SMALL WATERSHED ROTATING BASIN MONITORING PROGRAM
YEAR 5: LOWER RED BASIN

FINAL REPORT

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND AND DESCRIPTION

The Clean Water Act has charged each state's nonpoint source (NPS) pollution agency with two primary tasks: 1) identify all waters being impacted by NPS pollution, and 2) develop a management program describing programs to be implemented to correct any identified problems. In addition, each state's NPS agency is charged with identification of all programs which are actively planning or enforcing NPS controls in order to reduce NPS pollution in cooperation with local, regional, and interstate entities. The state NPS agency can then report on total program status with regard to efforts to address NPS impacts and improve water quality. The Oklahoma Conservation Commission (OCC) is charged by Oklahoma state statute as the NPS Program technical lead and therefore must monitor to determine the occurrence, nature, and extent of NPS impacts to state waters. Robust and meaningful assessment of the state's water quality is the foundation for meeting the long-term goals of the Oklahoma NPS program and water quality management in general.

Until recent years, Oklahoma did not have a consistent, statewide ambient monitoring program that allowed for the identification of nonpoint source (NPS) affected waters. Instead, pollution monitoring was confined to project-specific areas or was conducted on such a large scale that it was not effective in identifying sources of impairment. Without a comprehensive approach to monitoring and evaluation of the state's waters, it has been difficult to accurately and continually assess the impact of NPS pollution throughout the state, identify the causes and sources of the pollution, and determine the success of measures to improve water conditions.

In 2000, the Oklahoma Conservation Commission (OCC) initiated a progressive ambient monitoring program to assess NPS issues on a larger spatial and temporal scale than previously done. Known as the *Small Watershed Rotating Basin Monitoring Program* ("Rotating Basin Program"), this effort entails fixed station sampling at or near the outlets of complete eleven digit Hydrologic Unit Code watersheds (HUC-11). Oklahoma contains all or part of 414 U. S. Geological Survey (USGS) 11-digit HUC basins which have been collated into eleven larger planning basins for state water quality management purposes. The sampling units for the Rotating Basin Monitoring Program are based at the outlets of HUC 11 watersheds located entirely in the state, with secondary sites located upstream in selected watersheds where isolation of a particular tributary influence is necessary. Stations are segregated into strategic basin groups and are sampled every five weeks for a period of two years. Each year, sampling is initiated in a new basin group resulting in a statewide coverage of all sites in five years. This report focuses on the fifth and final set of planning basins monitored in the five year rotation, the Lower Red basin (see Figure 1).

Effectively coordinated with other state monitoring programs, OCC's Rotating Basin program is designed to accomplish the state's NPS monitoring needs in four stages. The first stage includes a comprehensive, coordinated investigation and analysis of the causes and sources of NPS pollution throughout the state. The second stage involves more intensive, specialized monitoring designed to identify specific causes and sources of NPS pollution—Diagnostic Monitoring. The data from diagnostic monitoring can be used to formulate an implementation plan to specifically address the sources and types of identified NPS pollution. The third stage of monitoring is

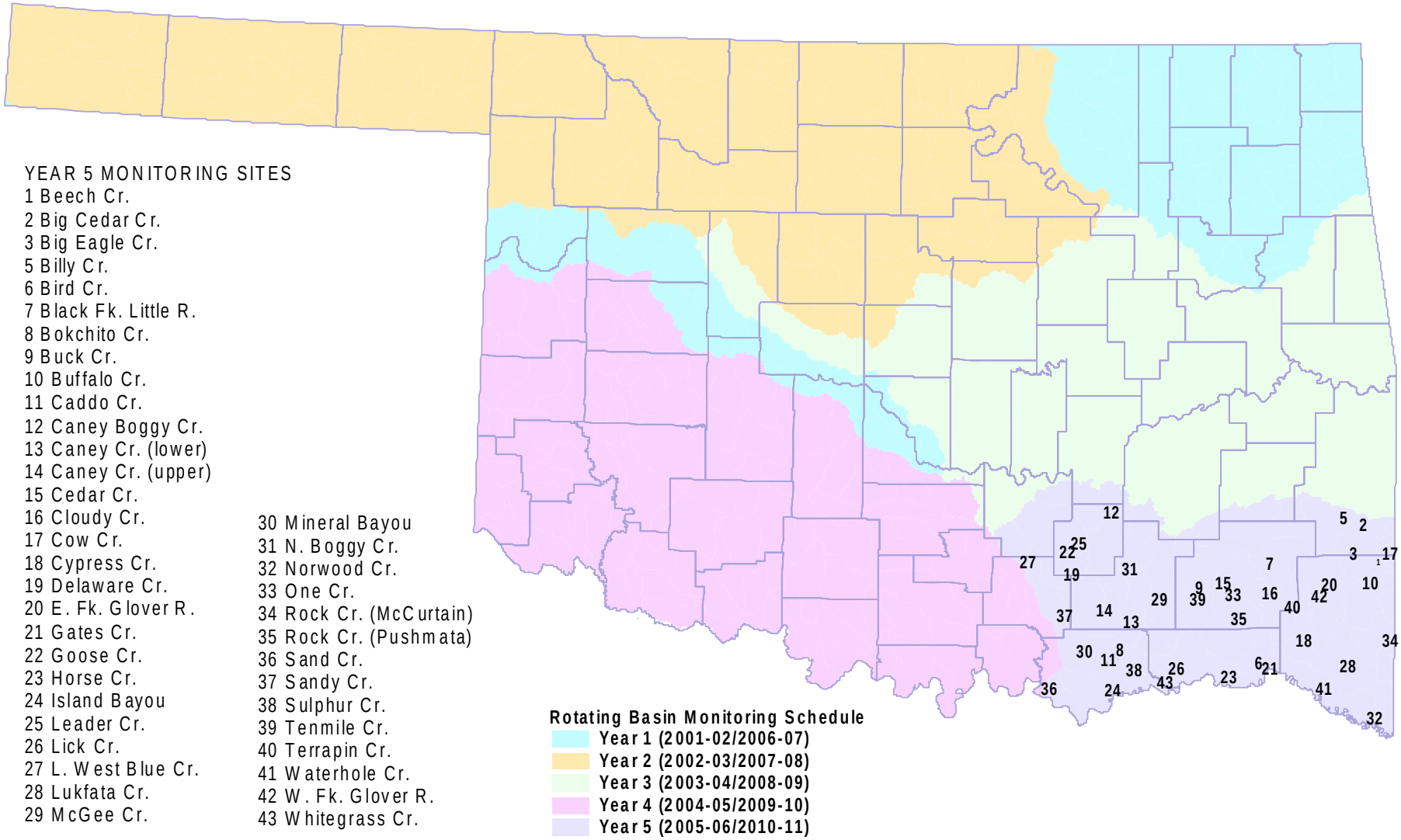


Figure 1. Monitoring Schedule and Year 5 Monitoring Sites for the Small Watershed Rotating Basin Monitoring Project.

designed to initiate remedial and/or mitigation efforts to address the NPS problems—Implementation Monitoring. Finally, the fourth stage evaluates the effectiveness of the implementation through assessment and post-implementation monitoring—Success Monitoring. This assessment program will provide a thorough and statistically sound evaluation of Oklahoma's waters every five years, which will help focus NPS program planning, education, and implementation efforts in areas where they can be most effective. The current project includes components of stages 1 and 2.

The Small Watershed Rotating Basin Monitoring Program considers the following specific questions in the context of Oklahoma Water Quality Standards and Use Support Assessment Protocols (USAPs) in addressing NPS pollution:

1. Which HUC 11 waterbodies are not-supporting assigned beneficial uses due to NPS or NPS plus point source (PS) pollution?
2. Which waterbodies show elevated or increasing levels of NPS or NPS plus PS pollutants, which may threaten water quality?
3. What are the sources and magnitude of pollution loading within threatened or impaired waterbodies?
4. Which land uses or changes in land use are sources or potential sources for pollutants causing beneficial use impairment?

In its entirety, OCC's Rotating Basin Monitoring Program provides an assessment of water quality, watershed condition, and support status for selected streams statewide necessary for planning, implementation, and eventual evaluation of mitigation efforts. Efforts summarized in this report constitute the *ambient monitoring* (routine physical, chemical, and biological sampling) and *diagnostic* (special parameter sampling) stages of the Rotating Basin program. This iteration of the Rotating Basin Program provides a thorough and current assessment of water quality and watershed conditions in the Lower Red basin and assessment of beneficial use support for the selected streams.

2.0 MATERIALS AND METHODS

2.1 GENERAL

Sampling stations were selected to effectively represent streams of the Lower Red Basin. Candidate streams were selected from subwatersheds within the Lower Red Basin located entirely within the state of Oklahoma having perennial water. Watersheds that did not have perennial water or were actually a segment of a larger river being sampled by another agency were not chosen. Where a particular watershed was monitored by another entity, the stream was dropped from consideration for a Rotating Basin site if the monitoring being conducted met the project data quality objectives. For most subwatersheds, the monitoring site was located near the outflow of the primary stream far enough upstream to limit backwater (surface and alluvial) effects of the waterbody to which it drained. For larger subwatersheds, an additional site was sometimes located upstream to isolate a particularly strong tributary influence. In some cases, sites were specifically chosen to monitor a stream draining an area of landuse different from the majority of the other streams being monitored in that region or subwatershed.

After reconnaissance of all of the potential sites within the Lower Red basin and removal of those sites which did not meet the sampling criteria, 42 sites were monitored regularly from June 2005 to June 2007 (Table 1). These sites occur over five Level III Ecoregions: the Ouachita Mountains (OM), Cross Timbers (CT), South Central Plains (SCP), Arkansas Valley (AV), and East Central Texas Plains (ECTP) (Woods et al., 2005). Both of the sites in the Cross Timbers ecoregion are located in the "Arbuckle Uplift" level 4 ecoregion, which is a unique area in this region.

All sampling and analyses performed during this project were conducted under a Quality Assurance Project Plan (QAPP) approved by EPA Region VI and on file at the OCC Water Quality Division, the Oklahoma Secretary of the Environment (OSE), and EPA Region VI in Dallas. The reader is encouraged to obtain and consult the QAPP for specific questions concerning laboratory analytical methods, detection limits, and accuracy and precision limits. All sampling and measurement activities of OCC Water Quality staff followed procedures outlined in the appropriate OCC Standard Operating Procedure (OCC 2006). Water quality chemical analyses were conducted by the Oklahoma Department of Agriculture, Food and Forestry (ODAFF) laboratory.

2.2 WATER QUALITY MONITORING

Starting in June 2005, sites were monitored for physical and chemical parameters on a fixed interval schedule of ten sampling events per year (five-week intervals) through June 2007 (usually 20 total events per site). This sampling frequency exceeds state data requirements for beneficial use assessment and meets a sample number necessary to provide a 90% level of confidence for principal water quality data (specifically phosphorus, a critical NPS concern) as determined from EPA's DEFT software. Samples were collected during both base flow and high flow conditions as they occurred on predetermined sampling dates. All sampling and measurement activities followed procedures outlined in the appropriate OCC SOP (OCC 2006). *In-situ* water quality parameters were measured at standardized sampling locations and include the following parameters: water temperature, dissolved oxygen, pH, specific conductance, alkalinity, turbidity, and instantaneous discharge.

One water sample was collected per site per 35-day interval in two, new, sample-rinsed HDPE bottles; one was preserved to a pH <2 with H_2SO_4, and both were stored and delivered on ice or at 4° C. Quality assurance/control samples were collected in accordance with DQOs outlined in the project QAPP. Samples were submitted to the ODAFF Laboratory for analysis of the following parameters: nitrate (NO_3), nitrite (NO_2), orthophosphate (PO_4), total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia (NH_4), chloride (Cl), sulfate (SO_4), total suspended solids (TSS), total dissolved solids (TDS), 5-day biochemical oxygen demand (BOD_5), and total hardness. An estimate of total nitrogen was calculated by summing the values of nitrite, nitrate, and TKN for each sample. Available nitrogen was calculated by summing the values of ammonia, nitrite, and nitrate.

Separate samples were collected and submitted concurrently for analysis of *E. coli* and *Enterococcus* bacteria during the recreational season (May 1 – September 30) ensuring that a minimum of 10 samples were assessed per site over the two-year monitoring period. In addition, site observations of odor, excessive bottom deposits, surface scum, oil/grease, foam and other observations were recorded each time. All data were compiled and entered into an Access

database for later analysis. Upon retrieval, data were proofed and quality assured, and the descriptive statistics were generated for each parameter using the statistical software package *Minitab V. 14*.

Table 1. Site List for Rotating Basin Monitoring Program (Year 5).

SiteName	WBID	Lat	Long	LegalDesc	County	EcoRegion
Beech Creek	OK410210-06-0320G	34.4868	-94.5392	SW¼ NW¼ NW¼ Section 12-1S-26E	McCurtain	OM
Big Cedar Creek	OK410310-02-0100D	34.6464	-94.6545	SE¼ SW¼ NW¼ Section 14-2N-25E	LeFlore	OM
Big Eagle Creek	OK410210-06-0160L	34.5217	-94.7228	NW¼ NE¼ NW¼ Section 31-1N-25E	LeFlore	OM
Billy Creek	OK410310-02-0070C	34.6822	-94.7759	SW¼ SE¼ SW¼ Section 34-3N-24E	LeFlore	OM
Bird Creek	OK410300-01-0100C	33.9721	-95.2819	NW¼ SE¼ SE¼ Section 2-7S-19E	Choctaw	SCP
Black Fork of Little River	OK410210-03-0020C	34.4729	-95.2171	NW¼ NE¼ NW¼ Section 16-1S-20E	Pushmataha	OM
Bokchito Creek	OK410600-01-0090G	34.0130	-96.1214	NE¼ SE¼ SW¼ Section 23-6S-11E	Bryan	SCP
Buck Creek	OK410300-03-0420C	34.3394	-95.6417	SE¼ SE¼ NE¼ Section 32-2S-16E	Pushmataha	OM
Buffalo Creek	OK410210-06-0020G	34.3695	-94.6225	NW¼ SW¼ NW¼ Section 19-2S-26W	McCurtain	OM
Caddo Creek	OK410600-01-0140G	33.9974	-96.1912	NE¼ NE¼ NW¼ Section 31-6S-11E	Bryan	SCP
Caney Boggy Creek	OK410400-06-0120G	34.7195	-96.1731	NE¼ SW¼ NW¼ Section 20-3N-11E	Coal	AV
Caney Creek (lower)	OK410400-02-0200G	34.1860	-96.0581	SE¼ SE¼ SE¼ Section 20-4S-12E	Atoka	SCP
Caney Creek (upper)	OK410400-03-0020C	34.2410	-96.2171	NW¼ NE¼ NE¼ Section 2-4S-10E	Atoka	SCP
Cedar Creek	OK410300-03-0020M	34.3313	-95.4777	NW¼ NW¼ NW¼ Section 1-3S-17E	Pushmataha	OM
Cloudy Creek	OK410210-02-0300C	34.3247	-95.2234	SE¼ SE¼ NE¼ Section 5-3S-20E	Pushmataha	OM
Cow Creek	OK410210-06-0350G	34.5068	-94.4939	NE¼ NW¼ NE¼ Section 5-1S-27E	McCurtain	OM
Cypress Creek	OK410210-01-0070G	34.0976	-95.0313	NE¼ NW¼ NW¼ Section 29-5S-22E	McCurtain	OM
Delaware Creek	OK410400-03-0240M	34.4070	-96.4244	NE¼ SE¼ SE¼ Section 2-2S-8E	Johnston	CT (Arb)
East Fork of Glover River	OK410210-09-0010G	34.3557	-94.8721	NE¼ SW¼ NW¼ Section 26-2S-23E	McCurtain	OM
Gates Creek	OK410300-01-0020F	33.9603	-95.2473	NW¼ NE¼ NE¼ Section 7-7S-20E	Choctaw	SCP
Goose Creek	OK410400-03-0490G	34.5460	-96.4404	SE¼ NE¼ NE¼ Section 22-1N-8E	Coal	AV
Horse Creek	OK410400-01-0040G	33.9100	-95.4758	NW¼ NW¼ NE¼ Section 36-7S-17E	Choctaw	SCP
Island Bayou	OK410700-00-0040G	33.8536	-96.1652	SW¼ SW¼ SW¼ Section 16-8S-11E	Bryan	ECTP
Leader Creek	OK410400-03-0370B	34.5502	-96.3745	NW¼ NE¼ Section 20-1N-9E	Coal	AV
Lick Creek	OK410400-01-0130G	33.9541	-95.7819	NE¼ NE¼ NE¼ Section 18-7S-15E	Choctaw	SCP
Little West Blue Creek	OK410600-02-0100C	34.4710	-96.6793	NE¼ NE¼ NW¼ Section 16-1S-6E	Johnston	CT (Arb)
Lukfata Creek	OK410210-07-0010G	33.9682	-94.7662	NW¼ NW¼ NE¼ Section 11-7S-24E	McCurtain	SCP
McGee Creek	OK410400-07-0010C	34.2929	-95.8893	NE¼ SE¼ NW¼ Section 13-3S-13E	Atoka	OM
Mineral Bayou	OK410600-01-0300G	34.0448	-96.3450	SE¼ SE¼ SW¼ Section 10-6S-9E	Bryan	SCP
North Boggy Creek	OK410400-08-0010M	34.4405	-96.0652	NE¼ NE¼ SW¼ Section 29-1S-12E	Atoka	OM
Norwood Creek	OK410100-01-0050H	33.7133	-94.6075	NW¼ NW¼ SW¼ Section 4-10S-26E	McCurtain	SCP
One Creek	OK410300-03-0060F	34.3168	-95.4699	SE¼ SE¼ SE¼ Section 1-3S-17E	Pushmataha	OM
Rock Creek (McCurtain Co.)	OK410200-03-0010G	34.0841	-94.4904	NW¼ NE¼ NW¼ Section 33-5S-27E	McCurtain	OM
Rock Creek (Pushmata Co.)	OK410300-02-0190G	34.2005	-95.4180	SE¼ SW¼ SE¼ Section 16-4S-18E	Pushmataha	OM
Sand Creek	OK410700-00-0260G	33.8530	-96.5499	NE¼ NW¼ NW¼ Section 23-8S-7E	Bryan	ECTP
Sandy Creek	OK410600-02-0020G	34.2169	-96.4593	SE¼ SE¼ SE¼ SectoN-9 4S-8E	Johnston	SCP
Sulphur Creek	OK410600-01-0030G	33.9466	-96.0499	SW¼ SW¼ NE¼ Section 16-7S-12E	Bryan	SCP
Tenmile Creek	OK410300-03-0270C	34.2991	-95.6612	SE¼ NW¼ NE¼ Section 18-3S-16E	Pushmataha	OM
Terrapin Creek	OK410210-02-0150G	34.2551	-95.0981	SW¼ NW¼ NW¼ Section 34-3S-21E	Pushmataha	OM
Waterhole Creek	OK410100-01-0340D	33.8530	-94.9135	SE¼ SE¼ SE¼ Section 17-8S-23E	McCurtain	SCP
West Fork of Glover River	OK410210-08-0010M	34.3089	-94.9359	SW¼ NE¼ NW¼ Section 7-3S-23E	McCurtain	OM
Whitegrass Creek	OK410400-01-0210G	33.8811	-95.8513	SW¼ SW¼ SW¼ Section 4-8S-14E	Bryan	SCP

2.3 BIOLOGICAL MONITORING

2.3.1 Habitat Assessment

In the summer of 2005, OCC staff conducted instream and riparian habitat assessments at sites concurrent with fish collections. All assessments were conducted in accordance with procedures outlined in the OCC Habitat Assessment SOP (OCC 2006). The OCC's habitat assessment adheres to a modified version of the EPA Rapid Bioassessment Protocols (RBP) (Plafkin et al., 1989) and is designed to assess habitat quality in relation to its ability to support biological communities in the stream. The assessment is based on particular parameters grouped into three categories for a total of eleven components (Plafkin et al. 1989). The eleven components are discussed in more detail below. The three primary categories assessed include micro scale habitat, macro scale habitat, and riparian/bank structure. Micro scale habitat includes substrate makeup, stable cover, canopy, depth, and velocity. Macro scale assesses the channel morphology, sediment deposits, and other parameters. The third category looks at the riparian zone quality, width, and general makeup (trees, shrubs, vines, and grasses) as well as bank features. Bank erosion and streamside vegetative cover are incorporated into this section.

OCC's habitat assessment components include:

(1) **Instream cover** is the component of habitat that organisms hide behind, within, or under. High quality cover consists of things like submerged logs, cobble and boulders, root wads, and beds of aquatic plants. Cover required by smaller members of the stream community will consist of gravel, cobbles, small woody debris, and dense beds of fine aquatic plants. At least 50% of the stream's area should be occupied by a mixture of stable cover types for this category to be considered optimal.

(2) **Pool bottom substrate** describes the type of stream bed found in pools. Pools are depositional areas of the stream, and as such, are easily damaged by materials that settle. A loose shifting pool bottom will not provide substrate for burrowing organisms and will not allow bottom-spawning fish to successfully spawn. It will not provide habitat to the smaller vertebrates and invertebrates that are necessary to support many of the pool dwelling fish. At least 80% of all pool bottoms must have stable substrate for a reach to be considered optimal for this habitat component.

(3) **Pool variability** describes the depth of pools. A healthy, diverse community of aquatic organisms requires both deep and shallow pools. A fairly even mix of pool depths from a few centimeters to 0.5 meters or greater is optimal.

(4) **Canopy cover** assesses the shading of the stream section. Plants lie at the base of almost all food chains. Since plants require light for growth and survival, a stream that is functioning well needs some amount of light. Moderation is optimal, however, because light is associated with heat, and most aquatic organisms are more stressed by the warmer waters and the lower oxygen solubility and higher metabolic rates that accompany the warming of water.

(5) The **percent of rocky runs and riffles** is calculated for the fifth component. Rocky runs and riffles offer a unique combination of highly oxygenated, turbulent water, flowing over high

quality cover and substrate. Turbulence prevents the formation of nutrient concentration gradients from cell membranes outward so that algae and other plants grow at a much higher rate than they would at the same concentration in pools. More food means more growth. Larger crops of algae are translated into larger invertebrate crops. It is these invertebrates, reared in riffle areas, that feed many of the fish in the stream. Because turbulent water is well oxygenated, there has been no selection pressure for riffle dwelling organisms to develop tolerance to poorly oxygenated waters. These are often the first animals to disappear from the stream if oxygen becomes scarce. The presence of rocky runs and riffles offers habitat for many highly adapted animals that will increase diversity of samples collected from the streams they occupy.

