Small Watershed Rotating Basin Monitoring Program

BASIN GROUP 3: Lower North Canadian, Lower Canadian, and Lower Arkansas Basins

Third Cycle

Final Report

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INTRODUCTION

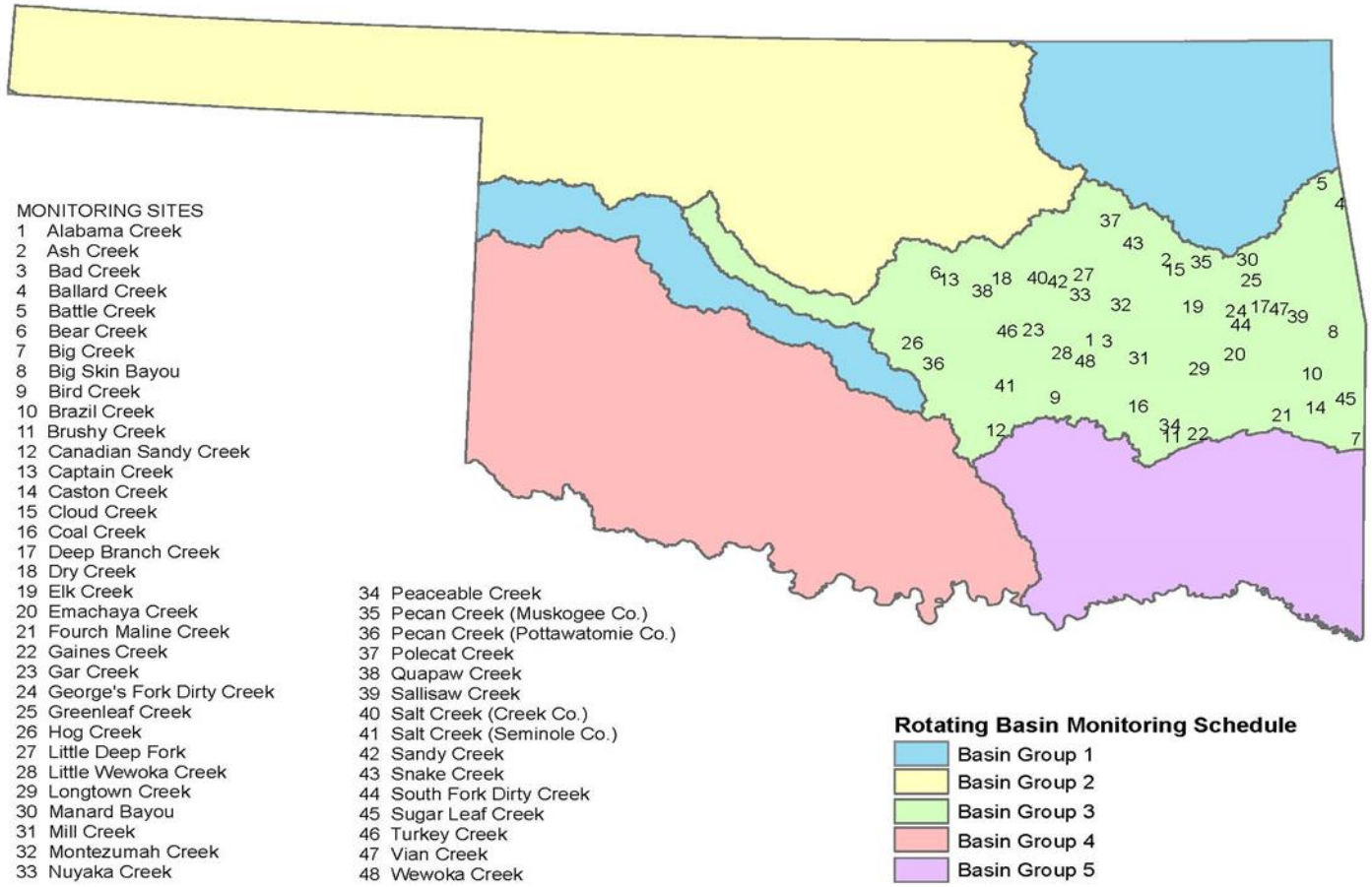
Project Background and Description

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.

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. Fixed 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 (Figure 1).

Effectively coordinated with other state monitoring programs, the 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—*Ambient Monitoring*. 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 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 provides a thorough and statistically sound evaluation of Oklahoma's waters every five years, which helps focus NPS program planning, education, and implementation efforts in areas where they can be most effective.

Figure 1. Fixed monitoring sites in "Basin Group 3" for the third cycle of the Small Watershed Rotating Basin Monitoring Project.



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. The statewide ambient monitoring program has allowed a comprehensive approach for the identification of nonpoint source (NPS) affected waters, as well as the identification of high quality streams. Results from this effort are used to assist the state in producing the 305(b) and 303(d) lists which are required by the EPA to assess beneficial use support for waterbodies biannually.

This report discusses the results of the *ambient* (routine physical, chemical, and biological sampling) and *diagnostic* (special parameter sampling) stages of the third cycle of the Rotating Basin program in the Lower North Canadian, Lower Canadian and Lower Arkansas basins (see Figure 1). *Implementation* and *success* monitoring are typically accomplished through priority watershed projects and reported on in project-specific final reports.

This program will continue to provide a robust baseline dataset to 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.

MATERIALS AND METHODS

General

Sampling stations were selected to effectively represent streams of the Lower North Canadian, Lower Canadian, and Lower Arkansas Basins. Candidate streams were selected from subwatersheds within these basins 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.

Reconnaissance of all of the potential sites within the Lower North Canadian, Lower Canadian, and Lower Arkansas basins was accomplished prior to monitoring, and sites which did not meet the sampling criteria were removed from the project. Thirty-four sites were monitored during the first rotating basin cycle, from 2003-2005. Thirty-three of the original streams were monitored in the second cycle from June 2008-May 2010. The third cycle of monitoring in these basins occurred from June 2013-May 2015. There were 48 sites during this cycle of monitoring.

The sites monitored in the Lower Arkansas basin occur over four level-three ecoregions: Arkansas Valley (AV), Central Irregular Plains (CIP), Ozark Highlands (OH), and Boston Mountains (BM) (Woods et al. 2005). In the Lower Canadian basin, sites are located in the Cross Timbers (CT) and Arkansas Valley ecoregions. The Lower North Canadian basin includes sites in the Cross Timbers ecoregion as well as in the Central Irregular Plains ecoregion. Five sites had a heavy influence from a bordering ecoregion (i.e., the sites are very close to the ecoregion border and have water originating in the other ecoregion), so they were grouped with the influencing ecoregion when compared to reference conditions: Polecat Creek and Snake Creek (located in CIP but influenced by CT), Sallisaw Creek Lower, Big Skin Bayou Creek and Deep Branch Creek (located in AV but influenced by BM). This is indicated by the "modified ecoregion" column in Table 1.

Table 1. Site List for Rotating Basin Monitoring Program: Basin Group 3, Cycle 3.

Site Name	WBID	Latitude	Longitude	Legal	County	Ecoregion	Modified Ecoregion
Alabama Creek	OK520500-01-0200D	35.3366	-96.1425	NW¼ SW¼ SE¼ SECTION 16-10N-11E	Okfuskee	CT	
Ash Creek	OK120410-01-0110E	35.7883	-95.6653	NW¼ SE¼ 12-15N-15E	Muskogee	CIP	
Bad Creek	OK520500-01-0170E	35.3376	-96.0468	NE¼ SW¼ 16-10N-12E	Okfuskee	CT	
Ballard Creek	OK121700-03-0370G	36.1063	-94.5646	NW¼ SW¼ SW¼ SECTION 20-19N-26E	Adair	OH	
Battle Creek	OK121700-06-0040G	36.2104	-94.6844	SW¼ NE¼ SW¼ Section 18-20N-25E	Delaware	OH	
Bear Creek	OK520700-05-0170A	35.7102	-97.1174	SE¼ SW¼ 5-14N-2E	Lincoln	CT	
Big Creek	OK220100-02-0080B	34.7692	-94.4981	SW¼ SW¼ 32-4N-27E	LeFlore	OM	
Big Skin Bayou	OK220200-01-0030H	35.3731	-94.6380	SE¼ NE¼ NE¼ 3-10N-25E	Sequoyah	AV	BM
Bird Creek	OK520800-01-0050G	35.0142	-96.3906	SW¼ SE¼ SE¼ Section 6-6N-9E	Hughes	CT	
Brazil Creek	OK220100-03-0010G	35.1388	-94.7690	SE¼ NW¼ NW¼ Section 27-8N-24E	LeFlore	AV	
Brushy Creek	OK220600-03-0010L	34.8014	-95.6547	SE¼ NE¼ SE¼ 19-4N-16E	Pittsburg	AV	
Canadian Sandy Creek	OK520600-03-0010D	34.8119	-96.7036	NE¼ NE¼ NE¼ SECTION 18-4N-6E	Pontotoc	CT	
Captain Creek	OK520700-05-0140H	35.6811	-97.0799	SE¼ SW¼ 15-14N-2E	Lincoln	CT	
Caston Creek	OK220100-01-0180B	34.9578	-94.7386	SE¼ 26-6N-24E	LeFlore	AV	
Cloud Creek	OK120410-01-0100T	35.7402	-95.6132	NW¼ NW¼ NE¼ 33-15N-16E	Muskogee	CIP	
Coal Creek	OK220600-02-0010F	34.9695	-95.8520	NE¼ NE¼ NW¼ 29-6N-14E	Pittsburg	AV	
Deep Branch	OK121700-01-0020A	35.5194	-95.0799	NE¼ NE¼ 16-12N-21E	Sequoyah	AV	BM
Dry Creek	OK520700-04-0020F	35.6848	-96.6949	SW¼ NW¼ SW¼ Section 17-14N-6E	Lincoln	CT	
Elk Creek	OK120400-02-0190F	35.5223	-95.5031	SW¼ SW¼ SW¼ 10-12N-17E	McIntosh	CIP	
Emachaya Creek	OK220300-00-0040C	35.2492	-95.2514	SW¼ 13-9N-19E	Haskell	AV	
Fourche Maline Creek	OK220100-04-0020H	34.9199	-94.9453	NW¼ NW¼ SW¼ 12-5N-22E	LeFlore	AV	
Gaines Creek	OK220600-04-0010P	34.8155	-95.4800	SE¼ Section 14-4N-17E	Latimer	AV	
Gar Creek	OK520510-00-0080C	35.3768	-96.5355	NW¼ NE¼ 2-10N-7E	Seminole	CT	
George's Fork of Dirty Creek	OK120400-02-0110D	35.4935	-95.2454	NW¼ NE¼ NE¼ Section 25-12N-19E	Muskogee	CIP	

Site Name	WBID	Latitude	Longitude	Legal	County	Ecoregion	Modified Ecoregion
Greenleaf Creek	OK120400-01-0120C	35.6713	-95.1316	SE¼ Section 24-14N-20E	Muskogee	BM	
Hog Creek	OK520810-00-0030D	35.3195	-97.2497	SE¼ SE¼ 24-10N-1W	Cleveland	CT	
Little Deep Fork	OK520700-06-0010D	35.6996	-96.2104	SW¼ SW¼ 12-14N-10E	Creek	CT	
Little Wewoka Creek	OK520500-02-0090D	35.2318	-96.2957	NE¼ NW¼ Section 30-9N-10E	Hughes	CT	
Longtown Creek	OK220600-01-0070P	35.1804	-95.4728	NE¼ SE¼ 11-8N-17E	Pittsburg	AV	
Manard Bayou	OK120400-01-0280E	35.7942	-95.1634	NE¼ NE¼ 10-15N-20E	Muskogee	BM	
Mill Creek	OK220600-01-0100P	35.2310	-95.8394	NW¼ NW¼ NW¼ Section 28-9N-14E	McIntosh	AV	
Montezumah Creek	OK520700-01-0220D	35.5359	-95.9521	NE¼ NE¼ 23-13N-10E	Okfuskee	CT	
Nuyaka Creek	OK520700-02-0200D	35.5954	-96.2121	NE¼ NE¼ 23-13N-10E	Okfuskee	CT	
Peaceable Creek	OK220600-03-0050F	34.8519	-95.6542	SW¼ NW¼ NW¼ Section 5-4N-16E	Pittsburg	AV	
Pecan Creek (Muskogee Co.)	OK120410-01-0030D	35.7842	-95.4497	NE¼ NE¼ 13-15N-17E	Muskogee	CIP	
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C	35.2032	-97.1182	SE¼ SW¼ 32-9N-2E	Pottawatomie	CT	
Polecat Creek	OK120420-02-0050G	36.0151	-96.0297	SW¼ NW¼ NW¼ Section 27-18N-12E	Tulsa	CIP	CT
Quapaw Creek	OK520700-04-0260C	35.6221	-96.8196	SE¼ NE¼ NE¼ Section 12-13N-4E	Lincoln	CT	
Sallisaw Creek	OK220200-03-0010C	35.4646	-94.8618	SW¼ SE¼ SW¼ Section 34-12N-23E	Sequoyah	AV	BM
Salt Creek (Creek Co.)	OK520700-03-0100B	35.6962	-96.4765	NW¼ NW¼ NW¼ Section 16-14N-8E	Creek	CT	
Salt Creek (Seminole Co.)	OK520800-03-0010D	35.0490	-96.6676	SE¼ SE¼ SE¼ Section 28-7N-6E	Seminole	CT	
Sandy Creek	OK520700-03-0040F	35.6683	-96.3587	NW¼ NE¼ 28-14N-9E	Creek	CT	
Snake Creek	OK120410-01-0220G	35.8860	-95.8724	SW¼ SW¼ SW¼ Section 6-16N-14E	Tulsa	CIP	CT
South Fork Dirty Creek	OK120400-02-0030H	35.4503	-95.2169	SE¼ SW¼ SW¼ 5-11N-20E	Muskogee	CIP	
Sugar Loaf Creek	OK220100-01-0160G	34.9989	-94.5756	SE¼ SE¼ Section 8-6N-26E	LeFlore	AV	
Turkey Creek	OK520510-00-0100F	35.3772	-96.6479	SE¼ SW¼ 35-11N-6E	Seminole	CT	
Vian Creek	OK220200-02-0130E	35.5074	-94.9837	NE¼ NE¼ NW¼ 21-21N-22E	Sequoyah	BM	
Wewoka Creek	OK520500-02-0010C	35.2187	-96.2135	NE¼ NW¼ NE¼ Section 35-9N-10E	Hughes	CT	

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 2011). Water quality chemical analyses were conducted by the Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) laboratory.

Water Quality Monitoring

Starting in June 2013, 48 sites were monitored for physical and chemical parameters on a fixed interval schedule of ten sampling events per year (five-week intervals) through May 2015 (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 2011).

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 at 4° C or lower. Quality assurance/control samples were collected in accordance with Data Quality Objectives (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), and

total dissolved solids (TDS). 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. In addition, *in-situ* water quality parameters were measured at each sampling locations and include the following: water temperature, dissolved oxygen, pH, conductivity, alkalinity, hardness, turbidity, and instantaneous discharge.

Separate samples were collected and submitted concurrently for analysis of *E. coli* 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. 17*.

Biological Monitoring

Habitat Assessment

In the summer of 2013, OCC staff began conducting 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 2011). 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.

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.

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.

Fish

Fish collections were obtained in the summer 2013 for each site. 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 (2011). 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 15' 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 2.5 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 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 2007). 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 17* 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. 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** 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

Macroinvertebrates

Collection of macroinvertebrates was attempted at all fixed sites for both the winter and summer index periods of July 2013 through March 2015 according to procedures outlined in the OCC SOP (2011). 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. In order for macroinvertebrate collections to be obtained, flowing water must be present. 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. 17* 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 (adapted from Plafkin et al., 1989).

Table 4. Bioassessment scoring criteria for macroinvertebrates.

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

***Modified HBI Using North Carolina Tolerance Values**
****RBP for Use in Streams and Rivers 1989**
*****Modified by OCC**

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

Watershed Assessment

To investigate potential sources of NPS pollution for streams showing beneficial use impairment, relevant data layers were explored using ArcView Geographic Information System (GIS) software. Data explored included the 2011 National Land Cover Dataset (NLCD) created by Multi-Resolution Land Characteristics (MRLC) Consortium, oil and gas wells, confined animal feeding operations (Dept. of Agriculture, April 2014), national pollution discharge elimination system permit holders (Department of Environmental Quality, May 2014), total retention sites (DEQ, 2009), biosolid land application sites (DEQ 2009), public water supplies (DEQ, January 2014), solid waste landfills (DEQ 2014) 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).

Beneficial Use Support Assessment

Each fixed site's assigned beneficial uses were evaluated following the protocols outlined in the state's *Continuing Planning Process, Integrated Water Quality Report Listing Methodology* (OWRB 2013) and

per *Oklahoma Administrative Code 785, Chapter 46: Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (OWRB 2013). 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 2010 Integrated Report submitted to EPA Region VI.

RESULTS AND DISCUSSION

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 fixed site, regardless of elevated or base flow. 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 Basin Group 3 Monitoring Sites, 2013-2015.

Site Name	WBID	DO (mg/L)	DO % Saturation	Turbidity (NTU)	Alkalinity (CaCO3)	Hardness (mg/L)	Temperature (°C)	Conductivity (uS/cm)	pH (SU)	Flow (cfs)
Alabama Creek	OK520500-01-0200D	6.52	60.46	22.17	103.6	184.2	15.5	517.2	7.17	2.34
Ash Creek	OK120410-01-0110E	9.00	88.59	39.51	99.5	200.0	16.5	449.4	7.83	1.01
Bad Creek	OK520500-01-0170E	7.64	71.73	29.61	74.8	158.7	15.9	478.9	7.51	1.54
Ballard Creek	OK121700-03-0370G	9.40	91.10	4.18	115.4	156.1	15.6	276.0	7.70	16.47
Battle Creek	OK121700-06-0040G	9.52	91.62	0.76	95.0	133.8	14.0	217.8	7.45	5.11
Bear Creek	OK520700-05-0170A	7.92	73.22	34.17	343.3	367.4	15.1	708.4	8.06	0.95
Big Creek	OK220100-02-0080B	9.08	88.67	8.12	20.8	35.8	16.7	36.3	7.00	10.58
Big Skin Bayou	OK220200-01-0030H	8.10	77.21	17.11	64.4	103.3	16.6	101.1	7.03	0.89
Bird Creek	OK520800-01-0050G	8.57	88.70	36.41	124.6	234.8	17.8	1104.6	7.96	0.82
Brazil Creek	OK220100-03-0010G	7.49	69.97	34.84	79.7	125.6	16.7	204.4	7.20	9.97
Brushy Creek	OK220600-03-0010L	6.78	63.24	46.38	66.2	122.1	16.7	150.7	7.05	1.11
Canadian Sandy Creek	OK520600-03-0010D	8.23	74.77	12.65	251.0	276.5	16.5	575.4	7.95	6.07
Captain Creek	OK520700-05-0140H	9.54	88.78	30.85	303.2	339.6	15.0	617.7	8.22	5.51
Caston Creek	OK220100-01-0180B	8.25	81.39	32.52	115.7	172.7	17.7	448.9	7.39	10.91
Cloud Creek	OK120410-01-0100T	8.22	79.43	83.28	75.1	154.0	15.9	306.5	7.69	3.88
Coal Creek	OK220600-02-0010F	7.09	66.80	49.66	89.0	151.4	16.4	405.9	7.29	10.54
Deep Branch	OK121700-01-0020A	6.47	62.10	6.81	51.3	73.0	16.5	97.6	7.07	3.80
Dry Creek	OK520700-04-0020F	8.66	88.45	41.23	242.4	297.0	19.0	643.9	8.00	2.76
Elk Creek	OK120400-02-0190F	6.93	65.89	25.77	129.4	213.5	16.9	476.6	7.00	0.29
Emachaya Creek	OK220300-00-0040C	6.81	67.53	24.78	93.5	137.9	17.1	223.5	7.15	0.00
Fourche Maline Creek	OK220100-04-0020H	7.49	74.38	36.22	55.4	103.2	17.1	132.2	6.88	16.38
Gaines Creek	OK220600-04-0010P	7.08	67.01	21.71	60.5	103.7	17.0	114.9	6.98	6.52
Gar Creek	OK520510-00-0080C	8.42	79.53	75.53	107.1	149.5	15.8	288.8	7.35	2.29
George's Fork of Dirty Creek	OK120400-02-0110D	6.76	63.95	33.39	101.8	151.7	16.4	246.6	7.11	3.73
Greenleaf Creek	OK120400-01-0120C	10.09	108.53	17.16	84.9	105.6	20.4	196.2	7.97	22.11

Site Name	WBID	DO (mg/L)	DO % Saturation	Turbidity (NTU)	Alkalinity (CaCO3)	Hardness (mg/L)	Temperature (°C)	Conductivity (uS/cm)	pH (SU)	Flow (cfs)
Hog Creek	OK520810-00-0030D	9.36	90.86	75.59	245.8	281.0	15.8	563.0	7.88	3.60
Little Deep Fork	OK520700-06-0010D	9.90	101.48	14.56	132.6	216.0	17.3	772.4	7.79	1.67
Little Wewoka Creek	OK520500-02-0090D	8.70	83.56	32.82	135.2	174.3	16.5	599.6	7.70	3.54
Longtown Creek	OK220600-01-0070P	8.07	79.55	19.23	78.6	127.8	17.2	184.1	7.03	4.48
Manard Bayou	OK120400-01-0280E	9.85	99.29	4.76	130.7	169.7	18.2	285.5	7.82	4.52
Mill Creek	OK220600-01-0100P	6.98	64.90	40.36	80.0	147.2	16.0	178.5	7.01	2.79
Montezumah Creek	OK520700-01-0220D	6.56	60.19	60.05	77.6	135.0	15.1	347.3	7.27	0.00
Nuyaka Creek	OK520700-02-0200D	6.61	62.76	36.05	136.3	190.4	15.4	616.0	7.39	1.30
Peaceable Creek	OK220600-03-0050F	6.79	63.98	47.97	73.0	146.1	16.6	383.0	7.14	3.81
Pecan Creek (Muskogee Co.)	OK120410-01-0030D	7.25	70.47	37.58	87.4	162.5	17.2	294.9	7.47	3.86
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C	10.09	96.81	62.04	235.9	258.6	15.0	493.3	8.14	5.68
Polecat Creek	OK120420-02-0050G	9.19	90.44	25.54	121.2	217.7	17.0	645.1	7.82	10.28
Quapaw Creek	OK520700-04-0260C	9.83	96.59	88.81	251.4	263.7	16.3	545.5	8.26	4.55
Sallisaw Creek	OK220200-03-0010C	8.79	87.42	7.23	93.8	139.8	17.9	175.8	7.43	14.44
Salt Creek (Creek Co.)	OK520700-03-0100B	8.30	77.42	18.34	170.5	282.3	14.5	798.3	7.60	1.33
Salt Creek (Seminole Co.)	OK520800-03-0010D	10.19	99.01	29.02	231.5	593.8	16.5	2308.0	8.05	14.67
Sandy Creek	OK520700-03-0040F	10.17	89.87	38.88	107.7	200.3	11.8	410.9	7.60	0.61
Snake Creek	OK120410-01-0220G	8.15	78.44	47.58	78.6	174.8	15.6	470.9	7.72	4.24
South Fork Dirty Creek	OK120400-02-0030H	7.26	68.26	16.90	126.3	211.1	16.6	452.2	7.25	3.08
Sugar Loaf Creek	OK220100-01-0160G	7.35	69.35	29.99	38.2	71.2	16.3	92.4	6.92	3.56
Turkey Creek	OK520510-00-0100F	7.88	74.84	104.98	208.3	469.4	15.4	2482.3	7.69	1.62
Vian Creek	OK220200-02-0130E	7.18	68.83	4.36	119.2	161.2	16.7	269.4	7.40	6.32
Wewoka Creek	OK520500-02-0010C	9.13	90.99	74.91	130.1	200.6	17.6	833.1	7.94	17.39

Table 7. Mean chemical water quality values for Basin Group 3 Monitoring Sites, 2013-2015.

