
pH ____________
Turbidity ____________
WQ Instrument Used __________

See insitu

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other ________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ________

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other ________

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ___________

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other None

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**
Bedrock		50
Boulder	> 256 mm (10")	5
Cobble	64-256 mm (2.5" – 10")	25
Gravel	2-64 mm (0.1" – 2.5")	15
Sand	0.06 – 2mm (gritty)	5
Silt	0.004-0.06 mm	0
Clay	<0.004 mm (slick)	0

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Characteristic**	**% Composition in Sampling Area**
Detritus	Sticks, wood, coarse plant materials (CPOM)	2%
Muck-Mud	Black, very fine organic (FPOM)	0
Marl	Grey, shell fragments	0

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET
(FRONT)

STREAM NAME Ref-1

STATION # 2 RIVERMILE ______

MAP DATUM:______________Zone:____________

UTM: Easting __________ Northing ______________

LOCATION

STREAM CLASS

RIVER BASIN

AGENCY

INVESTIGATORS

FORM COMPLETED BY POD

DATE 6/16/10

TIME 0815 AM PM

REASON FOR SURVEY

WEATHER CONDITIONS

Calm
warm

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
25 % ☐	%cloud cover	☐ 0-50 %
☐	clear/sunny	☐

Has there been a heavy rain in the last 7 days?
☐ Yes ☒ No

Air Temperature 80° F °C

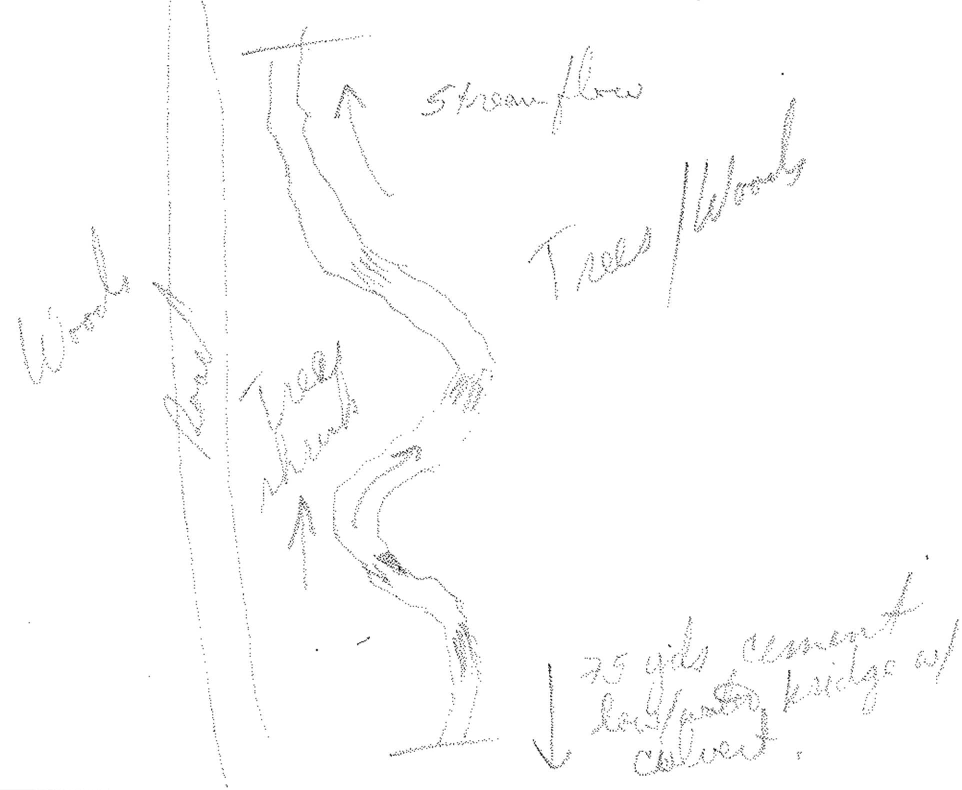
Other______________________

SITE LOCATION/MAP

Flow:

Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Velocity (f/s)

Draw a map of the site and indicate the areas sampled (or attach a photograph)



STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☐ Other Ground/runoff

Catchment Area____________km^2

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HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Ralf	LOCATION
STATION # ________ RIVERMILE ________	STREAM CLASS
LAT ____________ LONG ____________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY POD	DATE 6/16/10 TIME 0830 AM PM REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Ref 2

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	[✓ 20] 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank [✓ 10] 9	8 7 6	5 4 3	2 1 0

Total Score ___________

[illegible] Cox

Steven

301-570-2920

Ed Bruker

Ref-1 6/18/10 0730

In Situ

Temp	19.50	Staff Gauge	
DO	7.91	2300	Pass 1
pH	2.11	2140	Pass 2
Cond	2.90		

Ref 1 Flows

Mark	depth	V	Mark	depth	V
3.8	0.0	0	8.3	0.50	0.60
[illegible]	[illegible]	[illegible]	8.8	0.40	0.71
[illegible]	[illegible]	0.91	9.3	0.32	0.51
[illegible]	0.20	0.33	9.8	0.27	0.58
5.8	0.21	-0.11	10.3	0.20	0.53
6.3	0.28	-0.06	10.5	0.30	0.28
[illegible]	0.34	0.19	11.3	0.22	0.10
7.3	0.40	0.54	11.5	0.10	0.08
[illegible]	0.43	0.21	12.3	0.05	0
			12.7	0	0

Ref-1 checks

	Photo	Rubric	Flow	WQ	check Form
Ref 1	✓	✓	✓	✓	✓
BC-0	✓	✓	✓	✓	✓
BC-1	✓	✓	—	✓	✓
BC-2	NA		✓	✓	NA
SC-0			✓	✓	✓
SC-1	✓	✓	—	—	
UT-0	✓	✓	Estimated		NA

Weighting pts
9 Ref-1 u/s
10 " d/s

ftn

Pass 1

FISH SAMPLING FIELD DATA SHEET (FRONT)

page 1 of 1

ENTERED
omr

STREAM NAME Brushy	LOCATION BC-0
STATION # ______ RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY PDD	DATE 6/15 TIME 0900 AM PM REASON FOR SURVEY

SAMPLE COLLECTION	**How were the fish captured?** ☒ back pack ☐ tote barge ☐ other ______ **Block nets used?** ☒ Yes ☐ No **Sampling Duration** Start Time ______ End Time ______ Duration 3206 **Stream width (in meters)** Max ______ Mean ______
HABITAT TYPES	**Indicate the percentage of each habitat type present** ☐ Riffles ______% ☐ Pools ______% ☐ Runs ______ ☐ Snags ______% ☐ Submerged Macrophytes ______% ☐ Other ( ) ______%
GENERAL COMMENTS	

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
LSS	212	86/6.9	84/6.2	116/18.7	81/[illegible]	46/1.1								
		118/16.3	128/22.2	86/6.7	74/9.8	96/9.1	☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☐							
		90/2.5	41/0.9	84/6.8	97/10.9	79/5.0								
		102/13.0	86/7.5	82/6.3	81/7.7	107/14.7								
		91/7.3	82/6.4	92/8.7	88/8.9	73/5.1								
PNot	26	64/2.5	81/5.7	[illegible]	81/5.7	61/1.8								
		66/2.5	67/2.1	62/2.0	63/2.2	60/1.8	: ·							
		62/2.5	56/1.2	65/1.9	76/4.8	79/4.8								
		76/4.3	60/1.5	60/1.9	60/1.8	63/1.9								
		61/1.7	65/2.2	63/2.3	70/3.4	70/3.1								
LESF	40	138/37.9	56/[illegible]	84/9.7	72/5.7	70/5.5								
		97/15.2	90/12.9	80/9.6	94/16.9	84/11.5	☒ 1 :							
		88/14.4	55/3.5	55/3.1	58/3.2	157/75.5								
		85/11.0	95/17.8	78/8.9	76/8.1	109/28.9								
		81/10.0	51/2.6	45/1.5	57/4.0	59/3.7								
Chub Sucl	50	99/9.4	88/6.2	131/29.0	108/16.0	14[illegible]/38.7								
		151/49.3	149/38.1	131/30.6	104/13.6	120/23.1	☒ ☒ 1 :							
		129/24.9	140/38.1	123/25.1	136/33.2	79/6.1								
		90/9.4	99/14.6	116/20.0	135/24.5	99/13.2								
		71/3.9	76/5.4	89/6.7	78/5.7	92/8.5								

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

BC-0

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
Bsp7/M	41	79/3.5	79/4.2	56/1.3	65/2.3	53/1.3								
		57/1.8	54/1.5	78/4.4	72/3.5	68/3.0	☒							
		63/2.1	71/3.2	71/3.2	69/2.9	66/2.8								
		57/1.7	59/1.8	65/2.7	62/2.2	57/1.6								
		67/2.7	66/2.6	74/3.6	59/1.9	63/2.5								
Redf. sh.	8 ~~17~~	83/4.9	79/2.9	72/2.7	100/	[illegible]								
		~~67~~	~~58~~	~~68~~	~~68~~	~~58~~								
		~~59~~	~~67~~	~~65~~	70/3.4	63/2.0								
		69/2.9	64/2.2											
[illegible]	2	~~79~~	~~100~~											
Lepomis macrochirus		62/3.5	47/1.6											
Green Sunfish	15	91/13.3	116/27.1	94/14.7	82/10.1	101/19.5								
		93/15.5	94/15.5	119/31.7	158/84.4	82/9.9								
		84/11.0	78/8.5	63/4.2	56/3.3	119/30.5								
Yellow Bullhead	5	105/	117/23.6	235/188.0	121/20.7	93/10.7								
	2	138/36.7	38/0.7											
Micropterus salmoides														
	24	47/1.3	45/1.0	43/0.9	49/1.4	44/0.8								
Etheostoma spectabile		41/0.8	47/1.0	50/1.4	50/1.3	42/0.8								
		52/1.7	43/0.8	54/1.7	39/0.7	41/0.7								
		45/1.1	47/1.3	47/1.2	44/1.1	46/1.1								
		45/1.0	39/0.7	51/1.7	42/0.8									
	13	100/9.8	89/8.9	86/7.0	89/7.9	83/6.1								
Semotilus atromaculatus		90/8.5	47/0.9	33/0.3	88/7.3	86/7.2								
		81/5.2	39/0.6	37/0.5										

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page 1 of 2

ENTERED
dmc

STREAM NAME	LOCATION BC-O Pass 2
STATION #______ RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE______ TIME ______ AM PM REASON FOR SURVEY

SAMPLE COLLECTION

How were the fish captured? ☒ back pack ☐ tote barge ☐ other ______

Block nets used? ☒ Yes ☐ No

Sampling Duration Start Time ______ End Time ______ Duration 1908

Stream width (in meters) Max ______ Mean ______

HABITAT TYPES

Indicate the percentage of each habitat type present

☐ Riffles ______% ☐ Pools ______% ☐ Runs ______ ☐ Snags ______%

☐ Submerged Macrophytes ______% ☐ Other (______) ______%

GENERAL COMMENTS

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	110	111/15.0	80/5.6	75/4.8	94/9.5	78/4.4								
Campostoma oligolepis		88/7.2	75/5.5	77/4.9	99/10.6	111/15.5	☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒							
		85/7.1	84/6.9	72/4.4	38/0.5	47/0.9								
		83/5.5	83/6.1	50/1.0	75/5.0	85/5.9								
		42/0.6	83/5.8	81/5.8	38/0.5	45/0.7								
	25	63/2.1	63/2.2	58/1.7	70/2.8	84/6.6								
Pimephales notatus		59/1.6	77/4.3	76/4.2	57/1.9	59/1.8								
		65/2.5	64/2.5	68/3.1	64/2.3	54/1.5								
		60/2.2	61/2.2	60/1.9	64/2.6	59/2.0								
		67/2.8	57/1.5	64/2.6	61/2.1	58/2.0								
	15	86/11.9	117/29.7	117/28.4	61/4.1	81/9.3								
Lepomis cyanellus		45/1.7	109/25.2	92/16.3	76/7.6	64/4.9								
		86/11.7	114/28.6	82/11.3	67/5.6	55/3.5								
	75	137/50.3	78/8.7	95/16.6	58/3.7	77/9.0								
Lepomis megalotis		138/62.4	88/12.7	94/13.7	129/50.6	85/10.5	☒ ☒ ☒ ☒ ☒							
		60/4.1	65/5.3	62/4.3	64/5.3	82/10.4								
		86/13.1	73/7.3	63/4.7	55/3.3	60/4.0								
		109/26.5	54/3.0	87/13.3	80/9.6	72/6.5								

BC-0

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	15	79/4.7	78/4.0	57/1.5	67/3.0	64/2.4								
Fundulus olivaceus		60/2.0	66/2.6	50/1.2	82/5.1	65/2.6								
		68/3.0	68/3.0	66/2.8	52/1.2	60/2.0								
	5	190/98.2	105/14.6	119/23.2	103/10.0	87/8.0								
Ameiurus natalis														
	8	62/3.7	57/2.9	69/5.7	58/3.1	53/2.3								
Lepomis macrochirus		79/8.4	54/2.6	58/3.1										
	6	34/0.4	113/18.0	113/17.8	35/0.6	33/0.4								
Micropterus salmoides		150/51.4												
	10	115/15.9	82/6.7	87/7.9	39/0.5	31/0.2								
Semotilus atromaculatus		26/0.1	37/0.5	32/0.3	42/0.8	35/0.4								
	14	95/9.9	102/14.7	111/16.9	94/9.1	65/3.0								
Erimyzon oblongus		113/21.3	91/9.5	88/8.6	114/19.2	87/8.4								
		88/8.4	81/6.7	63/2.9	77/5.9									
	88	54/2.0	52/1.4	44/0.8	41/0.7	49/1.3								
Etheostoma spectabile		50/1.4	47/1.1	49/1.3	47/1.1	51/1.5	☒ ☒ ☒ ☒ ☒ ☒ :·							
		50/1.7	54/1.9	46/1.0	47/1.0	48/1.2								
		49/1.2	43/0.7	42/0.8	43/0.9	43/0.7								
		45/0.9	45/0.9	52/1.3	43/0.6	39/0.6								
	1	67/3.2												
Notropis boops														

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page 2 of 2

STREAM NAME
STATION # ______ RIVERMILE ______
LAT ______ LONG ______
STORET #
INVESTIGATORS
FORM COMPLETED BY

LOCATION BC-O Pass 2
STREAM CLASS
RIVER BASIN
AGENCY

ENTERED

DATE ______
TIME ______ AM PM

REASON FOR SURVEY

SAMPLE COLLECTION

How were the fish captured? ☐ back pack ☐ tote barge ☐ other ______

Block nets used? ☐ Yes ☐ No

Sampling Duration Start Time ______ End Time ______ Duration ______

Stream width (in meters) Max ______ Mean ______

HABITAT TYPES

Indicate the percentage of each habitat type present
☐ Riffles ____% ☐ Pools ____% ☐ Runs ____ ☐ Snags ____%
☐ Submerged Macrophytes ____% ☐ Other ( ) ____%

GENERAL COMMENTS

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
Gambusia affinis	1	46/1.4												
Lythrurus umbratilis	1	63/1.9												

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

Pass 1

page ___ of ____

STREAM NAME Brushy	LOCATION BC-1
STATION #______ RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY PDD	DATE 6/14 TIME ______ AM PM
	REASON FOR SURVEY

SAMPLE COLLECTION	**How were the fish captured?** ☒ back pack ☐ tote barge ☐ other ______ **Block nets used?** ☒ Yes ☐ No **Sampling Duration** Start Time ____ End Time ____ Duration ____ **Stream width (in meters)** Max ____ Mean ____
HABITAT TYPES	**Indicate the percentage of each habitat type present** ☐ Riffles ___% ☐ Pools ___% ☐ Runs ___ ☐ Snags ___% ☐ Submerged Macrophytes ___% ☐ Other (___) ___%
GENERAL COMMENTS	shocking Time: 8344

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
LSS	52	142/104	81/6.4	95/9.4	88/7.9	70/3.8								
		80/6.1	101/6.5	96/10.0	86/8.4	87/6.1	☒	☒						
		76/5.6	107/11.8	87/7.4	102/13.4	79/6.2	☐							
		88/6.8	105/14.8	69/6.7	76/5.9	61/3.7								
		89/7.0	88/12.1	95/15.8	74/4.1	56/3.1								
Pmot	82	69/2.3	57/1.5	60/1.2	63/2.3	65/2.2								
		77/4.7	68/3.1	70/3.2	69/3.0	70/3.4	☒ ☒	☒	☒					
		58/1.5	50/1.5	70/3.5	56/1.2	70/3.3	☒ ☐							
		64/2.3	68/[illegible]	70/2.3	67/2.6	60/1.8								
		65/2.5	66/2.5	80/5.1	62/2.5	66/2.8								
LESF	65	69/5.7	114/25.6	80/3.4	57/3.4	151/64.5								
		139/38.8	69/5.6	64/6.0	96/17.9	91/14.8	☒	☒	☒	☒				
		73/6.7	54/1.9	53/3.0	66/6.4	56/2.2								
		82/10.2	61/4.2	66/5.2	66/4.7	124/[illegible]								
		55/2.0	46/0.8	61/4.1										
BSpM	8	51/1.9	76/4.1	49/1.1	78/4.2	69/3.8								
		61/2.0	71/3.2	72/4.4										

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

BC-1 Pass 1

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
~~[illegible]~~ redfin shiner	3	66/2.6	61/1.8	54/1.9										
↳ further investigation determined fish to be redfin shiners														
creek chub	2	130/30.1	50/3.1											
chub sucker	8	146/40.2	116/24.1	126/23.8	125/19.1	149/27.0								
		70/4.2	121/18.6	107/14.6										
Camp sp	1	37/0.6												
Dot sp	1	29/0.3												
E. ~~caerul.~~ spectabile	11	50/1.4	41/0.7	45/0.8	46/1.2	45/1.2								
		41/1.1	38/0.9	37/0.4	41/0.6	38/0.6								
		41/0.7												
~~[illegible]~~ Microp sp	1	36/0.4												
Gr. SF	4	130/	68/5.0	116/15.2	113/24.7									

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page ___ of ____

STREAM NAME Brushy	LOCATION BC 1
STATION #________ RIVERMILE ___	STREAM CLASS
LAT ________ LONG ________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE________ TIME ________ AM PM
REASON FOR SURVEY	

SAMPLE COLLECTION	**How were the fish captured?** ☐ back pack ☐ tote barge ☐ other ________ **Block nets used?** ☐ Yes ☐ No **Sampling Duration** Start Time ______ End Time ______ Duration ______ **Stream width (in meters)** Max ______ Mean ______
HABITAT TYPES	**Indicate the percentage of each habitat type present** ☐ Riffles _____% ☐ Pools _____% ☐ Runs ______ ☐ Snags ________% ☐ Submerged Macrophytes ______% ☐ Other (____________)________%
GENERAL COMMENTS	Pass 1

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
G. affinis	1	42/0.8												
Bluegill BL	4	102/26.0	96/18.8	72/5.8	110/20.7									
Y. bullhead	3	124/24.7	110/14.5	162/58.7										
Lot. hoops	2	53/1.4	47/1.1											

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BC-1 Day 1

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
Redfin Sh	2	67/2.9	61/2.0											
CMB	1	108/27.2												
Sp. Bass	2	45/0.9	44/0.8											
(?)														

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page 1 of 2

STREAM NAME BC-1 Pass #2	LOCATION
STATION #____ RIVERMILE ____	STREAM CLASS
LAT ____ LONG ____	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE 6/14/10 TIME ____ AM PM REASON FOR SURVEY

SAMPLE COLLECTION

How were the fish captured? ☐ back pack ☐ tote barge ☐ other ____

Block nets used? ☐ Yes ☐ No

Sampling Duration Start Time ____ End Time ____ Duration 1902

Stream width (in meters) Max ____ Mean ____

HABITAT TYPES

Indicate the percentage of each habitat type present

☐ Riffles ____% ☐ Pools ____% ☐ Runs ____ ☐ Snags ____%

☐ Submerged Macrophytes ____% ☐ Other ( ) ____%

GENERAL COMMENTS

Pass 2: Time = 1902

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
Chb sucker	12	121/23.5	155/53.4	136/28.6	132/30.1	106/14.7								
		92/9.3	78/5.6	74/5.0	77/5.3	85/8.1								
		111/21.3	105/15.0											
Blue Gill	1	151/[illegible]												
LESF	95													
							☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒							
LSS	31													
							☒ ☒ ☒							

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
PNOT	62													
							⊠ ⊠ ⊠ ⊠ ⊠ ⊠ • •							
Yellow Bullhead	2	136/33.0	108/14.9											
Green sunfish	8	95/16.3	116/38.2	98/14.3	139/46.0	132/47.8								
		102/19.6	97/13.1	77/7.8										
LMB	1	200/105.0												
redfin ~~Emerald~~ shiner	4	66/2.4	49/1.1	66/2.5	54/1.5									
↳ further investigation determined fish to be redfin shiners														
BSPTM	23	86/5.4	71/2.2	79/2.8	78/4.2	64/2.4								
		64/2.1	72/3.0	77/4.0	77/4.0	56/1.5								
		77/4.1	76/4.2	77/3.6	56/1.6	57/1.8								
		82/5.3	66/2.2	76/4.0	67/2.6	70/2.8								
		56/1.7	56/1.7	56/1.5										
E. ~~CAUR~~	15	42/0.7	54/1.6	43/0.7	41/0.9	50/0.9								
Spectabile		45/0.9	40/0.7	40/0.7	47/0.9	37/0.5								
		42/0.6	40/0.5	41/0.9	38/0.5	42/1.1								
redfin ~~Ribbon~~ shiner	2	60/2.9	61/2.4											
↳ further investigation determined fish to be redfin shiners														

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page 2 of 2

STREAM NAME BC-1 Pass #2	LOCATION
STATION #_____ RIVERMILE _____	STREAM CLASS
LAT _____ LONG _____	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE 6/14/10 TIME _____ AM PM
	REASON FOR SURVEY

SAMPLE COLLECTION

How were the fish captured? ☐ back pack ☐ tote barge ☐ other _____

Block nets used? ☐ Yes ☐ No

Sampling Duration Start Time _____ End Time _____ Duration 1402

Stream width (in meters) Max _____ Mean _____

HABITAT TYPES

Indicate the percentage of each habitat type present

☐ Riffles _____% ☐ Pools _____% ☐ Runs _____ ☐ Snags _____%

☐ Submerged Macrophytes _____% ☐ Other (_____) _____%

GENERAL COMMENTS

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
Red fin shiner	10	80/4.8	69/	67/	55/	69/								
		63/	50/	59/	67/	65/								

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page 1 of 2

STREAM NAME
STATION # ________ RIVERMILE ________
LAT ________ LONG ________
STOREL #
INVESTIGATORS
FORM COMPLETED BY

LOCATION SC-0 Pass 1
STREAM CLASS
RIVER BASIN
AGENCY

DATE 6/15/10
TIME ________ AM PM

REASON FOR SURVEY

SAMPLE COLLECTION

How were the fish captured? ☒ back pack ☐ tote barge ☐ other ________

Block nets used? ☒ Yes ☐ No

Sampling Duration Start Time ________ End Time ________ Duration 2113

Stream width (in meters) Max ________ Mean ________

HABITAT TYPES

Indicate the percentage of each habitat type present
☐ Riffles ____% ☐ Pools ____% ☐ Runs ____ ☐ Snags ____%
☐ Submerged Macrophytes ____% ☐ Other ( ) ____%

GENERAL COMMENTS

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	34	97/9.9	76/5.5	80/6.3	65/3.0	72/4.0								
Campostoma oligolepis		71/4.4	45/0.8	44/0.6	40/0.6	40/0.6	☑							
		41/0.6	76/4.9	70/4.1	85/6.5	87/7.4								
		48/1.1	40/0.5	86/7.2	78/5.4	42/0.8								
		73/4.6	44/1.0	42/0.9	47/1.0	48/1.1								
	6	78/5.3	63/2.0	61/2.1	69/2.6	50/1.1								
Pimephales notatus		42/0.5												
	34	101/21.5	81/10.0	49/2.2	48/2.1	69/6.5								
Lepomis megalotis		78/9.2	80/10.7	96/17.8	54/3.0	51/2.5	☑							
		98/19.5	58/4.2	60/4.1	73/7.6	106/24.2								
		81/12.1	93/16.9	72/7.5	50/2.2	58/3.9								
		71/7.2	84/12.5	89/14.3	59/3.9	56/3.4								
	8	59/3.4	77/8.2	60/3.8	57/3.5	66/5.5								
Lepomis cyanellus		49/2.1	49/2.1	42/1.2										