(6) **Discharge** at representative low flow reflects stream size. Water is the most basic requirement of aquatic organisms. Larger streams tend to have more water, and thus, more varied high quality habitat. Overall habitat quality should rise as streams increase in size and discharge, other factors being equal.

(7) **Channel alteration** is the seventh category. The presence of newly formed point bars and islands is very significant. Unstable streambeds support fewer types of animals than those that are stable. This is because unstable streambeds tend to have unstable pool bottom substrate, riffle areas whose cobbles are embedded in finer material, and little cover because it is continually being buried. Few or no signs of channel alteration are considered optimal.

(8) **Channel sinuosity** measures how far a channel deviates from a straight line. More sinuous channels tend to have more undercut banks, root wads, submerged logs, etc. IBI scores should be higher as channels become more sinuous. Sinuosity was calculated from digital ortho quad maps using Geographic Information System technology (GIS).

(9) The **bank erosion** index assesses the stability of the stream bank. Stable stream banks tend to increase IBI scores for many reasons. Most importantly, they do not contribute sediment to the stream channel. As a rule, channels with stable banks tend to be deeper and narrower than channels with unstable banks. Because of the increased depth and decreased width, they tend to be cooler and they also tend to grow less algae for a given amount of nutrients than do shallow, wide channels. Overall habitat quality should increase as bank stability increases.

(10) The **vegetative stability of the stream bank** is an important component. Stream banks can be stabilized with a number of materials including rock, concrete, and fabric. Banks that are stabilized with vegetation benefit the aquatic community more than those stabilized with other materials. This is because the vegetation offers several extra advantages beyond that of bank stability. The riparian plants of the stream bank offer a high quality source of food and shade to the aquatic community. Riparian vegetation stabilizes point bars and contributes greatly to structure in the form of root wads and woody debris. Overall habitat quality should improve as bank vegetative stability increases.

(11) The last category is **streamside cover**. A large part of the energy and food input to the stream comes from the terrestrial vegetation along the banks. A mixture of grasses, forbs, shrubs, vines, saplings, and large trees transfer these necessities to the stream more effectively

than does any single type of vegetation. Habitat quality should increase as the form of bank vegetation increases in diversity.

Each stream segment was surveyed for 400 meters upstream or downstream of the starting point (usually a road crossing). Investigators recorded data for the described parameters for 20 stations at 20 meter intervals. Habitat data were entered, metrics were computed, and a "total habitat score" was rendered via *Access* programming. The total habitat score, which can reach a maximum of 180 points, was calculated based on quantitative weighting given to each of the habitat parameters in relation to their biological significance. Scores were computed for each of the eleven categories, summed, and assigned as an evaluation of that stream section and riparian zone.

2.3.2 Fish

In the summer of 2005, fish were collected from a 400-meter reach at all sites using a combination of seining and electroshocking according to procedures outlined in OCC SOP (2006). The collection of fish follows a modified version of the EPA Rapid Bioassessment Protocol V (Plafkin et al., 1989) supplemented by other documents. Specific techniques and relative advantages of seining and electrofishing vary considerably according to stream type and conductivity. Depending upon workable habitat, seining was performed first at all sites and was accomplished by use of either 6’ X 10’ or 6’ X 20’ seines of ¼ inch mesh equipped with 8’ brailes. Electroshocking was undertaken at all sites with suitable conductivities (usually < 1000 µS/cm) and involved the use of a Smith Root LR24 backpack shocker. For sites possessing long pools too deep to seine or backpack shock, OCC field personnel employed a boat electrofishing unit consisting of a Smith-Root GPP 5 shocking unit powered by a Honda 5kw generator.

Except for those individuals readily identifiable, fish were placed in 10% formalin upon capture and identified to species by a professional taxonomist. Fish species identified and released in the field were photographed on print film for reference. All fixed fish samples were transferred to ethanol and retained for future reference.

Fish data were compiled and analyzed by site using state biocriteria and methods outlined in the state’s *Use Support Assessment Protocols* (OWRB 2002). In addition, each site was assessed using a modified version of Karr’s Index of Biotic Integrity (IBI) (adapted from Plafkin et al., 1989). Descriptive statistics were determined for each metric using the *Minitab V. 14* software. The condition of the fish community was based on indices of species richness, community quality, trophic structure, and by comparison to the average scores of high-quality streams in that ecoregion (OCC 2006). The modified IBI score was calculated using the following metrics:

(1) The **total number of fish species** decreases with decreasing water or habitat quality.

(2) The **number of sensitive benthic species (darters, madtoms, sculpins)** decreases with increasing siltation and increasing benthic oxygen demand. Many of these fish actually live within the cobble and gravel interstices and are very good indicators of conditions that make this environment inhospitable. These species are weak swimmers that do not readily travel up and down a stream, so their presence or absence at a site relates well to both past and present habitat and water quality conditions at that site.

(3) The **number of sunfish species** decreases with decreasing pool quality and with decreasing cover. Sunfish also require a fairly stable substrate on which to spawn, so their long-term success is also tied to conditions that affect the amount of sediment that enters and leaves the stream.

(4) The **number of intolerant species** is a characteristic of the fish community that separates high quality from moderate quality sites. A high quality stream will have several members of the fish community that are intolerant to environmental stress. A stream of only moderate quality will have fish that are moderately and highly tolerant of environmental stress. The intolerant species will not be present in the moderate quality stream.

(5) The **proportion of tolerant individuals** is a characteristic that allows moderate quality streams to be separated from low quality streams. These are opportunistic, tolerant fish that dominate communities that have lost their competitors through loss of habitat or water quality.

(6) The **proportion of individuals as insectivorous cyprinids** increases as the quality and quantity of the invertebrate food base increases. These are the dominant minnows in North American streams but are replaced by either omnivorous or herbivorous minnows as the quality of the food base deteriorates. Often, as the density of aquatic invertebrates decreases, the standing crop of algae increases. This is because the aquatic invertebrates are the largest group of primary consumers. Fish that can switch their diet to algae or fish that eat only algae will replace fish that cannot adapt to the new conditions.

(7) The **proportion of individuals as lithophilic spawners** decreases as the quality of the stream decreases. Lithophilic spawners require cobble or gravel in order to spawn; hence, these fish are sensitive to siltation. This metric allows separation of excellent streams from moderate quality streams.

For each of these seven metrics, a score of 5, 3, or 1 was assigned (Table 2), and these scores were summed to get a total IBI score (35 point maximum) for each site. For all “proportion” metrics, the score was based on the actual metric. For all non-proportion metrics, the score was determined by dividing the monitoring site’s metric by the average high quality site metric of the same ecoregion. Each monitoring site’s total score was then compared to the high quality site total score in that ecoregion and given an integrity rating (as established and suggested by the EPA RBP; see Table 3, below). IBI scores that fell between the assessment ranges were classified in the closest scoring group. This score indicates the quality of the fish community (higher scores indicate higher quality) but says nothing about whether any deficiencies are due to degraded water quality or to degraded habitat.

Table 2. Index of Biotic Integrity (IBI) scoring criteria for fish.

Metrics	***5***	***3***	***1***
Number of species	>67%	33-67%	<33%
Number of sensitive benthic species	>67%	33-67%	<33%
Number of sunfish species	>67%	33-67%	<33%
Number of intolerant species	>67%	33-67%	<33%
Proportion tolerant individuals	<10%	10-25%	>25%
Proportion insectivorous cyprinid individuals	>45%	20-45%	<20%
Proportion individuals as lithophilic spawners	>36%	18-36%	<18%

Table 3. Index of Biotic Integrity (IBI) score interpretation for fish.

% Comparison to the Reference Score	Integrity Class	Characteristics
>97%	Excellent	Comparable to pristine conditions, exceptional species assemblage
80 - 87%	Good	Decreased species richness, especially intolerant species
67 - 73%	Fair	Intolerant and sensitive species rare or absent
47 - 57%	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant
26 - 37%	Very Poor	Few species and individuals present; tolerant species dominant; diseased fish frequent

2.3.3 Macroinvertebrates

Collection of macroinvertebrates was attempted at all sites for both the winter and summer index periods of July 2005 through March 2007 according to procedures outlined in the OCC SOP (2006). Index periods represent seasons of relative community stability that afford opportunity for meaningful site comparisons. For Oklahoma, the summer index occurs from July 1 to September 15; the winter index occurs from January 1 to March 15. Sampling efforts included attempts to procure animals from all available habitats at a site; thus, total effort at a site may entail up to three total samples with one from each of the following habitats: rocky riffles, streamside vegetation, and woody debris.

Collection methods involved sampling each of the habitats similar to methods outlined in the EPA Rapid Bioassessment Protocols (Plafkin et al., 1989). Riffle sampling effort consisted of three, one meter squared kicknet samples in areas of rocky substrate reflecting the breadth of the velocity regime at a site. Riffles with substrates of bedrock or tight clay were not sampled. Any streamside vegetation in the current that appeared to offer fine structure was sampled by agitation within a #30 mesh dip net for three minutes total agitation time. Any dead wood with or without bark which was in current fast enough to offer suitable habitat for organisms was sampled by agitation or by scraping/brushing upstream of a #30 mesh dip net for 5 minutes. Woody debris sampled generally ranged in size from 1/4" to about 8" in diameter. Each sample

type was preserved independently in quart mason jars with ethanol, labeled, and sent to a professional taxonomist for picking and identification.

Data was compiled, collated by year, season, and sample type and entered into a spreadsheet for metric calculations. The six metrics used to assess the macroinvertebrate community include the following:

(1) The **number of taxa** refers to the total number of taxonomically different types of animals in the sample. As is the case with the fish, this number rises with increasing water and/or habitat quality (Plafkin et al., 1989).

(2) The **Modified Hilsenhoff Biotic Index (HBI)** is a measure of the invertebrate community's tolerance to organic pollution. It ranges between 0 and 10 with 0 being the most pollution sensitive. The index used in the RBP Manual is based on the pollution tolerance of invertebrates from the upper midwest. The Index used here is calculated the same way, but uses tolerance values of North Carolina invertebrates (Plafkin et al., 1989).

(3) The **percent EPT** is a measure of how many individuals in the sample are members of the EPT group. This metric helps to separate high quality streams from those of moderately high quality. The highest quality streams will have many individuals of many different taxa of EPT. As conditions deteriorate, animals will begin to die or to drift downstream. At this point, the community will still have many taxa of EPT, but there will be fewer individuals (Plafkin et al., 1989).

(4) The **EPT Index** is the number of different taxa from the orders Ephemeroptera, Plecoptera, and Trichoptera, the mayflies, stoneflies, and caddis flies respectively. With few exceptions, these insects are more sensitive to pollution than any other groups. As a stream deteriorates in quality, members of this group will be the first to disappear. This robust metric allows discrimination between all but the worst of streams (Plafkin et al., 1989).

(5) **Percent dominant two taxa** is the percentage of the collection composed of the most common two taxa. As more and more species are excluded by increasing pollution, the remaining species can increase in numbers due to the unused resources left by the excluded animals. This metric helps to separate the high quality streams from those of moderate quality (Plafkin et al., 1989).

(6) The **Shannon-Weaver Species Diversity Index** measures the evenness of the species distribution. It increases as more and more taxa are found in the collection and as individual taxa become less dominant. This metric increases with increasing biotic quality (Plafkin et al., 1989).

Descriptive statistics of each season-specific sample type (e.g., summer riffle, winter vegetation, summer woody) for each site were determined via *Minitab V. 14* and were compared to the average respective metric of high-quality streams in the ecoregion. A bioassessment score was calculated similarly to the IBI score for fish. For each site, scores of 6, 4, 2, or 0 were assigned for each metric (according to the criteria in Table 4, below) and then summed to get a total bioassessment score for each site with a maximum of 36 points. For taxa richness and EPT taxa

richness, the percentages used to assign scores were obtained by dividing each monitoring site metric by the average high quality site metric in a particular ecoregion. For the HBI metric, the high quality site value was divided by the monitoring site value (high quality site metric / monitoring site metric). For the remaining metrics, the score was based on the actual values obtained instead of being relative to the high quality site metric. Each monitoring site's total score was then compared to the average high quality sites' total score (in that ecoregion) and classified according to the condition gradient outlined in Table 5, above (adapted from Plafkin et al., 1989).

Table 4. Bioassessment scoring criteria for macroinvertebrates. *Modified HBI Using North Carolina Tolerance Values, **RBP for Use in Streams and Rivers 1989, ***Modified by OCC

Metrics	***6***	***4***	***2***	***0***
Taxa Richness**	>80%	60-80%	40-60%	<40%
Modified HBI* (**)	>85%	70-85%	50-70%	<50%
EPT/Total***	>30%	20-30%	10-20%	<10%
EPT Taxa**	>90%	80-90%	70-80%	<70%
% Dominant 2 Taxa**	<20%	20-30%	30-40%	>40%
Shannon-Weaver***	>3.5	2.5-3.5	1.5-2.5	<1.5

Table 5. Bioassessment score interpretation for macroinvertebrates.

% Comparison to the Reference Score	Biological Condition	Characteristics
>83%	Non-impaired	Comparable to the best situation expected in that ecoregion; balanced trophic and community structure for stream size
54 - 79%	Slightly Impaired	Community structure and species richness less than expected; percent contribution of tolerant forms increased and loss of some intolerant species
21 - 50%	Moderately Impaired	Fewer species due to loss of most intolerant forms; reduction in EPT index
<17%	Severely Impaired	Few species present; may have high densities of 1 or 2 taxa

2.4 WATERSHED ASSESSMENT

To investigate potential sources of NPS pollution for streams showing beneficial use impairment, relevant data layers were explored using ArcView 3.2 Geographic Information System (GIS) software. Data explored included the 1992 USGS National Land Cover Dataset (NLCD), oil and gas wells, confined animal feeding operations, national pollution discharge elimination system permit holders, total retention sites, biosolid land application sites and other data layers. The NLCD was explored to determine percent occurrence of particular landuse types such as bare rock/sand/clay, vegetation (broken into several categories, both natural and agricultural), open water, and residential/commercial/industrial uses (divided into several categories).

2.5 BENEFICIAL USE SUPPORT ASSESSMENT

Each stream's assigned beneficial uses were evaluated following the protocols outlined in the state's *Continuing Planning Process, Integrated Water Quality Report Listing Methodology* (Oklahoma Department of Environmental Quality, 2006) and per *Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (OAC 785:46-15; Oklahoma Water Resource Board, 2006). Streams were considered non-supporting when Oklahoma Water Quality Standards were violated as determined by criteria and rules listed in these documents. Parameters not addressed in OAC 785:46-15 were assessed using applicable state and federal rules and regulations to determine support status. Assessment results were submitted to the ODEQ for final assimilation in the state's 2008 Integrated Report submitted to EPA Region VI.

3.0 RESULTS AND DISCUSSION

3.1 WATER QUALITY MONITORING

All chemical and physical water quality data collected for the project are included in Appendix A.1; appendix A.2 contains the bacteria data. Table 6 gives the mean values of all water quality parameters collected *in-situ* for each site, regardless of flow. Instantaneous discharge is recorded in the table as both "flow" (all discharges included) and "base flow" (elevated flows omitted). Table 7 provides the means for all chemical analytes assessed, regardless of flow. Descriptive statistics for water quality parameters are presented by site in Appendix A.3.

Table 6. Mean *In-Situ* Water Quality Values for Year 5 Monitoring Sites.

Site Name	WBID	DO (mg/L)	DO (% sat.)	Turb (NTU)	Alkalinity (CaCO3)	Temp (°C)	Cond (uS/cm)	pH (SU)	Flow (cfs)	Base Flow (cfs)
Beech Creek	OK410210-06-0320G	9.35	99	16.11	14	19.4	38.9	6.44	9.99	9.99
Big Cedar Creek	OK410310-02-0100D	7.71	77	13.46	21	16.8	57.3	7.07	5.20	5.20
Big Eagle Creek	OK410210-06-0160L	7.82	79	4.52	9	18.5	30.5	6.70	14.64	14.64
Billy Creek	OK410310-02-0070C	5.66	55	10.43	39	17.5	96.7	7.45	9.64	3.02
Bird Creek	OK410300-01-0100C	8.35	85	32.36	118	18.1	407.1	7.63	0.17	0.17
Black Fork of Little River	OK410210-03-0020C	6.88	70	5.40	16	19.5	62.8	6.61	19.81	12.01
Bokchito Creek	OK410600-01-0090G	6.88	68	33.50	136	18.8	443.6	7.27	1.36	0.82
Buck Creek	OK410300-03-0420C	7.38	73	9.59	31	17.6	131.5	6.96	19.10	7.49
Buffalo Creek	OK410210-06-0020G	8.53	89	8.12	16	18.9	50.2	6.63	13.78	13.78
Caddo Creek	OK410600-01-0140G	5.83	60	28.40	122	18.8	333.7	7.42	20.40	0.64
Caney Boggy Creek	OK410400-06-0120G	6.46	65	46.50	63	17.9	285.1	7.32	37.60	2.72
Caney Creek (lower)	OK410400-02-0200G	5.37	50	58.10	77	17.4	554.0	7.16	16.30	8.43
Caney Creek (upper)	OK410400-03-0020C	8.06	83	30.40	155	18.0	536.2	7.82	4.29	4.29
Cedar Creek	OK410300-03-0020M	6.92	71	5.32	32	18.8	139.5	6.86	20.80	6.98
Cloudy Creek	OK410210-02-0300C	7.36	75	44.80	23	18.7	94.0	6.73	4.39	3.33
Cow Creek	OK410210-06-0350G	8.01	82	21.77	16	18.1	41.3	6.62	4.28	3.83
Cypress Creek	OK410210-01-0070G	7.08	71	6.70	17	18.5	68.8	6.60	7.63	5.03
Delaware Creek	OK410400-03-0240M	7.91	82	21.78	200	17.9	512.7	7.92	10.41	5.97
East Fork of Glover River	OK410210-09-0010G	8.22	85	7.36	26	18.7	48.0	6.75	13.27	10.52
Gates Creek	OK410300-01-0020F	7.36	76	19.55	61	19.4	223.7	7.42	16.62	13.27

Site Name	WBID	DO (mg/L)	DO (% sat.)	Turb (NTU)	Alkalinity (CaCO3)	Temp (°C)	Cond (uS/cm)	pH (SU)	Flow (cfs)	Base Flow (cfs)
Goose Creek	OK410400-03-0490G	6.57	67	37.80	162	17.3	330.5	7.71	5.74	4.19
Horse Creek	OK410400-01-0040G	7.15	71	24.20	100	17.8	445.1	7.37	2.80	2.08
Island Bayou	OK410700-00-0040G	7.66	81	58.30	173	19.2	724.2	7.51	4.56	3.69
Leader Creek	OK410400-03-0370B	6.10	61	107.40	88	18.1	231.4	7.48	3.01	1.80
Lick Creek	OK410400-01-0130G	5.06	49	67.90	102	18.9	341.9	7.26	1.86	0.62
Little West Blue Creek	OK410600-02-0100C	9.34	106	4.14	310	18.6	564.9	7.57	5.94	4.34
Lukfata Creek	OK410210-07-0010G	6.24	64	5.89	121	18.7	187.1	7.24	6.08	3.94
McGee Creek	OK410400-07-0010C	8.37	86	13.25	31	17.9	75.8	7.37	10.28	10.28
Mineral Bayou	OK410600-01-0300G	8.57	91	80.40	114	18.8	314.5	7.64	3.86	3.19
North Boggy Creek	OK410400-08-0010M	7.31	82	13.92	101	18.9	1221.0	7.51	0.40	0.40
Norwood Creek	OK410100-01-0050H	4.39	45	21.27	87	18.2	465.1	7.10	0.73	0.73
One Creek	OK410300-03-0060F	7.28	74	7.70	45	18.3	208.9	7.04	11.26	4.33
Rock Creek (McCurtain Co.)	OK410200-03-0010G	8.00	82	17.00	20	18.9	58.5	6.99	9.87	4.68
Rock Creek (Pushmata Co.)	OK410300-02-0190G	6.04	62	7.93	35	19.2	113.2	6.82	6.26	3.09
Sand Creek	OK410700-00-0260G	9.15	92	36.00	93	19.8	284.5	7.83	2.99	2.02
Sandy Creek	OK410600-02-0020G	8.49	89	9.66	109	18.9	274.6	7.71	4.04	1.25
Sulphur Creek	OK410600-01-0030G	5.80	60	98.70	113	17.5	444.5	7.51	2.70	1.58
Tenmile Creek	OK410300-03-0270C	5.11	50	14.30	36	17.5	123.0	6.70	27.90	5.38
Terrapin Creek	OK410210-02-0150G	8.64	91	22.10	16	19.3	61.5	6.90	5.78	2.69
Waterhole Creek	OK410100-01-0340D	4.83	49	26.70	144	18.2	421.1	7.15	0.87	0.34
West Fork of Glover River	OK410210-08-0010M	8.16	84	6.39	20	19.1	63.2	7.02	35.80	11.70
Whitegrass Creek	OK410400-01-0210G	5.50	58	113.50	80	19.0	261.1	7.32	3.36	2.97

Table 7. Mean Water Quality Values for Year 5 Monitoring Sites.

