# Small Watershed Rotating Basin Monitoring Program

*Basin Group 1: Neosho-Grand and Upper Canadian Basins*

*Third Cycle*

*Final Report*

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*Submitted by:*

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# 1.0 INTRODUCTION

## 1.1 Project Background and Description

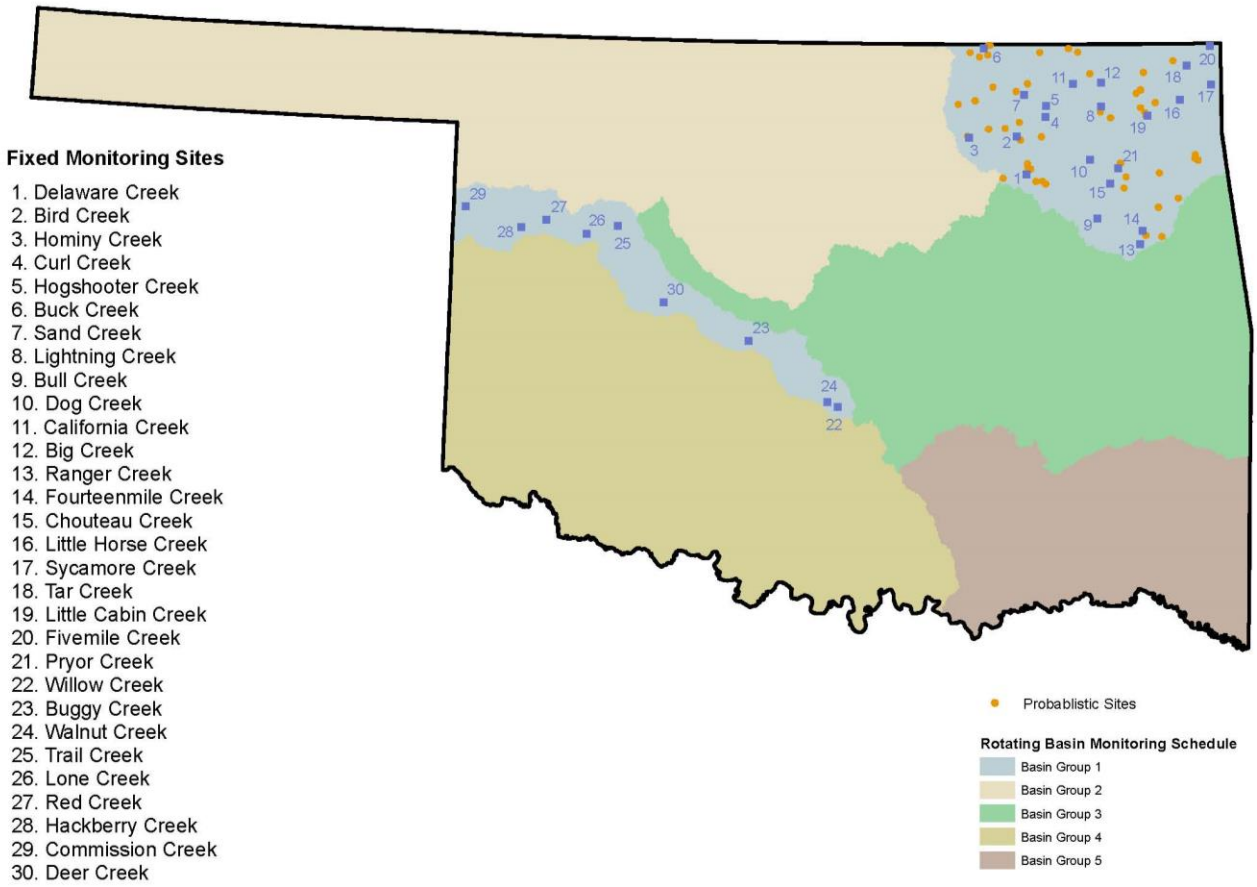
The Clean Water Act has charged each state's nonpoint source (NPS) pollution agency with two primary tasks: 1) identify all waters being impacted by NPS pollution, and 2) develop a management program describing programs to be implemented to correct any identified problems. In addition, each state's NPS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

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 11-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 11 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. The data collected as part of the Rotating Basin Monitoring Program is used to determine designated use attainment as part of the State's biannual integrated report in accordance with the protocol in State law (OAC 785:45 and 785:46). Monitoring sites are coordinated with other agencies in the state to assure that little or no overlapping data is collected. Data is used to help determine priority watershed projects as part of the state NPS management plan approximately every five years. This report focuses on the first set of planning basins monitored in the five year rotation, the Neosho-Grand and Upper Canadian River basins (Figure 1).

To complement the fixed site monitoring, the OCC added a probabilistic component to the Rotating Basin Monitoring Program in 2008. This addition to the Rotating Basin Program provides a statistically qualified assessment of water quality conditions throughout each of the project basin units. To accomplish this, sites are randomly selected from all of the waters of interest in a target area (i.e., basin unit), and the monitoring results are used to estimate water quality conditions in the larger area with known confidence (USGAO 2004). Through the probabilistic component, data will be collected from 250 stream locations over a five-year period, with 50 targeted sites sampled each year. The probabilistic sites will be coordinated with the basins being sampled by the rotating basin project in any given year;

thus, for 2011, rotating basin sites were sampled in the Neosho-Grand and Upper Canadian basins and probabilistic sites were sampled in the Neosho-Grand basin (Figure 1).

**Figure 1. Fixed and probabilistic monitoring sites in Basin Group 1, Cycle 3 in the Rotating Basin Monitoring Project.**




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.

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 designated 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 designated 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 designated 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 Neosho-Grand and Upper Canadian River basins (see Figure 1). Data from both fixed and probabilistic sites will be discussed. *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. The use of probabilistic monitoring in conjunction with the rotating basin monitoring program will allow a statistically valid and qualified assessment / representation of the percentage of stream miles across the state that are in good or bad condition and the percentage of stream miles that are fulfilling or not fulfilling their designated uses.

# 2.0 MATERIALS AND METHODS

## 2.1 General

Sampling stations were selected to effectively represent streams of the Neosho-Grand and Upper Canadian 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 Neosho-Grand and Upper Canadian basins was accomplished prior to the first round of monitoring in 2001, 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 2001-2003. Prior to each new cycle of basin monitoring, the site list is reconsidered, and any sites that are found to be unsuitable, perhaps due to intermittent conditions during the previous cycle, are dropped. In addition, if the landowner refuses to allow sampling, a site must be dropped. Replacement sites are usually found in both of these instances. Thirty-one of the original 34 streams were monitored in the second cycle from June 2006-May 2008. The third cycle of monitoring in these basins occurred from June 2011-May 2013. There were 30 fixed sites during this cycle of monitoring.

With the initiation of the probabilistic component of the Rotating Basin Program, the OCC sampled a total of 48 randomly selected sites in the Neosho-Grand basin during the summer of 2011. These sites were part of a master site list generated by Tony Olsen with the EPA Corvallis Lab which included 150 sites total. Sampling occurred in the order the list was generated in an attempt to get at least 50 sites assessed. The additional sites were "back-ups" to be used if one of the first 50 sites was inaccessible or if access permission was denied. Severe drought during the 2011 sampling period prevented attainment of data at 50 sites.

The sites monitored in the Neosho-Grand basin occur in five level-three ecoregions: Central Irregular Plains (CIP), Cross Timbers (CT), Boston Mountains (BM), Flint Hills (FH), and Ozark Highlands (OH) (Woods et al., 2005). In the Upper Canadian basin, one site is located in the Southwestern Tablelands (SWT), while the other sites are in the Central Great Plains (CGP) ecoregion.

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

| Site Name | WBID | Latitude | Longitude | Legal Description | County | Ecoregion |
|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | 36.7853 | -95.4634 | NW 35-27N-17E | Nowata | CIP |
| Bird Creek | OK121300-02-0010C | 36.4852 | -96.0610 | NW 7-23N-12E | Osage | CT |
| Buck Creek | OK121400-03-0170C | 36.9755 | -96.2947 | SE 23-29N-9E | Osage | CT |
| Buggy Creek | OK520610-02-0120C | 35.3343 | -97.9184 | NE NE NE 22-10N-7W | Grady | CGP |
| Bull Creek | OK121500-02-0090D | 36.0298 | -95.4940 | NW 22-18N-17E | Wagoner | CIP |
| California Creek | OK121510-02-0050C | 36.7802 | -95.6657 | Sections 36/35 27N-15E | Nowata | CIP |
| Chouteau Creek | OK121600-01-0430P | 36.2230 | -95.4047 | SE 8-20N-18E | Mayes | CIP |
| Commission Creek | OK520620-05-0160C | 36.0336 | -99.9170 | NW NE NW 18-18N-25W | Ellis | SWT |
| Curl Creek | OK121400-01-0270C | 36.5975 | -95.8598 | 31-25N-14E | Washington | CIP |
| Deer Creek | OK520620-06-0010F | 35.5365 | -98.5174 | NW NW NW 7-12N-12W | Caddo | CGP |
| Delaware Creek | OK121300-01-0150H | 36.2771 | -95.9924 | 25-21N-12E | Tulsa | CIP |

| Site Name | WBID | Latitude | Longitude | Legal Description | County | Ecoregion |
|---|---|---|---|---|---|---|
| Dog Creek | OK121500-04-0010M | 36.3562 | -95.5433 | NE SE 25-22N-16E | Rogers | CIP |
| Fivemile Creek | OK121600-07-0110G | 36.9835 | -94.6919 | NW NE 22-29N-24E | Ottawa | OH |
| Fourteenmile Creek | OK121600-01-0100G | 35.9591 | -95.1825 | 9-17N-20E | Cherokee | OH |
| Hackberry Creek | OK520620-04-0050D | 35.9320 | -99.5237 | SE NE SE 22-17N-22W | Ellis | CGP |
| Hogshooter Creek | OK121400-01-0300D | 36.6306 | -95.8620 | SW 19-25N-14E | Washington | CIP |
| Hominy Creek | OK121300-04-0280G | 36.4810 | -96.3980 | SE 12-23N-8E | Osage | CT |
| Lightning Creek | OK121510-01-0130N | 36.6523 | -95.4679 | NW NW 14-25N-17E | Nowata | CIP |
| Little Cabin Creek | OK121600-06-0080C | 36.5975 | -95.1385 | 2-24N-20E | Craig | CIP |
| Little Horse Creek | OK121600-03-0190A | 36.6862 | -94.9115 | 35-26N-22E | Ottawa | CIP |
| Lone Creek | OK520620-03-0020C | 35.9062 | -99.0650 | SW SE NE 36-17N-18W | Dewey | CGP |
| Pryor Creek | OK121610-00-0050D | 36.3074 | -95.3472 | NE NE 14-21N-18E | Mayes | CIP |
| Ranger Creek | OK121600-01-0060D | 35.8844 | -95.2001 | NW NW 9-16N-20E | Cherokee | BM |
| Red Creek | OK520620-03-0110F | 35.9778 | -99.3492 | NE SE 5-17N-20W | Dewey | CGP |
| Sand Creek | OK121400-04-0010F | 36.7192 | -96.0074 | 21-26N-12E | Osage | CT |
| Sycamore Creek | OK121600-03-0510D | 36.7685 | -94.6920 | NE NW 2-26N-24E | Ottawa | OH |
| Tar Creek | OK121600-04-0060D | 36.8748 | -94.8620 | SE SE SE 30-28N-23E | Ottawa | CIP |
| Trail Creek | OK520620-02-0090G | 35.9565 | -98.8480 | NW NW NW 18-17N-15W | Dewey | CGP |
| Walnut Creek | OK520610-03-0010F | 34.9992 | -97.3668 | NW NE NW 13-6N-2W | McClain | CGP |
| Willow Creek | OK520610-01-0080H | 34.9716 | -97.2937 | SE SW 22-6N-1W | Cleveland | CGP |

Table 2 shows the site information for the probabilistic sites which were sampled.

**Table 2. Probabilistic Site List for Rotating Basin Monitoring Program, Basin Group 1.**

| Site Name | WBID | Latitude | Longitude | Legal Description | County | Ecoregion |
|---|---|---|---|---|---|---|
| Bevan Creek – 105 | NEOGRD-105 | 36.4828 | -95.8838 | SW 12-23N-13E | Washington | CIP |
| Big Cabin Creek - 042 | NEOGRD-042 | 36.5978 | -95.1492 | Sec 2 &3-24N-20E | Craig | CIP |
| Big Cabin Creek - 095 | NEOGRD-095 | 36.7425 | -95.1865 | NE 17-26N-20E | Craig | CIP |
| Big Cabin Creek - 127 | NEOGRD-127 | 36.8389 | -95.1659 | 9-27N-20E | Craig | CIP |
| Bird Creek - 013 | NEOGRD-013 | 36.529 | -96.1403 | 29-24N-11E | Osage | CT |
| Bird Creek - 027 | NEOGRD-027 | 36.2362 | -95.879 | SW 1-20N-13E | Tulsa | CIP |
| Bird Creek - 047 | NEOGRD-047 | 36.682 | -96.354 | SE 32-26N-9E | Osage | CT |
| Bird Creek - 053 | NEOGRD-053 | 36.3033 | -95.9606 | 18-21N-13E | Tulsa | CIP |
| Bird Creek - 057 | NEOGRD-057 | 36.3347 | -95.9822 | 1-21N-12E | Tulsa | CIP |
| Bird Creek - 061 | NEOGRD-061 | 36.4644 | -96.0335 | SE 17-23N-12E | Osage | CT |

| Site Name | WBID | Latitude | Longitude | Legal Description | County | Ecoregion |
|---|---|---|---|---|---|---|
| Bird Creek - 069 | NEOGRD-069 | 36.234 | -95.9261 | NE 9-20N-13E | Tulsa | CIP |
| Brush Creek - 040 | NEOGRD-040 | 36.36 | -94.8076 | 25-22N-23E | Delaware | OH |
| Brush Creek - 058 | NEOGRD-058 | 36.3777 | -94.8026 | NW 24-22N-23E | Delaware | OH |
| Buck Creek - 045 | NEOGRD-045 | 36.9504 | -96.3879 | 36-29N-8E | Osage | FH |
| Bull Creek - 107 | NEOGRD-107 | 36.6149 | -95.1567 | SW 27-25N-20E | Craig | CIP |
| Candy Creek - 026 | NEOGRD-026 | 36.5622 | -96.0395 | NE 17-24N-12E | Osage | CT |
| Caney River - 021 | NEOGRD-021 | 36.9907 | -96.2609 | 18-29N-10E | Osage | CT |
| Caney River - 080 | NEOGRD-080 | 36.9913 | -96.2519 | 17-29N-10E | Osage | CT |
| Caney River - 131 | NEOGRD-131 | 36.778 | -95.9822 | 36-27N-12E | Washington | CIP |
| Chouteau Creek - 024 | NEOGRD-024 | 36.1949 | -95.3047 | NE SE 20-20N-19E | Mayes | CIP |
| Clear Creek - 060 | NEOGRD-060 | 36.6618 | -96.4712 | NW 28-25N-8E | Osage | FH |
| Delaware Creek - 150 | NEOGRD-150 | 36.2513 | -96.1532 | SW 32-21N-11E | Osage | CT |
| Double Spring Creek - 141 | NEOGRD-141 | 35.9297 | -95.1562 | NE 27-17N-20E | Cherokee | BM |
| Dry Creek - 140 | NEOGRD-140 | 36.9264 | -96.3221 | SE 3-28N-9E | Osage | CT |
| Fourmile Creek - 076 | NEOGRD-076 | 36.5243 | -96.2571 | SW 29-24N-10E | Osage | CT |
| Hominy Creek - 09 | NEOGRD-09 | 36.4859 | -96.4049 | NE 12-23N-8E | Osage | CT |
| Hominy Creek - 148 | NEOGRD-148 | 36.3087 | -95.9783 | SE 12-21N-12E | Tulsa | CIP |
| Lightning Creek - 079 | NEOGRD-079 | 36.652 | -95.4673 | NW 14-25N-17E | Nowata | CIP |
| Little Cabin Creek - 075 | NEOGRD-075 | 36.6718 | -95.084 | SW 5-25N-21E | Craig | CIP |
| Little Saline Creek - 097 | NEOGRD-097 | 36.2784 | -95.055 | 22/27-21N-21E | Mayes | OH |
| Mingo Creek - 145 | NEOGRD-145 | 36.2193 | -95.8567 | NE 18-20N-14E | Tulsa | CIP |
| Neosho River - 120 | NEOGRD-120 | 36.902 | -94.9547 | NE 21-28N-22E | Ottawa | CIP |
| North Fork Cotton Creek - 010 | NEOGRD-010 | 36.951 | -95.8958 | 34-29N-13E | Washington | CIP |
| Opossum Creek - 052 | NEOGRD-052 | 36.9522 | -95.6263 | 36-29N-15E | Nowata | CIP |
| Opossum Creek - 068 | NEOGRD-068 | 36.9747 | -95.6945 | SW 21-29N-15E | Nowata | CIP |
| Panther Creek - 011 | NEOGRD-011 | 36.6197 | -95.468 | 27-25N-17E | Nowata | CIP |
| Pawpaw Creek - 091 | NEOGRD-091 | 36.6422 | -95.1868 | SW SE 17-25N-20E | Craig | CIP |
| Pecan Creek - 016 | NEOGRD-016 | 35.9221 | -95.0431 | SW 26-17N-21E | Cherokee | OH |
| Pond Creek - 108 | NEOGRD-108 | 36.9375 | -96.2641 | NE 6-28N-10E | Osage | CT |
| Pryor Creek - 081 | NEOGRD-081 | 36.3329 | -95.3314 | NE 1-21N-18E | Mayes | CIP |
| Pryor Creek - 115 | NEOGRD-115 | 36.5863 | -95.3987 | SW 4-24N-18E | Rogers | CIP |
| Pryor Creek - 146 | NEOGRD-146 | 36.2573 | -95.2922 | 32-21N-19E | Mayes | CIP |
| Rock Creek - 116 | NEOGRD-116 | 36.7609 | -96.2254 | 4-26N-10E | Osage | CT |
| Sand Creek - 025 | NEOGRD-025 | 36.7364 | -96.0638 | NE 13-26N-11E | Osage | CT |
| Spavinaw Creek - 074 | NEOGRD-074 | 36.3484 | -94.7825 | 31-22N-24E | Delaware | OH |
| Spring Creek - 093 | NEOGRD-093 | 36.0876 | -95.068 | NE 33-19N-21E | Cherokee | OH |
| Spring Creek - 122 | NEOGRD-122 | 36.1363 | -94.9266 | SE 11-19N-22E | Cherokee | OH |

| Site Name | WBID | Latitude | Longitude | Legal Description | County | Ecoregion |
|---|---|---|---|---|---|---|
| Verdigris River - 139 | NEOGRD-139 | 36.8355 | -95.5423 | 12-27N-16E | Nowata | CIP |
| West Fork Big Cabin Creek - 123 | NEOGRD-123 | 36.7241 | -95.2148 | NW 19-26N-20E | Craig | CIP |

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.

## 2.2 Water Quality Monitoring

Starting in June 2011, 30 sites were monitored for physical and chemical parameters on a fixed interval schedule of ten sampling events per year (five-week intervals) through May 2013 (usually 20 total events per sites). This sampling frequency exceeds state data requirements for designated 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 ($NH_3$), 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 nitrate, nitrite, and TKN for each sample. Available nitrogen was calculated by summing the values of ammonia, nitrate, and nitrite. In addition, *in-situ* water quality parameters were measured at each sampling location and include the following: water temperature, dissolved oxygen, pH, conductivity, alkalinity, hardness, turbidity, and instantaneous discharge (flow).

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

Probabilistic sites were visited only twice, once to collect the physical and chemical parameters described above, as well as the bacteria sample, and once to collect biological and habitat data as discussed in later sections below. Data was collected only during base-flow conditions at the probabilistic sites.

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

## 2.3 Biological Monitoring

### 2.3.1 Habitat Assessment

In the summer of 2011, OCC staff began conducting instream and riparian habitat assessments at sites concurrent with fish collections; any sites not sampled in 2011 were sampled in the summer of 2012 (see Appendix B for exact dates). 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 the habitat component.

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

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

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

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

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

(8) **Channel sinuosity** measures how far a channel deviates from a straight line. More sinuous channels tend to have more undercut banks, root wads, submerged logs, etc. Index of Biotic Integrity (IBI) scores should be higher as channels become more sinuous. Sinuosity is calculated by dividing the length of the assessment (400 meters) by the distance between the GPS location of the start point and end point of the assessment.

(9) The **bank erosion** index assesses the stability of the stream bank. Stable stream banks tend to increase IBI scores for many reasons. Most importantly, they do not contribute sediment to the

stream channel. As a rule, channels with stable banks tend to be deeper and narrower than channels with unstable banks. Because of the increased depth and decreased width, they tend to be cooler and they also tend to grow less algae for a given amount of nutrients than do shallow, wide channels. Overall habitat quality should increase as bank stability increases.

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

(11) The last category is **streamside cover**. A large part of the energy and food input to the stream comes from the terrestrial vegetation along the banks. A mixture of grasses, forbs, shrubs, vines, saplings, and large trees transfer these necessities to the stream more effectively than does any single type of vegetation. Habitat quality should increase as the form of bank vegetation increases in diversity.

### 2.3.2 Fish

Fish collections were obtained in the summer of 2011 or 2012 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 20’ seines of ¼ inch mesh equipped with 8’ brailes. Electroshocking was undertaken at all sites with suitable conductivities (usually < 1000 µS/cm) and involved the use of a Smith Root LR 24 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 or a floating pram, a Smith-Root VVP-15B electrofisher system with a Honda 5 kw 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 2011). In addition, each site was assessed using a modified version of Karr’s Index of Biotic Integrity (IBI) (adapted from Plafkin et al., 1989). Descriptive statistics were determined for each metric using the *Minitab V 14* software. The condition of the fish community was based on indices of species richness, community quality, trophic structure, and by comparison to

the average scores of high-quality streams in that ecoregion. The modified IBI score was calculated using the following metrics:

(1) The **total number of fish species** decreases with decreasing water or habitat quality.
(2) The **number of sensitive benthic species (darters, madtoms, sculpins)** decreases with increasing siltation and increasing benthic oxygen demand. Many of these fish actually live within the cobble and gravel interstices and are very good indicators of conditions that make this environment inhospitable. These species are weak swimmers that do not readily travel up and down a stream, so their presence or absence at a site relates well to both past and present habitat and water quality conditions at that site.
(3) The **number of sunfish species** decreases with decreasing pool quality and with decreasing cover. Sunfish also require a fairly stable substrate on which to spawn, so their long-term success is also tied to conditions that affect the amount of sediment that enters and leaves the stream.
(4) The **number of intolerant species** is a characteristic of the fish community that separates high quality from moderate quality sites. A high quality stream will have several members of the fish community that are intolerant to environmental stress. A stream of only moderate quality will have fish that are moderately and highly tolerant of environmental stress. The intolerant species will not be present in the moderate quality stream.
(5) The **proportion of tolerant individuals** is a characteristic that allows moderate quality streams to be separated from low quality streams. These are opportunistic, tolerant fish that dominate communities that have lost their competitors through loss of habitat or water quality.
(6) The **proportion of individuals as insectivorous cyprinids** increases as the quality and quantity of the invertebrate food base increases. These are the dominant minnows in North American streams but are replaced by either omnivorous or herbivorous minnows as the quality of the food base deteriorates. Often, as the density of aquatic invertebrates decreases, the standing crop of algae increases. This is because the aquatic invertebrates are the largest group of primary consumers. Fish that can switch their diet to algae or fish that eat only algae will replace fish that cannot adapt to the new conditions.
(7) The **proportion of individuals as lithophilic spawners** decreases as the quality of the stream decreases. Lithophilic spawners require cobble or gravel in order to spawn; hence, these fish are sensitive to siltation. This metric allows separation of excellent streams from moderate quality streams.

For each of these seven metrics, a score of 5, 3, or 1 was assigned (Table 3), 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 4, 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 (high scores indicate higher quality) but says nothing about whether any deficiencies are due to degraded water quality or to degraded habitat.

**Table 3. 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 4. Index of Biotic Integrity (IBI) score interpretation for fish.**

| % Comparison to the Reference Score | Integrity Class | Characteristics |
|---|---|---|
| 97 – 100 % | 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 |
| 20 – 37% | Very Poor | Few species and individuals present; tolerant species dominant; diseased fish frequent |

### 2.3.3 Macroinvertebrates

Collection of macroinvertebrates was attempted at all fixed sites for both winter and summer index periods of July 2011 through March 2013 according to procedures outlined in the OCC SOP (2011). A single macroinvertebrate collection was obtained during the summer period for each probabilistic site. 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 at., 1989). Riffle sampling effort consisted of three, one meter squared kicknet samples in the 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 ¼”

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 used tolerance values of North Carolina invertebrates (Plafkin et al., 1989).
(3) 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).
(4) 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).
(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. The metric increases with increasing biotic quality (Plafkin et al., 1989).

Descriptive statistics of each season-specific sample type (e.g., summer riffle, winter vegetation, summer woody) for each site were determined via *Minitab V. 14* and were compared to the average respective metric of high-quality streams in the ecoregion. A Bioassessment score was calculated similarly to the IBI score for fish. For each site, scores of 6, 4, 2, or 0 were assigned for each metric (according to the criteria in Table 5, 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 6 (adapted from Plafkin et al., 1989).

**Table 5. 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** | <60% | 60-70% | 70-80% | >80% |
| 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 6. Bioassessment score interpretation for macroinvertebrates.**

| % Comparison to the Reference Score | Biological Condition | Characteristics |
|---|---|---|
| >83% | Non-Impaired | Comparable to the best situation expected within the ecoregion. Balanced trophic and community structure for stream size. |
| 54-79% | Slightly Impaired | Community structure less than expected. Species richness is less than expected due to loss of some intolerant forms. Percent contribution of tolerant forms is increased. |
| 21-50% | Moderately Impaired | Fewer species due to the loss of most intolerant forms. Reduction in EPT index. |
| <17% | Severely Impaired | Few species present. If high densities of organisms occur, they are dominated by 1 or 2 taxa. |

## 2.4 Watershed Assessment

To investigate potential sources of NPS pollution for streams showing designated use impairment, relevant data layers were explored using ArcView Geographic Information System (GIS) software. Data explored included the 2006 National Land Cover Database (NLCD) created by the Multi-Resolution Land Characteristics (MRLC) Consortium, oil and gas wells, confined animal feeding operations, national pollution discharge elimination system permit holders (NPDES), total retention sites, biosolid land application sites, and other data layers. The NLCD was explored to determine percent occurrence of particular landuse types such as bare rock/sand/clay, vegetation (broken into several categories, both natural and agricultural), open water, and residential/commercial/industrial uses (divided into several categories).