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	3	97/11.0	76/5.3	66/3.4										
Semotilus atromaculatus														
	11	104/14.9	100/14.4	73/4.8	72/4.2	75/5.6								
Erimyzon oblongus		70/3.9	35/0.4	35/0.3	92/9.9	105/15.6								
		69/4.5												
	11	67/2.7	65/2.2	69/3.2	59/1.9	55/1.5								
Notropis boops		56/1.5	48/0.9	63/2.2	48/0.9	45/0.8								
		70/2.9												
	9	105/10.7	99/9.5	88/6.7	83/4.7	86/5.5								
Luxilus zonatus		88/6.9	96/8.7	90/7.1	83/5.1									
	2	95/8.9	91/8.2											
Luxilus chrysocephalus														
	1	69/3.0												
Etheostoma blennioides														
	1	79/7.8												
Aphredoderus sayanus														
	1	110/17.0												
Ameiurus natalis														

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page 2 of 2

STREAM NAME
LOCATION SC-O Pass 1
STATION # ________ RIVERMILE ______
STREAM CLASS
LAT ________ LONG ______
RIVER BASIN
STORET #
AGENCY
INVESTIGATORS
FORM COMPLETED BY
DATE ________
TIME ________ AM PM
REASON FOR SURVEY

SAMPLE COLLECTION

How were the fish captured? ☐ back pack ☐ tote barge ☐ other ________

Block nets used? ☐ Yes ☐ No

Sampling Duration Start Time ______ End Time ______ Duration ______

Stream width (in meters) Max ______ Mean ______

HABITAT TYPES

Indicate the percentage of each habitat type present
☐ Riffles ____% ☐ Pools ____% ☐ Runs ______ ☐ Snags ______%
☐ Submerged Macrophytes ____% ☐ Other ( ) ______%

GENERAL COMMENTS

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	1	77/8.0												
Lepomis microlophus														
	1	41/1.2												
Lepomis macrochirus														
	1	29/0.3												
Gambusia affinis														
	2	75/3.0	62/2.0											
Notropis amblops														

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page ___ of _____

STREAM NAME
LOCATION SC-0 Pass 2
STATION #________ RIVERMILE ______
STREAM CLASS
LAT ________ LONG ________
RIVER BASIN
STORET #
AGENCY
INVESTIGATORS
FORM COMPLETED BY
DATE________
TIME ________ AM PM
REASON FOR SURVEY

SAMPLE COLLECTION

How were the fish captured? ☒ back pack ☐ tote barge ☐ other ________

Block nets used? ☒ Yes ☐ No

Sampling Duration Start Time ______ End Time ______ Duration 2050

Stream width (in meters) Max ________ Mean ________

HABITAT TYPES

Indicate the percentage of each habitat type present
☐ Riffles _____% ☐ Pools _____% ☐ Runs ______ ☐ Snags ________%
☐ Submerged Macrophytes ______% ☐ Other ( ) ________%

GENERAL COMMENTS

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	50	73/4.3	50/1.2	42/0.8	42/0.8	48/1.2								
Campostoma oligolepis		38/0.6	35/0.5	43/0.7	94/8.7	87/6.1	☒ ☒ ⁝ :							
		74/5.3	81/6.8	73/4.5	70/4.1	72/4.3								
		69/3.8	44/1.0	67/3.6	67/3.5	45/0.9								
		39/0.6	72/4.2	70/4.3	64/3.0	40/0.6								
	5	55/1.6	49/1.0	46/0.9	49/1.0	53/1.4								
Pimephales notatus														
	23	61/4.4	50/2.3	45/1.4	38/1.2	76/8.6								
Lepomis megalotis		75/8.6	85/11.9	56/3.5	63/4.6	53/2.7								
		45/1.5	81/10.8	69/6.4	58/3.4	66/5.8								
		76/9.6	53/3.0	90/15.5	58/3.9	54/3.2								
		97/18.7	64/5.3	48/1.9										
	3	62/4.0	58/2.8	47/1.5										
Lepomis macrochirus														

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	3	31/0.3	42/0.9	47/1.4										
Gambusia affinis														
	10	54/1.3	53/1.3	52/1.2	67/2.8	68/3.1								
Notropis boops		72/3.6	54/1.4	54/1.4	52/1.2	72/3.6								
	1	60/1.8												
Notropis amblops														
	1	57/1.6												
Lythrurus umbratilis														
	9	46/1.2	51/1.6	45/1.1	49/1.6	47/1.4								
Etheastoma spectabile		42/0.9	63/3.8	42/0.8	35/0.5									
	5	97/8.9	112/8.3	95/8.7	85/5.4	79/4.2								
Luxilus zonatus														
	1	69/3.6												
Luxilus chrysocephalus														
	1	73/3.6												
Etheostoma blennioides														

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page ___ of _____

STREAM NAME	LOCATION Sc-0 Pass 2
STATION #__________ RIVERMILE _____	STREAM CLASS
LAT __________ LONG ________	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE 6/15/10 TIME ________ AM PM REASON FOR SURVEY

SAMPLE COLLECTION	**How were the fish captured?** ☐ back pack ☐ tote barge ☐ other ________ **Block nets used?** ☐ Yes ☐ No **Sampling Duration** Start Time ______ End Time ______ Duration _______ **Stream width (in meters)** Max ________ Mean _______
HABITAT TYPES	**Indicate the percentage of each habitat type present** ☐ Riffles _____% ☐ Pools _____% ☐ Runs _____ ☐ Snags _______% ☐ Submerged Macrophytes _____% ☐ Other ( ) _______%
GENERAL COMMENTS	

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	8	88/13.5	62/4.1	58/3.5	112/29.2	91/14.1								
Lepomis cyanellus		66/5.0	71/6.6	56/3.4										
	8	118/21.2	107/16.2	99/12.9	82/7.1	76/6.1								
Erimyzon oblongus		115/20.4	77/6.0	110/18.2										
	2	104/13.8	104/11.5											
Micropterus salmoides														
	3	71/3.7	48/1.0	57/1.8										
Fundulus olivaceous														

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	1	80/5.5												
Semotilus atromaculatus														
	2	201/122.6	174/89.1											
Ameiurus natalis														

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FISH SAMPLING FIELD DATA SHEET (FRONT)

page 1 of 1

STREAM NAME	LOCATION Ref Pass 1 + 2 combined
STATION # ______ RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS	
FORM COMPLETED BY	DATE 6/16/10 TIME ______ AM PM REASON FOR SURVEY

SAMPLE COLLECTION	**How were the fish captured?** ☐ back pack ☐ tote barge ☐ other ______ **Block nets used?** ☐ Yes ☐ No **Sampling Duration** Start Time ______ End Time ______ Duration ______ **Stream width (in meters)** Max ______ Mean ______
HABITAT TYPES	**Indicate the percentage of each habitat type present** ☐ Riffles ______% ☐ Pools ______% ☐ Runs ______ ☐ Snags ______% ☐ Submerged Macrophytes ______% ☐ Other (______) ______%
GENERAL COMMENTS	Shock Time Pass 1 = 2300 Pass 2 = 2147

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	242	95/8.2	69/3.3	66/3.0	77/4.6	85/6.3								
Campostoma oligolepis		81/5.3	100/9.7	105/11.0	59/2.1	86/6.4	☒ ⊏							
		87/5.7	75/3.8	74/4.1	87/4.6	71/3.6								
		69/3.0	78/3.9	63/1.6	72/3.8	77/3.8								
		77/4.2	86/6.9	97/8.5	113/14.1	79/5.1								
	100	55/2.3	51/1.3	46/1.0	61/3.4	52/1.7								
Etheostoma spectabile		48/1.1	44/0.9	48/1.2	47/1.2	50/1.3	☒ ☒ ☒ ☒ ☒ ☒ ☒ ǀ :							
		40/0.7	38/0.5	64/3.5	46/0.8	55/2.4								
		42/0.7	40/0.6	47/1.2	45/1.0	43/0.6								
		41/0.7	44/1.0	57/2.3	49/1.5	46/0.9								
	120	65/2.1	62/2.1	47/0.7	53/1.3	66/2.6								
Phoxinus erythrogaster		69/2.7	61/2.0	66/2.5	62/2.1	68/2.5	☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ☒ ⌐ :							
		55/1.4	62/2.3	69/2.6	58/1.8	58/1.7								
		65/2.4	61/1.9	61/1.9	59/1.7	54/1.2								
		65/2.2	68/3.0	65/2.1	67/2.5	69/3.1								
	48	40/0.7	45/0.9	45/1.0	40/0.6	37/0.5								
Etheostoma flabellare		46/1.0	42/0.7	52/1.3	43/0.8	39/0.6	☒ ☒ : ·							
		36/0.5	41/0.8	53/1.4	37/0.5	54/1.3								
		37/0.6	43/0.8	49/1.2	41/0.8	42/0.8								
		51/1.3	39/0.6	40/0.7	35/0.4	37/0.5								

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

SPECIES	TOTAL (COUNT)	OPTIONAL: LENGTH (mm)/WEIGHT (g) (25 SPECIMENT MAX SUBSAMPLE)					ANOMALIES							
							D	E	F	L	M	S	T	Z
	26	82/9.3	63/4.3	73/6.6	141/67.8	118/35.1								
Lepomis cyanellus		123/35.9	91/14.4	87/10.7	85/11.0	85/11.7								
		120/29.5	99/18.2	143/63.0	163/94.8	100/19.1								
		92/12.5	81/9.5	72/6.5	54/2.7	72/6.5								
		55/2.7	120/29.2	83/10.8	78/7.8	145/63.0								
	14	90/15.6	53/2.6	98/17.7	77/9.1	51/2.2								
Lepomis megalotis		96/17.7	50/2.5	113/30.6	91/15.6	49/2.1								
		136/47.3	57/3.8	62/4.3	70/6.8									
	2	41/0.9	47/1.4											
Lepomis macrochirus														
	22	94/7.1	75/3.9	82/4.9	75/4.1	65/2.7								
Fundulus olivaceus		73/4.3	74/4.3	93/6.9	68/2.9	86/5.9								
		77/4.8	81/4.5	73/3.9	53/1.5	82/5.2								
		74/3.6	62/2.5	85/6.3	62/2.1	49/1.0								
		70/3.8	78/4.7											
	46	118/18.0	87/7.3	38/0.4	133/25.6	121/24.0								
Semotilus atromaculatus		109/14.4	126/21.3	105/12.7	107/15.9	86/6.9	☒	☒						
		33/0.2	93/9.3	113/16.1	33/0.2	129/25.9								
		137/28.3	38/0.5	118/19.8	105/13.5	118/18.0								
		76/4.9	67/3.5	107/13.7	115/16.7	125/24.6								
	8	70/3.2	70/3.6	79/5.7	71/3.6	62/2.6								
Erimyzon oblongus		78/5.6	60/2.4	71/4.7										
	6	64/2.8	100/9.4	66/2.9	88/6.7	72/3.7								
Noturus exilis		52/1.8												
	5	88/8.1	76/6.3	70/4.9	87/9.8	87/11.3								
Aphredoderus sayanus														

ANOMALY CODES: D=deformities; E=eroded fins; F=fungus; L=lesions; M=multiple DELT anomalies; S=emaciated; Z=other

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 9/29/10 1350
Observer
Project No. Vulcan
Stream Brushy Creek (BC-0)
Transect No.
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L 7.42
Temperature, C 29.75
Conductivity, uhmos 565 uS/cM
pH, su 7.49
ORP, mv NA

III. Physical Characterization

Stream Width, ft 3.0 ft
Channel Width, ft
Pool ______ Length, ft ______
Riffle/Run ______ Length, ft ______
Tape Down (ft)
GPS

RB

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow (cfs)	Comments
1	~~1.5~~ 23	.25			0		
2	3.5	.25			0		
3	4.4	.3			0		
4	5.0	.50			0		
5	6.5	.35			0		
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

There is some flow in riffles are to shallow to measure flow in

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 29 Sep 10
Observer BS & JCW
Project No. Unlcm UAA

Stream Brushy Creek
Transect No. BC-1
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L 5.64
Temperature, C 18.20
Conductivity, uhmos 619 µS/cm
pH, su 6.36
ORP, mv

III. Physical Characterization

Stream Width, ft
Channel Width, ft
Pool Length, ft
Riffle/Run Length, ft
Tape Down (ft)
GPS

LB

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow (cfs)	Comments
1	2.5	.2			0.0		
2	3	.2			0.0		
3	3.5	.5			0.08		
4	4.0	.4			0.0		
5	4.5	.5			0.05		
6	5.0	.4			0.04		
7	5.5	.35			0.06		
8	6.0	.35			0.04		
9	6.5	.3			0.03		
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

D

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 9/30/10 9:00am
Observer JLW BJG
Project No. Vulcan

Stream Brushy Creek (BC-2)
Transect No.
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L ~~6.53~~ 5.96
Temperature, C 16.55
Conductivity, uhmos 567
pH, su 7.50
ORP, mv

III. Physical Characterization

Stream Width, ft 4.5
Channel Width, ft
Pool 40 Length, ft
Riffle/Run ~~25~~ 40 Length, ft
Tape Down (ft)
GPS

.8 0 0

RB

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow ~~(cfs)~~	Comments M/sec
1	1.0	.2			~~14~~	.01	
2	1.5	.2				.06	
3	2.0	0.3				.16	
4	2.5	.2				.08	
5	3.0	.2				.06	
6	3.5	.2				.03	
7	3.8	0				0	
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 9/29 16:00
Observer JW BG
Project No. Vulcon

Stream Stennit Creek (SC-0)
Transect No.
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L 5.60
Temperature, C 21.67
Conductivity, uhmos 513 us/cm
pH, su 7.33
ORP, mv NA

III. Physical Characterization

Stream Width, ft 15ft
Channel Width, ft
Pool ______ Length, ft ______
Riffle/Run ______ Length, ft ______
Tape Down (ft)
GPS

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow (cfs)	Comments
1	2.0	NA	—	—	—	—	
2	3.0	0.2	1ft	0.2	0.0	0	
3	4.0	0.4	1ft	0.4	0.0	0	
4	5.0	0.6	1ft	0.6	0.0	0	
5	6.0	0.9	1ft	0.9	0.0	0	
6	7.0	1.00	1ft	1.00	0.0	0	
7	8.0	0.6	1ft	0.6	0.05		
8	9.0	0.8	1ft	0.8	0.07		
9	10.0	0.8	1ft	0.8	0.12		
10	11.0	1.0	1ft	1.0	0.05		
11	12.0	0.9	1ft	0.9	0.08		
12	13.0	0.8	1ft	0.8	0.10		
13	14.0	0.6	1ft	0.6	0.11		
14	15.0	0.6	1ft	0.6	0.0	0	
15	16.0	0.2	1ft	0.2	0.0	0	
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 9/29/10 1300
Observer JLW BJG
Project No. Vulcan
Stream Unamed trib to Brushy Creek
Transect No.
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L 8.77
Temperature, C 26.19
Conductivity, uhmos 690 uS/cm
pH, su 8.21
ORP, mv

III. Physical Characterization

Stream Width, ft 1.5 ft
Channel Width, ft NA
Pool ______ Length, ft ______
Riffle/Run ______ Length, ft ______
Tape Down (ft)
GPS

Stream to shallow for Wading Rod – Used outfall (pipe) at pond

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow (cfs)	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

5gal took 16.83 sec.

5gal = 0.668405 ft³/16.83 sec → 0.04 ft³/sec

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 9/30/10 1100
Observer JLW BJG
Project No. Vulcan
Stream Ref.
Transect No.
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L 6.24
Temperature, C 16.66
Conductivity, uhmos 518 uS/cm
pH, su 7.71
ORP, mv

III. Physical Characterization

Stream Width, ft 8 ft
Channel Width, ft
Pool 40 Length, ft
Riffle/Run 40 Length, ft
Tape Down (ft)
GPS

RB

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	*m/sec Velocity ~~(fs)~~	Area Flow (cfs)	Comments
1	5.8	0			0		
2	6.0	.2			0		
3	7	.4			0		
4	8	.3			.04		
5	9	.4			.07		
6	10	.4			.21		
7	11	.4			.11		
8	12	.3			.07		
9	13	.4			.04		
10	14	.4			0		
11	15	.2			0		
12	16	0			0		
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

LB
↓ Right at Bank line

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Brushy Creek	LOCATION
STATION # BC-0 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS JLW BJG	

FORM COMPLETED BY JLW BJG	DATE 7/29/10 TIME 1350 AM [✓ PM]	REASON FOR SURVEY

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
____% ☐	%cloud cover	☐ ____%
☒	clear/sunny	☒

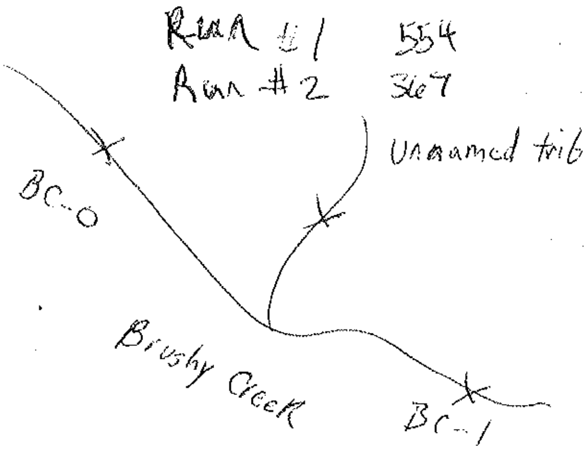
Has there been a heavy rain in the last 7 days?
☐ Yes ☒ No

Air Temperature 80°F

Other______

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)



Run #1 554
Run #2 367

STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☒ Other______

Catchment Area______ km²

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES	**Predominant Surrounding Landuse** ☐ Forest ☐ Commercial ☒ Field/Pasture ☐ Industrial ☒ Agricultural ☐ Other ____ ☐ Residential	**Local Watershed** ☐ No evidence ☒ Some potential sources ☐ Obvious sources **Local Watershed Erosion** ☐ None ☒ Moderate ☐ Heavy
RIPARIAN VEGETATION (18 meter buffer)	**Indicate the dominant type and record the dominant species present** ☐ Trees ☐ Shrubs ☒ Grasses ☐ Herbaceous **dominant species present** ____	
INSTREAM FEATURES	**Estimated Reach Length** ____m 40 yds **Estimated Stream Width** ____m 3.0 ft **Sampling Reach Area** ____m^2 **Area in km² (m^2x1000)** ____km^2 **Estimated Stream Depth** ____m 0.35 ft **Surface Velocity (at thalweg)** ____m/sec	**Canopy Cover** ☐ Partly open ☒ Partly shaded ☐ Shaded **High Water Mark**____m **Proportion of Reach Represented by Stream Morphology Types** ☐ Riffle____% ☐ Run____% ☐ Pool____% **Channelized** ☐ Yes ☒ No **Dam Present** ☐ Yes ☒ No
LARGE WOODY DEBRIS	**LWD** ____m^2 **Density of LWD** ____m^2/km^2 (LWD/reach area)	
AQUATIC VEGETATION	**Indicate the dominant type and record the dominant species present** ☒ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating ☐ Floating Algae ☐ Attached Algae dominant species present ____ Portion of the reach with aquatic vegetation 75 %	
WATER QUALITY	**Temperature**____°C 29.75 °C **Specific Conductance** 565 µS/cm **Dissolved Oxygen** 7.42 mg/L **pH** 7.49 **Turbidity** NA **WQ Instrument Used** MS 4a (ftn #5)	**Water Odors** ☒ Normal/None ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Fishy ☐ Other ____ **Water Surface Oils** ☐ Slick ☐ Sheen ☐ Globs ☐ Flecks ☒ None ☐ Other ____ **Turbidity (if not measured)** ☒ Clear ☐ Slightly turbid ☐ Turbid ☐ Opaque ☐ Stained ☐ Other____
SEDIMENT/ SUBSTRATE	**Odors** ☒ Normal ☐ Sewage ☐ Petroleum ☐ Chemical ☐ Anaerobic ☐ None ☐ Other ____ **Oils** ☒ Absent ☐ Slight ☐ Moderate ☐ Profuse	**Deposits** ☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand ☐ Relict shells ☐ Other ____ **Looking at stones which are not deeply embedded, are the undersides black in color?** ☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			**ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)**		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	Sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")	5			
Cobble	64-256 mm (2.5" – 10")	35	Muck-Mud	Black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1" – 2.5")	40			
Sand	0.06 – 2mm (gritty)	10	Marl	Grey, shell fragments	
Silt	0.004-0.06 mm	10			
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Brusky Creek	LOCATION Upstream from unnamed trib.
STATION # BC-O RIVERMILE	STREAM CLASS
LAT 36.13920 LONG -91.16516	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS JLW BJG	
FORM COMPLETED BY JLW BJG	DATE 9/29/10 TIME 1350 AM [✓ PM] REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 [✓ 9] 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 [✓ 14] 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 [✓ 9] 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

	Habitat Parameter	Condition Category			
		Optimal	Suboptimal	Marginal	Poor
Parameters to be evaluated broader than sampling reach	**6. Channel Alteration**	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
	SCORE	20 19 18 [✓ 17] 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1 0
	8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
	SCORE ___ (LB)	Left Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
	9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
	SCORE ___ (LB)	Left Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
	10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
	SCORE ___ (LB)	Left Bank 10 9	8 7 6	[✓ 5] 4 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 9	8 7 6	[✓ 5] 4 3	2 1 0

Total Score __________

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET
(FRONT)

Brushy Creek

STREAM NAME BC-1	LOCATION
STATION # BC-1 RIVERMILE	STREAM CLASS
LAT 36.13865 LONG -91.16251	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS JLW & BJG	

FORM COMPLETED BY JLW, BJG	DATE 9/29/10 TIME 0900 [✓ AM] PM	REASON FOR SURVEY Vulcan UAA

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
100 % ☐	%cloud cover	☐ ____%
☒	clear/sunny	☒

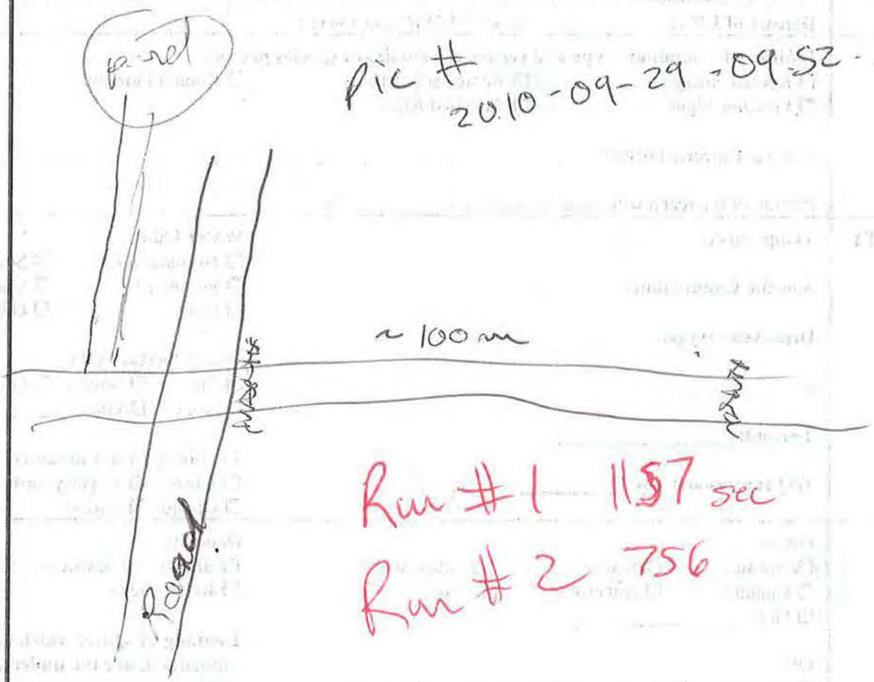
Has there been a heavy rain in the last 7 days?
☐ Yes ☒ No

Air Temperature ~18. °C

Other____________

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)



Pic # 2010-09-29-0952.53 JPG

Run #1 1157 sec

Run #2 756

STREAM CHARACTERIZATION

Stream Subsystem
☐ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☐ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☐ Other__________

Catchment Area________km²

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☐ Agricultural ☐ Other ________
☐ Residential