Site Name	WBID	Chloride (mg/L)	Sulfate (mg/L)	TotDisSolids (mg/L)	Ammonia (mg/L)	CBOD5 (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TKN (mg/L)	TotOrthoPhos (mg/L)	Total Phosphorus (mg/L)	TotSusSolids (mg/L)	TotHardness (mg/L)
Beech Creek	OK410210-06-0320G	2.62	2.96	39.2	0.0153	2.2	0.0816	0.0226	0.3058	0.0093	0.0258	12.4	11.1
Big Cedar Creek	OK410310-02-0100D	4.06	4.79	48.8	0.0154	2.2	0.0605	0.0220	0.1815	0.0094	0.0328	10.5	16.7
Big Eagle Creek	OK410210-06-0160L	2.11	2.74	28.6	0.0150	2.1	0.1345	0.0200	0.1635	0.0078	0.0237	10.0	9.1
Billy Creek	OK410310-02-0070C	11.36	5.55	56.0	0.0233	2.5	0.0915	0.0270	0.2835	0.0115	0.0418	13.7	26.4
Bird Creek	OK410300-01-0100C	12.33	48.38	249.2	0.0186	3.6	0.2590	0.0317	0.3683	0.0142	0.0721	27.3	168.7
Black Fork of Little River	OK410210-03-0020C	4.98	3.95	40.5	0.0200	2.1	0.0505	0.0200	0.2110	0.0069	0.0239	10.0	20.2
Bokchito Creek	OK410600-01-0090G	14.28	50.10	277.4	0.0159	2.5	0.2890	0.0225	0.2875	0.0207	0.0508	27.0	200.9
Buck Creek	OK410300-03-0420C	15.40	8.42	92.0	0.0150	2.1	0.0730	0.0200	0.2050	0.0095	0.0442	10.8	26.9
Buffalo Creek	OK410210-06-0020G	3.21	2.97	32.6	0.0152	2.3	0.1074	0.0221	0.2879	0.0095	0.0302	10.9	15.6
Caddo Creek	OK410600-01-0140G	6.60	17.96	203.5	0.0267	2.6	0.1150	0.0390	0.4105	0.0288	0.0661	18.8	144.2
Caney Boggy Creek	OK410400-06-0120G	11.68	19.50	154.5	0.0355	2.7	13.6000	0.0215	0.4610	0.0275	0.0670	19.9	81.8
Caney Creek (lower)	OK410400-02-0200G	40.19	40.43	243.4	0.0623	2.8	0.1333	0.0267	0.6128	0.0286	0.0822	49.2	129.0
Caney Creek (upper)	OK410400-03-0020C	44.66	47.93	333.9	0.0176	3.4	0.1000	0.0200	0.3411	0.0394	0.0671	71.8	219.3
Cedar Creek	OK410300-03-0020M	9.12	5.85	70.9	0.0150	2.2	0.1290	0.0240	0.2690	0.0100	0.0328	10.4	33.4
Cloudy Creek	OK410210-02-0300C	8.70	10.89	78.9	0.0180	2.6	0.0890	0.0220	0.2625	0.0218	0.0443	13.1	27.5
Cow Creek	OK410210-06-0350G	6.61	2.93	43.1	0.0153	2.2	0.0690	0.0230	0.1785	0.0096	0.0324	15.5	12.8
Cypress Creek	OK410210-01-0070G	6.48	4.13	51.0	0.0150	2.2	0.2665	0.0200	0.2370	0.0063	0.0247	10.0	20.5
Delaware Creek	OK410400-03-0240M	35.10	21.44	298.6	0.0414	3.0	0.3730	0.0225	0.2565	0.0513	0.0877	20.0	235.4
East Fork of Glover River	OK410210-09-0010G	3.06	2.66	35.0	0.0260	2.3	0.0880	0.0200	0.2145	0.0091	0.0282	10.5	15.1
Gates Creek	OK410300-01-0020F	24.64	9.44	152.1	0.0211	2.1	0.0805	0.0226	0.2379	0.0137	0.0372	14.2	73.0
Goose Creek	OK410400-03-0490G	4.25	8.81	210.0	0.0378	2.4	0.1122	0.0222	0.2511	0.0764	0.1216	20.7	178.7
Horse Creek	OK410400-01-0040G	44.08	32.00	278.9	0.1384	2.5	1.7440	0.0410	0.5630	0.4383	0.5044	15.9	131.3
Island Bayou	OK410700-00-0040G	58.58	82.58	456.8	0.0397	2.8	0.2700	0.0310	0.6235	0.1935	0.2551	39.8	259.2
Leader Creek	OK410400-03-0370B	11.96	11.24	190.1	0.0276	3.0	0.1242	0.0232	0.4926	0.0794	0.1425	56.7	79.9
Lick Creek	OK410400-01-0130G	27.89	17.46	212.8	0.0926	3.1	0.1171	0.0479	0.6321	0.0724	0.1596	29.9	95.6
Little West Blue Creek	OK410600-02-0100C	2.87	5.21	308.3	0.0149	2.1	0.3295	0.0200	0.1190	0.0129	0.0245	11.0	340.9
Lukfata Creek	OK410210-07-0010G	5.53	7.74	119.0	0.0182	2.1	0.1455	0.0215	0.3705	0.0135	0.0420	10.5	92.0
McGee Creek	OK410400-07-0010C	6.22	10.02	51.6	0.0151	2.3	0.1014	0.0236	0.2264	0.0126	0.0249	10.7	24.7
Mineral Bayou	OK410600-01-0300G	14.43	24.27	198.9	0.0267	2.8	0.2045	0.0325	0.2975	0.0257	0.0666	32.1	135.4
North Boggy Creek	OK410400-08-0010M	17.60	509.90	1072.0	0.0298	2.2	0.1875	0.0240	0.2645	0.0374	0.0646	12.0	709.0

Site Name	WBID	Chloride (mg/L)	Sulfate (mg/L)	TotDisSolids (mg/L)	Ammonia (mg/L)	CBOD5 (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	TKN (mg/L)	TotOrthoPhos (mg/L)	Total Phosphorus (mg/L)	TotSusSolids (mg/L)	TotHardness (mg/L)
Norwood Creek	OK410100-01-0050H	71.20	108.00	294.8	0.0386	2.6	0.2650	0.0300	0.6300	0.0720	0.1242	15.6	127.9
One Creek	OK410300-03-0060F	9.30	5.18	95.3	0.0166	2.6	0.0400	0.0200	0.2790	0.0132	0.0379	11.3	42.0
Rock Creek (McCurtain Co.)	OK410200-03-0010G	4.24	3.95	44.5	0.0167	2.3	0.1537	0.0226	0.3053	0.0077	0.0243	10.6	17.5
Rock Creek (Pushmata Co.)	OK410300-02-0190G	8.36	6.20	73.2	0.0186	2.6	0.1095	0.0200	0.2662	0.0085	0.0301	12.3	32.0
Sand Creek	OK410700-00-0260G	23.53	14.57	199.0	0.0447	2.6	0.5300	0.0360	0.4480	0.0446	0.1080	135.0	98.5
Sandy Creek	OK410600-02-0020G	15.96	30.77	203.4	0.0156	2.2	0.1326	0.0221	0.1789	0.0167	0.0336	13.8	131.6
Sulphur Creek	OK410600-01-0030G	46.90	20.82	275.6	0.0428	3.6	0.1082	0.0324	0.5840	0.0414	0.1114	91.2	155.3
Tenmile Creek	OK410300-03-0270C	9.93	10.23	91.8	0.0164	2.3	0.2315	0.0225	0.2705	0.0205	0.0458	11.6	41.7
Terrapin Creek	OK410210-02-0150G	4.41	3.97	59.5	0.0157	3.0	0.1010	0.0200	0.2705	0.0113	0.0359	14.4	16.3
Waterhole Creek	OK410100-01-0340D	31.82	16.61	241.6	0.0218	3.0	0.0630	0.0220	0.5005	0.0663	0.1175	14.5	176.5
West Fork of Glover River	OK410210-08-0010M	3.63	3.13	32.7	0.0191	2.1	0.1315	0.0200	0.2440	0.0094	0.0282	10.2	16.9
Whitegrass Creek	OK410400-01-0210G	23.15	17.28	191.4	0.0260	3.2	0.1080	0.0330	0.5360	0.0444	0.1091	53.7	98.0

Of particular significance for discussion, multiple streams in the Lower Red Basin exhibited markedly low dissolved oxygen concentrations. Table 8 (below) reflects the DO values* and their total percentage below the designated use criteria for each site. Twenty-seven of the sites are designated as Warm Water Aquatic Communities (WWAC) and have a critical DO level of 5.0 mg/L most of the year (4.0 mg/L from June 16-October 15). Fifteen of the sites are designated as Cool Water Aquatic Communities (CWAC), with a critical DO level of 6.0 mg/L most of the year (5.0 mg/L from June 1-October 15). Only Sand Creek, McGee Creek, and Mineral Bayou exhibited dissolved oxygen levels which were consistently above criteria values. The 27 streams with more than 10% of samples below the criteria are considered impaired and have been included on the state's pending 2008 303(d) list.

It is commonly known that systems in the southeastern portion of the state, particularly those in McCurtain, LeFlore, and Pushmataha counties, naturally tend toward sluggish, organically enriched conditions which promote high biological oxygen demand. These conditions result because few of these systems have a ground water influence, and most are high gradient riffle-pool habitat streams that cease flowing in early summer. Biological communities have developed under these naturally occurring conditions and are well adapted to the significantly lower DO trends. Fish and macroinvertebrate collections for many of these sites, which are discussed later, reflect good to excellent

* DO concentration is strongly dependent on time of day. Most ambient monitoring programs (OCC's included) collect DO data during the middle of daylight hours, which results in a bias toward higher means for a site than the true diurnal mean.

community assessment scores. In addition, this region of the state has some of the least developed landscapes, so there are few sources that would be causing the low DO. Because of this and other observations supporting these findings, OCC recommends for state consideration the development of site specific, if not regional, DO criteria that better reflect the naturally occurring low DO conditions that typify systems in this area.

Table 8. Low dissolved oxygen values (DO<5.0 mg/l for WWAC; DO<6.0 mg/l for CWAC).

% samples with low DO	SiteName	WBID	FWP	Date	DO (mg/L)
59%	Norwood Creek	OK410100-01-0050H	WWAC	28-Jun-05	3.18
				1-Aug-05	0.16
				17-Aug-05	0.53
				30-Aug-05	2.68
				13-Sep-05	1.43
				4-Oct-05	0.6
				15-Nov-05	4.07
				7-Mar-06	4.52
				16-May-06	4.31
				25-Jul-06	3.9
				29-Aug-06	3.12
				31-Oct-06	1.85
				27-Mar-07	4.57
15%	Gates Creek	OK410300-01-0020F	CWAC	30-Aug-05	4.48
				18-Jul-06	4.44
				22-Aug-06	2.6
33%	Cypress Creek	OK410210-01-0070G	CWAC	21-Jun-05	4.66
				30-Aug-05	4.64
				4-Oct-05	3.13
				8-Nov-05	4.69
				18-Jul-06	4.45
				22-Aug-06	3.04
				26-Sep-06	4.3
38%	Cedar Creek	OK410300-03-0020M	CWAC	14-Jul-05	2.93
				29-Aug-05	3.92
				7-Nov-05	4.92
				12-Dec-05	2.85
				12-Jun-06	4.9
				17-Jul-06	2.35
				21-Aug-06	4.87
				25-Sep-06	4.2
19%	One Creek	OK410300-03-0060F	WWAC	15-Jul-05	2.85
				7-Nov-05	0.96
				12-Dec-05	4.42
				17-Jul-06	3.55
41%	Billy Creek	OK410310-02-0070C	WWAC	2-Aug-05	3.11
				11-Aug-05	0.96
				29-Aug-05	2.45
				13-Sep-05	2.1
				3-Oct-05	2.08
				14-Nov-05	3.65
				12-Jun-06	4.27
				24-Jul-06	2.83
				28-Aug-06	2.25
10%	Buck Creek	OK410300-03-0420C	WWAC	17-Jul-06	2.66
				25-Sep-06	3.93

% samples with low DO	SiteName	WBID	FWP	Date	DO (mg/L)
55%	Waterhole Creek	OK410100-01-0340D	WWAC	16-Jun-05	3.29
				1-Aug-05	3.1
				13-Sep-05	3.01
				4-Oct-05	2.94
				15-Nov-05	0.76
				21-Dec-05	0.24
				11-Apr-06	4.32
				16-May-06	4.86
				13-Jun-06	3.57
				25-Jul-06	3.42
				29-Aug-06	3.74
				31-Oct-06	4.73
5%	Terrapin Creek	OK410210-02-0150G	CWAC	25-Jul-06	3.15
33%	Cloudy Creek	OK410210-02-0300C	CWAC	29-Jun-05	4.35
				13-Jul-05	4.73
				7-Sep-05	4.25
				15-Nov-05	5.25
				20-Jun-06	3.24
				21-Aug-06	4.97
				25-Sep-06	2.47
32%	Black Fork of Little River	OK410210-03-0020C	CWAC	29-Jun-05	4.76
				19-Jul-05	3.23
				24-Aug-05	2.08
				29-Aug-05	3.88
				7-Nov-05	5.15
				17-Jul-06	1.88
				21-Aug-06	4.19
5%	Island Bayou	OK410700-00-0040G	WWAC	8-Nov-05	2.89

% samples with low DO	SiteName	WBID	FWP	Date	DO (mg/L)
59%	Tenmile Creek	OK410300-03-0270C	WWAC	2-Jun-05	3.35
				20-Jun-05	3.17
				25-Jul-05	2.18
				24-Aug-05	2.15
				29-Aug-05	1.9
				3-Oct-05	2.78
				7-Nov-05	2.02
				12-Dec-05	1.76
				23-Jan-06	4.72
				12-Jun-06	4.06
				17-Jul-06	1.29
				21-Aug-06	2.72
				25-Sep-06	3.66
5%	Big Cedar Creek	OK410310-02-0100D	WWAC	28-Aug-06	3.17
19%	Horse Creek	OK410400-01-0040G	WWAC	8-Nov-05	4.52
				13-Jun-06	4.01
				18-Jul-06	2.4
				22-Aug-06	3.17
44%	Lick Creek	OK410400-01-0130G	WWAC	21-Jun-05	0.71
				19-Jul-05	2.66
				26-Jul-05	1.66
				13-Sep-05	1.95
				11-Oct-05	2.15
				4-Apr-06	4.95
				19-Jun-06	2.43
10%	Sandy Creek	OK410600-02-0020G	WWAC	4-Oct-05	3.62
				8-Nov-05	3.43
5%	Delaware Creek	OK410400-03-0240M	WWAC	8-Nov-05	1.61

% samples with low DO	SiteName	WBID	FWP	Date	DO (mg/L)
15%	Buffalo Creek	OK410210-06-0020G	CWAC	2-Aug-05	2.21
				11-Aug-05	3.56
				14-Nov-05	4.83
11%	Bird Creek	OK410300-01-0100C	WWAC	13-Jun-06	4.25
				18-Jul-06	3.27
29%	Big Eagle Creek	OK410210-06-0160L	CWAC	10-Aug-05	3.6
				29-Aug-05	4.07
				3-Oct-05	2.6
				24-Jul-06	2.53
				28-Aug-06	4.47
				8-Jan-07	5.92
5%	Beech Creek	OK410210-06-0320G	CWAC	9-Aug-05	4.33
24%	Cow Creek	OK410210-06-0350G	CWAC	29-Jun-05	4.63
				14-Nov-05	3.23
				24-Jul-06	4.36
				28-Aug-06	3.16
				25-Sep-06	4.74
38%	Lukfata Creek	OK410210-07-0010G	CWAC	30-Aug-05	2.13
				4-Oct-05	1.9
				15-Nov-05	1.78
				21-Dec-05	5.97
				13-Jun-06	4.97
				25-Jul-06	2.48
				29-Aug-06	1.72
				26-Sep-06	4.42
14%	North Boggy Creek	OK410400-08-0010M	WWAC	7-Nov-05	3.7
				12-Jun-06	4.12
				8-Jan-07	0.35

% samples with low DO	SiteName	WBID	FWP	Date	DO (mg/L)
27%	Whitegrass Creek	OK410400-01-0210G	WWAC	21-Jun-05	2.68
				13-Sep-05	1.43
				11-Oct-05	2.77
				8-Nov-05	2.22
				13-Dec-05	0.12
				28-Aug-06	1.95
21%	Goose Creek	OK410400-03-0490G	WWAC	17-Jun-05	3.98
				7-Nov-05	2.19
				12-Dec-05	0.36
				17-Jul-06	1.36
10%	Caney Creek (upper)	OK410400-03-0020C	WWAC	7-Nov-05	1.69
				30-Oct-06	3.76
43%	Leader Creek	OK410400-03-0370B	WWAC	15-Jun-05	2.5
				21-Jun-05	3.56
				3-Oct-05	3.75
				7-Nov-05	2.3
				4-Apr-06	3.85
				12-Jun-06	3.06
				17-Jul-06	3.66
				22-Aug-06	2.13
				30-Oct-06	3.4
25%	Rock Creek (McCurtain Co.)	OK410200-03-0010G	CWAC	15-Jun-05	3.34
				28-Jun-05	4.12
				25-Jul-06	3.83
				29-Aug-06	3.91
				26-Sep-06	4.7
10%	Bokchito Creek	OK410600-01-0090G	WWAC	24-Aug-05	3.21
				7-Nov-05	3.6

% samples with low DO	SiteName	WBID	FWP	Date	DO (mg/L)
19%	West Fork of Glover River	OK410210-08-0010M	CWAC	2-Aug-05	3.44
				18-Aug-05	2.44
				25-Jul-06	4.02
				21-Aug-06	4.47
19%	Caney Boggy Creek	OK410400-06-0120G	WWAC	22-Aug-05	1.91
				12-Dec-05	0.33
				21-Aug-06	1.89
				30-Oct-06	1.56
24%	East Fork of Glover River	OK410210-09-0010G	CWAC	2-Aug-05	4.73
				7-Sep-05	4.75
				15-Nov-05	5.8
				20-Jun-06	4.88
				21-Aug-06	3.96
40%	Caney Creek (lower)	OK410400-02-0200G	WWAC	20-Jun-05	2.91
				25-Jul-05	2.16
				28-Aug-05	1.38
				13-Sep-05	3.61
				10-Oct-05	3.34
				7-Nov-05	2.38
				12-Dec-05	4.32
				25-Jul-06	2.95
5%	Little West Blue Creek	OK410600-02-0100C	WWAC	13-Feb-07	0.33
28%	Sulphur Creek	OK410600-01-0030G	WWAC	20-Jul-05	3.21
				8-Nov-05	1.36
				13-Dec-05	2.37
				24-Jan-06	3.85
				20-Jun-06	2.34
29%	Caddo Creek	OK410600-01-0140G	WWAC	23-Aug-05	2.24
				10-Oct-05	2.73
				7-Nov-05	1.63
				12-Dec-05	4.53
				3-Apr-06	4.08
				20-Jun-06	2.7
45%	Rock Creek (Pushmata Co.)	OK410300-02-0190G	CWAC	20-Jul-05	3.04
				26-Jul-05	2.44
				30-Aug-05	2.48
				4-Oct-05	3.29
				8-Nov-05	5.38
				23-Jan-06	4.67
				4-Apr-06	5.2
				9-May-06	5.91
				12-Jun-06	2.26
				17-Jul-06	3.66

Table 9 shows the geometric mean of *Enterococcus* and *E.coli* bacteria samples for each site over the two-year monitoring period. Only Caney Creek Upper and Island Bayou were designated Secondary Body Contact Recreation (SBCR); all other sites were designated Primary Body Contact Recreation (PBCR). Most creeks exceeded the geometric mean criterion set for *Enterococcus*, and many exceeded the criterion for *E. coli* as well. Only twelve creeks did not exceed either the *E. coli* or *Enterococcus* criteria. To be listed on the state's 303(d) list, the geometric mean must exceed criteria and at least one sample must be above a set criterion value. Sites listed on the 303(d) list are denoted in Table 9.

Table 9. Geometric mean of bacteria values for Year 5 monitoring sites. Values in bold exceed designated PBCR or SBCR levels (* indicates SBCR designation; all others are PBCR). ^^=listed on 303(d) list .

WBID	Site Name	*E.Coli*	*Enterococcus*	WBID	Site Name	*E.Coli*	*Enterococcus*
OK410210-06-0320G	Beech Creek	14.03	18.94	OK410400-01-0040G	Horse Creek ^^	**223.58**	**248.35**
OK410310-02-0100D	Big Cedar Creek	32.90	**69.57**	OK410700-00-0040G	Island Bayou *	166.95	**207.48**
OK410210-06-0160L	Big Eagle Creek	8.97	16.99	OK410400-03-0370B	Leader Creek ^^	**277.62**	**184.85**
OK410310-02-0070C	Billy Creek	35.06	**63.92**	OK410400-01-0130G	Lick Creek	78.86	**106.72**
OK410300-01-0100C	Bird Creek	64.72	**45.82**	OK410600-02-0100C	Little West Blue Creek	**126.91**	**87.04**
OK410210-03-0020C	Black Fork of Little River	17.12	22.46	OK410210-07-0010G	Lukfata Creek	45.39	**56.02**
OK410600-01-0090G	Bokchito Creek	42.93	**62.16**	OK410400-07-0010C	McGee Creek	10.84	10.84
OK410300-03-0420C	Buck Creek ^^	29.21	**84.83**	OK410600-01-0300G	Mineral Bayou	**299.19**	**158.31**
OK410210-06-0020G	Buffalo Creek	17.02	14.43	OK410400-08-0010M	North Boggy Creek ^^	62.71	**46.51**
OK410600-01-0140G	Caddo Creek	74.93	**76.83**	OK410100-01-0050H	Norwood Creek	104.84	**118.28**
OK410400-06-0120G	Caney Boggy Creek ^^	71.48	**95.29**	OK410300-03-0060F	One Creek	54.10	**70.70**
OK410400-02-0200G	Caney Creek (lower)	**173.39**	**286.86**	OK410200-03-0010G	Rock Creek (McCurtain Co.)	21.45	19.85
OK410400-03-0020C	Caney Creek (upper) * ^^	67.45	**218.07**	OK410300-02-0190G	Rock Creek (Pushmata Co.) ^^	69.33	**87.88**
OK410300-03-0020M	Cedar Creek	36.81	**36.40**	OK410700-00-0260G	Sand Creek	94.04	**116.77**
OK410210-02-0300C	Cloudy Creek	16.01	19.58	OK410600-02-0020G	Sandy Creek ^^	60.54	**92.53**
OK410210-06-0350G	Cow Creek	29.36	21.47	OK410600-01-0030G	Sulphur Creek	93.59	**227.21**
OK410210-01-0070G	Cypress Creek	16.26	19.91	OK410300-03-0270C	Tenmile Creek ^^	75.84	**70.28**
OK410400-03-0240M	Delaware Creek ^^	121.25	**92.79**	OK410210-02-0150G	Terrapin Creek	8.91	13.90
OK410210-09-0010G	East Fork of Glover River	20.73	29.52	OK410100-01-0340D	Waterhole Creek	100.42	**115.04**
OK410300-01-0020F	Gates Creek	48.30	**36.70**	OK410210-08-0010M	West Fork of Glover River	11.21	17.99
OK410400-03-0490G	Goose Creek	**180.12**	**131.30**	OK410400-01-0210G	Whitegrass Creek	111.77	**133.20**

Select water quality parameters are summarized by box plots in Figure 2, below. To account for natural differences, sites were collated and analyzed by Level III ecoregions (Woods et al. 2005). Additionally, sites were compared to streams determined to be "high quality" sites in each ecoregion (see App. E for high quality streams details) to determine general stream condition. Figure 2 shows interquartile range plots by site for four important indicators of pollution: estimated available nitrogen (ammonia plus nitrate/nitrite), estimated total nitrogen (TKN plus nitrate/nitrite), total orthophosphorus, and total phosphorus. All elevated flow data were omitted in these analyses.