## 2.5 Designated Use Support Assessment

Each fixed site's designated uses were evaluated following the protocols outlined in the state's *Continuing Planning Process, Integrated Water Quality Report Listing Methodology* (Oklahoma

Department of Environmental Quality, 2012) and per *Oklahoma Administrative Code 785, Chapter 46: Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (OWRB 2011). 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 2014 Integrated Report to be submitted to EPA Region VI.

# 3.0 RESULTS AND DISCUSSION

## 3.1 Water Quality Monitoring

All chemical and physical water quality data collected for the project are included in Appendix A.1; Appendix A.2 contains the bacteria data. Table 7 gives the mean values of all water quality parameters collected in-situ for each fixed site. Instantaneous discharge is recorded in the table as "flow." Due to the extreme drought during this rotation period, most of the flow values measured were lower than normal base flow. Table 8 provides the means for all chemical analytes assessed. Descriptive statistics for water quality parameters are presented by site in Appendix A.3

**Table 7. Mean *in-situ* water quality values for Basin Group 1 Fixed Monitoring Sites, 2011-2013. *These sites were only sampled once due to drought conditions.**

| Site Name | WBID | Water Temp (°C) | DO (mg/L) | Oxygen % Saturation | Alkalinity (CaCO3) | Conductivity (µS/cm) | Hardness (mg/L) | pH (SU) | Turbidity (NTU) | Flow (cfs) |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | 18.1 | 9.22 | 92.50 | 141 | 312.2 | 166.8 | 7.81 | 22.13 | 7.26 |
| Bird Creek | OK121300-02-0010C | 18.3 | 8.99 | 92.68 | 94 | 436.5 | 135.5 | 7.85 | 11.83 | 29.87 |
| Buck Creek | OK121400-03-0170C | 16.0 | 6.85 | 65.44 | 153 | 590.1 | 209.7 | 7.64 | 13.14 | 6.15 |
| Buggy Creek | OK520610-02-0120C | 17.6 | 9.76 | 99.42 | 267 | 1680.8 | 687.7 | 8.23 | 17.96 | 5.16 |
| Bull Creek | OK121500-02-0090D | 17.3 | 6.31 | 64.83 | 87 | 372.6 | 180.5 | 7.22 | 35.50 | 0.89 |
| California Creek | OK121510-02-0050C | 15.9 | 5.22 | 49.38 | 149 | 667.1 | 209.3 | 7.41 | 37.80 | 0.35 |
| Chouteau Creek | OK121600-01-0430P | 16.2 | 6.06 | 54.86 | 102 | 417.4 | 162.3 | 7.16 | 40.74 | 1.89 |
| Commission Creek | OK520620-05-0160C | 15.2 | 10.54 | 107.47 | 229 | 912.0 | 317.3 | 8.30 | 9.55 | 5.92 |
| Curl Creek | OK121400-01-0270C | 15.3 | 4.77 | 47.69 | 112 | 409.8 | 153.1 | 7.21 | 45.35 | 0.16 |
| Deer Creek | OK520620-06-0010F | 18.9 | 10.27 | 112.65 | 172 | 1456.3 | 668.5 | 8.31 | 8.91 | 27.39 |
| Delaware Creek | OK121300-01-0150H | 18.1 | 7.19 | 73.95 | 82 | 415.8 | 148.8 | 7.19 | 36.27 | 1.71 |
| Dog Creek | OK121500-04-0010M | 17.7 | 4.78 | 44.07 | 97 | 358.4 | 165.7 | 6.86 | 21.83 | 0.02 |
| Fivemile Creek | OK121600-07-0110G | 17.0 | 8.83 | 90.25 | 120 | 273.9 | 165.9 | 7.73 | 1.47 | 9.45 |
| Fourteenmile Creek | OK121600-01-0100G | 18.9 | 10.38 | 105.33 | 77 | 192.3 | 116.8 | 7.74 | 2.90 | 15.00 |
| Hackberry Creek* | OK520620-04-0050D | 17.4 | 6.01 | 65.60 | 190 | 2369.0 | 690.0 | 7.81 | 203.19 | 3.85 |
| Hogshooter Creek | OK121400-01-0300D | 15.2 | 4.16 | 45.98 | 182 | 498.0 | 234.5 | 7.36 | 60.13 | 0.64 |
| Hominy Creek | OK121300-04-0280G | 15.5 | 8.18 | 70.80 | 111 | 1601.7 | 407.4 | 7.54 | 10.56 | 1.71 |
| Lightning Creek | OK121510-01-0130N | 17.1 | 9.55 | 94.64 | 168 | 2743.5 | 2351.6 | 7.80 | 23.68 | 12.51 |
| Little Cabin Creek | OK121600-06-0080C | 16.1 | 5.33 | 51.82 | 114 | 341.4 | 167.4 | 7.21 | 62.68 | 2.32 |
| Little Horse Creek | OK121600-03-0190A | 14.1 | 5.82 | 53.24 | 114 | 296.7 | 183.8 | 7.30 | 17.96 | 2.11 |
| Lone Creek | OK520620-03-0020C | 13.5 | 12.07 | 114.65 | 171 | 3171.6 | 1879.2 | 8.07 | 45.86 | 1.51 |
| Pryor Creek | OK121610-00-0050D | 16.6 | 5.79 | 55.74 | 90 | 291.2 | 151.2 | 7.03 | 43.76 | 6.00 |
| Ranger Creek | OK121600-01-0060D | 19.3 | 9.30 | 90.60 | 111 | 254.9 | 156.9 | 7.76 | 4.01 | 8.19 |
| Red Creek* | OK520620-03-0110F | 20.8 | 8.03 | 89.90 | 84 | 1288.0 | 935.0 | 7.84 | 224.00 | 1.11 |
| Sand Creek | OK121400-04-0010F | 17.7 | 8.12 | 78.73 | 124 | 517.9 | 184.9 | 7.54 | 120.46 | 5.52 |
| Sycamore Creek | OK121600-03-0510D | 16.0 | 9.21 | 88.31 | 114 | 255.6 | 144.8 | 7.62 | 1.92 | 10.14 |
| Tar Creek | OK121600-04-0060D | 16.2 | 10.36 | 96.86 | 210 | 1381.4 | 752.8 | 7.45 | 13.44 | 8.06 |
| Trail Creek | OK520620-02-0090G | 18.0 | 9.23 | 97.44 | 158 | 2749.6 | 2076.3 | 7.97 | 31.97 | 3.62 |
| Walnut Creek | OK520610-03-0010F | 20.4 | 9.63 | 106.62 | 348 | 692.1 | 428.6 | 8.31 | 64.59 | 9.90 |
| Willow Creek | OK520610-01-0080H | 18.9 | 9.52 | 100.45 | 270 | 576.2 | 329.6 | 8.09 | 12.09 | 0.83 |

**Table 8. Mean water quality values for Basin Group 1 Fixed Monitoring Sites, 2011-2013. *These sites were only sampled once due to drought conditions.**

| Site Name | WBID | Chloride (mg/L) | Sulfate (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrate (mg/L) | Nitrite (mg/L) | TKN (mg/L) | OrthoP (mg/L) | Total P (mg/L) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | 8.72 | 22.41 | 202.0 | 0.0366 | 0.9560 | 0.0250 | 0.7070 | 0.0172 | 0.0503 | 19.7 |
| Bird Creek | OK121300-02-0010C | 34.11 | 16.95 | 175.7 | 0.0150 | 0.0420 | 0.0200 | 0.5965 | 0.0070 | 0.0350 | 11.6 |
| Buck Creek | OK121400-03-0170C | 27.24 | 22.44 | 232.5 | 0.0482 | 0.1685 | 0.0270 | 0.5545 | 0.0074 | 0.0345 | 11.3 |
| Buggy Creek | OK520610-02-0120C | 68.02 | 719.99 | 1520.5 | 0.0431 | 0.2105 | 0.0232 | 0.9005 | 0.0756 | 0.1284 | 20.1 |
| Bull Creek | OK121500-02-0090D | 23.09 | 69.62 | 237.2 | 0.0392 | 0.2290 | 0.0225 | 1.1055 | 0.0293 | 0.1037 | 17.5 |
| California Creek | OK121510-02-0050C | 31.60 | 37.16 | 291.1 | 0.0357 | 0.0570 | 0.0200 | 1.0875 | 0.0432 | 0.1236 | 77.3 |
| Chouteau Creek | OK121600-01-0430P | 9.42 | 61.51 | 236.8 | 0.1974 | 0.2270 | 0.0250 | 1.3365 | 0.0342 | 0.1308 | 21.8 |
| Commission Creek | OK520620-05-0160C | 137.74 | 33.70 | 540.5 | 0.0169 | 0.2079 | 0.0200 | 0.4400 | 0.0108 | 0.0224 | 17.1 |
| Curl Creek | OK121400-01-0270C | 18.52 | 19.45 | 209.3 | 0.0412 | 0.0865 | 0.0215 | 1.0450 | 0.0840 | 0.1682 | 44.7 |
| Deer Creek | OK520620-06-0010F | 25.63 | 400.03 | 974.3 | 0.0663 | 1.9300 | 0.0532 | 0.6532 | 0.1652 | 0.1972 | 22.7 |
| Delaware Creek | OK121300-01-0150H | 65.92 | 20.84 | 250.4 | 0.0553 | 0.0675 | 0.0200 | 0.9510 | 0.0230 | 0.0790 | 16.6 |
| Dog Creek | OK121500-04-0010M | 9.85 | 57.14 | 154.8 | 0.0861 | 0.1142 | 0.0216 | 0.6821 | 0.0221 | 0.0671 | 10.9 |
| Fivemile Creek | OK121600-07-0110G | 11.32 | 47.95 | 205.6 | 0.0213 | 0.3915 | 0.0200 | 0.1600 | 0.0092 | 0.0155 | 10.0 |
| Fourteenmile Creek | OK121600-01-0100G | 7.00 | 9.25 | 100.3 | 0.0178 | 0.7095 | 0.0200 | 0.1535 | 0.0224 | 0.0275 | 10.0 |
| Hackberry Creek* | OK520620-04-0050D | 50.30 | 709.60 | 1171.0 | | 0.0800 | 0.0200 | 1.9800 | 0.2530 | 0.4430 | 361.0 |
| Hogshooter Creek | OK121400-01-0300D | 38.58 | 122.84 | 291.0 | 0.0431 | 0.0765 | 0.0210 | 1.0565 | 0.0317 | 0.1199 | 34.7 |
| Hominy Creek | OK121300-04-0280G | 503.21 | 26.06 | 985.9 | 0.0384 | 0.0485 | 0.0200 | 0.5390 | 0.0069 | 0.0283 | 11.1 |
| Lightning Creek | OK121510-01-0130N | 14.47 | 1866.74 | 2854.4 | 0.0150 | 0.0685 | 0.0200 | 0.5225 | 0.0277 | 0.0613 | 27.6 |
| Little Cabin Creek | OK121600-06-0080C | 9.27 | 70.32 | 245.2 | 0.0408 | 0.4815 | 0.0305 | 1.0720 | 0.0483 | 0.1140 | 21.6 |
| Little Horse Creek | OK121600-03-0190A | 12.98 | 28.74 | 196.9 | 0.3263 | 0.5058 | 0.0363 | 1.2600 | 0.1795 | 0.2397 | 11.3 |
| Lone Creek | OK520620-03-0020C | 31.32 | 1724.88 | 2301.9 | 0.0163 | 0.1958 | 0.0242 | 0.6192 | 0.0231 | 0.0608 | 46.8 |
| Pryor Creek | OK121610-00-0050D | 28.69 | 30.84 | 196.0 | 0.0473 | 0.1980 | 0.0235 | 0.8645 | 0.0515 | 0.1199 | 16.0 |
| Ranger Creek | OK121600-01-0060D | 5.66 | 17.90 | 152.8 | 0.0243 | 0.6690 | 0.0200 | 0.4300 | 0.0187 | 0.0480 | 14.1 |
| Red Creek* | OK520620-03-0110F | 13.60 | 717.80 | 1137.0 | | 0.1600 | 0.0200 | 1.0700 | 0.0810 | 0.1780 | 137.0 |
| Sand Creek | OK121400-04-0010F | 73.19 | 28.96 | 309.9 | 0.0477 | 0.1220 | 0.0215 | 0.8835 | 0.0322 | 0.0963 | 75.6 |
| Sycamore Creek | OK121600-03-0510D | 9.38 | 6.03 | 149.9 | 0.0151 | 2.4135 | 0.0200 | 0.2070 | 0.0196 | 0.0272 | 10.0 |
| Tar Creek | OK121600-04-0060D | 30.23 | 801.20 | 1235.6 | 0.0750 | 0.3860 | 0.0300 | 0.8260 | 0.0483 | 0.0884 | 11.8 |
| Trail Creek | OK520620-02-0090G | 24.23 | 1670.07 | 2488.4 | 0.0271 | 0.0642 | 0.0200 | 0.6816 | 0.0374 | 0.0758 | 52.5 |
| Walnut Creek | OK520610-03-0010F | 37.26 | 49.91 | 427.9 | 0.0174 | 0.0511 | 0.0216 | 0.7479 | 0.0505 | 0.1093 | 101.8 |
| Willow Creek | OK520610-01-0080H | 16.73 | 29.83 | 539.1 | 0.0573 | 1.7563 | 0.0537 | 0.6521 | 0.1188 | 0.1864 | 18.9 |

Tables 9 and 10 give the sample values for the Probabilistic sites.

**Table 9. *In-situ* water quality values for Basin Group 1 Probabilistic Sites.**

| Site Name | WBID | Water Temp (°C) | DO (mg/L) | Oxygen % Saturation | Alkalinity (CaCO3) | Conductivity (µS/cm) | pH (SU) | Turbidity (NTU) | Flow (cfs) |
|---|---|---|---|---|---|---|---|---|---|
| Bevan Creek – 105 | NEOGRD-105 | 23.3 | | | 183 | 334.0 | 7.17 | 8.03 | 0 |
| Big Cabin Creek - 042 | NEOGRD-042 | 24.2 | 4.76 | 59 | 144 | 137 | 7.2 | 12 | 0.409 |
| Big Cabin Creek - 095 | NEOGRD-095 | 24.6 | 3 | 36 | 241 | 557 | 7.2 | 33 | 0 |
| Big Cabin Creek - 127 | NEOGRD-127 | | | | 101 | 1607 | 7.7 | 4.5 | 0 |
| Bird Creek - 013 | NEOGRD-013 | 29.8 | 6.39 | 84 | 85 | 293 | 7.6 | 7.5 | 15.6 |
| Bird Creek - 027 | NEOGRD-027 | 30.7 | 5.7 | 76 | 84 | 300 | 7.1 | 25 | 0 |
| Bird Creek - 047 | NEOGRD-047 | 30.9 | 4.48 | 60 | 138 | 325 | 7.5 | 5.8 | 0 |
| Bird Creek - 053 | NEOGRD-053 | 33.6 | 6.97 | 98 | 102 | 384 | 8.2 | 32 | 33.02 |
| Bird Creek - 057 | NEOGRD-057 | 19.4 | 8.26 | 90 | 125 | 334 | 7.6 | 78 | |
| Bird Creek - 061 | NEOGRD-061 | 19.4 | 8.46 | 92 | 76 | 309 | 7.7 | 18 | |
| Bird Creek - 069 | NEOGRD-069 | 28 | 5.56 | 71 | 76 | 311 | 7.4 | 31 | 172.7 |
| Brush Creek - 040 | NEOGRD-040 | 21.6 | 6.61 | 87 | 80 | 221 | 6.9 | 6.3 | < 0.1 |
| Brush Creek - 058 | NEOGRD-058 | 19.8 | 8.21 | 90 | 111 | 243 | 7.4 | 0.7 | 7.931 |
| Buck Creek - 045 | NEOGRD-045 | 27.2 | 7.68 | 93 | 147 | 341 | 8.2 | 7.9 | 0.254 |
| Bull Creek - 107 | NEOGRD-107 | 22.8 | 0.46 | 6 | 104 | 358 | 7.1 | 19 | |
| Candy Creek - 026 | NEOGRD-026 | 31.6 | 7.75 | 104 | 70 | 306 | 7.4 | 6.5 | 0.1 |
| Caney River - 021 | NEOGRD-021 | 27.6 | 8.28 | 105 | 156 | 493 | 7.8 | 34 | 0 |
| Caney River - 080 | NEOGRD-080 | 15.5 | 7.48 | 73 | 211 | 591 | 7.6 | 25 | 0 |
| Caney River - 131 | NEOGRD-131 | 27.3 | 7.27 | 96 | 94 | 429 | 7.1 | 118 | 0 |
| Chouteau Creek - 024 | NEOGRD-024 | 31.1 | 5.2 | 69 | 187 | 643 | 7.2 | 24 | 0 |
| Clear Creek - 060 | NEOGRD-060 | 25.3 | 3.45 | 42 | 144 | 346 | 7.6 | 17 | 0.448 |
| Delaware Creek - 150 | NEOGRD-150 | 39.5 | 1.21 | 16 | 147 | 540 | 7.2 | 66 | 0 |
| Double Spring Creek - 141 | NEOGRD-141 | 27.6 | 2.28 | 30 | 47 | 182 | 6.8 | 2.6 | 0.557 |
| Dry Creek - 140 | NEOGRD-140 | 32 | 5.97 | 81 | 158 | 702 | 7.9 | 20 | 0 |
| Fourmile Creek – 076 | NEOGRD-076 | 30.9 | 4.84 | | 73 | 290 | 7.2 | 7.87 | 0 |
| Hominy Creek - 09 | NEOGRD-009 | 26 | 4.94 | 61 | 121 | 743 | 7.6 | 12 | 16.88 |
| Hominy Creek - 148 | NEOGRD-148 | 19.8 | 8.71 | 95 | 94 | 306 | 7.7 | 21 | |
| Lightning Creek - 079 | NEOGRD-079 | 25.2 | 6.82 | 83 | 228 | 1529 | 7.6 | 13 | 0.463 |
| Little Cabin Creek - 075 | NEOGRD-075 | 27.9 | 1.2 | 15 | 104 | 290 | 7.2 | 16 | 0 |
| Little Saline Creek - 097 | NEOGRD-097 | 19 | 9.37 | 101 | 53 | 140 | 7.3 | 1.4 | 14.81 |
| Mingo Creek - 145 | NEOGRD-145 | 32.1 | 7.55 | 104 | 94 | 476 | 8 | 3.9 | 0.806 |
| Neosho River - 120 | NEOGRD-120 | 23.1 | 8 | 94 | 101 | 315 | 7.7 | 83 | 210 |
| North Fork Cotton Creek - 010 | NEOGRD-010 | 25.7 | 3.18 | 39 | 147 | 271 | 7.2 | 35 | 0 |
| Opossum Creek - 052 | NEOGRD-052 | 26.5 | 4.4 | 55 | 78 | 448 | 7.2 | 7.9 | 0.47 |
| Opossum Creek - 068 | NEOGRD-068 | 26.7 | 1.46 | 24 | 112 | 340 | 7.3 | 14 | 0.219 |
| Panther Creek - 011 | NEOGRD-011 | 24.3 | 6.25 | 74 | 135 | 1221 | 7.3 | 12 | 1.448 |
| Pawpaw Creek - 091 | NEOGRD-091 | 17 | 2.75 | 35 | 176 | 1890 | 7.4 | 49 | 0 |
| Pecan Creek - 016 | NEOGRD-016 | 24.3 | 5.8 | 70 | 125 | 283 | 7.2 | 7 | 0.356 |
| Pond Creek - 108 | NEOGRD-108 | 28 | 2.08 | 27 | 80 | 249 | 7.6 | 48 | 0 |
| Pryor Creek - 081 | NEOGRD-081 | 26.6 | 3.67 | 35 | 120 | 260 | 6.8 | 17 | 0 |

| Site Name | WBID | Water Temp (°C) | DO (mg/L) | Oxygen % Saturation | Alkalinity (CaCO3) | Conductivity (µS/cm) | pH (SU) | Turbidity (NTU) | Flow (cfs) |
|---|---|---|---|---|---|---|---|---|---|
| Pryor Creek - 115 | NEOGRD-115 | 27.5 | 3.75 | 50 | 86 | 227 | 6.3 | 37 | 0 |
| Pryor Creek - 146 | NEOGRD-146 | 26.9 | 4.47 | 55 | 78 | 428 | 7.1 | 8.2 | 5.378 |
| Rock Creek - 116 | NEOGRD-116 | 32.9 | 5.46 | 76 | 175 | 452 | 7.7 | 9.2 | 2.364 |
| Sand Creek - 025 | NEOGRD-025 | 30.5 | 6.44 | 87 | 87 | 330 | 7.5 | 41 | 0 |
| Spavinaw Creek - 074 | NEOGRD-074 | 22.9 | 11.21 | 130 | 98 | 244 | 7.7 | 1.9 | 115.6 |
| Spring Creek - 093 | NEOGRD-093 | 19.3 | 8.92 | 97 | 81 | 139 | 7.3 | 1.5 | 0.006 |
| Spring Creek - 122 | NEOGRD-122 | 25.4 | 7.87 | 98 | 103 | 232 | 7.3 | 2.3 | 4.387 |
| Verdigris River - 139 | NEOGRD-139 | 29.5 | 3.66 | 48 | 127 | 365 | 7.8 | 11 | 67.09 |
| West Fork Big Cabin Creek - 123 | NEOGRD-123 | 29.7 | 7.5 | 107 | 175 | 2661 | 7.7 | 7.1 | 0 |

**Table 10. Water quality values for Basin Group 1 Probabilistic Sites.**

| Site Name | WBID | Chloride (mg/L) | Sulfate (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrate (mg/L) | Nitrite (mg/L) | TKN (mg/L) | OrthoP (mg/L) | Total P (mg/L) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bevan Creek – 105 | NEOGRD-105 | 12.4 | 20.3 | 202 | 0.02 | 0.08 | < 0.02 | 0.44 | 0.015 | | < 10 |
| Big Cabin Creek - 042 | NEOGRD-042 | 7.4 | 783.90 | 1256 | < 0.015 | < 0.02 | < 0.02 | 1.37 | 0.009 | 0.073 | < 10 |
| Big Cabin Creek - 095 | NEOGRD-095 | 9.1 | 428.70 | 676 | < 0.015 | < 0.02 | < 0.02 | 0.85 | 0.015 | 0.078 | < 10 |
| Big Cabin Creek - 127 | NEOGRD-127 | 15.1 | 929.30 | 1165 | < 0.015 | 0.03 | < 0.02 | 0.86 | 0.009 | 0.041 | < 10 |
| Bird Creek - 013 | NEOGRD-013 | 37.9 | 13.10 | 167 | < 0.015 | < 0.02 | < 0.02 | 0.64 | 0.005 | 0.031 | < 10 |
| Bird Creek - 027 | NEOGRD-027 | 36.3 | 14.60 | 175 | < 0.015 | 0.06 | < 0.02 | 0.44 | 0.020 | 0.047 | < 10 |
| Bird Creek - 047 | NEOGRD-047 | 10.2 | 17.10 | 183 | < 0.015 | < 0.02 | < 0.02 | 0.50 | < 0.005 | 0.025 | < 10 |
| Bird Creek - 053 | NEOGRD-053 | 49.4 | 14.70 | 224 | < 0.015 | 0.06 | < 0.02 | 0.64 | 0.009 | 0.058 | < 10 |
| Bird Creek - 057 | NEOGRD-057 | 45.9 | 13.70 | 177 | 0.057 | 0.08 | < 0.02 | 0.78 | 0.036 | 0.1 | 59 |
| Bird Creek - 061 | NEOGRD-061 | 38.6 | 12.70 | 147 | 0.021 | 0.03 | < 0.02 | 0.53 | 0.010 | 0.046 | < 10 |
| Bird Creek - 069 | NEOGRD-069 | 41.3 | 14.70 | 173 | 0.028 | 0.12 | < 0.02 | 1.09 | 0.029 | 0.081 | 18 |
| Brush Creek - 040 | NEOGRD-040 | 7.6 | 5.60 | 113 | 0.043 | 0.52 | < 0.02 | 0.53 | 0.008 | 0.061 | < 10 |
| Brush Creek - 058 | NEOGRD-058 | 10.5 | 6.90 | 133 | < 0.015 | 1.36 | < 0.02 | < 0.11 | 0.015 | 0.02 | < 10 |
| Buck Creek - 045 | NEOGRD-045 | 5.3 | 26.00 | 177 | 0.021 | < 0.02 | < 0.02 | 0.40 | 0.007 | 0.02 | < 10 |
| Bull Creek - 107 | NEOGRD-107 | 20.5 | 41.10 | 235 | 0.842 | 0.11 | < 0.02 | 1.91 | 0.242 | 0.302 | < 10 |
| Candy Creek - 026 | NEOGRD-026 | 27.9 | 37.40 | 169 | 0.016 | < 0.02 | < 0.02 | 0.57 | 0.005 | 0.024 | < 10 |
| Caney River - 021 | NEOGRD-021 | 51.5 | 59.20 | 304 | < 0.015 | 0.07 | < 0.02 | 1.00 | 0.014 | 0.044 | 13 |
| Caney River - 080 | NEOGRD-080 | 60.6 | 16.50 | 324 | < 0.015 | < 0.02 | < 0.02 | 0.64 | 0.010 | 0.059 | 12 |
| Caney River - 131 | NEOGRD-131 | 64.3 | 17.30 | 330 | < 0.015 | 0.40 | < 0.02 | 1.49 | 0.059 | 0.164 | 38 |
| Chouteau Creek - 024 | NEOGRD-024 | 29.8 | 102.00 | 423 | 0.105 | < 0.02 | < 0.02 | 1.04 | 0.059 | 0.132 | 14 |
| Clear Creek - 060 | NEOGRD-060 | 8.3 | 21.20 | 226 | 0.021 | < 0.02 | < 0.02 | 0.77 | 0.007 | 0.038 | < 10 |
| Delaware Creek - 150 | NEOGRD-150 | 50.2 | 25.10 | 300 | < 0.015 | 0.07 | < 0.02 | 0.95 | 0.013 | 0.103 | < 10 |