Local Watershed
☐ No evidence ☐ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☐ Trees ☐ Shrubs ☒ Grasses ☐ Herbaceous

dominant species present ________

INSTREAM FEATURES

Estimated Reach Length _____m

Estimated Stream Width _____m

Sampling Reach Area _____m^2

Area in km^2 (m^2x1000) _____km^2

Estimated Stream Depth _____m

Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☒ Partly open ☐ Partly shaded ☐ Shaded

High Water Mark______m

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle____% ☐ Run______%
☐ Pool______%

Channelized ☐ Yes ☐ No

Dam Present ☐ Yes ☐ No

LARGE WOODY DEBRIS

LWD ________m^2

Density of LWD ________m^2/km^2 **(LWD/reach area)** NA

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☐ Rooted emergent ☒ Rooted submergent ☐ Rooted Floating ☐ Free floating
☒ Floating Algae ☒ Attached Algae

dominant species present ________

Portion of the reach with aquatic vegetation ________%

WATER QUALITY

Temperature______°C 18.20

Specific Conductance 619 uS/cm

Dissolved Oxygen 5.64 mg/L

pH 6.36

Turbidity ________

WQ Instrument Used MS 4a FHN #5

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other ________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ________

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other________

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ________

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other ________

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☐ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	Sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5" – 10")	10%	Muck-Mud	Black, very fine organic (FPOM)	100%
Gravel	2-64 mm (0.1" – 2.5")	25%			
Sand	0.06 – 2mm (gritty)		Marl	Grey, shell fragments	
Silt	0.004-0.06 mm	65%			
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Brushy Creek	LOCATION
STATION # BC-1 RIVERMILE	STREAM CLASS
LAT 36.13865 LONG 91.16251	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS JLW & BJG	
FORM COMPLETED BY JLW & BJG	DATE 9/29/10 TIME 9:00 [✓ AM] PM REASON FOR SURVEY UAA

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	[✓ 5] 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	[✓ 5] 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

	Habitat Parameter	Condition Category			
		Optimal	Suboptimal	Marginal	Poor
Parameters to be evaluated broader than sampling reach	**6. Channel Alteration**	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
	SCORE	20 19 18 17 16	15 [✓ 14] 13 12 11	10 9 8 7 6	5 4 3 2 1 0
	7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
	SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1 0
	8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
	SCORE ___ (LB)	Left Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
	9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
	SCORE ___ (LB)	Left Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
	10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
	SCORE ___ (LB)	Left Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
	SCORE ___ (RB)	Right Bank 10 9	8 7 [✓ 6]	5 4 3	2 1 0

Total Score __________

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 9/28/10
Observer JLW
Project No. Vulcan

Stream Quarry, Black Rock, AR outfall (001)
Transect No.
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L 5.17
Temperature, C 20.76
Conductivity, uhmos 785 us/cm
pH, su 6.67
ORP, mv 447

III. Physical Characterization

Stream Width, ft
Channel Width, ft
Pool ____ Length, ft ____
Riffle/Run ____ Length, ft ____
Tape Down (ft)
GPS

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow (cfs)	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

* outfill does not normally have a flow in current conditions per David smith. pump was turned on to collect sample. David said he will caculate a millions of gallons per day for the pumps tomorow

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME out fall 001	LOCATION
STATION #______ RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS BJG JLW	
FORM COMPLETED BY	DATE 28Sep10 TIME 16:40 AM PM

REASON FOR SURVEY UAA

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
___% ☐	%cloud cover	☐ ___%
☑	clear/sunny	☐

Has there been a heavy rain in the last 7 days?
☐ Yes ☑ No

Air Temperature ~78 °C

Other______

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)

photo on phone

STREAM CHARACTERIZATION

Stream Subsystem
☐ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☐ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☐ Other______

Catchment Area______km²

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☐ Field/Pasture ☒ Industrial
☐ Agricultural ☐ Other ___________
☐ Residential

Local Watershed
☐ No evidence ☐ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☐ None ☐ Moderate ☒ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☐ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous

dominant species present ____

INSTREAM FEATURES

Estimated Reach Length _____m

Estimated Stream Width _____m

Sampling Reach Area _____m^2

Area in km^2 (m^2x1000) _____km^2

Estimated Stream Depth _____m

Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☐ Partly open ☐ Partly shaded ☐ Shaded

High Water Mark_______m

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle_____% ☐ Run_______%
☐ Pool______%

Channelized ☐ Yes ☐ No

Dam Present ☐ Yes ☐ No

LARGE WOODY DEBRIS

LWD ________m^2

Density of LWD _________m^2/km^2 **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☐ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae

dominant species present ____

Portion of the reach with aquatic vegetation _________%

WATER QUALITY

Temperature_______°C

Specific Conductance ________

Dissolved Oxygen ___________

pH______________

Turbidity ________________

WQ Instrument Used __________

Water Odors
☐ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other __________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☐ None ☐ Other ________________

Turbidity (if not measured)
☐ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other__________

SEDIMENT/ SUBSTRATE

Odors
☐ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ______________________

Oils
☐ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other _______________

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☐ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			**ORGANIC SUBSTRATE COMPONENTS** (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	Sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5" – 10")		Muck-Mud	Black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1" – 2.5")				
Sand	0.06 – 2mm (gritty)		Marl	Grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	<0.004 mm (slick)				

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Unnamed trib to Brushy
STATION # UT-0 RIVERMILE ______
LAT ______ LONG ______
STOREF #
INVESTIGATORS JLW & BJG
FORM COMPLETED BY JLW BJG

LOCATION
STREAM CLASS
RIVER BASIN
AGENCY

DATE 9/29/10
TIME 1300 AM [✓ PM]

REASON FOR SURVEY

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
___% ☐	%cloud cover	☐ ___%
☒	clear/sunny	☒

Has there been a heavy rain in the last 7 days?
☐ Yes ☒ No

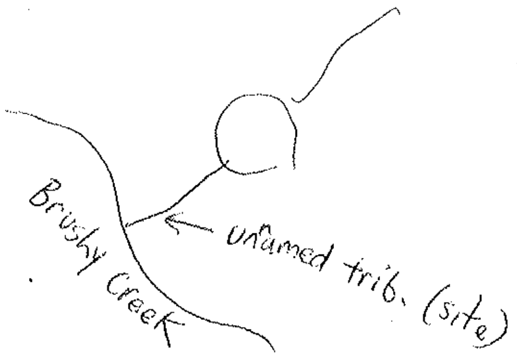
Air Temperature 77°F ☒

Other______

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)

Run 1 152 sec
Run 2 156 sec



STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ~~☒ Intermittent~~ ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☒ Mixture of origins
☐ Swamp and bog ☐ Other outfall from quarry

Catchment Area ______km²

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PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest
☒ Field/Pasture
☐ Agricultural
☐ Residential
☐ Commercial
☐ Industrial
☐ Other ____________

Local Watershed
☐ No evidence ☒ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☐ Trees ☐ Shrubs ☒ Grasses ☐ Herbaceous

dominant species present ____________________________________

INSTREAM FEATURES

Estimated Reach Length 13 m

Estimated Stream Width 0.5 m

Sampling Reach Area 7 m²

Area in km² (m²x1000) _____km²

Estimated Stream Depth _____~~m~~ 0.2 ft

Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☐ Partly open ☐ Partly shaded ☐ Shaded

High Water Mark _______m NA

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle_____% ☐ Run 100 %
☐ Pool_____%

Channelized ☐ Yes ☒ No

Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD __________m²
Density of LWD __________m²/km² (LWD/reach area) NA

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☒ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☒ Floating Algae ☒ Attached Algae

dominant species present ____________________________________

Portion of the reach with aquatic vegetation 5 %

WATER QUALITY

Temperature______°C 26.19

Specific Conductance 690 µs/cm

Dissolved Oxygen 8.77

pH 8.21

Turbidity ________________

WQ Instrument Used MS 4a (ftn#5)

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other ____________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ________________

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other__________

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ____________________

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other ______________

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)

Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		
Boulder	> 256 mm (10")	
Cobble	64-256 mm (2.5" – 10")	
Gravel	2-64 mm (0.1" – 2.5")	35
Sand	0.06 – 2mm (gritty)	5
Silt	0.004-0.06 mm	60
Clay	<0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	Sticks, wood, coarse plant materials (CPOM)	
Muck-Mud	Black, very fine organic (FPOM)	35
Marl	Grey, shell fragments	

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Unnamed trib to Brushy	LOCATION	
STATION # UT-D RIVERMILE ______	STREAM CLASS	
LAT ______ LONG ______	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS JLW & BJG		
FORM COMPLETED BY JLW & BJG	DATE 9/29/10 TIME 1300 AM [✓ PM]	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 [✓ 12] 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 [✓ 4] 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 17 [✓ 16]	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 [✓ 2] 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0

Total Score __________

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Stennit Creek	LOCATION
STATION # SC-0 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS JLW BJG	
FORM COMPLETED BY JLW BJG	DATE 9/29 TIME 1600 AM PM

REASON FOR SURVEY

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
____% ☐	%cloud cover	☐ ____%
☑	clear/sunny	☑

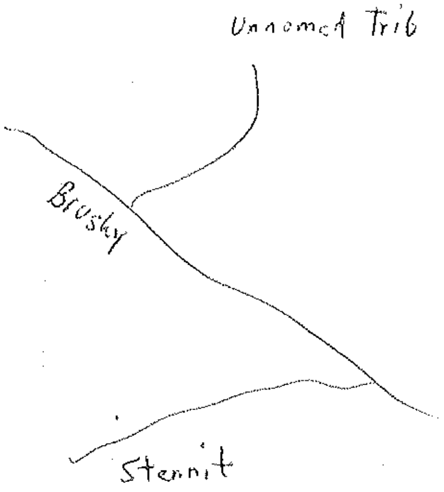
Has there been a heavy rain in the last 7 days?
☐ Yes ☒ No

Air Temperature 83 °C

Other ____________

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)



Run 1: 570
Run 2: 574

STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☒ Other ______

Catchment Area ________ km²

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☐ Agricultural ☐ Other ________
☐ Residential

Local Watershed
☐ No evidence ☐ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☒ Trees ☐ Shrubs ☒ Grasses ☐ Herbaceous
dominant species present ________

INSTREAM FEATURES

Estimated Reach Length _____m 120 yds
Estimated Stream Width _____m 15 ft
Sampling Reach Area _____m²
Area in km² (m²x1000) _____km²
Estimated Stream Depth _____m
Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☐ Partly open ☒ Partly shaded ☐ Shaded

High Water Mark _____m 6 ft

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle _____% 10 ☐ Run 60 _____%
☐ Pool _____% 30

Channelized ☐ Yes ☒ No
Dam Present ☐ Yes ☒ No

LARGE WOODY DEBRIS

LWD ________m² Some present
Density of LWD ________m²/km² **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☒ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae

dominant species present ________

Portion of the reach with aquatic vegetation ________%

WATER QUALITY

Temperature______°C 21.67°C
Specific Conductance 513 MS/cm
Dissolved Oxygen 5.60
pH 7.33
Turbidity NA
WQ Instrument Used MS4a (ftn #5)

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other ________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ________

Turbidity (if not measured)
☐ Clear ☒ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other ________

SEDIMENT/ SUBSTRATE

Odors
☐ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☒ Other Methane

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other ________

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)

Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		
Boulder	> 256 mm (10")	
Cobble	64-256 mm (2.5" – 10")	
Gravel	2-64 mm (0.1" – 2.5")	
Sand	0.06 – 2mm (gritty)	
Silt	0.004-0.06 mm	100
Clay	<0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	Sticks, wood, coarse plant materials (CPOM)	20
Muck-Mud	Black, very fine organic (FPOM)	20
Marl	Grey, shell fragments	

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Stennett Creek
LOCATION
STATION # SC-0 RIVERMILE ________
STREAM CLASS
LAT ________ LONG ________
RIVER BASIN
STORET #
AGENCY
INVESTIGATORS JLW BJG
FORM COMPLETED BY JLW BJG
DATE 9/29
TIME 1600 AM [✓ PM]
REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 [✓ 11]	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 [✓ 1] 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 [✓ 17] 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 [✓ 13] 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 [✓ 17] 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 [✓ 2] 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	[✓ 8] 7 6	5 4 3	2 1 0

Total Score __________

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 9/30/10 7:40am
Observer
Project No.
Stream Spring River (SR-1)
Transect No.
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L 6.61
Temperature, C 19.02
Conductivity, uhmos 463 us/cm
pH, su 7.78
ORP, mv

III. Physical Characterization

Stream Width, ft
Channel Width, ft
Pool _____ Length, ft _____
Riffle/Run _____ Length, ft _____
Tape Down (ft)
GPS

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow (cfs)	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
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16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (FRONT)

STREAM NAME Brushy Creek	LOCATION
STATION # BC-2 RIVERMILE ______	STREAM CLASS
LAT ______ LONG ______	RIVER BASIN
STORET #	AGENCY
INVESTIGATORS JLW BJG	
FORM COMPLETED BY	DATE 9/30/10 TIME 9:00 [✓ AM] PM REASON FOR SURVEY

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
____% ☐	%cloud cover	☐ ____%
☒	clear/sunny	☒

Has there been a heavy rain in the last 7 days?
☐ Yes ☒ No

Air Temperature 55°F

Other ______

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)

Run1 778
Run2 532

STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☐ Mixture of origins
☐ Swamp and bog ☒ Other ______

Catchment Area ______ km^2

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition – Form 1

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☐ Forest ☐ Commercial
☒ Field/Pasture ☐ Industrial
☐ Agricultural ☐ Other ____________
☐ Residential

Local Watershed
☐ No evidence ☒ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☐ None ☒ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☒ Trees ☐ Shrubs ☒ Grasses ☐ Herbaceous
dominant species present ______________________________

INSTREAM FEATURES

Estimated Reach Length _____m
Estimated Stream Width _____m
Sampling Reach Area _____m^2
Area in km^2 (m^2x1000) _____km^2
Estimated Stream Depth _____m
Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☐ Partly open ☐ Partly shaded ☐ Shaded

High Water Mark_______m

Proportion of Reach Represented by Stream Morphology Types *
☐ Riffle ~~20~~ % 40 ☐ Run 10 %
☐ Pool 50 %

Channelized ☐ Yes ☐ No
Dam Present ☒ Yes ☐ No Bridge w/pipe

LARGE WOODY DEBRIS

LWD _________m^2
Density of LWD Some m^2/km^2 **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☒ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae

dominant species present ______________________________

Portion of the reach with aquatic vegetation __________%

WATER QUALITY

Temperature______°C 16.55
Specific Conductance 567 μS/cm
Dissolved Oxygen 5.96
pH 7.50
Turbidity NA
WQ Instrument Used MS 4a (flat#5)

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other __________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ______________

Turbidity (if not measured)
☐ Clear ☒ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other__________

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ____________________

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other ______________

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)

Substrate Type	Diameter	% Composition in Sampling Reach
Bedrock		
Boulder	> 256 mm (10")	
Cobble	64-256 mm (2.5" – 10")	5%
Gravel	2-64 mm (0.1" – 2.5")	25%
Sand	0.06 – 2mm (gritty)	25%
Silt	0.004-0.06 mm	45%
Clay	<0.004 mm (slick)	

ORGANIC SUBSTRATE COMPONENTS (does not necessarily add up to 100%)

Substrate Type	Characteristic	% Composition in Sampling Area
Detritus	Sticks, wood, coarse plant materials (CPOM)	[illegible]
Muck-Mud	Black, very fine organic (FPOM)	some
Marl	Grey, shell fragments	

* Note that this is to compare to SC-0. SC-0 was dominated by Pool/Run morphology. ~~we~~ this is as close in stream morphology as we can find to SC-0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Brushy Creek	LOCATION	
STATION # BC-2 RIVERMILE ______	STREAM CLASS	
LAT 36.14820 LONG 91.14528	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS JLW BJG		
FORM COMPLETED BY	DATE 9/30/10 TIME 9:00 [✓ AM] PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	**Suboptimal**	**Marginal**	**Poor**
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 14 13 12 11	[✓ 10] 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 [✓ 8] 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	[✓ 5] 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 18 [✓ 17] 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 17 16	15 14 13 12 11	10 9 8 [✓ 7] 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 [✓ 7] 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 9	8 7 6	[✓ 5] 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 9	8 7 6	[✓ 5] 4 3	2 1 0

Total Score ____________

FTN Associates, LTD.
Physical Characterization - Worksheet

I. General

Date/Time 14 40 30Sep10
Observer BJG JLW
Project No.

Stream Spring River
Transect No. SR-0
Picture No.

II. In-Situ Data

Dissolved Oxygen, mg/L 6.49
Temperature, C 21.75
Conductivity, uhmos 398 µs/cm
pH, su 7.97
ORP, mv NA

III. Physical Characterization

Stream Width, ft
Channel Width, ft
Pool Length, ft
Riffle/Run Length, ft
Tape Down (ft)
GPS

Transect Reading	Tape Reading from LB/RB	Depth (ft)	Section Length (ft)	Area (ft2)	Velocity (fs)	Area Flow (cfs)	Comments
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
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20							
21							
22							
23							
24							
25							
26							
27							
Totals	0		0			0.000	cfs
						0	gpm

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET
(FRONT)

STREAM NAME Ref	LOCATION	
STATION # Ref RIVERMILE ______	STREAM CLASS	
LAT ______ LONG ______	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS JLW BJG		
FORM COMPLETED BY JLW BJG	DATE 9/30 TIME 1100 [✓ AM] PM	REASON FOR SURVEY

WEATHER CONDITIONS

Now		Past 24 Hours
☐	storm (heavy rain)	☐
☐	rain (steady rain)	☐
☐	showers (intermittent)	☐
____% ☐	%cloud cover	☐ ____%
☒	clear/sunny	☒

Has there been a heavy rain in the last 7 days?
☐ Yes ☒ No

Air Temperature 75 °C

Other______

SITE LOCATION/MAP

Draw a map of the site and indicate the areas sampled (or attach a photograph)

Run #1 956

Run #2 611

STREAM CHARACTERIZATION

Stream Subsystem
☒ Perennial ☐ Intermittent ☐ Tidal

Stream Type
☐ Coldwater ☒ Warmwater

Stream Origin
☐ Glacial ☐ Spring-fed
☐ Non-glacial montane ☒ Mixture of origins
☐ Swamp and bog ☐ Other______

Catchment Area______km²

PHYSICAL CHARACTERIZATION/WATER QUALITY FIELD DATA SHEET (BACK)

WATERSHED FEATURES

Predominant Surrounding Landuse
☒ Forest ☐ Commercial
☐ Field/Pasture ☐ Industrial
☐ Agricultural ☐ Other ____________
☐ Residential

Local Watershed
☐ No evidence ☒ Some potential sources
☐ Obvious sources

Local Watershed Erosion
☒ None ☐ Moderate ☐ Heavy

RIPARIAN VEGETATION (18 meter buffer)

Indicate the dominant type and record the dominant species present
☒ Trees ☐ Shrubs ☐ Grasses ☐ Herbaceous
dominant species present ______________________________

INSTREAM FEATURES

Estimated Reach Length _____m
Estimated Stream Width _____m
Sampling Reach Area _____m^2
Area in km^2 (m^{2}x1000) _____km^2
Estimated Stream Depth _____m
Surface Velocity (at thalweg) _____m/sec

Canopy Cover
☐ Partly open ☒ Partly shaded ☐ Shaded

High Water Mark_______m

Proportion of Reach Represented by Stream Morphology Types
☐ Riffle_____% ☐ Run_______%
☐ Pool_____%

Channelized ☐ Yes ☐ No
Dam Present ☐ Yes ☐ No

LARGE WOODY DEBRIS

LWD __________m^2
Density of LWD __________m^2/km^2 **(LWD/reach area)**

AQUATIC VEGETATION

Indicate the dominant type and record the dominant species present
☒ Rooted emergent ☐ Rooted submergent ☐ Rooted Floating ☐ Free floating
☐ Floating Algae ☐ Attached Algae

dominant species present ______________________________

Portion of the reach with aquatic vegetation __________%

WATER QUALITY

Temperature_______°C 16.66°C
Specific Conductance 518 uS/cm
Dissolved Oxygen 6.24 mg/L
pH 7.71
Turbidity NA
WQ Instrument Used MS 4a (ftn#5)

Water Odors
☒ Normal/None ☐ Sewage
☐ Petroleum ☐ Chemical
☐ Fishy ☐ Other ___________

Water Surface Oils
☐ Slick ☐ Sheen ☐ Globs ☐ Flecks
☒ None ☐ Other ____________

Turbidity (if not measured)
☒ Clear ☐ Slightly turbid ☐ Turbid
☐ Opaque ☐ Stained ☐ Other__________

SEDIMENT/ SUBSTRATE

Odors
☒ Normal ☐ Sewage ☐ Petroleum
☐ Chemical ☐ Anaerobic ☐ None
☐ Other ______________________

Oils
☒ Absent ☐ Slight ☐ Moderate ☐ Profuse

Deposits
☐ Sludge ☐ Sawdust ☐ Paper fiber ☐ Sand
☐ Relict shells ☐ Other ______________

Looking at stones which are not deeply embedded, are the undersides black in color?
☐ Yes ☒ No

INORGANIC SUBSTRATE COMPONENTS (should add up to 100%)			**ORGANIC SUBSTRATE COMPONENTS** (does not necessarily add up to 100%)		
Substrate Type	**Diameter**	**% Composition in Sampling Reach**	**Substrate Type**	**Characteristic**	**% Composition in Sampling Area**
Bedrock			Detritus	Sticks, wood, coarse plant materials (CPOM)	
Boulder	> 256 mm (10")				
Cobble	64-256 mm (2.5" - 10")	50	Muck-Mud	Black, very fine organic (FPOM)	
Gravel	2-64 mm (0.1" - 2.5")	45			
Sand	0.06 – 2mm (gritty)	5	Marl	Grey, shell fragments	
Silt	0.004-0.06 mm				
Clay	<0.004 mm (slick)				

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (FRONT)

STREAM NAME Ref	LOCATION	
STATION # Ref RIVERMILE ______	STREAM CLASS	
LAT ______ LONG ______	RIVER BASIN	
STORET #	AGENCY	
INVESTIGATORS JLW BJG		
FORM COMPLETED BY JLW	DATE 9/30 TIME 1100 [✓ AM] PM	REASON FOR SURVEY

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are <u>not</u> new fall and <u>not</u> transient).	40-70% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	20-40% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 20% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE	20 19 18 17 16	15 [✓ 14] 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment. Layering of cobble provides diversity of niche space.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Velocity/Depth Regime	All four velocity/depth regimes present (slow-deep, slow-shallow, fast-deep, fast-shallow). (Slow is < 0.3 m/s, deep is > 0.5 m.)	Only 3 of the 4 regimes present (if fast-shallow is missing, score lower than if missing other regimes).	Only 2 of the 4 habitat regimes present (if fast-shallow or slow-shallow are missing, score low).	Dominated by 1 velocity/ depth regime (usually slow-deep).
SCORE	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 30-50% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE	20 19 18 17 16	[✓ 15] 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

HABITAT ASSESSMENT FIELD DATA SHEET—HIGH GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE	20 19 [✓ 18] 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Frequency of Riffles (or bends)	Occurrence of riffles relatively frequent; ratio of distance between riffles divided by width of the stream <7:1 (generally 5 to 7); variety of habitat is key. In streams where riffles are continuous, placement of boulders or other large, natural obstruction is important.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream is between 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is a ratio of >25.
SCORE	20 19 18 [✓ 17] 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank) Note: determine left or right side by facing downstream.	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE ___ (LB)	Left Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank)	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE ___ (LB)	Left Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 [✓ 9]	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impaeted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE ___ (LB)	Left Bank 10 [✓ 9]	~~8~~ 7 6	5 4 3	2 1 0
SCORE ___ (RB)	Right Bank 10 [✓ 9]	~~8~~ 7 6	5 4 3	2 1 0

Total Score __________

FTN Associates Calibration Form

Pre Calibration (FTN #5)

Date/Time: 7/28/10
Prepared By: JLW
Location: Quarry, BlackRock, AR
Project #: Vulcan QAA

Instrument Type	Instrument ID	Parameter	Standard (su)	Units	Temp. of Standard (degrees C)	Reading Prior to Calibration	Calibrated	Post Calibration Reading	Comments
MS4a	5	~~pH~~	~~7~~	su			Y N		
		pH	4	su	30.95	3.79	[✓ Y] N	4.00	
		pH	10	su	29.89	7.00	[✓ Y] N	7.00	
		Cond	0	uS/cm	30.13	0.00	[✓ Y] N	0.00	
		Cond	447	uS/cm	29.77	460	[✓ Y] N	447	
		DO	755	mm/Hg	30.19	8.21 mg/l	[✓ Y] N	8.33 mg/l	
		Temp	30.25	Degrees C	30.25		Y N	N/A	
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		

Notes:

pH Calibration (pH Method: EPA 150.1)

Specific Conductivity Calibration: Calibrate first to zero using air, then to standard using standard solution.