Regarding boxplot composition, the median of each site is shown by a line within the box with outliers denoted by asterisks. The mean of the high quality stream sites in a particular ecoregion is represented by a solid horizontal line, while dashed lines indicate +/- two standard deviations (representing 95% of the high quality data) for high quality site parameters. Due to lack of reference data in the East Central Texas Plains ecoregion, no reference lines are shown for the parameters. Also, there was insufficient base flow nutrient data for the high quality Arbuckle Uplift sites, except for total phosphorus, so no reference lines are given in that ecoregion for those parameters.

Streams in the Arkansas Valley ecoregion tended to exhibit significantly higher nutrient concentrations than the high quality sites (Figure 2), and Island Bayou in the East Central Texas Plains ecoregion had high nutrient concentrations relative to most other streams in that region. Without reference data for this ecoregion, it is not clear whether these values are significantly high for that area. North Boggy Creek, in the Ouachita Mountains ecoregion, had high phosphorus and orthophosphorus values relative to the high quality mean. Horse Creek, in the South Central Plains ecoregion, had significantly high values for all four nutrient parameters, and Norwood Creek, in the same ecoregion, had high orthophosphorus values. Possible explanations for these results will be discussed at the end of this report.

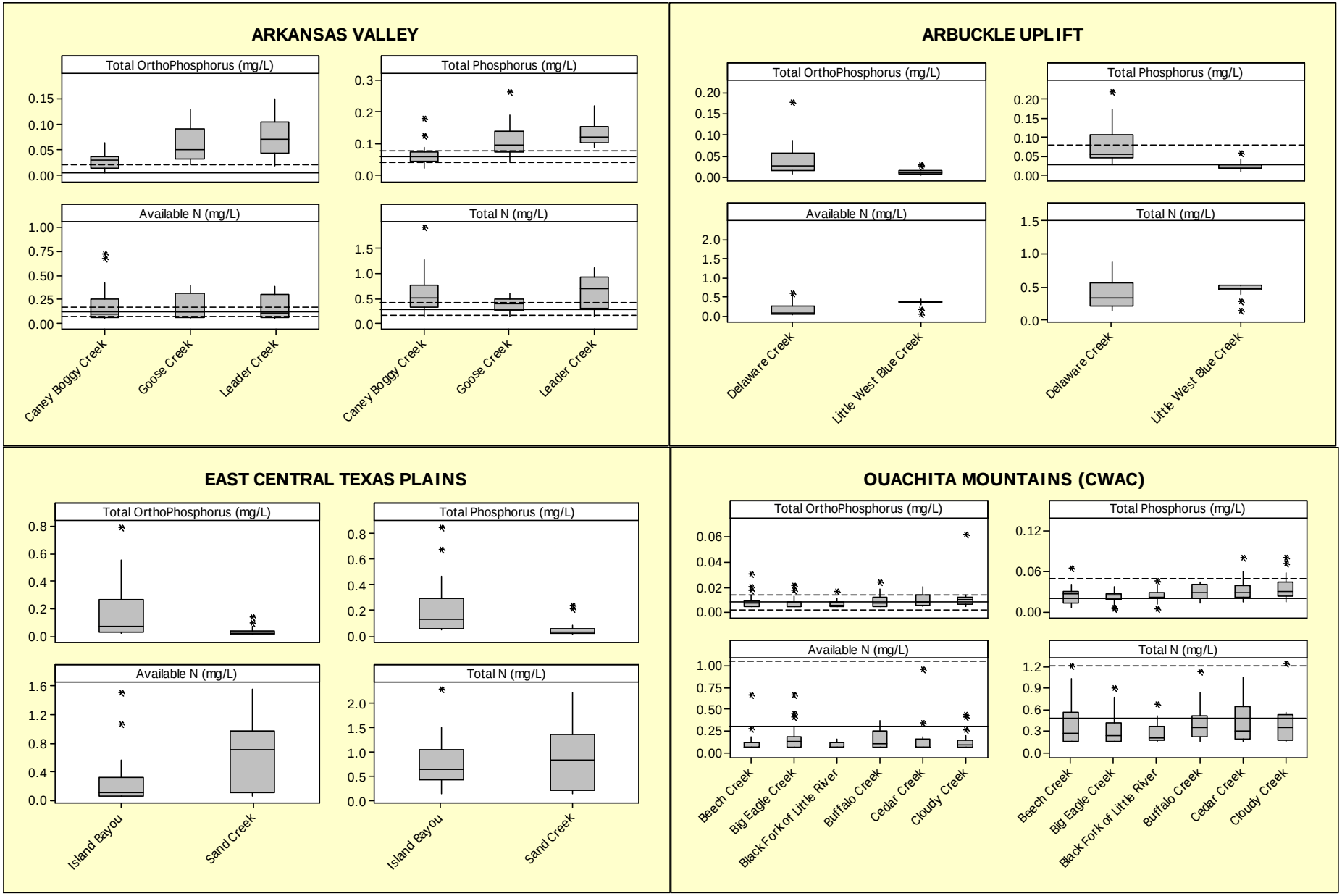


Figure 2. Nutrient parameters for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).

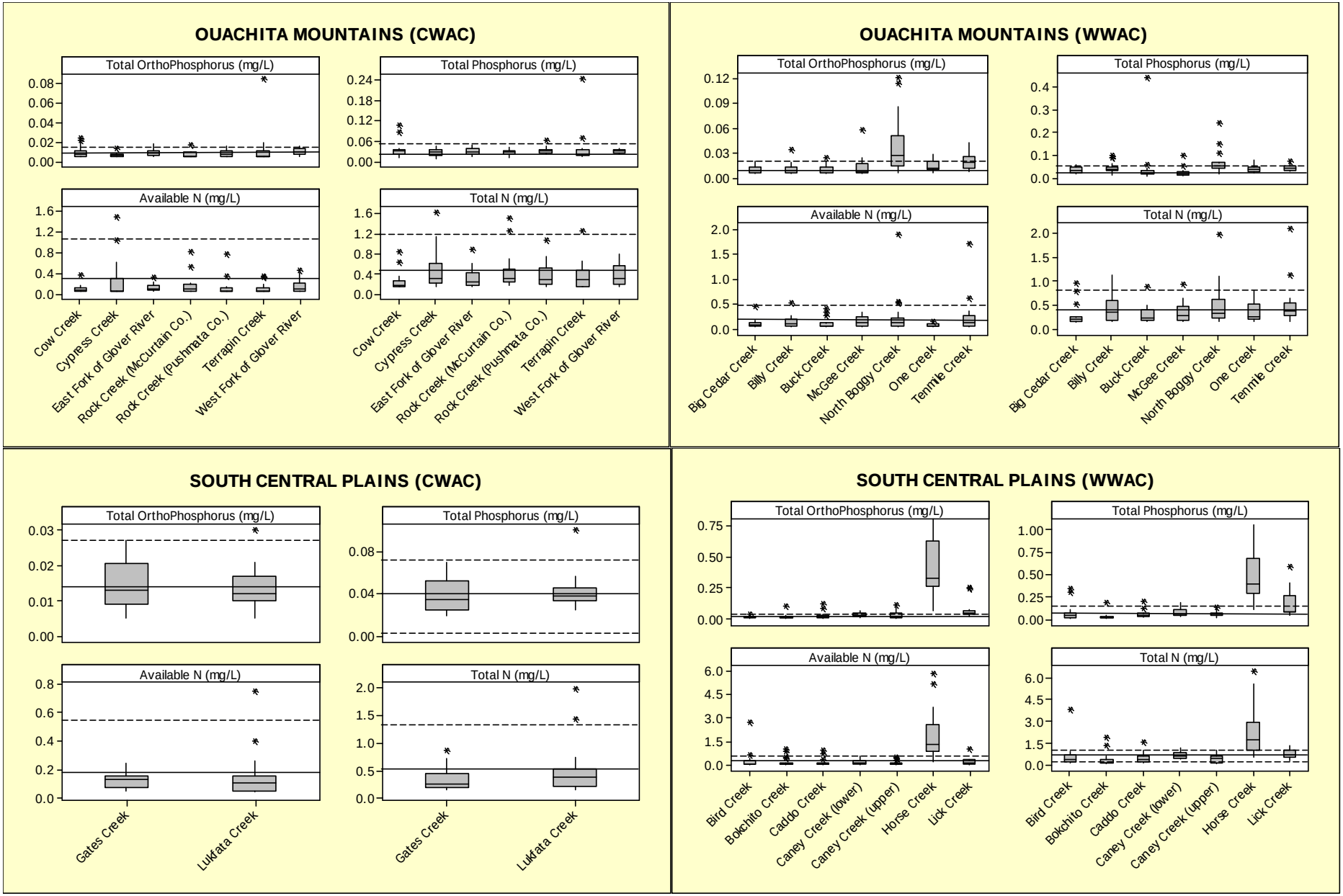


Figure 2, cont. Nutrient parameters for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).

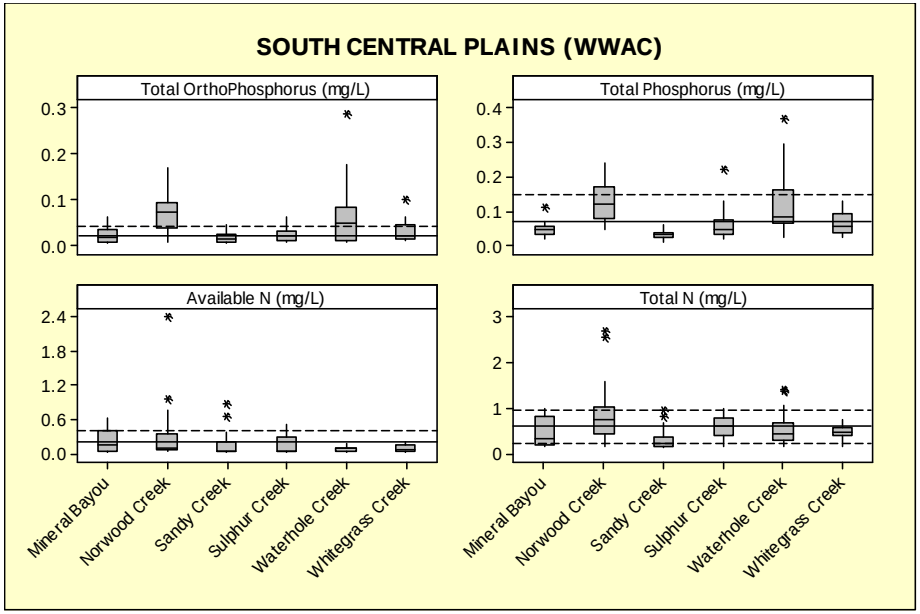


Figure 2, cont. Nutrient parameters for each site by ecoregion.
Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).

Figure 3 shows interquartile range plots for four physical parameters (all high flow data excluded): dissolved oxygen (percent saturation), pH, turbidity, and total suspended solids. Leader Creek had significantly higher turbidity (primarily inorganic) than the high quality sites in the Arkansas Valley ecoregion, and the median turbidity value of Gates Creek was higher (primarily organic) than the high quality range in the South Central Plains ecoregion. Other streams fell within the high quality range for the other parameters. These findings will be discussed further at the end of this report.

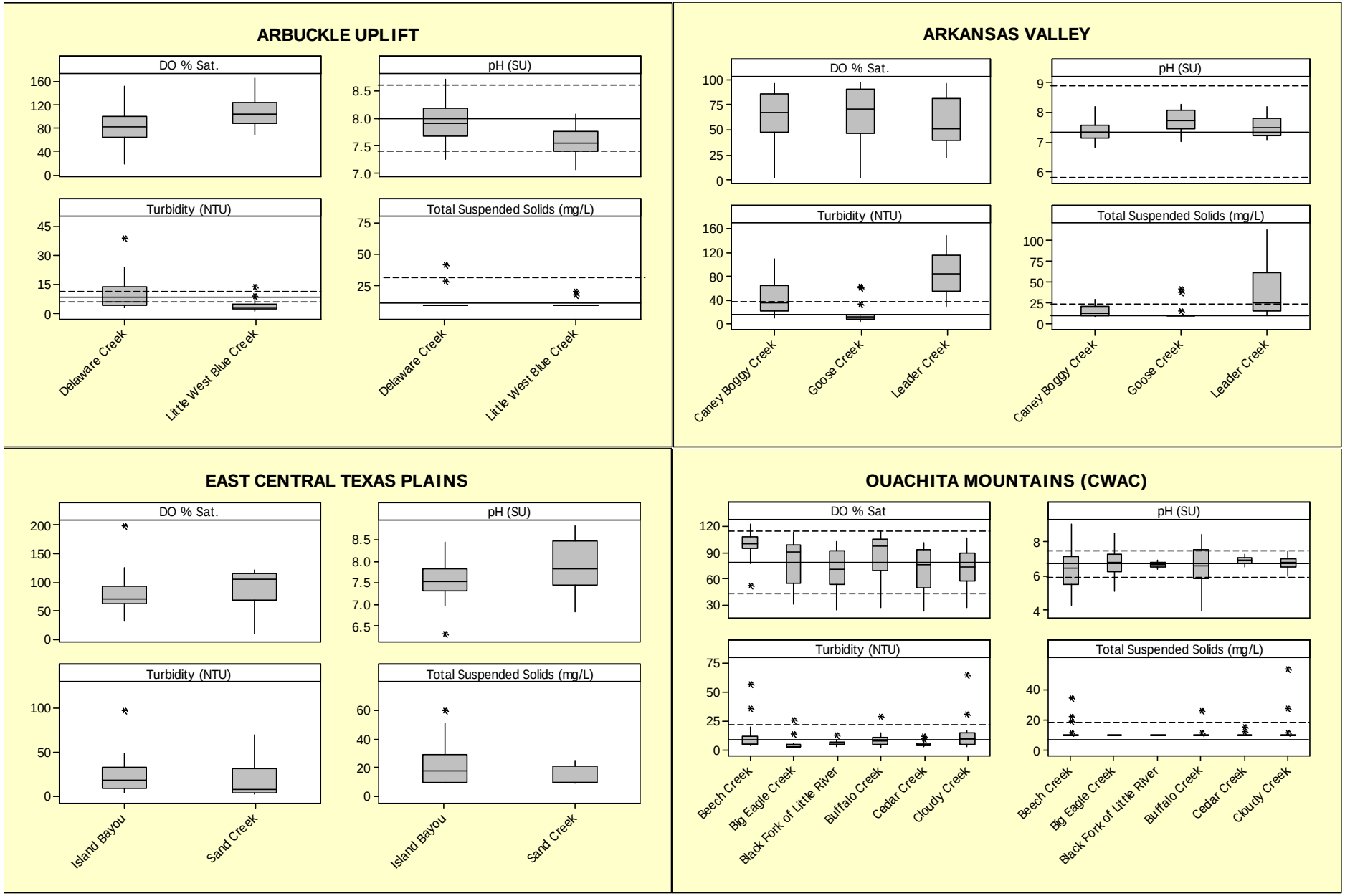


Figure 3. Selected physical water quality parameters for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).

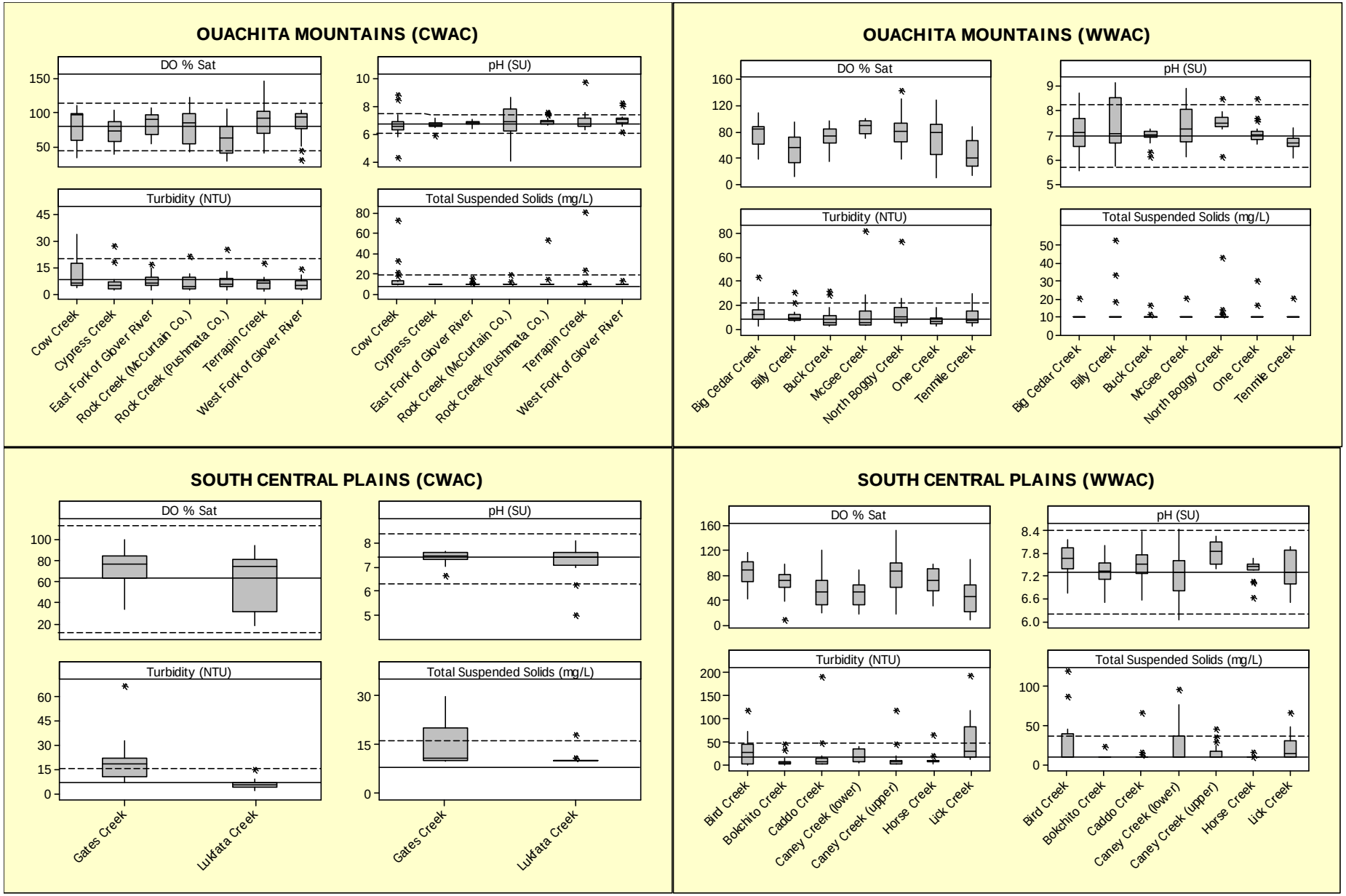


Figure 3, cont. Selected physical water quality parameters for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).

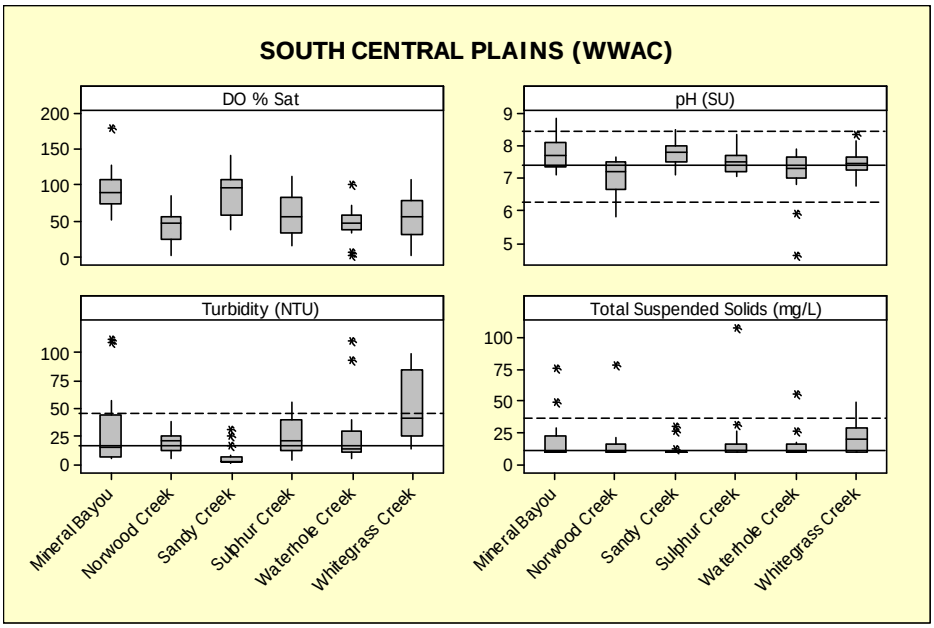


Figure 3, cont. Selected physical water quality parameters for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).

Table 10 shows a comparison between water quality data collected for the same site in previous projects and the rotating basin project in order to examine whether water conditions have improved, worsened, or remained the same at a particular site. Sixteen of the sites could be compared with past data; however, many of these sites had only been sampled a few times a year, thus limiting the power of statistical comparisons. One-way ANOVAs were performed for each set of data after all high flow data had been excluded. Only statistically significant differences between the means of each parameter in past projects and the means collected during this project are shown in the table. Level of significance is indicated by p-values, with any $p<0.05$ denoted by three asterisks (significant) and $p<0.10$ marked with one asterisk (marginally significant). Once the newest LandSat imagery is available, changes in landuse will be examined for potential sources of increase/decrease.