| Site Name | WBID | Chloride (mg/L) | Sulfate (mg/L) | TDS (mg/L) | Ammonia (mg/L) | Nitrate (mg/L) | Nitrite (mg/L) | TKN (mg/L) | OrthoP (mg/L) | Total P (mg/L) | TSS (mg/L) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Double Spring Creek - 141 | NEOGRD-141 | 6.5 | 11.20 | 103 | < 0.015 | 0.07 | < 0.02 | 0.19 | 0.059 | 0.084 | < 10 |
| Dry Creek - 140 | NEOGRD-140 | 131.6 | 13.40 | 438 | 0.026 | 0.06 | < 0.02 | 1.51 | 0.005 | 0.038 | < 10 |
| Fourmile Creek – 076 | NEOGRD-076 | 22.4 | 13.50 | 168 | 0.048 | 0.02 | < 0.02 | 0.95 | 0.014 | 0.059 | 10 |
| Hominy Creek - 09 | NEOGRD-009 | 137.5 | 23.20 | 429 | 0.029 | < 0.02 | < 0.02 | 0.54 | 0.008 | 0.02 | < 10 |
| Hominy Creek - 148 | NEOGRD-148 | 36.0 | 12.90 | 160 | 0.163 | 0.09 | 0.1 | 0.53 | 0.036 | 0.04 | 24 |
| Lightning Creek - 079 | NEOGRD-079 | 3.5 | 1166.40 | 2084 | < 0.015 | < 0.02 | < 0.02 | 0.64 | 0.012 | 0.015 | < 10 |
| Little Cabin Creek - 075 | NEOGRD-075 | 7.4 | 42.80 | 151 | < 0.015 | < 0.02 | < 0.02 | 0.77 | 0.025 | 0.077 | < 10 |
| Little Saline Creek - 097 | NEOGRD-097 | 6.7 | 4.30 | 103 | < 0.015 | 0.85 | < 0.02 | < 0.11 | 0.009 | 0.015 | < 10 |
| Mingo Creek - 145 | NEOGRD-145 | 30.2 | 72.30 | 330 | 0.095 | 0.59 | < 0.02 | 1.43 | 0.038 | 0.067 | < 10 |
| Neosho River - 120 | NEOGRD-120 | 8.0 | 70.50 | 205 | 0.070 | 0.85 | < 0.02 | 1.18 | 0.112 | 0.248 | 45 |
| North Fork Cotton Creek - 010 | NEOGRD-010 | 3.4 | 14.30 | 166 | 0.049 | < 0.02 | < 0.02 | 1.20 | 0.014 | 0.075 | < 10 |
| Opossum Creek - 052 | NEOGRD-052 | 61.5 | 19.50 | 242 | 0.115 | 0.03 | < 0.02 | 0.82 | 0.024 | 0.4 | 12 |
| Opossum Creek - 068 | NEOGRD-068 | 12.9 | 11.70 | 149 | 0.026 | < 0.02 | < 0.02 | 0.92 | 0.013 | 0.064 | < 10 |
| Panther Creek - 011 | NEOGRD-011 | 5.2 | 657.80 | 1059 | 0.026 | 0.05 | < 0.02 | 0.41 | 0.021 | 0.02 | < 10 |
| Pawpaw Creek - 091 | NEOGRD-091 | 7.7 | 1039.70 | 1660 | < 0.015 | < 0.02 | < 0.02 | 0.50 | 0.017 | 0.035 | 14 |
| Pecan Creek - 016 | NEOGRD-016 | 3.6 | 5.20 | 169 | 0.021 | 0.29 | < 0.02 | 0.46 | 0.021 | 0.055 | < 10 |
| Pond Creek - 108 | NEOGRD-108 | 15.4 | 6.40 | 219 | 0.020 | < 0.02 | < 0.02 | 1.63 | 0.011 | 0.105 | < 10 |
| Pryor Creek - 081 | NEOGRD-081 | 18.8 | 31.50 | 152 | 0.075 | 0.24 | < 0.02 | 0.56 | 0.040 | 0.063 | < 10 |
| Pryor Creek - 115 | NEOGRD-115 | 15.6 | 13.20 | 150 | 0.194 | < 0.02 | < 0.02 | 1.09 | 0.016 | 0.066 | < 10 |
| Pryor Creek - 146 | NEOGRD-146 | 30.4 | 73.60 | 263 | 0.085 | 1.67 | 0.5 | 1.49 | 1.796 | 1.792 | < 10 |
| Rock Creek - 116 | NEOGRD-116 | 32.0 | 11.50 | 256 | 0.039 | 0.03 | < 0.02 | 0.87 | < 0.005 | 0.045 | < 10 |
| Sand Creek - 025 | NEOGRD-025 | 41.7 | 10.80 | 178 | 0.061 | < 0.02 | < 0.02 | 2.31 | 0.008 | 0.127 | 15 |
| Spavinaw Creek - 074 | NEOGRD-074 | 9.2 | 7.70 | 137 | 0.015 | 3.55 | < 0.02 | < 0.11 | 0.037 | 0.034 | < 10 |
| Spring Creek - 093 | NEOGRD-093 | 6.3 | 5.00 | 100 | < 0.015 | 0.49 | < 0.02 | < 0.11 | 0.010 | 0.007 | < 10 |
| Spring Creek - 122 | NEOGRD-122 | 13.3 | 53.30 | 141 | < 0.015 | 0.77 | < 0.02 | 0.42 | 0.027 | 0.033 | < 10 |
| Verdigris River - 139 | NEOGRD-139 | 20.6 | 25.50 | 192 | 0.058 | < 0.02 | < 0.02 | 0.91 | 0.009 | 0.06 | < 10 |
| West Fork Big Cabin Creek - 123 | NEOGRD-123 | 7.5 | 1488.40 | 2151 | < 0.015 | < 0.02 | < 0.02 | 0.91 | 0.010 | 0.087 | < 10 |

Of particular significance for discussion, multiple streams in the Neosho-Grand and Upper Canadian basins exhibited markedly low dissolved oxygen concentrations. Table 11 (below) reflects the DO values[1] and their total percentage with the designated use criteria for each site. Twenty-eight of the fixed sites are designated as Warm Water Aquatic Communities (WWAC) and have a critical DO level of 5.0 mg/L most of the year (4.0 mg/L from June 16-October 15). Three of the sites are designated as Cool Water Aquatic Communities (CWAC), with a critical DO level of 6.0 mg/L most of the year (5.0 mg/L from June 1-October 15). Tar Creek and Trail Creek are designated as Habitat Limited Aquatic Community. Ten sites (including all three

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

designated as CWAC ) exhibited dissolved oxygen levels which were always above criteria values: Big Creek, Bird Creek, Commission Creek, Deer Creek, Fivemile Creek, Fourteenmile Creek, Lightning Creek, Red Creek, Sycamore Creek, and Tar Creek. Seven sites were consistently above the criteria levels: Delaware Creek, Hominy Creek, Lone Creek, Ranger Creek, Sand Creek, Walnut Creek, and Willow Creek. The 13 sites (39% of the fixed sites) with more than 10% of the samples below the criteria are considered impaired and have been included on the state's pending 2014 303(d) list.

Twenty-five percent of the probabilistic sites had DO values (in Table 9) below the appropriate WWAC or CWAC standard. These sites were monitored during a severe drought this cycle, and often there was little or no flow. These conditions may be affecting the dissolved oxygen results.

**Table 11. Low dissolved oxygen values at fixed monitoring sites (based on OAC 785:46-15; OWRB 2011).**

| % Samples with Low DO | Site Name | WBID | FWP | Date | DO (mg/L) |
|---|---|---|---|---|---|
| 32% | Buck Creek | OK121400-03-0170C | WWAC | 7/11/11 | 2.59 |
| | | | | 8/15/11 | 2.36 |
| | | | | 9/19/11 | 3.70 |
| | | | | 9/10/12 | 4.00 |
| | | | | 10/22/12 | 2.33 |
| | | | | 11/26/12 | 4.50 |
| 11% | Buggy Creek | OK520610-02-0120C | WWAC | 6/25/12 | 3.38 |
| | | | | 8/14/12 | 1.77 |
| 24% | Bull Creek | OK121500-02-0090D | WWAC | 10/25/11 | 4.71 |
| | | | | 7/9/12 | 2.62 |
| | | | | 8/7/12 | 2.44 |
| | | | | 9/11/12 | 3.70 |
| | | | | 10/16/12 | 3.49 |
| 30% | California Creek | OK121510-02-0050C | WWAC | 10/25/11 | 1.43 |
| | | | | 9/11/12 | 3.70 |
| | | | | 10/23/12 | 1.14 |
| | | | | 11/27/12 | 1.30 |
| | | | | 1/8/13 | 0.55 |
| | | | | 2/4/13 | 2.09 |
| 48% | Chouteau Creek | OK121600-01-0430P | WWAC | 6/13/11 | 3.04 |
| | | | | 6/14/11 | 2.76 |
| | | | | 7/12/11 | 2.97 |
| | | | | 8/16/11 | 2.83 |
| | | | | 9/20/11 | 3.73 |
| | | | | 10/25/11 | 4.80 |
| | | | | 5/30/12 | 2.17 |
| | | | | 7/9/12 | 2.62 |
| | Choteau Creek | (continued) | | 8/7/12 | 2.48 |
| | | | | 10/16/12 | 3.02 |
| 47% | Curl Creek | OK121400-01-0270C | WWAC | 6/7/11 | 4.40 |
| | | | | 6/13/11 | 4.64 |
| | | | | 7/12/11 | 3.58 |
| | | | | 10/25/11 | 4.88 |
| | | | | 7/10/12 | 3.66 |
| | | | | 8/7/12 | 3.78 |
| | | | | 10/23/12 | 0.95 |
| | | | | 11/27/12 | 0.59 |
| | | | | 1/8/13 | 0.72 |
| 10% | Delaware Creek | OK121300-01-0150H | WWAC | 6/1/11 | 3.16 |
| | | | | 10/22/12 | 2.28 |
| 55% | Dog Creek | OK121500-04-0010M | WWAC | 7/6/11 | 2.99 |
| | | | | 7/12/11 | 3.13 |
| | | | | 8/16/11 | 2.36 |
| | | | | 9/20/11 | 2.97 |
| | | | | 10/25/11 | 3.62 |
| | | | | 5/30/12 | 2.87 |
| | | | | 7/9/12 | 1.57 |
| | | | | 8/7/12 | 1.74 |
| | | | | 9/11/12 | 3.66 |
| | | | | 10/16/12 | 3.11 |
| | | | | 11/26/12 | 3.41 |
| 50% | Hackberry Creek | OK520620-04-0050D | WWAC | 4/30/12 | 4.70 |
| 55% | Hogshooter Creek | OK121400-01-0300D | WWAC | 7/12/11 | 2.04 |
| | | | | 8/16/11 | 3.24 |

| % Samples with Low DO | Site Name | WBID | FWP | Date | DO (mg/L) |
|---|---|---|---|---|---|
| | Hogshooter Creek | (continued) | | 10/25/11 | 2.18 |
| | | | | 12/7/11 | 0.60 |
| | | | | 2/14/12 | 4.14 |
| | | | | 7/10/12 | 3.21 |
| | | | | 9/11/12 | 3.03 |
| | | | | 10/23/12 | 0.40 |
| | | | | 11/27/12 | 0.54 |
| | | | | 1/8/13 | 2.76 |
| | | | | 2/4/13 | 1.60 |
| 10% | Hominy Creek | OK121300-04-0280G | WWAC | 6/6/11 | 4.99 |
| | | | | 10/22/12 | 4.28 |
| 55% | Little Cabin Creek | OK121600-06-0080C | WWAC | 6/6/11 | 4.07 |
| | | | | 7/11/11 | 3.05 |
| | | | | 7/26/11 | 3.60 |
| | | | | 8/15/11 | 2.33 |
| | | | | 9/19/11 | 2.73 |
| | | | | 10/24/11 | 4.34 |
| | | | | 3/19/12 | 4.88 |
| | | | | 5/29/12 | 3.62 |
| | | | | 8/6/12 | 3.01 |
| | | | | 9/10/12 | 1.91 |
| | | | | 11/27/12 | 2.20 |
| 45% | Little Horse Creek | OK121600-03-0190A | WWAC | 6/6/11 | 4.28 |
| | | | | 7/11/11 | 2.23 |

| % Samples with Low DO | Site Name | WBID | FWP | Date | DO (mg/L) |
|---|---|---|---|---|---|
| | Little Horse Creek | (Continued) | | 8/15/11 | 1.25 |
| | | | | 3/19/12 | 2.32 |
| | | | | 5/28/12 | 2.45 |
| | | | | 7/10/12 | 2.72 |
| | | | | 8/6/12 | 1.85 |
| | | | | 11/27/12 | 4.18 |
| | | | | 1/7/13 | 4.35 |
| 8% | Lone Creek | OK520620-03-0020C | WWAC | 10/23/12 | 4.73 |
| 38% | Pryor Creek | OK121610-00-0050D | WWAC | 7/12/11 | 3.56 |
| | | | | 8/16/11 | 2.04 |
| | | | | 10/25/11 | 3.81 |
| | | | | 7/9/12 | 1.48 |
| | | | | 8/7/12 | 3.71 |
| | | | | 9/11/12 | 3.16 |
| | | | | 11/26/12 | 4.27 |
| | | | | 1/8/13 | 4.87 |
| 5% | Ranger Creek | OK121600-01-0060D | WWAC | 7/25/11 | 3.42 |
| 5% | Sand Creek | OK121400-04-0010F | WWAC | 6/15/11 | 4.69 |
| 15% | Trail Creek | OK520620-02-0090G | WWAC | 8/13/12 | 3.60 |
| | | | | 9/17/12 | 2.74 |
| | | | | 10/23/12 | 0.88 |
| 5% | Walnut Creek | OK520610-03-0010F | WWAC | 7/14/11 | 3.28 |
| 10% | Willow Creek | OK520610-01-0080H | WWAC | 7/7/11 | 3.92 |
| | | | | 10/22/12 | 3.44 |

Table 12 shows the geometric mean of *E. coli* bacteria samples for each site over the two-year monitoring period and the geometric mean of *Enterococcus* samples for 2012 only; beginning in the summer of 2013, *Enterococcus* was no longer assessed. Creeks highlighted in yellow are designated Secondary Body Contact Recreation (SBCR), which allows for a higher bacteria concentration: Tar Creek and Trail Creek. All other sites are designated Primary Body Contact Recreation (PBCR). Most creeks exceeded the geometric mean criterion set for *Enterococcus*, and 10% exceeded the criterion for *E. coli*. Eleven creeks did not exceed either the *E. coli* or *Enterococcus* criteria. To be listed on the state's 303(d) list, the geometric mean must exceed the set criteria for at least one of the bacteria types (OWRB 2011).

**Table 12. Geometric mean of bacteria values for Basin Group 1 fixed monitoring sites, 2011-2013 OCC data. An asterisk (*) indicates that the stream meets state standards for that bacteria type. Many streams are impaired by bacteria, and these streams either will be added to the state 303(d) list, are currently on the 303(d) list, or have been moved to Category 4 for bacteria after a TMDL has been produced. Those highlighted in yellow have a SBCR designation, allowing higher bacteria concentrations.**

| Site Name | WBID | *E. coli* | *Enterococcus* | *Comments* |
|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | 57.71 * | 42.53 | Geometric Mean |
| Bird Creek | OK121300-02-0010C | 10.51 * | 18.45* | Geometric Mean |
| Buck Creek | OK121400-03-0170C | 10.99 * | 31.38* | Geometric Mean |
| Buggy Creek | OK520610-02-0120C | 133.76 | 256.34 | Geometric Mean |
| Bull Creek | OK121500-02-0090D | 22.04 * | 21.27* | Geometric Mean |
| California Creek | OK121510-02-0050C | 36.43 * | 47.13 | Geometric Mean |
| Chouteau Creek | OK121600-01-0430P | 38.38 * | 74.60 | Geometric Mean |
| Commission Creek | OK520620-05-0160C | 49.96 * | 232.59 | Geometric Mean |
| Curl Creek | OK121400-01-0270C | 31.35 * | 64.07 | Geometric Mean |
| Deer Creek | OK520620-06-0010F | 22.30 * | 88.48 | Geometric Mean |
| Delaware Creek | OK121300-01-0150H | 12.13 * | 39.35 | Geometric Mean |
| Dog Creek | OK121500-04-0010M | 8.38 * | 24.43* | Geometric Mean |
| Fivemile Creek | OK121600-07-0110G | 12.84 * | 12.46* | Geometric Mean |
| Fourteenmile Creek | OK121600-01-0100G | 7.30 * | 11.76* | Geometric Mean |
| Hackberry Creek | OK520620-04-0050D | 760.00 | | Single Value |

| Site Name | WBID | *E. coli* | *Enterococcus* | *Comments* |
|---|---|---|---|---|
| Hogshooter Creek | OK121400-01-0300D | 107.02 * | 79.77 | Geometric Mean |
| Hominy Creek | OK121300-04-0280G | 34.95 * | 45.26 | Geometric Mean |
| Lightning Creek | OK121510-01-0130N | 13.35 * | 32.91* | Geometric Mean |
| Little Cabin Creek | OK121600-06-0080C | 40.51 * | 42.61 | Geometric Mean |
| Little Horse Creek | OK121600-03-0190A | 153.39 | 25.61* | Geometric Mean |
| Lone Creek | OK520620-03-0020C | 110.68 * | | Geometric Mean |
| Pryor Creek | OK121610-00-0050D | 20.32 * | 79.93 | Geometric Mean |
| Ranger Creek | OK121600-01-0060D | 13.13 * | 8.48* | Geometric Mean |
| Red Creek | OK520620-03-0110F | 50.00 * | | Single Value |
| Sand Creek | OK121400-04-0010F | 70.47 * | 77.62 | Geometric Mean |
| Sycamore Creek | OK121600-03-0510D | 32.93 * | 8.91* | Geometric Mean |
| Tar Creek | OK121600-04-0060D | 222.33 * | 44.30* | Geometric Mean |
| Trail Creek | OK520620-02-0090G | 45.60 * | 72.19* | Geometric Mean |
| Walnut Creek | OK520610-03-0010F | 45.55 * | 137.50 | Geometric Mean |
| Willow Creek | OK520610-01-0080H | 71.49 * | 305.63 | Geometric Mean |

Based on a single grab sample at each of the probabilistic sites (results in Table 13, below), the geometric mean of the probabilistic sites is 20.4 colonies per 100 mL for *E. coli* and 30.5 colonies per 100 mL for *Enterococcus*. This indicates that streams in this basin are attaining for both *E. coli* bacteria (standard is 126 colonies/100 mL) and *Enterococcus* bacteria (standard is 33 colonies/100 mL). It should be noted that all the probabilistic samples were taken at base flow, whereas samples at fixed sites are taken regardless of flow, which could result in higher bacteria levels being observed at the fixed sites.

**Table 13. Bacteria values for probabilistic sites.**

| Site Name | WBID | *E. coli* | *Enterococcus* | Comments |
|---|---|---|---|---|
| Bevan Creek – 105 | NEOGRD-105 | 580 | 320 | One-time sample |
| Big Cabin Creek - 042 | NEOGRD-042 | 375 | 90 | One-time sample |
| Big Cabin Creek - 095 | NEOGRD-095 | 10 * | 5 * | One-time sample |
| Big Cabin Creek - 127 | NEOGRD-127 | 155 | 175 | One-time sample |
| Bird Creek - 013 | NEOGRD-013 | 275 | 20 * | One-time sample |
| Bird Creek - 027 | NEOGRD-027 | 40 * | 55 | One-time sample |
| Bird Creek - 047 | NEOGRD-047 | < 5 * | 5 * | One-time sample |
| Bird Creek - 053 | NEOGRD-053 | < 5 * | < 5 * | One-time sample |
| Bird Creek - 057 | NEOGRD-057 | 315 | 270 | One-time sample |
| Bird Creek - 061 | NEOGRD-061 | 40 * | 40 | One-time sample |
| Bird Creek - 069 | NEOGRD-069 | 25 * | 15 * | One-time sample |
| Brush Creek - 040 | NEOGRD-040 | 5 * | 10 * | One-time sample |
| Brush Creek - 058 | NEOGRD-058 | < 5 * | 30 * | One-time sample |
| Buck Creek - 045 | NEOGRD-045 | < 5 * | 20 * | One-time sample |
| Bull Creek - 107 | NEOGRD-107 | 120 * | 95 | One-time sample |
| Candy Creek - 026 | NEOGRD-026 | 5 * | 5 * | One-time sample |
| Caney River - 021 | NEOGRD-021 | 5 * | 55 | One-time sample |
| Caney River - 131 | NEOGRD-131 | 30 * | 130 | One-time sample |
| Chouteau Creek - 024 | NEOGRD-024 | < 5 * | 5 * | One-time sample |
| Clear Creek - 060 | NEOGRD-060 | < 5 * | 25 * | One-time sample |
| Delaware Creek - 150 | NEOGRD-150 | 35 * | 25 * | One-time sample |
| Double Spring Creek - 141 | NEOGRD-141 | < 5 * | 25 * | One-time sample |
| Dry Creek - 140 | NEOGRD-140 | 5 * | 5 * | One-time sample |
| Hominy Creek - 09 | NEOGRD-009 | < 5 * | 45 | One-time sample |
| Hominy Creek - 148 | NEOGRD-148 | 55 * | 65 | One-time sample |
| Lightning Creek - 079 | NEOGRD-079 | 45 * | 5 * | One-time sample |
| Little Cabin Creek - 075 | NEOGRD-075 | 5 * | 25 * | One-time sample |
| Little Saline Creek - 097 | NEOGRD-097 | 15 * | < 5 * | One-time sample |
| Mingo Creek - 145 | NEOGRD-145 | 85 * | 110 | One-time sample |
| Neosho River - 120 | NEOGRD-120 | 1650 | 1250 | One-time sample |
| North Fork Cotton Creek | NEOGRD-010 | 60 * | 60 | One-time sample |
| Opossum Creek - 052 | NEOGRD-052 | 10 * | 5 * | One-time sample |
| Opossum Creek - 068 | NEOGRD-068 | 180 | 15 * | One-time sample |
| Panther Creek - 011 | NEOGRD-011 | < 5 * | 120 | One-time sample |
| Pawpaw Creek - 091 | NEOGRD-091 | 40 * | 30 * | One-time sample |
| Pecan Creek - 016 | NEOGRD-016 | 70 * | 590 | One-time sample |
| Pond Creek - 108 | NEOGRD-108 | < 5 * | 245 | One-time sample |
| Pryor Creek - 081 | NEOGRD-081 | 65 * | 155 | One-time sample |
| Pryor Creek - 115 | NEOGRD-115 | 10 * | 45 | One-time sample |
| Pryor Creek - 146 | NEOGRD-146 | 80 * | 5 * | One-time sample |
| Rock Creek - 116 | NEOGRD-116 | < 5 * | 15 * | One-time sample |
| Sand Creek - 025 | NEOGRD-025 | < 5 * | 15 * | One-time sample |
| Spavinaw Creek - 074 | NEOGRD-074 | < 5 * | 10 * | One-time sample |
| Spring Creek - 093 | NEOGRD-093 | < 5 * | 10 * | One-time sample |
| Spring Creek - 122 | NEOGRD-122 | 15 * | 70 | One-time sample |
| Verdigris River - 139 | NEOGRD-139 | 65 * | 10 * | One-time sample |
| West Fork Big Cabin Creek | NEOGRD-123 | < 5 * | 195 | One-time sample |

Select water quality parameters are summarized by box plots in Figures 2 and 3, 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 to determine general stream condition. Figure 2 shows interquartile range plots by site for four important nutrients as indicators of pollution: orthophosphorus, total phosphorus, estimated available nitrogen (ammonia plus nitrate/nitrite), and estimated total nitrogen (TKN plus nitrate/nitrite). The probabilistic samples were composited by ecoregion as if they were samples from a single site in order to show the range and mean of those sites. These values are shown in each boxplot labeled "probabilistic."

Regarding boxplot composition, the median of each site is shown by a line within the box with most outliers denoted by asterisks. The extreme outliers are denoted by values within 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 or the upper value was above the graph. On the dissolved oxygen % saturation charts a green line indicates 80% or 130% saturation and a red line indicates 50% or 150% saturation. For ecoregions where the high quality sites fall outside the standard saturation, the high quality data is shown in addition to the red and green lines.

In the Central Great Plains, Deer Creek had higher orthophosphorus values than the high quality sites. Hackberry and Red Creeks each had only one data point due to drought conditions. While Hackberry Creek shows high orthophosphorus and total phosphorus, these single points are similar to the highest values in the other streams. Streams in the Central Irregular Plains had many high outliers, but most of the values were well within 95% of the high quality sites.