DO Calibration: Use 100% air saturation method. Use pressure in mm/Hg as standard to calibrate in DO% saturation. Record readings in mg/l.

Temperature Calibration: No calibration is necessary. Simply record temperature of standard using thermometer while in calibration cup. Then record hydrolab temperature reading.

Precision and accuracy targets are commonly based on relative percent differences. Precision is either based on a relative percent difference between replicates (analytical precision) or duplicate samples (method precision) as follows:

Relative Percent Difference (RPD) = 100 * (rep1 - rep2)/(rep1 + rep2)/2

The standard deviation of the average of a group of replicate (or duplicate) pairs represents the precision for a measurement parameter. For accuracy, percent difference is determined relative to a known or target value and is as follows:

Percent Difference = 100 * (observed - target)/target

FTN Associates Calibration Form

Date/Time: 30 Sep09 07:09
Prepared By: JLW
Location: Hotel
Project #: Vulcan V4t

Instrument Type	Instrument ID	Parameter	Standard (su)	Units	Temp. of Standard (degrees C)	Reading Prior to Calibration	Calibrated	Post Calibration Reading	Comments
		pH	7	su	16.23	6.98	[✓ Y] N	7.00	
		pH	4	su	16.22	4.15	[✓ Y] N	4.00	
		pH	~~10~~	su	—	—	Y N		
		Cond	0	uS/cm	15.72	0	[✓ Y] N	0	
		Cond		uS/cm	[illegible]/15.99	438 [illegible]	[✓ Y] N	447	
		DO	762	mm/Hg	15.99	8.33 mg/l	[✓ Y] N	8.21 mg/l	
		Temp	16.0	Degrees C	16.0		Y N	N/A	
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		

Notes:

pH Calibration (pH Method: EPA 150.1)

Specific Conductivity Calibration: Calibrate first to zero using air, then to standard using standard solution.

DO Calibration: Use 100% air saturation method. Use pressure in mm/Hg as standard to calibrate in DO% saturation. Record readings in mg/l.

Temperature Calibration: No calibration is necessary. Simply record temperature of standard using thermometer while in calibration cup. Then record hydrolab temperature reading.

Precision and accuracy targets are commonly based on relative percent differences. Precision is either based on a relative percent difference between replicates (analytical precision) or duplicate samples (method precision) as follows:

Relative Percent Difference (RPD) = 100 * (rep1 - rep2)/(rep1 + rep2)/2

The standard deviation of the average of a group of replicate (or duplicate) pairs represents the precision for a measurement parameter. For accuracy, percent difference is determined relative to a known or target value and is as follows:

Percent Difference = 100 * (observed - target)/target

FTN Associates Calibration Form

Date/Time: 9/29/10 8:00 am
Prepared By: JLW
Location: Hotel, Pocahontas, AR
Project #: Vulcan

Instrument Type	Instrument ID	Parameter	Standard (su)	Units	Temp. of Standard (degrees C)	Reading Prior to Calibration	Calibrated	Post Calibration Reading	Comments
		pH	7	su	17.46	6.72	[✓ Y] N	7.00	
		pH	4	su	16.58	3.85	[✓ Y] N	4.00	
		pH	~~10~~	su			Y N		
		Cond	0	uS/cm	17.41	0.0	[✓ Y] N	0.0	
		Cond	447	uS/cm	17.41	436	[✓ Y] N	447	
		DO	762	mm/Hg	17.52	8.81 mg/l	Y N	96.94 mg/l	
		Temp		Degrees C			Y N	N/A	
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		
							Y N		

Notes:
pH Calibration (pH Method: EPA 150.1)
Specific Conductivity Calibration: Calibrate first to zero using air, then to standard using standard solution.
DO Calibration: Use 100% air saturation method. Use pressure in mm/Hg as standard to calibrate in DO% saturation. Record readings in mg/l.
Temperature Calibration: No calibration is necessary. Simply record temperature of standard using thermometer while in calibration cup. Then record hydrolab temperature reading.

Precision and accuracy targets are commonly based on relative percent differences. Precision is either based on a relative percent difference between replicates (analytical precision) or duplicate samples (method precision) as follows:

Relative Percent Difference (RPD) = 100 * (rep1 - rep2)/(rep1 + rep2)/2

The standard deviation of the average of a group of replicate (or duplicate) pairs represents the precision for a measurement parameter. For accuracy, percent difference is determined relative to a known or target value and is as follows:

Percent Difference = 100 * (observed - target)/target

AMERICAN INTERPLEX CORPORATION LABORATORIES

CHAIN OF CUSTODY / ANALYSIS REQUEST FORM

PAGE OF

Client: FTN

Project Reference: 6532-021

Project Manager: PJD

Sampled By: JLW/BJG

PO No.

AIC CONTROL NO:

AIC PROPOSAL NO:

Carrier:

Received Temperature C 2 C

AIC No.	Sample Identification	Date/Time Collected	GRAB	COMP	SAMPLE MATRIX WATER	SOIL		NO OF BOTTLES	Cl, SO4, Alk, TDS	Metals *	Toxicity **										Remarks
1	001	9/28/10 1640	✓		✓			5	X	X	X										
2	BC-1	9/29/10 0900	✓		✓			2	X	X											
3	UT-0	9/29/10 1300	✓		✓			2	X	X											
4	BC-0	9/29/10 1350	✓		✓			5	X	X	X										
5	SC-0	9/29/10 1600	✓		✓			2	X	X											
6	SR-1	9/30/10 0740	✓		✓			2	X	X											
7	SR-11	9/30/10 0740	✓		✓			2	X	X											Field pH calibration
		Container Type							P	P	P										on ________ @ ______
		Preservative							NO	N	NO										Buffer:

G = Glass
NO = none
P = Plastic
S = Sulfuric acid pH2
V = VOA vials
N = Nitric acid pH2
H = HCl to pH2
B = NaOH to pH12
T = Sodium Thiosulfate
Z = Zinc acetate

Turnaround Time Requested: (Please circle)
NORMAL or EXPEDITED IN ____ DAYS
Expedited results requested by: ____________
Who should AIC contact with questions: ____________
Phone: ____________ Fax: ____________
Report Attention to:
Report Address to:

Relinquished By:	Date/Time 10/1/10 1000	Received By:	Date/Time
Relinquished By:	Date/Time	Received in Lab By:	Date/Time 10-1-10 1001

Comments:
*Metals: Ca, Mg, K, Na
** See protocol provided by Pat Downey

5/01 WS 5981 8/02 FORM 0060

AMERICAN INTERPLEX CORPORATION LABORATORIES

CHAIN OF CUSTODY / ANALYSIS REQUEST FORM

PAGE OF

Client: FTN

Project Reference: 6532-021

Project Manager: PJD

Sampled By: JLW BJG

PO No.

AIC CONTROL NO:

AIC PROPOSAL NO:

Carrier:

Received Temperature C 2°C

AIC No.	Sample Identification	Date/Time Collected	GRAB	COMP	SAMPLE MATRIX WATER	SAMPLE MATRIX SOIL		NO OF BOTTLES	Cl, SO4, Alk, TDS	Metals*	Toxicity**										Remarks
8	BC-2	9/30/10 0900	✓		✓			2	X	X											
9	Ref	9/30/10 1100	✓		✓			2	X	X											
10	SR-0	9/30/10 1440	✓		✓			2	X	X											
																					Field pH calibration
		Container Type							P	P											on ________ @ ______
		Preservative							NO	N											Buffer:

G = Glass
NO = none
P = Plastic
S = Sulfuric acid pH2
V = VOA vials
N = Nitric acid pH2
H = HCl to pH2
B = NaOH to pH12
T = Sodium Thiosulfate
Z = Zinc acetate

Turnaround Time Requested: (Please circle)
NORMAL or EXPEDITED IN ____ DAYS
Expedited results requested by: ____________
Who should AIC contact with questions: ____________
Phone: ____________ Fax: ____________
Report Attention to:
Report Address to:

Relinquished By:	Date/Time 10/1/10 1000	Received By:	Date/Time
Relinquished By:	Date/Time	Received in Lab By:	Date/Time 10-1-10 1000

Comments:
* Metals: Ca, Mg, K, Na
** See protocol provided by Pat Downey

APPENDIX F

Benthic Invertibrate Taxa and Counts from Spring and Fall Surveys

Table F.1. Benthic invertebrate taxa counts for the unnamed tributary during the spring survey (June 14, 2010).

Subclass	**Order**	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
	Diptera	Chironomidae		40	GC	22.99
	Decapoda	Cambaridae	*Cambarus*	1	GC	0.57
	Trichoptera	Hydropsychidae	*Hydropsyche*	6	FC	3.45
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	9	FC	5.17
Oligochaeta				90	GC	51.72
	Amphipoda	Hyalellidae	*Hyalella*	2	GC	1.15
	Basommatophora	Physidae	*Physa*	1	SC	0.57
	Basommatophora	Lymnaeidae	*Pseudosuccinea*	2	SC	1.15
	Trichoptera	Philopotamoidae	*Chimarra*	1	FC	0.57
	Ephemeroptera	Caenidae	*Caenis*	8	GC	4.60
	Diptera	Tipulidae		6	SH	3.45
	Diptera	Tabanidae		2	PR	1.15
	Ephemeroptera	Baetidae	*Baetis*	2	GC	1.15
	Odonata	Coenagrionidae	*Argia*	1	PR	0.57
	Coleoptera	Haliplidae	*Peltodytes*	2	SH	1.15
	Odonata	Aeshnidae	*Boyeria*	1	PR	0.57
Totals				**174**		**100**

Table F.2. Benthic invertebrate taxa and counts for Brushy Creek at BC0 during the spring survey (June 15, 2010).

Order	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
Diptera	Chironomidae		55	GC	28.21
Trichoptera	Hydropsychidae	*Hydropsyche*	50	FC	25.64
Trichoptera	Philopotamoidae	*Chimarra*	4	FC	2.05
Ephemeroptera	Caenidae	*Caenis*	30	GC	15.38
Trichoptera	Hydropsychidae	*Cheumatopsyche*	37	FC	18.97
Decapoda	Cambaridae		1	GC	0.51
Coleoptera	Elmidae	*Stenelmis*	8	SC	4.10
Ephemeroptera	Heptageniidae	*Stenonema*	2	SC	1.03
Ephemeroptera	Heptageniidae	*Stenacron*	1	SC	0.51
Isopoda			3	GC	1.54
Diptera	Tipulidae		3	SH	1.54
Odonata	Aeshnidae	*Boyeria*	1	PR	0.51
Totals			**195**		**100**

Table F.3. Benthic invertebrate taxa and counts for Brushy Creek at BC1 during the spring survey (June 14, 2010).

Class	**Order**	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	2	FC	1.20
	Diptera	Chironomidae		38	GC	22.89
	Ephemeroptera	Baetidae	*Baetis*	*2*	GC	1.20
	Ephemeroptera	Caenidae	*Caenis*	5	GC	3.01
	Decapoda	Cambaridae		1	GC	0.60
	Coleoptera	Gyrinidae	*Dineutus*	5	PR	3.01
	Coleoptera	Elmidae	*Stenelmis*	8	SC	4.82
	Coleoptera	Elmidae	*Dubiraphia*	1	GC	0.60
	Ephemeroptera	Heptageniidae		2	SC	1.20
	Odonata	Coenagrionidae	*Amphiagrion*	17	PR	10.24
	Odonata	Macromiidae	*Macromia*	2	PR	1.20
	Odonata	Gomphidae	*Progomphus*	1	PR	0.60
	Odonata	Gomphidae	*Dromogomphus*	5	PR	3.01
	Odonata	Calopteryginidae	*Calopteryx*	1	PR	0.60
	Basommatophora	Physidae	*Physa*	8	SC	4.82
	Coleoptera	Hydrophilidae	*Berosus*	3	PR	1.81
	Hemiptera	Gelastocoridae	*Gelastocoris*	1	SC	0.60
Pelecypoda				60	FC	36.14
	Hemiptera	Veliidae	*Rhagovelia*	2	PR	1.20
	Diptera	Tabanidae		2	PR	1.20
Totals				**166**		**100**

Table F.4. Benthic invertebrate taxa and counts for Stennitt Creek at SC0 during the spring survey (June 15, 2010).

Class	Subclass	Order	Family	Genus	Total Organisms	Feeding Group	Percent Relative Abundance
		Trichoptera	Hydropsychidae	*Potamyia*	12	FC	8.63
		Trichoptera	Hydropsychidae	*Hydropsyche*	3	FC	2.16
		Diptera	Chironomidae		34	GC	24.46
		Odonata	Coenagrionidae	*Argia*	1	PR	0.72
		Odonata	Coenagrionidae		1	PR	0.72
		Isopoda			19	GC	13.67
		Basommatophora	Ancylidae	*Laevapex*	2	SC	1.44
Pelecypoda					24	FC	17.27
		Coleoptera	Elmidae	*Dubiraphia*	10	SC	7.19
		Ephemeroptera	Heptageniidae		4	SC	2.88
		Diptera	Simuliidae		1	FC	0.72
		Odonata	Gomphidae	*Dromogomphus*	1	PR	0.72
	Oligochaeta				16	GC	11.51
		Coleoptera	Elmidae	*Ancyronyx*	2	OM	1.44
		Trichoptera			4		2.88
		Plecoptera	Perlidae	*Neoperla*	1	PR	0.72
		Odonata	Macromiidae	*Didymops*	1	PR	0.72
		Decapoda	Cambaridae		2	GC	1.44
		Basommatophora	Physidae	*Physa*	1	SC	0.72
Totals					**139**		**100**

Table F.5. Benthic invertebrate taxa and counts for Clear Creek at REF during the spring survey (June 16, 2010).

Subclass	**Order**	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	29	FC	16.57
	Trichoptera	Hydropsychidae	*Hydropsyche*	1	FC	0.57
	Ephemeroptera	Baetidae	*Baetis*	7	GC	4.00
	Amphipoda			16	GC	9.14
	Basommatophora	Planorbidae	*Gyraulus*	1	SC	0.57
	Basommatophora	Lymnaeidae		46	SC	26.29
	Diptera	Chironomidae		9	GC	5.14
	Ephemeroptera	Heptageniidae		36	SC	20.57
	Odonata	Aeshnidae	*Boyeria*	2	PR	1.14
	Odonata	Gomphidae	*Stylogomphus*	1	PR	0.57
	Odonata	Gomphidae	*Dromogomphus*	1	PR	0.57
Oligochaeta				3	GC	1.71
	Trichoptera	Philopotamoidae	*Chimarra*	9	FC	5.14
	Megaloptera	Corydalidae	*Nigronia*	2	PR	1.14
	Coleoptera	Psephenidae	*Ectopria*	10	SC	5.71
	Coleoptera	Elmidae	*Stenelmis*	2	SC	1.14
Totals				**175**		**100**

Table F.6. Benthic invertebrate taxa and counts for unnamed tributary during the fall survey (September 29, 2010).

Class	**Subclass**	**Order**	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
		Diptera	Chironomidae		14	GC	14.14
		Decapoda	Cambaridae	*Cambarus*	1	GC	1.01
		Trichoptera	Hydropsychidae	*Cheumatopsyche*	1	FC	1.01
	Oligochaeta				22	GC	22.22
		Isopoda			14	GC	14.14
		Basommatophora	Physidae	*Physa*	22	SC	22.22
		Ephemeroptera	Caenidae	*Caenis*	1	GC	1.01
		Coleoptera	Elmidae	*Stenelmis*	1	SC	1.01
		Basommatophora	Lymnaeidae	*Fossaria*	6	SC	6.06
		Odonata	Libellulidae	*Libellula*	4	PR	4.04
		Odonata	Coenagrionidae		2	PR	2.02
		Diptera	Stratiomyidae		2	GC	2.02
Pelecypoda					9	FC	9.09
Totals					**99**		**100**

Table F.7. Benthic invertebrate taxa and counts for Brushy Creek at BC0 during the fall survey (September 29, 2010).

Class	Subclass	Order	Family	Genus	Total Organisms	Feeding Group	Percent Relative Abundance
		Diptera	Chironomidae		9	GC	4.81
		Odonata	Calopteryginidae	*Calopteryx*	3	PR	1.60
		Odonata	Coenagrionidae	*Argia*	26	PR	13.90
	Oligocheata				10	GC	5.35
		Odonata	Gomphidae	*Gomphus*	1	PR	0.53
		Coleoptera	Hydrophilidae	*Berosus*	1	PR	0.53
		Coleoptera	Elmidae	*Dubriaphia*	5	GC	2.67
		Hemiptera	Gerridae	*Trepobates*	1	PR	0.53
		Hemiptera	Gerridae	*Limnoporus*	1	PR	0.53
		Basommatophora	Lymnaeidae	*Pseudocuccinea*	2	SC	1.07
		Basommatophora	Physidae	*Physa*	1	SC	0.53
Gastropoda					1	SC	0.53
		Trichoptera	Philopotamoidae	*Chimarra*	7	FC	3.74
		Ephemeroptera	Caenidae	*Caenis*	5	GC	2.67
		Trichoptera	Hydropsychidae	*Hydropsyche*	2	FC	1.07
		Trichoptera	Hydropsychidae	*Cheumatopsyche*	15	FC	8.02
		Decapoda	Cambaridae		4	GC	2.14
		Coleoptera	Elmidae	*Stenelmis*	20	SC	10.70
		Ephemeroptera	Heptageniidae		65	SC	34.76
		Coleoptera	Gyrinidae	*Dineutus*	2	PR	1.07
		Isopoda			2	GC	1.07
		Diptera	Tipulidae		3	SH	1.60
		Odonata	Aeshnidae	*Boyeria*	1	PR	0.53
Totals					**187**		**100**

Table F.8. Benthic invertebrate taxa and counts for Brushy Creek at BC1 during the fall survey (September 30, 2010).

Class	**Order**	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	2	FC	1.20
	Diptera	Chironomidae		38	GC	22.89
	Ephemeroptera	Baetidae	*Baetis*	*2*	GC	1.20
	Ephemeroptera	Caenidae	*Caenis*	5	GC	3.01
	Decapoda	Cambaridae		1	GC	0.60
	Coleoptera	Gyrinidae	*Dineutus*	5	PR	3.01
	Coleoptera	Elmidae	*Stenelmis*	8	SC	4.82
	Coleoptera	Elmidae	*Dubiraphia*	1	GC	0.60
	Ephemeroptera	Heptageniidae		2	SC	1.20
	Odonata	Coenagrionidae	*Amphiagrion*	17	PR	10.24
	Odonata	Macromiidae	*Macromia*	2	PR	1.20
	Odonata	Gomphidae	*Progomphus*	1	PR	0.60
	Odonata	Gomphidae	*Dromogomphus*	5	PR	3.01
	Odonata	Calopteryginidae	*Calopteryx*	1	PR	0.60
	Basommatophora	Physidae	*Physa*	8	SC	4.82
	Coleoptera	Hydrophilidae	*Berosus*	3	PR	1.81
	Hemiptera	Gelastocoridae	*Gelastocoris*	1	SC	0.60
Pelecypoda				60	FC	36.14
	Hemiptera	Veliidae	*Rhagovelia*	2	PR	1.20
	Diptera	Tabanidae		2	PR	1.20
Totals				**166**		**100**

Table F.9. Benthic invertebrate taxa and counts for Brushy Creek at BC2 during the fall survey (September 30, 2010).

Class	**Subclass**	**Order**	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
		Trichoptera	Hydropsychidae	*Cheumatopsyche*	1	FC	0.47
		Odonata	Libellulidae	*Libellula*	8	PR	3.74
		Odonata	Coenagrionidae	*Argia*	8	PR	3.74
		Diptera	Chironomidae		116	GC	54.21
		Ephemeroptera	Baetidae	*Baetis*	1	GC	0.47
		Ephemeroptera	Caenidae	*Caenis*	30	GC	14.02
		Isopoda			1	GC	0.47
		Diptera	Brachycera		1		0.47
Pelecypoda					8	FC	3.74
		Coleoptera	Elmidae	*Dubiraphia*	3	SC	1.40
		Coleoptera	Elmidae	*Stenelmis*	4	SC	1.87
		Coleoptera	Hydrophilidae	*Berosus*	1	PR	0.47
		Coleoptera	Haliplidae	*Peltodytes*	1	SH	0.47
	Oligochaeta				20	GC	9.35
		Decapoda	Cambaridae		2	GC	0.93
		Basommatophora	Physidae	*Physa*	9	SC	4.21
Totals					**214**		**100**

Table F.10. Benthic invertebrate taxa and counts for Stennitt Creek at SC0 during the fall survey (September 29, 2010).

Class	**Subclass**	**Order**	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
		Trichoptera	Hydropsychidae	*Cheumatopsyche*	3	FC	1.56
		Odonata	Calopteryginidae	*Hetaerina*	1	PR	0.52
		Odonata	Calopteryginidae	*Calopteryx*	2	PR	1.04
		Diptera	Chironomidae		70	GC	36.46
		Odonata	Coenagrionidae	*Argia*	10	PR	5.21
		Odonata	Macromiidae	*Macromia*	2	PR	1.04
		Odonata	Gomphidae	*Progomphus*	2	PR	1.04
		Odonata	Gomphidae	*Dromogomphus*	6	PR	3.13
		Isopoda			17	GC	8.85
Pelecypoda					7	FC	3.65
		Coleoptera	Elmidae	*Dubiraphia*	18	SC	9.38
		Coleoptera	Elmidae	*Stenelmis*	18	SC	9.38
	Oligochaeta				20	GC	10.42
		Ephemeroptera	Heptageniidae		9	SC	4.69
		Gastropoda	Planorbidae	*Planorbula*	1	SC	0.52
		Gastropoda	Planorbidae	*Helisoma*	1	SC	0.52
		Coleoptera	Elmidae	*Ancyronyx*	3	OM	1.56
		Decapoda	Cambaridae		2	GC	1.04
Totals					**192**		**100**

Table F.11. Benthic invertebrate taxa and counts for Clear Creek at REF during the fall survey (September 30, 2010).

Subclass	**Order**	**Family**	**Genus**	**Total Organisms**	**Feeding Group**	**Percent Relative Abundance**
	Trichoptera	Hydropsychidae	*Cheumatopsyche*	29	FC	16.57
	Trichoptera	Hydropsychidae	*Hydropsyche*	1	FC	0.57
	Ephemeroptera	Baetidae	*Baetis*	7	GC	4.00
	Amphipoda			16	GC	9.14
	Basommatophora	Planorbidae	*Gyraulus*	1	SC	0.57
	Basommatophora	Lymnaeidae		46	SC	26.29
	Diptera	Chironomidae		9	GC	5.14
	Ephemeroptera	Heptageniidae		36	SC	20.57
	Odonata	Aeshnidae	*Boyeria*	2	PR	1.14
	Odonata	Gomphidae	*Stylogomphus*	1	PR	0.57
	Odonata	Gomphidae	*Dromogomphus*	1	PR	0.57
Oligochaeta				3	GC	1.71
	Trichoptera	Philopotamoidae	*Chimarra*	9	FC	5.14
	Megaloptera	Corydalidae	*Nigronia*	2	PR	1.14
	Coleoptera	Psephenidae	*Ectopria*	10	SC	5.71
	Coleoptera	Elmidae	*Stenelmis*	2	SC	1.14
Totals				**175**		**100**

APPENDIX G

TDS and Sulfate Data from Outfall 001

Table G.1. Monitoring data for TDS and SO_4^{-2} and proportion of TDS as SO_4^{-2} at Outfall 001, from 2003 to 2011.