Table 10. Statistical comparison of historic and current (Rotating Basin Project, 2005-2007) water quality data.

WBID	Site Name	Parameter	Date of Collection	N	Mean	Standard Deviation	p value	Comments
Beech Creek	OK410210-06-0320G	Alkalinity	1991-1997	11	7.0360	3.0490	0.022***	increased
			2005-2007	21	14.5860	10.0780		
		Conductivity	1991-1997	13	25.3800	5.2100	0.006***	increased
			2005-2007	21	39.3500	16.7100		
		Ammonia	1991-1997	5	0.0120	0.0040	0.006***	increased
			2005-2007	20	0.0153	0.0010		
		Nitrite	1991-1997	6	0.0092	0.0020	0.000***	increased
			2005-2007	20	0.0225	0.0080		
		TKN	1991-1997	13	0.1662	0.0795	0.076*	increased
			2005-2007	20	0.2960	0.2453		

WBID	Site Name	Parameter	Date of Collection	N	Mean	Standard Deviation	p value	Comments
Beech, cont.		Total Phosphorus	1991-1997	13	0.0140	0.0061	0.005***	increased
			2005-2007	20	0.0258	0.0131		
Buffalo Creek	OK410210-06-0020G	Alkalinity	1991-1997	11	9.6090	2.6760	0.012***	increased
			2005-2007	18	17.8780	9.8480		
		Conductivity	1991-1997	13	39.2800	5.5900	0.005***	increased
			2005-2007	18	51.1200	12.9900		
		Ammonia	1991-1997	5	0.0120	0.0040	0.009***	increased
			2005-2007	17	0.0152	0.0010		
		Chloride	1991-1997	10	4.0100	1.0898	0.037***	decreased
			2005-2007	17	3.2882	0.6183		
		Hardness	1991-1997	10	11.6000	2.9140	0.004***	increased
			2005-2007	17	16.4000	4.1710		
		Total Phosphorus	1991-1997	13	0.0239	0.0105	0.072*	increased
			2005-2007	17	0.0311	0.0104		
		Total Suspended Solids	1991-1997	13	4.6460	4.1130	0.000***	increased
			2005-2007	17	11.0000	3.8730		
Caney Boggy Creek	OK410400-06-0120G	Total Suspended Solids	1991-1993	7	32.7140	12.9190	0.001***	decreased
			2005-2007	18	17.1670	8.1110		
Caney Creek (lower)	OK410400-02-0200G	Total Phosphorus	1991-1993	7	0.0386	0.0168	0.088*	increased
			2005-2007	16	0.0813	0.0614		
Cow Creek	OK410210-06-0350G	Dissolved Oxygen	1991-1992	3	11.3000	1.6090	0.080*	decreased
			2005-2007	21	8.0130	3.0030		
		Ammonia	1991-1992	3	0.0100	0.0000	0.000***	increased
			2005-2007	20	0.0153	0.0011		
		Nitrate	1991-1992	3	0.0100	0.0000	0.035***	increased
			2005-2007	20	0.0230	0.0098		
Cypress Creek	OK410210-01-0070G	Ammonia	1991-1997	6	0.0300	0.0352	0.056*	decreased
			2005-2007	20	0.0150	0.0005		
		Total OrthoPhosphorus	1991-1997	5	0.0100	0.0000	0.000***	decreased
			2005-2007	20	0.0063	0.0019		
		Total Suspended Solids	1991-1997	14	3.5290	2.6980	0.000***	increased
			2005-2007	20	10.0000	0.0000		
East Fork of Glover River	OK410210-09-0010G	Dissolved Oxygen	1991-1997	13	9.5110	2.2630	0.096*	decreased
			2005-2007	20	8.0390	2.4900		
		Turbidity	1991-1997	13	11.5420	5.2540	0.013***	decreased
			2005-2007	20	7.3760	3.8200		
		Conductivity	1991-1997	14	30.8500	5.3800	0.000***	increased
			2005-2007	20	48.6600	14.4200		
		pH	1991-1997	12	6.4742	0.2004	0.000***	increased
			2005-2007	20	6.7530	0.1618		
		Nitrite	1991-1997	6	0.0133	0.0052	0.000***	increased
			2005-2007	19	0.0200	0.0000		
		Hardness	1991-1997	11	10.8180	3.5730	0.021***	increased
			2005-2007	19	15.3420	5.4500		

WBID	Site Name	Parameter	Date of Collection	N	Mean	Standard Deviation	p value	Comments
East Fk. Glover R., cont.		Total Phosphorus	1991-1997	14	0.0181	0.0062	0.003***	increased
			2005-2007	19	0.0286	0.0111		
		Total Suspended Solids	1991-1997	14	3.6770	3.5520	0.000***	increased
			2005-2007	19	10.4740	1.4290		
Goose Creek	OK410400-03-0490G	Conductivity	1991-1993	8	419.2500	107.7800	0.051*	decreased
			2005-2007	16	337.0600	83.3000		
		Chloride	1991-1993	8	8.1750	3.4870	0.001***	decreased
			2005-2007	15	4.1070	1.4390		
		TKN	1991-1993	8	0.5163	0.2100	0.000***	decreased
			2005-2007	15	0.2213	0.0877		
Island Bayou	OK410700-00-0040G	TKN	1991-1993	4	0.8000	0.2160	0.047***	decreased
			2005-2007	18	0.5372	0.2259		
Lukfata Creek	OK410210-07-0010G	Conductivity	1991-1997	16	160.2900	21.3700	0.003***	increased
			2005-2007	20	191.2700	32.9100		
		Nitrate	1991-1997	15	0.2199	0.1635	0.072*	decreased
			2005-2007	19	0.1126	0.1699		
		Hardness	1991-1997	12	76.1700	10.5100	0.000***	increased
			2005-2007	19	93.1200	11.0200		
		Total Suspended Solids	1991-1997	15	4.6330	3.6610	0.000***	increased
			2005-2007	19	10.5260	1.8370		
Mineral Bayou	OK410600-01-0300G	Dissolved Oxygen	1991-1993	6	6.6830	0.5150	0.091*	increased
			2005-2007	20	8.6350	2.6650		
		Alkalinity	1991-1993	5	164.0000	27.8200	0.009***	decreased
			2005-2007	19	117.2600	33.0700		
		Conductivity	1991-1993	6	424.0000	65.2300	0.002***	decreased
			2005-2007	20	314.5000	69.2900		
		Chloride	1991-1993	5	20.0000	3.5360	0.087*	decreased
			2005-2007	19	14.9420	5.9850		
		Sulfate	1991-1993	5	35.2200	10.4420	0.041***	decreased
			2005-2007	19	24.8370	9.3100		
		Hardness	1991-1993	5	184.8000	18.8600	0.002***	decreased
			2005-2007	19	138.3900	27.4500		
Rock Creek (McCurtain Co.)	OK410200-03-0010G	Nitrite	1991-1992	3	0.0100	0.0000	0.033***	increased
			2005-2007	19	0.0226	0.0093		
Sulphur Creek	OK410600-01-0030G	Alkalinity	1991-1993	4	178.5000	21.3000	0.009***	decreased
			2005-2007	16	122.2600	36.1600		
Terrapin Creek	OK410210-02-0150G	Turbidity	1991-1997	15	13.6890	9.8800	0.004***	decreased
			2005-2007	19	6.0390	3.5630		
		Conductivity	1991-1997	15	37.5300	8.8200	0.001***	increased
			2005-2007	19	63.3400	25.1400		
		Ammonia	1991-1997	6	0.0300	0.0359	0.090*	decreased
			2005-2007	18	0.0157	0.0036		

WBID	Site Name	Parameter	Date of Collection	N	Mean	Standard Deviation	p value	Comments
Terrapin, cont.		Hardness	1991-1997	11	12.8180	4.7710	0.077*	increased
			2005-2007	18	16.7110	5.9480		
		Total OrthoPhosphorus	1991-1997	5	0.0100	0.0000	0.099*	decreased
			2005-2007	18	0.0071	0.0037		
		Total Suspended Solids	1991-1997	14	4.4430	4.0640	0.000***	increased
			2005-2007	18	10.8330	3.2940		
West Fork of Glover River	OK410210-08-0010M	Turbidity	1991-1993	7	19.1290	12.6250	0.000***	decreased
			2005-2007	19	5.8380	3.1490		
		Conductivity	1991-1993	7	37.8100	4.9600	0.039***	increased
			2005-2007	19	65.1500	32.6100		
		pH	1991-1993	7	6.5314	0.4935	0.030***	increased
			2005-2007	19	7.0158	0.4704		
		Nitrite	1991-1993	5	0.0140	0.0089	0.006***	increased
			2005-2007	18	0.0200	0.0000		
		Sulfate	1991-1993	3	5.3470	2.6370	0.020***	decreased
			2005-2007	18	3.1330	1.1620		
		Hardness	1991-1993	3	9.6670	1.5280	0.022***	increased
			2005-2007	18	17.3280	5.1690		
		Total Phosphorus	1991-1993	6	0.0217	0.0133	0.082*	increased
			2005-2007	18	0.0287	0.0059		
Whitegrass Creek	OK410400-01-0210G	Total Phosphorus	1991-1993	6	0.0367	0.0200	0.071*	increased
			2005-2007	16	0.0650	0.0339		
		Total Suspended Solids	1991-1993	6	41.0000	20.2400	0.026***	decreased
			2005-2007	16	23.5000	13.0300		

3.2 BIOLOGICAL MONITORING

3.2.1 Habitat Assessment

Total habitat scores for each site and computed metric scores are listed below (Table 11). Lukfata and Tenmile Creeks had the highest habitat scores of all the sites, while Big Cedar Creek had the lowest habitat score.

Table 11. Habitat assessment metric values for monitoring sites in the Rotating Basin Project Year 5.

SiteName	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Beech Creek	OK410210-06-0320G	12.4	7.7	5	3	7.5	0.4	7.7	1.3	9.8	4.8	10	**69.6**
Big Cedar Creek	OK410310-02-0100D	2.5	9	0	1.2	0	0	8.7	0.4	2.6	5.1	10	**39.5**
Big Eagle Creek	OK410210-06-0160L	11.3	13.4	13	15.3	0	0	2.8	0.9	7.1	3.8	9.5	**77.1**
Billy Creek	OK410310-02-0070C	9.7	15.9	9	13.1	0	0	9.9	3.6	6	5	9.9	**82.1**
Bird Creek	OK410300-01-0100C	5.8	10.2	4.5	11.5	4.1	2	2.8	1.5	5.6	4.2	9.9	**62.1**

SiteName	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Black Fork of Little River	OK410210-03-0020C	11.6	16.6	14	11	0	0.2	13.7	2.1	9.6	5.9	9.1	**93.8**
Bokchito Creek	OK410600-01-0090G	9.3	8.7	20.2	19.9	9	0.3	1.4	1.8	7.7	5.1	8.8	**92.2**
Buck Creek	OK410300-03-0420C	12.2	16	18.8	14.5	9	1.6	5	1.3	9.1	7.1	10	**105**
Buffalo Creek	OK410210-06-0020G	13.7	16.7	19	12.7	5.9	0.3	12.3	1.1	9.5	6.7	10	**108**
Caddo Creek	OK410600-01-0140G	11.7	7.6	13.8	8.3	2.2	3.9	16.5	0.8	9.1	5.8	9.9	**89.6**
Caney Boggy Creek	OK410400-06-0120G	7.7	5.7	19	17.4	7.5	9.6	1.8	3.7	4.8	5.9	10	**93.1**
Caney Creek (lower)	OK410400-02-0200G	2.7	7.3	20	19.1	7.5	0	2.8	1.1	5.9	3.3	10	**79.7**
Caney Creek (upper)	OK410400-03-0020C	3.8	1.5	0	18.8	4.1	0.1	2.3	1.5	5	4.5	9.3	**50.9**
Cedar Creek	OK410300-03-0020M	12.1	18.6	18.1	15.4	0	1.1	13.7	0.5	9.8	6.4	10	**106**
Cloudy Creek	OK410210-02-0300C	15.3	18.7	18.2	7.5	15.2	13	15.1	1	10	7.7	10	**131**
Cow Creek	OK410210-06-0350G	9	12.9	0	5.5	4.1	11	6.7	1.2	5.5	5.2	10	**71.3**
Cypress Creek	OK410210-01-0070G	13.1	18.9	13.5	13.4	0	0.4	8.7	5	8.4	4.6	9.5	**95.5**
Delaware Creek	OK410400-03-0240M	5.8	5.9	14.6	18.4	5.9	13	3.5	6.1	7.4	4.9	10	**95.5**
East Fork of Glover River	OK410210-09-0010G	7.6	13.7	17.9	6	0	0	16.5	0.4	9	3.6	10	**84.7**
Gates Creek	OK410300-01-0020F	9.3	0.4	0	5.7	2.2	11	16.5	1.2	9.7	4.4	8.8	**68.9**
Goose Creek	OK410400-03-0490G	8.2	2.5	19.8	16.9	14.1	14	0.4	3.2	4.5	3.1	4	**91**
Horse Creek	OK410400-01-0040G	4.2	3.3	20.2	19.7	4.1	5.9	5	3.4	6.1	5.3	10	**87.2**
Island Bayou	OK410700-00-0040G	4.5	4.2	16.1	14.3	0	5.5	5.8	1.4	7.6	5.8	3.2	**68.4**
Leader Creek	OK410400-03-0370B	4.1	0.7	19.2	18.3	0	3.6	11.1	1.9	5.1	3.3	3.6	**70.9**
Lick Creek	OK410400-01-0130G	2	1.8	9	19.9	0	0	6.7	4.6	4.4	3.7	8.7	**60.8**
Little West Blue Creek	OK410600-02-0100C	13	10.2	3.5	20	14.7	13	16.5	3.2	6.5	3.2	10	**114**
Lukfata Creek	OK410210-07-0010G	7.6	13.2	19.9	19	5.9	20	5	1.9	7.9	5.2	9.2	**115**
McGee Creek	OK410400-07-0010C	8.5	6.1	13.2	9.1	4.1	18	16.5	0	9.3	7	10	**102**
Mineral Bayou	OK410600-01-0300G	5.6	4.6	17.2	17.9	13.3	8.1	1.8	0.8	7.3	3.9	9.6	**90.1**
North Boggy Creek	OK410400-08-0010M	6.3	16.3	17.2	17.4	11.4	0.4	13.7	2.1	9.9	7.1	10	**112**
Norwood Creek	OK410100-01-0050H	4.6	5.4	20.2	16.6	0	0	9.9	0.5	6.7	6.2	9.9	**80**
One Creek	OK410300-03-0060F	7.4	15.8	7.7	19.8	4.1	0.9	8.7	3.5	8.4	5.5	10	**91.8**
Rock Creek (McCurtain Co.)	OK410200-03-0010G	15.1	13.1	20.2	14.1	10.3	5	3.5	1.4	8.4	5.9	10	**107**
Rock Creek (Pushmata Co.)	OK410300-02-0190G	5.8	12.1	14.6	12.9	0	0	16.5	0.2	9.9	7.6	10	**89.6**
Sand Creek	OK410700-00-0260G	8.2	7.1	0	16	5.9	2.4	1	1.5	7.6	4.8	3.2	**57.7**
Sandy Creek	OK410600-02-0020G	2.5	2.4	0	19.4	0	10	0.4	0.5	7	3.7	10	**56.2**
Sulphur Creek	OK410600-01-0030G	2.8	4.5	14.6	20	0	0.2	5.8	4.7	7.5	5.5	10	**75.6**
Tenmile Creek	OK410300-03-0270C	8.8	5.5	14.6	20	11.4	16	11.1	0.6	10	7	10	**115**
Terrapin Creek	OK410210-02-0150G	9.7	15.4	17.2	1.2	0	0	16.5	1.5	9.3	4.4	10	**85.2**
Waterhole Creek	OK410100-01-0340D	2.4	5.2	17.7	19	4.1	0.2	9.9	0.2	3.7	3.2	9.3	**74.9**
West Fork of Glover River	OK410210-08-0010M	13.2	13.1	14	14.7	0	1.8	15.1	0	8.9	5.8	9.7	**96.3**
Whitegrass Creek	OK410400-01-0210G	4.8	0.8	16.7	19	0	7.4	12.3	0.3	4	3.5	9.3	**78.1**

Sites were compared relative to the mean total habitat score of high quality sites in the respective ecoregion (Figure 4), with the exception of the ECTP ecoregion, which has no high quality sites determined at this time due to inadequate site representation. All of the sites in the AV and Arbuckle Uplift ecoregions were within two standard deviations of the high quality sites. Most of the sites in the OM ecoregion were below the high quality value; only Buffalo, North Boggy,

and Tenmile Creeks were within two standard deviations of the high quality mean, but Cloudy Creek had a significantly higher habitat score than the average high quality sites. Similarly, in the SCP ecoregion, only 5 of the 14 sites were within the high quality range, with the others being below. Sites with scores that are within +/- two standard deviations of the mean of the high quality sites do not necessarily have "reference" conditions; rather, sites outside of these values have either extremely good or extremely poor conditions which merit further investigation.

Low habitat scores could be the result of anthropogenic activities, could be naturally occurring, or could indicate an unrepresentative reach. During the monitoring period for the Year 5 sites, Oklahoma experienced a severe drought which most likely resulted in lower habitat scores. Parameters like pool variability and flow would be particularly affected by lack of water or low water conditions. The reference sites were sampled at a different time period (not during a drought), so this could explain the large number of sites that had significantly lower habitat scores than the reference sites.

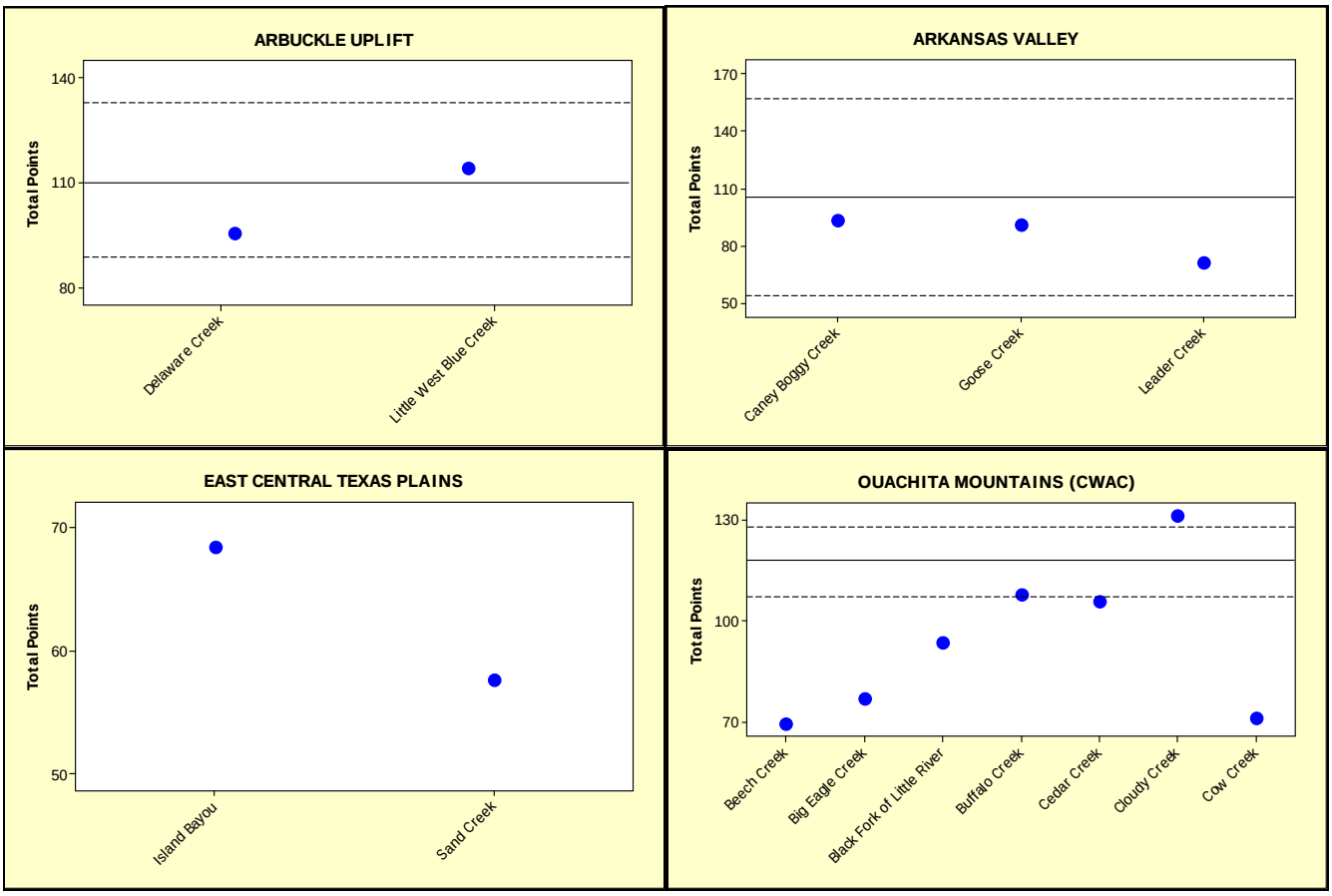


Figure 4. Total habitat score for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

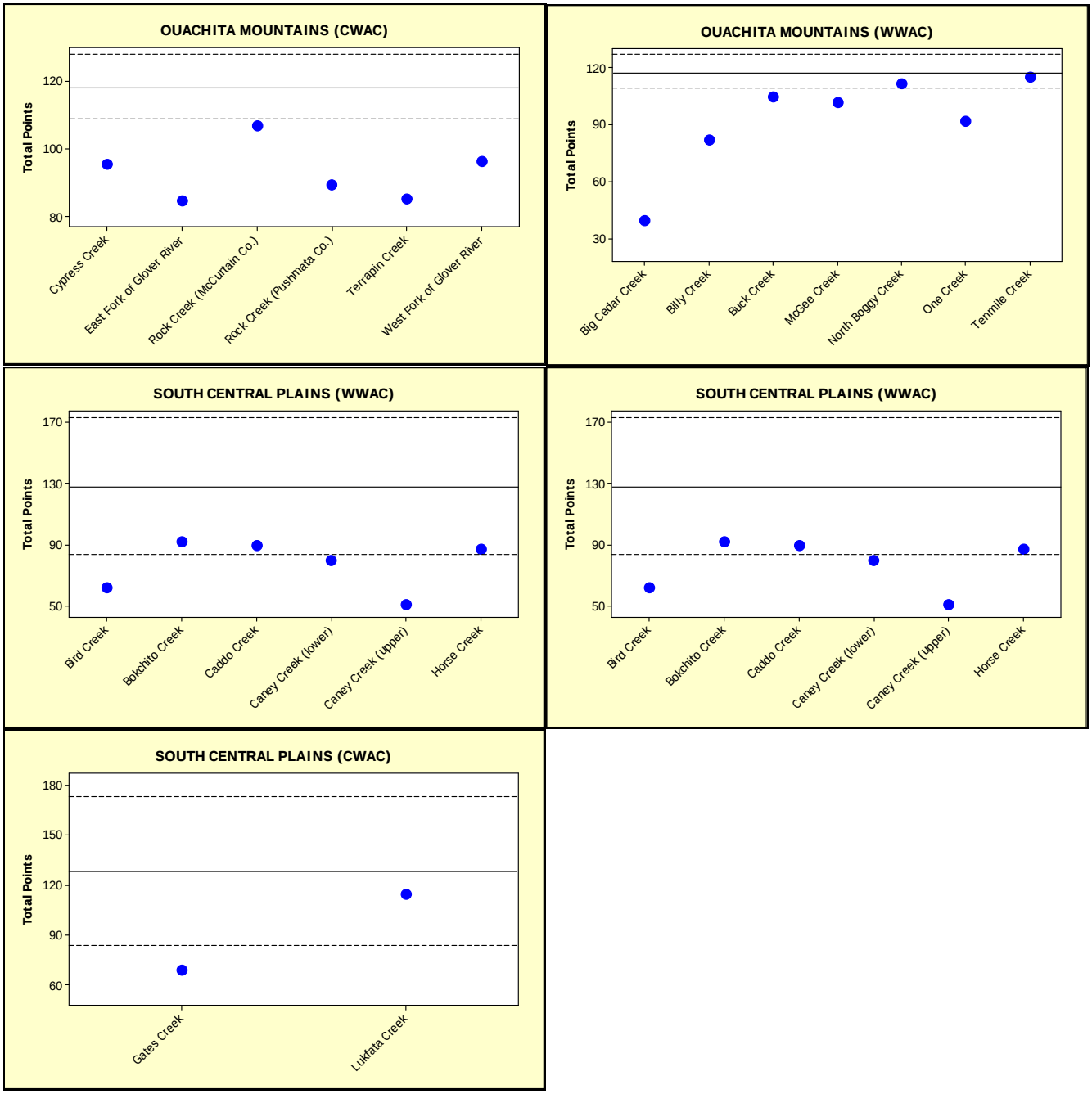


Figure 4, cont. Total habitat score for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

3.2.2 Fish Collections

Fish metrics used to compute IBI scores for the Year 5 Rotating Basin sites using the OCC method are listed in Table 12. Use of this IBI method allows assessment of streams which lack definite support assignment using the state biocriteria method. For a complete listing of fish collection data, including species and numbers caught, consult Appendix B.