**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). Red and Hackberry Creeks were only sampled once due to drought conditions.**

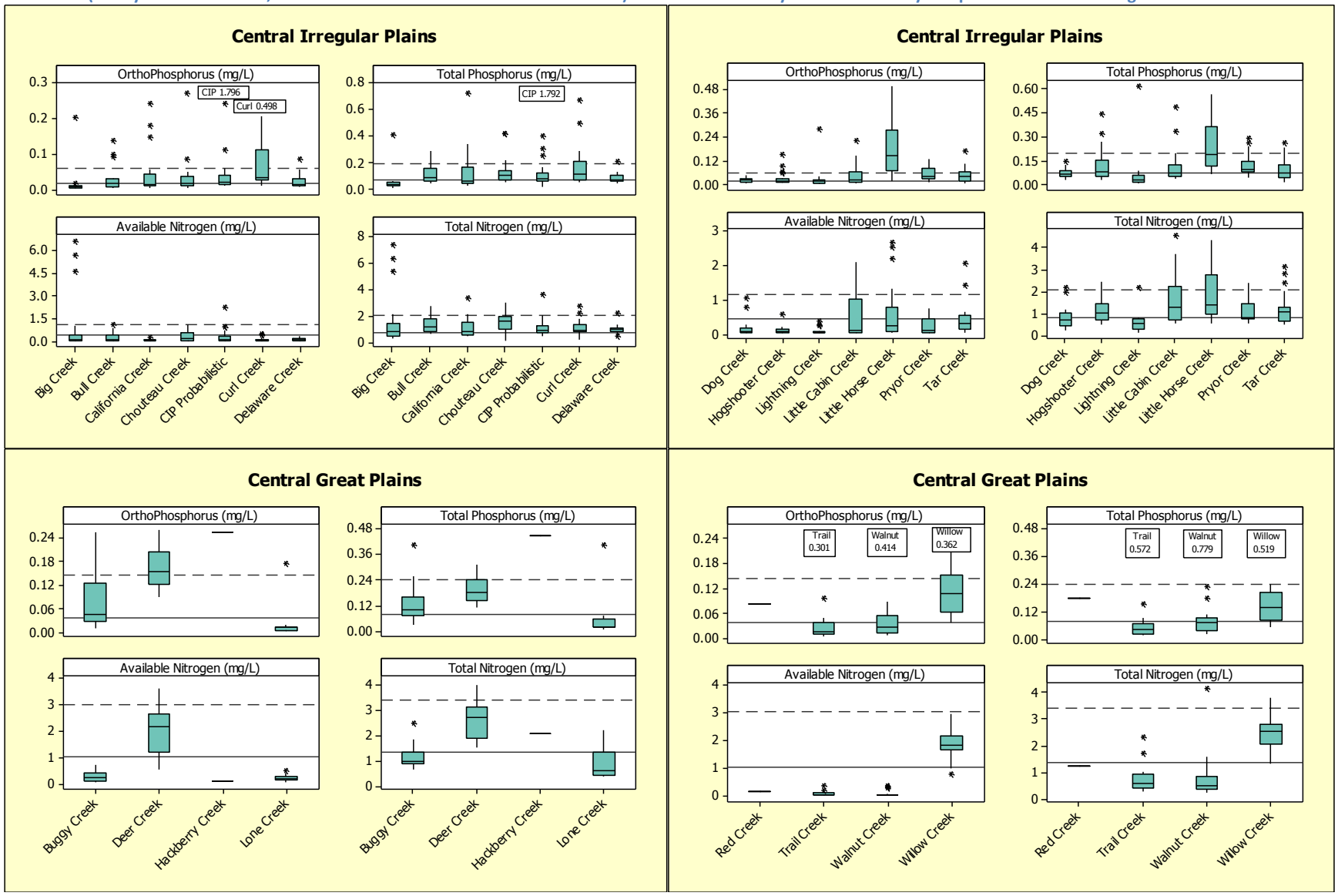


**Figure 2 , cont. Select nutrients for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero).**

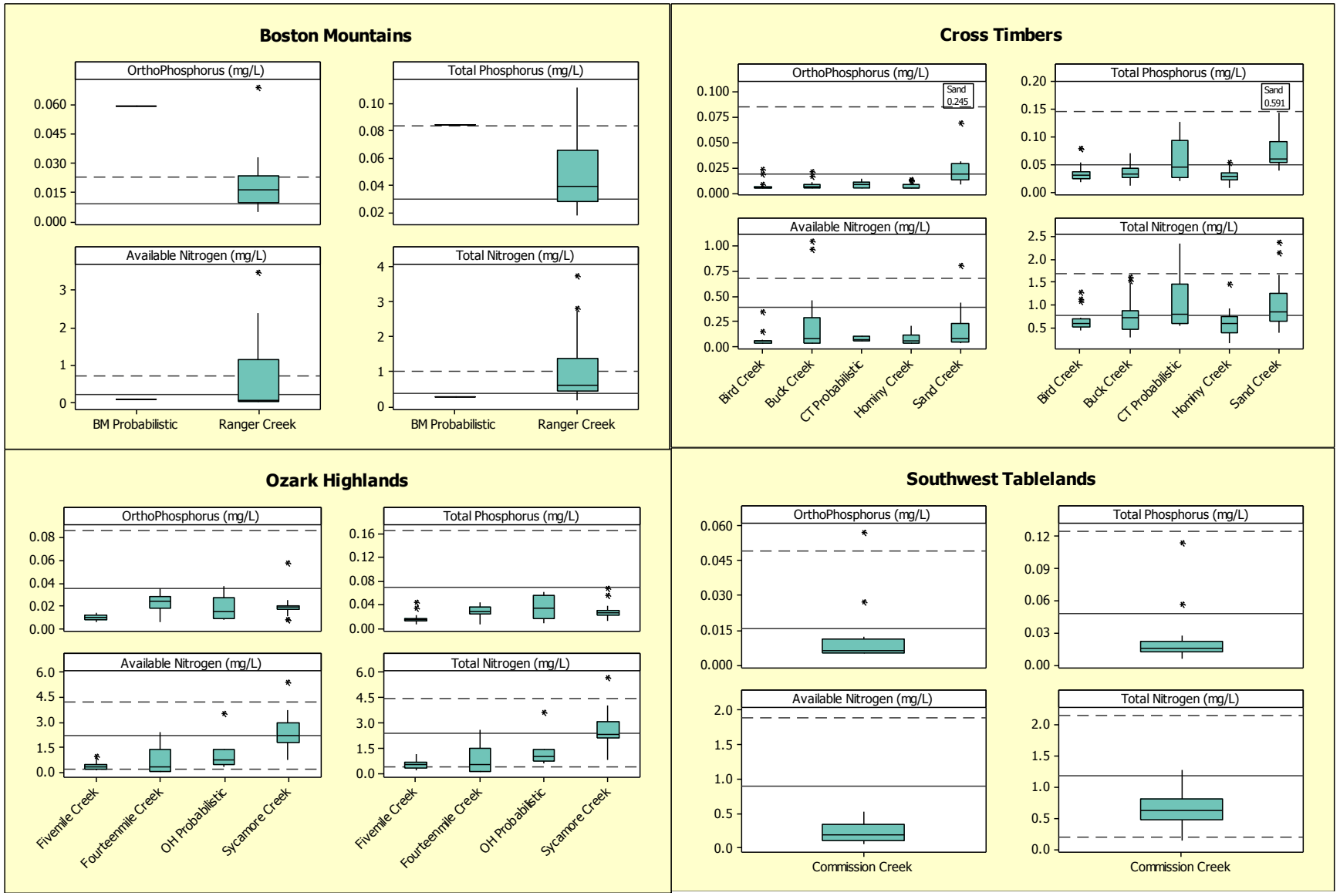


Figure 3 shows interquartile range plots for four physical parameters: dissolved oxygen (percent saturation), pH, turbidity, and total suspended solids. The Central Irregular Plains and Cross Timbers ecoregions have high quality sites with oxygen saturations lower than the other ecoregions included in these basins. In these two ecoregions the charts show both the "rule of thumb" reference lines and the lines marking +/- two standard deviations from the high quality mean. This helps show that while the oxygen saturation in the sites in these ecoregions is slightly low, they still fall within 95% of the high quality sites. Hackberry Creek and Red Creek in the Central Great Plains show high values for turbidity and total suspended solids, but as mentioned before, only a single reading was obtained at these two sites because of drought.

**Figure 3. Select physical parameters for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dashed line, the lower standard deviation was below zero). DO % saturation charts use a green line to indicate 80% and a red line to indicate 50% DO saturation.**

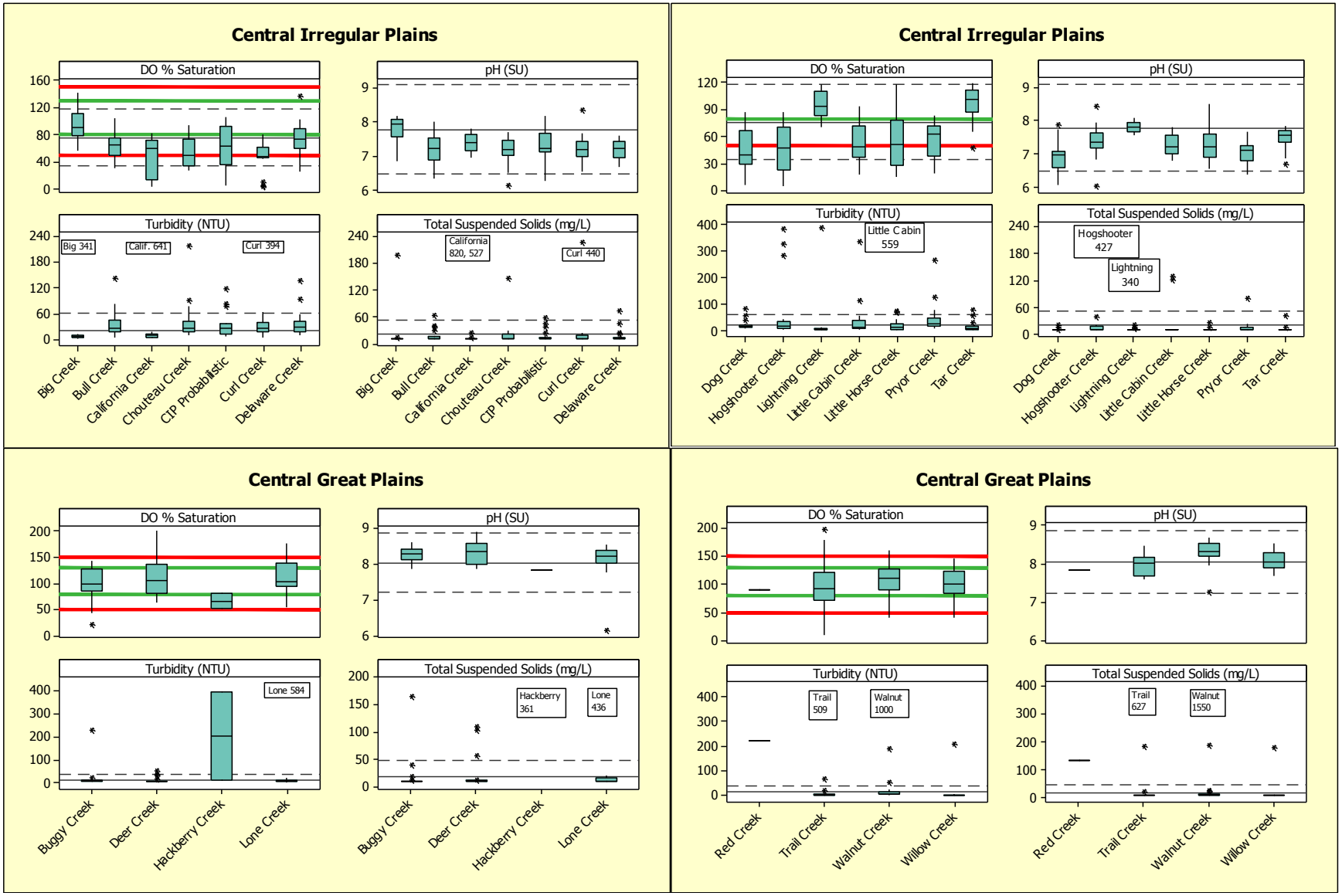


**Figure 3 , cont. Select parameters for each site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations (if only one dash line, the lower standard deviation was below zero). DO % saturation charts use a green line to indicate 80% and a red line to indicate 50% DO saturation.**

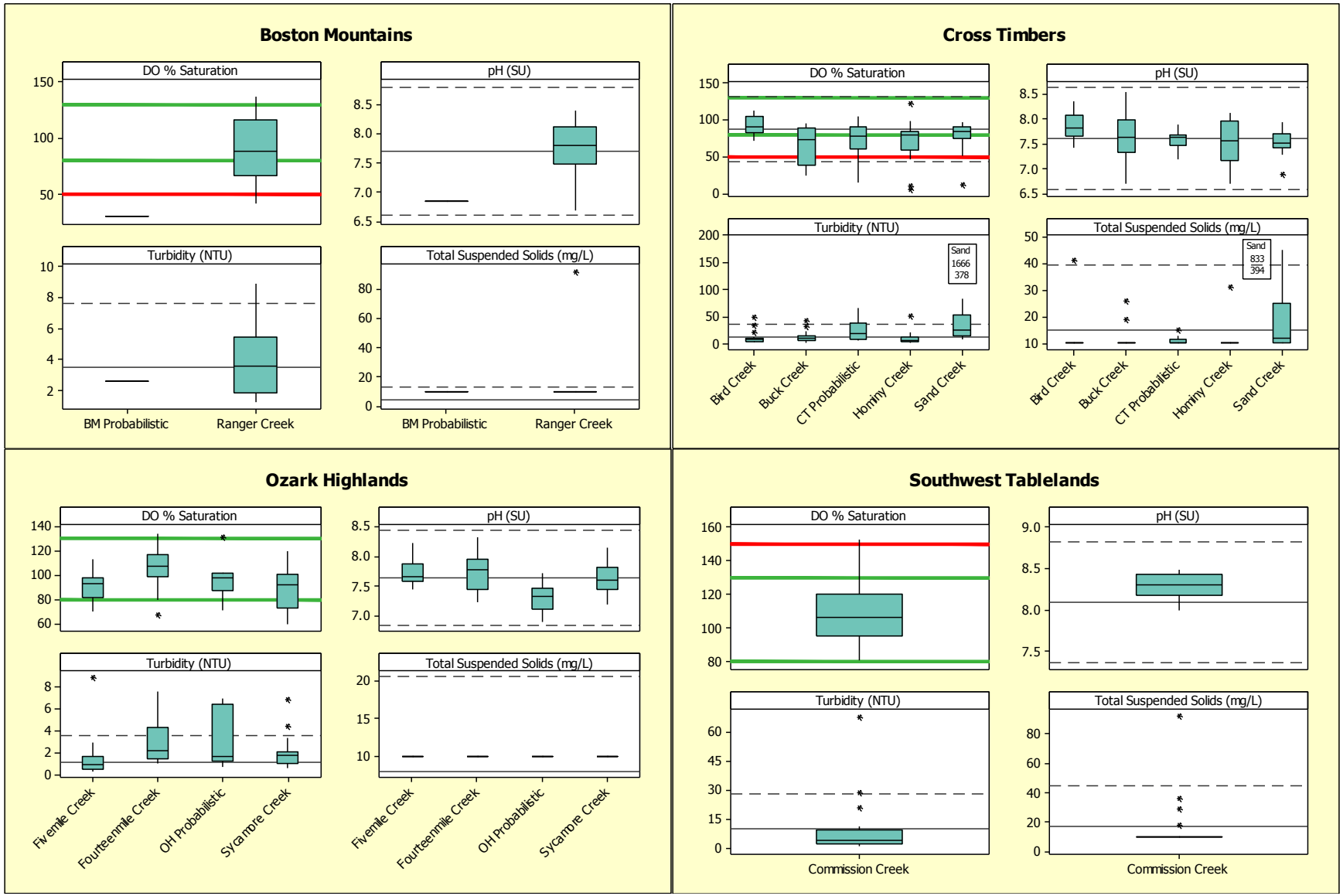


Table 14 shows a comparison between base flow water quality data collected for the same site in the previous rotating basin cycles and the third cycle in order to examine whether water conditions have improved, worsened, or remained the same at a particular site. One-way ANOVAs were performed for each set of data. Only statistically significant differences between the means of each parameter 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.

Six streams had significantly higher levels of dissolved oxygen (DO), but ten streams had reduced DO. Ammonia was increased in five streams and other forms of nitrogen were significantly increased in 15 streams. Six streams showed significant decreases in nitrogen. Many streams showed increases in total Kjeldahl nitrogen (TKN) and decreases in nitrate/nitrite nitrogen. Phosphorus decreased in eight streams. Turbidity and/or total suspended solids (TSS) was significantly lower in one stream; alkalinity and/or hardness was significantly higher in 16 streams and reduced in one streams; nine streams exhibited increased salt concentrations (sulfate, chloride, or total dissolved solids) while four show lower salt concentrations. Low flow conditions during this third monitoring cycle likely influenced some of these significant differences, particularly the increases in alkalinity, hardness, and minerals.

**Table 14. Statistical comparisons of cycles one, two and three 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.**