Site Name	WBID	Ammonia (mg/L)	Chloride (mg/L)	Dissolved Solids, Total (mg/L)	Kjeldahl, Nitrogen (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ortho Phosphorus, Total (mg/L)	Phosphorus, Total (mg/L)	Sulfate (mg/L)	Suspended Solids, Total (mg/L)
Alabama Creek	OK520500-01-0200D	0.045	91.6	280	0.60	0.03	0.03	0.012	0.044	18.8	11
Ash Creek	OK120410-01-0110E	0.032	58.0	280	0.82	0.12	0.03	0.043	0.103	48.6	20
Bad Creek	OK520500-01-0170E	0.045	109.4	385	0.69	0.03	0.04	0.010	0.048	18.5	10
Ballard Creek	OK121700-03-0370G	0.015	11.2	168	0.27	2.24	0.02	0.066	0.075	12.8	10
Battle Creek	OK121700-06-0040G	0.015	8.1	133	0.12	3.32	0.02	0.039	0.043	4.8	10
Bear Creek	OK520700-05-0170A	0.059	27.2	420	0.82	0.05	0.05	0.044	0.101	16.2	130
Big Creek	OK220100-02-0080B	0.015	2.8	30	0.14	0.08	0.02	0.005	0.012	3.1	10
Big Skin Bayou	OK220200-01-0030H	0.022	4.9	55	0.26	0.13	0.02	0.006	0.025	9.0	11
Bird Creek	OK520800-01-0050G	0.037	285.5	633	0.81	1.25	0.05	0.204	0.256	26.5	17
Brazil Creek	OK220100-03-0010G	0.030	6.7	133	0.55	0.25	0.02	0.033	0.079	33.7	14
Brushy Creek	OK220600-03-0010L	0.025	6.8	117	0.62	0.06	0.02	0.027	0.094	14.6	39
Canadian Sandy Creek	OK520600-03-0010D	0.089	29.4	339	0.48	0.04	0.02	0.079	0.102	21.8	15
Captain Creek	OK520700-05-0140H	0.049	35.2	374	0.36	0.10	0.04	0.015	0.033	17.0	18
Caston Creek	OK220100-01-0180B	0.057	8.6	285	0.58	0.30	0.03	0.059	0.101	116.9	15
Cloud Creek	OK120410-01-0100T	0.056	34.3	206	0.84	0.12	0.02	0.051	0.129	38.1	81
Coal Creek	OK220600-02-0010F	0.034	23.0	286	0.99	0.27	0.03	0.198	0.264	91.3	35

Site Name	WBID	Ammonia (mg/L)	Chloride (mg/L)	Dissolved Solids, Total (mg/L)	Kjeldahl, Nitrogen (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Ortho Phosphorus, Total (mg/L)	Phosphorus, Total (mg/L)	Sulfate (mg/L)	Suspended Solids, Total (mg/L)
Deep Branch	OK121700-01-0020A	0.021	4.3	58	0.26	0.05	0.02	0.005	0.015	12.4	10
Dry Creek	OK520700-04-0020F	0.024	84.2	401	0.74	0.03	0.04	0.028	0.079	15.7	23
Elk Creek	OK120400-02-0190F	0.040	24.2	328	0.70	0.25	0.02	0.098	0.140	149.7	17
Emachaya Creek	OK220300-00-0040C	0.023	11.1	131	0.70	0.34	0.02	0.022	0.066	25.7	14
Fourche Maline Creek	OK220100-04-0020H	0.029	8.7	99	0.50	0.11	0.02	0.022	0.069	15.7	18
Gaines Creek	OK220600-04-0010P	0.019	4.6	80	0.36	0.07	0.02	0.007	0.039	10.3	11
Gar Creek	OK520510-00-0080C	0.017	33.4	185	0.60	0.04	0.02	0.016	0.073	9.0	101
George's Fork of Dirty Creek	OK120400-02-0110D	0.032	13.5	168	1.05	0.12	0.03	0.072	0.149	32.8	19
Greenleaf Creek	OK120400-01-0120C	0.020	5.5	121	0.22	0.04	0.02	0.011	0.026	22.9	10
Hog Creek	OK520810-00-0030D	0.034	33.7	337	0.50	0.04	0.03	0.023	0.057	10.8	45
Little Deep Fork	OK520700-06-0010D	0.025	179.8	434	0.96	0.15	0.05	0.026	0.083	11.9	15
Little Wewoka Creek	OK520500-02-0090D	0.023	117.1	349	0.72	0.04	0.02	0.016	0.061	15.0	28
Longtown Creek	OK220600-01-0070P	0.022	10.4	109	0.47	0.18	0.02	0.023	0.056	28.7	11
Manard Bayou	OK120400-01-0280E	0.027	7.0	171	0.34	0.15	0.02	0.028	0.047	18.3	10
Mill Creek	OK220600-01-0100P	0.039	9.8	134	0.70	0.08	0.02	0.020	0.067	14.1	11
Montezumah Creek	OK520700-01-0220D	0.043	55.4	245	0.90	0.04	0.02	0.038	0.104	19.9	29
Nuyaka Creek	OK520700-02-0200D	0.126	112.7	441	1.04	0.04	0.03	0.029	0.095	14.2	18
Peaceable Creek	OK220600-03-0050F	0.041	36.1	260	0.84	0.14	0.02	0.096	0.163	68.2	24
Pecan Creek (Muskogee Co.)	OK120410-01-0030D	0.039	11.2	216	0.91	0.13	0.02	0.071	0.135	58.7	19
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C	0.015	24.1	392	0.36	0.04	0.03	0.010	0.031	11.0	35
Polecat Creek	OK120420-02-0050G	0.035	120.9	367	1.10	1.36	0.12	0.252	0.331	29.9	19
Quapaw Creek	OK520700-04-0260C	0.028	34.6	357	0.74	0.11	0.05	0.032	0.083	26.6	164
Sallisaw Creek	OK220200-03-0010C	0.016	4.8	104	0.22	0.12	0.02	0.006	0.021	8.4	10
Salt Creek (Creek Co.)	OK520700-03-0100B	0.025	169.0	483	0.74	0.02	0.07	0.022	0.065	20.4	13
Salt Creek (Seminole Co.)	OK520800-03-0010D	0.015	681.7	1336	0.54	0.03	0.03	0.016	0.039	38.1	17
Sandy Creek	OK520700-03-0040F	0.065	66.5	251	0.61	0.05	0.03	0.012	0.047	11.3	17
Snake Creek	OK120410-01-0220G	0.037	89.3	306	0.75	0.09	0.02	0.029	0.084	36.3	28
South Fork Dirty Creek	OK120400-02-0030H	0.035	8.5	255	0.60	0.11	0.02	0.016	0.054	95.8	12
Sugar Loaf Creek	OK220100-01-0160G	0.037	6.1	72	0.39	0.14	0.02	0.017	0.058	10.6	12
Turkey Creek	OK520510-00-0100F	0.021	759.6	1399	1.09	0.13	0.02	0.067	0.144	28.5	128
Vian Creek	OK220200-02-0130E	0.015	5.1	140	0.16	0.05	0.02	0.006	0.012	12.4	10
Wewoka Creek	OK520500-02-0010C	0.064	206.3	520	1.12	0.58	0.15	0.158	0.237	24.2	73

Most of the sites are designated as Warm Water Aquatic Communities (WWAC) and have a critical dissolved oxygen (DO) level of 5.0 mg/L most of the year (6.0 mg/L from April 1 – June 15). Bird Creek has a Habitat Limited Aquatic Community (HLAC) designation, with a critical DO level of 3.0 mg/L most of the year (4.0 mg/L from April 1 – June 15). Ballard Creek, Big Creek, Sallisaw Creek, and Vian Creek sites have Cool Water Aquatic Community (CWAC) designations, with a critical DO level of 6.0 mg/L most of the year (7.0 mg/L March 1 – May 31). Table 8 shows all instances of criteria exceedance; nearly half of the streams in this rotation exceeded the DO standard. Alabama, Bad, Ballard, Bear, Brushy, Canadian Sandy, Cloud, Coal, Deep Branch, Elk, Emachaya, Fourche Maline, Gaines, George's Fork of Dirty, Longtown, Mill, Montezumah, Nuyaka, Peaceable, Pecan (Muskogee Co.), Sallisaw, Salt (Creek Co.),

South Fork of Dirty Creek, Sugarloaf, Turkey, and Vian Creeks all had more than 10% of samples below the criteria and are expected to be included on the state's 2016 303(d) list as impaired by low DO.

Table 8. Low dissolved oxygen values (based on OAC 785:46-15; OWRB 2013)

% Sample with Low DO	Site Name	WBID	FWP	DATE	DO (mg/L)
40.91%	Alabama Creek	OK520500-01-0200D	WWAC	7/1/2013	3.25
				7/16/2013	3.17
				9/3/2013	3.34
				10/14/2013	3.41
				5/12/2014	5.84
				6/16/2014	4.93
				7/21/2014	3.43
				8/25/2014	2.28
				9/29/2014	3.40
36.36%	Bad Creek	OK520500-01-0170E	WWAC	7/1/2013	3.85
				7/17/2013	4.42
				8/5/2013	4.74
				9/3/2013	3.84
				10/14/2013	4.59
				6/16/2014	4.59
				8/25/2014	3.15
				9/29/2014	4.44
19.05%	Ballard Creek	OK121700-03-0370G	CWAC	6/13/2013	5.18
				6/25/2013	4.51
				7/30/2013	3.95
				9/4/2013	4.87
19.05%	Bear Creek	OK520700-05-0170A	WWAC	7/29/2013	4.39
				5/12/2014	4.52
				6/16/2014	4.69
				8/25/2014	3.60
9.52%	Big Creek	OK220100-02-0080B	CWAC	8/27/2013	5.23
				9/16/2013	5.77
19.05%	Big Skin Bayou	OK220200-01-0030H	WWAC	9/4/2013	4.81
				7/9/2014	4.02
				8/26/2014	4.87
				9/30/2014	3.55

% Sample with Low DO	Site Name	WBID	FWP	DATE	DO (mg/L)
31.82%	Brazil Creek	OK220100-03-0010G	WWAC	6/25/2013	4.44
				7/22/2013	4.34
				7/30/2013	4.71
				9/17/2013	4.27
				6/24/2014	4.44
				7/29/2014	4.25
				9/3/2014	3.72
36.36%	Brushy Creek	OK220600-03-0010L	WWAC	6/24/2013	4.71
				7/29/2013	4.06
				9/16/2013	2.44
				10/7/2013	3.80
				11/18/2013	1.59
				7/28/2014	2.63
				9/2/2014	2.42
				10/6/2014	3.29
22.73%	Canadian Sandy Creek	OK520600-03-0010D	WWAC	9/9/2013	2.53
				10/14/2013	3.73
				11/18/2013	3.95
				9/9/2014	4.80
				11/10/2014	4.93
9.09%	Captain Creek	OK520700-05-0140H	WWAC	5/12/2014	4.21
				8/25/2014	3.77
9.52%	Caston Creek	OK220100-01-0180B	WWAC	8/28/2013	4.58
				9/2/2014	4.95
9.09%	Cloud Creek	OK120410-01-0100T	WWAC	8/1/2013	4.68
				9/3/2013	3.16
19.05%	Coal Creek	OK220600-02-0010F	WWAC	6/24/2013	3.81
				7/29/2013	4.23
				8/26/2013	4.39
				9/16/2013	3.72
38.10%	Deep Branch	OK121700-01-0020A	WWAC	5/29/2013	3.95
				6/18/2013	3.54
				8/6/2013	3.37
				9/4/2013	3.70
				10/15/2013	4.55
				5/13/2014	3.52
				6/17/2014	3.53
				8/26/2014	3.58

% Sample with Low DO	Site Name	WBID	FWP	DATE	DO (mg/L)
5.88%	Dry Creek	OK520700-04-0020F	WWAC	7/25/2013	2.25
31.82%	Elk Creek	OK120400-02-0190F	WWAC	5/28/2013	4.96
				8/5/2013	4.19
				10/14/2013	3.35
				11/13/2013	2.68
				6/16/2014	4.76
				8/25/2014	4.11
				9/29/2014	3.27
23.81%	Emachaya Creek	OK220300-00-0040C	WWAC	6/25/2013	4.17
				9/17/2013	3.96
				10/8/2013	3.91
				9/17/2013	3.96
				10/8/2013	3.91
23.81%	Fourche Maline Creek	OK220100-04-0020H	WWAC	8/29/2013	4.56
				9/16/2013	4.55
				6/23/2014	4.36
				9/2/2014	3.86
				10/6/2014	4.83
38.10%	Gaines Creek	OK220600-04-0010P	WWAC	6/24/2013	3.01
				7/28/2014	4.44
				9/2/2014	4.09
				7/29/2013	2.55
				9/16/2013	3.92
				10/7/2013	3.08
				8/28/2014	3.28
				10/6/2014	3.08
10.53%	Gar Creek	OK520510-00-0080C	WWAC	8/6/2013	4.57
				9/10/2013	4.56
59.09%	George's Fork of Dirty Creek	OK120400-02-0110D	WWAC	5/28/2013	4.87
				7/1/2013	2.81
				8/5/2013	2.49
				9/3/2013	3.14
				9/26/2013	4.15
				10/14/2013	4.66
				11/12/2013	4.92
				6/16/2014	3.66
				7/21/2014	4.86
				8/25/2014	2.71

% Sample with Low DO	Site Name	WBID	FWP	DATE	DO (mg/L)
				9/29/2014	3.15
				11/3/2014	2.51
				12/8/2014	4.21
5.00%	Greenleaf Creek	OK120400-01-0120C	WWAC	7/23/2013	3.78
4.76%	Hog Creek	OK520810-00-0030D	WWAC	9/9/2014	4.10
4.76%	Little Deep Fork	OK520700-06-0010D	WWAC	8/26/2014	4.80
4.76%	Little Wewoka Creek	OK520500-02-0090D	WWAC	7/1/2014	4.88
19.05%	Longtown Creek	OK220600-01-0070P	WWAC	9/9/2013	3.45
				11/19/2013	2.68
				9/3/2014	3.07
				10/7/2014	3.19
4.76%	Manard Bayou	OK120400-01-0280E	WWAC	9/3/2013	2.80
31.82%	Mill Creek	OK220600-01-0100P	WWAC	7/1/2013	4.06
				8/5/2013	4.02
				9/3/2013	2.45
				9/10/2013	3.19
				6/16/2014	4.71
				8/25/2014	2.36
				9/29/2014	4.31
42.86%	Montezumah Creek	OK520700-01-0220D	WWAC	6/25/2013	3.50
				7/12/2013	1.57
				7/30/2013	3.95
				9/4/2013	2.10
				10/8/2013	3.25
				7/22/2014	4.15
				8/26/2014	2.32
				9/30/2014	3.20
				11/18/2014	2.66
42.86%	Nuyaka Creek	OK520700-02-0200D	WWAC	5/21/2013	4.45
				7/11/2013	2.96
				7/30/2013	3.40
				9/4/2013	4.30
				5/13/2014	4.48
				6/17/2014	4.94
				7/22/2014	3.00
				9/30/2014	2.62
				11/18/2014	3.77

% Sample with Low DO	Site Name	WBID	FWP	DATE	DO (mg/L)
45.45%	Peaceable Creek	OK220600-03-0050F	WWAC	5/20/2013	4.55
				6/24/2013	2.81
				7/18/2013	3.96
				7/29/2013	4.24
				9/16/2013	3.95
				10/7/2013	4.92
				11/18/2013	3.52
				7/28/2014	4.87
				9/2/2014	4.59
				10/6/2014	3.83
23.81%	Pecan Creek (Muskogee Co.)	OK120410-01-0030D	WWAC	5/20/2013	3.42
				6/24/2013	4.77
				7/29/2013	3.74
				11/12/2013	4.07
				6/23/2014	4.30
4.76%	Polecat Creek	OK120420-02-0050G	WWAC	5/20/2013	4.92
9.09%	Quapaw Creek	OK520700-04-0260C	WWAC	8/25/2014	4.75
				9/29/2014	3.62
13.64%	Sallisaw Creek	OK220200-03-0010C	CWAC	9/4/2013	4.56
				10/15/2013	4.66
				8/26/2014	4.52
19.05%	Salt Creek (Creek Co.)	OK520700-03-0100B	WWAC	7/10/2013	3.70
				10/8/2013	4.60
				5/13/2014	2.15
				9/30/2014	4.44
13.64%	Snake Creek	OK120410-01-0220G	WWAC	6/24/2013	3.96
				9/3/2013	4.63
				12/9/2014	4.67
27.27%	South Fork Dirty Creek	OK120400-02-0030H	WWAC	7/1/2013	4.61
				8/5/2013	4.35
				9/14/2013	3.33
				11/12/2013	4.65
				6/16/2014	3.38
				9/29/2014	3.18

% Sample with Low DO	Site Name	WBID	FWP	DATE	DO (mg/L)
28.57%	Sugar Loaf Creek	OK220100-01-0160G	WWAC	7/23/2013	2.85
				7/30/2013	4.37
				9/17/2013	2.46
				10/8/2013	2.88
				7/29/2014	4.20
				9/3/2014	2.07
20.00%	Turkey Creek	OK520510-00-0100F	WWAC	8/6/2013	3.31
				9/10/2013	1.25
				7/1/2014	2.55
				9/9/2014	4.59
52.38%	Vian Creek	OK220200-02-0130E	CWAC	6/11/2013	5.90
				7/2/2013	5.95
				8/6/2013	4.19
				9/4/2013	4.88
				10/15/2013	3.54
				6/17/2014	5.88
				7/22/2014	5.26
				8/26/2014	3.07
				9/30/2014	4.07
				11/4/2014	5.69
				3/31/2015	4.42

Table 9 shows the geometric mean of *E.coli* bacteria samples for each site over the two-year monitoring period. Only Bird Creek is designated Secondary Body Contact Recreation (SBCR), which allows for a higher bacteria concentration; all other sites are designated Primary Body Contact Recreation (PBCR). All but three of the streams meet the *E. coli* standard, as denoted by the asterisk in Table 9. OCC does not currently test for *Enterococcus* so only Elk Creek, Polecat Creek, and Bird Creek (SBCR) are fully attaining the Recreation designated use, meeting the standards for both types of bacteria. To be listed on the state's 303(d) list, the geometric mean must exceed the set criteria for at least one of the bacteria types (OWRB 2011).

Table 9. Geometric mean of bacteria values for Basin Group 3 fixed monitoring sites, 2013-2015 OCC data. An asterisk (*) indicates that the stream *meets* state standards for that bacteria type. Most streams are impaired by Enterococcus bacteria, and are currently on the 303(d) list or have been moved to Category 4 for bacteria after a TMDL has been produced. Bird Creek (highlighted in yellow) has a SBCR designation, allowing higher bacteria concentrations.

Site Name	WBID	E.coli	Comments	Site Name	WBID	E.coli	Comments
Alabama Creek	OK520500-01-0200D	12.94 *	Geometric Mean	Greenleaf Creek	OK120400-01-0120C	14.42 *	Geometric Mean
Ash Creek	OK120410-01-0110E	364.79	Geometric Mean	Hog Creek	OK520810-00-0030D	85.91 *	Geometric Mean
Bad Creek	OK520500-01-0170E	55.55 *	Geometric Mean	Little Deep Fork	OK520700-06-0010D	70.99 *	Geometric Mean
Ballard Creek	OK121700-03-0370G	61.31 *	Geometric Mean	Little Wewoka Creek	OK520500-02-0090D	63.51 *	Geometric Mean
Battle Creek	OK121700-06-0040G	23.86 *	Geometric Mean	Longtown Creek	OK220600-01-0070P	57.91 *	Geometric Mean
Bear Creek	OK520700-05-0170A	112.80 *	Geometric Mean	Manard Bayou	OK120400-01-0280E	21.88 *	Geometric Mean
Big Creek	OK220100-02-0080B	10.25 *	Geometric Mean	Mill Creek	OK220600-01-0100P	13.46 *	Geometric Mean
Big Skin Bayou	OK220200-01-0030H	28.40 *	Geometric Mean	Montezumah Creek	OK520700-01-0220D	121.70 *	Geometric Mean
Bird Creek	OK520800-01-0050G	116.85 *	Geometric Mean	Nuyaka Creek	OK520700-02-0200D	285.32	Geometric Mean
Brazil Creek	OK220100-03-0010G	30.84 *	Geometric Mean	Peaceable Creek	OK220600-03-0050F	56.55 *	Geometric Mean
Brushy Creek	OK220600-03-0010L	43.26 *	Geometric Mean	Pecan Creek (Muskogee Co.)	OK120410-01-0030D	54.37 *	Geometric Mean
Canadian Sandy Creek	OK520600-03-0010D	27.03 *	Geometric Mean	Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C	47.08 *	Geometric Mean
Captain Creek	OK520700-05-0140H	72.96 *	Geometric Mean	Polecat Creek	OK120420-02-0050G	24.01 *	Geometric Mean
Caston Creek	OK220100-01-0180B	18.67 *	Geometric Mean	Quapaw Creek	OK520700-04-0260C	32.57 *	Geometric Mean
Cloud Creek	OK120410-01-0100T	121.31 *	Geometric Mean	Sallisaw Creek	OK220200-03-0010C	14.67 *	Geometric Mean
Coal Creek	OK220600-02-0010F	57.01 *	Geometric Mean	Salt Creek (Creek Co.)	OK520700-03-0100B	93.96 *	Geometric Mean
Deep Branch	OK121700-01-0020A	23.60 *	Geometric Mean	Salt Creek (Seminole Co.)	OK520800-03-0010D	57.11 *	Geometric Mean
Dry Creek	OK520700-04-0020F	122.59 *	Geometric Mean	Sandy Creek	OK520700-03-0040F	221.88	Geometric Mean
Elk Creek	OK120400-02-0190F	31.08 *	Geometric Mean	Snake Creek	OK120410-01-0220G	86.10 *	Geometric Mean
Emachaya Creek	OK220300-00-0040C	79.81 *	Geometric Mean	South Fork Dirty Creek	OK120400-02-0030H	26.11 *	Geometric Mean
Fourche Maline Creek	OK220100-04-0020H	27.94 *	Geometric Mean	Sugar Loaf Creek	OK220100-01-0160G	58.30 *	Geometric Mean
Gaines Creek	OK220600-04-0010P	26.53 *	Geometric Mean	Turkey Creek	OK520510-00-0100F	77.83 *	Geometric Mean
Gar Creek	OK520510-00-0080C	31.94 *	Geometric Mean	Vian Creek	OK220200-02-0130E	12.41 *	Geometric Mean
George's Fork of Dirty Creek	OK120400-02-0110D	28.88 *	Geometric Mean	Wewoka Creek	OK520500-02-0010C	36.58 *	Geometric Mean

Select water quality parameters are summarized by box plots in Figures 2-7, 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 Appendix E for high quality streams details) to determine general stream condition. Figures 2-4 show interquartile range plots by site for four important indicators of pollution: ortho-phosphorus, total phosphorus, available nitrogen (ammonia, nitrate, and nitrite) and estimated total nitrogen (TKN plus nitrate/nitrite). All elevated flow data were omitted in these analyses in order to standardize the results.