Table 12. Metric values for calculation of fish IBI scores (OCC method) for Rotating Basin Year 5 monitoring sites.

SiteName	WBID	Total Spp.	# Sensitive Benthic Spp.	# Sunfish Spp.	# Intolerant Spp.	Proportion Tolerant Individuals	Proportion Insect. Cyprinid Individuals	Proportion Lithophilic Spawner Individuals
Beech Creek	OK410210-06-0320G	10	2	2	4	0.0787	0.7405	0.2245
Big Cedar Creek	OK410310-02-0100D	9	2	2	3	0.1672	0.0096	0.8199
Big Eagle Creek	OK410210-06-0160L	13	2	3	5	0.1529	0.1353	0.7794
Billy Creek	OK410310-02-0070C	18	4	5	5	0.2745	0.1877	0.1653
Bird Creek	OK410300-01-0100C	15	1	6	2	0.6641	0.1563	0.1055
Black Fork of Little River	OK410210-03-0020C	21	5	6	6	0.4770	0.1799	0.3264
Bokchito Creek	OK410600-01-0090G	19	2	6	4	0.3571	0.0574	0.5238
Buck Creek	OK410300-03-0420C	17	6	4	4	0.3389	0.1464	0.4268
Buffalo Creek	OK410210-06-0020G	15	3	5	4	0.1808	0.2165	0.4799
Caddo Creek	OK410600-01-0140G	21	5	7	4	0.3422	0.0267	0.4278
Caney Boggy Creek	OK410400-06-0120G	23	6	8	5	0.4836	0.0655	0.3455
Caney Creek (lower)	OK410400-02-0200G	25	7	9	6	0.8107	0.0688	0.0746
Caney Creek (upper)	OK410400-03-0020C	17	4	7	2	0.4477	0.1516	0.3935
Cedar Creek	OK410300-03-0020M	18	5	5	6	0.4453	0.1314	0.2482
Cloudy Creek	OK410210-02-0300C	21	6	5	7	0.3353	0.3353	0.2695
Cow Creek	OK410210-06-0350G	8	3	2	4	0.4314	0.1373	0.5490
Cypress Creek	OK410210-01-0070G	22	4	7	7	0.4975	0.2488	0.1940
Delaware Creek	OK410400-03-0240M	22	7	7	6	0.3992	0.3185	0.2581
East Fork of Glover River	OK410210-09-0010G	23	6	7	9	0.2130	0.0991	0.6350
Gates Creek	OK410300-01-0020F	27	6	7	5	0.5347	0.0417	0.3472
Goose Creek	OK410400-03-0490G	14	4	4	4	0.5146	0.1911	0.2465
Horse Creek	OK410400-01-0040G	22	4	8	5	0.5512	0.3498	0.0561
Island Bayou	OK410700-00-0040G	25	4	7	2	0.6652	0.1245	0.0987
Leader Creek	OK410400-03-0370B	19	5	6	4	0.7241	0.1621	0.0172
Lick Creek	OK410400-01-0130G	17	3	4	5	0.3161	0.2487	0.2435
Little West Blue Creek	OK410600-02-0100C	23	8	4	8	0.1617	0.3158	0.7752
Lukfata Creek	OK410210-07-0010G	25	5	7	5	0.2912	0.5675	0.2248
McGee Creek	OK410400-07-0010C	24	6	7	6	0.6159	0.3696	0.3225
Mineral Bayou	OK410600-01-0300G	21	7	4	4	0.2670	0.2897	0.4383
North Boggy Creek	OK410400-08-0010M	18	1	7	3	0.6464	0.2376	0.1713
Norwood Creek	OK410100-01-0050H	17	1	5	1	0.8641	0.0291	0.0291
One Creek	OK410300-03-0060F	15	4	5	5	0.5049	0.1699	0.4806
Rock Creek (McCurtain Co.)	OK410200-03-0010G	14	3	6	6	0.2016	0.4341	0.7287

SiteName	WBID	Total Spp.	# Sensitive Benthic Spp.	# Sunfish Spp.	# Intolerant Spp.	Proportion Tolerant Individuals	Proportion Insect. Cyprinid Individuals	Proportion Lithophilic Spawner Individuals
Rock Creek (Pushmata Co.)	OK410300-02-0190G	16	3	6	2	0.4319	0.1643	0.2488
Sand Creek	OK410700-00-0260G	17	4	5	3	0.2936	0.2399	0.3842
Sandy Creek	OK410600-02-0020G	14	4	5	1	0.3281	0.2344	0.4313
Sulphur Creek	OK410600-01-0030G	21	3	5	3	0.6620	0.0720	0.1773
Tenmile Creek	OK410300-03-0270C	14	4	3	2	0.2875	0.2063	0.5000
Terrapin Creek	OK410210-02-0150G	13	2	5	3	0.2570	0.0615	0.6201
Waterhole Creek	OK410100-01-0340D	13	1	6	1	0.7821	0.1154	0.0128
West Fork of Glover River	OK410210-08-0010M	19	5	7	8	0.5336	0.3041	0.2966
Whitegrass Creek	OK410400-01-0210G	19	3	6	3	0.5382	0.3359	0.0878

Table 13 presents the results of fish assessment based on the OCC's modified RBP method compared with the fish assessment based on Oklahoma state biocriteria (as described in Oklahoma Water Resource Board, *Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (USAP), OAC 785:46-15). The state biocriteria are based on older delineations of the level 3 ecoregions, so there were some differences in scoring based on the differences in grouping of sites. The two ECTP ecoregion sites could not be given an IBI score due to lack of high quality sites or biocriteria for comparison. The OCC method allowed greater discrimination of the biological condition among sites. Only five sites had fish communities that were "fair," and only two sites were "poor" relative to high quality sites in the ecoregion.

Table 13. IBI scores based on Use Support Assessment Protocol biocriteria (OWRB 2002) and OCC's modified RBP method. WWAC=warm water aquatic community, CWAC=cold water aquatic community. S=supporting, NS=not supporting, U=undetermined, *=no criteria for that ecoregion, NR=no reference sites determined for that ecoregion.

EcoRegion	SiteName	WBID	FWProp	IBI Total Score (USAP)	FWProp Support (USAP)	IBI Total Score (OCC)	Percent of Reference	Score Interpretation (OCC)
SCP	Norwood Creek	OK410100-01-0050H	WWAC	27	*	24	0.63	poor
SCP	Waterhole Creek	OK410100-01-0340D	WWAC	27	*	24	0.54	poor
OM	Rock Creek (McCurtain Co.)	OK410200-03-0010G	CWAC	41	S	27	1.15	excellent
OM	Cypress Creek	OK410210-01-0070G	CWAC	39	S	27	1.00	excellent
OM	Terrapin Creek	OK410210-02-0150G	CWAC	35	S	27	0.85	good
OM	Cloudy Creek	OK410210-02-0300C	CWAC	33	U	27	1.00	excellent
OM	Black Fork of Little River	OK410210-03-0020C	CWAC	35	S	27	0.93	excellent
OM	Buffalo Creek	OK410210-06-0020G	CWAC	37	S	27	1.15	excellent
OM	Big Eagle Creek	OK410210-06-0160L	CWAC	35	S	27	0.93	excellent
OM	Beech Creek	OK410210-06-0320G	CWAC	33	U	27	1.00	excellent

EcoRegion	SiteName	WBID	FWProp	IBI Total Score (USAP)	FWProp Support (USAP)	IBI Total Score (OCC)	Percent of Reference	Score Interpretation (OCC)
OM	Cow Creek	OK410210-06-0350G	CWAC	31	U	27	0.85	good
SCP	Lukfata Creek	OK410210-07-0010G	CWAC	39	*	24	1.21	excellent
OM	West Fork of Glover River	OK410210-08-0010M	CWAC	35	S	27	1.00	excellent
OM	East Fork of Glover River	OK410210-09-0010G	CWAC	43	S	27	1.07	excellent
SCP	Gates Creek	OK410300-01-0020F	CWAC	37	*	24	1.04	excellent
SCP	Bird Creek	OK410300-01-0100C	WWAC	31	*	24	0.71	fair
OM	Rock Creek (Pushmata Co.)	OK410300-02-0190G	CWAC	35	S	27	0.85	good
OM	Cedar Creek	OK410300-03-0020M	CWAC	35	S	27	0.93	excellent
OM	One Creek	OK410300-03-0060F	WWAC	35	S	27	1.00	excellent
OM	Tenmile Creek	OK410300-03-0270C	WWAC	31	U	27	0.93	excellent
OM	Buck Creek	OK410300-03-0420C	WWAC	37	S	27	1.00	excellent
OM	Billy Creek	OK410310-02-0070C	WWAC	39	S	27	0.85	good
OM	Big Cedar Creek	OK410310-02-0100D	WWAC	33	U	27	0.78	fair
SCP	Horse Creek	OK410400-01-0040G	WWAC	35	*	24	1.04	excellent
SCP	Lick Creek	OK410400-01-0130G	WWAC	35	*	24	0.96	excellent
SCP	Whitegrass Creek	OK410400-01-0210G	WWAC	31	*	24	0.88	good
SCP	Caney Creek (lower)	OK410400-02-0200G	WWAC	33	*	24	0.96	excellent
SCP	Caney Creek (upper)	OK410400-03-0020C	WWAC	37	*	24	1.04	excellent
Arb	Delaware Creek	OK410400-03-0240M	WWAC	41	S	25	1.08	excellent
AV	Leader Creek	OK410400-03-0370B	WWAC	29	U	27.5	0.76	fair
AV	Goose Creek	OK410400-03-0490G	WWAC	33	U	27.5	0.69	fair
AV	Caney Boggy Creek	OK410400-06-0120G	WWAC	35	S	27.5	0.91	good
OM	McGee Creek	OK410400-07-0010C	WWAC	39	S	27	1.00	excellent
OM	North Boggy Creek	OK410400-08-0010M	WWAC	29	U	27	0.70	fair
SCP	Sulphur Creek	OK410600-01-0030G	WWAC	33	*	24	0.79	good
SCP	Bokchito Creek	OK410600-01-0090G	WWAC	41	*	24	1.04	excellent
SCP	Caddo Creek	OK410600-01-0140G	WWAC	39	*	24	1.13	excellent
SCP	Mineral Bayou	OK410600-01-0300G	WWAC	43	*	24	1.13	excellent
SCP	Sandy Creek	OK410600-02-0020G	WWAC	35	*	24	1.04	excellent
Arb	Little West Blue Creek	OK410600-02-0100C	WWAC	43	S	25	1.16	excellent
ECTP	Island Bayou	OK410700-00-0040G	WWAC	31	*	NR		
ECTP	Sand Creek	OK410700-00-0260G	WWAC	41	*	NR		

Figure 5 shows the IBI score for each site (indicated by a blue dot) relative to the mean value for the high quality sites in that ecoregion (indicated by a solid line). The dashed lines in each graph represent +/- two standard deviations of the mean IBI score of the high quality sites in that ecoregion. There was only one high quality site in the SCP ecoregion for the WWAC designation and the CWAC designation, so no range is indicated. There were no high quality sites in the East Central Texas Plains ecoregion, so that data is not shown in Figure 5. Any sites with IBI scores equal to or better than the mean of the high quality streams will be examined for possible inclusion in the high quality sites list, and an effort will be made to find sites to represent good quality in the ECTP ecoregion.

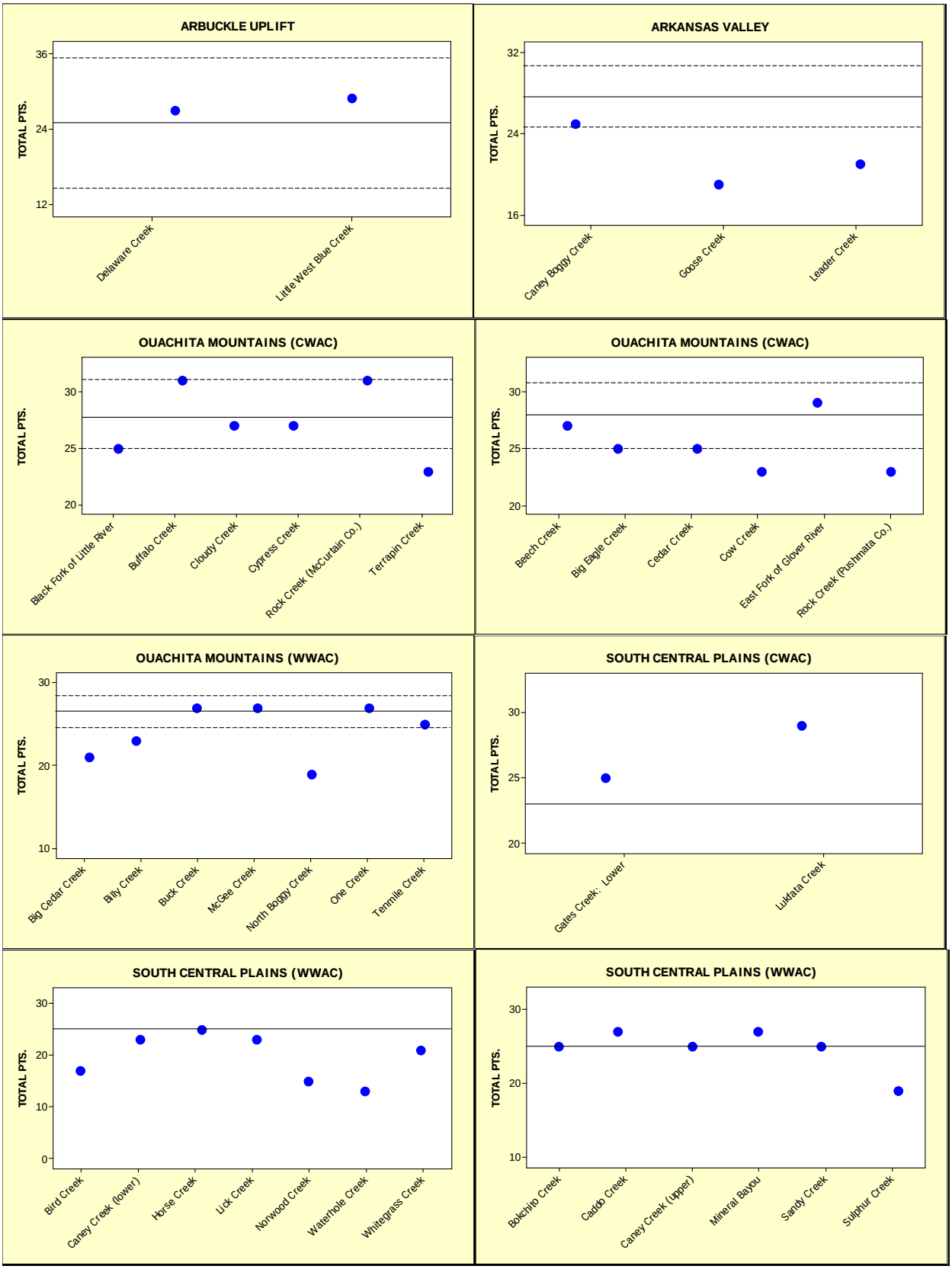


Figure 5. IBI score (fish) for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

Five sites had fish collections which indicated a "fair" condition: Bird, Big Cedar, Goose, Leader, and North Boggy. Two collections resulted in a rating of "poor": Norwood and Waterhole. It is possible that these collections were lower than normal due to drought conditions. These results will be discussed further at the end of this report.

Table 14 shows a comparison between fish data collected in previous projects and the rotating basin project in order to examine whether biological conditions have improved, worsened, or remained the same at a particular site. Many of the rotating basin sites had not been previously monitored; only five sites could be compared with past data. The fish community remained in the same condition for four of the sites compared. The fish community in Terrapin Creek exhibited a declining trend from 1991 to 2005, from "excellent" condition to "good." While the stream is still in good shape, this trend could indicate a response to declining stream conditions (the habitat score was low), or it could simply be a result of drought conditions.

Table 14. Comparison of fish data from previous projects to the Rotating Basin Year 5 project (2005-2006).

SiteName	WBID	Year	Total Individuals	Total Species	# Sensitive Benthic Spp.	# Sunfish Spp.	# Intolerant Spp.	Proportion Tolerant Individuals	Proportion Insect. Cyprinid Individuals	Proportion Lithophilic Spawners	Total Score	IBI	Condition
Cypress Creek	OK410210-01-0070G	1991	237	19	3	7	6	0.26	0.47	0.52	27	1.00	excellent
		1994	410	23	4	8	7	0.46	0.17	0.40	27	1.00	excellent
		2005	201	22	4	7	7	0.50	0.25	0.19	27	1.00	excellent
Lukfata Creek	OK410210-07-0010G	1991	150	20	5	8	4	0.68	0.03	0.05	23	0.96	excellent
		2005	467	25	5	7	5	0.29	0.57	0.22	29	1.21	excellent
Mineral Bayou	OK410600-01-0300G	1994	777	18	5	6	2	0.42	0.34	0.23	23	0.96	excellent
		2005	397	21	7	4	4	0.27	0.29	0.44	27	1.13	excellent
Terrapin Creek	OK410210-02-0150G	1991	280	14	3	4	5	0.39	0.30	0.51	27	1.00	excellent
		1994	365	13	4	4	5	0.50	0.07	0.34	25	0.93	excellent
		2005	179	13	2	5	3	0.26	0.06	0.62	23	0.85	good
West Fork of Glover River	OK410210-08-0010M	2003	772	16	5	5	6	0.30	0.47	0.66	27	1.00	excellent
		2005	536	19	5	7	8	0.53	0.30	0.30	27	1.00	excellent

In future reports, all sites will be compared with the data collected during the first years of the rotating basin project in order to track changes. All data was compared relative to the same mean of the high quality sites for the respective ecoregion in order to obtain the IBI score (OCC method). Although, ideally, one would use collections from the same years for comparison, multiyear collections at sites deemed "high quality" were not available.

3.2.3 Macroinvertebrate Collections

The complete macroinvertebrate dataset, including species and numbers captured per site, can be found in Appendix C. Macroinvertebrates were collected for each site at least once during the project period except for Bird, Sulphur, Lick, and Caddo Creeks, where no samples were obtained over the course of the project period due to lack of flow during the collection periods. Few collections were obtained during the summer of 2006 due to a severe drought in the state. Only two sites, the West Fork of the Glover River and Little West Blue Creek, had four collections over the two-year project period.

Table 15 presents the mean values, by season and sample type, for each metric at each site for the two-year monitoring period. Riffle samples were collected at most sites and, generally, best reflect the macroinvertebrate community as a single habitat (Plafkin et al. 1989). Summer samples, as opposed to winter samples, represent the harshest time for macroinvertebrates; thus their use constitutes a more conservative approach in assessing the communities. Table 16 contains the overall bioassessment scores determined for each monitoring site averaged over sample types and seasons.

Table 15. Macroinvertebrate metric values determined for each monitoring site, averaged per season and habitat (*no reference data). NI=non-impaired, SI=slightly impaired, MI=moderately impaired.