Date	TDS (mg/L)	SO_4^{-2} (mg/L)	SO_4^{-2}/TDS	Date	TDS (mg/L)	SO_4^{-2} (mg/L)	SO_4^{-2}/TDS
01/29/2003	590	NM	NA	02/27/2006	654	NM	NA
02/27/2003	566	NM	NA	03/22/2006	621	NM	NA
03/26/2003	496	NM	NA	04/25/2006	704	NM	NA
04/29/2003	664	NM	NA	05/24/2006	690	NM	NA
05/27/2003	510	NM	NA	06/27/2006	623	NM	NA
06/23/2003	630	NM	NA	07/20/2006	802	NM	NA
07/28/2003	672	NM	NA	08/24/2006	676	NM	NA
08/27/2003	728	NM	NA	09/22/2006	562	NM	NA
09/25/2003	784	NM	NA	10/24/2006	720	NM	NA
10/29/2003	704	NM	NA	11/27/2006	601	NM	NA
11/19/2003	588	NM	NA	12/18/2006	538	NM	NA
12/18/2003	648	NM	NA	01/18/2007	379	NM	NA
01/20/2004	492	NM	NA	02/20/2007	536	NM	NA
02/24/2004	432	NM	NA	04/26/2007	526	NM	NA
03/25/2004	477	NM	NA	05/24/2007	520	NM	NA
04/22/2004	502	NM	NA	06/25/2007	559	NM	NA
05/24/2004	444	NM	NA	07/30/2007	580	NM	NA
06/22/2004	566	NM	NA	09/24/2007	674	NM	NA
07/27/2004	482	NM	NA	10/24/2007	712	NM	NA
08/25/2004	490	NM	NA	11/26/2007	566	NM	NA
09/23/2004	570	NM	NA	12/19/2007	630	NM	NA
10/26/2004	428	NM	NA	01/22/2008	557	NM	NA
11/17/2004	466	NM	NA	02/25/2008	514	NM	NA
12/21/2004	498	NM	NA	03/25/2008	390	NM	NA
01/27/2005	424	NM	NA	04/25/2008	404	NM	NA
02/24/2005	450	NM	NA	05/25/2008	427	NM	NA
03/28/2005	440	NM	NA	06/25/2008	498	NM	NA
04/26/2005	438	NM	NA	07/22/2008	592	NM	NA
05/31/2005	460	NM	NA	08/25/2008	582	NM	NA
06/27/2005	541	NM	NA	09/25/2008	526	NM	NA
07/27/2005	580	NM	NA	10/25/2008	628	NM	NA
08/24/2005	566	NM	NA	11/25/2008	542	NM	NA
09/26/2005	694	NM	NA	12/25/2008	544	NM	NA
10/24/2005	632	NM	NA	02/24/2009	500	200	0.4
11/28/2005	654	NM	NA	12/14/2009	494	164	0.33
12/20/2005	610	NM	NA	01/25/2010	388	112	0.29
01/30/2006	719	NM	NA	02/23/2010	362	111	0.31

Table G.1. Continued.

Date	TDS (mg/L)	SO_4^{-2} (mg/L)	SO_4^{-2}/TDS	Date	TDS (mg/L)	SO_4^{-2} (mg/L)	SO_4^{-2}/TDS
03/24/2010	436	72	0.17	09/28/2010	530	190	0.36
04/19/2010	360	130	0.36	10/20/2010	554	135	0.24
04/26/2010	327	91	0.28	11/15/2010	410	142	0.35
05/10/2010	400	140	0.35	11/23/2010	609	134	0.22
05/24/2010	428	105	0.24	12/13/2010	570	159	0.28
06/15/2010	430	120	0.28	01/25/2011	618	132	0.21
06/28/2010	496	127	0.26	02/22/2011	600	250	0.42
07/26/2010	495	156	0.31	03/21/2011	469	114	0.24
08/18/2010	470	150	0.32	04/25/2011	394	108	0.27
08/24/2010	582	115	0.20	05/23/2011	384	74	0.19
09/27/2010	570	171	0.30	06/22/2011	459	78	0.17

APPENDIX B

Membrane Alternatives

EXAMPLE CALCULATIONS

Determine overall flow that must be treated to assure complaince with TDS and Sulfate
Assume mixing of treated and untreated flow to achieve compliance based on treatment efficiency

Treatment Plant Hours of operation per day (recommend 8)	8	hrs/day	
Treatment plant safety factor (recommend 1.5)	1.5		
Average Daily Flow (QA)	0.384	mgd	
Initial concentration TDS	394	mg/L	
Initial Concentration sulfate	101.1	mg/L	
Target concentration TDS	240	mg/L	
Target Concentration sulfate	30	mg/L	
Removal percentage of TDS	95	%	0.05
Removal percentage of sulfate	95	%	
Reject ratio (RR)	30	%	
No of passes (NP)	3		

Example Design based on TDS - Determine the treated flow rate (QT)
to reduce the overall conc of TDS down to compliance level
Design flow (QD) considers 1.5 safety factor and 8 hr/day operation

QT = Avg Total flow (QA) - untreated flow (QU) = 0.384 - QU		0.226	
(0.384-QU)*(394*0.05) + 394*QU = 0.384*240			
(394-19.7)*QU=92.16-7.56			
QU=0.23 MGD	QU	0.226	mgd
QU=0.23 MGD			
QT=0.154 mgd	QT	0.158	mgd
QD=0.154*1.5*24/8 =.71 mgd	QD	0.711	mgd
Reject Ratio Factor (RRF) = RR/100^NP = 30/100^3 = .027	RRF	0.027	
(WT) weight sludge = amount of solids generated by treated flow	WT	493.194	lb/day
=QT*TDSi*RTDS/100*8.34 = lbs/day=488			
Flow of sludge/yr (QR) = WT*365/0.027/8.34=gpy=791,000 gsl/yr	QR	2200	gal/day
	QRyr	803,000	gal/yr

rmr:12/18/2017

RO CALCULATIONS (TDS)

Determine overall flow that must be treated to assure compliance with TDS using RO
Assume mixing of treated and untreated flow to achieve compliance based on treatment efficiency

Treatment Plant Hours of operation per day (recommend 8)	8	hrs/day	
Treatment plant safety factor (recommend 1.5)	1.5		
Average Daily Flow (QA)	0.384	mgd	
Initial concentration TDS	394	mg/L	
Initial Concentration sulfate	101.1	mg/L	
Target concentration TDS	240	mg/L	
Target Concentration sulfate	30	mg/L	
Removal percentage of TDS	95	%	0.05
Removal percentage of sulfate	95	%	
Reject ratio (RR)	30	%	
No of passes (NP)	3		

See Example calcs on separate sheet

Design based on TDS - Determine the treated flow rate (QT)
to reduce the overall conc of TDS down to compliance level
Design flow (QD) considers 1.5 safety factor and 8 hr/day operation

		0.226	
	QU	0.226	mgd
	QT	0.158	mgd
Design Flow	**QD**	0.711	mgd
	RRF	0.027	
	WT	493.194	lb/day
	QR	2200	gal/day
	QRyr	803,000	gal/yr

RO CALCULATIONS (sulfate)

Determine overall flow that must be treated to assure compliance with Sulfate using RO
Assume mixing of treated and untreated flow to achieve compliance based on treatment efficiency

Treatment Plant Hours of operation per day (recommend 8)	8	hrs/day	
Treatment plant safety factor (recommend 1.5)	1.5		
Average Daily Flow (QA)	0.384	mgd	
Initial concentration TDS	394	mg/L	
Initial Concentration sulfate	101.1	mg/L	
Target concentration TDS	240	mg/L	
Target Concentration sulfate	30	mg/L	
Removal percentage of TDS	95	%	0.05
Removal percentage of sulfate	95	%	0.05
Reject ratio (RR)	30	%	
No of passes (NP)	3		

See Example calcs on separate sheet

Design based on SO4 - Determine the treated flow rate (QT)
to reduce the overall conc of SO4 down to compliance level
Design flow (QD) considers safety factor and partial daily operation

0.099733

QU	0.100	mgd
QT	0.284	mgd
QD	1.279	mgd
RRF	0.027	
WT	887.385	lb/day
QR	3900	gal/day
QRyr	1,423,500	gal/yr

NF CALCULATIONS (TDS)

Determine overall flow that must be treated to assure complaince with TDS using nanofiltration
Assume mixing of treated and untreated flow to achieve compliance based on treatment efficiency

Treatment Plant Hours of operation per day (recommend 8)	8	hrs/day	
Treatment plant safety factor (recommend 1.5)	1.5		
Average Daily Flow (QA)	0.384	mgd	
Initial concentration TDS	394	mg/L	
Initial Concentration sulfate	101.1	mg/L	
Target concentration TDS	240	mg/L	
Target Concentration sulfate	30	mg/L	
Removal percentage of TDS	60	%	0.4
Removal percentage of sulfate	95	%	
Reject ratio (RR)	30	%	
No of passes (NP)	3		

See Example calcs on separate sheet

Design based on TDS - Determine the treated flow rate (QT)
to reduce the overall conc of TDS down to compliance level
Design flow (QD) considers 1.5 safety factor and 8 hr/day operation

0.134

QU	0.134	mgd
QT	0.250	mgd
QD	1.126	mgd
RRF	0.027	
WT	493.194	lb/day
QR	2200	gal/day
QRyr	803,000	gal/yr

NF CALCULATIONS (sulfate)

Determine overall flow that must be treated to assure compliance with Sulfate using nanofiltration
Assume mixing of treated and untreated flow to achieve compliance based on treatment efficiency

Treatment Plant Hours of operation per day (recommend 8)	8	hrs/day	
Treatment plant safety factor (recommend 1.5)	1.5		
Average Daily Flow (QA)	0.384	mgd	
Initial concentration TDS	394	mg/L	
Initial Concentration sulfate	101.1	mg/L	
Target concentration TDS	240	mg/L	
Target Concentration sulfate	30	mg/L	
Removal percentage of TDS	60	%	0.4
Removal percentage of sulfate	95	%	0.05
Reject ratio (RR)	30	%	
No of passes (NP)	3		

See Example calcs on separate sheet

Design based on SO4 - Determine the treated flow rate (QT)
to reduce the overall conc of SO4 down to compliance level
Design flow (QD) considers 1.5 safety factor and 8 hr/day operation

0.099733

QU	0.100	mgd
QT	0.284	mgd
QD	1.279	mgd
RRF	0.027	
WT	560.454	lb/day
QR	2500	gal/day
QRyr	912,500	gal/yr

ECONOMIC ANALYSIS

	Unit Cost	Units	RO TDS	RO SO4	NF TDS	NF SO4
Treated Flow (QT)		mgd	0.158	0.284	0.250	0.28426675
Design Treatment Flow rate (QD)		mgd	0.711	1.279	1.126	1.279200375
Volume of reject to be treated		mgd	0.213	0.384	0.338	0.384
Reject Volume Generated Qryr		gallons/year	803,000	1,423,500	803,000	912,500
Cap Cost of RO membrane system	$3.20 per gpd	$million	$2.3	$4.1		
Cap Cost of NF membrane system	$2.40 per gpd	$million			$2.7	$3.1
Cap Cost of pretreatment	$1.00 per gpd	$million	$0.7	$1.3	$1.1	$1.3
Cap Cost of reject water treatment	$3.20 per gpd	$million	$0.7	$1.2	$1.1	$1.2
Total Cap Cost		$million	$3.7	$6.6	$4.9	$5.6
Membrane Operating and maintenance cost	$0.0010 per gal	$million/yr	$0.0577	$0.1038	$0.0913	$0.1038
Pretreatment/disposal operations	$0.0012 per gallon	$million/yr	$0.0692	$0.1245	$0.1096	$0.1245
Disposal Cost	$0.25 per gallon disposed	$million/yr	$0.2008	$0.3559	$0.2008	$0.2281
Total operating Cost		$million/yr	$0.328	$0.584	$0.402	$0.456
Capital cost to meet limitation			$3.67	$6.60	$4.91	$5.58
Oerating cost to meet limitation			$0.328	$0.584	$0.402	$0.456
Present worth of operating cost based on 4% interest rate and 20 year term			$4.45	$7.94	$5.46	$6.20
Totl Present worth (cap+O/M)			$8.12	$14.54	$10.37	$11.78
				$14.54		$11.78
*Lowest total present worth (must meet both limitations)		$11.78				

APPENDIX C

Fish Data

Table C.1. Fish collection data set for Brushy Creek (2015) and Clear Creek (Fall 2016).

			Count																	
			BC-0A						**BC-1A**						**REF**					
Family	**Scientific Name**	**Common Name**	**Pool 1**	**Pool 2**	**Pool 3**	**Riffle 1**	**Riffle 2**	**Riffle 3**	**Pool 1**	**Pool 2**	**Pool 3**	**Riffle 1**	**Riffle 2**	**Riffle 3**	**Pool 1**	**Pool 2**	**Pool 3**	**Riffle 1**	**Riffle 2**	**Riffle 3**
Cyprinidae	*Campostoma anomalum*	central stoneroller	34	239	215	74	151	2	54	62	106	9	73	64	56	15	16	10	0	2
	Chrosomus erythrogaster	southern redbelly dace	0	0	0	0	0	0	0	0	0	0	0	0	36	14	18	2	0	1
	Hybognathus nuchalis	Mississippi silvery minnow	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0
	Luxilus chrysocephalus	striped shiner	0	0	0	0	0	0	5	0	16	0	0	5	0	0	0	0	0	0
	Luxilus zonatus	bleeding shiner	2	0	3	0	0	0	3	6	3	0	4	29	2	0	1	0	0	0
	Notropis boops	bigeye shiner	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
	Pimephales notatus	bluntnose minnow	41	0	8	1	0	0	7	13	3	2	1	6	0	0	0	0	0	0
	Semotilus atromaculatus	creek chub	1	6	3	4	8	0	1	0	0	0	0	0	37	19	4	1	0	3
Catostomidae	*Erimyzon oblongus*	creek chubsucker	19	5	3	0	0	0	6	1	3	0	0	0	5	2	2	0	0	1
Ictaluridae	*Ameiurus natalis*	yellow bullhead	0	1	3	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
	Noturus albater	Ozark madtom	0	0	0	0	0	0	0	0	0	0	0	0	6	7	11	0	8	2
Aphredoderidae	*Aphredoderus sayanus*	pirate perch	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	1
Fundulidae	*Fundulus catenatus*	northern studfish	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Fundulus olivaceus	blackspotted topminnow	49	38	38	6	13	8	16	10	23	0	0	3	8	11	8	0	0	2
Poeciliidae	*Gambusia affinis*	mosquitofish	4	1	0	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0
Centrarchidae	*Lepomis cyanellus*	green sunfish	4	21	7	2	0	0	9	3	7	0	2	1	11	7	5	0	0	2
	Lepomis macrochirus	bluegill	2	4	2	0	0	0	3	1	3	0	0	0	0	3	0	0	0	0
	Lepomis megalotis	longear sunfish	56	86	51	12	2	0	65	40	76	4	13	6	18	9	2	0	0	3
	Lepomis microlophus	redear sunfish	1	0	0	0	0	0	2	0	1	0	0	0	0	0	0	0	0	0
	Micropterus salmoides	largemouth bass	1	0	0	1	0	0	0	0	3	0	0	2	0	0	0	0	0	0
Percidae	*Etheostoma blennioides*	greenside darter	0	0	1	0	0	0	0	2	1	0	2	7	0	0	0	0	0	0
	Etheostoma flabellare	fantail darter	0	0	0	1	2	1	0	0	0	3	6	9	0	0	2	8	16	8
	Etheostoma uniporum	current darter	2	53	42	58	109	66	1	5	0	22	12	8	10	0	10	3	7	8
		Total	**1,572**						**856**						**450**					

APPENDIX D

Metric Values and Scores

Table D.1. Summary of Community Structure index values for fish sampling conducted in the reach of Brushy Creek upstream from the mouth of the unnamed tributary.

	BC-0A																	
	Pools								**Riffles**									
	1		**2**		**3**		**All Pools**		**1**		**2**		**3**		**All Riffles**		**All Pools and Riffles**	
Biocriteria Metric	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**
% Sensitive Individuals	1	0.9	0	0.0	1	1.1	1	0.6	1	0.6	1	0.7	1	1.3	1	0.8	1	0.6
% Cyprinidae	1	36.1	5	54.0	5	60.9	5	52.8	5	49.4	5	55.0	1	2.6	3	45.6	5	50.4
% Ictaluridae	0	0.0	1	0.2	1	0.8	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0	1	0.3
(% bullheads)	--	0.0	--	0.2		0.8	--	0.4		0.0	--	0.0	--	0.0	--	0.0	--	0.3
% Centrarchidae	1	29.6	1	24.4	3	16.0	1	22.5	5	9.4	3	0.7	0	0.0	3	3.2	1	16.0
(% Green sunfish)	--	1.9	--	4.6		1.9	--	3.1		1.3	--	0.0	--	0.0	--	0.4	--	2.2
% Percidae	1	0.9	5	11.7	5	11.4	3	9.4	5	36.9	5	38.4	5	87.0	5	45.1	5	21.3
% Primary Feeders	5	34.7	1	52.6	1	59.3	1	51.3	3	46.9	1	52.2	5	2.6	3	43.3	3	48.7
% Key Individuals	1	1.9	1	11.7	1	12.0	1	9.8	5	36.3	5	37.7	5	85.7	5	44.3	3	21.3
Diversity	3	2.7	1	2.1	1	2.1	3	2.4	1	1.9	1	1.5	1	0.7	1	1.7	1	2.3
# Species	3	13	1	10	1	12	3	15	1	10	1	7	1	4	1	10	3	16
IBI Score	16		16		19		19		26		22		19		22		23	
Watershed size (sq mi)	1.35																	
lower index	13																	
upper index	17																	

S - Metric score; V - Metric value

Table D.2. Summary of Community Structure index values for fish sampling conducted in the reach of Brushy Creek downstream from the mouth of the unnamed tributary.

	BC-1A																	
	Pools								Riffles								All Pools and Riffles	
	1		2		3		All Pools		1		2		3		All Riffles			
Biocriteria Metric	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**
% Sensitive Individuals	1	2.3	1	5.6	1	1.6	1	2.8	1	7.5	1	10.6	5	32.1	3	20.5	1	8.9
% Cyprinidae	3	40.2	5	56.6	5	52.0	5	49.6	1	27.5	3	69.0	1	74.3	3	65.9	5	55.1
% Ictaluridae	1	0.6	0	0.0	1	0.4	1	0.4	0	0.0	0	0.0	0	0.0	0	0.0	1	0.2
(% bullheads)	--	0.6		0.0		0.4	--	0.4		0.0		0.0		0.0	--	0.0	--	0.2
% Centrarchidae	1	45.4	1	30.8	1	36.6	1	37.8	5	10.0	5	13.3	5	6.4	5	9.6	1	28.2
(% Green sunfish)	--	5.2		2.1		2.8	--	3.4		0.0		1.8		0.7	--	1.0	--	2.6
% Percidae	1	0.6	1	4.9	1	0.4	1	1.6	5	62.5	5	17.7	5	17.1	5	23.5	3	9.1
% Primary Feeders	5	35.1	1	52.4	3	44.3	3	43.5	5	27.5	1	65.5	1	50.0	1	52.9	3	46.7
% Key Individuals	1	2.3	1	7.7	1	1.2	1	3.2	5	55.0	1	14.2	5	26.4	5	25.6	1	10.9
Diversity	3	2.5	1	2.3	1	2.3	3	2.4	1	1.8	1	1.8	3	2.5	3	2.4	3	2.6
# Species	3	14	1	10	3	13	3	16	1	5	1	8	1	11	1	11	3	17
IBI Score	19		12		17		19		24		18		26		26		21	
Watershed size (sq mi)	1.68																	
lower index	13																	
upper index	17																	

S - Metric score; V - Metric value

Table D.3. Summary of Community Structure index values for fish sampling conducted in Clear Creek (reference).

	REF																	
	Pools								Riffles									
	1		2		3		All Pools		1		2		3		All Riffles		All Pools and Riffles	
Biocriteria Metric	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**	**S**	**V**
% Sensitive Individuals	3	23.2	3	23.6	5	40.5	3	27.1	5	41.7	5	77.4	5	33.3	5	51.1	5	31.8
% Cyprinidae	3	69.1	5	53.9	5	49.4	5	61.0	5	54.2	0	0.0	1	18.2	1	21.6	5	53.3
% Ictaluridae	5	3.1	5	7.9	5	13.9	5	6.6	0	0.0	5	25.8	5	6.1	5	11.4	5	7.6
(% bullheads)	--	0.0		0.0		0.0	--	0.0		0.0		0.0		0.0	--	0.0	--	0.0
% Centrarchidae	1	14.9	1	21.3	1	8.9	1	15.2	0	0.0	0	0.0	1	15.2	1	5.7	1	13.3
(% Green sunfish)	--	5.7		7.9		6.3	--	6.4		0.0		0.0		6.1	--	2.3	--	5.6
% Percidae	3	5.2	0	0.0	5	15.2	3	6.1	5	45.8	5	74.2	5	48.5	5	56.8	5	16.0
% Primary Feeders	3	48.5	5	32.6	3	43.0	3	43.4	1	50.0	5	0.0	5	9.1	5	17.0	5	38.2
% Key Individuals	1	6.2	0	0.0	1	13.9	1	6.4	1	12.5	3	22.6	5	24.2	3	20.5	1	9.1
Diversity	5	2.9	5	3.0	5	3.0	5	3.1	1	1.9	1	1.5	5	3.1	3	2.7	5	3.3
# Species	3	13	1	10	1	11	3	15	1	5	1	3	1	11	1	11	3	15
IBI Score	27		25		31		29		19		25		33		29		35	
Watershed size (sq mi)		1.62																
lower index		13																
upper index		17																

S - Metric score; V - Metric value

APPENDIX E

Macroinvertebrate Data

Table E.1. Benthic macroinvertebrate collection data set from the five-minute travel kick method in Brushy Creek during Fall 2015.

Family	Scientific Name	Subsample Count	
		BC-0A	BC-1A
Acari	*Acari*	0	0
	Atractides sp.	0	0
	Hygrobates sp.	4	0
	Lebertia sp.	3	1
	Limnesia sp.	0	0
	Sperchon sp.	0	0
Annelida	*Aulodrilus pigueti*	0	0
	Branchiobdellidae	0	0
	Branchiura sowerbyi	2	0
	Bratislavia unidentata	0	0
	Enchytraeidae	0	1
	Limnodrilus hoffmeisteri	11	14
	Limnodrilus rubripenis	0	0
	Lumbricina	0	0
	Nais sp.	0	0
	Tubificidae w/ cap setae sp.	0	0
	Tubificidae w/o cap setae sp.	0	0
Bivalvia	*Corbicula sp.*	0	59
	Pisidium sp.	3	2
	Sphaeriidae	0	0
Coleoptera	*Berosus sp.*	0	1
	Dubiraphia sp.	9	5
	Ectopria sp.	0	0
	Elmidae	0	1
	Helichus basalis	0	0
	Helichus lithophilus	0	0
	Heterosternuta sp.	1	0
	Hydrophilidae	1	1
	Microcylloepus sp.	2	2
	Peltodytes sp.	6	0
	Psephenus herricki	0	0
	Stenelmis sp.	11	15
Crustacea	*Amphipoda*	1	0
	Cambaridae	0	0
	Crangonyctidae	0	0
	Crangonyx sp.	0	0
	Lirceus sp.	63	8
	Orconectes sp.	0	0

Table E.1. Benthic macroinvertebrate collection data set from the five-minute travel kick method in Brushy Creek during Fall 2015 (continued).

Family	**Scientific Name**	**Subsample Count**	
		BC-0A	**BC-1A**
Diptera-Chironomidae	*Ablabesmyia mallochi*	0	0
	Ablabesmyia sp.	0	0
	Chironomus sp.	0	0
	Cladotanytarsus sp.	0	0
	Clinotanypus sp.	0	0
	Corynoneura sp.	0	1
	Cricotopus bicinctus gr.	0	0
	Cricotopus sp.	0	1
	Cryptochironomus sp.	2	0
	Cryptotendipes sp.	0	0
	Dicrotendipes fumidus	1	0
	Dicrotendipes modestus	0	0
	Dicrotendipes sp.	0	0
	Diplocladius sp.	0	0
	Eukiefferiella brevicalcar gr.	0	0
	Eukiefferiella sp.	0	0
	Hydrobaenus sp.	0	0
	Larsia sp.	0	0
	Limnophyes sp.	0	0
	Microtendipes pedellus gr.	1	0
	Nanocladius sp.	0	0
	Nilotanypus sp.	0	0
	Orthocladius Complex	0	0
	Orthocladius sp.	0	1
	Parakiefferiella sp.	0	0
	Parametriocnemus sp.	0	1
	Paraphaenocladius sp.	0	0
	Paratanytarsus sp.	0	0
	Paratendipes sp.	0	0
	Phaenopsectra sp.	0	0
	Polypedilum aviceps	0	0
	Polypedilum flavum	0	10
	Polypedilum halterale gr.	0	0
	Polypedilum illinoense gr.	0	1
	Polypedilum scalaenum gr.	0	0
	Polypedilum sp.	0	0
	Polypedilum tritum	1	0
	Procladius sp.	0	0
	Pseudochironomus sp.	2	2
	Rheocricotopus sp.	0	0

Table E.1. Benthic macroinvertebrate collection data set from the five-minute travel kick method in Brushy Creek during Fall 2015 (continued).