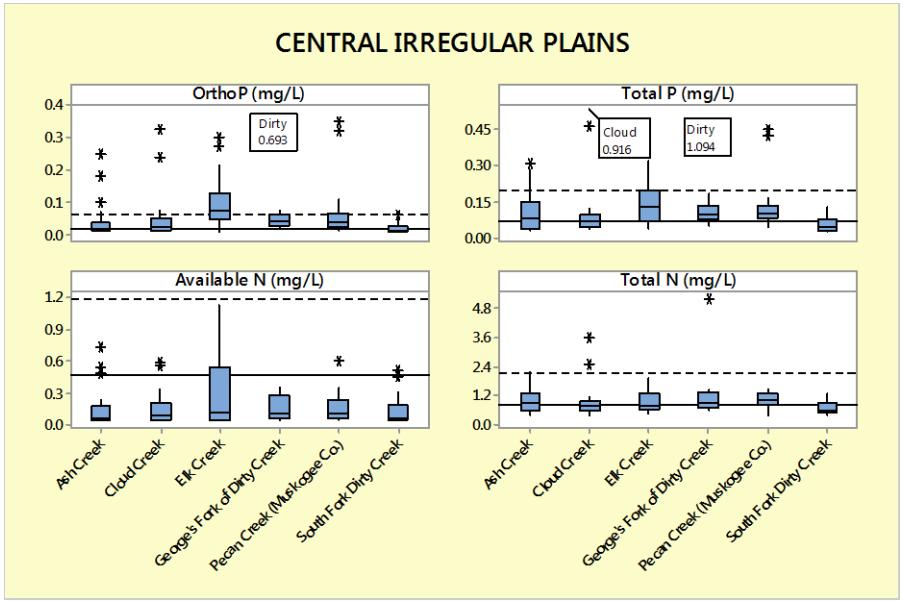
Regarding boxplot composition, the median of each site is shown by a line within the box with most outliers denoted by asterisks. Extreme outliers are denoted by values inside a box on the graph. The mean of the high quality stream sites in a particular ecoregion is represented by a solid horizontal line, while dashed lines indicate +/- two standard deviations (representing 95% of the high quality data) for high quality site parameters. In instances where only one dashed line is present, the lower value was below zero.

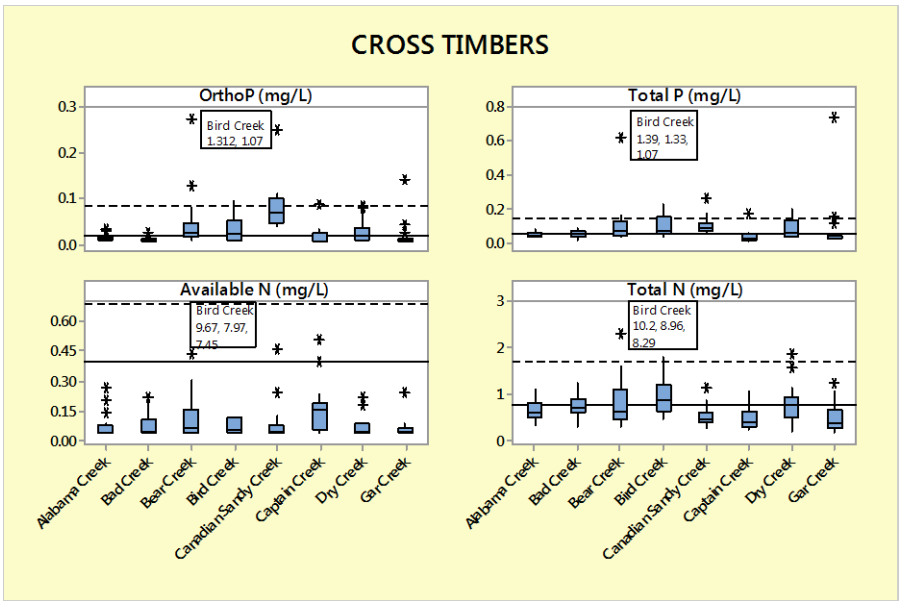
Several sites in the Arkansas Valley (AV) ecoregion had significantly high nutrient values relative to the high quality sites for that ecoregion. Coal and Peaceable Creeks had high values of phosphorous and nitrogen and the Mill Creek mean total nitrogen level was higher than the high quality sites. In the Cross Timbers ecoregion Polecat Creek had high nutrient values relative to high quality sites. All sites in the Boston Mountains, Central Irregular Plains, and Ozark Highlands ecoregions were within two standard deviations of the high quality sites in the ecoregions, indicating no significant difference from the high quality sites.

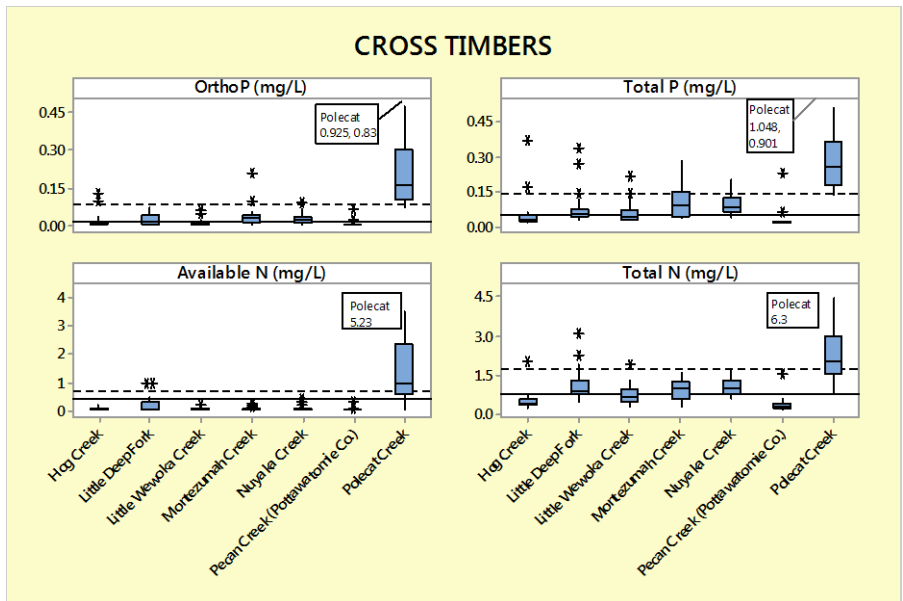
Figures 5-7 show interquartile range plots for four physical parameters: dissolved oxygen (percent saturation), pH, turbidity, and total suspended solids (TSS). Results from most of the sites fall within two standard deviations of the high quality sites in the ecoregions, indicating no significant difference from the high quality sites, with the exception of Montezumah Creek (Cross Timbers ecoregion) and Big Skin Bayou (Boston Mountains ecoregion) where the turbidity was high. On the dissolved oxygen % saturation charts a green line indicates 80% or 130% saturation and a red line indicates 50% or 150% saturation.

Figure 2. Select nutrients 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. Select nutrients 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).







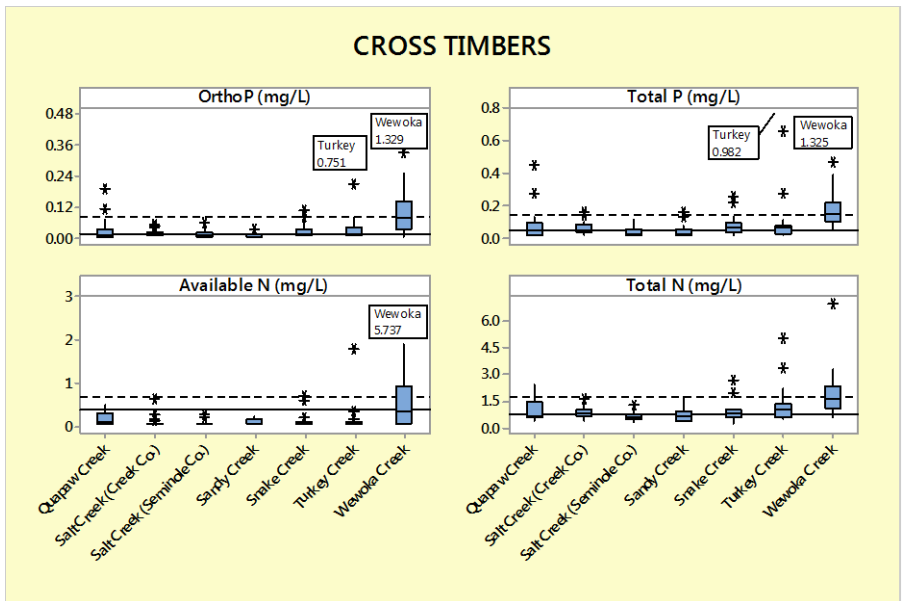
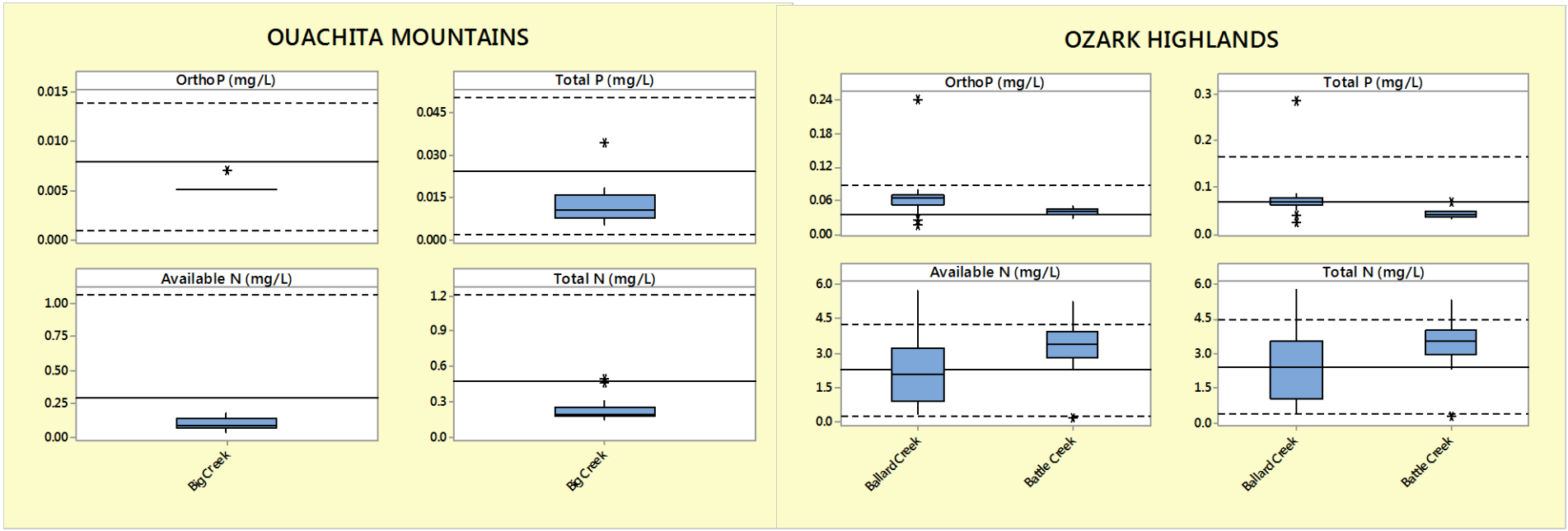


Figure 4. Select nutrients for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).



tFigure 5. Select physical parameters 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). Oxygen charts use a green line to indicate 80% and 130% and a red line to indicate 50% and 150% DO saturation.

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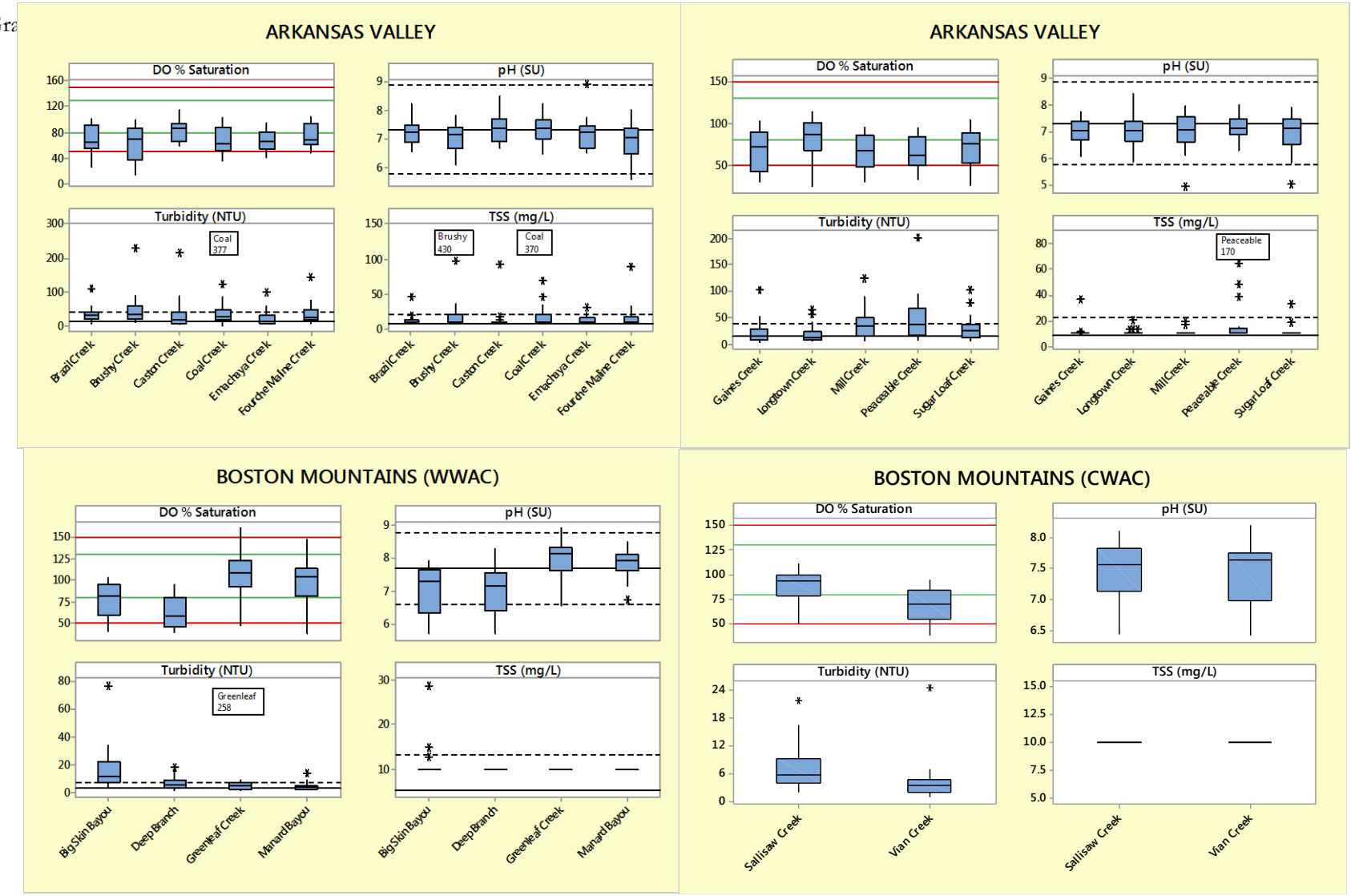


Figure 6. Select physical parameters by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero). Oxygen charts use a green line to indicate 80% and a red line to indicate 50% DO saturation.

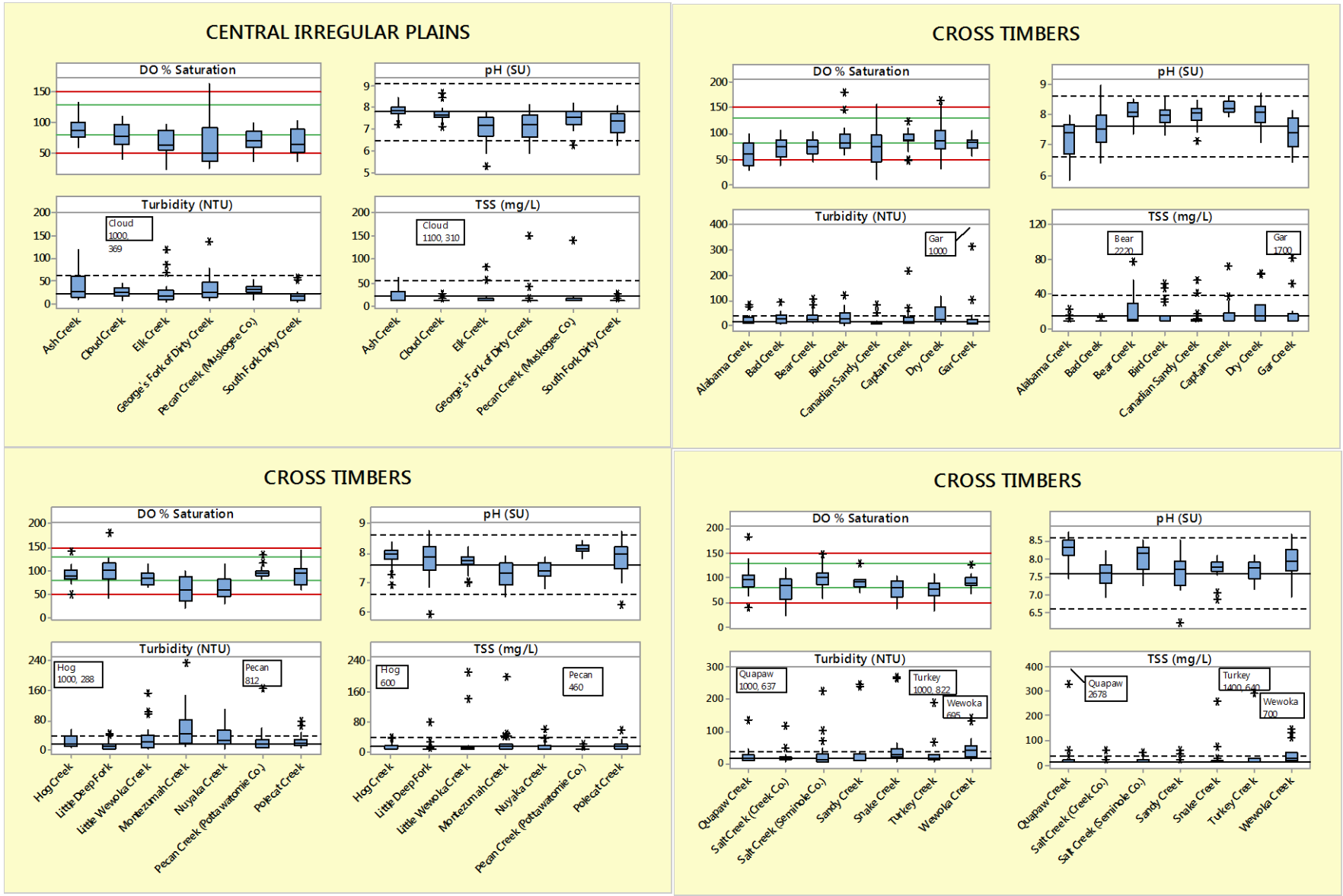


Figure 7. Select physical parameters by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero). Oxygen charts use a green line to indicate 80% and a red line to indicate 50% DO saturation.