Sitename	Wbid	Sample Type	Winter or Summer	Total Species	EPT Taxa	Percent EPT	Shannon Diversity	HBI	Percent Dominant 2 Taxa	Total Points	% of Reference
Norwood Creek	OK410100-01-0050H	rif	W	16	8	0.18	1.99	5.69	0.55	1.08	NI
Waterhole Creek	OK410100-01-0340D	rif	S	10	2	0.04	1.53	6.81	0.74	0.31	MI
			W	13	2	0.04	1.20	6.17	0.84	0.42	MI
		veg	W	13	2	0.09	1.64	6.24	0.73	0.58	SI
Rock Creek (McCurtain Co.)	OK410200-03-0010G	rif	S	18	9	0.52	2.48	4.22	0.34	1.23	NI
			W	14	7.5	0.76	1.78	3.01	0.62	0.75	SI
Cypress Creek	OK410210-01-0070G	rif	S	13	4	0.25	1.65	4.28	0.64	0.77	SI
			W	17	9	0.28	1.94	5.21	0.60	0.86	NI
Terrapin Creek	OK410210-02-0150G	rif	S	25	11	0.35	2.80	5.10	0.29	1.31	NI
			W	13	9	0.57	2.19	4.69	0.45	1.00	NI
Cloudy Creek	OK410210-02-0300C	rif	S	16	5	0.43	2.20	5.20	0.44	0.92	NI
			W	19	8.5	0.47	2.33	4.26	0.41	1.00	NI
		veg	S	17	8	0.43	2.30	5.01	0.42	1.23	NI
		wood	S	11	3	0.15	1.67	5.72	0.65	0.82	NI
Black Fork of Little River	OK410210-03-0020C	rif	S	21	9	0.40	2.45	4.99	0.41	1.23	NI
			W	17.5	8.5	0.31	2.14	4.38	0.50	0.86	NI
Buffalo Creek	OK410210-06-0020G	rif	S	28	15	0.27	2.72	5.46	0.36	1.23	NI
			W	15	8.5	0.76	1.88	3.47	0.57	0.93	NI
Big Eagle Creek	OK410210-06-0160L	rif	S	20	8	0.57	2.57	4.73	0.36	1.23	NI
			W	13	6.5	0.73	1.77	3.72	0.63	0.86	NI
Beech Creek	OK410210-06-0320G	rif	S	22	13	0.37	2.50	4.35	0.39	1.23	NI
			W	22.5	13	0.52	2.58	5.01	0.36	1.18	NI
Cow Creek	OK410210-06-0350G	rif	S	23	9	0.59	2.53	4.97	0.39	1.31	NI
			W	15.5	7.5	0.50	2.15	4.52	0.48	0.82	NI
Lukfata Creek	OK410210-07-0010G	rif	S	9	1	0.18	1.77	6.03	0.48	0.62	SI
			W	15	8	0.56	2.09	4.13	0.50	1.33	NI
West Fork of Glover River	OK410210-08-0010M	rif	S	18	10	0.40	2.48	4.77	0.31	1.27	NI
			W	15	7	0.37	1.98	4.41	0.54	0.86	NI
East Fork of Glover River East Fork Glover R., cont.	OK410210-09-0010G	rif	S	15	8	0.41	2.06	5.10	0.53	1.08	NI
			W	17	7.5	0.43	2.08	4.12	0.56	0.93	NI
Gates Creek	OK410300-01-0020F	rif	S	11.5	5	0.41	1.47	5.18	0.77	0.73	SI
			W	13	6	0.44	2.29	5.05	0.41	1.25	NI
		wood	S	15	4	0.21	2.31	5.45	0.33	0.85	NI

Sitename	Wbid	Sample Type	Winter or Summer	Total Species	EPT Taxa	Percent EPT	Shannon Diversity	HBI	Percent Dominant 2 Taxa	Total Points	% of Reference
Rock Creek (Pushmata Co.)	OK410300-02-0190G	rif	W	18	10	0.34	2.11	4.73	0.56	1.07	NI
Cedar Creek	OK410300-03-0020M	rif	S	22	9	0.39	2.22	4.49	0.57	1.23	NI
			W	24.5	10	0.36	2.51	4.53	0.38	1.00	NI
		veg	S	18	5	0.32	2.21	4.72	0.51	1.08	NI
		wood	S	14	2	0.03	1.97	5.66	0.53	0.91	NI
One Creek	OK410300-03-0060F	rif	S	14	6	0.57	2.03	4.72	0.49	0.92	NI
			W	17	8	0.52	2.10	4.29	0.56	0.93	NI
		wood	S	9	3	0.07	1.41	6.95	0.79	0.36	MI
Tenmile Creek	OK410300-03-0270C	rif	S	17	9	0.55	2.00	5.24	0.57	1.23	NI
			W	18	6	0.17	1.69	5.97	0.69	0.64	SI
		veg	S	11	5	0.45	1.76	5.21	0.61	0.92	NI
		wood	S	7	1	0.24	1.34	6.18	0.74	0.64	SI
Buck Creek	OK410300-03-0420C	rif	S	21	10	0.48	2.52	5.26	0.37	1.31	NI
			W	21	9	0.46	2.46	5.21	0.44	1.04	NI
Billy Creek	OK410310-02-0070C	rif	W	26	11	0.29	2.71	5.03	0.40	1.14	NI
Big Cedar Creek	OK410310-02-0100D	rif	S	20	10	0.33	2.04	6.18	0.59	1.15	NI
			W	18	10.5	0.39	2.27	5.03	0.48	1.00	NI
Horse Creek	OK410400-01-0040G	rif	S	19	8	0.50	2.36	5.16	0.45	1.23	NI
			W	17	5.5	0.36	2.11	5.11	0.51	1.25	NI
		veg	S	18	7	0.29	2.30	5.91	0.50	1.07	NI
			W	14	5	0.36	1.63	5.30	0.67	1.08	NI
		wood	S	12	4	0.37	1.87	5.81	0.51	0.85	NI
Whitegrass Creek	OK410400-01-0210G	rif	S	23	8	0.68	2.59	4.55	0.35	1.31	NI
Caney Creek (lower)	OK410400-02-0200G	rif	S	15	4	0.24	2.04	6.13	0.50	0.85	NI
			W	13	1	0.03	1.73	6.81	0.69	0.58	SI
Caney Creek (upper)	OK410400-03-0020C	rif	S	18	6	0.11	1.80	5.88	0.63	0.92	NI
			W	11	2.5	0.13	1.10	5.58	0.82	0.54	SI
		wood	S	16	7	0.19	1.59	5.94	0.69	0.92	NI
Delaware Creek	OK410400-03-0240M	rif	S	19	11	0.31	2.27	5.66	0.49	1.07	NI
			W	18.5	6.5	0.47	2.14	4.79	0.52	1.19	NI
		wood	S	16	7	0.11	1.73	6.36	0.72	*	*
Leader Creek	OK410400-03-0370B	rif	S	18	5	0.21	1.70	4.50	0.71	0.77	SI
			W	14	4	0.31	2.22	4.55	0.33	1.00	NI
Goose Creek	OK410400-03-0490G	rif	S	17	7	0.47	2.38	4.32	0.44	0.46	MI
			W	12	5	0.13	0.96	5.55	0.85	1.00	NI
		wood	S	12	5	0.14	1.74	6.07	0.67	0.92	NI
Caney Boggy Creek	OK410400-06-0120G	rif	S	13	4	0.51	1.77	4.91	0.65	0.85	NI
			W	15	4	0.12	1.84	6.45	0.62	0.69	SI
		veg	W	4	1	0.01	0.57	5.97	0.98	0.13	SVI
McGee Creek	OK410400-07-0010C	rif	S	12.5	6.5	0.59	1.95	5.85	0.49	0.85	NI
			W	14	4	0.22	1.92	6.22	0.57	0.71	SI
		wood	S	18	8	0.53	2.35	4.93	0.40	1.45	NI

Sitename	Wbid	Sample Type	Winter or Summer	Total Species	EPT Taxa	Percent EPT	Shannon Diversity	HBI	Percent Dominant 2 Taxa	Total Points	% of Reference
North Boggy Creek	OK410400-08-0010M	rif	S	21	6	0.41	2.36	5.33	0.49	1.00	NI
			W	12.5	2.5	0.17	1.89	6.56	0.53	0.61	SI
Bokchito Creek	OK410600-01-0090G	rif	S	17	6	0.23	1.97	4.37	0.58	1.15	NI
			W	19	3	0.06	2.42	6.87	0.46	0.75	SI
Mineral Bayou	OK410600-01-0300G	rif	S	14.5	6.5	0.26	2.13	5.47	0.46	1.12	NI
Sandy Creek	OK410600-02-0020G	rif	W	18	5.5	0.32	2.07	4.86	0.54	1.21	NI
		veg	S	24	7	0.31	2.55	5.22	0.38	1.21	NI
		wood	S	16	5	0.26	2.22	5.80	0.49	0.85	NI
Little West Blue Creek	OK410600-02-0100C	rif	S	36	15	0.58	3.01	4.86	0.24	1.21	NI
			W	26	13	0.64	2.49	5.46	0.42	1.23	NI
		veg	S	21.5	8	0.39	1.99	6.02	0.54	0.77	SI
			W	16	7	0.42	1.91	5.42	0.65	0.93	NI
Island Bayou	OK410700-00-0040G	rif	S	15.5	6	0.57	2.09	4.48	0.49	*	*
Sand Creek	OK410700-00-0260G	rif	S	17	7	0.66	2.18	4.93	0.49	*	*
			W	18	4	0.15	1.72	5.85	0.70	*	*

Table 16. Overall bioassessment of sites based on all macroinvertebrate collections at a site (averaged per season and habitat type). NI=non-impaired, SI=slightly impaired, MI=moderately impaired.

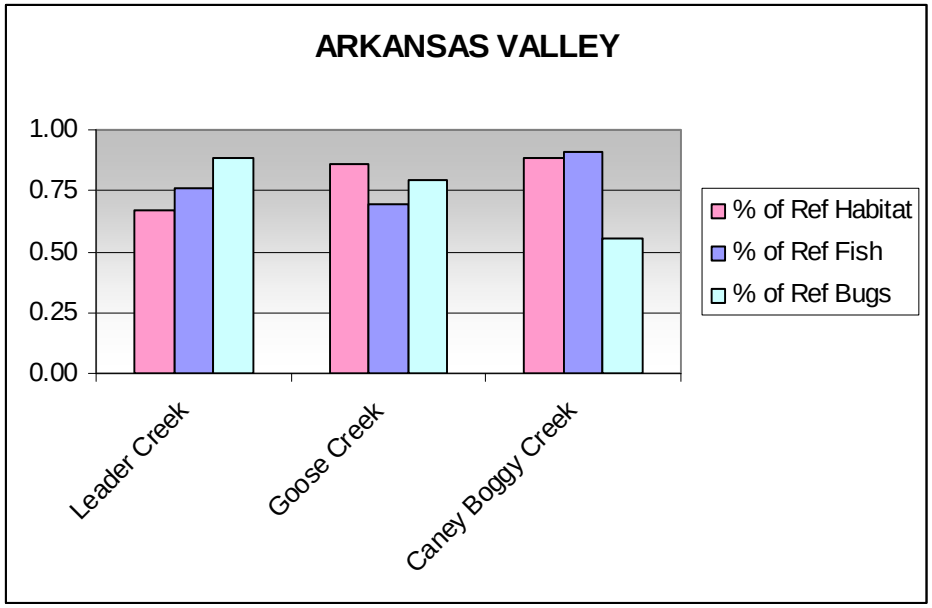
Site	WBID	Overall Biological Condition	Site	WBID	Overall Biological Condition
Norwood Creek	OK410100-01-0050H	NI	Tenmile Creek	OK410300-03-0270C	NI
Waterhole Creek	OK410100-01-0340D	MI	Buck Creek	OK410300-03-0420C	NI
Rock Creek (McCurtain Co.)	OK410200-03-0010G	NI	Billy Creek	OK410310-02-0070C	NI
Cypress Creek	OK410210-01-0070G	NI	Big Cedar Creek	OK410310-02-0100D	NI
Terrapin Creek	OK410210-02-0150G	NI	Horse Creek	OK410400-01-0040G	NI
Cloudy Creek	OK410210-02-0300C	NI	Whitegrass Creek	OK410400-01-0210G	NI
Black Fork of Little River	OK410210-03-0020C	NI	Caney Creek (lower)	OK410400-02-0200G	NI
Buffalo Creek	OK410210-06-0020G	NI	Caney Creek (upper)	OK410400-03-0020C	NI
Big Eagle Creek	OK410210-06-0160L	NI	Delaware Creek	OK410400-03-0240M	NI
Beech Creek	OK410210-06-0320G	NI	Leader Creek	OK410400-03-0370B	NI
Cow Creek	OK410210-06-0350G	NI	Goose Creek	OK410400-03-0490G	NI
Lukfata Creek	OK410210-07-0010G	NI	Caney Boggy Creek	OK410400-06-0120G	SI
West Fork of Glover River	OK410210-08-0010M	NI	McGee Creek	OK410400-07-0010C	NI
East Fork of Glover River	OK410210-09-0010G	NI	North Boggy Creek	OK410400-08-0010M	NI
Gates Creek	OK410300-01-0020F	NI	Bokchito Creek	OK410600-01-0090G	NI
Rock Creek (Pushmata Co.)	OK410300-02-0190G	NI	Mineral Bayou	OK410600-01-0300G	NI
Cedar Creek	OK410300-03-0020M	NI	Sandy Creek	OK410600-02-0020G	NI
One Creek	OK410300-03-0060F	NI	Little West Blue Creek	OK410600-02-0100C	NI

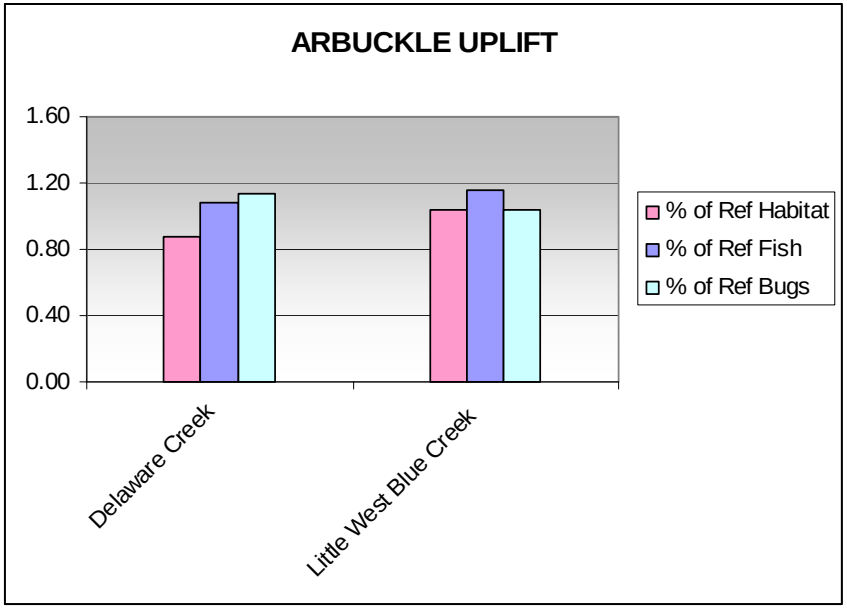
Most sites had non-impaired macroinvertebrate communities overall; only Waterhole Creek was moderately impaired, and Caney Boggy Creek was slightly impaired. Poor macroinvertebrate scores could indicate water quality problems where habitat scores are acceptable; however, it is possible that the macroinvertebrate collection was not taken at a time which would best represent the community there (i.e., drought influences). Hence, the macroinvertebrate scores should be examined in conjunction with habitat and fish scores to better represent the general health of the stream.

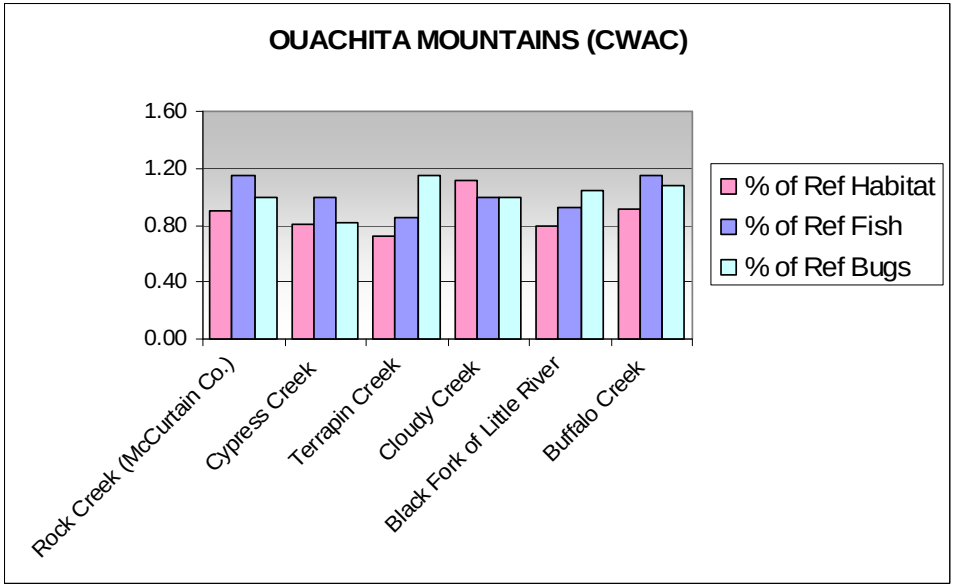
3.2.4 Overall Biological Assessment

In order to synthesize the biological findings into a meaningful representation of the quality of each site, habitat, fish, and macroinvertebrate scores (relative to the mean of high quality sites in the respective ecoregions) were examined in concert with one another (Figure 6). A determination of "good" or "excellent" stream health is indicated by a relatively high score for all three parameters. It is generally recognized that fish communities are especially sensitive to habitat degradation and that macroinvertebrates more quickly integrate effects of water quality decline. Thus, sites with a high habitat and fish score yet a low macroinvertebrate score could indicate potential water quality impairment. Low habitat scores correlated with low fish scores yet high bug scores could indicate habitat impairments despite good water quality. An example of this condition would be Whitegrass Creek in the SCP ecoregion. Waterhole Creek in the SCP ecoregion has poor overall biological quality, as indicated by scores for all three parameters which were about 50% of high quality parameters (fish condition rated "poor" and macroinvertebrate condition rates "moderately impaired").

These generalizations will be reassessed each cycle of the Rotating Basin project. It is possible that the reach examined for these assessments is not representative of the whole stream, so that habitat is better at other areas of the stream than the area sampled. Also, the drought conditions under which most of the fish and habitat collections were obtained do not represent typical Oklahoma conditions. Habitat scores in particular may have been skewed lower during this sampling period relative to the reference sampling period due to the drought.







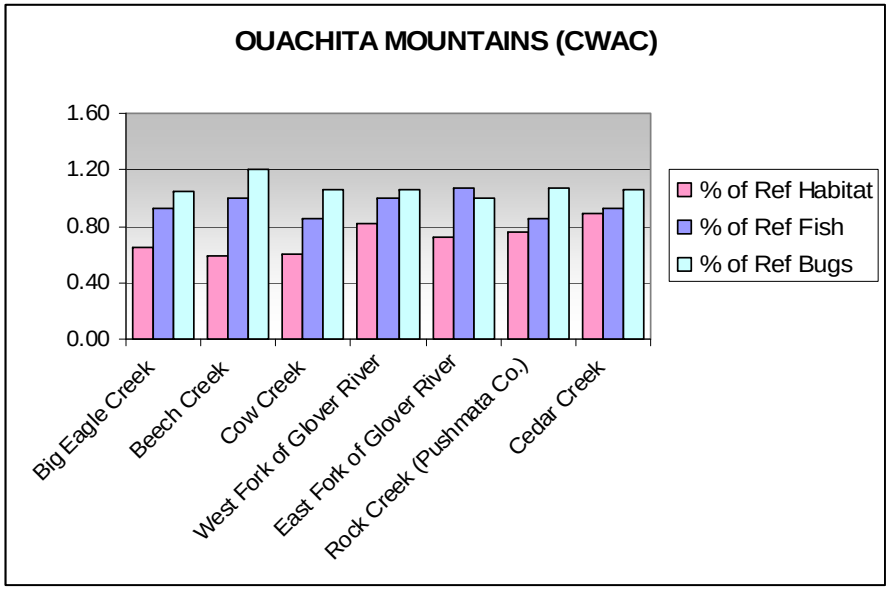


Figure 6. Comparison of habitat, fish, and bug scores relative to the average high quality site in each ecoregion.