Family	Scientific Name	Subsample Count	
		BC-0A	BC-1A
Diptera-Chironomidae	*Rheotanytarsus exiguus gr.*	0	1
	Stempellinella sp.	0	0
	Stictochironomus sp.	3	3
	Tanytarsini	0	0
	Tanytarsus sp.	0	2
	Thienemanniella sp.	0	0
	Thienemannimyia gr. sp.	2	1
	Tvetenia bavarica gr.	0	0
	Zavrelimyia sp.	1	0
Diptera	*Atrichopogon sp.*	0	0
	Bezzia/Palpomyia sp.	0	1
	Ceratopogoninae	1	1
	Chrysops sp.	0	1
	Dasyhelea sp.	1	2
	Dolichopodidae	0	0
	Hemerodromia sp.	0	2
	Hexatoma sp.	1	0
	Hybomitra sp.	0	0
	Limonia sp.	0	0
	Simulium sp.	0	1
	Tipula sp.	3	1
Ephemeroptera	*Baetis sp.*	1	0
	Caenis latipennis	124	0
	Caenis sp.	0	69
	Centroptilum sp.	1	2
	Isonychia sp.	0	0
	Maccaffertium sp.	5	0
	Maccaffertium terminatum	0	60
	Stenacron interpunctatum	8	0
	Stenacron sp.	0	0
	Stenonema femoratum	7	3
	Tricorythodes sp.	0	0
Gastropoda	*Ancylidae*	0	0
	Ferrissia sp.	0	3
	Gyraulus sp.	0	0
	Lymnaeidae	0	0
	Physa sp.	0	1
	Planorbidae	0	0
Hemiptera	*Belostoma sp.*	1	0
	Ranatra sp.	2	0

Table E.1. Benthic macroinvertebrate collection data set from the five-minute travel kick method in Brushy Creek during Fall 2015 (continued).

Family	**Scientific Name**	**Subsample Count**	
		BC-0A	**BC-1A**
Megaloptera	*Corydalus cornutus*	0	0
Odonata	*Anisoptera*	0	0
	Argia sp.	8	7
	Calopterygidae	0	0
	Calopteryx sp.	1	1
	Coenagrion/Enallagma sp.	0	0
	Coenagrionidae	4	3
	Gomphidae	1	0
	Hetaerina sp.	0	0
	Progomphus sp.	0	1
Plecoptera	*Acroneuria sp.*	0	0
	Neoperla sp.	0	1
	Plecoptera	0	0
Trichoptera	*Cheumatopsyche sp.*	7	10
	Chimarra sp.	2	5
	Helicopsyche borealis	2	2
	Hydropsyche betteni	9	0
	Hydropsyche sp.	0	0
	Hydroptila sp.	0	0
	Limnephilidae	11	2
	Oecetis persimilis	0	0
	Oecetis sp.	0	2
	Oxyethira sp.	0	0
	Polycentropodidae	0	0
	Polycentropus sp.	0	1
	Pycnopsyche sp.	0	0
Other Organisms	*Hydra sp.*	0	0
	Nematoda	0	0
	Prostoma sp.	0	1
	Turbellaria	8	10
	Total	**338**	**327**

Table E.2. Benthic macroinvertebrate collection data set from the five-minute travel kick method in Clear Creek during Fall 2016.

Family	Scientific Name	Subsample Count	
		REF-R2	REF-R3
Amphipoda	*Gammarus sp.*	3	7
Coleoptera	*Ectopria sp.*	0	7
	Dubiraphia sp.	0	3
	Helichus sp.	1	2
	Macronychus glabratus	1	0
	Microcylloepus sp.	5	5
	Optioservus sp.	2	1
Decapoda	*Cambaridae*	1	0
Diptera	*Atrichopogon sp.*	0	1
	Brillia sp.	2	1
	Caloparyphus/Euparyphus sp.	1	0
	Corynoneura sp.	2	3
	Cricotopus/Orthocladius sp.	0	1
	Empididae	1	0
	Hemerodromia sp.	1	1
	Microtendipes pedellus gr.	0	2
	Parametriocnemus sp.	1	1
	Paratanytarsus sp.	1	0
	Polypedilum aviceps	12	4
	Polypedilum flavum	15	17
	Rheotanytarsus pellucidus gr.	1	0
	Simulium sp.	5	2
	Stempellinella sp.	0	1
	Stenochironomus sp.	0	1
	Tanytarsus sp.	0	5
	Thienemanniella sp.	17	1
	Thienemannimyia gr. sp.	0	5
	Tipula sp.	22	14
	Tvetenia bavarica gr.	7	4
Ephemeroptera	*Baetis flavistriga*	0	5
	Baetis sp.	3	0
	Caenis sp.	1	5
	Ephemerellidae	1	0
	Isonychia sp.	5	12
	Maccaffertium sp.	26	56
	Stenacron sp.	4	18
Hoplonemertea	*Prostoma sp.*	0	2
Lepidoptera	*Petrophila sp.*	1	0

Table E.2. Benthic macroinvertebrate collection data set from the five-minute travel kick method in Clear Creek during Fall 2016 (continued).

Family	**Scientific Name**	**Subsample Count**	
		REF-R2	**REF-R3**
Littoridinomorpha	*Pleuroceridae*	30	19
Megaloptera	*Corydalus cornutus*	1	0
	Nigronia serricornis	1	1
Odonata	*Argia sp.*	1	0
	Calopteryx sp.	0	2
	Gomphidae	4	0
	Stylogomphus sp.	0	7
Plecoptera	*Perlodidae*	1	0
Trichoptera	*Cheumatopsyche sp.*	49	29
	Chimarra sp.	74	26
	Helicopsyche borealis	1	8
	Hydropsyche sp.	2	1
	Limnephilidae	1	0
	Oecetis sp.	4	7
	Polycentropus sp.	2	1
Trombidiformes	*Torrenticola sp.*	1	0
Tubificida	*Aulodrilus pigueti*	0	1
	Branchiura sowerbyi	0	2
	tubificoid Naididae w/o cap setae	0	1
Veneroida	*Pisidium sp.*	1	8
Other Organisms	*Turbellaria*	1	1
Total		316	301

Table E.3. Benthic macroinvertebrate collection data set from the modified multi- habitat approach based on Barbour et al. (1999) in Stennitt Creek during Fall 2016.

Family	Scientific Name	Subsample Count	
		SC-0	SC-1
Amphipoda	*Hyalella sp.*	0	3
Coleoptera	*Dubiraphia sp.*	30	46
	Helophorus sp.	0	2
	Macronychus glabratus	2	0
	Scirtidae	0	2
	Stenelmis sp.	1	3
	Tropisternus sp.	0	1
Decapoda	*Cambaridae*	2	3
Diptera	*Ablabesmyia mallochi*	0	5
	Ablabesmyia sp.	0	1
	Anopheles sp.	1	1
	Bezzia/Palpomyia sp.	0	1
	Ceratopogoninae	16	3
	Chironomus sp.	1	0
	Chrysops sp.	1	0
	Clinotanypus sp.	2	1
	Corynoneura sp.	5	0
	Dasyhelea sp.	0	1
	Dicrotendipes fumidus	8	0
	Hemerodromia sp.	3	0
	Hydrosmittia sp.	1	0
	Labrundinia sp.	3	0
	Limnophyes sp.	4	0
	Microtendipes pedellus gr.	0	2
	Myxosargus sp.	2	0
	Nilothauma sp.	0	1
	Paratanytarsus sp.	0	11
	Pericoma/Telmatoscopus sp.	3	0
	Paraphaenocladius sp.	2	0
	Paratanytarsus sp.	8	0
	Phaenopsectra sp.	2	0
	Polypedilum fallax gr.	2	2
	Polypedilum flavum	0	41
	Polypedilum illinoense gr.	29	11
	Potthastia longimana gr.	0	1
	Probezzia sp.	0	1
	Pseudochironomus sp.	1	0
	Rheocricotopus sp.	0	1

Table E.3. Benthic macroinvertebrate collection data set from the modified multi- habitat approach based on Barbour et al. (1999) in Stennitt Creek during Fall 2016 (continued).

Family	**Scientific Name**	**Subsample Count**	
		SC-0	**SC-1**
Diptera	*Rheotanytarsus exiguus gr.*	0	12
	Rheotanytarsus pellucidus gr.	0	5
	Stempellinella sp.	4	7
	Stenochironomus sp.	1	1
	Tanytarsus sp.	4	3
	Thienemanniella sp.	2	0
	Thienemannimyia gr. sp.	3	7
	Tribelos sp.	1	0
	Zavrelimyia sp.	0	1
Enchytraeida	*Enchytraeidae*	2	0
Ephemeroptera	*Caenis sp.*	26	56
	Maccaffertium sp.	0	3
	Stenacron sp.	0	2
Hoplonemertea	*Prostoma sp.*	2	0
Hygrophila	*Ferrissia sp.*	8	4
	Laevapex fuscus	2	1
	Lymnaeidae	2	0
	Micromenetus sp.	5	6
	Physa sp.	5	0
Isopoda	*Lirceus sp.*	13	6
Littoridinomorpha	*Hydrobiidae*	0	7
Littoridinomorpha	*Pleuroceridae*	1	0
Megaloptera	*Sialis sp.*	1	0
Odonata	*Argia sp.*	2	0
	Coenagrion/Enallagma sp.	1	5
	Gomphidae	1	0
	Hagenius brevistylus	0	1
Trichoptera	*Cheumatopsyche sp.*	0	2
	Leptoceridae	1	0
	Limnephilidae	1	3
	Oecetis sp.	5	2
Trombidiformes	*Lebertia sp.*	1	0
	Pionidae	1	0
Tubificida	*Aulodrilus pigueti*	1	0
	Dero digitata	0	1
	Dero flabelliger	0	1
	Limnodrilus sp.	1	1
	Pristina jenkinae	0	1
	Slavina appendiculata	0	1
	tubificoid Naididae w/ cap setae	2	0

Table E.3. Benthic macroinvertebrate collection data set from the modified multi- habitat approach based on Barbour et al. (1999) in Stennitt Creek during Fall 2016 (continued).

Family	**Scientific Name**	**Subsample Count**	
		SC-0	**SC-1**
Tubificida	*tubificoid Naididae w/o cap setae*	2	6
Veneroida	*Corbicula sp.*	20	3
	Pisidium sp.	54	10
Other Organisms	*Acari*	1	0
	Nematoda	0	1
	Total	**305**	**303**

Table E.4. Benthic macroinvertebrate collection data set from rock bag artificial substrates at BC-0A in Brushy Creek during Fall 2015.

Family	Scientific Name	Subsample Count								
		BC-0 R1 USRB	**BC-0 R1 MRB**	**BC-0 R1 DSRB**	**BC-0 R2 USRB**	**BC-0 R2 MRB**	**BC-0 R2 DSRB**	**BC-0 R3 USRB**	**BC-0 R3 MRB**	**BC-0 R3 DSRB**
Acari	*Acari*	0	0	0	0	0	0	0	1	1
	Atractides sp.	0	0	0	2	0	0	0	0	0
	Hygrobates sp.	0	0	0	0	0	1	0	0	0
	Lebertia sp.	2	1	2	8	0	1	0	3	1
	Limnesia sp.	0	0	0	0	0	2	0	1	0
	Sperchon sp.	0	1	0	1	0	0	0	0	0
Annelida	*Aulodrilus pigueti*	0	0	0	0	0	0	1	0	2
	Branchiobdellidae	0	1	0	0	0	0	1	0	0
	Branchiura sowerbyi	0	0	0	0	0	1	0	0	0
	Enchytraeidae	0	0	0	1	0	1	0	0	0
	Limnodrilus hoffmeisteri	16	12	0	6	8	34	24	8	10
	Limnodrilus rubripenis	4	0	0	0	0	1	0	0	0
	Lumbricina	0	0	0	0	1	0	0	0	0
	Tubificidae w/ cap setae sp.	0	1	0	0	0	0	0	0	0
	Tubificidae w/o cap setae sp.	0	0	4	0	0	0	0	0	0
Bivalvia	*Pisidium sp.*	173	14	0	4	24	20	22	21	10
Coleoptera	*Berosus sp.*	1	1	0	0	0	2	1	0	2
	Dubiraphia sp.	2	3	2	5	9	11	8	17	9
	Ectopria sp.	0	2	0	0	0	0	0	0	0
	Helichus basalis	0	0	0	0	0	1	0	0	1
	Microcylloepus sp.	0	1	6	1	2	1	0	1	3
	Psephenus herricki	0	1	0	0	4	0	0	1	2
	Stenelmis sp.	4	13	13	4	10	20	11	44	25
Crustacea	*Amphipoda*	0	0	0	0	0	0	0	1	0
	Cambaridae	0	0	0	0	5	1	0	0	0
	Crangonyctidae	0	0	0	0	0	0	1	0	0
	Crangonyx sp.	0	2	0	0	0	0	0	0	0
	Lirceus sp.	3	32	21	4	17	7	2	3	7
	Orconectes sp.	0	3	1	2	0	0	3	0	0
Diptera-Chironomidae	*Ablabesmyia mallochi*	0	2	0	1	0	0	0	0	0
	Ablabesmyia sp.	0	0	0	0	1	0	6	1	0
	Chironomus sp.	1	2	0	0	0	0	0	0	0
	Cladotanytarsus sp.	1	1	0	0	0	0	8	2	2
	Clinotanypus sp.	0	2	0	0	0	1	0	0	0
	Corynoneura sp.	0	1	0	1	0	1	3	1	0
	Cricotopus bicinctus gr.	0	2	0	0	0	0	0	1	0
	Cricotopus sp.	0	2	4	0	0	4	2	0	4
	Cryptochironomus sp.	9	4	1	1	3	6	5	4	9
	Dicrotendipes modestus	0	0	0	2	0	0	0	0	0
	Dicrotendipes sp.	2	16	1	0	0	2	1	1	1
	Diplocladius sp.	0	0	0	0	1	0	0	0	0
	Eukiefferiella brevicalcar gr.	0	0	1	0	0	0	0	0	0

Table E.4. Benthic macroinvertebrate collection data set from rock bag artificial substrates at BC-0A in Brushy Creek during Fall 2015 (continued).

Family	Scientific Name	Subsample Count								
		BC-0 R1 USRB	**BC-0 R1 MRB**	**BC-0 R1 DSRB**	**BC-0 R2 USRB**	**BC-0 R2 MRB**	**BC-0 R2 DSRB**	**BC-0 R3 USRB**	**BC-0 R3 MRB**	**BC-0 R3 DSRB**
Diptera-Chironomidae	*Eukiefferiella sp.*	0	0	0	0	1	0	0	0	0
	Hydrobaenus sp.	0	0	2	0	0	0	1	0	0
	Larsia sp.	1	0	0	0	0	0	4	0	0
	Limnophyes sp.	0	0	0	0	0	0	0	0	1
	Microtendipes pedellus gr.	2	0	3	2	0	1	1	1	5
	Orthocladius Complex	1	2	0	0	0	1	0	1	0
	Orthocladius sp.	0	1	1	1	4	5	1	1	1
	Parakiefferiella sp.	0	1	0	0	0	0	0	0	0
	Parametriocnemus sp.	2	3	40	0	16	3	3	1	0
	Paraphaenocladius sp.	0	0	0	0	0	0	0	1	0
	Paratanytarsus sp.	0	2	0	0	0	0	4	2	0
	Paratendipes sp.	0	1	0	0	5	1	2	0	0
	Phaenopsectra sp.	0	0	0	0	0	0	1	0	0
	Polypedilum aviceps	0	0	1	0	0	0	0	0	0
	Polypedilum flavum	0	0	30	0	0	1	0	0	0
	Polypedilum halterale gr.	0	0	0	0	0	2	0	1	2
	Polypedilum scalaenum gr.	1	0	0	0	5	4	1	0	11
	Polypedilum sp.	1	4	0	1	8	0	4	1	2
	Procladius sp.	0	0	0	1	0	0	0	0	1
	Pseudochironomus sp.	3	0	0	0	0	1	1	2	0
	Rheotanytarsus exiguus gr.	1	5	6	0	4	0	0	0	3
	Stempellinella sp.	0	0	0	0	0	0	1	0	0
	Stictochironomus sp.	6	0	0	0	0	5	1	1	4
	Tanytarsus sp.	1	0	9	3	0	0	2	0	1
	Thienemannimyia gr. sp.	6	12	21	21	16	15	38	13	20
	Tvetenia bavarica gr.	0	0	3	0	3	0	0	0	0
	Zavrelimyia sp.	0	0	0	1	0	1	0	0	1
Diptera	*Atrichopogon sp.*	0	0	0	0	1	0	0	0	0
	Bezzia/Palpomyia sp.	1	1	0	0	0	0	3	8	0
	Ceratopogoninae	0	0	0	0	0	2	0	0	2
	Dasyhelea sp.	1	0	1	0	4	0	3	1	1
	Dolichopodidae	0	0	0	1	0	0	0	0	0
	Hemerodromia sp.	0	5	7	0	3	3	0	8	5
	Hexatoma sp.	1	2	0	2	0	3	7	7	11
	Hybomitra sp.	0	0	0	1	0	0	1	0	4
	Limonia sp.	1	0	1	0	0	0	1	0	0
	Tipula sp.	1	0	8	3	5	2	2	0	0

Table E.4. Benthic macroinvertebrate collection data set from rock bag artificial substrates at BC-0A in Brushy Creek during Fall 2015 (continued).

Family	Scientific Name	Subsample Count								
		BC-0 R1 USRB	**BC-0 R1 MRB**	**BC-0 R1 DSRB**	**BC-0 R2 USRB**	**BC-0 R2 MRB**	**BC-0 R2 DSRB**	**BC-0 R3 USRB**	**BC-0 R3 MRB**	**BC-0 R3 DSRB**
Ephemeroptera	*Caenis latipennis*	0	0	0	0	0	0	0	0	90
	Caenis sp.	50	99	23	86	66	125	100	163	0
	Isonychia sp.	0	0	0	0	1	0	0	0	1
	Maccaffertium sp.	0	0	6	5	6	5	4	2	17
	Maccaffertium terminatum	0	9	0	0	0	0	0	0	0
	Stenacron interpunctatum	0	8	0	16	6	3	0	0	0
	Stenacron sp.	0	0	0	0	0	0	3	1	0
	Stenonema femoratum	1	10	1	5	3	4	1	0	0
Gastropoda	*Ancylidae*	0	0	0	10	0	0	0	2	2
	Ferrissia sp.	4	8	3	0	0	4	4	0	0
	Lymnaeidae	2	0	0	0	1	0	1	1	0
	Physa sp.	1	1	0	0	0	0	0	1	0
Megaloptera	*Corydalus cornutus*	0	0	1	0	0	0	0	0	0
Odonata	*Anisoptera*	1	0	0	0	0	0	0	0	0
	Argia sp.	0	0	2	1	1	1	2	2	1
	Calopteryx sp.	1	0	0	0	0	0	1	0	0
	Coenagrion/Enallagma sp.	0	0	0	0	0	0	0	0	1
	Hetaerina sp.	0	0	0	1	0	1	0	0	1
Plecoptera	*Acroneuria sp.*	0	0	0	0	0	0	1	0	0
	Plecoptera	0	0	3	0	2	0	0	0	1
Trichoptera	*Cheumatopsyche sp.*	1	6	18	0	12	3	6	1	10
	Chimarra sp.	0	1	7	1	1	2	0	0	0
	Helicopsyche borealis	3	0	3	0	0	8	7	5	10
	Hydropsyche betteni	0	2	26	2	9	0	0	0	0
	Hydropsyche sp.	0	0	0	0	0	1	1	0	0
	Hydroptila sp.	0	2	5	0	1	0	0	1	0
	Limnephilidae	1	3	0	1	7	3	0	2	0
	Oecetis sp.	2	1	0	0	0	0	6	8	0
	Polycentropodidae	0	1	0	0	0	1	0	0	0
	Polycentropus sp.	0	0	0	1	0	0	0	0	0
	Pycnopsyche sp.	0	0	8	0	0	0	3	0	0
Other Organisms	*Prostoma sp.*	2	0	0	0	1	1	0	1	7
	Turbellaria	0	2	3	0	6	3	4	4	4
	Total	**317**	**312**	**298**	**209**	**283**	**333**	**325**	**354**	**309**

Table E.5. Benthic macroinvertebrate collection data set from rock bag artificial substrates at BC-1A in Brushy Creek during Fall 2015.

Family	Scientific Name	Subsample Count								
		BC-1 R1 USRB	BC-1 R1 MRB	BC-1 R1 DSRB	BC-1 R2 USRB	BC-1 R2 MRB	BC-1 R2 DSRB	BC-1 R3 USRB	BC-1 R3 MRB	BC-1 R3 DSRB
Acari	*Lebertia sp.*	0	0	0	0	0	0	1	0	0
	Sperchon sp.	1	0	1	0	0	0	0	0	2
Annelida	*Bratislavia unidentata*	0	0	0	0	0	0	1	0	5
	Enchytraeidae	0	0	1	1	0	0	0	0	0
	Limnodrilus hoffmeisteri	0	0	0	0	0	0	9	3	5
	Nais sp.	1	0	0	1	0	0	0	0	1
	Tubificidae w/o cap setae sp.	2	0	3	5	1	0	0	0	0
Bivalvia	*Corbicula sp.*	9	1	21	67	32	5	33	59	30
	Pisidium sp.	0	0	0	0	0	0	0	3	0
	Sphaeriidae	1	0	2	5	1	0	1	0	2
Coleoptera	*Berosus sp.*	1	0	0	1	2	1	0	0	1
	Dubiraphia sp.	2	0	1	1	7	1	4	6	1
	Helichus lithophilus	0	0	0	0	0	0	0	1	0
	Microcylloepus sp.	5	1	2	0	6	1	2	8	3
	Stenelmis sp.	4	6	15	19	18	4	7	11	11
Crustacea	*Lirceus sp.*	3	0	0	0	0	2	1	0	1
Diptera-Chironomidae	*Ablabesmyia sp.*	0	0	0	1	0	0	0	0	0
	Cladotanytarsus sp.	0	0	0	0	1	0	0	2	0
	Corynoneura sp.	0	0	0	0	0	1	0	0	0
	Cricotopus bicinctus gr.	0	1	2	0	0	4	0	0	9
	Cricotopus sp.	2	32	15	1	10	20	19	4	12
	Cryptochironomus sp.	1	0	0	0	0	0	1	0	1
	Cryptotendipes sp.	1	0	0	1	0	0	0	0	0
	Dicrotendipes sp.	0	1	0	0	0	1	0	0	1
	Eukiefferiella brevicalcar gr.	1	7	2	0	0	0	0	0	0
	Eukiefferiella sp.	1	0	0	0	0	0	0	0	1
	Larsia sp.	2	1	0	0	0	0	0	1	0
	Nanocladius sp.	0	0	0	0	0	0	0	0	1
	Nilotanypus sp.	2	0	0	0	1	0	1	0	1
	Orthocladius Complex	6	0	2	0	1	9	5	0	1
	Orthocladius sp.	1	0	0	0	1	1	0	1	0
	Parakiefferiella sp.	0	0	1	0	0	0	0	0	0
	Parametriocnemus sp.	8	4	6	20	20	19	12	7	0
	Paraphaenocladius sp.	0	0	0	0	0	0	1	0	0
	Paratanytarsus sp.	0	0	0	0	0	0	2	0	0
	Paratendipes sp.	0	0	0	0	0	0	0	0	1
	Polypedilum flavum	74	109	75	42	58	109	50	46	39
	Polypedilum scalaenum gr.	2	0	2	4	2	1	0	1	8
	Pseudochironomus sp.	3	0	0	0	0	0	0	0	0

Table E.5. Benthic macroinvertebrate collection data set from rock bag artificial substrates at BC-1A in Brushy Creek during Fall 2015 (continued).