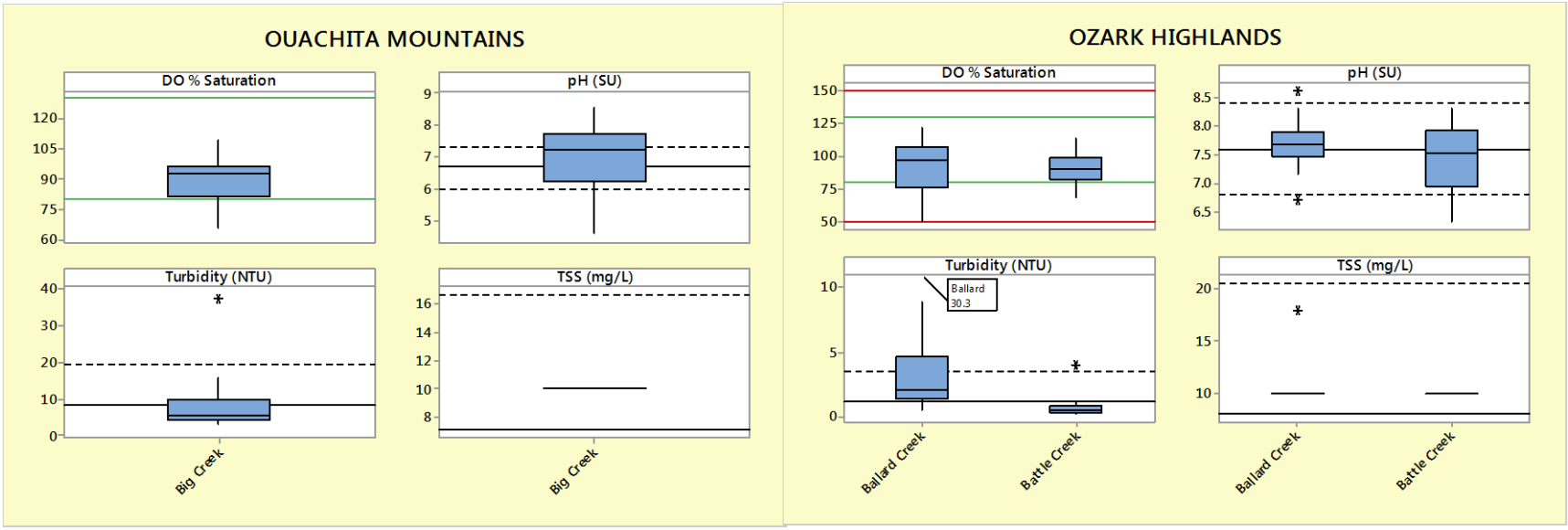


Table 10 shows an example of a comparison between base flow water quality data collected for the same site in the previous rotating basin cycles and the third cycle in order to examine whether water conditions have improved, worsened, or remained the same at a particular site. One-way ANOVAs were performed for each set of data. Only statistically significant differences between the means of each parameter in all three cycles or between cycle 2 and cycle 3 are shown in the table. Level of significance is indicated by p-values, with any $p < 0.050$ considered significant and $0.050 < p < 0.100$ considered marginally significant. To give a visual indication of the changes across the cycles, mini-graphs, called sparklines, have been added to the table. Since the table is more than 16 pages long, it is included in this document as Appendix A.4.

Twenty-four sites had significant changes in parameter values this cycle. The basin was in a drought during this cycle, and 14 of the sites had lower flows; nine were significant. One stream had significantly higher levels of dissolved oxygen (DO), but seven streams had reduced DO. Forms of nitrogen increased during this cycle with 20 of the sites showing significant increases in total Kjeldahl nitrogen (TKN). Three sites showed significant decreases in nitrate/nitrite. Phosphorus increased in five streams and decreased in two streams. Turbidity was significantly higher in two streams; alkalinity and/or hardness was significantly higher in nine streams and reduced in seven streams; nine streams exhibited increased salt concentrations (sulfate, chloride, or total dissolved solids) while two show lower salt concentrations.

Table 10. Example of statistical comparisons of cycles one (2003-2005), two (2009-2010) and three (2013-2015) of Rotating Basin Project water quality data. "N" is the number of base flow samples included in the analyses. * indicates significant. Sparklines show the change. The entire table can be found in Appendix A 4.

Site Name	WBID	Parameter	Cycle	N	Mean	Standard Deviation	Relative Change	P Value 2 v. 3	P Value All Cycles
Alabama Creek	OK520500-01-0200D	Alkalinity	1	17	58	25.31		0.579	0.000 *
			2	17	98.06	37.43			
			3	20	104.4	31.42			
		Conductivity	1	16	597.6	321.1		0.007 *	0.009 *
			2	17	945	571			
			3	20	530.4	286.7			
		DO %sat	1	17	75.44	17.26		0.064	0.024 *
			2	16	71.17	18.4			
			3	20	58.61	20.37			
		Hardness	1	17	114.6	48.8		0.755	0.002 *
			2	16	193.1	98.2			
			3	20	185.3	45.9			
		Chloride	1	17	123.2	72		0.001 *	0.000 *
			2	16	251.5	167.9			
			3	19	94.9	59.6			
		TDS	1	17	337.8	135.7		0.002 *	0.001 *
			2	16	543.9	302.7			
			3	19	286	127.4			
		TKN	1	17	0.445	0.358		0.008 *	0.085
			2	16	0.403	0.217			
			3	19	0.593	0.186			
		Nitrate	1	17	0.0553	0.05		0.076	0.096
			2	16	0.1244	0.23			
			3	19	0.027	0.024			
		available N	1	17	0.12	0.09		0.078	0.129
			2	16	0.18	0.23			
			3	19	0.08	0.06			
		ortho-phosphorus	1	17	0.023	0.019		0.706	0.025 *
			2	16	0.013	0.009			
			3	19	0.012	0.008			
		TP	1	17	0.081	0.031		0.765	0.000 *
			2	16	0.042	0.025			
			3	19	0.044	0.016			
		Sulfate	1	17	18.69	5.59		0.007 *	0.005 *
			2	16	25.11	7.41			
			3	19	18.71	5.57			
		TSS	1	17	16	8.33		0.280	0.006 *
			2	16	11.44	3.46			
			3	19	10.47	1.5			

Biological Monitoring

Habitat Assessment

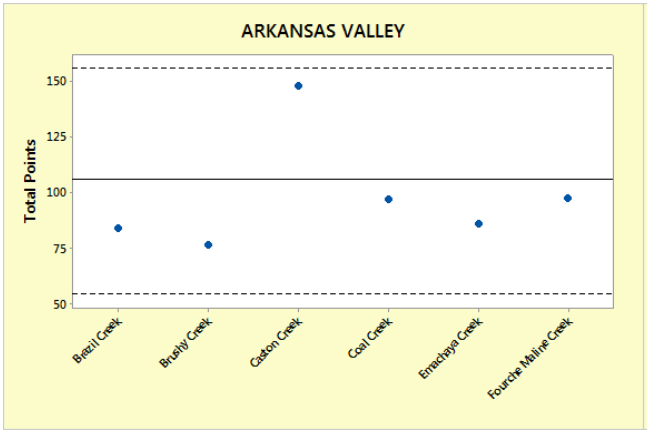
Total habitat scores for each site and computed metric scores are listed below (Table 10). Lower Ballard, Battle, Big, Caston, Sallisaw and Vian Creeks had the highest habitat scores, while Bear, Dry, and Quapaw Creeks had the lowest habitat scores. Figures 8 and 9 show the total habitat score for each site plotted against the mean value of the high quality reference conditions for each ecoregion. All of the sites scored within two standard deviations of the mean for their ecoregions. Caston Creek in the Arkansas Valley ecoregion was near the top; Mill Creek in the Central Irregular Plains and Dry Creek in the Cross Timbers were near the bottom of their respective ecoregions.

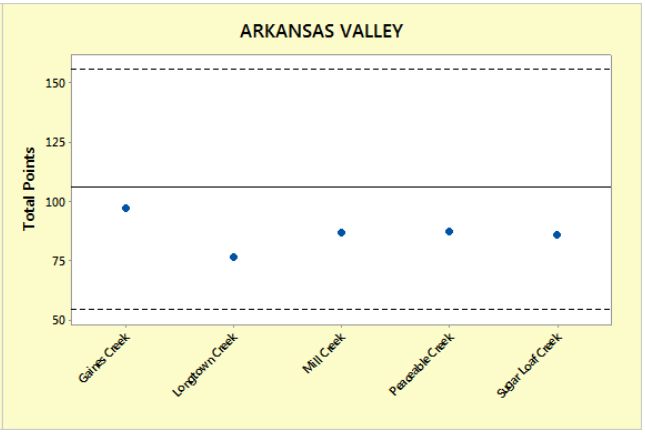
Table 11. Habitat assessment metric values for monitoring sites in the Rotating Basin Group 3, Cycle 3.

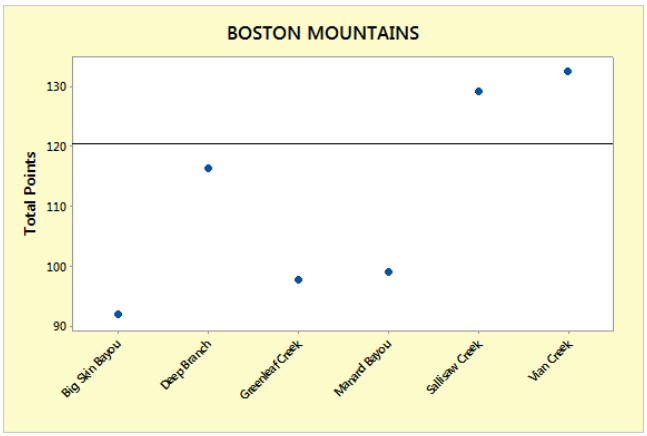
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Alabama Creek	OK520500-01-0200D	9.3	8.4	20.2	16	4.1	0	6.7	0.8	6	6.7	10	88.2
Ash Creek	OK120410-01-0110E	6.6	0.9	16.1	2.6	2.2	6.6	1.4	5.4	6.2	3.6	8.8	60.4
Bad Creek	OK520500-01-0170E	7.6	3.6	14.4	6.5	4.1	0	12.3	0.8	7.1	6.3	9.7	72.4
Ballard Creek	OK121700-03-0370G	18.5	15.2	20.1	11.3	16.2	18.4	1.8	1.6	7.7	7.4	9.2	127
Battle Creek	OK121700-06-0040G	17.7	15.7	15.6	19.9	16.1	16.5	0.4	1.1	9.9	6.2	9.6	129
Bear Creek	OK520700-05-0170A	1.7	0.7	20.2	2.5	0	5	0.4	-0.1	6.6	7	5	49
Big Creek	OK220100-02-0080B	19.6	15.6	18.8	18.3	15.6	11.9	12.3	2	10	9.6	10	144
Big Skin Bayou	OK220200-01-0030H	5.2	3.8	14.6	17.4	0	12.8	11.1	4.9	6.1	6.4	9.6	91.9
Bird Creek	OK520800-01-0050G	1	1.7	0	13.2	0	1	13.7	1.3	10	8.9	10	60.8
Brazil Creek	OK220100-03-0010G	11.2	9.2	14.6	11	5.9	0.5	11.1	1.6	5.6	3.7	9.5	83.9
Brushy Creek	OK220600-03-0010L	4.5	8.3	15.7	10.6	2.2	1.2	11.1	4.5	5.2	4	9.2	76.5
Canadian Sandy Creek	OK520600-03-0010D	3.9	3.7	19.8	18.4	0	15.6	0.4	5.8	7	7	9.2	90.8
Captain Creek	OK520700-05-0140H	2.8	2	18.7	9.9	0	19.9	12.3	-0.1	3.7	4.7	8.9	82.8
Caston Creek	OK220100-01-0180B	18.7	15.9	20.2	18.7	13.3	14.1	16.5	2.2	9.5	8.5	10	148
Cloud Creek	OK120410-01-0100T	6.8	1.5	20.2	11.3	0	1.5	0.5	1.1	7	7.6	9.9	67.4
Coal Creek	OK220600-02-0010F	12	12.8	13.6	10.9	4.1	10.8	11.1	2	5.5	4.5	9.5	96.8
Deep Branch	OK121700-01-0020A	17	10.1	20.2	16	7.5	4.7	11.1	1.1	10	8.7	10	116
Dry Creek	OK520700-04-0020F	2.2	1.6	0	18.9	0	4.3	0.5	0	2.6	2.8	9.1	42
Elk Creek	OK120400-02-0190F	5.3	5.6	20.2	16.4	0	0.5	8.7	1.5	5.3	4.5	9.2	77.2
Emachaya Creek	OK220300-00-0040C	7.5	5.7	13.6	13.8	4.1	0	9.9	8	7.2	5.9	10	85.7
Fourche Maline Creek	OK220100-04-0020H	6.1	11.3	13.4	12.5	4.1	13.3	16.5	1.5	5.6	3.6	9.7	97.6
Gaines Creek	OK220600-04-0010P	14.4	9.1	13.5	19.8	5.9	1.5	9.9	5.2	5.8	5.5	6.4	97

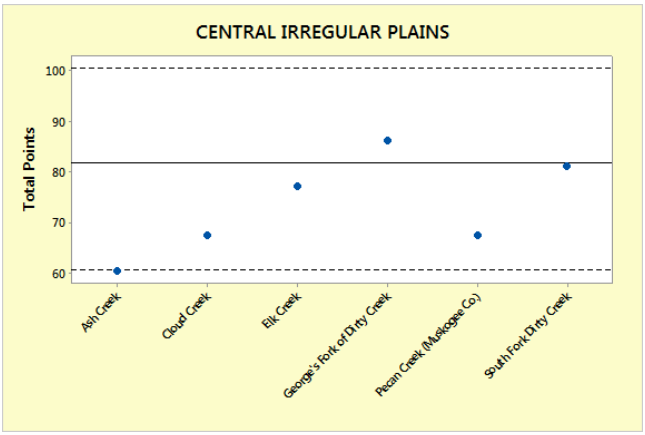
Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points
Gar Creek	OK520510-00-0080C	4.2	5.5	16.6	12.6	10.3	10.9	6.7	2	8.1	5.8	10	92.7
George's Fork of Dirty Creek	OK120400-02-0110D	10.4	7.5	15.7	16	4.1	0.5	12.3	2.2	5.7	5.4	6.4	86.2
Greenleaf Creek	OK120400-01-0120C	15.8	14.3	15	8.7	9	0.2	6.7	0.8	7.6	9.7	9.9	97.7
Hog Creek	OK520810-00-0030D	3.7	1.2	19.3	7	2.2	15.2	2.8	0.5	5	6.7	3.2	66.8
Little Deep Fork	OK520700-06-0010D	2.3	1.9	17.2	12.3	0	10.1	0.5	1.9	7.7	6.6	10	70.5
Little Wewoka Creek	OK520500-02-0090D	3.1	1.1	15	13.7	2.2	14.8	8.7	1.8	4.1	3.1	9.3	76.9
Longtown Creek	OK220600-01-0070P	8.5	13.4	13	19.8	0	0	0.4	4	4.6	6.1	6.6	76.4
Manard Bayou	OK120400-01-0280E	10.4	4.8	13.2	13.3	5.9	15.9	11.1	1.4	7.2	6.1	9.7	99
Mill Creek	OK220600-01-0100P	6.2	4.2	20	17	4.1	0.5	6.7	4.7	6.7	6.7	10	86.8
Montezumah Creek	OK520700-01-0220D	4.3	3.1	18	20	0	0	9.9	4.6	2	2.2	8.8	72.9
Nuyaka Creek	OK520700-02-0200D	2.2	1.5	14.6	19.8	0	0	15.1	0.3	6.6	5.3	8.9	74.3
Peaceable Creek	OK220600-03-0050F	8	6.7	14.2	17	4.1	5.6	8.7	3.1	5.7	5.3	8.8	87.2
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C	1.1	1.6	9.9	14.6	0	13.7	8.7	0.5	6	4.5	10	70.6
Pecan Creek (Muskogee Co.)	OK120410-01-0030D	5.9	6.4	20.1	9.7	2.2	0.4	5.8	0.6	3.8	3.8	8.8	67.5
Polecat Creek	OK120420-02-0050G	8.8	6.2	14.6	1.4	9	15.8	5	1.6	8.7	7.2	10	88.3
Quapaw Creek	OK520700-04-0260C	1.9	1.4	0	7	0	13.2	2.8	0.3	5.7	5.3	9.7	47.3
Sallisaw Creek	OK220200-03-0010C	17.9	8.6	14.6	19.8	11.4	20	16.5	0.7	9.3	7	3.4	129
Salt Creek (Creek Co.)	OK520700-03-0100B	1.5	0.9	20.2	15.9	0	1.2	0.7	0.5	4.6	3	9.6	58.1
Salt Creek (Seminole Co.)	OK520800-03-0010D	2.2	3.3	0	11.8	2.2	20	0.5	1.1	6.1	3.4	6	56.6
Sandy Creek	OK520700-03-0040F	2.5	1.8	14	16.1	0	7	1.8	2.4	7.5	6.5	9.5	69.1
Snake Creek	OK120410-01-0220G	4.6	2.2	4.1	5.3	2.2	17.3	7.7	4.7	4.9	4.2	10	67.2
South Fork Dirty Creek	OK120400-02-0030H	7.6	8.4	16.3	19.4	0	0	4.2	3.7	5.8	6.2	9.5	81.1
Sugar Loaf Creek	OK220100-01-0160G	10.1	12.7	13.4	17.3	0	0	12.3	3.2	5.4	2.8	8.8	86
Turkey Creek	OK520510-00-0100F	0.8	0.6	20.2	14.2	2.2	11.5	1.4	3	4.9	3.3	10	72.1
Vian Creek	OK220200-02-0130E	18.4	15.2	19.8	10.1	14.1	16.1	12.3	1.6	8.6	6.8	9.5	133
Wewoka Creek	OK520500-02-0010C	0.9	3.4	19.4	0.5	0	16.7	7.7	4.3	5.4	3.6	9.9	71.8

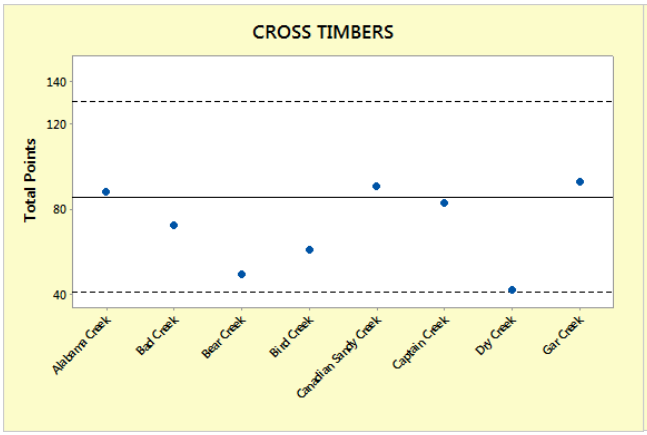
Figure 8. Total habitat score for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.











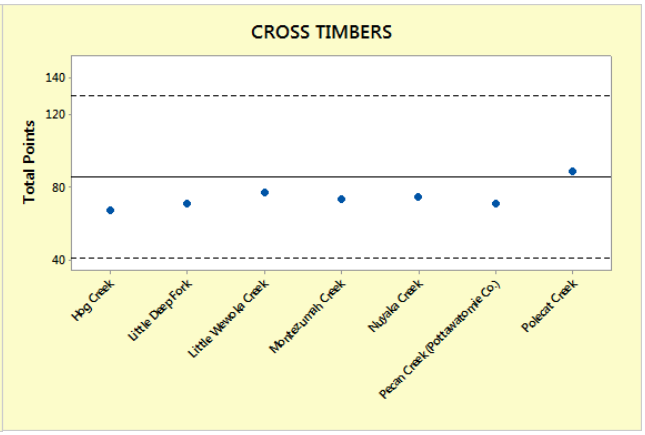
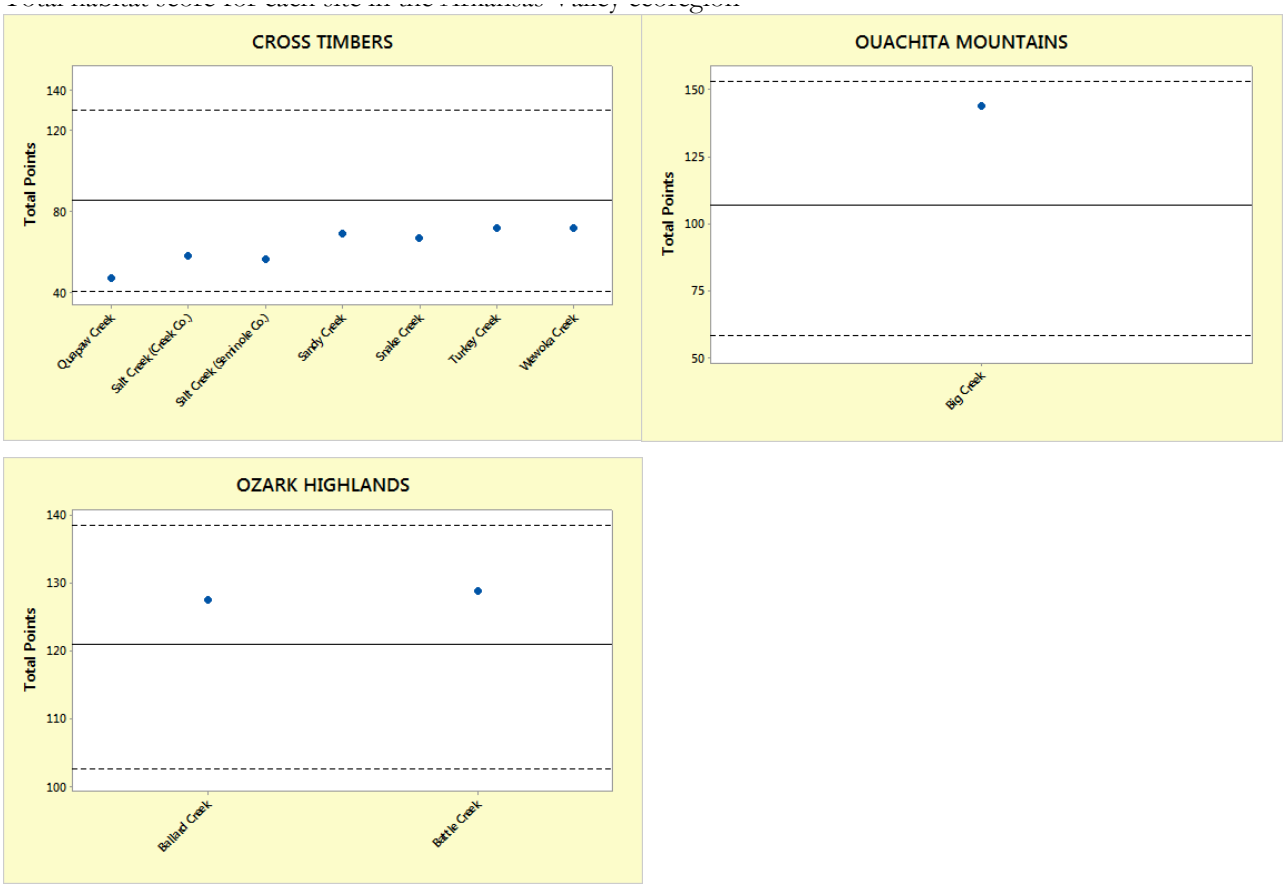


Figure 9. Total habitat score for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.



Fish Collections

Fish metrics used to compute index of biotic integrity (IBI) scores for the Rotating Basin sites using the OCC method are listed in Table 11. 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. 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.