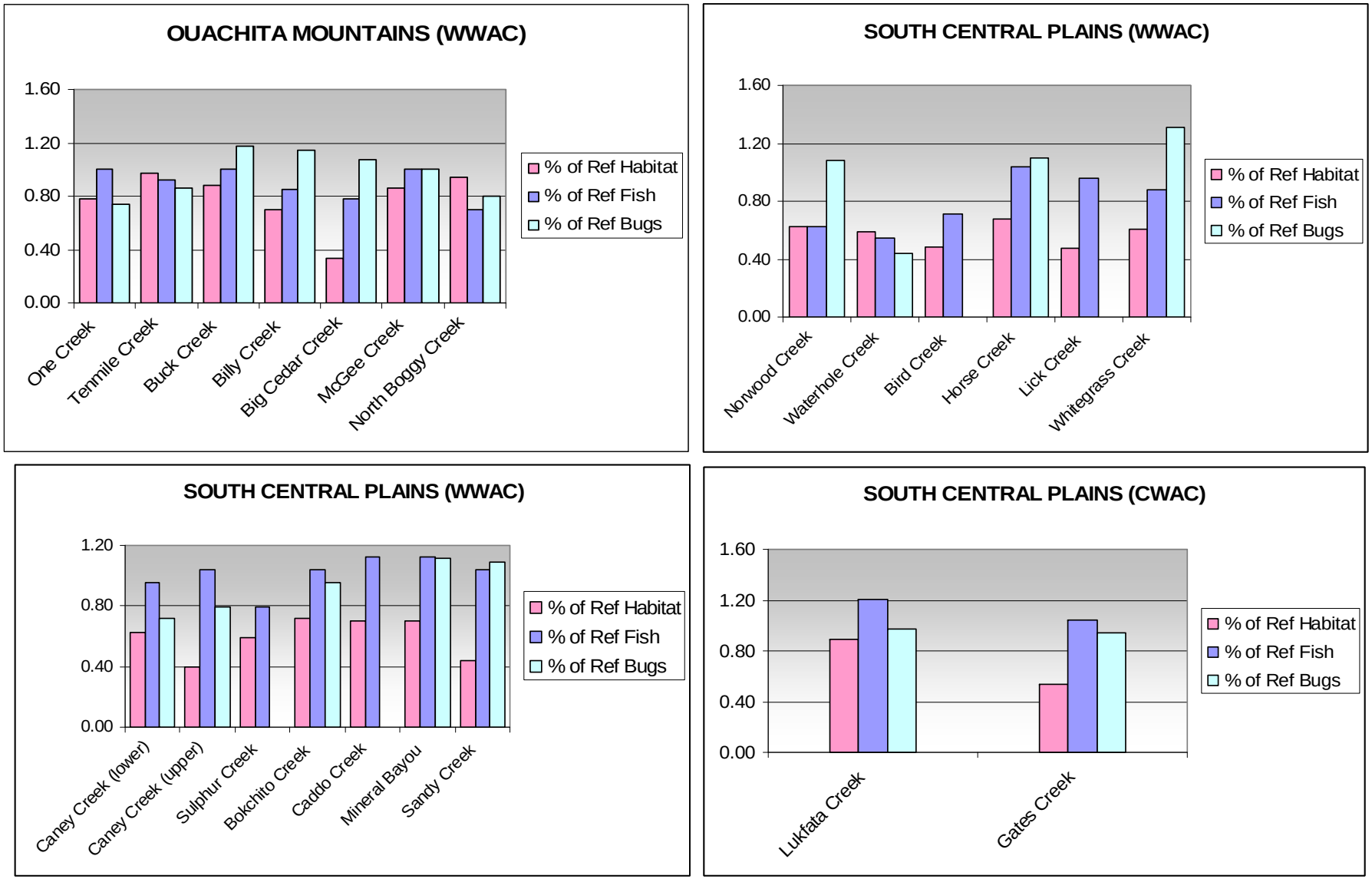


Figure 6, cont. Comparison of habitat, fish, and bug scores relative to the average high quality site in each ecoregion.

3.3 WATERSHED ASSESSMENT

Table 17 shows the landuse upstream of each monitoring site as obtained through GIS using the 1992 NRCS National Land Cover Dataset. Over 50% of the land in the Lower Red basin is forest. Approximately 18% is grassland, and another 18% is pasture. There is very little development in the area. Table 18 presents the types and number of permitted activities that occur in the watershed upstream of each site. Ten sites had no permitted activities in the watershed: Beech, Big Eagle, Buffalo, Cedar, Cloudy, Cow, Cypress, One, and Terrapin Creeks and the West Fork of the Glover River.

Seven sites had national pollution discharge elimination systems (NPDES) in the watershed. NPDES are classified as either major or minor based upon their size and/or their potential to impact the receiving stream, with majors having larger effects than minors. Of the sites in this project, only one site (Island Bayou) had a major NPDES, while the other sites only had minor NPDESs (Table 18). To examine the effects of point source versus non-point source pollution on nutrient levels at the monitoring sites, one-way ANOVAs were performed comparing sites with either a major or a minor NPDES to sites with no NPDES. There were no significant differences between sites with a NPDES and sites with no NPDES.

In general, the high nutrient levels observed at a few sites like Horse, Goose, and Leader Creeks are likely due to pasture management practices, with forestry activities and / or oil and gas activities possibly contributing to high TSS and turbidity at a couple of sites. Sixty-nine percent of the Horse Creek watershed is pastureland, and the City of Hugo land-applies its sludge in the watershed. These are potential sources of the high nutrients as well as the high levels of bacteria seen. The biological communities in this watershed appear to be well adapted to these conditions, as evidenced by a “non-impaired” macroinvertebrate community and an “excellent” fish community despite poor water quality. On the other hand, Waterhole Creek is a similar watershed, with approximately the same amount of pastureland and one NPDES, yet it has water quality that seems within normal range but a “poor” fish community and “moderately impaired” macroinvertebrates.

The effects of the drought make it hard to accurately explain the results seen in this cycle of the Rotating Basin Project. Habitat assessments, in particular, are not likely to be representative of normal conditions in this area. Sites in this basin will be resampled starting in 2010, and it will be important to examine results under what will hopefully be more representative climatic conditions.

Table 17. Watershed landuse for each Year 5 monitoring site (USGS 1992).

SiteName	WBID	Barren Land (Rock/Sand/Clay)	Cultivated Crops	Deciduous Forest	Developed, High Intensity	Developed, Low Intensity	Developed, Medium Intensity	Developed, Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/Hay	Shrub/Scrub	Woody Wetlands	Total Acres
Beech Creek	OK410210-06-0320G	0.00%	0.01%	51.07%	0.00%	0.00%	0.00%	1.81%	0.00%	36.49%	3.97%	5.76%	0.00%	0.00%	0.85%	0.04%	14,777
Big Cedar Creek	OK410310-02-0100D	0.00%	0.00%	38.02%	0.00%	0.24%	0.00%	7.07%	0.00%	48.22%	0.50%	5.88%	0.00%	0.06%	0.00%	0.00%	5,222
Big Eagle Creek	OK410210-06-0160L	0.00%	0.00%	60.94%	0.00%	0.19%	0.00%	3.58%	0.00%	19.91%	3.91%	10.30%	0.03%	0.00%	0.70%	0.44%	31,492
Billy Creek	OK410310-02-0070C	0.00%	0.00%	15.31%	0.00%	0.01%	0.00%	2.23%	0.00%	74.62%	0.52%	3.58%	0.01%	3.69%	0.03%	0.01%	13,760
Bird Creek	OK410300-01-0100C	0.41%	0.65%	12.34%	0.09%	0.51%	0.22%	4.33%	0.00%	6.53%	8.52%	10.40%	2.33%	51.72%	1.69%	0.25%	9,046
Black Fork of Little River	OK410210-03-0020C	0.00%	0.00%	28.48%	0.00%	0.13%	0.00%	3.18%	0.00%	38.47%	14.41%	7.07%	0.02%	4.69%	3.35%	0.19%	45,153
Bokchito Creek	OK410600-01-0090G	0.00%	1.07%	21.28%	0.00%	0.12%	0.03%	4.26%	0.00%	0.38%	30.61%	0.00%	0.30%	41.94%	0.00%	0.00%	15,371
Buck Creek	OK410300-03-0420C	0.00%	0.01%	31.31%	0.00%	0.28%	0.05%	2.35%	0.00%	36.07%	4.99%	6.80%	0.08%	14.98%	2.41%	0.66%	67,007
Buffalo Creek	OK410210-06-0020G	0.03%	0.03%	31.17%	0.00%	0.63%	0.04%	5.15%	0.00%	27.75%	5.56%	11.63%	0.04%	16.53%	1.33%	0.10%	70,274
Caddo Creek	OK410600-01-0140G	0.00%	0.21%	24.63%	0.01%	0.37%	0.10%	4.49%	0.01%	0.24%	37.77%	0.00%	0.28%	31.89%	0.00%	0.00%	24,866
Caney Boggy Creek	OK410400-06-0120G	0.01%	1.23%	47.18%	0.00%	0.01%	0.00%	3.06%	0.02%	1.00%	21.60%	0.00%	1.02%	24.86%	0.00%	0.01%	57,841
Caney Creek (lower)	OK410400-02-0200G	0.00%	0.08%	42.03%	0.00%	0.00%	0.01%	3.68%	0.02%	0.01%	22.84%	0.00%	0.36%	30.98%	0.00%	0.00%	19,252
Caney Creek (upper)	OK410400-03-0020C	0.00%	0.59%	40.78%	0.00%	0.55%	0.14%	3.38%	0.03%	0.34%	38.64%	0.00%	0.87%	14.68%	0.00%	0.00%	30,235
Cedar Creek	OK410300-03-0020M	0.00%	0.00%	26.44%	0.00%	0.16%	0.00%	2.77%	0.00%	37.98%	13.13%	8.63%	0.04%	6.80%	3.51%	0.55%	64,280
Cloudy Creek	OK410210-02-0300C	0.01%	0.02%	19.33%	0.00%	0.12%	0.00%	2.98%	0.00%	54.81%	15.47%	4.06%	0.01%	1.08%	1.89%	0.23%	36,266
Cow Creek	OK410210-06-0350G	0.00%	0.00%	36.41%	0.00%	0.00%	0.00%	2.97%	0.00%	51.62%	4.02%	2.56%	0.04%	2.15%	0.23%	0.00%	7,236
Cypress Creek	OK410210-01-0070G	0.00%	0.00%	13.69%	0.00%	0.49%	0.00%	4.58%	0.00%	49.59%	21.53%	8.84%	0.00%	0.00%	1.16%	0.11%	18,810
Delaware Creek	OK410400-03-0240M	0.17%	1.84%	39.34%	0.00%	0.02%	0.01%	2.73%	0.01%	0.30%	35.57%	0.00%	0.71%	19.30%	0.00%	0.00%	31,040
East Fork of Glover River	OK410210-09-0010G	0.00%	0.05%	16.62%	0.00%	0.34%	0.00%	5.73%	0.00%	56.08%	6.19%	8.28%	0.00%	5.19%	1.19%	0.33%	36,393
Gates Creek	OK410300-01-0020F	0.03%	0.26%	29.02%	0.01%	0.19%	0.04%	3.41%	0.04%	30.43%	5.99%	7.35%	0.71%	20.28%	1.33%	0.93%	39,269
Goose Creek	OK410400-03-0490G	0.00%	0.60%	43.09%	0.00%	0.00%	0.00%	1.67%	0.01%	0.04%	36.08%	0.00%	0.98%	17.52%	0.00%	0.00%	18,746
Horse Creek	OK410400-01-0040G	0.08%	0.00%	10.44%	0.08%	3.50%	0.61%	9.33%	0.00%	1.24%	0.37%	4.69%	0.39%	69.23%	0.00%	0.04%	12,834
Island Bayou	OK410700-00-0040G	0.01%	2.33%	17.46%	0.06%	0.38%	0.16%	3.42%	0.05%	0.23%	33.93%	4.80%	0.99%	35.87%	0.00%	0.31%	84,972
Leader Creek	OK410400-03-0370B	0.00%	0.06%	35.15%	0.00%	0.20%	0.01%	4.08%	0.01%	0.04%	39.51%	0.00%	0.86%	20.07%	0.00%	0.00%	59,267
Lick Creek	OK410400-01-0130G	0.00%	0.00%	28.39%	0.01%	0.17%	0.06%	4.51%	0.07%	0.02%	11.40%	0.70%	0.33%	54.32%	0.00%	0.01%	19,969
Little West Blue Creek	OK410600-02-0100C	0.13%	2.34%	15.86%	0.01%	0.32%	0.03%	2.44%	0.00%	0.01%	64.83%	0.00%	0.26%	13.77%	0.00%	0.00%	73,729
Lukfata Creek	OK410210-07-0010G	0.04%	0.07%	22.26%	0.00%	0.38%	0.01%	5.68%	0.00%	36.82%	5.56%	8.15%	0.06%	20.39%	0.42%	0.17%	29,150
McGee Creek	OK410400-07-0010C	0.03%	0.03%	37.56%	0.00%	0.01%	0.00%	1.18%	0.00%	25.42%	9.83%	5.38%	3.09%	11.99%	4.93%	0.55%	114,347
Mineral Bayou	OK410600-01-0300G	0.03%	1.33%	22.54%	1.21%	6.34%	1.94%	9.63%	0.00%	0.30%	34.05%	0.00%	0.55%	22.07%	0.00%	0.02%	24,870

SiteName	WBID	Barren Land (Rock/Sand/Clay)	Cultivated Crops	Deciduous Forest	Developed, High Intensity	Developed, Low Intensity	Developed, Medium Intensity	Developed, Open Space	Emergent Herbaceous Wetlands	Evergreen Forest	Grassland/ Herbaceous	Mixed Forest	Open Water	Pasture/Hay	Shrub/Scrub	Woody Wetlands	Total Acres
North Boggy Creek	OK410400-08-0010M	0.12%	0.19%	54.38%	0.02%	0.50%	0.12%	3.83%	0.03%	1.69%	16.71%	0.81%	5.46%	14.67%	1.27%	0.20%	112,512
Norwood Creek	OK410100-01-0050H	0.00%	0.80%	21.83%	0.00%	0.13%	0.04%	3.08%	3.07%	31.83%	2.44%	8.83%	1.12%	19.30%	0.14%	7.38%	38,430
One Creek	OK410300-03-0060F	0.00%	0.02%	26.33%	0.00%	0.11%	0.00%	3.16%	0.00%	35.45%	16.17%	9.42%	0.02%	4.34%	4.43%	0.55%	27,494
Rock Creek (McCurtain Co.)	OK410200-03-0010G	0.00%	0.00%	27.22%	0.00%	0.67%	0.02%	5.18%	0.00%	26.62%	6.95%	30.89%	0.07%	0.00%	2.11%	0.25%	29,713
Rock Creek (Pushmata Co.)	OK410300-02-0190G	0.00%	0.00%	30.00%	0.00%	0.10%	0.02%	2.45%	0.00%	26.73%	31.20%	4.87%	0.26%	1.42%	2.49%	0.45%	21,207
Sand Creek	OK410700-00-0260G	1.49%	8.97%	23.11%	0.00%	0.76%	0.09%	4.61%	0.06%	0.73%	34.09%	0.00%	1.70%	24.39%	0.00%	0.00%	11,750
Sandy Creek	OK410600-02-0020G	0.01%	3.73%	38.63%	0.01%	0.06%	0.04%	3.26%	0.00%	0.13%	35.75%	0.00%	0.34%	18.03%	0.00%	0.01%	25,091
Sulphur Creek	OK410600-01-0030G	0.02%	0.83%	31.13%	0.00%	0.26%	0.06%	5.56%	0.00%	0.07%	27.53%	0.00%	0.42%	34.13%	0.00%	0.00%	15,898
Tenmile Creek	OK410300-03-0270C	0.00%	0.03%	29.72%	0.00%	0.44%	0.19%	3.11%	0.00%	16.07%	10.06%	6.28%	0.05%	31.16%	2.43%	0.45%	63,631
Terrapin Creek	OK410210-02-0150G	0.00%	0.00%	15.37%	0.00%	0.28%	0.00%	3.61%	0.00%	67.53%	6.51%	5.89%	0.02%	0.00%	0.59%	0.20%	32,794
Waterhole Creek	OK410100-01-0340D	0.03%	4.93%	12.19%	0.00%	0.46%	0.02%	5.05%	0.00%	0.75%	0.52%	3.08%	0.77%	71.92%	0.02%	0.27%	19,029
West Fork of Glover River	OK410210-08-0010M	0.01%	0.02%	16.45%	0.00%	0.28%	0.01%	5.53%	0.02%	53.53%	6.96%	7.90%	0.02%	7.77%	1.15%	0.36%	115,233
Whitegrass Creek	OK410400-01-0210G	0.01%	0.09%	38.32%	0.00%	0.01%	0.01%	3.26%	0.03%	0.07%	19.56%	0.46%	0.41%	37.77%	0.00%	0.01%	40,878

Table 18. Permitted landuse for each Year 5 monitoring site. For the NPDES category, the total number of NPDES in the watershed is given, followed by the number of major NPDES in parentheses, if applicable.

Site Name	WBID#	# Oil and Gas	# CAFO	# NPDES	# Tot. Retention Lagoons	# Land Apps.	Site Name	WBID#	# Oil and Gas	# CAFO	# NPDES	# Tot. Retention Lagoons	# Land Apps.
Big Cedar Creek	OK410310-02-0100D	1					Leader Creek	OK410400-03-0370B	422				
Billy Creek	OK410310-02-0070C	1					Lick Creek	OK410400-01-0130G	3				
Bird Creek	OK410300-01-0100C	1		2			Little West Blue Creek	OK410600-02-0100C	41		1	2	1
Black Fork of Little River	OK410210-03-0020C	1					Lukfata Creek	OK410210-07-0010G		1			
Bokchito Creek	OK410600-01-0090G	3		1			McGee Creek	OK410400-07-0010C	253				
Buck Creek	OK410300-03-0420C	139					Mineral Bayou	OK410600-01-0300G	48			1	
Caddo Creek	OK410600-01-0140G	4		1			North Boggy Creek	OK410400-08-0010M	479		5		
Caney Boggy Creek	OK410400-06-0120G	176	3				Norwood Creek	OK410100-01-0050H	7				
Caney Creek (lower)	OK410400-02-0200G	6					Rock Creek (McCurtain Co.)	OK410200-03-0010G		1			
Caney Creek (upper)	OK410400-03-0020C	11			2		Rock Creek (Pushmata Co.)	OK410300-02-0190G	4				
Delaware Creek	OK410400-03-0240M	37	1				Sand Creek	OK410700-00-0260G	7				
East Fork of Glover River	OK410210-09-0010G		1				Sandy Creek	OK410600-02-0020G	3	1		1	
Gates Creek	OK410300-01-0020F	7					Sulphur Creek	OK410600-01-0030G	4			1	
Goose Creek	OK410400-03-0490G	60					Tenmile Creek	OK410300-03-0270C	33				
Horse Creek	OK410400-01-0040G	2				1	Waterhole Creek	OK410100-01-0340D	26	1			
Island Bayou	OK410700-00-0040G	19		2 (1M)			Whitegrass Creek	OK410400-01-0210G	8				

3.4 DESIGNATED USE SUPPORT ASSESSMENT

The designated uses assessed for the monitoring sites are presented below, along with the current attainment status of each use (based on OCC assessment results submitted for the 2008 Integrated Report). The causes and potential source(s) (if known) of any impairments are presented in Appendix D.1, and the key for the cause and source codes is given in Appendix D.2.

Table 19. Beneficial use support assessment. F=fully supporting, N=not supporting, I=insufficient information, *use not assessed.

SITENAME	WBID	COOL WATER AQ. COMM.	WARM WATER AQ. COMM.	PRIMARY CONTACT (RECR)	SECONDARY CONTACT (RECR)	AESTHETICS	AGRICULTURE	EMERGENCY WATER SUPPLY	INDUSTRIAL	FISH CONSUMPTION	SENSITIVE WATER SUPPLY	HIGH QUALITY WATER	PUBLIC/PRIVATE WATER SUP.	OUTSTANDING RESOURCE
Norwood Creek	OK410100-01-0050H		N	I		I	F		*	*			*	
Waterhole Creek	OK410100-01-0340D		N	I		F	F		*	*			*	
Rock Creek (McCurtain Co.)	OK410200-03-0010G	N		I		F	F		*	*			*	
Cypress Creek	OK410210-01-0070G	N		F		F	F		*	*		*	*	
Terrapin Creek	OK410210-02-0150G	N		F		F	F			*			*	
Cloudy Creek	OK410210-02-0300C	N		F		F	F			*		*	*	
Black Fork of Little River	OK410210-03-0020C	N		F		I	F			*		*	*	
Buffalo Creek	OK410210-06-0020G	N		I		F	F			*	*		*	
Big Eagle Creek	OK410210-06-0160L	N		I		F	F			*			*	*
Beech Creek	OK410210-06-0320G	N		I		F	F			*			*	*
Cow Creek	OK410210-06-0350G	N		I		F	F			*			*	*
Lukfata Creek	OK410210-07-0010G	N		I		I	F			*		*	*	
West Fork of Glover River	OK410210-08-0010M	F		F		I	F			*				
East Fork of Glover River	OK410210-09-0010G	F		F		F	F			*		*	*	
Gates Creek	OK410300-01-0020F	N		F		I	F		*	*			*	
Bird Creek	OK410300-01-0100C		N	I		F	F		*	*			I	
Rock Creek (Pushmata Co.)	OK410300-02-0190G	N		N		I	F		*	*			*	
Cedar Creek	OK410300-03-0020M	N		F		F	F			*		*	*	
One Creek	OK410300-03-0060F		N	F		F	F		*	*				
Tenmile Creek	OK410300-03-0270C		N	N		I	F		*	*			N	
Buck Creek	OK410300-03-0420C		F	N		F	F		*	*			*	
Billy Creek	OK410310-02-0070C		N	I		F	F		*	*				
Big Cedar Creek	OK410310-02-0100D		N	I		F	F		*	*				
Horse Creek	OK410400-01-0040G		F	N		F	F		*	*			*	
Lick Creek	OK410400-01-0130G		N	I		F	F		*	*			*	
Whitegrass Creek	OK410400-01-0210G		N	I		N	F		*	*			*	
Caney Creek (lower)	OK410400-02-0200G		N	I		F	F		*	*				
Caney Creek (upper)	OK410400-03-0020C		F		N	F	F		*	*				
Delaware Creek	OK410400-03-0240M		F	N		F	F		*	*			*	
Leader Creek	OK410400-03-0370B		N	N		F	F		*	*				
Goose Creek	OK410400-03-0490G		N	I		F	F		*	*				
Caney Boggy Creek	OK410400-06-0120G		N	N		F	F		*	*			*	
McGee Creek	OK410400-07-0010C		F	I		I	F			*	*		*	
North Boggy Creek	OK410400-08-0010M		N	N		F	N			*	*		*	
Sulphur Creek	OK410600-01-0030G		N	I		F	F		*	*				
Bokchito Creek	OK410600-01-0090G		F	I		F	F		*	*				

SITENAME	WBID	COOL WATER AQ. COMM.	WARM WATER AQ. COMM.	PRIMARY CONTACT (RECR)	SECONDARY CONTACT (RECR)	AESTHETICS	AGRICULTURE	EMERGENCY WATER SUPPLY	INDUSTRIAL	FISH CONSUMPTION	SENSITIVE WATER SUPPLY	HIGH QUALITY WATER	PUBLIC/PRIVATE WATER SUP.	OUTSTANDING RESOURCE
Caddo Creek	OK410600-01-0140G		N	I		F	F		*	*				
Mineral Bayou	OK410600-01-0300G		F	I		F	F	F	*	*				
Sandy Creek	OK410600-02-0020G		F	N		F	F		*	*			*	
Little West Blue Creek	OK410600-02-0100C		F	F		F	F		*	*				
Island Bayou	OK410700-00-0040G		F		I	F	N	F	*	*				
Sand Creek	OK410700-00-0260G		F	I		F	F		*	*				

4.0 LITERATURE CITED

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