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | DO % Saturation | 2001-2002 | 20 | 72.25 | 18.41 | 0.005 * | |
| | | | 2006-2007 | 19 | 78.55 | 16.68 | | |
| | | | 2011-2013 | 20 | 92.50 | 21.90 | | |
| | | Ammonia | 2001-2002 | 20 | 0.14 | 0.20 | 0.018 * | |
| | | | 2006-2007 | 19 | 0.02 | 0.03 | | |
| | | | 2011-2013 | 9 | 0.04 | 0.04 | | |
| | | TKN | 2001-2002 | 20 | 0.54 | 0.56 | 0.040 * | |
| | | | 2006-2007 | 19 | 0.35 | 0.27 | | |
| | | | 2011-2013 | 20 | 0.71 | 0.37 | | |
| | | Nitrite | 2001-2002 | 20 | 0.07 | 0.09 | 0.037 * | |
| | | | 2006-2007 | 19 | 0.03 | 0.02 | | |
| | | | 2011-2013 | 20 | 0.03 | 0.02 | | |
| | | Total N | 2001-2002 | 20 | 0.98 | 0.67 | 0.061 | |
| | | | 2006-2007 | 19 | 0.69 | 0.57 | | |
| | | | 2011-2013 | 20 | 1.69 | 2.11 | | |
| | | Alkalinity | 2001-2002 | 20 | 110.80 | 32.83 | 0.021 * | |
| | | | 2006-2007 | 19 | 144.58 | 47.26 | | |
| | | | 2011-2013 | 21 | 141.00 | 41.15 | | |
| | | Flow | 2001-2002 | 20 | 14.71 | 29.53 | 0.026 * | |
| | | | 2006-2007 | 15 | 34.48 | 42.93 | | |
| | | | 2011-2013 | 21 | 7.26 | 11.60 | | |
| Bird Creek | OK121300-02-0010C | Ammonia | 2001-2002 | 19 | 0.12 | 0.16 | 0.007 * | |
| | | | 2006-2007 | 20 | 0.02 | 0.03 | | |
| | | | 2011-2013 | 9 | 0.02 | 0.00 | | |
| | | Nitrate | 2001-2002 | 19 | 0.39 | 0.29 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.12 | 0.12 | | |
| | | | 2011-2013 | 20 | 0.04 | 0.07 | | |
| | | Total N | 2001-2002 | 19 | 1.00 | 0.77 | 0.052 | |
| | | | 2006-2007 | 20 | 0.56 | 0.59 | | |
| | | | 2011-2013 | 20 | 0.66 | 0.23 | | |
| | | Available N | 2001-2002 | 19 | 0.54 | 0.42 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.16 | 0.13 | | |
| | | | 2011-2013 | 20 | 0.07 | 0.07 | | |
| | | Alkalinity | 2001-2002 | 19 | 65.47 | 26.45 | 0.002 * | |
| | | | 2006-2007 | 20 | 82.45 | 23.18 | | |
| | | | 2011-2013 | 21 | 94.48 | 22.88 | | |
| | | Hardness | 2001-2002 | 19 | 106.09 | 30.69 | 0.057 | |
| | | | 2006-2007 | 20 | 107.80 | 28.68 | | |
| | | | 2011-2013 | 13 | 135.46 | 51.21 | | |
| | | pH | 2001-2002 | 19 | 7.40 | 0.43 | 0.000 * | |
| | | | 2006-2007 | 18 | 7.69 | 0.27 | | |
| | | | 2011-2013 | 21 | 7.85 | 0.28 | | |
| Buck Creek | OK121400-03-0170C | DO | 2001-2002 | 20 | 8.79 | 1.75 | 0.086 | |
| | | | 2006-2007 | 20 | 8.16 | 3.03 | | |
| | | | 2011-2013 | 19 | 6.85 | 3.17 | | |
| | | DO % Saturation | 2001-2002 | 20 | 93.35 | 15.61 | 0.000 * | |
| | | | 2006-2007 | 20 | 78.04 | 20.72 | | |
| | | | 2011-2013 | 19 | 65.44 | 25.07 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Buck Creek | (continued) | Ammonia | 2001-2002 | 20 | 0.07 | 0.07 | 0.001 * | |
| | | | 2006-2007 | 20 | 0.01 | 0.01 | | |
| | | | 2011-2013 | 9 | 0.05 | 0.03 | | |
| | | Nitrate | 2001-2002 | 20 | 0.32 | 0.28 | 0.022 * | |
| | | | 2006-2007 | 20 | 0.12 | 0.09 | | |
| | | | 2011-2013 | 20 | 0.17 | 0.28 | | |
| | | Available N | 2001-2002 | 20 | 0.45 | 0.34 | 0.002 * | |
| | | | 2006-2007 | 20 | 0.15 | 0.09 | | |
| | | | 2011-2013 | 20 | 0.22 | 0.30 | | |
| | | Chloride | 2001-2002 | 20 | 7.96 | 3.94 | 0.004 * | |
| | | | 2006-2007 | 20 | 18.90 | 14.26 | | |
| | | | 2011-2013 | 20 | 27.24 | 26.37 | | |
| | | Sulfate | 2001-2002 | 20 | 18.44 | 6.31 | 0.082 | |
| | | | 2006-2007 | 20 | 17.85 | 7.50 | | |
| | | | 2011-2013 | 20 | 22.44 | 6.86 | | |
| | | Hardness | 2001-2002 | 20 | 167.97 | 36.20 | 0.022 * | |
| | | | 2006-2007 | 20 | 163.97 | 58.74 | | |
| | | | 2011-2013 | 14 | 209.71 | 50.93 | | |
| Buggy Creek | OK520610-02-0120C | DO % Saturation | 2001-2002 | 20 | 109.60 | 22.96 | 0.060 | |
| | | | 2006-2007 | 18 | 90.87 | 13.43 | | |
| | | | 2011-2013 | 19 | 99.42 | 31.06 | | |
| | | Nitrate | 2001-2002 | 20 | 0.93 | 0.29 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.90 | 0.58 | | |
| | | | 2011-2013 | 20 | 0.23 | 0.18 | | |
| | | Nitrite | 2001-2002 | 20 | 0.01 | 0.00 | 0.002 * | |
| | | | 2006-2007 | 19 | 0.04 | 0.04 | | |
| | | | 2011-2013 | 20 | 0.03 | 0.02 | | |
| | | Total N | 2001-2002 | 20 | 1.58 | 0.81 | 0.032 * | |
| | | | 2006-2007 | 19 | 2.00 | 1.46 | | |
| | | | 2011-2013 | 20 | 1.15 | 0.45 | | |
| | | Available N | 2001-2002 | 20 | 1.12 | 0.46 | 0.000 * | |
| | | | 2006-2007 | 19 | 1.03 | 0.56 | | |
| | | | 2011-2013 | 20 | 0.27 | 0.19 | | |
| | | Ortho P | 2001-2002 | 17 | 0.11 | 0.10 | 0.062 | |
| | | | 2006-2007 | 19 | 0.21 | 0.28 | | |
| | | | 2011-2013 | 20 | 0.08 | 0.07 | | |
| | | Total P | 2001-2002 | 17 | 0.16 | 0.13 | 0.083 | |
| | | | 2006-2007 | 19 | 0.38 | 0.61 | | |
| | | | 2011-2013 | 20 | 0.13 | 0.09 | | |
| | | Chloride | 2001-2002 | 20 | 39.00 | 10.87 | 0.000 * | |
| | | | 2006-2007 | 19 | 37.82 | 22.68 | | |
| | | | 2011-2013 | 20 | 67.05 | 32.93 | | |
| | | Sulfate | 2001-2002 | 20 | 431.60 | 149.50 | 0.000 * | |
| | | | 2006-2007 | 19 | 301.20 | 104.60 | | |
| | | | 2011-2013 | 20 | 709.10 | 282.50 | | |
| | | Conductivity | 2001-2002 | 20 | 1309.10 | 352.70 | 0.000 * | |
| | | | 2006-2007 | 18 | 1103.20 | 325.00 | | |
| | | | 2011-2013 | 20 | 1680.80 | 561.40 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Buggy Creek | (continued) | Hardness | 2001-2002 | 20 | 548.20 | 90.70 | 0.002 * | |
| | | | 2006-2007 | 19 | 515.70 | 150.00 | | |
| | | | 2011-2013 | 13 | 687.70 | 151.10 | | |
| | | Turbidity | 2001-2002 | 20 | 62.50 | 164.40 | 0.085 | |
| | | | 2006-2007 | 19 | 160.00 | 304.50 | | |
| | | | 2011-2013 | 20 | 18.00 | 49.80 | | |
| | | TDS | 2001-2002 | 20 | 1004.10 | 234.20 | 0.010 * | |
| | | | 2006-2007 | 19 | 834.70 | 233.90 | | |
| | | | 2011-2013 | 20 | 1500.50 | 1136.80 | | |
| | | TSS | 2001-2002 | 20 | 39.90 | 46.10 | 0.048 * | |
| | | | 2006-2007 | 19 | 443.20 | 1032.30 | | |
| | | | 2011-2013 | 20 | 19.60 | 34.80 | | |
| | | pH | 2001-2002 | 20 | 8.12 | 0.22 | 0.014 * | |
| | | | 2006-2007 | 19 | 8.03 | 0.20 | | |
| | | | 2011-2013 | 20 | 8.23 | 0.20 | | |
| | | Flow | 2001-2002 | 20 | 9.31 | 6.96 | 0.047 * | |
| | | | 2006-2007 | 17 | 33.04 | 62.55 | | |
| | | | 2011-2013 | 19 | 5.16 | 10.04 | | |
| Bull Creek | OK121500-02-0090D | DO % Saturation | 2001-2002 | 20 | 52.75 | 17.95 | 0.030 * | |
| | | | 2006-2007 | 19 | 69.28 | 21.93 | | |
| | | | 2011-2013 | 21 | 64.83 | 19.19 | | |
| | | Ammonia | 2001-2002 | 20 | 0.27 | 0.24 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.03 | 0.04 | | |
| | | | 2011-2013 | 9 | 0.04 | 0.03 | | |
| | | TKN | 2011-2013 | 9 | 0.04 | 0.03 | 0.006 * | |
| | | | 2006-2007 | 19 | 0.63 | 0.35 | | |
| | | | 2011-2013 | 20 | 1.11 | 0.42 | | |
| | | Nitrate | 2001-2002 | 20 | 0.56 | 0.26 | 0.001 * | |
| | | | 2006-2007 | 19 | 0.35 | 0.21 | | |
| | | | 2011-2013 | 20 | 0.23 | 0.31 | | |
| | | Total N | 2001-2002 | 20 | 1.60 | 0.77 | 0.020 * | |
| | | | 2006-2007 | 19 | 1.02 | 0.43 | | |
| | | | 2011-2013 | 20 | 1.36 | 0.61 | | |
| | | Available N | 2001-2002 | 20 | 0.89 | 0.46 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.42 | 0.23 | | |
| | | | 2011-2013 | 20 | 0.27 | 0.31 | | |
| | | Alkalinity | 2001-2002 | 20 | 72.70 | 28.16 | 0.012 * | |
| | | | 2006-2007 | 19 | 62.63 | 18.04 | | |
| | | | 2011-2013 | 21 | 87.05 | 27.40 | | |
| | | Conductivity | 2001-2002 | 20 | 327.40 | 121.80 | 0.012 * | |
| | | | 2006-2007 | 19 | 274.90 | 80.00 | | |
| | | | 2011-2013 | 21 | 372.60 | 93.10 | | |
| | | Hardness | 2001-2002 | 20 | 121.74 | 34.94 | 0.000 * | |
| | | | 2006-2007 | 19 | 97.21 | 24.82 | | |
| | | | 2011-2013 | 13 | 180.54 | 33.82 | | |
| | | TDS | 2001-2002 | 20 | 220.10 | 60.62 | 0.009 * | |
| | | | 2006-2007 | 19 | 185.84 | 39.36 | | |
| | | | 2011-2013 | 20 | 237.20 | 49.63 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Bull Creek | (continued) | pH | 2001-2002 | 19 | 8.35 | 0.78 | 0.000 * | |
| | | | 2006-2007 | 16 | 7.30 | 0.65 | | |
| | | | 2011-2013 | 21 | 7.22 | 0.46 | | |
| California Creek | OK121510-02-0050C | DO | 2001-2002 | 20 | 5.99 | 2.49 | 0.069 | |
| | | | 2006-2007 | 19 | 7.47 | 3.60 | | |
| | | | 2011-2013 | 20 | 5.22 | 2.86 | | |
| | | DO % Saturation | 2001-2002 | 20 | 59.65 | 21.77 | 0.042 * | |
| | | | 2006-2007 | 19 | 70.71 | 26.68 | | |
| | | | 2011-2013 | 20 | 49.38 | 28.18 | | |
| | | Ammonia | 2001-2002 | 19 | 0.15 | 0.12 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.02 | 0.02 | | |
| | | | 2011-2013 | 9 | 0.04 | 0.02 | | |
| | | TKN | 2001-2002 | 19 | 0.52 | 0.26 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.42 | 0.29 | | |
| | | | 2011-2013 | 20 | 1.09 | 0.69 | | |
| | | Nitrate | 2001-2002 | 20 | 0.37 | 0.28 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.26 | 0.29 | | |
| | | | 2011-2013 | 20 | 0.06 | 0.06 | | |
| | | Total N | 2001-2002 | 20 | 0.90 | 0.48 | 0.044 * | |
| | | | 2006-2007 | 19 | 0.69 | 0.49 | | |
| | | | 2011-2013 | 20 | 1.16 | 0.71 | | |
| | | Available N | 2001-2002 | 20 | 0.56 | 0.34 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.29 | 0.31 | | |
| | | | 2011-2013 | 20 | 0.09 | 0.07 | | |
| | | Alkalinity | 2001-2002 | 20 | 99.00 | 33.13 | 0.003 * | |
| | | | 2006-2007 | 19 | 106.74 | 43.38 | | |
| | | | 2011-2013 | 21 | 148.81 | 62.19 | | |
| | | Hardness | 2001-2002 | 20 | 176.22 | 60.44 | 0.087 | |
| | | | 2006-2007 | 19 | 157.32 | 42.98 | | |
| | | | 2011-2013 | 14 | 209.29 | 92.48 | | |
| | | pH | 2001-2002 | 20 | 8.06 | 0.65 | 0.000 * | |
| | | | 2006-2007 | 15 | 7.52 | 0.38 | | |
| | | | 2011-2013 | 19 | 7.41 | 0.27 | | |
| | | Flow | 2001-2002 | 20 | 2.77 | 6.72 | 0.018 * | |
| | | | 2006-2007 | 17 | 6.46 | 9.18 | | |
| | | | 2011-2013 | 21 | 0.35 | 0.90 | | |
| Chouteau Creek | OK121600-01-0430M | Ammonia | 2001-2002 | 19 | 0.21 | 0.24 | 0.092 | |
| | | | 2006-2007 | 19 | 0.07 | 0.09 | | |
| | | | 2011-2013 | 9 | 0.20 | 0.32 | | |
| | | TKN | 2001-2002 | 19 | 0.85 | 0.51 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.59 | 0.36 | | |
| | | | 2011-2013 | 20 | 1.34 | 0.55 | | |
| | | Nitrate | 2001-2002 | 19 | 0.64 | 0.32 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.22 | 0.18 | | |
| | | | 2011-2013 | 20 | 0.23 | 0.26 | | |
| | | Total N | 2001-2002 | 19 | 1.56 | 0.71 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.84 | 0.43 | | |
| | | | 2011-2013 | 20 | 1.59 | 0.68 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Chouteau Creek | (continued) | Available N | 2001-2002 | 19 | 0.92 | 0.48 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.31 | 0.19 | | |
| | | | 2011-2013 | 20 | 0.34 | 0.33 | | |
| | | Sulfate | 2001-2002 | 19 | 37.79 | 21.10 | 0.013 * | |
| | | | 2006-2007 | 19 | 25.29 | 13.35 | | |
| | | | 2011-2013 | 20 | 61.51 | 58.86 | | |
| | | Alkalinity | 2001-2002 | 18 | 74.83 | 21.51 | 0.005 * | |
| | | | 2006-2007 | 19 | 69.11 | 22.35 | | |
| | | | 2011-2013 | 21 | 102.24 | 46.18 | | |
| | | Conductivity | 2001-2002 | 19 | 255.00 | 86.10 | 0.040 * | |
| | | | 2006-2007 | 19 | 219.60 | 48.90 | | |
| | | | 2011-2013 | 21 | 417.40 | 420.20 | | |
| | | Hardness | 2001-2002 | 19 | 93.31 | 21.99 | 0.000 * | |
| | | | 2006-2007 | 19 | 79.88 | 20.18 | | |
| | | | 2011-2013 | 12 | 162.33 | 50.89 | | |
| | | TDS | 2001-2002 | 19 | 170.72 | 49.62 | 0.005 * | |
| | | | 2006-2007 | 19 | 166.05 | 49.20 | | |
| | | | 2011-2013 | 20 | 236.80 | 101.99 | | |
| | | pH | 2001-2002 | 18 | 8.09 | 0.86 | 0.000 * | |
| | | | 2006-2007 | 16 | 7.14 | 0.55 | | |
| | | | 2011-2013 | 21 | 7.16 | 0.39 | | |
| | | Flow | 2001-2002 | 15 | 42.93 | 84.41 | 0.062 | |
| | | | 2006-2007 | 12 | 12.61 | 30.22 | | |
| | | | 2011-2013 | 20 | 1.89 | 3.24 | | |
| Commission Creek | OK520620-05-0160C | DO % Saturation | 2001-2002 | 19 | 103.84 | 5.61 | 0.010 * | |
| | | | 2006-2007 | 18 | 95.44 | 9.65 | | |
| | | | 2011-2013 | 19 | 107.47 | 17.08 | | |
| | | Ammonia | 2001-2002 | 19 | 0.03 | 0.04 | 0.033 * | |
| | | | 2006-2007 | 18 | 0.01 | 0.00 | | |
| | | | 2011-2013 | 9 | 0.02 | 0.00 | | |
| | | Nitrate | 2001-2002 | 19 | 0.64 | 0.23 | 0.000 * | |
| | | | 2006-2007 | 18 | 0.36 | 0.12 | | |
| | | | 2011-2013 | 20 | 0.20 | 0.15 | | |
| | | Nitrite | 2001-2002 | 19 | 0.01 | 0.00 | 0.070 | |
| | | | 2006-2007 | 18 | 0.04 | 0.07 | | |
| | | | 2011-2013 | 20 | 0.02 | 0.00 | | |
| | | Total N | 2001-2002 | 19 | 0.96 | 0.23 | 0.001 * | |
| | | | 2006-2007 | 18 | 0.70 | 0.26 | | |
| | | | 2011-2013 | 20 | 0.66 | 0.26 | | |
| | | Available N | 2001-2002 | 19 | 0.68 | 0.25 | 0.000 * | |
| | | | 2006-2007 | 18 | 0.40 | 0.13 | | |
| | | | 2011-2013 | 20 | 0.23 | 0.15 | | |
| | | Ortho P | 2001-2002 | 18 | 0.01 | 0.01 | 0.096 | |
| | | | 2006-2007 | 18 | 0.02 | 0.01 | | |
| | | | 2011-2013 | 20 | 0.01 | 0.01 | | |
| | | Chloride | 2001-2002 | 19 | 103.76 | 21.53 | 0.000 * | |
| | | | 2006-2007 | 18 | 103.13 | 22.55 | | |
| | | | 2011-2013 | 20 | 137.79 | 36.39 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Commission Creek | (continued) | Sulfate | 2001-2002 | 19 | 30.44 | 5.85 | 0.022 * | |
| | | | 2006-2007 | 18 | 55.44 | 48.32 | | |
| | | | 2011-2013 | 20 | 33.73 | 15.79 | | |
| | | Hardness | 2001-2002 | 19 | 233.08 | 60.63 | 0.000 * | |
| | | | 2006-2007 | 18 | 258.04 | 18.27 | | |
| | | | 2011-2013 | 11 | 317.27 | 70.03 | | |
| | | pH | 2001-2002 | 18 | 8.29 | 0.14 | 0.046 * | |
| | | | 2006-2007 | 18 | 8.16 | 0.25 | | |
| | | | 2011-2013 | 20 | 8.30 | 0.14 | | |
| Curl Creek | OK121400-01-0270C | DO | 2001-2002 | 20 | 6.73 | 2.64 | 0.052 | |
| | | | 2006-2007 | 20 | 6.94 | 3.77 | | |
| | | | 2011-2013 | 19 | 4.77 | 2.31 | | |
| | | DO % Saturation | 2001-2002 | 20 | 68.90 | 26.83 | 0.026 * | |
| | | | 2006-2007 | 20 | 64.99 | 27.22 | | |
| | | | 2011-2013 | 19 | 47.69 | 20.71 | | |
| | | Ammonia | 2001-2002 | 19 | 0.15 | 0.13 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.02 | 0.03 | | |
| | | | 2011-2013 | 9 | 0.04 | 0.03 | | |
| | | TKN | 2001-2002 | 19 | 0.67 | 0.31 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.51 | 0.29 | | |
| | | | 2011-2013 | 20 | 1.05 | 0.49 | | |
| | | Nitrate | 2001-2002 | 20 | 0.33 | 0.29 | 0.001 * | |
| | | | 2006-2007 | 20 | 0.15 | 0.14 | | |
| | | | 2011-2013 | 20 | 0.09 | 0.13 | | |
| | | Total N | 2001-2002 | 20 | 1.00 | 0.49 | 0.015 * | |
| | | | 2006-2007 | 20 | 0.70 | 0.35 | | |
| | | | 2011-2013 | 20 | 1.15 | 0.59 | | |
| | | Available N | 2001-2002 | 20 | 0.51 | 0.37 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.20 | 0.13 | | |
| | | | 2011-2013 | 20 | 0.13 | 0.14 | | |
| | | Chloride | 2001-2002 | 20 | 40.54 | 27.49 | 0.002 * | |
| | | | 2006-2007 | 20 | 26.20 | 15.64 | | |
| | | | 2011-2013 | 20 | 18.52 | 8.71 | | |
| | | Flow | 2001-2002 | 19 | 2.16 | 4.50 | 0.015 * | |
| | | | 2006-2007 | 14 | 6.29 | 9.66 | | |
| | | | 2011-2013 | 18 | 0.16 | 0.59 | | |
| Deer Creek | OK520620-06-0010F | Ortho P | 2001-2002 | 19 | 0.09 | 0.06 | 0.099 | |
| | | | 2006-2007 | 19 | 0.22 | 0.31 | | |
| | | | 2011-2013 | 20 | 0.16 | 0.05 | | |
| | | Alkalinity | 2001-2002 | 20 | 167.15 | 25.31 | 0.035 * | |
| | | | 2006-2007 | 18 | 194.11 | 35.28 | | |
| | | | 2011-2013 | 20 | 172.20 | 36.77 | | |
| | | pH | 2001-2002 | 19 | 8.19 | 0.18 | 0.084 | |
| | | | 2006-2007 | 19 | 8.10 | 0.33 | | |
| | | | 2011-2013 | 21 | 8.31 | 0.33 | | |
| | | Flow | 2001-2002 | 20 | 41.61 | 11.75 | 0.019 * | |
| | | | 2006-2007 | 14 | 68.10 | 72.02 | | |
| | | | 2011-2013 | 19 | 27.39 | 21.78 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Delaware Creek | OK121300-01-0150H | Ammonia | 2001-2002 | 19 | 0.11 | 0.09 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.01 | 0.01 | | |
| | | | 2011-2013 | 9 | 0.06 | 0.07 | | |
| | | TKN | 2001-2002 | 19 | 0.52 | 0.18 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.45 | 0.27 | | |
| | | | 2011-2013 | 20 | 0.95 | 0.35 | | |
| | | Nitrate | 2001-2002 | 19 | 0.41 | 0.25 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.11 | 0.07 | | |
| | | | 2011-2013 | 20 | 0.07 | 0.08 | | |
| | | Total N | 2001-2002 | 19 | 0.93 | 0.30 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.60 | 0.35 | | |
| | | | 2011-2013 | 20 | 1.04 | 0.36 | | |
| | | Available N | 2001-2002 | 19 | 0.52 | 0.27 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.16 | 0.13 | | |
| | | | 2011-2013 | 20 | 0.11 | 0.09 | | |
| | | Chloride | 2001-2002 | 19 | 201.10 | 188.20 | 0.001 * | |
| | | | 2006-2007 | 19 | 89.10 | 63.60 | | |
| | | | 2011-2013 | 20 | 65.90 | 25.30 | | |
| | | Sulfate | 2001-2002 | 19 | 23.48 | 16.34 | 0.002 * | |
| | | | 2006-2007 | 19 | 57.48 | 55.47 | | |
| | | | 2011-2013 | 20 | 20.84 | 8.57 | | |
| | | Conductivity | 2001-2002 | 19 | 836.80 | 608.20 | 0.001 * | |
| | | | 2006-2007 | 19 | 472.00 | 212.40 | | |
| | | | 2011-2013 | 21 | 415.80 | 109.30 | | |
| | | Hardness | 2001-2002 | 19 | 191.91 | 101.00 | 0.050 | |
| | | | 2006-2007 | 19 | 132.84 | 51.23 | | |
| | | | 2011-2013 | 13 | 148.77 | 50.89 | | |
| | | TDS | 2001-2002 | 19 | 497.10 | 337.90 | 0.002 * | |
| | | | 2006-2007 | 19 | 307.50 | 148.00 | | |
| | | | 2011-2013 | 20 | 250.40 | 40.60 | | |
| | | pH | 2001-2002 | 19 | 7.92 | 0.82 | 0.000 * | |
| | | | 2006-2007 | 15 | 7.05 | 0.27 | | |
| | | | 2011-2013 | 21 | 7.19 | 0.28 | | |
| | | Flow | 2001-2002 | 19 | 3.84 | 7.90 | 0.097 | |
| | | | 2006-2007 | 17 | 7.93 | 12.11 | | |
| | | | 2011-2013 | 18 | 1.71 | 3.06 | | |
| Dog Creek | OK121500-02-0360D | DO | 2001-2002 | 17 | 5.54 | 3.12 | 0.065 | |
| | | | 2006-2007 | 19 | 7.09 | 3.35 | | |
| | | | 2011-2013 | 20 | 4.78 | 2.65 | | |
| | | DO % Saturation | 2001-2002 | 17 | 50.65 | 22.28 | 0.004 * | |
| | | | 2006-2007 | 19 | 68.75 | 22.77 | | |
| | | | 2011-2013 | 20 | 44.07 | 22.18 | | |
| | | Ammonia | 2001-2002 | 17 | 2.44 | 2.76 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.20 | 0.45 | | |
| | | | 2011-2013 | 9 | 0.09 | 0.07 | | |
| | | TKN | 2001-2002 | 17 | 3.60 | 3.01 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.77 | 0.65 | | |
| | | | 2011-2013 | 19 | 0.68 | 0.32 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Dog Creek | (continued) | Nitrate | 2001-2002 | 17 | 3.58 | 2.98 | 0.000 * | |
| | | | 2006-2007 | 19 | 1.57 | 1.02 | | |
| | | | 2011-2013 | 19 | 0.11 | 0.25 | | |
| | | Total N | 2001-2002 | 17 | 7.52 | 3.90 | 0.000 * | |
| | | | 2006-2007 | 19 | 2.40 | 1.32 | | |
| | | | 2011-2013 | 19 | 0.82 | 0.51 | | |
| | | Available N | 2001-2002 | 17 | 6.37 | 3.71 | 0.000 * | |
| | | | 2006-2007 | 19 | 1.83 | 1.15 | | |
| | | | 2011-2013 | 19 | 0.18 | 0.28 | | |
| | | Ortho P | 2001-2002 | 16 | 1.01 | 0.52 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.68 | 0.70 | | |
| | | | 2011-2013 | 19 | 0.02 | 0.01 | | |
| | | Total P | 2001-2002 | 16 | 1.23 | 0.59 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.75 | 0.71 | | |
| | | | 2011-2013 | 19 | 0.07 | 0.03 | | |
| | | Chloride | 2001-2002 | 17 | 40.89 | 14.71 | 0.000 * | |
| | | | 2006-2007 | 19 | 25.97 | 16.34 | | |
| | | | 2011-2013 | 19 | 9.85 | 2.81 | | |
| | | Hardness | 2001-2002 | 17 | 132.63 | 18.52 | 0.000 * | |
| | | | 2006-2007 | 19 | 115.73 | 22.72 | | |
| | | | 2011-2013 | 12 | 165.67 | 33.10 | | |
| | | TDS | 2001-2002 | 16 | 281.47 | 60.47 | 0.000 * | |
| | | | 2006-2007 | 19 | 227.05 | 62.82 | | |
| | | | 2011-2013 | 19 | 154.84 | 26.34 | | |
| | | pH | 2001-2002 | 16 | 8.13 | 0.76 | 0.000 * | |
| | | | 2006-2007 | 16 | 7.31 | 0.46 | | |
| | | | 2011-2013 | 20 | 6.86 | 0.46 | | |
| | | Flow | 2001-2002 | 16 | 17.21 | 14.68 | 0.001 * | |
| | | | 2006-2007 | 17 | 12.70 | 18.26 | | |
| | | | 2011-2013 | 19 | 0.02 | 0.09 | | |
| Fivemile Creek | OK121600-05-0110G | DO | 2001-2002 | 20 | 10.38 | 2.01 | 0.056 | |
| | | | 2006-2007 | 20 | 9.83 | 2.05 | | |
| | | | 2011-2013 | 21 | 8.83 | 2.08 | | |
| | | DO % Saturation | 2001-2002 | 20 | 104.45 | 11.08 | 0.001 * | |
| | | | 2006-2007 | 20 | 98.62 | 12.04 | | |
| | | | 2011-2013 | 21 | 90.25 | 11.74 | | |
| | | Ammonia | 2001-2002 | 20 | 0.01 | 0.00 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.01 | 0.00 | | |
| | | | 2011-2013 | 9 | 0.02 | 0.01 | | |
| | | Nitrate | 2001-2002 | 20 | 0.59 | 0.20 | 0.003 * | |
| | | | 2006-2007 | 20 | 0.35 | 0.21 | | |
| | | | 2011-2013 | 20 | 0.39 | 0.26 | | |
| | | Nitrite | 2001-2002 | 20 | 0.01 | 0.01 | 0.026 * | |
| | | | 2006-2007 | 20 | 0.02 | 0.02 | | |
| | | | 2011-2013 | 20 | 0.02 | 0.00 | | |
| | | Available N | 2001-2002 | 20 | 0.61 | 0.20 | 0.004 * | |
| | | | 2006-2007 | 20 | 0.38 | 0.21 | | |
| | | | 2011-2013 | 20 | 0.42 | 0.26 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Fivemile Creek | (continued) | Hardness | 2001-2002 | 20 | 138.51 | 16.50 | 0.006 * | |
| | | | 2006-2007 | 20 | 135.87 | 28.39 | | |
| | | | 2011-2013 | 13 | 165.92 | 35.79 | | |
| Fourteenmile Creek | OK121600-01-0100G | DO % Saturation | 2001-2002 | 20 | 100.50 | 16.97 | 0.023 * | |
| | | | 2006-2007 | 20 | 92.34 | 11.80 | | |
| | | | 2011-2013 | 20 | 105.33 | 14.74 | | |
| | | Chloride | 2001-2002 | 20 | 5.64 | 1.15 | 0.089 | |
| | | | 2006-2007 | 20 | 6.01 | 2.26 | | |
| | | | 2011-2013 | 20 | 7.00 | 2.33 | | |
| | | Ortho P | 2001-2002 | 19 | 0.02 | 0.02 | 0.052 | |
| | | | 2006-2007 | 20 | 0.03 | 0.02 | | |
| | | | 2011-2013 | 20 | 0.02 | 0.01 | | |
| | | Total P | 2001-2002 | 19 | 0.05 | 0.04 | 0.028 * | |
| | | | 2006-2007 | 20 | 0.05 | 0.04 | | |
| | | | 2011-2013 | 20 | 0.03 | 0.01 | | |
| | | Hardness | 2001-2002 | 20 | 82.59 | 6.65 | 0.000 * | |
| | | | 2006-2007 | 20 | 79.31 | 17.66 | | |
| | | | 2011-2013 | 13 | 116.85 | 17.95 | | |
| Hogshooter Creek | OK121400-01-0300D | DO | 2001-2002 | 18 | 5.78 | 3.55 | 0.014 * | |
| | | | 2006-2007 | 20 | 7.30 | 3.53 | | |
| | | | 2011-2013 | 20 | 4.16 | 2.65 | | |
| | | DO % Saturation | 2001-2002 | 18 | 58.22 | 32.59 | 0.043 * | |
| | | | 2006-2007 | 20 | 69.20 | 26.40 | | |
| | | | 2011-2013 | 20 | 45.98 | 26.48 | | |
| | | Ammonia | 2001-2002 | 18 | 0.13 | 0.22 | 0.034 * | |
| | | | 2006-2007 | 20 | 0.01 | 0.01 | | |
| | | | 2011-2013 | 9 | 0.04 | 0.03 | | |
| | | TKN | 2001-2002 | 18 | 0.50 | 0.60 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.36 | 0.24 | | |
| | | | 2011-2013 | 20 | 1.06 | 0.48 | | |
| | | Nitrate | 2001-2002 | 18 | 0.38 | 0.30 | 0.007 * | |
| | | | 2006-2007 | 20 | 0.27 | 0.37 | | |
| | | | 2011-2013 | 20 | 0.08 | 0.12 | | |
| | | Total N | 2001-2002 | 18 | 0.95 | 0.76 | 0.033 * | |
| | | | 2006-2007 | 20 | 0.66 | 0.47 | | |
| | | | 2011-2013 | 20 | 1.15 | 0.51 | | |
| | | Available N | 2001-2002 | 18 | 0.58 | 0.48 | 0.001 * | |
| | | | 2006-2007 | 20 | 0.31 | 0.38 | | |
| | | | 2011-2013 | 20 | 0.12 | 0.13 | | |
| | | Alkalinity | 2001-2002 | 18 | 130.44 | 19.17 | 0.000 * | |
| | | | 2006-2007 | 20 | 138.93 | 39.18 | | |
| | | | 2011-2013 | 21 | 181.57 | 44.48 | | |
| | | Hardness | 2001-2002 | 18 | 182.98 | 30.60 | 0.002 * | |
| | | | 2006-2007 | 20 | 181.58 | 38.95 | | |
| | | | 2011-2013 | 13 | 234.46 | 60.50 | | |
| Hominy Creek | OK121300-04-0280G | DO % Saturation | 2001-2002 | 20 | 102.35 | 7.04 | 0.000 * | |
| | | | 2006-2007 | 20 | 84.91 | 11.20 | | |
| | | | 2011-2013 | 20 | 70.80 | 27.52 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Hominy Creek | (continued) | Ammonia | 2001-2002 | 16 | 0.08 | 0.09 | 0.005 * | |
| | | | 2006-2007 | 20 | 0.01 | 0.01 | | |
| | | | 2011-2013 | 9 | 0.04 | 0.02 | | |
| | | TKN | 2001-2002 | 17 | 0.43 | 0.28 | 0.030 * | |
| | | | 2006-2007 | 20 | 0.32 | 0.19 | | |
| | | | 2011-2013 | 20 | 0.54 | 0.27 | | |
| | | Nitrate | 2001-2002 | 17 | 0.23 | 0.27 | 0.023 * | |
| | | | 2006-2007 | 20 | 0.17 | 0.22 | | |
| | | | 2011-2013 | 20 | 0.05 | 0.05 | | |
| | | Nitrite | 2001-2002 | 17 | 0.01 | 0.00 | 0.084 | |
| | | | 2006-2007 | 20 | 0.03 | 0.04 | | |
| | | | 2011-2013 | 20 | 0.02 | 0.00 | | |
| | | Available N | 2001-2002 | 20 | 0.36 | 0.32 | 0.001 * | |
| | | | 2006-2007 | 20 | 0.22 | 0.22 | | |
| | | | 2011-2013 | 20 | 0.09 | 0.05 | | |
| | | Chloride | 2001-2002 | 17 | 225.20 | 146.00 | 0.000 * | |
| | | | 2006-2007 | 20 | 262.70 | 214.40 | | |
| | | | 2011-2013 | 20 | 503.20 | 272.20 | | |
| | | Conductivity | 2001-2002 | 20 | 1188.70 | 534.30 | 0.073 | |
| | | | 2006-2007 | 17 | 1162.80 | 690.70 | | |
| | | | 2011-2013 | 21 | 1601.70 | 750.30 | | |
| | | Hardness | 2001-2002 | 20 | 309.90 | 119.30 | 0.049 * | |
| | | | 2006-2007 | 20 | 292.00 | 136.30 | | |
| | | | 2011-2013 | 14 | 407.40 | 162.00 | | |
| | | TDS | 2001-2002 | 20 | 694.50 | 327.20 | 0.032 * | |
| | | | 2006-2007 | 20 | 702.70 | 386.90 | | |
| | | | 2011-2013 | 20 | 985.90 | 443.20 | | |
| | | pH | 2001-2002 | 20 | 7.86 | 0.41 | 0.048 * | |
| | | | 2006-2007 | 18 | 7.65 | 0.38 | | |
| | | | 2011-2013 | 21 | 7.54 | 0.43 | | |
| Little Cabin Creek | OK121600-06-0080C | Ammonia | 2001-2002 | 19 | 0.16 | 0.12 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.04 | 0.05 | | |
| | | | 2011-2013 | 9 | 0.04 | 0.02 | | |
| | | TKN | 2001-2002 | 19 | 0.68 | 0.35 | 0.017 * | |
| | | | 2006-2007 | 20 | 0.67 | 0.50 | | |
| | | | 2011-2013 | 20 | 1.07 | 0.59 | | |
| | | Available N | 2001-2002 | 19 | 0.88 | 0.50 | 0.050 | |
| | | | 2006-2007 | 20 | 0.50 | 0.38 | | |
| | | | 2011-2013 | 20 | 0.53 | 0.64 | | |
| | | Alkalinity | 2001-2002 | 19 | 73.47 | 35.29 | 0.002 * | |
| | | | 2006-2007 | 20 | 99.55 | 32.55 | | |
| | | | 2011-2013 | 20 | 114.10 | 36.78 | | |
| | | pH | 2001-2002 | 19 | 7.92 | 0.65 | 0.004 * | |
| | | | 2006-2007 | 20 | 7.42 | 0.85 | | |
| | | | 2011-2013 | 20 | 7.21 | 0.29 | | |
| Little Horse Creek | OK121600-03-0190A | DO % Saturation | 2001-2002 | 20 | 69.50 | 21.99 | 0.088 | |
| | | | 2006-2007 | 18 | 65.93 | 19.36 | | |
| | | | 2011-2013 | 20 | 53.24 | 28.93 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Little Horse Creek | (continued) | TKN | 2001-2002 | 20 | 0.69 | 0.37 | 0.021 * | |
| | | | 2006-2007 | 18 | 0.85 | 0.72 | | |
| | | | 2011-2013 | 19 | 1.26 | 0.76 | | |
| | | Ortho P | 2001-2002 | 20 | 0.11 | 0.11 | 0.019 * | |
| | | | 2006-2007 | 18 | 0.28 | 0.25 | | |
| | | | 2011-2013 | 19 | 0.18 | 0.14 | | |
| | | Total P | 2001-2002 | 20 | 0.16 | 0.12 | 0.018 * | |
| | | | 2006-2007 | 18 | 0.36 | 0.30 | | |
| | | | 2011-2013 | 19 | 0.24 | 0.16 | | |
| | | Hardness | 2001-2002 | 20 | 144.18 | 57.75 | 0.017 * | |
| | | | 2006-2007 | 18 | 128.72 | 39.75 | | |
| | | | 2011-2013 | 12 | 183.75 | 50.77 | | |
| | | pH | 2001-2002 | 17 | 6.99 | 0.41 | 0.068 | |
| | | | 2006-2007 | 18 | 7.46 | 0.81 | | |
| | | | 2011-2013 | 20 | 7.30 | 0.47 | | |
| Lone Creek | OK520620-03-0020C | DO | 2001-2002 | 20 | 9.55 | 1.64 | 0.015 * | |
| | | | 2006-2007 | 17 | 10.40 | 1.39 | | |
| | | | 2011-2013 | 13 | 12.07 | 3.80 | | |
| | | Nitrate | 2001-2002 | 20 | 0.71 | 0.28 | 0.000 * | |
| | | | 2006-2007 | 17 | 0.31 | 0.23 | | |
| | | | 2011-2013 | 13 | 0.19 | 0.11 | | |
| | | Nitrite | 2001-2002 | 20 | 0.01 | 0.01 | 0.043 * | |
| | | | 2006-2007 | 17 | 0.02 | 0.03 | | |
| | | | 2011-2013 | 13 | 0.02 | 0.01 | | |
| | | Total N | 2001-2002 | 20 | 1.35 | 1.03 | 0.047 * | |
| | | | 2006-2007 | 17 | 0.70 | 0.52 | | |
| | | | 2011-2013 | 13 | 0.93 | 0.63 | | |
| | | Available N | 2001-2002 | 20 | 0.82 | 0.40 | 0.000 * | |
| | | | 2006-2007 | 17 | 0.39 | 0.30 | | |
| | | | 2011-2013 | 13 | 0.21 | 0.12 | | |
| | | Chloride | 2001-2002 | 20 | 38.16 | 7.40 | 0.000 * | |
| | | | 2006-2007 | 17 | 42.27 | 7.22 | | |
| | | | 2011-2013 | 13 | 31.30 | 5.76 | | |
| Pryor Creek | OK121610-00-0050D | DO | 2001-2002 | 18 | 5.44 | 2.20 | 0.062 | |
| | | | 2006-2007 | 19 | 7.36 | 2.93 | | |
| | | | 2011-2013 | 21 | 5.79 | 2.58 | | |
| | | DO % Saturation | 2001-2002 | 18 | 53.50 | 16.47 | 0.010 * | |
| | | | 2006-2007 | 19 | 71.11 | 20.45 | | |
| | | | 2011-2013 | 21 | 55.74 | 18.77 | | |
| | | Ammonia | 2001-2002 | 18 | 0.20 | 0.16 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.05 | 0.05 | | |
| | | | 2011-2013 | 9 | 0.05 | 0.05 | | |
| | | TKN | 2001-2002 | 18 | 0.82 | 0.29 | 0.012 * | |
| | | | 2006-2007 | 19 | 0.54 | 0.42 | | |
| | | | 2011-2013 | 20 | 0.86 | 0.31 | | |
| | | Nitrate | 2001-2002 | 18 | 0.55 | 0.20 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.26 | 0.16 | | |
| | | | 2011-2013 | 20 | 0.20 | 0.22 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Pryor Creek | (continued) | Total N | 2001-2002 | 18 | 1.40 | 0.44 | 0.005 * | |
| | | | 2006-2007 | 19 | 0.83 | 0.55 | | |
| | | | 2011-2013 | 20 | 1.09 | 0.52 | | |
| | | Available N | 2001-2002 | 18 | 0.78 | 0.31 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.34 | 0.21 | | |
| | | | 2011-2013 | 20 | 0.24 | 0.24 | | |
| | | Chloride | 2001-2002 | 18 | 86.03 | 93.69 | 0.001 * | |
| | | | 2006-2007 | 19 | 22.13 | 20.11 | | |
| | | | 2011-2013 | 20 | 28.69 | 19.26 | | |
| | | Alkalinity | 2001-2002 | 16 | 73.81 | 28.30 | 0.039 * | |
| | | | 2006-2007 | 19 | 62.92 | 21.03 | | |
| | | | 2011-2013 | 21 | 90.48 | 44.39 | | |
| | | Conductivity | 2001-2002 | 18 | 472.20 | 272.00 | 0.000 * | |
| | | | 2006-2007 | 19 | 259.80 | 78.10 | | |
| | | | 2011-2013 | 21 | 291.20 | 88.40 | | |
| | | Hardness | 2001-2002 | 18 | 111.94 | 32.59 | 0.000 * | |
| | | | 2006-2007 | 19 | 82.74 | 17.90 | | |
| | | | 2011-2013 | 13 | 151.15 | 32.36 | | |
| | | TDS | 2001-2002 | 18 | 303.47 | 164.38 | 0.000 * | |
| | | | 2006-2007 | 19 | 175.00 | 44.70 | | |
| | | | 2011-2013 | 20 | 196.00 | 41.47 | | |
| | | pH | 2001-2002 | 17 | 7.95 | 0.85 | 0.000 * | |
| | | | 2006-2007 | 16 | 7.28 | 0.60 | | |
| | | | 2011-2013 | 21 | 7.03 | 0.37 | | |
| Ranger Creek | OK121600-01-0060D | Ammonia | 2001-2002 | 20 | 0.06 | 0.07 | 0.005 * | |
| | | | 2006-2007 | 20 | 0.01 | 0.01 | | |
| | | | 2011-2013 | 9 | 0.02 | 0.02 | | |
| | | TKN | 2001-2002 | 20 | 0.30 | 0.21 | 0.001 * | |
| | | | 2006-2007 | 20 | 0.19 | 0.15 | | |
| | | | 2011-2013 | 20 | 0.43 | 0.23 | | |
| | | Total N | 2001-2002 | 20 | 0.77 | 0.41 | 0.011 * | |
| | | | 2006-2007 | 20 | 0.47 | 0.29 | | |
| | | | 2011-2013 | 20 | 1.12 | 1.03 | | |
| | | Ortho P | 2001-2002 | 19 | 0.03 | 0.02 | 0.067 | |
| | | | 2006-2007 | 20 | 0.03 | 0.02 | | |
| | | | 2011-2013 | 20 | 0.02 | 0.01 | | |
| Sand Creek | OK121400-04-0010F | Ammonia | 2001-2002 | 20 | 0.10 | 0.11 | 0.003 * | |
| | | | 2006-2007 | 20 | 0.02 | 0.02 | | |
| | | | 2011-2013 | 9 | 0.05 | 0.05 | | |
| | | TKN | 2001-2002 | 20 | 0.53 | 0.34 | 0.002 * | |
| | | | 2006-2007 | 20 | 0.44 | 0.43 | | |
| | | | 2011-2013 | 20 | 0.88 | 0.41 | | |
| | | Nitrate | 2001-2002 | 20 | 0.34 | 0.25 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.10 | 0.09 | | |
| | | | 2011-2013 | 20 | 0.12 | 0.19 | | |
| | | Total N | 2001-2002 | 20 | 0.88 | 0.45 | 0.012 * | |
| | | | 2006-2007 | 20 | 0.57 | 0.45 | | |
| | | | 2011-2013 | 20 | 1.03 | 0.54 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Sand Creek | (continued) | Available N | 2001-2002 | 20 | 0.45 | 0.32 | 0.000 * | |
| | | | 2006-2007 | 20 | 0.15 | 0.10 | | |
| | | | 2011-2013 | 20 | 0.17 | 0.19 | | |
| | | Alkalinity | 2001-2002 | 20 | 93.45 | 24.78 | 0.003 * | |
| | | | 2006-2007 | 20 | 98.80 | 37.46 | | |
| | | | 2011-2013 | 21 | 123.95 | 23.09 | | |
| | | TDS | 2001-2002 | 20 | 239.88 | 50.72 | 0.048 * | |
| | | | 2006-2007 | 20 | 303.40 | 133.10 | | |
| | | | 2011-2013 | 20 | 309.85 | 88.13 | | |
| | | pH | 2001-2002 | 20 | 7.31 | 0.32 | 0.025 * | |
| | | | 2006-2007 | 19 | 7.43 | 0.20 | | |
| | | | 2011-2013 | 21 | 7.54 | 0.24 | | |
| Sycamore Creek | OK121600-03-0510D | DO % Saturation | 2001-2002 | 19 | 109.47 | 18.43 | 0.000 * | |
| | | | 2006-2007 | 20 | 91.63 | 13.52 | | |
| | | | 2011-2013 | 21 | 88.31 | 16.52 | | |
| | | TKN | 2001-2002 | 19 | 0.13 | 0.07 | 0.092 | |
| | | | 2006-2007 | 20 | 0.13 | 0.18 | | |
| | | | 2011-2013 | 20 | 0.21 | 0.10 | | |
| | | Nitrate | 2001-2002 | 19 | 1.89 | 0.51 | 0.033 * | |
| | | | 2006-2007 | 20 | 1.68 | 0.91 | | |
| | | | 2011-2013 | 20 | 2.41 | 1.12 | | |
| | | Total N | 2001-2002 | 19 | 2.05 | 0.53 | 0.019 * | |
| | | | 2006-2007 | 20 | 1.83 | 0.94 | | |
| | | | 2011-2013 | 20 | 2.64 | 1.14 | | |
| | | Available N | 2001-2002 | 19 | 1.94 | 0.54 | 0.038 * | |
| | | | 2006-2007 | 20 | 1.71 | 0.91 | | |
| | | | 2011-2013 | 20 | 2.44 | 1.12 | | |
| | | Ortho P | 2001-2002 | 16 | 0.01 | 0.01 | 0.038 * | |
| | | | 2006-2007 | 20 | 0.03 | 0.03 | | |
| | | | 2011-2013 | 20 | 0.02 | 0.01 | | |
| | | Total P | 2001-2002 | 17 | 0.02 | 0.01 | 0.094 | |
| | | | 2006-2007 | 20 | 0.04 | 0.05 | | |
| | | | 2011-2013 | 20 | 0.03 | 0.01 | | |
| | | Hardness | 2001-2002 | 19 | 124.95 | 10.17 | 0.008 * | |
| | | | 2006-2007 | 20 | 117.39 | 32.55 | | |
| | | | 2011-2013 | 13 | 144.85 | 21.55 | | |
| Tar Creek | OK121600-04-0060D | Ammonia | 2001-2002 | 19 | 0.18 | 0.14 | 0.009 * | |
| | | | 2006-2007 | 19 | 0.08 | 0.08 | | |
| | | | 2011-2013 | 9 | 0.08 | 0.07 | | |
| | | TKN | 2001-2002 | 19 | 0.62 | 0.38 | 0.008 * | |
| | | | 2006-2007 | 19 | 0.42 | 0.36 | | |
| | | | 2011-2013 | 20 | 0.83 | 0.42 | | |
| | | Available N | 2001-2002 | 20 | 1.82 | 0.98 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.46 | 0.21 | | |
| | | | 2011-2013 | 20 | 0.45 | 0.49 | | |
| | | Ortho P | 2001-2002 | 19 | 0.25 | 0.20 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.06 | 0.07 | | |
| | | | 2011-2013 | 20 | 0.05 | 0.04 | | |