Family	Scientific Name	Subsample Count								
		BC-1 R1 USRB	BC-1 R1 MRB	BC-1 R1 DSRB	BC-1 R2 USRB	BC-1 R2 MRB	BC-1 R2 DSRB	BC-1 R3 USRB	BC-1 R3 MRB	BC-1 R3 DSRB
Diptera-Chironomidae	*Rheocricotopus sp.*	0	0	0	0	0	2	0	0	0
	Rheotanytarsus exiguus gr.	3	4	6	1	3	19	15	21	12
	Stempellinella sp.	0	0	0	2	0	0	0	0	0
	Tanytarsini	0	0	0	0	0	1	0	0	0
	Tanytarsus sp.	0	2	0	1	0	0	12	1	5
	Thienemanniella sp.	1	1	0	0	0	0	0	0	4
	Thienemannimyia gr. sp.	8	9	6	30	12	8	17	13	9
	Tvetenia bavarica gr.	0	1	0	1	0	2	1	0	2
Diptera	*Bezzia/Palpomyia sp.*	0	0	0	0	1	0	0	1	0
	Ceratopogoninae	0	0	0	2	0	0	0	2	1
	Dasyhelea sp.	2	0	0	4	1	0	0	3	3
	Hemerodromia sp.	13	6	14	16	14	13	3	10	3
	Hexatoma sp.	0	0	0	3	1	0	0	0	0
	Simulium sp.	3	0	0	0	0	0	0	0	0
	Tipula sp.	1	0	0	4	2	0	0	0	0
Ephemeroptera	*Caenis sp.*	9	5	5	6	13	2	37	35	25
	Isonychia sp.	1	0	1	0	1	0	0	0	0
	Maccaffertium sp.	18	0	0	24	17	0	11	19	0
	Maccaffertium terminatum	0	35	43	0	0	10	0	0	19
Gastropoda	*Ancylidae*	0	0	3	0	2	0	0	0	0
	Ferrissia sp.	3	3	0	8	0	5	22	25	44
	Gyraulus sp.	0	1	0	1	0	0	0	0	0
	Lymnaeidae	0	0	0	1	0	0	0	0	0
	Physa sp.	1	0	0	0	0	0	0	0	0
	Planorbidae	0	0	0	0	0	0	0	1	0
Megaloptera	*Corydalus cornutus*	0	0	0	0	1	1	0	0	0
Odonata	*Argia sp.*	0	0	2	6	4	2	1	6	3
	Calopterygidae	0	0	0	1	0	0	0	0	0
	Coenagrion/Enallagma sp.	0	0	0	0	0	0	1	0	1
	Gomphidae	0	0	0	0	0	0	1	0	0
	Hetaerina sp.	0	2	1	0	1	2	1	0	0
	Tricorythodes sp.	0	0	0	0	2	1	1	0	0
Plecoptera	*Plecoptera*	0	0	0	0	0	0	0	0	1
Trichoptera	*Cheumatopsyche sp.*	70	38	45	31	80	37	24	26	23
	Chimarra sp.	11	17	17	8	29	30	2	4	3
	Helicopsyche borealis	0	0	0	0	0	0	1	7	1
	Hydropsyche betteni	0	3	16	0	6	4	0	0	4
	Hydropsyche sp.	2	0	0	0	0	0	1	5	0
	Hydroptila sp.	1	1	1	0	0	0	0	1	4
	Limnephilidae	0	0	0	0	0	1	0	0	0
	Oecetis persimilis	0	0	0	0	0	0	0	1	0

Table E.5. Benthic macroinvertebrate collection data set from rock bag artificial substrates at BC-1A in Brushy Creek during Fall 2015 (continued).

Family	**Scientific Name**	**Subsample Count**								
		BC-1 R1 USRB	**BC-1 R1 MRB**	**BC-1 R1 DSRB**	**BC-1 R2 USRB**	**BC-1 R2 MRB**	**BC-1 R2 DSRB**	**BC-1 R3 USRB**	**BC-1 R3 MRB**	**BC-1 R3 DSRB**
Trichoptera	*Oecetis sp.*	2	0	2	0	1	0	2	0	0
	Oxyethira sp.	1	0	0	0	0	0	0	0	1
	Polycentropodidae	0	0	0	0	0	0	0	0	1
	Polycentropus sp.	0	0	0	0	0	0	0	0	1
	Pycnopsyche sp.	1	0	0	0	0	0	0	0	0
Other Organisms	*Hydra sp.*	1	0	0	0	0	0	0	0	0
	Nematoda	0	0	0	1	0	0	0	0	0
	Prostoma sp.	0	0	0	0	0	0	0	0	1
	Turbellaria	13	2	8	5	5	7	0	0	2
Total		**298**	**293**	**321**	**325**	**357**	**326**	**303**	**334**	**310**

Table E.6. Benthic macroinvertebrate collection data set from Hester-Dendy artificial substrates in Stennitt Creek during Fall 2016.

Family	Scientific Name	Subsample Count					
		SC-0 AS1	SC-0 AS2	SC-0 AS3	SC-1 AS1	SC-1 AS2	SC-1 AS3
Coleoptera	*Ancyronyx variegatus*	0	2	0	0	0	0
	Berosus sp.	1	0	0	0	0	0
	Dubiraphia sp.	1	10	0	0	1	1
	Hydroporinae	0	0	0	0	0	1
	Macronychus glabratus	2	0	0	0	0	0
Diptera	*Ablabesmyia mallochi*	49	75	53	11	6	20
	Bezzia/Palpomyia sp.	0	0	1	0	0	0
	Ceratopogoninae	0	1	0	0	0	0
	Chironomus sp.	3	4	0	0	0	1
	Cladotanytarsus sp.	11	30	2	0	0	0
	Cryptochironomus sp.	0	0	3	0	0	0
	Dicrotendipes modestus	12	3	0	0	0	0
	Dicrotendipes neomodestus	0	9	20	0	1	0
	Dicrotendipes sp.	0	19	0	0	0	0
	Labrundinia sp.	7	10	2	0	0	0
	Limnophyes sp.	0	1	0	0	0	0
	Micropsectra sp.	0	0	1	0	0	0
	Microtendipes pedellus gr.	0	1	0	0	1	0
	Nanocladius sp.	1	4	0	0	0	0
	Parakiefferiella sp.	0	7	0	0	0	0
	Paratanytarsus sp.	1	14	6	2	0	2
	Paratendipes sp.	0	13	1	0	0	0
	Phaenopsectra sp.	1	1	1	0	0	1
	Polypedilum fallax gr.	2	3	13	2	1	2
	Polypedilum halterale gr.	0	0	0	0	0	5
	Polypedilum illinoense gr.	0	10	0	3	0	3
	Polypedilum scalaenum gr.	0	13	8	1	0	0
	Probezzia sp.	1	0	0	0	0	0
	Rheotanytarsus exiguus gr.	0	0	6	0	1	1
	Rheotanytarsus sp.	0	1	0	0	0	0
	Stempellinella sp.	0	0	0	0	0	1
	Stictochironomus sp.	0	1	0	0	0	0
	Tanytarsus sp.	22	32	15	2	0	2
	Thienemanniella sp.	6	1	0	0	0	0
	Thienemannimyia gr. sp.	2	10	11	2	1	3
	Tribelos jucundum	1	1	0	1	0	0
	Caenis latipennis	0	8	0	0	0	0

Table E.6. Benthic macroinvertebrate collection data set from Hester-Dendy artificial substrates in Stennitt Creek during Fall 2016 (continued).

		Subsample Count					
Family	**Scientific Name**	**SC-0 AS1**	**SC-0 AS2**	**SC-0 AS3**	**SC-1 AS1**	**SC-1 AS2**	**SC-1 AS3**
Ephemeroptera	*Caenis sp.*	3	0	0	1	0	1
	Maccaffertium sp.	0	2	1	0	0	0
	Stenacron interpunctatum	0	4	0	0	0	0
	Stenacron sp.	8	0	4	1	0	0
Hoplonemertea	*Prostoma sp.*	1	2	0	0	0	0
Hygrophila	*Ferrissia sp.*	0	5	0	0	0	0
	Laevapex fuscus	2	3	0	0	0	0
	Micromenetus sp.	0	2	0	0	0	0
Megaloptera	*Corydalus cornutus*	0	0	0	0	0	1
	Sialis sp.	0	1	0	0	0	0
Odonata	*Argia sp.*	1	2	0	5	0	1
Plecoptera	*Taeniopteryx sp.*	0	1	0	0	0	0
Rhynchobdellida	*Helobdella sp.*	0	1	0	0	0	0
Trichoptera	*Hydroptila sp.*	4	1	0	0	0	0
	Mystacides sepulchralis	1	0	0	0	0	0
	Nyctiophylax sp.	1	0	1	0	0	0
	Oecetis sp.	0	1	1	0	0	0
	Polycentropodidae	0	1	0	0	0	0
Trombidiformes	*Koenikea sp.*	0	0	0	0	0	0
	Lebertia sp.	0	1	1	0	0	0
Tubificida	*tubificoid Naididae w/o cap setae*	0	1	0	0	0	1
Veneroida	*Corbicula sp.*	0	10	0	0	0	1
Other Organisms	*Turbellaria*	1	3	1	1	0	1
	Total	**145**	**325**	**152**	**32**	**12**	**49**

APPENDIX F

Summary Tables-Macroinvertebrate Data

Table F.1. Corrected abundance and percent composition of the 10 most abundant taxa from instream sampling at the BC-0A, BC-1A, and REF locations.

Loc	CA	%	Cum %	CLASS	ORDER	FAMILY	GENUS
BC-0A	541	37	37	Insecta	Ephemeroptera	Caenidae	*Caenis*
	275	19	55	Malacostraca	Isopoda	Asellidae	*Lirceus*
	48	3	59	Clitellata	Tubificida	Tubificidae	*Limnodrilus*
	48	3	62	Insecta	Coleoptera	Elmidae	*Stenelmis*
	48	3	65	Insecta	Trichoptera	Limnephilidae	
	39	3	68	Insecta	Coleoptera	Elmidae	*Dubiraphia*
	39	3	70	Insecta	Trichoptera	Hydropsychidae	*Hydropsyche*
	35	2	73	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*
	35	2	75	Insecta	Odonata	Coenagrionidae	*Argia*
	35	2	78	Turbellaria			
BC-1A	473	21	21	Insecta	Ephemeroptera	Caenidae	*Caenis*
	411	18	39	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*
	405	18	57	Bivalvia	Veneroida	Corbiculidae	*Corbicula*
	103	5	62	Insecta	Coleoptera	Elmidae	*Stenelmis*
	96	4	66	Clitellata	Tubificida	Tubificidae	*Limnodrilus*
	69	3	69	Insecta	Diptera	Chironomidae	*Polypedilum*
	69	3	72	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*
	69	3	76	Turbellaria			
	55	2	78	Malacostraca	Isopoda	Asellidae	*Lirceus*
	48	2	80	Insecta	Odonata	Coenagrionidae	*Argia*
REF-3	158	19	19	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*
	82	10	28	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*
	73	9	37	Insecta	Trichoptera	Philopotamidae	*Chimarra*
	54	6	43	Gastropoda	Littoridinomorpha	Pleuroceridae	
	51	6	49	Insecta	Ephemeroptera	Heptageniidae	*Stenacron*
	48	6	55	Insecta	Diptera	Chironomidae	*Polypedilum*
	40	5	59	Insecta	Diptera	Tipulidae	*Tipula*
	34	4	63	Insecta	Ephemeroptera	Isonychiidae	*Isonychia*
	23	3	66	Bivalvia	Veneroida	Sphaeriidae	*Pisidium*
	23	3	69	Insecta	Trichoptera	Helicopsychidae	*Helicopsyche*
REF-2	254	30	30	Insecta	Trichoptera	Philopotamidae	*Chimarra*
	168	16	16	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*
	103	9	25	Gastropoda	Littoridinomorpha	Pleuroceridae	
	89	8	33	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*
	75	7	40	Insecta	Diptera	Tipulidae	*Tipula*
	58	5	46	Insecta	Diptera	Chironomidae	*Thienemanniella*
	51	5	50	Insecta	Diptera	Chironomidae	*Polypedilum*
	41	4	54	Insecta	Diptera	Chironomidae	*Polypedilum*
	24	2	56	Insecta	Diptera	Chironomidae	*Tvetenia*
	17	2	58	Insecta	Coleoptera	Elmidae	*Microcylloepus*

Loc - location; % - percent composition; Cum % - cumulative percent composition; CA - abundance corrected for sub-sampling

Table F.2. Corrected abundance and percent composition of the 10 most abundant taxa from the artificial substrate (rock basket) samplers at the BC-0A and BC-1A locations.

Loc	CA	%	Cum %	CLASS	ORDER	FAMILY	GENUS
BC-0A	1467	30	30	Insecta	Ephemeroptera	Caenidae	*Caenis*
	745	15	45	Bivalvia	Veneroida	Sphaeriidae	*Pisidium*
	283	6	50	Insecta	Coleoptera	Elmidae	*Stenelmis*
	261	5	55	Insecta	Diptera	Chironomidae	*Thienemannimyia*
	231	5	60	Clitellata	Tubificida	Tubificidae	*Limnodrilus*
	137	3	63	Malacostraca	Isopoda	Asellidae	*Lirceus*
	123	2	65	Insecta	Coleoptera	Elmidae	*Dubiraphia*
	121	2	68	Insecta	Diptera	Chironomidae	*Polypedilum*
	89	2	70	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*
	88	2	71	Insecta	Diptera	Chironomidae	*Cryptochironomus*
BC-1A	6610	24	24	Insecta	Diptera	Chironomidae	*Polypedilum*
	3476	13	37	Insecta	Trichoptera	Hydropsychidae	*Cheumatopsyche*
	1939	7	44	Bivalvia	Veneroida	Corbiculidae	*Corbicula*
	1715	6	51	Insecta	Ephemeroptera	Heptageniidae	*Maccaffertium*
	1493	6	56	Insecta	Diptera	Chironomidae	*Cricotopus*
	1343	5	61	Insecta	Trichoptera	Philopotamidae	*Chimarra*
	1181	4	66	Insecta	Ephemeroptera	Caenidae	*Caenis*
	998	4	69	Insecta	Diptera	Chironomidae	*Thienemannimyia*
	990	4	73	Insecta	Diptera	Chironomidae	*Parametriocnemus*
	909	3	76	Gastropoda	Basommatophora	Ancylidae	*Ferrissia*

Loc - location; % - percent composition; Cum % - cumulative percent composition; CA - abundance corrected for sub-sampling

Table F.3. Corrected abundance and percent composition of the 10 most abundant taxa from instream sampling at the SC-0 and SC-1 locations.

Loc	CA	%	Cum %	CLASS	ORDER	FAMILY	GENUS
SC-0	1037	18	18	Bivalvia	Veneroida	Sphaeriidae	*Pisidium*
	576	10	28	Insecta	Coleoptera	Elmidae	*Dubiraphia*
	557	10	37	Insecta	Diptera	Chironomidae	*Polypedilum*
	499	9	46	Insecta	Ephemeroptera	Caenidae	*Caenis*
	384	7	52	Bivalvia	Veneroida	Corbiculidae	*Corbicula*
	307	5	57	Insecta	Diptera	Ceratopogonidae	
	250	4	62	Malacostraca	Isopoda	Asellidae	*Lirceus*
	154	3	64	Gastropoda	Hygrophila	Planorbidae	*Ferrissia*
	154	3	67	Insecta	Diptera	Chironomidae	*Dicrotendipes*
	154	3	70	Insecta	Diptera	Chironomidae	*Paratanytarsus*
SC-1	3584	18	18	Insecta	Ephemeroptera	Caenidae	Caenis
	2944	15	34	Insecta	Coleoptera	Elmidae	Dubiraphia
	2624	14	47	Insecta	Diptera	Chironomidae	Polypedilum
	768	4	51	Insecta	Diptera	Chironomidae	Rheotanytarsus
	704	4	55	Insecta	Diptera	Chironomidae	Paratanytarsus
	704	4	58	Insecta	Diptera	Chironomidae	Polypedilum
	640	3	62	Bivalvia	Veneroida	Sphaeriidae	Pisidium
	448	2	64	Gastropoda	Littoridinomorpha	Hydrobiidae	
	448	2	66	Insecta	Diptera	Chironomidae	Stempellinella
	448	2	69	Insecta	Diptera	Chironomidae	Thienemannimyia

Loc - location; % - percent composition; Cum % - cumulative percent composition; CA - abundance corrected for sub-sampling

Table F.4. Corrected abundance and percent composition of the 10 most abundant taxa from artificial substrate (Hester-Dendy) samplers at the SC-0 and SC-1 locations.

Loc	CA	%	Cum %	CLASS	ORDER	FAMILY	GENUS
SC-0	182	28	28	Insecta	Diptera	Chironomidae	*Ablabesmyia*
	71	11	39	Insecta	Diptera	Chironomidae	*Tanytarsus*
	65	10	49	Insecta	Diptera	Chironomidae	*Dicrotendipes*
	51	8	57	Insecta	Diptera	Chironomidae	*Polypedilum*
	45	7	64	Insecta	Diptera	Chironomidae	*Cladotanytarsus*
	22	3	68	Insecta	Diptera	Chironomidae	*Paratanytarsus*
	22	3	71	Insecta	Diptera	Chironomidae	*Thienemannimyia*
	20	3	74	Insecta	Diptera	Chironomidae	*Labrundinia*
	15	2	76	Insecta	Diptera	Chironomidae	*Paratendipes*
	15	2	79	Insecta	Ephemeroptera	Caenidae	*Caenis*
SC-1	37	40	40	Insecta	Diptera	Chironomidae	*Ablabesmyia*
	17	18	58	Insecta	Diptera	Chironomidae	*Polypedilum*
	6	6	65	Insecta	Diptera	Chironomidae	*Thienemannimyia*
	6	6	71	Insecta	Odonata	Coenagrionidae	*Argia*
	4	4	75	Insecta	Diptera	Chironomidae	*Tanytarsus*
	4	4	80	Insecta	Diptera	Chironomidae	*Paratanytarsus*
	2	2	82	Insecta	Coleoptera	Elmidae	*Dubiraphia*
	2	2	84	Insecta	Ephemeroptera	Caenidae	*Caenis*
	2	2	86	Insecta	Diptera	Chironomidae	*Rheotanytarsus*
	2	2	88	Turbellaria			

Loc - location; % - percent composition; Cum % - cumulative percent composition; CA - abundance corrected for sub-sampling

Table F.5. Selected metric values from Brushy and Clear Creek instream samples.

Metric Type	**Site ID**	**BC-0A**	**BC-1A**	**REF-R2**	**REF-R3**
	Collection Date	**11/24/15**	**11/24/2015**	**10/26/16**	**10/26/16**
Abundance	Corrected Abundance	1,475	2,242	1,083	850
Richness	Species Richness	43	49	43	44
	EPT Richness	11	11	14	11
	Ephemeroptera	6	4	6	5
	Plecoptera	0	1	1	0
	Trichoptera	5	6	7	6
	Chironomidae	8	11	9	13
	Oligochaeta	2	2	0	3
	Non-Chiro. Non-Olig.	33	36	34	28
Community Composition	% Ephemeroptera	43	41	13	32
	% Plecoptera	0	0	0	0
	% Trichoptera	9	7	42	24
	% EPT	52	48	55	56
	% Coleoptera	9	8	3	6
	% Diptera	6	10	28	21
	% Oligochaeta	4	5	0	1
	% Chironomidae	4	7	18	15
	% Hydropsychidae	5	3	16	10
Functional Group Composition	% Filterers	7	24	44	28
	% Gatherers	10	32	15	20
	% Predators	11	11	5	7
	% Scrapers	10	26	19	30
	% Shredders	6	5	17	13
	% Piercer-Herbivores	0	0	0	0
Functional Group Composition	% Unclassified	57	2	0	2
	Filterer Richness	5	7	8	8
	Gatherer Richness	11	13	12	16
	Predator Richness	14	16	10	8
	Scraper Richness	5	6	5	5
	Shredder Richness	3	6	7	5
	Piercer-Herbivore Richness	0	0	0	0
	Unclassified	5	1	1	1
Diversity Evenness Measures	Shannon-Weaver H	3.67	3.95	3.96	4.47
	Margalef's Richness	5.76	6.22	6.01	6.38
	Pielou's J'	0.68	0.70	0.73	0.82
	Simpson's Heterogeneity	0.82	0.88	0.89	0.93
Biotic Indices	% Indiv. w/ HBI Value	96	98	98	97
	Hilsenhoff Biotic Index	6.81	5.94	4.90	4.83

Table F.6. Selected metric values (averaged across all 9 substrate units form each location) from Brushy Creek artificial substrates.

Metric Type	**Site ID**	**BC-0A**	**BC-1A**
	Collection Date	**11-23-2015**	**11-23-2015**
Abundance	**Corrected Abundance**	**552**	**30,079**
Dominance	**% Dominant Taxon**	**34.2**	**23.4**
Richness	Species Richness	44.4	35.2
	EPT Richness	8.9	7.8
	Ephemeroptera Richness	3.6	2.7
	Plecoptera Richness	0.4	0.1
	Trichoptera Richness	4.9	5.0
	Chironomidae Richness	15.7	12.3
	Oligochaeta Richness	2.2	1.6
	Non-Chiro. Non-Olig. Richness	26.6	21.3
Community Composition	% Ephemeroptera	33.9	11.9
	% Plecoptera	0.3	0.01
	% Trichoptera	7.4	19.6
	% EPT	41.6	31.6
	% Coleoptera	8.6	5.2
	% Diptera	25.6	45.0
	% Oligochaeta	4.9	1.4
	% Chironomidae	21.1	40.6
	% Ephemerellidae	0.0	0.0
	% Hydropsychidae	3.7	14.4
Functional Group Composition	% Filterers	16.3	31.8
	% Gatherers	41.5	14.5
	% Predators	15.4	11.2
	% Scrapers	13.4	14.7
	% Shredders	5.2	27.0
	% Piercer-Herbivores	0.3	0.4
	% Unclassified	7.7	0.3
	Filterer Richness	5.3	6.9
	Gatherer Richness	13.2	10.4
	Predator Richness	11.3	8.2
	Scraper Richness	6.6	4.0
	Shredder Richness	4.7	4.2
	Piercer-Herbivore Richness	0.4	0.8
	Unclassified	2.7	0.7
Diversity/Evenness Measures	Shannon-Weaver H' (log 2)	3.9	3.9
	Margalef's Richness	7.0	4.3
	Pielou's J'	0.7	0.8
	Simpson's Heterogeneity	0.8	0.9
Biotic Indices	% Indiv. w/ HBI Value	91.2	94.8
	Hilsenhoff Biotic Index	6.64	5.82

Table F.7. Selected metric values from Stennitt Creek instream samples.

Metric Type	**Site ID**	**SC-0**	**SC-1**
	Collection Date		
Abundance Measures	Corrected Abundance	5,856	19,392
Richness Measures	Species Richness	55	52
	EPT Richness	4	6
	Ephemeroptera Richness	1	3
	Plecoptera Richness	0	0
	Trichoptera Richness	3	3
	Chironomidae Richness	19	18
	Oligochaeta Richness	5	6
	Non-Chiro. Non-Olig. Richness	31	28
Community Composition	% Ephemeroptera	9	20
	% Plecoptera	0	0
	% Trichoptera	2	2
	% EPT	11	22
	% Coleoptera	11	18
	% Diptera	36	40
	% Oligochaeta	3	4
	% Chironomidae	27	37
	% Hydropsychidae	0	1
	% Odonata	1	2
Functional Group Composition	% Filterers	26	13
	% Gatherers	35	47
	% Predators	14	10
	% Scrapers	6	6
	% Shredders	11	19
	% Piercer-Herbivores	0	0
	% Unclassified	7	4
	Filterer Richness	4	8
	Gatherer Richness	21	17
	Predator Richness	15	12
	Scraper Richness	6	5
	Shredder Richness	4	5
	Piercer-Herbivore Richness	0	0
	Unclassified	3	3
Diversity/Evenness Measures	Shannon-Weaver H'	4.61	4.44
	Margalef's Richness	6.22	5.17
	Pielou's J'	0.80	0.78
	Simpson's Heterogeneity	0.93	0.91
Biotic Indices	% Indiv. w/ HBI Value	93	94
	Hilsenhoff Biotic Index	6.64	6.59

Table F.8. Selected metric values from artificial substrate (Hester-Dendy) samplers at the SC-0 and SC-1 locations.