Table 12 Metric values for calculation of fish IBI scores (OCC method) for Rotating Basin Group 3 Cycle 3 monitoring sites.

Site Name	WBID	Date	Total Number	Total Spp	Darter Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent Insectivorous Cyprinids	Percent Lithophylic Spawners
Alabama Creek	OK520500-01-0200D	7/16/2013	238	17	2	7	1	89.92%	0.00%	7.56%
Ash Creek	OK120410-01-0110E	5/28/2013	255	16	1	7	2	70.59%	0.39%	14.51%
Bad Creek	OK520500-01-0170E	7/17/2013	321	24	3	7	2	69.47%	0.00%	20.25%
Ballard Creek	OK121700-03-0370G	6/13/2013	997	21	4	6	10	16.85%	33.60%	82.65%
Battle Creek	OK121700-06-0040G	6/4/2013	620	17	4	4	12	1.29%	15.65%	73.39%
Bear Creek	OK520700-05-0170A	8/8/2013	361	16	0	6	1	99.45%	0.28%	0.28%
Big Creek	OK220100-02-0080B	8/27/2013	571	18	5	5	8	25.57%	4.73%	70.40%
Big Skin Bayou	OK220200-01-0030H	7/9/2014	453	24	4	8	6	59.16%	9.05%	21.19%
Bird Creek	OK520800-01-0050G	8/28/2013	535	23	1	9	1	76.82%	1.87%	12.71%
Brazil Creek	OK220100-03-0010G	7/22/2013	377	24	4	7	6	41.11%	3.45%	57.56%
Brushy Creek	OK220600-03-0010L	7/28/2014	750	35	7	9	6	31.73%	4.67%	45.07%
Canadian Sandy Creek	OK520600-03-0010D	8/8/2013	316	20	1	6	1	91.14%	5.70%	2.85%
Captain Creek	OK520700-05-0140H	8/21/2013	208	16	0	4	1	98.08%	1.92%	0.00%
Caston Creek	OK220100-01-0180B	8/28/2013	417	28	5	8	4	36.21%	8.63%	19.66%
Cloud Creek	OK120410-01-0100T	8/1/2013	554	27	2	8	3	69.49%	5.42%	5.60%
Coal Creek	OK220600-02-0010F	8/26/2013	664	32	2	9	4	51.51%	0.00%	30.42%
Deep Branch	OK121700-01-0020A	6/18/2013	167	9	0	5	1	52.69%	3.59%	40.72%
Dry Creek	OK520700-04-0020F	7/25/2013	672	19	0	7	2	91.82%	2.68%	0.00%
Elk Creek	OK120400-02-0190F	9/12/2013	475	19	3	7	3	42.53%	5.05%	20.63%
Emachaya Creek	OK220300-00-0040C	5/29/2014	404	20	2	8	2	65.35%	0.50%	24.01%
Fourche Maline Creek	OK220100-04-0020H	8/29/2013	557	44	11	8	15	47.40%	11.31%	38.06%
Gaines Creek	OK220600-04-0010P	8/28/2014	261	25	6	7	7	46.36%	5.36%	34.87%
Gar Creek	OK520510-00-0080C	6/27/2013	516	20	1	7	2	78.88%	1.74%	7.75%
George's Fork of Dirty Creek	OK120400-02-0110D	9/26/2013	540	21	3	7	2	69.44%	0.56%	21.85%
Greenleaf Creek	OK120400-01-0120C	7/23/2013	984	25	5	7	6	20.73%	4.78%	45.33%
Hog Creek	OK520810-00-0030D	8/15/2013	353	15	0	7	0	98.30%	0.00%	0.00%
Little Deep Fork	OK520700-06-0010D	6/27/2013	521	14	0	7	1	98.85%	0.38%	0.77%
Little Wewoka Creek	OK520500-02-0090D	6/26/2013	488	14	1	6	2	87.09%	1.43%	10.86%
Longtown Creek	OK220600-01-0070P	9/9/2013	480	21	3	8	2	34.58%	8.96%	11.25%
Manard Bayou	OK120400-01-0280E	6/18/2013	1170	29	3	7	8	45.47%	23.16%	51.45%
Mill Creek	OK220600-01-0100P	9/10/2013	291	17	1	6	1	61.51%	0.00%	34.36%
Montezumah Creek	OK520700-01-0220D	7/12/2013	166	22	2	9	2	83.73%	3.61%	10.84%
Nuyaka Creek	OK520700-02-0200D	7/11/2013	171	19	0	8	1	92.98%	2.34%	4.09%

Site Name	WBID	Date	Total Number	Total Spp	Darter Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	Percent Insectivorous Cyprinids	Percent Lithophylic Spawners
Peaceable Creek	OK220600-03-0050F	7/18/2013	394	19	3	7	3	73.86%	1.27%	20.30%
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C	6/12/2013	330	13	0	6	2	90.00%	9.70%	0.30%
Pecan Creek (Muskogee Co.)	OK120410-01-0030D	7/2/2013	411	18	1	8	3	78.10%	14.36%	6.08%
Polecat Creek	OK120420-02-0050G	8/22/2013	1612	30	3	8	4	80.46%	5.71%	5.83%
Quapaw Creek	OK520700-04-0260C	8/8/2013	94	9	0	3	0	100.00%	0.00%	0.00%
Sallisaw Creek	OK220200-03-0010C	6/20/2013	815	35	4	12	13	32.88%	37.67%	63.44%
Salt Creek (Creek Co.)	OK520700-03-0100B	7/10/2013	211	15	0	7	1	98.10%	1.42%	0.47%
Salt Creek (Seminole Co.)	OK520800-03-0010D	8/7/2013	251	12	1	5	2	96.41%	1.99%	1.20%
Sandy Creek	OK520700-03-0040F	5/30/2013	639	13	1	7	1	99.84%	0.31%	0.00%
Snake Creek	OK120410-01-0220G	5/29/2013	667	23	3	8	4	76.01%	9.00%	11.84%
South Fork Dirty Creek	OK120400-02-0030H	9/14/2013	635	21	3	8	3	48.50%	1.89%	13.39%
Sugar Loaf Creek	OK220100-01-0160G	7/23/2013	269	27	3	8	3	56.51%	2.23%	33.83%
Turkey Creek	OK520510-00-0100F	6/19/2013	709	18	1	7	1	98.87%	0.14%	0.00%
Vian Creek	OK220200-02-0130E	6/11/2013	294	19	4	5	7	35.37%	34.35%	61.90%
Wewoka Creek	OK520500-02-0010C	8/8/2013	261	19	1	5	2	77.78%	21.07%	0.77%

Table 13 presents the results of the fish assessment based on the OCC's modified rapid bioassessment protocol (RBP) method. At this time, the fish assessment based on Oklahoma state biocriteria (as described in Oklahoma Water Resources Board, *Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (USAP), OAC 785:46-15) is not complete. 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 OCC method allows greater discrimination of the biological condition among sites. Eighteen sites had fish communities that were "excellent" when compared with high quality sites in the same ecoregion, 8 sites had fish communities that were "good," 18 sites were "fair," and 4 sites were "poor" relative to high quality sites in the ecoregion. Wewoka and Bird Creeks have a Habitat Limited Aquatic Community designation, indicating that irreversible, man-made conditions are constraining the fish and wildlife propagation use.

Fish collections indicate that 54% of the sites fall into the "excellent" or "good" category, 8% of the sites are in "poor" condition, and the remainder are "fair."

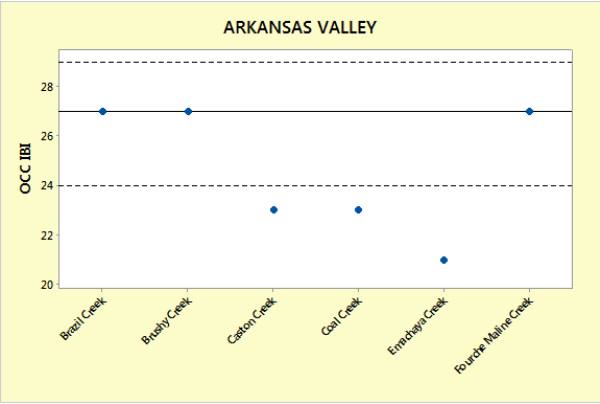
Table 13. **IBI scores based on OCC's modified RBP method.**

Ecoregion	Site Name	WBID	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
CT	Alabama Creek	OK520500-01-0200D	21	84.00%	Good
CIP	Ash Creek	OK120410-01-0110E	19	70.37%	Fair
CT	Bad Creek	OK520500-01-0170E	25	100.00%	Excellent
OH	Ballard Creek	OK121700-03-0370G	31	114.81%	Excellent
OH	Battle Creek	OK121700-06-0040G	31	114.81%	Excellent
CT	Bear Creek	OK520700-05-0170A	17	68.00%	Fair
OM	Big Creek	OK220100-02-0080B	27	93.10%	Excellent
BM	Big Skin Bayou	OK220200-01-0030H	25	92.59%	Excellent
CT	Bird Creek	OK520800-01-0050G	19	76.00%	Fair
AV	Brazil Creek	OK220100-03-0010G	27	100.00%	Excellent
AV	Brushy Creek	OK220600-03-0010L	27	100.00%	Excellent
CT	Canadian Sandy Creek	OK520600-03-0010D	21	84.00%	Good
CT	Captain Creek	OK520700-05-0140H	15	60.00%	Poor
AV	Caston Creek	OK220100-01-0180B	23	85.19%	Good
CIP	Cloud Creek	OK120410-01-0100T	21	77.78%	Fair
AV	Coal Creek	OK220600-02-0010F	23	85.19%	Good
BM	Deep Branch	OK121700-01-0020A	17	62.96%	Fair
CT	Dry Creek	OK520700-04-0020F	21	84.00%	Good
CIP	Elk Creek	OK120400-02-0190F	23	85.19%	Good
AV	Emachaya Creek	OK220300-00-0040C	21	77.78%	Fair
AV	Fourche Maline Creek	OK220100-04-0020H	27	100.00%	Excellent
AV	Gaines Creek	OK220600-04-0010P	25	92.59%	Excellent
CT	Gar Creek	OK520510-00-0080C	23	92.00%	Excellent
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	21	77.78%	Fair
BM	Greenleaf Creek	OK120400-01-0120C	29	107.41%	Excellent
CT	Hog Creek	OK520810-00-0030D	15	60.00%	Poor
CT	Little Deep Fork	OK520700-06-0010D	17	68.00%	Fair
CT	Little Wewoka Creek	OK520500-02-0090D	21	84.00%	Good
AV	Longtown Creek	OK220600-01-0070P	19	70.37%	Fair
BM	Manard Bayou	OK120400-01-0280E	29	107.41%	Excellent
AV	Mill Creek	OK220600-01-0100P	19	70.37%	Fair
CT	Montezumah Creek	OK520700-01-0220D	23	92.00%	Excellent
CT	Nuyaka Creek	OK520700-02-0200D	19	76.00%	Fair

Ecoregion	Site Name	WBID	IBI Total Score (OCC)	% of Reference	Score Interpretation (OCC)
AV	Peaceable Creek	OK220600-03-0050F	21	77.78%	Fair
CT	Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C	17	68.00%	Fair
CIP	Pecan Creek (Muskogee Co.)	OK120410-01-0030D	21	77.78%	Fair
CT	Polecat Creek: 33rd West	OK120420-02-0050G	23	92.00%	Excellent
CT	Quapaw Creek	OK520700-04-0260C	11	44.00%	Poor
BM	Sallisaw Creek: Lower	OK220200-03-0010C	29	107.41%	Excellent
CT	Salt Creek (Creek Co.)	OK520700-03-0100B	17	68.00%	Fair
CT	Salt Creek (Seminole Co.)	OK520800-03-0010D	19	76.00%	Fair
CT	Sandy Creek	OK520700-03-0040F	15	60.00%	Poor
CT	Snake Creek	OK120410-01-0220G	23	92.00%	Excellent
CIP	South Fork Dirty Creek	OK120400-02-0030H	21	77.78%	Fair
AV	Sugar Loaf Creek	OK220100-01-0160G	23	85.19%	Good
CT	Turkey Creek	OK520510-00-0100F	19	76.00%	Fair
BM	Vian Creek	OK220200-02-0130E	29	107.41%	Excellent
CT	Wewoka Creek: Downstream	OK520500-02-0010C	23	92.00%	Excellent

Figures 10 and 11 show 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. 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. The Boston Mountains and Ozark Highlands ecoregions limited high quality sites, so no range is given for these ecoregions.

Figure 10. 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.



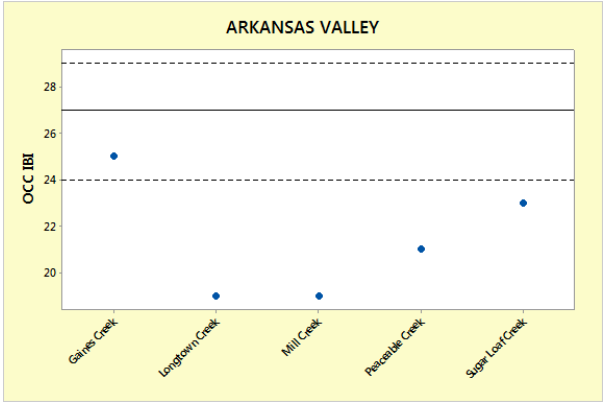
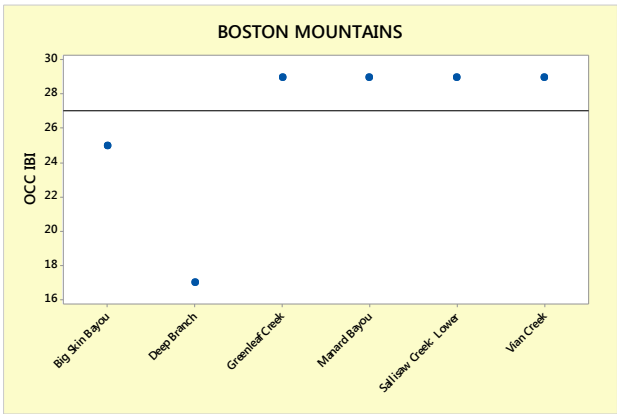
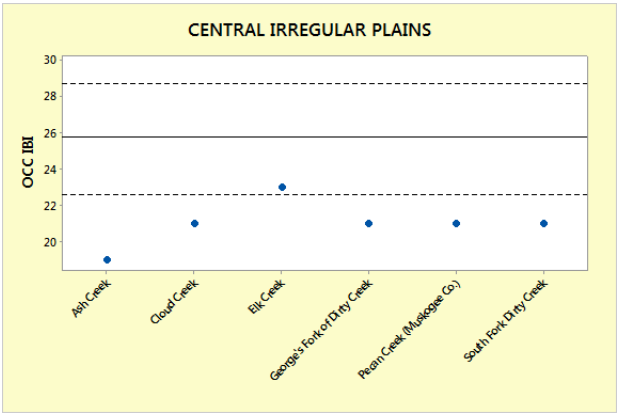
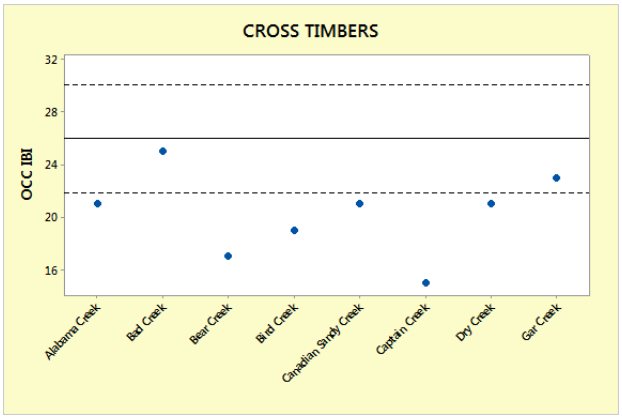
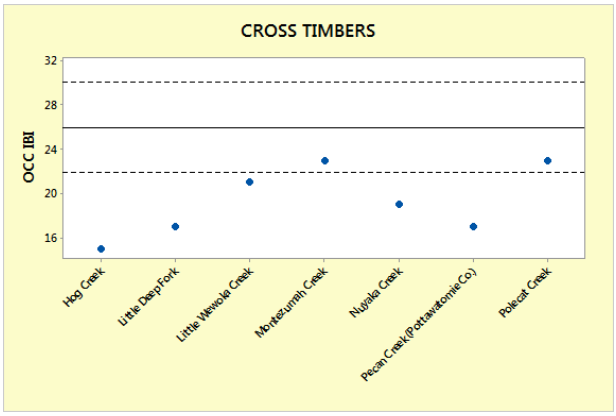


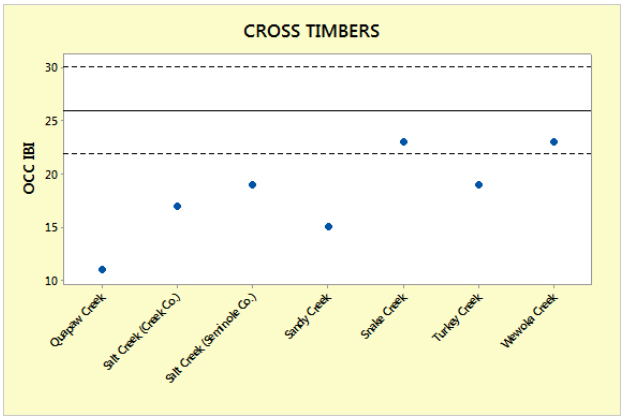
Figure 11. IBI score (fish) for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.

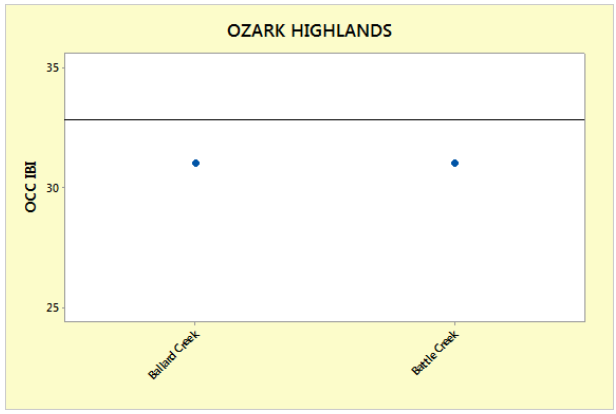


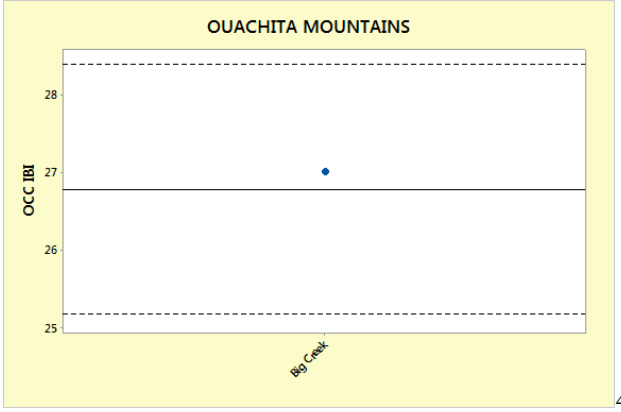












Most sites had significantly lower IBI scores than the high quality sites, as indicated by an IBI score below the bottom dashed line in Figures 10 and 11. Usually, the only sites that fall out of the high quality range score "fair," "poor," or "very poor" using the OCC IBI method (Table 12); however, only a few of the "good" sites were within two standard deviations of the high quality sites in this rotation. Conditions were drier during this monitoring cycle, in general, so it is likely that this contributed to these low fish scores relative to the high quality site scores, which were collected in previous years.

Table 14 shows a comparison between fish data collected in cycle 1 (2003-2005), cycle 2 (2008-2010), and cycle 3 (2013-2015) of the rotating basin project in order to examine whether biological conditions have improved, worsened, or remained the same at a particular site. Several site locations have changed, though they are still in the same stream segment. Slightly different metrics were used for the cycle 1 analysis so there are no results for sensitive benthic species and percent of lithophylic spawners shown in Table 14. IBI scores were calculated relative to the same high quality sites data for all cycles, so any change in condition is due only to a change in rotating basin cycle 3 collection, not to a change in high quality sites. The fish community remained in the same condition as cycle 2 for eleven of the 24 sites, which were collected across all three cycles, with IBI scores to be compared. Two streams had worse fish community conditions in cycle 3 relative to cycle 2, while eleven streams had improved fish communities.