| Site Name | WBID | Parameter | Cycle | N | Mean | Standard Deviation | p value | Relarive Change |
|---|---|---|---|---|---|---|---|---|
| Tar Creek | (continued) | Total P | 2001-2002 | 19 | 0.33 | 0.23 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.09 | 0.11 | | |
| | | | 2011-2013 | 20 | 0.09 | 0.07 | | |
| | | Sulfate | 2001-2002 | 20 | 633.30 | 244.00 | 0.080 | |
| | | | 2006-2007 | 19 | 567.10 | 314.40 | | |
| | | | 2011-2013 | 20 | 801.20 | 407.60 | | |
| Trail Creek | OK520620-02-0090G | TKN | 2001-2002 | 19 | 0.29 | 0.16 | 0.039 * | |
| | | | 2006-2007 | 19 | 0.45 | 0.58 | | |
| | | | 2011-2013 | 20 | 0.67 | 0.48 | | |
| | | Nitrate | 2001-2002 | 19 | 0.42 | 0.27 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.16 | 0.12 | | |
| | | | 2011-2013 | 20 | 0.06 | 0.08 | | |
| | | Nitrite | 2001-2002 | 19 | 0.01 | 0.00 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.02 | 0.02 | | |
| | | | 2011-2013 | 20 | 0.02 | 0.00 | | |
| | | Available N | 2001-2002 | 19 | 0.51 | 0.32 | 0.000 * | |
| | | | 2006-2007 | 19 | 0.24 | 0.17 | | |
| | | | 2011-2013 | 20 | 0.09 | 0.08 | | |
| | | Sulfate | 2001-2002 | 19 | 1532.50 | 388.50 | 0.025 * | |
| | | | 2006-2007 | 19 | 1411.40 | 208.50 | | |
| | | | 2011-2013 | 20 | 1679.80 | 271.70 | | |
| | | Hardness | 2001-2002 | 19 | 1714.70 | 130.00 | 0.007 * | |
| | | | 2006-2007 | 19 | 1917.80 | 290.70 | | |
| | | | 2011-2013 | 12 | 2076.30 | 472.70 | | |
| Walnut Creek | OK520610-03-0010F | DO % Saturation | 2001-2002 | 20 | 95.60 | 17.58 | 0.033 * | |
| | | | 2006-2007 | 17 | 87.66 | 11.43 | | |
| | | | 2011-2013 | 21 | 106.62 | 30.22 | | |
| | | Nitrate | 2001-2002 | 20 | 0.56 | 0.27 | 0.055 | |
| | | | 2006-2007 | 19 | 0.54 | 1.24 | | |
| | | | 2011-2013 | 20 | 0.06 | 0.10 | | |
| | | Chloride | 2001-2002 | 20 | 25.59 | 8.26 | 0.029 * | |
| | | | 2006-2007 | 19 | 39.74 | 25.38 | | |
| | | | 2011-2013 | 20 | 36.84 | 13.35 | | |
| | | Hardness | 2001-2002 | 20 | 318.10 | 92.80 | 0.041 * | |
| | | | 2006-2007 | 19 | 356.20 | 91.70 | | |
| | | | 2011-2013 | 14 | 428.60 | 180.80 | | |
| | | pH | 2001-2002 | 19 | 8.13 | 0.24 | 0.002 * | |
| | | | 2006-2007 | 19 | 8.00 | 0.26 | | |
| | | | 2011-2013 | 22 | 8.31 | 0.30 | | |
| | | Flow | 2001-2002 | 20 | 46.39 | 77.57 | 0.100 | |
| | | | 2006-2007 | 15 | 36.33 | 42.56 | | |
| | | | 2011-2013 | 19 | 9.90 | 15.50 | | |

## 3.2 Biological Monitoring

### 3.2.1 Habitat Assessment

Total habitat scores for each site and computed metric scores are listed below (Table 15). Fivemile and Fourteenmile Creeks had the highest habitat scores, while Trail Creek had the lowest habitat score. No biological or habitat data was obtained for Red Creek due to drought conditions. Table 16 presents the habitat scores for the probabilistic sites.

**Table 15. Habitat assessment metric values for fixed monitoring sites in the Rotating Basin Group 1, 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | 7.8 | 4.8 | 17 | 14 | 2.2 | 17 | 15 | 0.2 | 8.9 | 7 | 9.7 | 104 |
| Bird Creek | OK121300-02-0010C | 3.8 | 0.4 | 0 | 5.5 | 0 | 20 | 14 | 0 | 9.5 | 8.5 | 10 | 71.4 |
| Buck Creek | OK121400-03-0170C | 11 | 8.6 | 14 | 10 | 12 | 15 | 2.8 | 2.2 | 6.7 | 6.3 | 6.8 | 95.1 |
| Buggy Creek | OK520610-02-0120C | 7.7 | 2.4 | 0 | 7.6 | 0 | 13 | 0.4 | 1.6 | 9.1 | 5.9 | 9.3 | 57 |
| Bull Creek | OK121500-02-0090D | 7.4 | 7.7 | 18 | 10 | 0 | 0 | 5 | 3.6 | 5.1 | 3.6 | 9.3 | 69.7 |
| California Creek | OK121510-02-0050C | 11 | 14 | 20 | 19 | 12 | 6 | 1.8 | 4.7 | 5.2 | 5.8 | 6.4 | 107 |
| Chouteau Creek | OK121600-01-0430P | 7.1 | 5.6 | 20 | 18 | 2.2 | 0 | 0.7 | 5.9 | 3.7 | 3 | 9.5 | 75.6 |
| Commission Creek | OK520620-05-0160C | 14 | 3.3 | 0 | 14 | 12 | 4 | 0.4 | 2.4 | 6.4 | 4.9 | 4 | 65.8 |
| Curl Creek | OK121400-01-0270C | 5.3 | 3.6 | 19 | 16 | 0 | 0 | 11 | 2.9 | 8.3 | 5.3 | 9.5 | 81.2 |
| Deer Creek | OK520620-06-0010F | 8.5 | 1.8 | 19 | 3.9 | 0 | 20 | 0.5 | 2 | 10 | 7.4 | 9.5 | 82.4 |
| Delaware Creek | OK121300-01-0150H | 2 | 3.2 | 16 | 5.1 | 0 | 0.5 | 14 | 6.7 | 7.2 | 7.2 | 9.9 | 71.8 |
| Dog Creek | OK121500-04-0010M | 2.9 | 2.3 | 15 | 13 | 0 | 0 | 11 | 4.1 | 9.7 | 6.7 | 10 | 74.3 |
| Fivemile Creek | OK121600-07-0110G | 19 | 19 | 20 | 20 | 16 | 16 | 0.4 | 0.5 | 10 | 4.3 | 9.7 | 135 |
| Fourteenmile Creek | OK121600-01-0100G | 17 | 20 | 17 | 9.9 | 16 | 18 | 0.4 | 0.8 | 8.3 | 5.4 | 10 | 122 |
| Hackberry Creek | OK520620-04-0050D | 5.3 | 0.4 | 0 | 16 | 0 | 0.4 | 9.9 | 5.2 | 9.5 | 7.6 | 5 | 59.6 |
| Hogshooter Creek | OK121400-01-0300G | 9.4 | 12 | 19 | 20 | 7.5 | 3.9 | 0.7 | 1.8 | 4.7 | 4.4 | 8.9 | 92.6 |
| Hominy Creek | OK121300-04-0280G | 9.3 | 7.6 | 5.5 | 6.8 | 10 | 10 | 2.8 | 0.5 | 7.6 | 7.7 | 9.3 | 77.8 |
| Lightning Creek | OK121510-01-0130N | 5 | 6.2 | 15 | 16 | 0 | 16 | 17 | 1.3 | 5.8 | 4.2 | 7.4 | 93.1 |
| Little Cabin Creek | OK121600-06-0080C | 4.5 | 7.8 | 6.6 | 20 | 0 | 0 | 3.5 | 1 | 4.9 | 5.5 | 6.8 | 60.4 |
| Little Horse Creek | OK121600-03-0190A | 20 | 14 | 0 | 20 | 4.1 | 0 | 11 | 0 | 8.1 | 4.7 | 7.6 | 89.3 |
| Lone Creek | OK520620-03-0020C | 17 | 3.3 | 1.8 | 17 | 0 | 3.6 | 0.7 | 0.6 | 8.5 | 7.5 | 3.2 | 92.6 |
| Pryor Creek | OK121610-00-0050D | 7.6 | 6.7 | 14 | 20 | 4.1 | 12 | 11 | 0.6 | 7.7 | 4.4 | 7.2 | 95.3 |
| Ranger Creek | OK121600-01-0060D | 18 | 18 | 11 | 9.5 | 0 | 0 | 11 | 0.6 | 10 | 6 | 10 | 94.2 |
| Sand Creek | OK121400-04-0010F | 8.6 | 5.6 | 16 | 13 | 9.4 | 19 | 7.3 | 0.6 | 8.5 | 6 | 8.3 | 102 |
| Sycamore Creek | OK121600-03-0510D | 19 | 16 | 17 | 8.1 | 16 | 20 | 1.4 | 0.9 | 6.3 | 1.5 | 8 | 115 |
| Tar Creek | OK121600-04-0060D | 7 | 9.8 | 3.5 | 2.4 | 4.1 | 13 | 5 | 0 | 10 | 7.9 | 10 | 72.4 |
| Trail Creek | OK520620-02-0090G | 12 | 2.4 | 0 | 11 | 0 | 0.3 | 0.4 | 6 | 6.3 | 4.6 | 4.8 | 47.4 |
| Walnut Creek | OK520610-03-0010F | 3.8 | 0.8 | 0 | 15 | 0 | 2.5 | 0.5 | 1.6 | 8.8 | 6.6 | 9.7 | 49.6 |
| Willow Creek | OK520610-01-0080H | 11 | 1.6 | 0 | 20 | 2.2 | 2.8 | 0.4 | 2.4 | 10 | 6.8 | 8.8 | 65.9 |