Metric Type	**Site ID**	**SC-0**	**SC-1**
	Collection Date		
Abundance Measures	Corrected Abundance	214.6	31.0
Richness Measures	Species Richness	30.3	12.7
	EPT Richness	6.0	1.0
	Ephemeroptera Richness	2.3	1.0
	Plecoptera Richness	0.3	0.0
	Trichoptera Richness	3.3	0.0
	Chironomidae Richness	15.7	8.3
	Oligochaeta Richness	0.3	0.3
	Non-Chiro. Non-Olig. Richness	14.3	4.0
Community Composition	% Ephemeroptera	4.4	2.8
	% Plecoptera	0.1	0.0
	% Trichoptera	2.8	0.0
	% EPT	7.3	2.8
	% Coleoptera	2.2	4.1
	% Diptera	83.7	83.4
	% Oligochaeta	0.1	0.7
	% Chironomidae	83.2	83.4
	% Hydropsychidae	0.0	0.0
	% Odonata	2.0	5.9
Functional Group Composition	% Filterers	14.5	10.4
	% Gatherers	23.4	12.7
	% Predators	43.9	57.6
	% Scrapers	1.9	0.7
	% Shredders	8.5	12.4
	% Piercer-Herbivores	0.3	0.0
	% Unclassified	6.4	6.2
	Filterer Richness	3.0	2.0
	Gatherer Richness	9.7	3.7
	Predator Richness	9.3	4.0
	Scraper Richness	2.3	0.3
	Shredder Richness	3.0	2.0
	Piercer-Herbivore Richness	0.7	0.0
	Unclassified	1.7	0.7
Diversity/Evenness Measures	Shannon-Weaver H'	3.7	2.9
	Margalef's Richness	5.5	3.4
	Pielou's J'	0.76	0.82
	Simpson's Heterogeneity	0.87	0.81
Biotic Indices	% Indiv. w/ HBI Value	94.9	92.4
	Hilsenhoff Biotic Index	6.28	5.72

APPENDIX G

Cluster Analysis Dendrograms

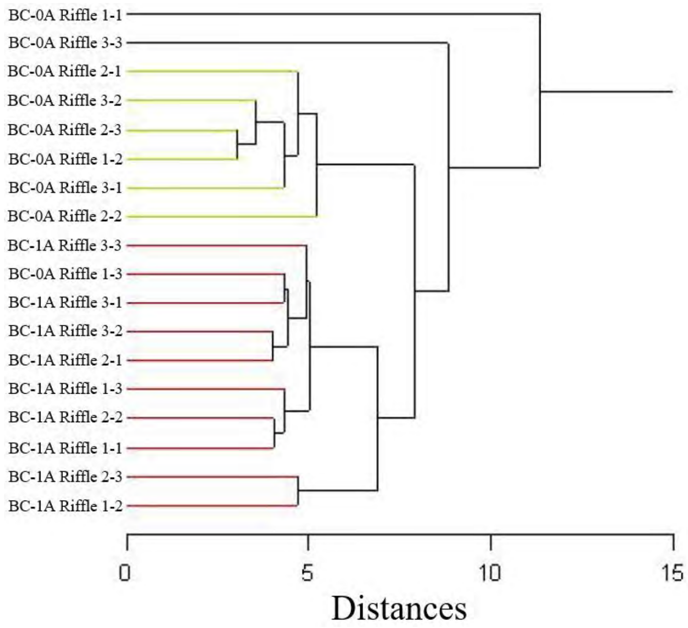

Figure G.1. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Brushy Creek using the single linkage method with Euclidean distances.

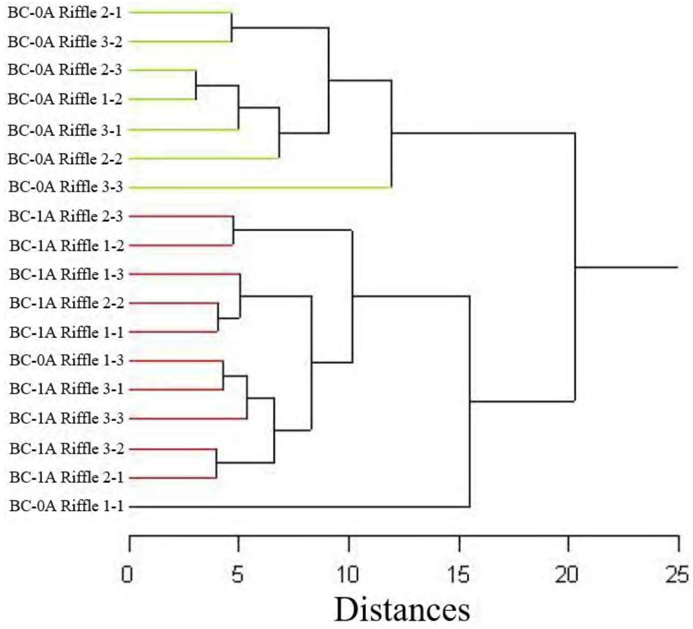

Figure G.2. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Brushy Creek using the complete linkage method with Euclidean distances.

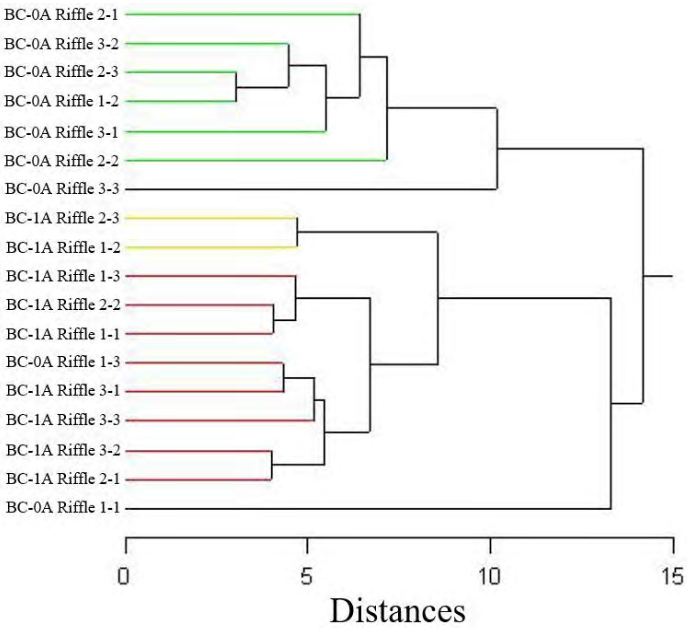

Figure G.3. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Brushy Creek using the average linkage method with Euclidean distances.

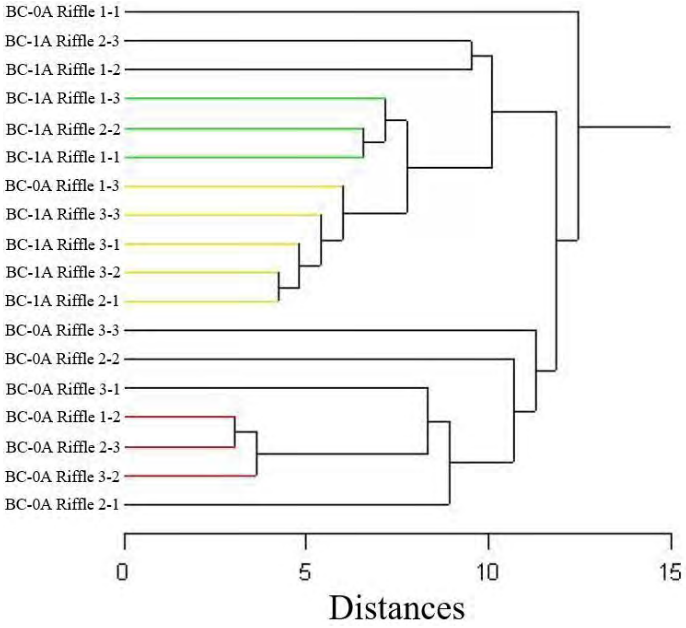

Figure G.4. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Brushy Creek using the centroid linkage method with Euclidean distances.

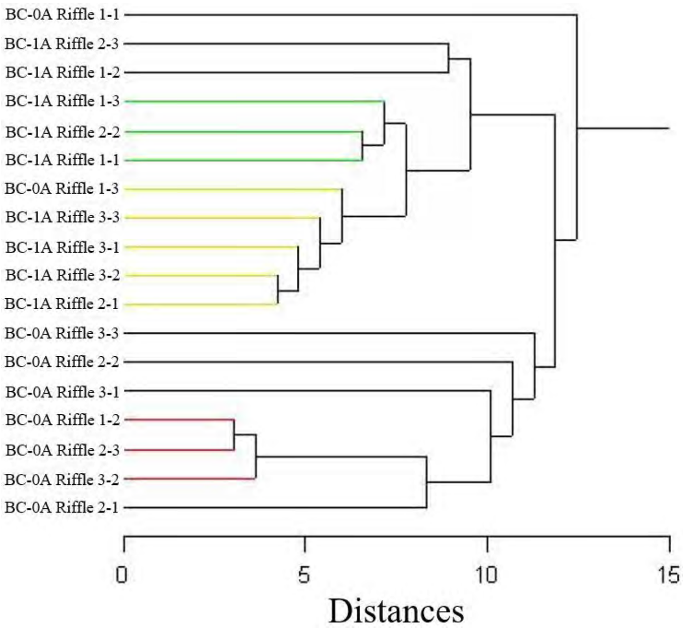

Figure G.5. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Brushy Creek using the median linkage method with Euclidean distances.

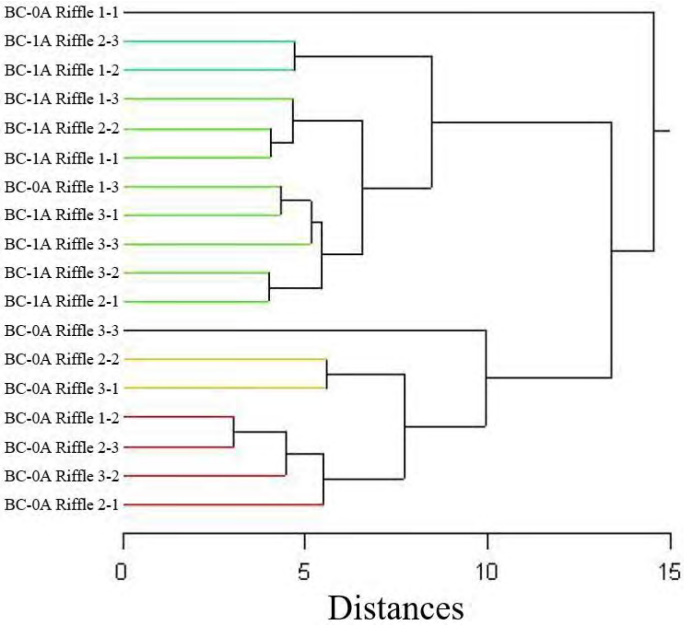

Figure G.6. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Brushy Creek using the weighted linkage method with Euclidean distances.

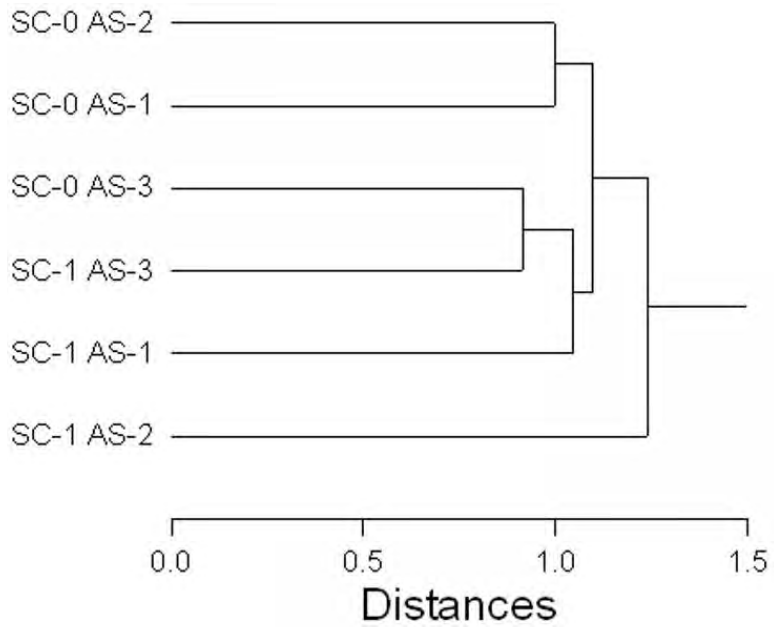

Figure G.7. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Stennitt Creek using the single linkage method with Euclidean distances.

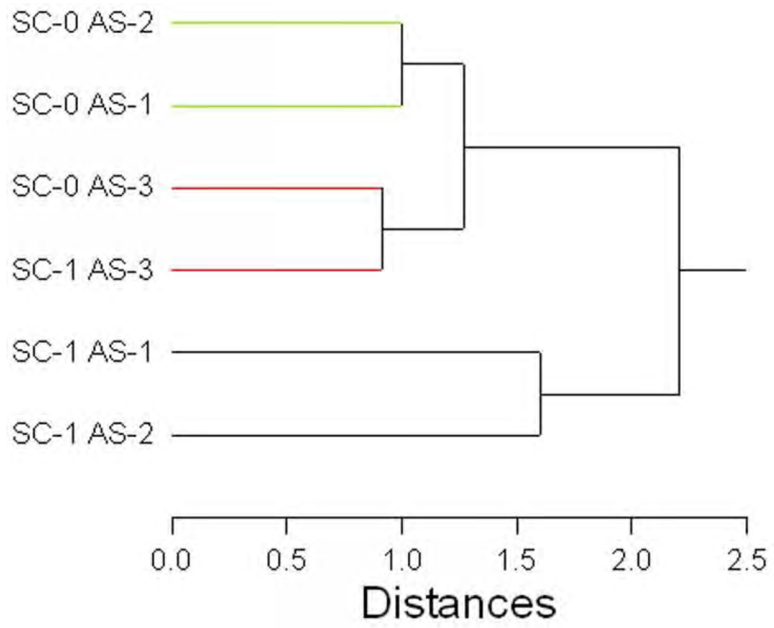

Figure G.8. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Stennitt Creek using the complete linkage method with Euclidean distances.

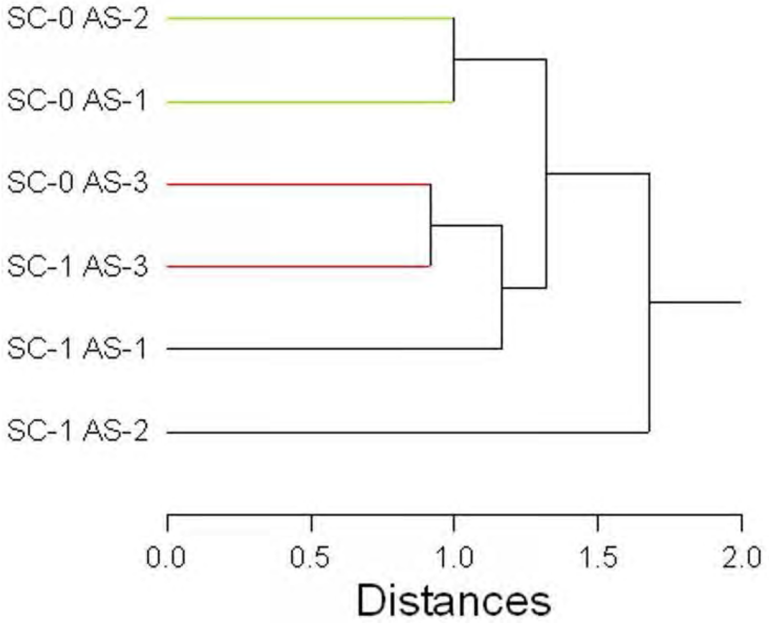

Figure G.9. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Stennitt Creek using the average linkage method with Euclidean distances.

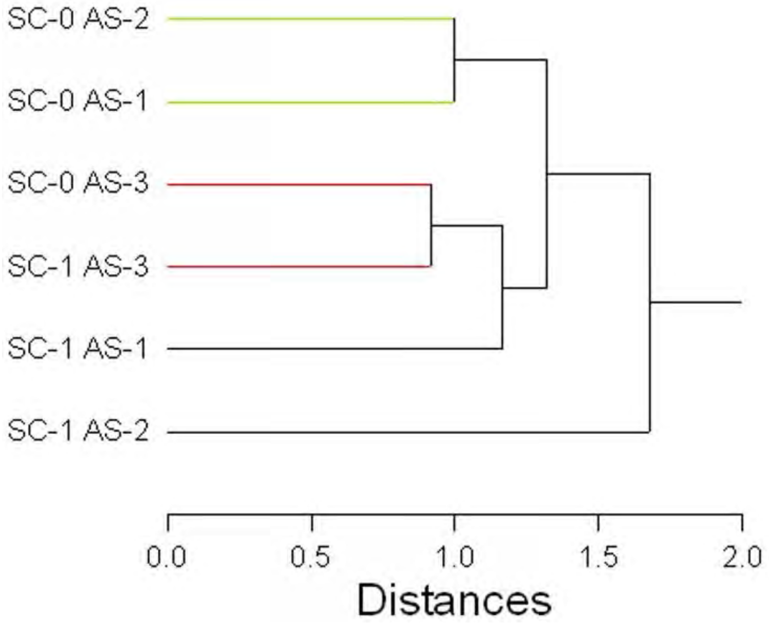

Figure G.10. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Stennitt Creek using the centroid linkage method with Euclidean distances.

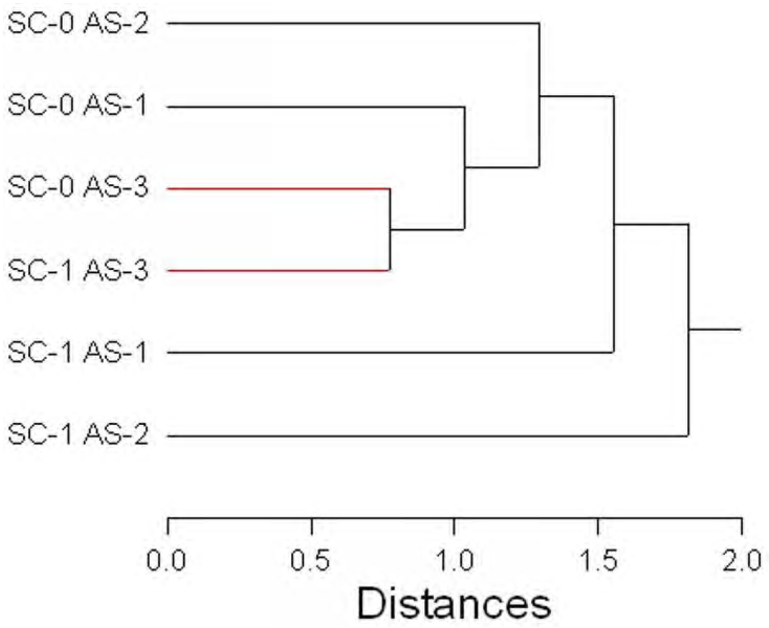

Figure G.11. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Stennitt Creek using the median linkage method with Euclidean distances.

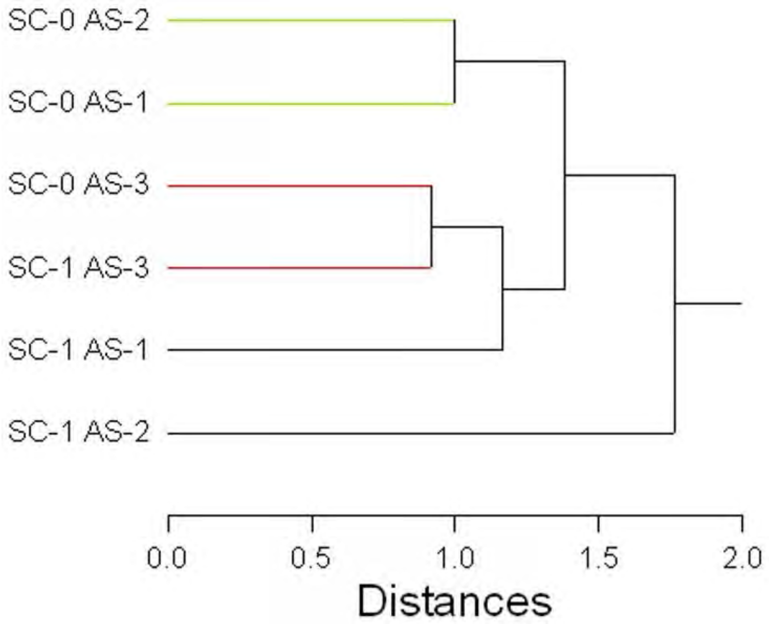

Figure G.12. Dendogram resulting from the hierarchical cluster analysis of benthic macroinvertebrate metrics from rock bag artificial substrates in Stennitt Creek using the weighted linkage method with Euclidean distances.

APPENDIX H

Arkansas Department of Health Letter

Arkansas Department of Health

4815 West Markham Street • Little Rock, Arkansas 72205-3867 • Telephone (501) 661-2000
Governor Mike Beebe
Paul K. Halverson, DrPH, FACHE, Director and State Health Officer

Engineering Section, Slot 37
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After Hours Emergency 501-661-2136

March 24, 2009

Stacy Whittington, Environmental Specialist
Vulcan Construction Material, LP
1200 Urban Center Drive
Birmingham, AL 35242

RE: FTN's UAA Letter dated March 18, 2009
Black Rock, Lawrence County
09-70941

Dear Mr. Whittington:

In response to FTN's letter dated March 18, 2009, there are no present or future plans for using the Brushy Creek as a Public Water Supply. However, there is a proposed surface water intake that will be located approximately five (5) miles downstream on the Spring River (e.g., below its confluence with the Eleven Point River).

When submitting correspondence pertaining to this project, please include our plan identification number 09-70941.

Sincerely,

Jeff A. Stone, P.E.
Chief Engineer
Engineering Section

JAS:GAG:SGB:sgb

cc: Pat Downey, FTN Associates (3 Innwood Circle, Suite 220; Little Rock, AR 7221)
Marcy Taylor, Mitchell Williams (425 W. Capitol AVE, Suite 1800; Little Rock 72201-3525)

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Keeping the Natural State natural.

Arkansas Game and Fish Commission

Scott Henderson
Director

April 16, 2009

Ms. Stacy Whittington
Environmental Specialist
Vulcan Construction Materials, LP
1200 Urban Center Drive
Birmingham, AL 35242

Re: Vulcan Materials Company Discharge to Brushy Creek via
Unnamed Tributary Black Rock, Lawrence County, Arkansas
FNT No. 6532-020

Dear Ms. Whittington:

This is in response to a letter dated March 24, 2009, from Mr. Pat Downey of FTN Associates, LTD concerned with the above referenced project and the proposed removal of the Domestic Water Supply designated use for Brushy Creek.

It is our determination that the proposed use removal will not conflict with the protection of fish and wildlife in the area.

Thank you for giving us the opportunity to comment on this proposal.

Sincerely,

Mike Armstrong
Chief of Fisheries

cc: Mr. Pat Downey
Ms. Marcy Taylor

2 Natural Resources Drive • Little Rock, AR 72205 • www.agfc.com
Phone (800) 364-4263 • (501) 223-6300 • Fax (501) 223-6448

Arkansas Natural Resources Commission

J. Randy Young, PE
Executive Director

101 East Capitol, Suite 350
Little Rock, Arkansas 72201
http://www.anrc.arkansas.gov/

Phone: (501) 682-1611
Fax: (501) 682-3991
E-mail: anrc@arkansas.gov

Mike Beebe
Governor

July 16, 2009

Ms. Stacy Whittington
Environmental Specialist
Vulcan Construction Materials, LP
1200 Urban Center Drive
Birmingham, AL 35242

Dear Ms. Whittington:

My staff has reviewed the following request for evaluation, and determined that removal of the Designated Domestic Water Supply Use from the below listed stream segment does not conflict with the Arkansas Water Plan at this time:

Lawrence County: Brushy Creek extending up stream from its confluence with Stennitt Creek

Sincerely,

J. Randy Young, P.E.
Executive Director

JRY/KB/atd

cc: Mr. Pat Downey FTN Associates, Ltd 3 Innwood Circle, Suite 220 Little Rock, AR 72211

Ms. Marcy Taylor Mitchell Williams 425 West Capitol Ave., Suite 1800 Little Rock, AR 72201

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JUL 17 2009