Table 14. Comparison of fish data from fixed sites in cycles 1 (2003-2005), 2 (2008-2010), 3 (2013-2015)

Modified Ecoregion	Site Name	WBID	Cycle	Total Number	Total Spp	Darter Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	percent insect. Cyprinid	Percent lithophylic spawners	IBI Score	Percent of Reference	Condition
CT	Alabama Creek	OK520500-01-0200D	1	113	13	0		5	0	0.96	0.00	0.02	26	0.65	Fair
CT	Alabama Creek	OK520500-01-0200D	2	318	25	1	2	8	2	0.83	0.02	0.11	21	0.84	Good
CT	Alabama Creek	OK520500-01-0200D	3	238	17	2	3	7	1	0.90	0.00	0.08	21	0.84	Good
CT	Bad Creek	OK520500-01-0170L	1	434	20	1		8	1	0.42	0.02	0.18	32	0.80	Good
CT	Bad Creek	OK520500-01-0170L	2	295	25	1	2	7	2	0.64	0.05	0.28	23	0.92	Excellent
CT	Bad Creek	OK520500-01-0170E	3	321	24	3	3	7	2	0.69	0.00	0.20	25	1.00	Excellent
OH	Ballard Creek	OK121700-03-0370G	1	910	23	3		6	12	0.03	0.42	0.97	44	0.96	Excellent
OH	Ballard Creek	OK121700-03-0370G	2	682	21	3	6	7	10	0.09	0.54	0.91	35	1.40	Excellent
OH	Ballard Creek	OK121700-03-0370G	3	997	21	4	8	6	10	0.17	0.34	0.83	31	0.97	Excellent
OH	Battle Creek	OK121700-06-0040G	1	566	15	3		1	12	0.00	0.35	1.00	40	0.91	Good
OH	Battle Creek	OK121700-06-0040G	2	409	14	3	5	4	8	0.02	0.11	0.98	31	1.24	Excellent
OH	Battle Creek	OK121700-06-0040G	3	620	17	4	7	4	12	0.01	0.16	0.73	31	0.97	Excellent
CT	Bird Creek	OK520800-01-0050G	1	406	16	0		4	1	0.77	0.16	0.00	17	0.65	Fair
CT	Bird Creek	OK520800-01-0050G	2	868	21	0	0	6	1	0.92	0.01	0.01	17	0.68	Fair

Modified Ecoregion	Site Name	WBID	Cycle	Total Number	Total Spp	Darter Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	percent insect. Cyprinid	Percent lithophylic spawners	IBI Score	Percent of Reference	Condition
CT	Bird Creek	OK520800-01-0050G	3	535	23	1	2	9	1	0.77	0.02	0.13	19	0.76	Fair
AV	Brazil Creek	OK220100-03-0010G	1	515	26	5		7	5	0.31	0.18	0.53	40	1.00	Excellent
AV	Brazil Creek	OK220100-03-0010G	2	333	26	3	6	5	6	0.32	0.13	0.24	23	0.85	Good
AV	Brazil Creek	OK220100-03-0010G	3	377	24	4	6	7	6	0.41	0.03	0.58	27	1.00	Excellent
AV	Brushy Creek	OK220600-03-0010J	1	329	28	4		9	3	0.41	0.11	0.26	42	1.05	Excellent
AV	Brushy Creek	OK220600-03-0010J	2	358	31	2	5	9	4	0.81	0.01	0.13	21	0.78	Good
AV	Brushy Creek	OK220600-03-0010L	3	750	35	7	9	9	6	0.32	0.05	0.45	27	1.00	Excellent
CT	Canadian Sandy Creek	OK520600-03-0010D	1	453	14	0		5	0	0.93	0.06	0.01	24	0.60	Poor
CT	Canadian Sandy Creek	OK520600-03-0010D	2	464	14	0	1	4	1	0.85	0.10	0.05	15	0.60	Poor
CT	Canadian Sandy Creek	OK520600-03-0010D	3	316	20	1	3	6	1	0.91	0.06	0.03	21	0.84	Good
CIP	Cloud Creek	OK120410-01-0100H	1	729	28	3		9	3	0.83	0.02	0.08	23	0.88	Good
CIP	Cloud Creek	OK120410-01-0100T	2	429	26	1	4	9	3	0.66	0.13	0.02	21	0.84	Good
CIP	Cloud Creek	OK120410-01-0100T	3	554	27	2	4	8	3	0.69	0.05	0.06	21	0.78	Fair
CT	Dry Creek	OK520700-04-0020F	1	289	15	1		4	0	0.99	0.00	0.01	24	0.60	Poor
CT	Dry Creek	OK520700-04-0020F	2	332	15	1	2	4	2	0.99	0.00	0.00	19	0.76	Fair
CT	Dry Creek	OK520700-04-0020F	3	672	19	0	2	7	2	0.92	0.03	0.00	21	0.84	Good
CIP	Elk Creek	OK120400-02-0190D	1	231	18	1		8	1	0.66	0.01	0.22	32	0.80	Good
CIP	Elk Creek	OK120400-02-0190D	2	397	20	0	2	8	2	0.80	0.01	0.09	17	0.68	Fair
CIP	Elk Creek	OK120400-02-0190F	3	475	19	3	4	7	3	0.43	0.05	0.21	23	0.85	Good
AV	Fourche Maline Creek	OK220100-04-0020M	1	549	39	7		9	9	0.44	0.26	0.40	29	1.07	Excellent
AV	Fourche Maline Creek	OK220100-04-0020H	2	371	36	3	7	10	7	0.76	0.08	0.16	21	0.78	Good
AV	Fourche Maline Creek	OK220100-04-0020H	3	557	44	11	15	8	15	0.47	0.11	0.38	27	1.00	Excellent
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	1	242	19	1		7	0	0.85	0.00	0.03	30	0.75	Fair
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	2	59	9	1	2	6	2	0.97	0.00	0.02	17	0.68	Fair
CIP	George's Fork of Dirty Creek	OK120400-02-0110D	3	540	21	3	4	7	2	0.69	0.01	0.22	21	0.78	Fair
CT	Little Wewoka Creek	OK520500-02-0090D	1	268	8	0		5	0	0.94	0.00	0.06	26	0.65	Fair
CT	Little Wewoka Creek	OK520500-02-0090D	2	587	14	1	2	5	2	0.78	0.16	0.06	21	0.84	Good
CT	Little Wewoka Creek	OK520500-02-0090D	3	488	14	1	2	6	2	0.87	0.01	0.11	21	0.84	Good
AV	Mill Creek	OK220600-01-0100P	1	242	16	1		6	2	0.45	0.00	0.53	36	0.90	Good
AV	Mill Creek	OK220600-01-0100P	2	346	21	1	1	10	1	0.71	0.00	0.22	17	0.63	Fair
AV	Mill Creek	OK220600-01-0100P	3	291	17	1	3	6	1	0.62	0.00	0.34	19	0.70	Fair
AV	Peaceable Creek	OK220600-03-0050F	1	229	19	4		6	2	0.41	0.08	0.27	38	0.95	Excellent
AV	Peaceable Creek	OK220600-03-0050F	2	163	17	2	3	7	2	0.74	0.09	0.14	19	0.70	Fair
AV	Peaceable Creek	OK220600-03-0050F	3	394	19	3	4	7	3	0.74	0.01	0.20	21	0.78	Fair
CT	Polecat Creek	OK120420-02-0050D	1	446	23	4		5	3	0.92	0.31	0.04	36	0.90	Good
CT	Polecat Creek	OK120420-02-0050D	2	326	20	1	2	6	2	0.94	0.03	0.02	21	0.84	Good
CT	Polecat Creek	OK120420-02-0050G	3	1612	30	3	6	8	4	0.80	0.06	0.06	23	0.92	Excellent

Modified Ecoregion	Site Name	WBID	Cycle	Total Number	Total Spp	Darter Spp	Sensitive Benthic Spp	Sunfish Spp	Intolerant Spp	Percent tolerant	percent insect. Cyprinid	Percent lithophylic spawners	IBI Score	Percent of Reference	Condition
CT	Quapaw Creek	OK520700-04-0260C	1	440	18	1		6	0	0.92	0.06	0.02	26	0.65	Fair
CT	Quapaw Creek	OK520700-04-0260C	2	910	16	0	0	6	0	1.00	0.00	0.00	15	0.60	Poor
CT	Quapaw Creek	OK520700-04-0260C	3	94	9	0	0	3	0	1.00	0.00	0.00	11	0.44	Poor
BM	Sallisaw Creek	OK220200-03-0010C	1	430	31	5		7	11	0.21	0.30	0.60	42	0.91	Good
BM	Sallisaw Creek	OK220200-03-0010C	2	479	32	3	8	9	13	0.25	0.19	0.51	27	0.82	Good
BM	Sallisaw Creek	OK220200-03-0010C	3	815	35	4	10	12	13	0.33	0.38	0.63	29	1.07	Excellent
CT	Salt Creek (Creek Co.)	OK520700-03-0100B	1	294	15	1		3	2	0.98	0.01	0.00	26	0.65	Fair
CT	Salt Creek (Creek Co.)	OK520700-03-0100B	2	200	12	1	3	4	3	0.96	0.01	0.01	17	0.68	Fair
CT	Salt Creek (Creek Co.)	OK520700-03-0100B	3	211	15	0	1	7	1	0.98	0.01	0.00	17	0.68	Fair
CT	Salt Creek (Seminole Co.)	OK520800-03-0010D	1	203	8	0		1	1	0.94	0.16	0.00	16	0.40	Very poor
CT	Salt Creek (Seminole Co.)	OK520800-03-0010D	2	349	12	0	1	5	1	0.98	0.01	0.00	15	0.60	Poor
CT	Salt Creek (Seminole Co.)	OK520800-03-0010D	3	251	12	1	2	5	2	0.96	0.02	0.01	19	0.76	Fair
CT	Snake Creek	OK120410-01-0220G	1	453	25	1		7	2	0.62	0.03	0.14	38	0.95	Excellent
CT	Snake Creek	OK120410-01-0220G	2	130	16	1	2	5	2	0.92	0.04	0.04	21	0.84	Good
CT	Snake Creek	OK120410-01-0220G	3	667	23	3	4	8	4	0.76	0.09	0.12	23	0.92	Excellent
CIP	South Fork Dirty Creek	OK120400-02-0030F	1	354	32	2		9	3	0.55	0.00	0.07	40	1.00	Excellent
CIP	South Fork Dirty Creek	OK120400-02-0030F	2	262	19	1	2	7	3	0.73	0.00	0.08	21	0.84	Good
CIP	South Fork Dirty Creek	OK120400-02-0030H	3	635	21	3	4	8	3	0.49	0.02	0.13	21	0.78	Fair
CT	Wewoka Creek	OK520500-02-0010C	1	622	16	1		4	1	0.99	0.12	0.00	26	0.65	Fair
CT	Wewoka Creek	OK520500-02-0010C	2	438	15	0	1	5	1	0.89	0.11	0.00	17	0.68	Fair
CT	Wewoka Creek	OK520500-02-0010C	3	261	19	1	2	5	2	0.78	0.21	0.01	23	0.92	Excellent

Macroinvertebrate Collections

The complete macroinvertebrate dataset, including species and numbers captured per site, can be found in Appendix C. Macroinvertebrates were collected for most sites at least once during the project period. Three sites had no macroinvertebrate collections due to inadequate flow conditions during the sample index periods: Elk Creek, Emachaya Creek, and Little Deep Fork. Lack of flow prevented collection of all planned samples over the cycle at many other sites as well; 20 sites (41%) had four collections over the two-year project period, 12 sites (24%) had three collections, 5 sites (10%) had two collections, and 8 sites (16%) had only one collection.

Table 15 presents the mean values, by season and sample type, for each metric at each site for the two-year Cycle 3 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 15. Macroinvertebrate metric values determined for each monitoring site, averaged per season and habitat. NI = non-impaired, SI = slightly impaired, MI = moderately impaired.

Site Name	WBID	# of Samples	Habitat	Season	total species	EPT Taxa	Number	Total Id'd	Percent EPT	Shannon Diversity	HBI	Percent dominant 2 taxa	Total Points	% of Reference	Condition
Alabama Creek	OK520500-01-0200D	2	Riffle	S	12.5	3.5	1	104.5	7.36%	1.69	5.38	64.32%	12	47.06%	MI
		2	Riffle	W	23.5	6.5	1	106	23.18%	2.09	5.54	60.93%	22	88.00%	NI
Ash Creek	OK120410-01-0110E	1	Riffle	S	9	1	1	144	0.69%	1.52	7.00	68.06%	6	23.08%	MI
		2	Riffle	W	12	3.5	1	96.5	35.66%	1.87	5.79	54.26%	18	80.00%	NI
Bad Creek	OK520500-01-0170E	2	Riffle	S	11	4	1	106.5	23.19%	1.81	5.25	56.28%	16	62.75%	SI
		2	Riffle	W	11	4	1	102	39.96%	1.43	5.95	77.46%	16	64.00%	SI
Ballard Creek	OK121700-03-0370G	2	Riffle	S	17	7.5	1	127	69.98%	2.10	4.34	52.71%	24	92.31%	NI
		2	Riffle	W	16.5	7.5	1	110.5	32.82%	1.84	4.93	63.97%	16	54.55%	SI
Battle Creek	OK121700-06-0040G	2	Riffle	S	20.5	6.5	1	135.5	41.75%	2.32	4.47	44.65%	22	84.62%	NI
		2	Riffle	W	20	11.5	1	134	59.17%	2.06	3.31	55.00%	24	81.83%	NI
Bear Creek	OK520700-05-0170A	1	Woody	S	13	3	1	95	7.37%	1.58	7.29	69.47%	12	48.00%	MI
		2	Woody	W	14	2	1	113.5	12.13%	2.09	7.09	50.17%	14	63.64%	SI
Big Creek	OK220100-02-0080B	2	Riffle	S	16.5	7	1	100.5	28.92%	1.88	5.60	59.68%	16	55.81%	SI
		1	Riffle	W	23	11	1	118	39.83%	2.54	4.59	36.44%	30	104.64%	NI
Big Skin Bayou	OK220200-01-0030H	1	Riffle	W	20	10	1	118	50.85%	2.31	4.84	47.46%	24	92.31%	NI
Bird Creek	OK520800-01-0050G	1	Riffle	S	16	7	1	110	40.00%	2.25	5.13	44.55%	26	101.96%	NI
Brazil Creek	OK220100-03-0010G	2	Riffle	S	14.5	6	1	121.5	19.24%	2.01	5.63	55.38%	20	76.92%	SI
		1	Riffle	W	16	6	1	121	28.10%	1.71	5.66	68.60%	20	76.92%	SI
Brushy Creek	OK220600-03-0010L	1	Riffle	S	10	5	1	110	10.00%	1.42	5.10	74.55%	8	30.77%	MI
Canadian Sandy Creek	OK520600-03-0010D	1	Riffle	S	20	9	1	107	28.04%	2.24	5.51	47.66%	22	86.27%	NI
		2	Riffle	W	17.5	3	1	116	37.70%	2.13	7.01	50.62%	18	72.00%	SI
		1	Sveg	S	9	2	1	132	1.52%	1.02	7.12	84.85%	6	24.00%	MI
Captain Creek	OK520700-05-0140H	2	Riffle	S	10	2.5	1	113.5	13.18%	1.48	5.15	74.17%	10	39.22%	MI
		2	Riffle	W	13	2	1	120.5	25.72%	1.78	5.34	64.70%	16	64.00%	SI
Caston Creek	OK220100-01-0180B	1	Riffle	S	16	6	1	97	38.14%	2.26	4.36	41.24%	26	100.00%	NI
		1	Riffle	W	14	8	1	117	46.15%	1.94	4.91	52.99%	26	100.00%	NI
Cloud Creek	OK120410-01-0100T	2	Riffle	W	16.5	3.5	1	106	7.70%	1.65	6.37	66.00%	12	53.33%	SI
Coal Creek	OK220600-02-0010F	2	Riffle	S	9.5	2.5	1	117	8.04%	1.38	5.00	76.14%	8	30.77%	MI
		2	Riffle	W	11.5	2	1	108	3.57%	1.49	6.01	69.81%	10	38.46%	MI

Site Name	WBID	# of Samples	Habitat	Season	total species	EPT Taxa	Number	Total Id'd	Percent EPT	Shannon Diversity	HBI	Percent dominant 2 taxa	Total Points	% of Reference	Condition
Deep Branch	OK121700-01-0020A	2	Riffle	S	18	7	1	154	25.77%	1.86	6.04	59.38%	22	81.48%	NI
		2	Riffle	W	15.5	8.5	1	107	60.15%	1.94	4.14	58.44%	24	92.31%	NI
Dry Creek	OK520700-04-0020F	1	Woody	S	11	5	1	112	15.18%	1.44	6.40	77.68%	14	56.00%	SI
		1	Woody	W	9	1	1	91	6.59%	1.36	6.68	78.02%	8	36.36%	MI
Fourche Maline Creek	OK220100-04-0020H	2	Riffle	S	16.5	6	1	109	20.99%	2.11	5.54	50.22%	22	84.62%	NI
		1	Riffle	W	17	4	1	110	16.36%	2.24	5.79	49.09%	16	61.54%	SI
Gaines Creek	OK220600-04-0010P	1	Riffle	S	20	9	1	112	26.79%	2.59	4.88	32.14%	28	107.69%	NI
		1	Riffle	W	14	9	1	107	38.32%	1.76	4.40	68.22%	26	100.00%	NI
		1	Sveg	W	10	4	1	102	7.84%	0.76	5.73	88.24%	6	23.08%	MI
Gar Creek	OK520510-00-0080C	1	Riffle	S	17	3	1	140	12.86%	2.02	7.71	55.71%	12	47.06%	MI
George's Fork of Dirty Creek	OK120400-02-0110D	2	Riffle	S	12.5	4	1	125.5	8.16%	1.36	5.07	79.52%	10	38.46%	MI
		2	Riffle	W	19.5	7	1	123	31.98%	2.22	5.85	47.01%	26	115.56%	NI
Greenleaf Creek	OK120400-01-0120C	2	Riffle	S	12.5	4	1	115	34.78%	1.66	5.53	65.22%	16	59.26%	SI
		2	Riffle	W	19.5	8	1	117.5	61.04%	1.89	3.96	66.35%	22	84.62%	NI
Hog Creek	OK520810-00-0030D	1	Riffle	S	17	6	1	111	17.12%	2.04	7.35	61.26%	16	62.75%	SI
		2	Riffle	W	16.5	3.5	1	115	15.86%	2.12	6.49	50.33%	14	56.00%	SI
		1	Sveg	S	9	4	1	121	6.61%	0.59	7.70	90.91%	6	24.00%	MI
		1	Sveg	W	19	6	1	122	27.87%	2.24	6.25	47.54%	24	105.87%	NI
		1	Woody	S	19	7	1	140	22.14%	2.07	5.96	54.29%	24	96.00%	NI
Little Wewoka Creek	OK520500-02-0090D	2	Riffle	S	13	4	1	100.5	39.52%	1.82	6.01	56.46%	16	62.75%	SI
		1	Riffle	W	19	6	1	103	30.10%	2.42	5.66	34.95%	24	96.00%	NI
Longtown Creek	OK220600-01-0070P	1	Riffle	S	13	4	1	103	12.62%	1.82	5.56	59.22%	12	46.15%	MI
		2	Riffle	W	17.5	6.5	1	113	22.94%	2.03	5.05	59.17%	22	84.62%	NI
Manard Bayou	OK120400-01-0280E	2	Riffle	S	14	4.5	1	130.5	23.61%	1.91	5.02	52.52%	16	59.26%	SI
		2	Riffle	W	16.5	5.5	1	114	20.84%	1.92	6.18	56.43%	14	53.85%	SI
Mill Creek	OK220600-01-0100P	2	Riffle	S	12.5	3	1	113.5	44.97%	1.58	5.99	68.46%	16	61.54%	SI
		2	Riffle	W	15	2.5	1	114	18.77%	1.95	6.29	52.96%	14	53.85%	SI
Montezumah Creek	OK520700-01-0220D	1	Woody	W	13	2	1	84	10.71%	1.61	6.57	72.62%	14	63.64%	SI
Nuyaka Creek	OK520700-02-0200D	1	Riffle	S	10	5	1	128	25.00%	1.64	5.23	58.59%	16	62.75%	SI
		2	Riffle	W	11	2	1	103	7.80%	1.62	8.45	64.95%	8	32.00%	MI
Peaceable Creek	OK220600-03-0050F	2	Riffle	S	16	5.5	1	114	20.35%	2.00	4.78	56.84%	22	84.62%	NI
		1	Riffle	W	13	2	1	105	15.24%	1.94	5.94	56.19%	14	53.85%	SI
		1	Sveg	S	23	8	1	109	49.54%	2.71	5.32	27.52%	32	123.08%	NI
Pecan Creek (Muskogee Co.)	OK120410-01-0030D	1	Riffle	S	6	1	1	96	2.08%	1.10	6.04	88.54%	4	15.38%	Svl
		1	Riffle	W	11	2	1	114	12.28%	1.63	7.95	66.67%	10	44.44%	MI

Site Name	WBID	# of Samples	Habitat	Season	total species	EPT Taxa	Number	Total Id'd	Percent EPT	Shannon Diversity	HBI	Percent dominant 2 taxa	Total Points	% of Reference	Condition
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C	2	Riffle	S	21	6.5	1	122	39.02%	2.46	4.92	36.27%	28	109.80%	NI
		2	Riffle	W	21	5.5	1	116.5	42.34%	2.26	5.90	50.07%	22	88.00%	NI
		1	Sveg	S	14	4	1	127	26.77%	1.50	7.10	77.17%	12	48.00%	MI
Polecat Creek	OK120420-02-0050G	2	Riffle	S	12	2.5	1	123.5	7.11%	1.48	5.97	76.72%	8	31.37%	MI
		2	Riffle	W	10.5	0.5	1	102	0.52%	1.71	5.64	61.23%	10	40.00%	MI
		1	Woody	S	5	2	1	105	4.76%	0.90	6.33	94.29%	6	24.00%	MI
Quapaw Creek	OK520700-04-0260C	1	Woody	S	10	5	1	111	5.41%	1.18	7.20	81.98%	10	40.00%	MI
		2	Woody	W	12.5	1.5	1	92.5	16.48%	1.73	7.12	65.82%	14	63.64%	SI
Sallisaw Creek	OK220200-03-0010C	2	Riffle	S	17.5	8	1	122.5	32.09%	2.07	5.43	52.87%	24	88.89%	NI
		2	Riffle	W	14.5	7.5	1	109.5	21.64%	1.32	5.26	77.58%	14	53.85%	SI
		1	Sveg	S	8	2	1	104	8.65%	1.44	6.04	69.23%	8	30.77%	Svl
Salt Creek (Seminole Co.)	OK520800-03-0010D	2	Riffle	W	10	1.5	1	97.5	16.41%	1.48	6.32	74.86%	8	32.00%	MI
		2	Woody	S	18	6.5	1	99.5	31.19%	1.87	6.78	64.08%	24	96.00%	NI
Salt Creek (Creek Co.)	OK520700-03-0100B	2	Woody	S	11.5	4	1	104	13.26%	1.78	6.33	57.84%	14	56.00%	SI
		2	Woody	W	12	3	1	101.5	16.88%	1.44	5.85	73.18%	14	63.64%	SI
Sandy Creek	OK520700-03-0040F	1	Woody	W	10	0	1	83	0.00%	0.96	6.27	84.34%	10	45.45%	MI
Snake Creek	OK120410-01-0220G	1	Riffle	S	11	4	1	163	6.13%	1.63	5.48	68.71%	10	39.22%	MI
		2	Riffle	W	12	3.5	1	113.5	20.49%	1.89	5.60	55.84%	16	64.00%	SI
South Fork Dirty Creek	OK120400-02-0030H	2	Riffle	S	13.5	2.5	1	109.5	7.81%	1.88	5.55	58.55%	14	53.85%	SI
		2	Riffle	W	15	3	1	104	8.16%	1.54	6.24	71.15%	12	53.33%	SI
Sugar Loaf Creek	OK220100-01-0160G	1	Riffle	W	13	5	1	96	7.29%	1.26	5.69	77.08%	10	38.46%	MI
Turkey Creek	OK520510-00-0100F	1	Riffle	S	9	2	1	108	45.37%	1.47	6.55	69.44%	12	47.06%	MI
Vian Creek	OK220200-02-0130E	2	Riffle	S	14.5	6.5	1	118	26.70%	1.76	6.13	58.61%	18	66.67%	SI
		2	Riffle	W	21	9	1	107.5	42.57%	2.23	4.37	52.75%	24	92.31%	NI
Wewoka Creek	OK520500-02-0010C	1	Riffle	S	9	4	1	103	24.27%	1.80	5.95	51.46%	12	47.06%	MI
		1	Woody	S	12	4	1	102	14.71%	1.36	7.27	74.51%	12	48.00%	MI

Most sites had either non-impaired or slightly impaired macroinvertebrate communities overall (when averaging the scores across sample types). Eighteen percent of the sites indicated non-impaired macroinvertebrate communities, 53% of the sites had slightly impaired communities, and 29% had moderately impaired communities. In general winter collections scored better than summer collections at the same site.