**Table 16. Habitat assessment metric values for probabilistic monitoring sites in the Rotating Basin Group 1, 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bevan Creek - 105 | NEOGRD-105 | 8.4 | 13.2 | 1.1 | 18.9 | 0 | 0 | 1 | 2 | 10 | 6.8 | 10 | 71.4 |
| Big Cabin Creek - 042 | NEOGRD-042 | 4.2 | 12 | 16 | 13 | 5.9 | 4.5 | 2.3 | 5.8 | 5.1 | 4.6 | 8 | 81.9 |
| Big Cabin Creek - 095 | NEOGRD-095 | 9.4 | 4.9 | 17 | 12 | 0 | 0 | 4.2 | 4.3 | 8.9 | 5.1 | 10 | 75.6 |
| Big Cabin Creek - 127 | NEOGRD-127 | 7.3 | 6.8 | 9.9 | 13 | 0 | 0 | 0.7 | 1.1 | 5 | 4.1 | 10 | 58.1 |
| Bird Creek - 013 | NEOGRD-013 | 8.1 | 8 | 14 | 10 | 4.1 | 19 | 8.7 | 0.3 | 6.7 | 5.5 | 9.9 | 93.7 |
| Bird Creek - 027 | NEOGRD-027 | 2.4 | 1.3 | 15 | 4.4 | 0 | 0 | 14 | 1.5 | 8.8 | 5.4 | 9.2 | 61.3 |
| Bird Creek - 047 | NEOGRD-047 | 2.4 | 1.6 | 15 | 14 | 0 | 0 | 17 | 0.6 | 9.4 | 6.8 | 10 | 76.2 |
| Bird Creek - 053 | NEOGRD-053 | 4.9 | 3.2 | 14 | 3.6 | 0 | 20 | 17 | 0.7 | 6.7 | 4.2 | 9.3 | 83.3 |
| Bird Creek - 057 | NEOGRD-057 | 1.3 | 1.3 | 15 | 4.6 | 0 | 0 | 17 | 0.3 | 10 | 7.3 | 9.9 | 65.8 |
| Bird Creek - 061 | NEOGRD-061 | 0.7 | 0.4 | 15 | 0 | 0 | 0 | 6.7 | 0.6 | 8.5 | 7.8 | 10 | 49.3 |
| Bird Creek - 069 | NEOGRD-069 | 9.8 | 0.4 | 0 | 1 | 11 | 20 | 17 | -0 | 9.9 | 8.9 | 10 | 87.8 |
| Brush Creek - 058 | NEOGRD-058 | 19 | 20 | 14 | 12 | 16 | 0 | 0.4 | 1.3 | 9.5 | 6.4 | 10 | 108 |
| Buck Creek - 045 | NEOGRD-045 | 17 | 13 | 19 | 5.5 | 2.2 | 0 | 3.5 | 1.1 | 6.1 | 3.8 | 8.7 | 80.2 |
| Bull Creek - 107 | NEOGRD-107 | 19 | 16 | 20 | 11 | 0 | 0 | 17 | 2 | 8.4 | 6.2 | 8 | 108 |
| Candy Creek - 026 | NEOGRD-026 | 14 | 13 | 17 | 6.6 | 4.1 | 0.5 | 8.7 | 2.7 | 6 | 5.1 | 3.4 | 81 |
| Caney River - 021 | NEOGRD-021 | 2.7 | 4.9 | 15 | 7.1 | 0 | 0 | 5 | 1.6 | 6.5 | 4.9 | 9.3 | 56.6 |
| Caney River - 080 | NEOGRD-080 | 12 | 4.5 | 15 | 9.6 | 0 | 0 | 17 | 0.4 | 8.4 | 4.8 | 4.8 | 75.3 |
| Caney River - 131 | NEOGRD-131 | 1.8 | 2 | 15 | 6.9 | 0 | 0 | 17 | 0.5 | 9.9 | 5.1 | 9.3 | 66.6 |
| Chouteau Creek - 024 | NEOGRD-024 | 8.8 | 11 | 13 | 12 | 0 | 0 | 3.5 | 1.5 | 5 | 3.3 | 6.8 | 64.9 |
| Clear Creek - 060 | NEOGRD-060 | 7.7 | 7.4 | 14 | 4 | 0 | 2.2 | 12 | 1.1 | 7.3 | 4.5 | 4.8 | 65.3 |
| Delaware  Creek - 150 | NEOGRD-150 | 1.4 | 5.4 | 15 | 20 | 0 | 0 | 17 | 5.7 | 8.8 | 6.2 | 10 | 88.9 |
| Double Spring Creek - 141 | NEOGRD-141 | 17 | 5.5 | 7.7 | 19 | 2.2 | 2.7 | 2.8 | 3.2 | 6.9 | 3.8 | 9.9 | 80.6 |
| Dry Creek - 140 | NEOGRD-140 | 2.7 | 6.8 | 20 | 10 | 0 | 0 | 12 | 2.4 | 8.1 | 4.9 | 10 | 77.5 |
| Fourmile Creek - 076 | NEOGRD-076 | 12.9 | 9.7 | 16.3 | 9 | 0 | 0 | 11.1 | 0.9 | 10 | 8.8 | 10 | 88.7 |
| Hominy Creek - 009 | NEOGRD-09 | 2.8 | 1.8 | 16 | 3 | 0 | 19 | 1 | 1.7 | 2.9 | 3.5 | 9.1 | 60.9 |
| Hominy Creek - 148 | NEOGRD-148 | 1 | 0.4 | 0 | 0 | 0 | 0 | 11 | 3.4 | 8.7 | 4.6 | 5 | 34.2 |
| Lightning Creek - 079 | NEOGRD-079 | 7.7 | 5.1 | 0 | 17 | 10 | 2.3 | 5 | 2.4 | 10 | 8.6 | 9.9 | 78 |
| Little Cabin Creek - 075 | NEOGRD-075 | 3.2 | 5.8 | 20 | 15 | 0 | 0 | 17 | 2.4 | 8.1 | 3.7 | 10 | 84.2 |
| Little Saline Creek - 097 | NEOGRD-097 | 20 | 19 | 13 | 20 | 16 | 0 | 0.4 | 6.5 | 9.3 | 4.3 | 10 | 118 |
| Mingo Creek - 145 | NEOGRD-145 | 17 | 15 | 18 | 7.6 | 10 | 4 | 7.7 | 0.9 | 7.8 | 7 | 10 | 105 |
| Neosho River - 120 | NEOGRD-120 | 4.2 | 4.6 | 15 | 3.3 | 0 | 20 | 8.7 | 0.8 | 6.2 | 2.7 | 8 | 73.1 |
| North Fork Cotton Creek - 010 | NEOGRD-010 | 3.2 | 4.7 | 0 | 20 | 2.2 | 0 | 3.5 | 8.8 | 3.1 | 3.4 | 8.7 | 57.1 |
| Opossum Creek - 052 | NEOGRD-052 | 6.6 | 3.9 | 20 | 18 | 10 | 2.3 | 1 | 3.8 | 4.7 | 2.9 | 9.5 | 82.7 |
| Opossum Creek - 068 | NEOGRD-068 | 5.8 | 10 | 20 | 19 | 0 | 1.1 | 8.7 | 2 | 5.1 | 3.8 | 9.7 | 84.9 |

| 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Panther Creek - 011 | NEOGRD-011 | 12 | 5.9 | 6.1 | 14 | 11 | 7.2 | 1.8 | 4.3 | 10 | 5.7 | 9.9 | 88.1 |
| Pawpaw Creek - 091 | NEOGRD-091 | 6.1 | 2.8 | 14 | 6.2 | 0 | 0 | 6.7 | 0.4 | 6.5 | 4.6 | 9.5 | 56.4 |
| Pecan Creek - 016 | NEOGRD-016 | 18 | 14 | 13 | 20 | 7.5 | 1.9 | 2.8 | 2.4 | 8.8 | 3.6 | 10 | 101 |
| Pond Creek - 108 | NEOGRD-108 | 5.5 | 2.3 | 15 | 11 | 0 | 0 | 14 | 2.4 | 10 | 2.4 | 10 | 72.4 |
| Pryor Creek - 081 | NEOGRD-081 | 3.1 | 2.1 | 15 | 20 | 0 | 0 | 17 | 1.9 | 7.3 | 3.4 | 9.4 | 78.2 |
| Pryor Creek - 115 | NEOGRD-115 | 3.5 | 2.2 | 19 | 9.4 | 0 | 0 | 3.5 | 3.1 | 4.4 | 3.6 | 10 | 58.2 |
| Pryor Creek - 146 | NEOGRD-146 | 13 | 9.6 | 19 | 10 | 9 | 0 | 1.4 | 1.1 | 4.2 | 4.3 | 10 | 81.9 |
| Rock Creek - 116 | NEOGRD-116 | 19 | 17 | 20 | 6.7 | 15 | 12 | 17 | 3.4 | 10 | 8.7 | 10 | 138 |
| Sand Creek - 025 | NEOGRD-025 | 6.4 | 6.1 | 15 | 6.7 | 0 | 0 | 6.7 | 4.3 | 9.2 | 6.8 | 10 | 71.2 |
| Spavinaw Creek - 074 | NEOGRD-074 | 17 | 15 | 13 | 9.7 | 16 | 20 | 1 | 0.4 | 8.1 | 5.5 | 9.7 | 115 |
| Spring Creek - 093 | NEOGRD-093 | 20 | 18 | 15 | 9.9 | 16 | 0 | 0.4 | 4.4 | 9.9 | 3.5 | 10 | 107 |
| Spring Creek - 122 | NEOGRD-122 | 19 | 18 | 18 | 5.9 | 11 | 14 | 3.5 | 1.7 | 4.4 | 1.9 | 9.3 | 107 |
| Verdigris River - 139 | NEOGRD-139 | 14 | 17 | 0 | 7.4 | 16 | 20 | 5.8 | 0.2 | 8.6 | 3 | 6.8 | 99 |
| West Fork Big Cabin Creek - 123 | NEOGRD-123 | 12 | 8.9 | 17 | 16 | 2.2 | 0 | 3.5 | 3.4 | 5.9 | 3.5 | 9.7 | 81.4 |

Sites were compared relative to the mean total habitat score of high quality sites in the respective ecoregion and a range determined by +/- two standard deviations (Figure 4). Sites with scores that are within +/- two standard deviations of the mean of the high quality sites do not necessarily have "reference" conditions; rather, sites outside of these values have either extremely good or extremely poor conditions which merit further investigation. Low habitat scores could be the result of anthropogenic activities, could be naturally occurring, or could indicate an unrepresentative reach. During the monitoring period Oklahoma experienced a severe drought which most likely resulted in lower habitat scores. Parameters like pool variability and flow would be particularly affected by lack of water or low water conditions.

Fixed sites (Figure 4): Habitat scores for all of the sites in all of the ecoregions were within two standard deviations of the high quality sites with the exception of Ranger Creek in the Boston Mountains.

Probabilistic sites (Figure 5): Double Spring Creek in the Boston Mountains scored significantly lower than the high quality reference conditions. Of the 25 sites in the Central Irregular Plains, only Hominy Creek (148) showed significantly poor habitat. Twelve sites were monitored in the Cross Timbers: Bird Creek (161) showed significantly poor habitat and Rock Creek (116) was significantly better than the habitat in the high quality sites. The rest of the sites fell within two standard deviations of the high quality sites for the same ecoregion.

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

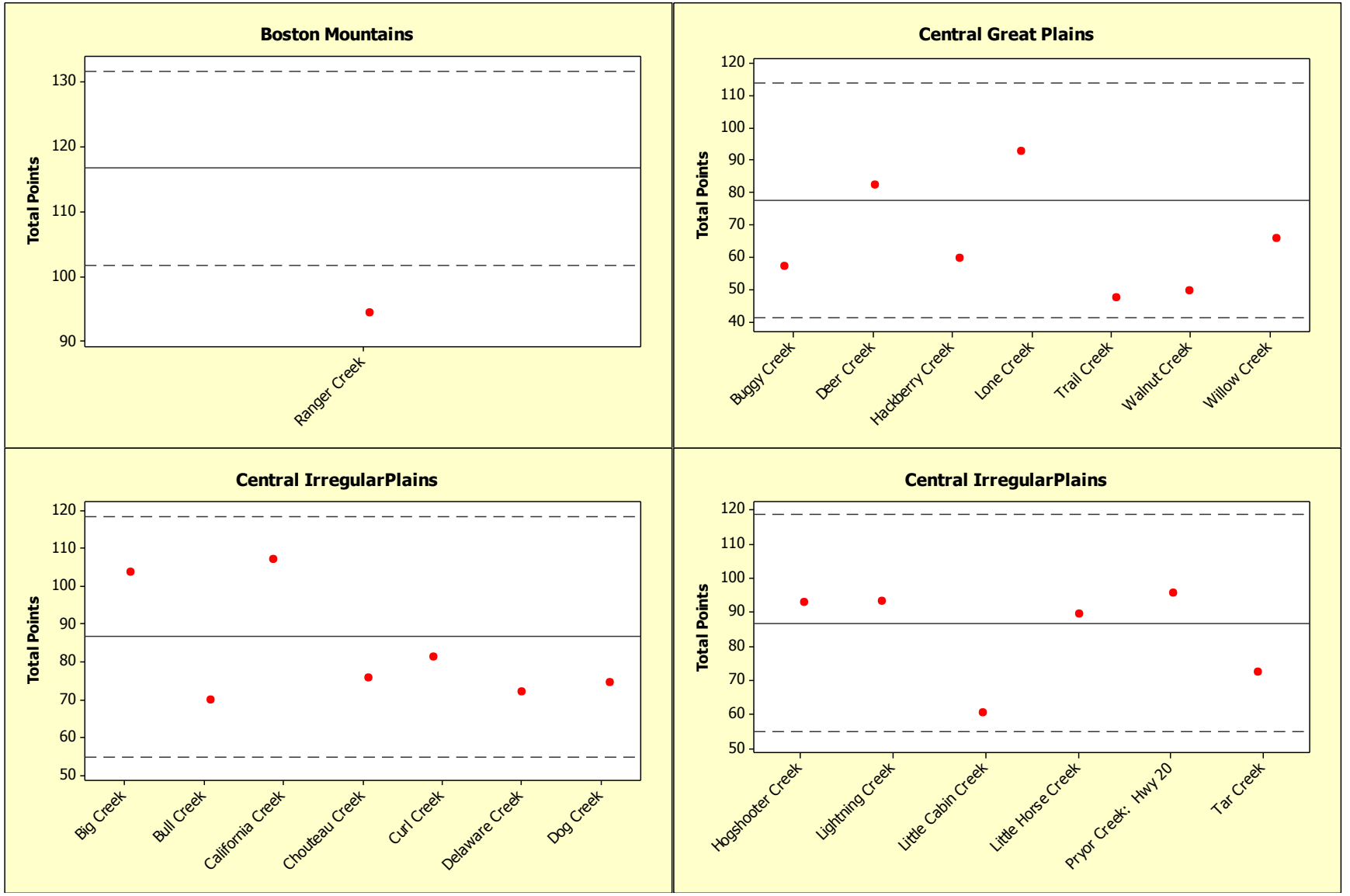


**Figure 4, cont. Total habitat score for each fixed site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.**

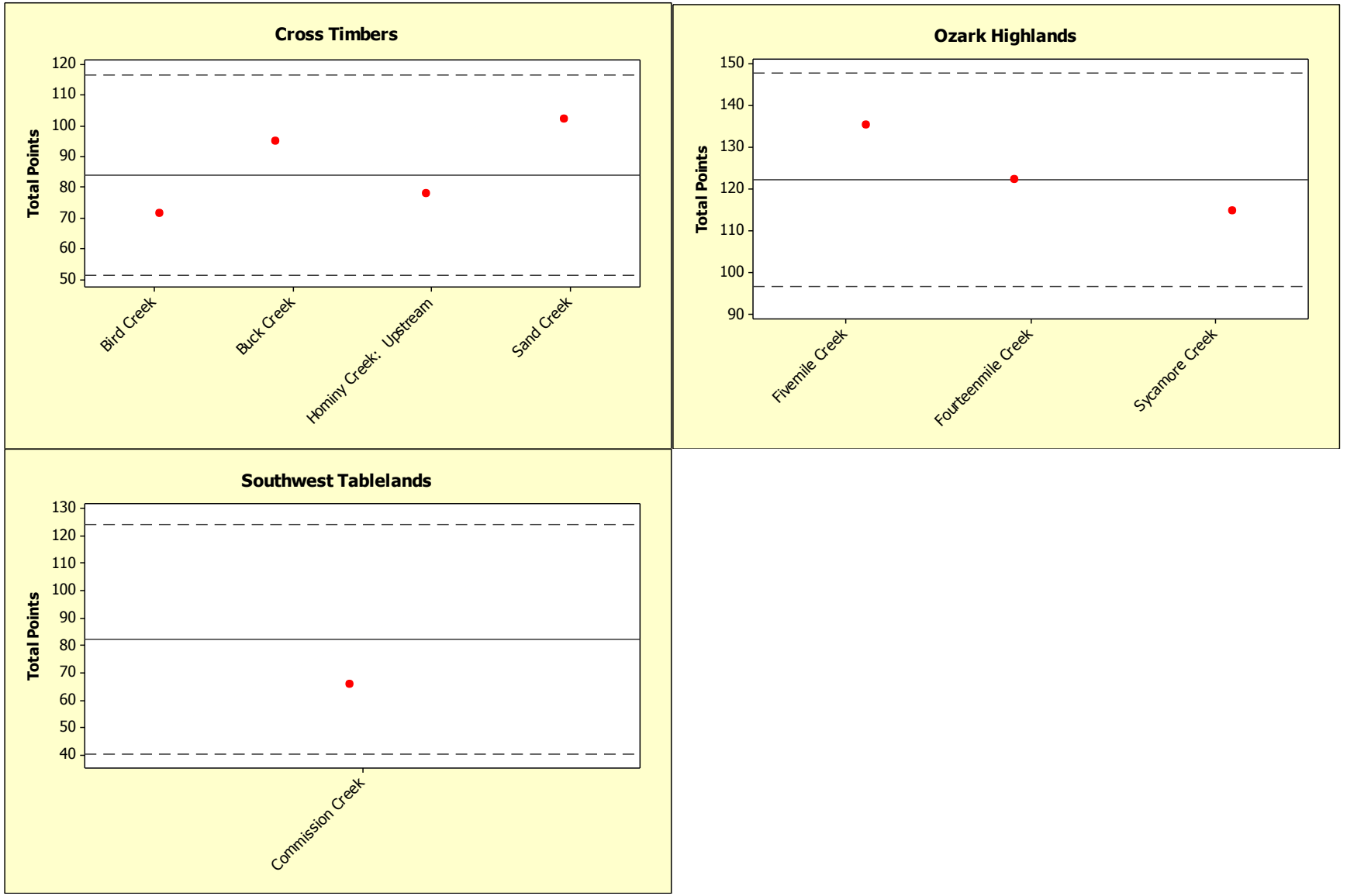


**Figure 5. Total habitat score for each probabilistic site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.**

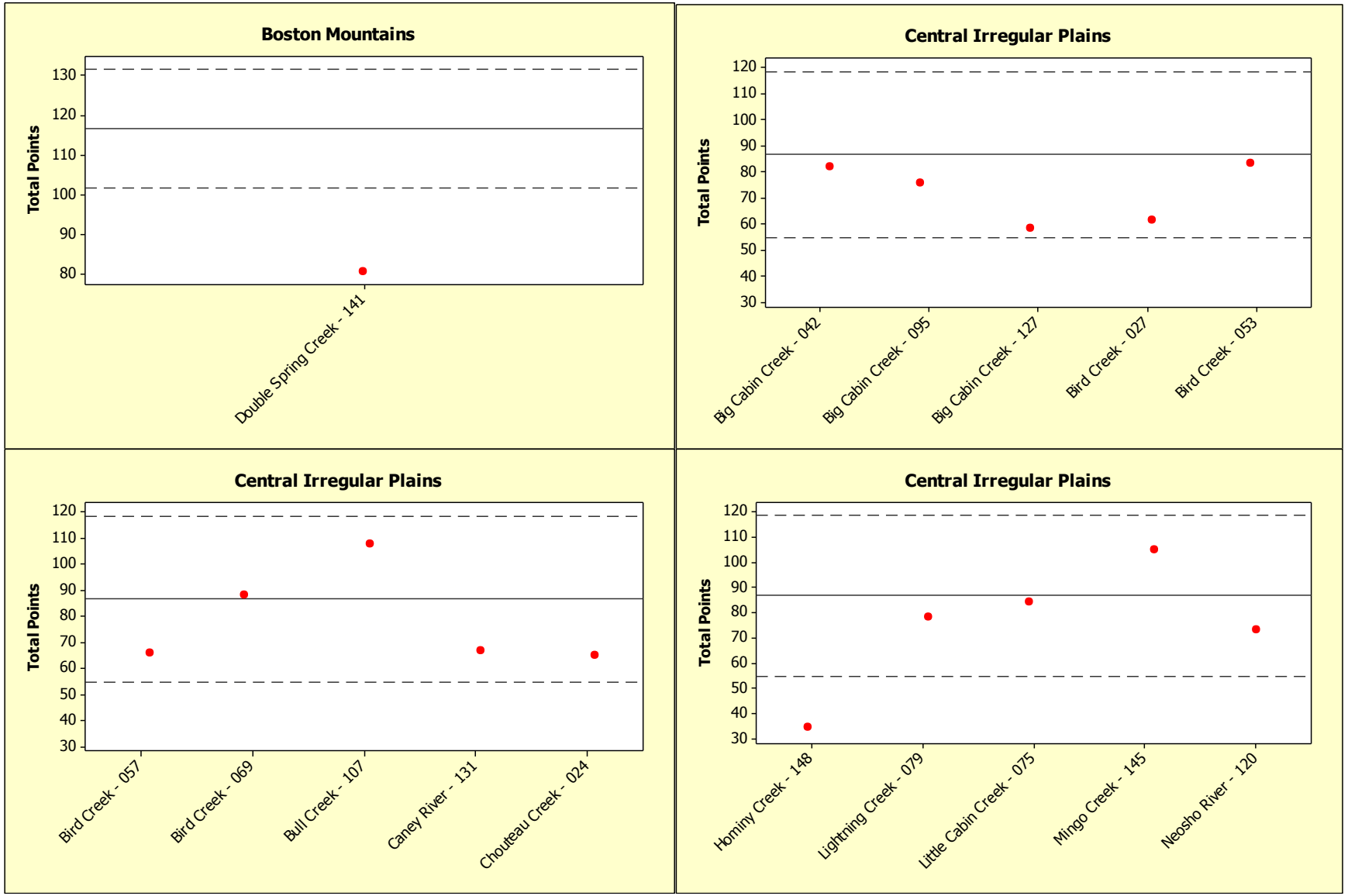


**Figure 5, cont. Total habitat score for each probabilistic site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.**

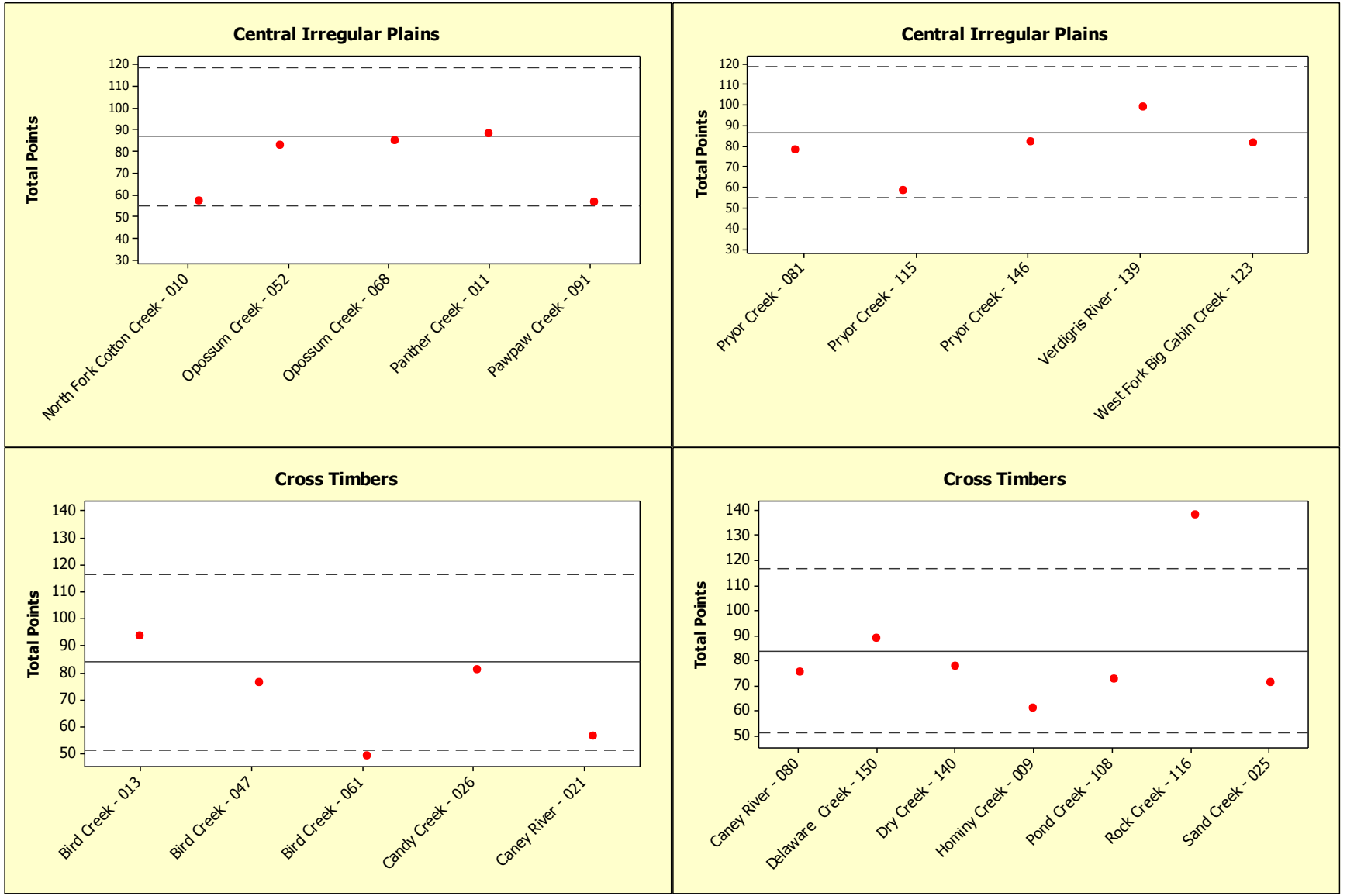
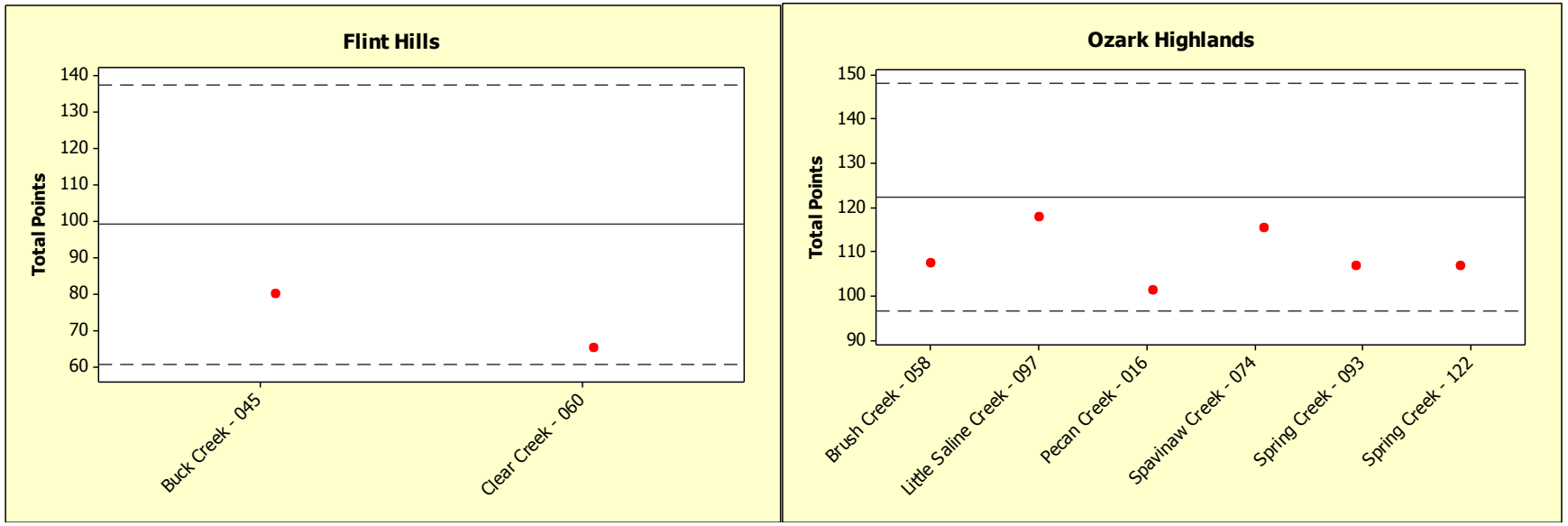


**Figure 5, cont. Total habitat score for each probabilistic site by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.**