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.

Overall Assessment

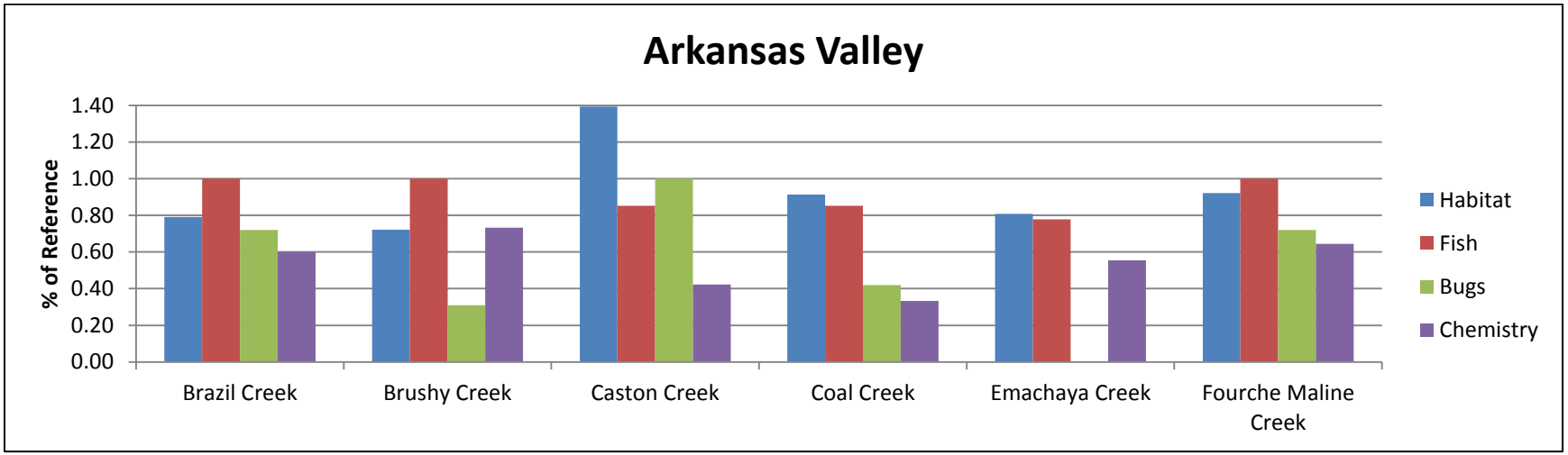
In order to synthesize the biological findings into a meaningful representation of the overall quality of each site, the biological assessments were compared with the habitat and water chemistry results. A water quality score was computed similarly to the other index scores by comparing rotating basin site values relative to high quality site values. The parameters included in this score were phosphorus, nitrogen, DO, turbidity, and salts (TDS, chloride, and sulfate). Then the habitat, fish, water quality, and macroinvertebrate scores (relative to the mean of high quality sites in the respective ecoregions) were examined in concert with one another (Figures 12-15).

A determination of "good" or "excellent" stream health is indicated by a relatively high score for all categories. Most streams had relatively good agreement among the categories, but there are instances where one score is quite different than the others. 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 and water chemistry score could indicate potential water quality impairment. Low habitat scores correlated with low fish scores yet high bug scores suggests that habitat impairments are the predominant cause of the poor fish community, as exemplified in Figure 14 by Bird Creek.

Many of the sites sampled during this rotation have macroinvertebrate collections that indicate poorer conditions than the rest of the parameters, most likely due to extreme drought conditions.

These generalizations will be reassessed each cycle of the Rotating Basin project. It is possible that the reach examined for these assessments in 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 12. Comparison of habitat, fish, macroinvertebrate, and chemistry scores for sites relative to the average high quality site in each ecoregion.



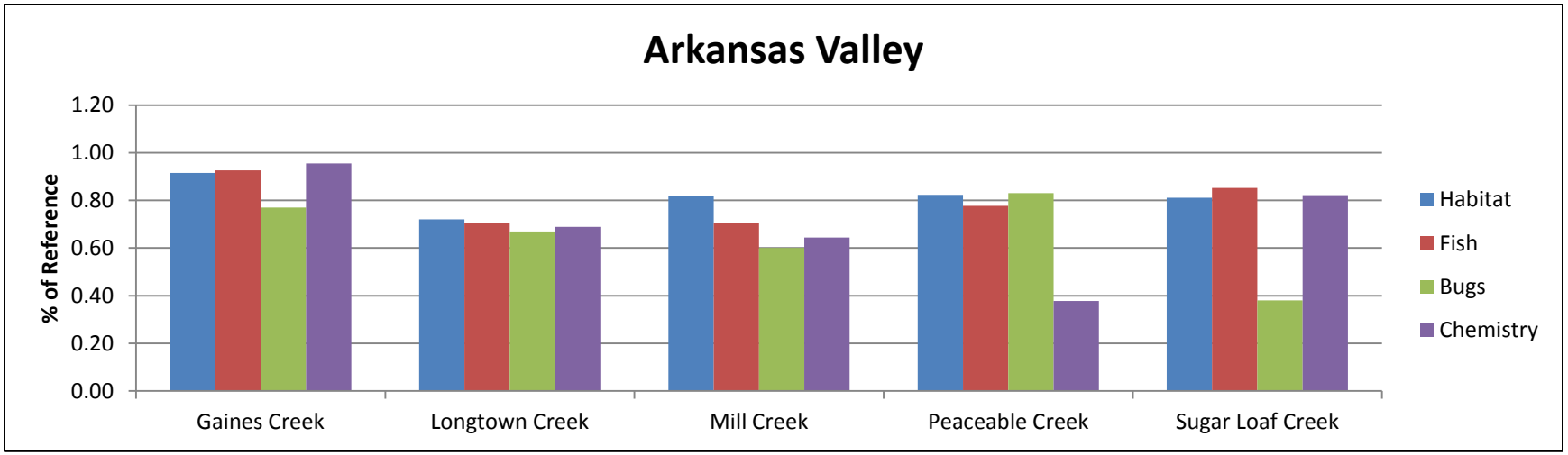


Figure 13. Comparison of habitat, fish, macroinvertebrate, and chemistry scores for sites relative to the average high quality site in each ecoregion.

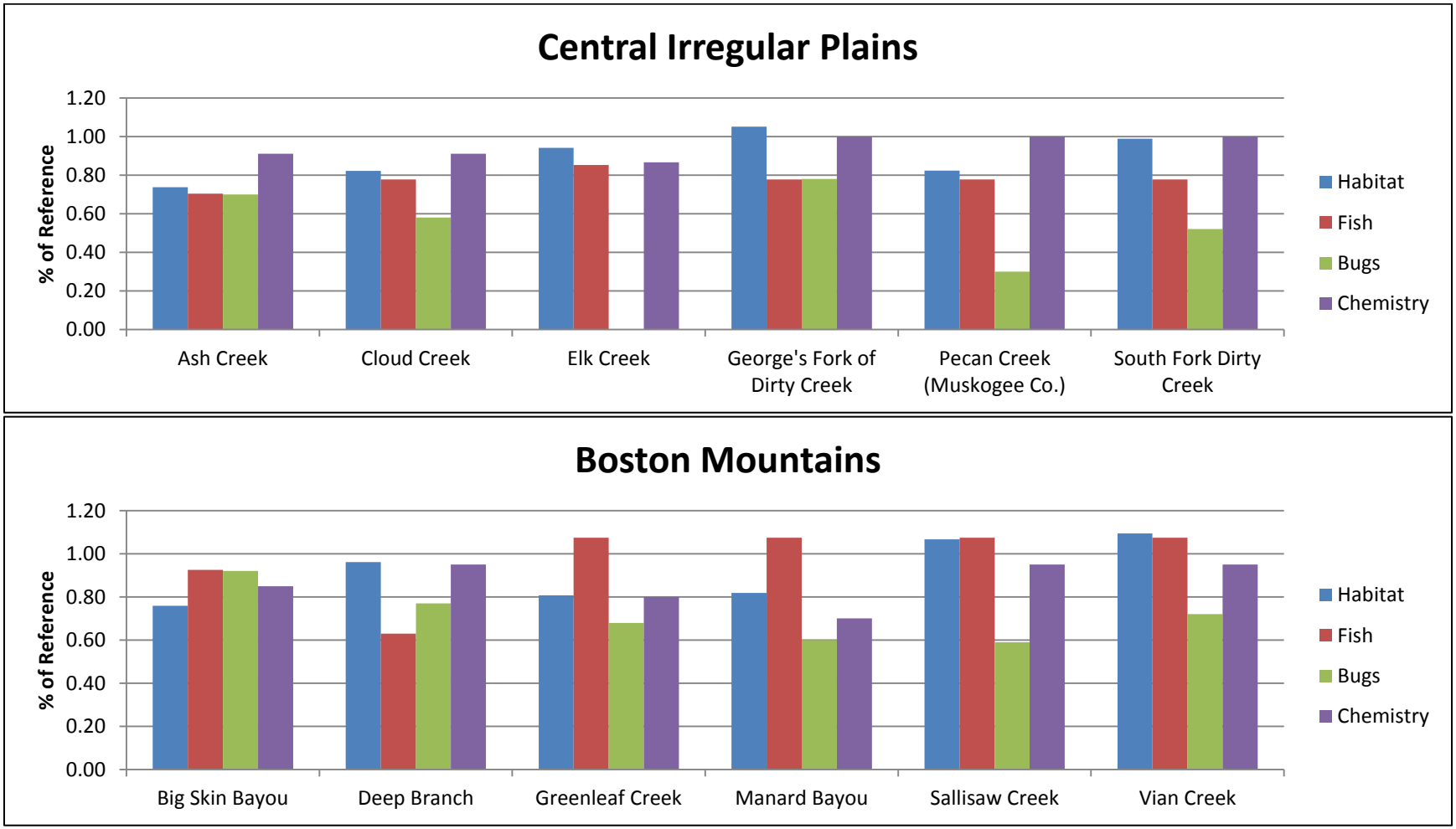
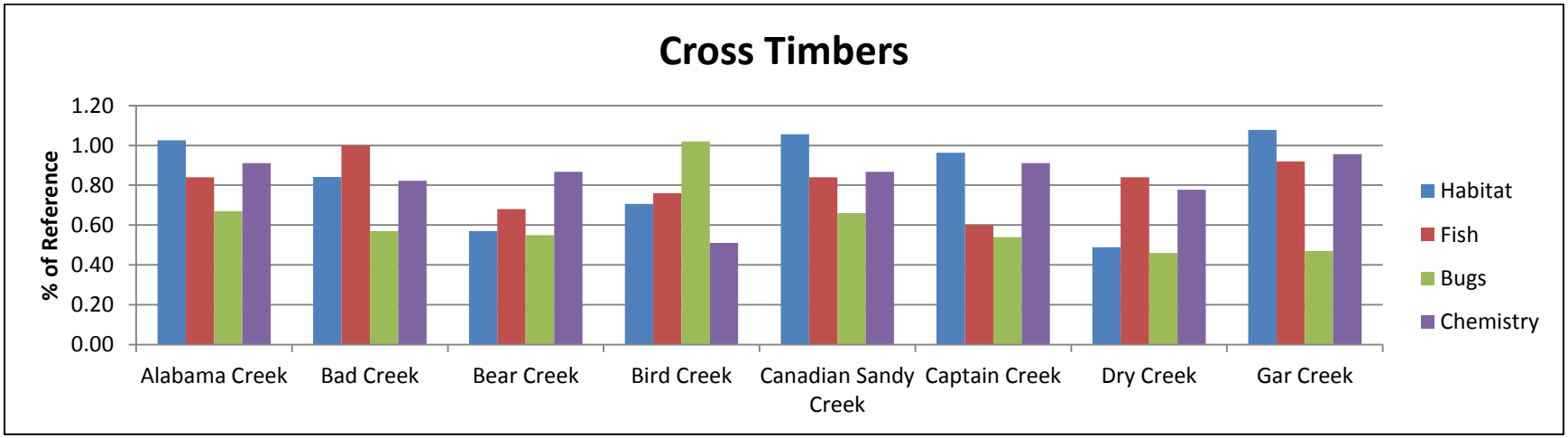


Figure 14. Comparison of habitat, fish, macroinvertebrate, and chemistry scores for sites relative to the average high quality site in each ecoregion.



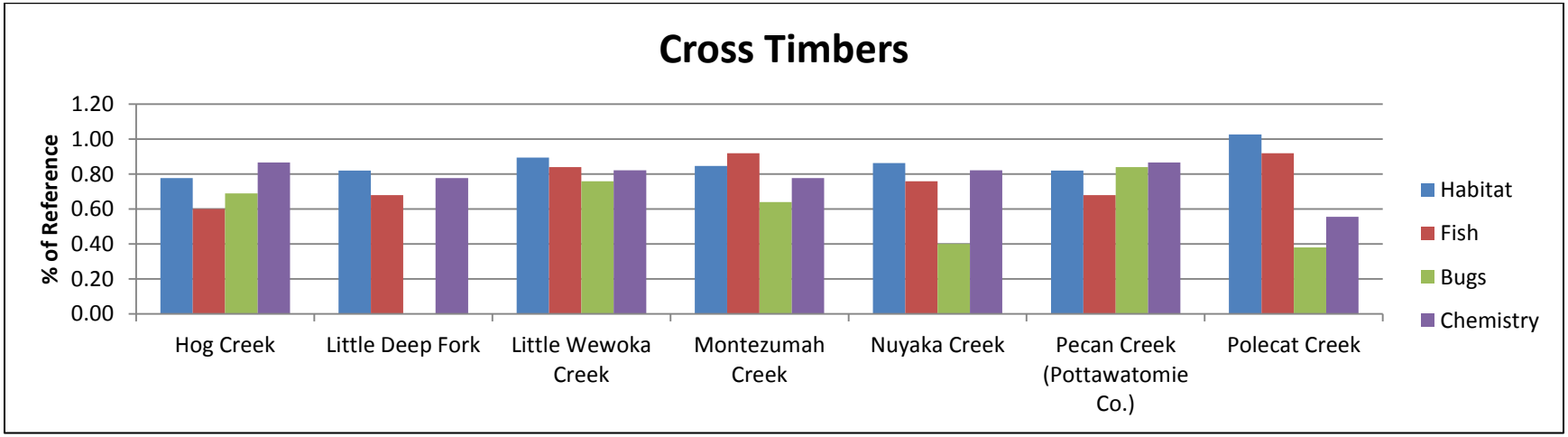
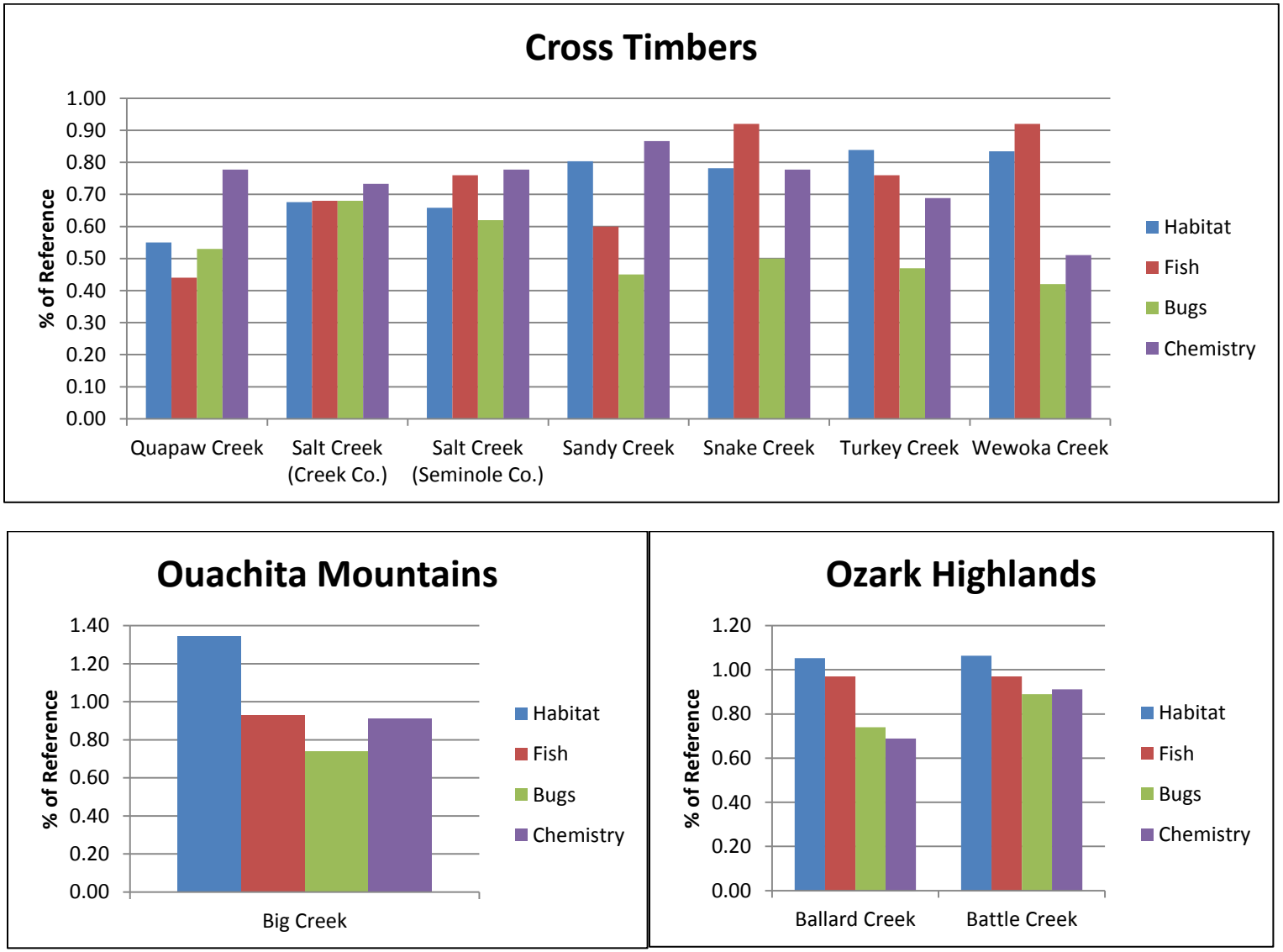


Figure 15. Comparison of habitat, fish, macroinvertebrate, and chemistry scores for sites relative to the average high quality site in each ecoregion.



Assessment

Table 16 shows the landuse upstream of each monitoring site as obtained through GIS using the 2006 NRCS National Land Cover Dataset. In general, the Arkansas Valley watersheds are primarily deciduous forest (40%), with another 28% of the acres in the watersheds being pastureland and 14% grassland. The Boston Mountains sites' watersheds are also mainly forest (53% of watershed acres) and pasture (32% of watershed acres). The Central Irregular Plains and Ozark Highlands watersheds have more pasture than forest overall: 53% of the CIP watershed acres are pasture, with 20% grasslands and 17% deciduous forest; 57% of the OH watershed acres are pasture, with 31% forest. Finally, the Cross Timbers sites' watersheds are 39% forest, 34% grassland, and 17% pasture.

Table 17 presents the types and number of permitted activities that occur in the watershed upstream of each site. Twenty-two sites had national pollution discharge elimination systems (NPDES) in the watershed. To examine the effects of point source versus non-point source pollution on parameters at the monitoring sties, one-way ANOVAs were performed comparing sites with an NPDES to sites with no NPDES.

The Ballard Creek, Battle Creek, and Deep Branch watersheds had no permitted activities in them, indicating relatively little potential human impact apart from the large amount of pastureland in each watershed. Fourteen other sites had only oil/gas permits in the watershed. Twenty-two of the 48 sites currently have national pollution discharge elimination system (NPDES) permits. 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. Dirty, Polecat, Peaceable, and Wewoka Creeks and the Deep Fork of the North Canadian River had at least one major NPDES permit, while the other sites only had minor NPDES permits. Potential sources of pollution for impaired streams are included on the 2014 303(d) list (ODEQ 2014).

Table 18 shows the results where the P values are less than 0.1. Sites in the Arkansas Valley ecoregion with NPDES permits had significantly higher values for chloride, conductivity, phosphorus, total dissolved solids, and flow. Sites with no NPDES permits had moderately significantly higher values for alkalinity, hardness, nitrogen and sulfate. Sites in the Boston Mountains ecoregion with NPDES permits showed higher values for alkalinity, conductivity, dissolved oxygen, hardness, pH, total dissolved solids, and flow. Sites with no NPDES permits had higher values for nitrogen and phosphorus. In the Central Irregular Plains ecoregion sites with NPDES permits showed higher values for alkalinity and sulfate while sites with no NPDES permits showed higher values for dissolved oxygen, pH and chloride. In the Cross Timbers ecoregion sites with NPDES permits had significantly higher values for dissolved oxygen, hardness, pH, nitrogen, phosphorus, sulfate, and flow; they had moderately significantly higher values for conductivity and chloride.

Table 16. Watershed landuse (% of total watershed area) for each Group 3 monitoring site.

Site Name	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	Grasslands/Herbaceous	Mixed Forest	Open Water	Pasture/Hay	Shrub/Scrub	Woody Wetlands	Total Acres
Alabama Creek	OK520500-01-0200D		1.3%	51.4%		0.3%	0.1%	5.0%		0.0%	25.2%		0.4%	16.4%			13,321.3
Ash Creek	OK120410-01-0110E		3.0%	15.4%		0.0%	0.0%	4.5%		0.0%	28.4%		0.2%	48.5%		0.0%	23,220.8
Bad Creek	OK520500-01-0170E		1.4%	48.0%	0.0%	0.4%	0.0%	5.6%		0.0%	22.0%		0.4%	22.2%		0.0%	23,805.0
Ballard Creek	OK121700-03-0370G	0.0%	0.1%	26.0%	0.1%	0.8%	0.5%	6.1%		0.5%	1.1%	0.2%	0.0%	64.2%	0.0%	0.4%	29,282.5
Battle Creek	OK121700-06-0040G			36.7%	0.1%	0.1%	0.2%	3.9%		0.6%	7.7%	0.1%		49.6%	0.9%	0.0%	5,044.3
Bear Creek	OK520700-05-0170A	0.0%	4.4%	39.1%	0.0%	0.0%	0.0%	4.1%		0.2%	47.7%		1.2%	3.3%			73,686.1
Big Creek	OK220100-02-0080B			45.2%		0.0%	0.0%	4.5%		39.6%	1.9%	4.1%		2.3%	2.2%	0.1%	20,001.7
Big Skin Bayou	OK220200-01-0030H	0.0%		37.1%		0.9%	0.1%	4.0%		1.0%	6.8%	0.9%	0.1%	46.9%	1.7%	0.6%	36,525.5
Bird Creek	OK520800-01-0050G	0.0%	1.4%	45.4%	0.1%	0.4%	0.1%	5.0%		0.0%	31.5%		0.3%	15.7%	0.0%		16,681.9
Brazil Creek	OK220100-03-0010G	0.5%	0.2%	37.8%	0.0%	0.0%	0.1%	2.4%	0.1%	11.7%	9.3%	7.6%	0.3%	26.8%	2.0%	1.0%	117,584.0
Brushy Creek	OK220600-03-0010L	0.0%	0.1%	42.6%	0.0%	0.2%	0.2%	2.8%	0.0%	5.8%	12.7%	2.7%	0.4%	29.4%	2.5%	0.8%	88,730.3
Canadian Sandy Creek	OK520600-03-0010D	0.0%	4.7%	27.9%	0.1%	1.1%	0.3%	4.6%		0.0%	43.5%		0.6%	17.1%			129,625.5
Captain Creek	OK520700-05-0140H	0.1%	1.9%	44.7%	0.0%	0.2%	0.3%	5.8%		0.1%	40.8%		0.2%	6.0%			37,923.7
Caston Creek	OK220100-01-0180B	0.7%	0.6%	39.5%	0.0%	0.2%	0.2%	3.5%	0.0%	8.4%	13.6%	6.6%	0.6%	23.0%	3.0%	0.2%	45,777.4
Cloud Creek	OK120410-01-0100T		4.5%	11.3%	0.0%	0.0%	0.0%	5.0%	0.0%	0.0%	25.0%		0.9%	53.2%	0.0%	0.0%	98,795.8
Coal Creek	OK220600-02-0010F	0.5%	0.7%	46.7%	0.2%	1.2%	0.5%	5.3%	0.0%	1.1%	21.3%	0.0%	0.4%	21.4%	0.6%	0.0%	145,533.5
Deep Branch	OK121700-01-0020A		0.1%	45.1%	0.0%			1.9%		0.5%	2.4%	2.5%	0.0%	47.0%	0.2%	0.1%	6,437.1
Dry Creek	OK520700-04-0020F	0.0%	4.0%	28.0%	0.0%	0.3%	0.3%	5.3%		0.6%	51.6%		0.6%	9.3%		0.0%	111,505.5
Elk Creek	OK120400-02-0190F	0.0%	4.0%	10.8%	0.2%	1.4%	0.5%	6.1%	0.1%	0.1%	17.2%		0.6%	59.2%	0.0%		56,637.0
Emachaya Creek	OK220300-00-0040C	0.3%	0.5%	25.5%	0.0%	0.2%	0.2%	3.2%	0.0%	2.7%	9.7%	3.7%	0.5%	51.1%	1.9%	0.5%	17,052.8
Fourche Maline Creek	OK220100-04-0020H	0.1%	0.1%	42.3%	0.1%	0.4%	0.2%	2.7%	0.1%	14.6%	6.1%	10.0%	0.4%	18.9%	2.4%	1.6%	170,704.5

Site Name	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	Grasslands/Herbaceous	Mixed Forest	Open Water	Pasture/Hay	Shrub/Scrub	Woody Wetlands	Total Acres
Gaines Creek	OK220600-04-0010P	0.0%	0.0%	52.3%		0.1%	0.0%	1.4%	0.0%	11.2%	9.6%	7.6%	0.0%	12.5%	3.6%	1.7%	83,004.7
Gar Creek	OK520510-00-0080C	0.1%	1.0%	43.8%		0.0%	0.0%	4.2%			34.7%		0.2%	15.9%			23,360.0
George's Fork of Dirty Creek	OK120400-02-0110D	0.0%	0.3%	26.4%	0.1%	1.1%	0.4%	6.7%	0.0%	0.0%	11.1%		0.6%	53.3%	0.0%		33,448.2
Greenleaf Creek	OK120400-01-0120C	0.2%		67.5%	0.0%	0.1%	0.0%	3.1%		0.1%	8.2%	0.2%	0.1%	19.3%	0.5%	0.6%	42,891.8
Hog Creek	OK520810-00-0030D	0.0%		39.4%	0.1%	3.4%	0.8%	17.0%		0.0%	34.8%		0.3%	4.1%			26,482.4
Little Deep Fork	OK520700-06-0010D	0.0%	0.7%	47.0%	0.1%	0.5%	0.3%	5.7%	0.0%	0.0%	31.5%		0.7%	13.5%		0.0%	160,989.2
Little Wewoka Creek	OK520500-02-0090D	0.0%	2.8%	35.2%		0.1%	0.0%	4.5%		0.0%	29.2%		1.2%	26.9%			39,612.0
Longtown Creek	OK220600-01-0070P	0.0%	0.1%	32.7%				2.1%		1.9%	7.3%	3.2%	0.1%	51.2%	1.3%	0.2%	17,368.3
Manard Bayou	OK120400-01-0280E	0.2%		41.7%	0.0%	0.4%	0.5%	4.1%	0.0%	0.5%	6.4%	0.5%	0.1%	44.3%	1.2%	0.1%	33,981.7
Mill Creek	OK220600-01-0100P	0.1%	0.7%	47.2%	0.0%	0.2%	0.1%	3.7%		0.8%	28.4%		0.3%	18.2%	0.4%		42,263.1
Montezumah Creek	OK520700-01-0220D		0.5%	34.4%	0.0%	0.3%	0.1%	4.7%		0.0%	32.1%		0.2%	27.8%			30,610.1
Nuyaka Creek	OK520700-02-0200D	0.0%	2.7%	32.2%	0.0%	0.4%	0.1%	4.4%			20.5%		0.4%	39.2%			40,772.9
Peaceable Creek	OK220600-03-0050F	0.2%	0.3%	39.0%	0.3%	0.8%	0.8%	5.1%	0.0%	0.2%	27.0%	0.0%	1.1%	24.7%	0.4%	0.1%	85,152.7
Pecan Creek (Muskogee Co.)	OK120410-01-0030D	0.0%	0.1%	18.3%	0.1%	0.1%	0.1%	5.2%	0.0%	0.2%	22.6%		0.6%	52.7%	0.0%	0.0%	33,005.2
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C		0.0%	60.0%	0.0%	0.2%	0.0%	6.9%	0.0%	0.0%	29.0%		0.2%	3.6%			20,680.1
Polecat Creek	OK120420-02-0050G	0.0%	0.4%	52.7%	0.4%	2.0%	0.9%	8.8%		0.0%	23.4%		0.7%	10.6%		0.0%	211,799.6
Quapaw Creek	OK520700-04-0260C	0.0%	3.6%	32.3%	0.0%	0.4%	0.1%	5.2%		0.0%	48.1%		1.1%	9.2%		0.0%	95,529.8
Sallisaw Creek	OK220200-03-0010C	0.1%	0.2%	60.2%	0.0%	0.3%	0.1%	3.2%		0.5%	9.3%	0.5%	0.6%	23.0%	1.7%	0.3%	116,005.1
Salt Creek (Creek Co.)	OK520700-03-0100B	0.0%	1.5%	38.1%	0.2%	0.5%	0.4%	5.2%	0.0%	0.1%	41.1%		1.5%	11.4%		0.0%	59,304.2
Salt Creek (Seminole Co.)	OK520800-03-0010D	0.0%	1.0%	42.0%	0.0%	0.2%	0.0%	4.9%	0.0%	0.0%	43.6%		1.2%	6.8%	0.0%	0.1%	134,940.8
Sandy Creek	OK520700-03-0040F	0.0%	0.9%	43.0%		0.0%	0.0%	4.2%			35.4%		0.2%	16.3%			21,505.0
Snake Creek	OK120410-01-0220G	0.0%	2.4%	33.1%	0.0%	0.5%	0.1%	5.0%		0.0%	21.9%		0.3%	36.7%		0.0%	104,323.0
South Fork Dirty Creek	OK120400-02-0030H	0.1%	0.8%	22.1%	0.0%	0.4%	0.2%	5.3%	0.0%	0.1%	17.1%		0.8%	53.2%	0.0%	0.0%	29,511.9

Site Name	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	Grasslands/Herbaceous	Mixed Forest	Open Water	Pasture/Hay	Shrub/Scrub	Woody Wetlands	Total Acres
Sugar Loaf Creek	OK220100-01-0160G	0.1%	0.2%	36.6%	0.0%	0.0%	0.2%	2.8%		24.5%	5.6%	6.0%	0.0%	21.9%	1.9%	0.2%	56,846.0
Turkey Creek	OK520510-00-0100F	0.0%	2.7%	15.0%	0.0%	0.9%	0.2%	5.2%		0.0%	48.9%		0.6%	26.3%	0.0%		33,369.4
Vian Creek	OK220200-02-0130E		0.0%	68.8%		0.3%	0.0%	5.3%		0.1%	10.4%	0.4%	0.0%	12.6%	1.8%	0.2%	16,151.9
Wewoka Creek	OK520500-02-0010C	0.1%	2.1%	30.6%	0.1%	1.1%	0.4%	6.7%	0.0%	0.1%	30.2%		1.8%	26.9%	0.0%	0.0%	229,524.6

Table 17. Permitted landuse for each Group 3 monitoring site.

Site Name	WBID	#CAFO	# Landfill	#NPDES Permits	# O&G	#Total Retention Lagoon	# Land Application	# Public Water Intakes	# Storage Disposal
Alabama Creek	OK520500-01-0200D				444				
Ash Creek	OK120410-01-0110E				1224				
Bad Creek	OK520500-01-0170E				1083				
Ballard Creek	OK121700-03-0370G								
Battle Creek	OK121700-06-0040G								
Bear Creek	OK520700-05-0170A				898	1	5		
Big Creek	OK220100-02-0080B				32				
Big Skin Bayou	OK220200-01-0030H		1		32				
Bird Creek	OK520800-01-0050G	2			613		1		
Brazil Creek	OK220100-03-0010G			23	836			2	
Brushy Creek	OK220600-03-0010L				186				
Canadian Sandy Creek	OK520600-03-0010D		2	3	1041		1		
Captain Creek	OK520700-05-0140H				398		1		
Caston Creek	OK220100-01-0180B			23	113		1		
Cloud Creek	OK120410-01-0100T			12	6287		1		
Coal Creek	OK220600-02-0010F		2	4	1071	1			1
Deep Branch	OK121700-01-0020A								
Dry Creek	OK520700-04-0020F			2	2316	10	1		
Elk Creek	OK120400-02-0190F			3	213	1			
Emachaya Creek	OK220300-00-0040C				140				
Fourche Maline Creek	OK220100-04-0020H		1	14	428			1	
Gaines Creek	OK220600-04-0010P			2	322				
Gar Creek	OK520510-00-0080C				557				
George's Fork of Dirty Creek	OK120400-02-0110D			2	131			1	
Greenleaf Creek	OK120400-01-0120C		1	3	2				
Hog Creek	OK520810-00-0030D				113	3			
Little Deep Fork	OK520700-06-0010D		2	4	6417	1	4		1
Little Wewoka Creek	OK520500-02-0090D	5			1466				
Longtown Creek	OK220600-01-0070P				186				
Manard Bayou	OK120400-01-0280E				7				
Mill Creek	OK220600-01-0100P				181				

Site Name	WBID	#CAFO	# Landfill	#NPDES Permits	# O&G	#Total Retention Lagoon	# Land Application	# Public Water Intakes	# Storage Disposal
Montezumah Creek	OK520700-01-0220D	1			1618				
Nuyaka Creek	OK520700-02-0200D				1089				
Peaceable Creek	OK220600-03-0050F			6	280			1	1
Pecan Creek (Muskogee Co.)	OK120410-01-0030D		1		599		12		
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C				116				
Polecat Creek	OK120420-02-0050G		1	12	8520	12	21	3	
Quapaw Creek	OK520700-04-0260C			1	658	2			
Sallisaw Creek	OK220200-03-0010C			1	8	6		2	
Salt Creek (Creek Co.)	OK520700-03-0100B			1	1329	1	2	2	1
Salt Creek (Seminole Co.)	OK520800-03-0010D			2	4229				
Sandy Creek	OK520700-03-0040F				577				
Snake Creek	OK120410-01-0220G			3	4408	3	22		
South Fork Dirty Creek	OK120400-02-0030H			1	35				
Sugar Loaf Creek	OK220100-01-0160G				164				
Turkey Creek	OK520510-00-0100F				958				
Vian Creek	OK220200-02-0130E			1	2				
Wewoka Creek	OK520500-02-0010C	9	1	7	8472	2	1	1	

Table 18. Comparison of sites by ecoregion with and without NPDES permits based on one-way ANOVAs. (AV = Arkansas Valley; BM = Boston Mountains; CIP = Central Irregular Plains; CT = Cross Timbers)

Ecoregion	Parameter	NPDES Permit?	N	Mean	Standard Deviation	P Value	Result
AV	Alkalinity	No	105	71.29	28.56	0.098	
		Yes	125	78.92	39.19		Higher
AV	Conductivity	No	104	165.67	68.82	0.000	
		Yes	125	282.9	219		Higher
AV	Hardness	No	105	121.24	50.86	0.069	
		Yes	126	133.79	52.79		Higher
AV	Chloride	No	100	8.85	3.68	0.001	
		Yes	120	14.62	17.37		Higher

Ecoregion	Parameter	NPDES Permit?	N	Mean	Standard Deviation	P Value	Result
AV	TDS	No	100	112.61	36.7	0.000	
		Yes	120	190.5	139.9		Higher
AV	Nitrite	No	100	0.02	0.003	0.093	
		Yes	120	0.023	0.017		Higher
AV	OrthoP	No	100	0.021	0.025	0.001	
		Yes	120	0.069	0.137		Higher
AV	TP	No	100	0.068	0.053	0.001	
		Yes	120	0.119	0.149		Higher
AV	Sulfate	No	100	18.75	10.57	0.000	
		Yes	120	56	73.03		Higher
AV	Flow	No	75	2.53	4.28	0.000	
		Yes	68	9.44	10.3		Higher
BM	Alkalinity	No	63	82.11	43	0.010	
		Yes	62	99.53	29.72		Higher
BM	Conductivity	No	63	161.4	93.9	0.003	
		Yes	62	214.1	96.9		Higher
BM	DO % Saturation	No	63	79.53	25.93	0.071	
		Yes	62	87.94	25.72		Higher
BM	Hardness	No	63	115.33	55.49	0.017	
		Yes	62	135.98	37.85		Higher
BM	pH	No	62	7.3	0.73	0.019	
		Yes	61	7.59	0.6		Higher
BM	TDS	No	59	93.31	56.24	0.001	
		Yes	59	121.61	27.84		Higher
BM	TKN	No	59	0.286	0.189	0.003	Higher
		Yes	59	0.199	0.108		
BM	TN	No	59	0.412	0.244	0.001	Higher
		Yes	59	0.287	0.125		
BM	OrthoP	No	59	0.013	0.022	0.071	Higher
		Yes	59	0.008	0.005		
BM	TP	No	59	0.0289	0.031	0.036	Higher
		Yes	59	0.02	0.013		
BM	Flow	No	42	3.02	5.36	0.001	
		Yes	47	14.09	20.05		Higher
CIP	Alkalinity	No	42	93.48	25.84	0.031	
		Yes	84	108.17	39.7		Higher

Ecoregion	Parameter	NPDES Permit?	N	Mean	Standard Deviation	P Value	Result
CIP	DO % Saturation	No	42	79.53	19.63	0.024	Higher
		Yes	84	69.38	25.11		
CIP	pH	No	40	7.65	0.4	0.000	Higher
		Yes	84	7.26	0.6		
CIP	Chloride	No	39	35.18	42.3	0.006	Higher
		Yes	79	20.19	15.01		
CIP	Sulfate	No	39	53.52	36.89	0.057	
		Yes	79	79.69	80.98		Higher
CT	Conductivity	No	266	717.8	738.4	0.061	
		Yes	183	847.7	694.9		Higher
CT	DO	No	268	8.27	3.35	0.012	
		Yes	184	9.08	3.31		Higher
CT	DO % Saturation	No	268	78.35	22.66	0.000	
		Yes	184	88.63	28.18		Higher
CT	Hardness	No	268	242.86	134.48	0.013	
		Yes	184	279.2	174.8		Higher
CT	pH	No	268	7.69	0.52	0.000	
		Yes	184	7.9	0.47		Higher
CT	Chloride	No	253	136.8	265.2	0.087	
		Yes	174	180	240.2		Higher
CT	TKN	No	253	0.703	0.489	0.049	
		Yes	173	0.796	0.461		Higher
CT	Nitrite	No	253	0.032	0.038	0.000	
		Yes	173	0.063	0.117		Higher
CT	TN	No	253	0.88	1.067	0.015	
		Yes	174	1.129	0.985		Higher
CT	Available N	No	253	0.191	0.912	0.062	
		Yes	174	0.35	0.787		Higher
CT	OrthoP	No	253	0.039	0.143	0.018	
		Yes	174	0.073	0.149		Higher
CT	TP	No	253	0.085	0.165	0.017	
		Yes	174	0.124	0.163		Higher
CT	Sulfate	No	253	16.82	8.89	0.000	
		Yes	174	25.29	15.48		Higher
CT	Flow	No	212	2.77	6.42	0.000	
		Yes	147	6.79	10.74		Higher

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 2016 Integrated Report). The impairments and TMDLs for the sites are presented in Appendix D.

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

SiteName	WBID	Cool Water Aquatic Comm	Warm Water Aquatic Comm	Habitat Limited Aquatic Comm	Primary Body Contact Rec	Secondary Body Contact Rec	Aesthetic	Agriculture	Fish Consumption	Public & Private Water Supply	Emergency Water Supply	High Quality Water	Outstanding Resource Water	Sensitive Water Supply
Alabama Creek	OK520500-01-0200D		N		N		I	N	X	I				
Ash Creek	OK120410-01-0110E		I		N		I	F	X	I				
Bad Creek	OK520500-01-0170E		N		N		F	F	X	I				
Ballard Creek	OK121700-03-0370G	N			N		I	F	X	X			X	
Battle Creek	OK121700-06-0040G		F		N		F	F	X					
Bear Creek	OK520700-05-0170A		N		F		X	F	X	X				
Big Creek	OK220100-02-0080B	N			F		X	F	X	X				
Big Skin Bayou	OK220200-01-0030H		I		X		I	I	X	X				
Bird Creek	OK520800-01-0050G			N		F	I	N	X					
Brazil Creek	OK220100-03-0010G		I		N		F	F	X	I				
Brushy Creek	OK220600-03-0010L		N		N		N	F	N	N				
Canadian Sandy Creek	OK520600-03-0010D		N		N		I	F	X	I				
Captain Creek	OK520700-05-0140H		I		F		F	F	X	F				
Caston Creek	OK220100-01-0180B		F		F		X	N	X	X				
Cloud Creek	OK120410-01-0100T		I		N		I	F	X	I				
Coal Creek	OK220600-02-0010F		N		F		X	F	X	X				
Deep Branch	OK121700-01-0020A		N		I		X	F	X					
Dry Creek	OK520700-04-0020F		N		N		I	F	X	I				
Elk Creek	OK120400-02-0190F		N		I		I	N	X					
Emachaya Creek	OK220300-00-0040C		N		F		X	X	X	X				
Fourche Maline Creek	OK220100-04-0020H		N		N		F	F	F	I				
Gaines Creek	OK220600-04-0010P		N		F		F	F	X	F				
Gar Creek	OK520510-00-0080C		I		F		X	X	X					
George's Fork of Dirty Creek	OK120400-02-0110D		N		N		F	F	X	I	F			
Greenleaf Creek	OK120400-01-0120C		F		I		I	F	X	X				
Hog Creek	OK520810-00-0030D		I		N		I	F	X	X				
Little Deep Fork	OK520700-06-0010D		N		I		I	F	I					
Little Wewoka Creek	OK520500-02-0090D		F		N		I	F	X	I				
Longtown Creek	OK220600-01-0070P		N		N		F	F	X	F				
Manard Bayou	OK120400-01-0280E		N		I		X	X	X	X				
Mill Creek	OK220600-01-0100P		N		N		I	F	X	I				
Montezumah Creek	OK520700-01-0220D		N		F		I	X	X					

SiteName	WBID	Cool Water Aquatic Comm	Warm Water Aquatic Comm	Habitat Limited Aquatic Comm	Primary Body Contact Rec	Secondary Body Contact Rec	Aesthetic	Agriculture	Fish Consumption	Public & Private Water Supply	Emergency Water Supply	High Quality Water	Outstanding Resource Water	Sensitive Water Supply
Nuyaka Creek	OK520700-02-0200D		N		N		I	F	X	X				
Peaceable Creek	OK220600-03-0050F		N		N		F	F	I	I				
Pecan Creek (Muskogee Co.)	OK120410-01-0030D		N		I		X	X	X	X				
Pecan Creek (Pottawatomie Co.)	OK520800-02-0080C		I		F		F	F	X					
Polecat Creek	OK120420-02-0050G		N		N		I	F	X					
Quapaw Creek	OK520700-04-0260C		N		N		F	F	X	I				
Sallisaw Creek	OK220200-03-0010C	F			N		I	F	X	I		X		
Salt Creek (Creek Co.)	OK520700-03-0100B		N		N		F	N	X	I				
Salt Creek (Seminole Co.)	OK520800-03-0010D		N		N		I	N	X	I				
Sandy Creek	OK520700-03-0040F		N		X		I	F	X	I				
Snake Creek	OK120410-01-0220G		I		N		F	F	X	I				
South Fork Dirty Creek	OK120400-02-0030H		N		N		F	N	X					
Sugar Loaf Creek	OK220100-01-0160G		N		F		I	I	X	X				
Turkey Creek	OK520510-00-0100F		N		F		F	N	X	F				
Vian Creek	OK220200-02-0130E	N			F		I	I	X	X				
Wewoka Creek	OK520500-02-0010C		N		N		F	N	X		F			

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APPENDICES