### 3.2.2 Fish Collections

Fish metrics used to compute IBI scores for the Rotating Basin sites using the OCC method are listed in Tables 17 (fixed sites) and 18 (probabilistic sites). 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 17. Metric values for calculation of fish IBI scores (OCC method) for fixed sites in Rotating Basin Year 1, Cycle 3.**

| Site Name | WBID | Total Number | Total Spp | Darter Spp | Sensitive Benthic Spp | Sunfish Spp | Intolerant Spp | Percent Tolerant | Percent Insectivorous Cyprinid | Percent Lithophylic Spawners |
|---|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | 389 | 21 | 0 | 3 | 6 | 2 | 0.473 | 0.270 | 0.383 |
| Bird Creek | OK121300-02-0010C | 1221 | 17 | 2 | 5 | 5 | 4 | 0.955 | 0.021 | 0.035 |
| Buck Creek | OK121400-03-0170C | 395 | 17 | 1 | 4 | 4 | 5 | 0.580 | 0.342 | 0.296 |
| Buggy Creek | OK520610-02-0120C | 1321 | 9 | 0 | 1 | 3 | 1 | 0.696 | 0.304 | 0.000 |
| Bull Creek | OK121500-02-0090D | 467 | 20 | 0 | 3 | 8 | 1 | 0.951 | 0.000 | 0.017 |
| California Creek | OK121510-02-0050C | 504 | 19 | 0 | 2 | 5 | 3 | 0.685 | 0.099 | 0.284 |
| Chouteau Creek | OK121600-01-0430P | 340 | 21 | 0 | 2 | 8 | 1 | 0.859 | 0.026 | 0.071 |
| Commission Creek | OK520620-05-0160C | 475 | 7 | 0 | 1 | 2 | 1 | 0.269 | 0.731 | 0.000 |
| Curl Creek | OK121400-01-0270C | 247 | 17 | 0 | 1 | 8 | 1 | 0.907 | 0.020 | 0.065 |
| Deer Creek | OK520620-06-0010F | 2342 | 20 | 0 | 1 | 5 | 1 | 0.944 | 0.066 | 0.000 |
| Delaware Creek | OK121300-01-0150H | 152 | 16 | 1 | 3 | 6 | 1 | 0.868 | 0.000 | 0.046 |
| Dog Creek | OK121500-04-0010M | 90 | 7 | 0 | 0 | 4 | 0 | 0.978 | 0.000 | 0.000 |
| Fivemile Creek | OK121600-07-0110G | 500 | 21 | 4 | 8 | 7 | 13 | 0.062 | 0.426 | 0.938 |
| Fourteenmile Creek | OK121600-01-0100G | 490 | 26 | 6 | 9 | 6 | 13 | 0.376 | 0.206 | 0.596 |
| Hackberry Creek | OK520620-04-0050D | 250 | 12 | 0 | 0 | 2 | 0 | 0.992 | 0.008 | 0.000 |
| Hogshooter Creek | OK121400-01-0300G | 814 | 21 | 2 | 7 | 7 | 4 | 0.587 | 0.016 | 0.382 |
| Hominy Creek | OK121300-04-0280G | 777 | 18 | 0 | 2 | 6 | 1 | 0.803 | 0.095 | 0.163 |
| Lightning Creek | OK121510-01-0130N | 134 | 13 | 1 | 2 | 4 | 0 | 0.806 | 0.000 | 0.112 |
| Little Cabin Creek | OK121600-06-0080C | 421 | 22 | 3 | 6 | 6 | 3 | 0.862 | 0.010 | 0.074 |
| Little Horse Creek | OK121600-03-0190A | 716 | 21 | 2 | 4 | 7 | 1 | 0.559 | 0.000 | 0.409 |
| Lone Creek | OK520620-03-0020C | 628 | 11 | 0 | 1 | 4 | 1 | 0.873 | 0.127 | 0.000 |
| Pryor Creek | OK121610-00-0050D | 457 | 16 | 2 | 4 | 6 | 3 | 0.871 | 0.000 | 0.125 |
| Ranger Creek | OK121600-01-0060D | 640 | 21 | 2 | 6 | 7 | 5 | 0.720 | 0.139 | 0.205 |
| Sand Creek | OK121400-04-0010F | 434 | 18 | 0 | 4 | 6 | 3 | 0.963 | 0.009 | 0.012 |
| Sycamore Creek | OK121600-03-0510D | 390 | 22 | 3 | 7 | 9 | 11 | 0.264 | 0.290 | 0.667 |
| Tar Creek | OK121600-04-0060D | 498 | 16 | 0 | 3 | 6 | 1 | 0.878 | 0.000 | 0.084 |
| Trail Creek | OK520620-02-0090G | 1023 | 6 | 0 | 1 | 0 | 1 | 0.765 | 0.235 | 0.000 |
| Walnut Creek | OK520610-03-0010F | 1106 | 15 | 0 | 0 | 6 | 0 | 0.944 | 0.079 | 0.000 |
| Willow Creek | OK520610-01-0080H | 1051 | 14 | 0 | 2 | 6 | 1 | 0.741 | 0.247 | 0.011 |

**Table 18. Metric values for calculation of fish IBI scores (OCC method) for probabilistic sites in Rotating Basin Year1, Cycle 3.**

| Site Name | WBID | Total Number | Total Spp | Darter Spp | Sensitive Benthic Spp | Sunfish Spp | Intolerant Spp | Percent Tolerant | Percent Insectivorous Cyprinid | Percent Lithophylic Spawners |
|---|---|---|---|---|---|---|---|---|---|---|
| Bevan Creek – 105 | NEOGRD-105 | 202 | 6 | 0 | 1 | 3 | 0 | 0.168 | 0.000 | 0.025 |
| Big Cabin Creek - 042 | NEOGRD-042 | 473 | 26 | 4 | 5 | 8 | 4 | 0.740 | 0.004 | 0.137 |
| Big Cabin Creek - 095 | NEOGRD-095 | 940 | 32 | 4 | 9 | 9 | 6 | 0.700 | 0.029 | 0.207 |
| Big Cabin Creek - 127 | NEOGRD-127 | 1285 | 21 | 3 | 5 | 7 | 3 | 0.578 | 0.019 | 0.353 |
| Bird Creek - 013 | NEOGRD-013 | 804 | 23 | 1 | 6 | 5 | 4 | 0.660 | 0.162 | 0.199 |
| Bird Creek - 027 | NEOGRD-027 | 59 | 11 | 0 | 1 | 1 | 1 | 0.983 | 0.017 | 0.000 |
| Bird Creek - 047 | NEOGRD-047 | 13 | 10 | 0 | 0 | 4 | 0 | 0.846 | 0.000 | 0.077 |
| Bird Creek - 053 | NEOGRD-053 | 939 | 21 | 1 | 5 | 5 | 4 | 0.934 | 0.032 | 0.032 |
| Bird Creek - 057 | NEOGRD-057 | 108 | 19 | 0 | 1 | 5 | 1 | 0.907 | 0.019 | 0.019 |
| Bird Creek - 061 | NEOGRD-061 | 498 | 22 | 1 | 4 | 6 | 4 | 0.809 | 0.018 | 0.157 |
| Bird Creek - 069 | NEOGRD-069 | 590 | 17 | 0 | 4 | 4 | 3 | 0.956 | 0.015 | 0.019 |
| Brush Creek - 058 | NEOGRD-058 | 542 | 16 | 3 | 6 | 3 | 9 | 0.024 | 0.245 | 0.976 |
| Buck Creek - 045 | NEOGRD-045 | 1631 | 22 | 0 | 4 | 5 | 5 | 0.330 | 0.387 | 0.636 |
| Bull Creek - 107 | NEOGRD-107 | 104 | 12 | 0 | 0 | 5 | 0 | 0.971 | 0.000 | 0.000 |
| Candy Creek - 026 | NEOGRD-026 | 368 | 20 | 1 | 4 | 7 | 1 | 0.690 | 0.109 | 0.084 |
| Caney River - 021 | NEOGRD-021 | 728 | 30 | 3 | 7 | 7 | 5 | 0.591 | 0.048 | 0.231 |
| Caney River - 080 | NEOGRD-080 | 258 | 30 | 3 | 7 | 6 | 6 | 0.721 | 0.124 | 0.190 |
| Caney River - 131 | NEOGRD-131 | 75 | 10 | 0 | 0 | 2 | 0 | 1.000 | 0.000 | 0.000 |
| Chouteau Creek - 024 | NEOGRD-024 | 604 | 20 | 0 | 0 | 7 | 0 | 0.914 | 0.000 | 0.000 |
| Clear Creek - 060 | NEOGRD-060 | 237 | 15 | 0 | 2 | 6 | 1 | 0.793 | 0.084 | 0.135 |
| Delaware  Creek - 150 | NEOGRD-150 | 445 | 16 | 0 | 1 | 5 | 0 | 0.800 | 0.009 | 0.004 |
| Double Spring Creek - 141 | NEOGRD-141 | 675 | 21 | 3 | 6 | 6 | 8 | 0.178 | 0.098 | 0.815 |
| Dry Creek - 140 | NEOGRD-140 | 513 | 19 | 1 | 4 | 7 | 4 | 0.349 | 0.242 | 0.423 |
| Fourmile Creek – 076 | NEOGRD-076 | 354 | 8 | 0 | 0 | 5 | 0 | 0.582 | 0.000 | 0.014 |
| Hominy Creek - 009 | NEOGRD-09 | 1015 | 17 | 0 | 3 | 7 | 1 | 0.943 | 0.004 | 0.047 |
| Hominy Creek - 148 | NEOGRD-148 | 86 | 16 | 0 | 1 | 3 | 0 | 0.837 | 0.000 | 0.140 |
| Lightning Creek - 079 | NEOGRD-079 | 216 | 8 | 1 | 2 | 4 | 0 | 0.537 | 0.000 | 0.463 |
| Little Cabin Creek - 075 | NEOGRD-075 | 789 | 21 | 1 | 2 | 9 | 2 | 0.807 | 0.004 | 0.038 |
| Little Saline Creek - 097 | NEOGRD-097 | 457 | 11 | 3 | 5 | 1 | 6 | 0.007 | 0.582 | 0.993 |
| Mingo Creek - 145 | NEOGRD-145 | 370 | 18 | 2 | 4 | 5 | 3 | 0.241 | 0.008 | 0.170 |
| Neosho River - 120 | NEOGRD-120 | 774 | 20 | 1 | 4 | 3 | 2 | 0.987 | 0.010 | 0.009 |
| North Fork Cotton Creek - 010 | NEOGRD-010 | 160 | 13 | 1 | 3 | 4 | 1 | 0.731 | 0.013 | 0.256 |
| Opossum Creek - 052 | NEOGRD-052 | 458 | 18 | 0 | 3 | 5 | 3 | 0.891 | 0.031 | 0.096 |
| Opossum Creek - 068 | NEOGRD-068 | 254 | 14 | 0 | 3 | 4 | 1 | 0.866 | 0.039 | 0.083 |
| Panther Creek - 011 | NEOGRD-011 | 256 | 11 | 1 | 2 | 6 | 0 | 0.336 | 0.000 | 0.609 |
| Pawpaw Creek - 091 | NEOGRD-091 | 570 | 17 | 0 | 0 | 9 | 0 | 0.851 | 0.012 | 0.046 |
| Pecan Creek - 016 | NEOGRD-016 | 591 | 16 | 1 | 4 | 4 | 4 | 0.288 | 0.139 | 0.709 |
| Pond Creek - 108 | NEOGRD-108 | 1608 | 33 | 4 | 10 | 8 | 10 | 0.461 | 0.104 | 0.420 |
| Pryor Creek - 081 | NEOGRD-081 | 55 | 11 | 0 | 0 | 3 | 0 | 1.000 | 0.000 | 0.000 |
| Pryor Creek - 115 | NEOGRD-115 | 401 | 20 | 1 | 5 | 6 | 2 | 0.800 | 0.047 | 0.087 |
| Pryor Creek - 146 | NEOGRD-146 | 734 | 20 | 2 | 4 | 7 | 2 | 0.640 | 0.000 | 0.178 |
| Rock Creek - 116 | NEOGRD-116 | 261 | 22 | 2 | 4 | 7 | 4 | 0.586 | 0.222 | 0.352 |
| Sand Creek - 025 | NEOGRD-025 | 396 | 20 | 1 | 3 | 6 | 2 | 0.884 | 0.030 | 0.071 |
| Spavinaw Creek - 074 | NEOGRD-074 | 1696 | 29 | 4 | 9 | 10 | 14 | 0.092 | 0.414 | 0.884 |
| Spring Creek - 093 | NEOGRD-093 | 568 | 15 | 3 | 6 | 3 | 10 | 0.007 | 0.572 | 0.993 |
| Spring Creek - 122 | NEOGRD-122 | 679 | 16 | 3 | 7 | 3 | 8 | 0.010 | 0.436 | 0.988 |

| Site Name | WBID | Total Number | Total Spp | Darter Spp | Sensitive Benthic Spp | Sunfish Spp | Intolerant Spp | Percent Tolerant | Percent Insectivorous Cyprinid | Percent Lithophylic Spawners |
|---|---|---|---|---|---|---|---|---|---|---|
| Verdigris River - 139 | NEOGRD-139 | 611 | 29 | 3 | 8 | 7 | 4 | 0.782 | 0.015 | 0.115 |
| West Fork Big Cabin Creek - 123 | NEOGRD-123 | 329 | 19 | 1 | 6 | 6 | 2 | 0.584 | 0.055 | 0.319 |

Table 19 presents the results of the fixed site fish assessment based on the OCC's modified RBP method. At this time the fish assessment based on Oklahoma state biocriteria (as described in Oklahoma Water Resource Board, *Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (USAP), OAC 785:46-15) 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. Not all data was available at the time of analysis so the USAP results will be compared in the next report. The OCC method allows greater discrimination of the biological condition among sites. Of the 29 sites, 14 were "excellent" when compared with high quality sites in the same ecoregion, 8 were "good", 4 were "fair", 2 were "poor" and 1 was "very poor."

**Table 19. IBI scores for fixed sites based on OCC's modified RBP method.**

| Ecoregion | Site Name | WBID | OCC IBI | % of Reference | Condition |
|---|---|---|---|---|---|
| BM | Ranger Creek | OK121600-01-0060D | 23 | 0.70 | Fair |
| CGP | Buggy Creek | OK520610-02-0120C | 23 | 1.05 | Excellent |
| CGP | Deer Creek | OK520620-06-0010F | 21 | 0.95 | Excellent |
| CGP | Hackberry Creek | OK520620-04-0050D | 13 | 0.59 | Poor |
| CGP | Lone Creek | OK520620-03-0020C | 21 | 0.95 | Excellent |
| CGP | Trail Creek | OK520620-02-0090G | 17 | 0.77 | Fair |
| CGP | Walnut Creek | OK520610-03-0010F | 15 | 0.68 | Fair |
| CGP | Willow Creek | OK520610-01-0080H | 25 | 1.14 | Excellent |
| CIP | Big Creek | OK121510-03-0010D | 25 | 1.07 | Excellent |
| CIP | Bull Creek | OK121500-02-0090D | 19 | 0.81 | Good |
| CIP | California Creek | OK121510-02-0050C | 23 | 0.98 | Excellent |
| CIP | Chouteau Creek | OK121600-01-0430P | 19 | 0.81 | Good |
| CIP | Curl Creek | OK121400-01-0270C | 17 | 0.73 | Fair |
| CIP | Delaware Creek | OK121300-01-0150H | 19 | 0.81 | Good |
| CIP | Dog Creek | OK121500-04-0010M | 9 | 0.38 | Very Poor |
| CIP | Hogshooter Creek | OK121400-01-0300G | 27 | 1.15 | Excellent |
| CIP | Lightning Creek | OK121510-01-0130N | 13 | 0.56 | Poor |
| CIP | Little Cabin Creek | OK121600-06-0080C | 23 | 0.98 | Excellent |
| CIP | Little Horse Creek | OK121600-03-0190A | 23 | 0.98 | Excellent |

| Ecoregion | Site Name | WBID | OCC IBI | % of Reference | Condition |
|---|---|---|---|---|---|
| CIP | Pryor Creek | OK121610-00-0050D | 21 | 0.90 | Good |
| CIP | Tar Creek | OK121600-04-0060D | 19 | 0.81 | Good |
| CT | Bird Creek | OK121300-02-0010C | 23 | 1.01 | Excellent |
| CT | Buck Creek | OK121400-03-0170C | 25 | 1.10 | Excellent |
| CT | Hominy Creek | OK121300-04-0280G | 19 | 0.84 | Good |
| CT | Sand Creek | OK121400-04-0010F | 23 | 1.01 | Excellent |
| OH | Fivemile Creek | OK121600-07-0110G | 33 | 1.00 | Excellent |
| OH | Fourteenmile Creek | OK121600-01-0100G | 29 | 0.88 | Good |
| OH | Sycamore Creek | OK121600-03-0510D | 29 | 0.88 | Good |
| SWT | Commission Creek | OK520620-05-0160C | 23 | 1.00 | Excellent |

Table 20 presents the results of the probabilistic site fish assessment based on the OCC's modified RBP method. Of the 48 sites, 22 rated "excellent", 8 were "good", 10 were "fair" and 8 were "poor."

**Table 20. IBI scores for probabilistic sites based on OCC's modified RBP method.**

| Ecoregion | Site Name | WBID | OCC IBI | % of Reference | Condition |
|---|---|---|---|---|---|
| BM | Double Spring Creek - 141 | NEOGRD-141 | 29 | 0.88 | Good |
| CIP | Bevan Creek - 105 | NEOGRD-105 | 11 | 0.47 | Poor |
| CIP | Big Cabin Creek - 042 | NEOGRD-042 | 23 | 0.98 | Excellent |
| CIP | Big Cabin Creek - 095 | NEOGRD-095 | 25 | 1.07 | Excellent |
| CIP | Big Cabin Creek - 127 | NEOGRD-127 | 25 | 1.07 | Excellent |
| CIP | Bird Creek - 027 | NEOGRD-027 | 11 | 0.47 | Poor |
| CIP | Bird Creek - 053 | NEOGRD-053 | 23 | 0.98 | Excellent |
| CIP | Bird Creek - 057 | NEOGRD-057 | 17 | 0.73 | Fair |
| CIP | Bird Creek - 069 | NEOGRD-069 | 19 | 0.81 | Good |
| CIP | Bull Creek - 107 | NEOGRD-107 | 13 | 0.56 | Poor |
| CIP | Caney River - 131 | NEOGRD-131 | 11 | 0.47 | Poor |
| CIP | Chouteau Creek - 024 | NEOGRD-024 | 15 | 0.64 | Fair |
| CIP | Hominy Creek - 148 | NEOGRD-148 | 13 | 0.56 | Poor |
| CIP | Lightning Creek - 079 | NEOGRD-079 | 17 | 0.73 | Fair |
| CIP | Little Cabin Creek - 075 | NEOGRD-075 | 19 | 0.81 | Good |
| CIP | Mingo Creek - 145 | NEOGRD-145 | 23 | 0.98 | Excellent |

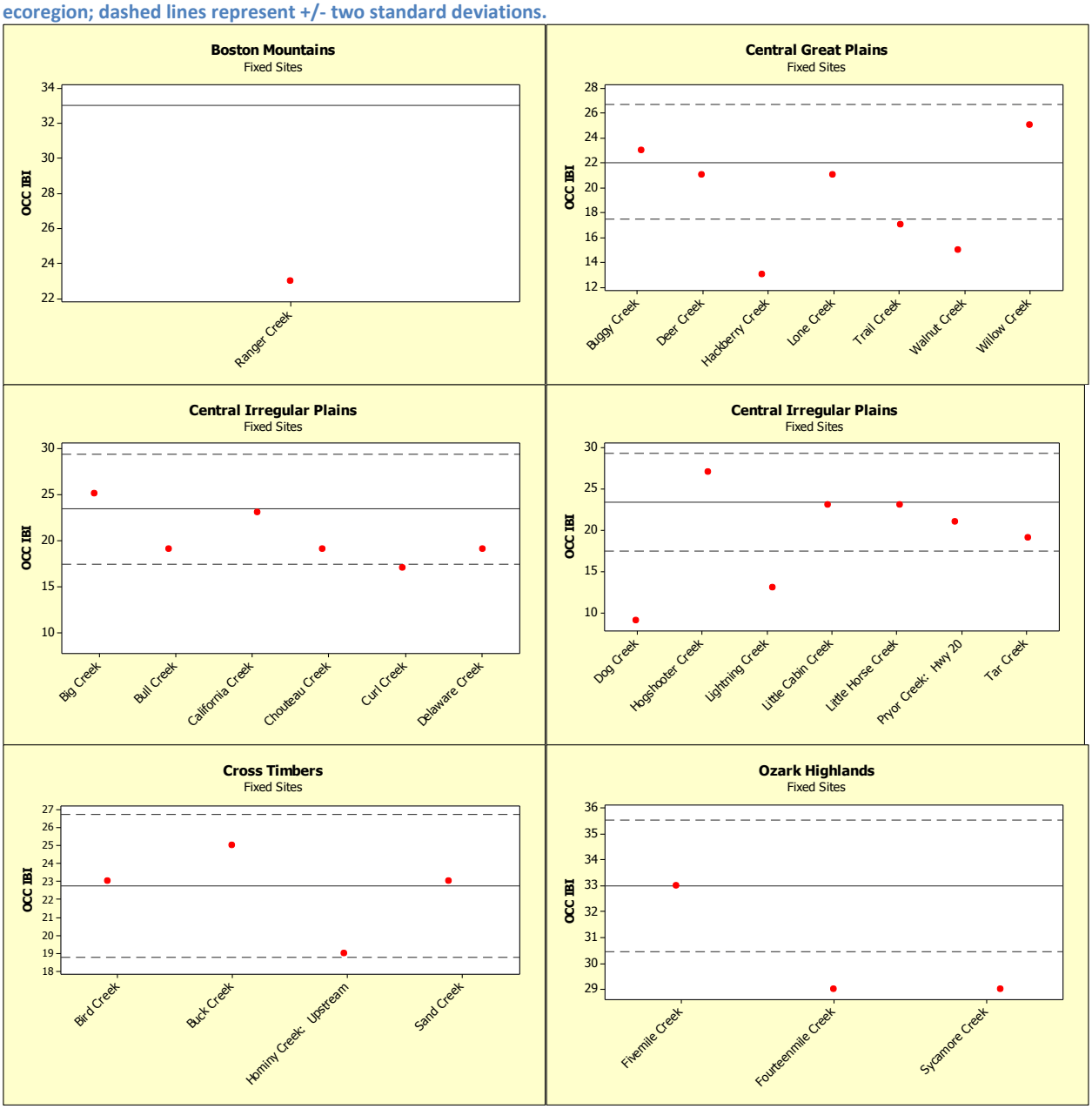
| Ecoregion | Site Name | WBID | OCC IBI | % of Reference | Condition |
|---|---|---|---|---|---|
| CIP | Neosho River - 120 | NEOGRD-120 | 17 | 0.73 | Fair |
| CIP | North Fork Cotton Creek - 010 | NEOGRD-010 | 17 | 0.73 | Fair |
| CIP | Opossum Creek - 052 | NEOGRD-052 | 21 | 0.90 | Good |
| CIP | Opossum Creek - 068 | NEOGRD-068 | 15 | 0.64 | Fair |
| CIP | Panther Creek - 011 | NEOGRD-011 | 19 | 0.81 | Good |
| CIP | Pawpaw Creek - 091 | NEOGRD-091 | 15 | 0.64 | Fair |
| CIP | Pryor Creek - 081 | NEOGRD-081 | 11 | 0.47 | Poor |
| CIP | Pryor Creek - 115 | NEOGRD-115 | 21 | 0.90 | Good |
| CIP | Pryor Creek - 146 | NEOGRD-146 | 19 | 0.81 | Good |
| CIP | Verdigris River - 139 | NEOGRD-139 | 23 | 0.98 | Excellent |
| CIP | West Fork Big Cabin Creek - 123 | NEOGRD-123 | 23 | 0.98 | Excellent |
| CT | Bird Creek - 013 | NEOGRD-013 | 25 | 1.10 | Excellent |
| CT | Bird Creek - 047 | NEOGRD-047 | 11 | 0.48 | Poor |
| CT | Bird Creek - 061 | NEOGRD-061 | 23 | 1.01 | Excellent |
| CT | Candy Creek - 026 | NEOGRD-026 | 21 | 0.92 | Excellent |
| CT | Caney River - 021 | NEOGRD-021 | 25 | 1.10 | Excellent |
| CT | Caney River - 080 | NEOGRD-080 | 25 | 1.10 | Excellent |
| CT | Delaware  Creek - 150 | NEOGRD-150 | 15 | 0.66 | Fair |
| CT | Dry Creek - 140 | NEOGRD-140 | 29 | 1.27 | Excellent |
| CT | Fourmile Creek - 076 | NEOGRD-076 | 13 | 0.57 | Poor |
| CT | Hominy Creek - 009 | NEOGRD-09 | 21 | 0.92 | Excellent |
| CT | Pond Creek - 108 | NEOGRD-108 | 27 | 1.19 | Excellent |
| CT | Rock Creek - 116 | NEOGRD-116 | 27 | 1.19 | Excellent |
| CT | Sand Creek - 025 | NEOGRD-025 | 23 | 1.01 | Excellent |
| FH | Buck Creek - 045 | NEOGRD-045 | 27 | 1.00 | Excellent |
| FH | Clear Creek - 060 | NEOGRD-060 | 19 | 0.70 | Fair |
| OH | Brush Creek - 058 | NEOGRD-058 | 33 | 1.00 | Excellent |
| OH | Little Saline Creek - 097 | NEOGRD-097 | 29 | 0.88 | Good |
| OH | Pecan Creek - 016 | NEOGRD-016 | 23 | 0.70 | Fair |
| OH | Spavinaw Creek - 074 | NEOGRD-074 | 33 | 1.00 | Excellent |
| OH | Spring Creek - 093 | NEOGRD-093 | 35 | 1.06 | Excellent |
| OH | Spring Creek - 122 | NEOGRD-122 | 33 | 1.00 | Excellent |

Overall, when looking at fish communities, the streams in the Central Irregular Plains ecoregion were most likely to score in the “fair” and “poor” range.  Combining all of the ecoregions, the fish communities in the fixed sites were 48% “excellent”, 28% “good”, 14% “fair”, 7% “poor”, 3% “very poor”; the fish in the

probabilistic sites were 46% “excellent”, 17% “good”, 20% “fair”, and 7% “poor”, with no “very poor” sites. In the entire basin, approximately 68% of the sites have at least good fish communities and 14% have poor communities relative to high quality sites in the ecoregions of this basin.

Figure 6 shows the IBI score for each fixed site (indicated by a red dot) relative to the mean value for the high quality sites in that ecoregion (indicated by a solid line). Figure 7 shows the probabilistic site scores. 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.

**Figure 6. IBI score (fish) for each fixed site plotted by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.**



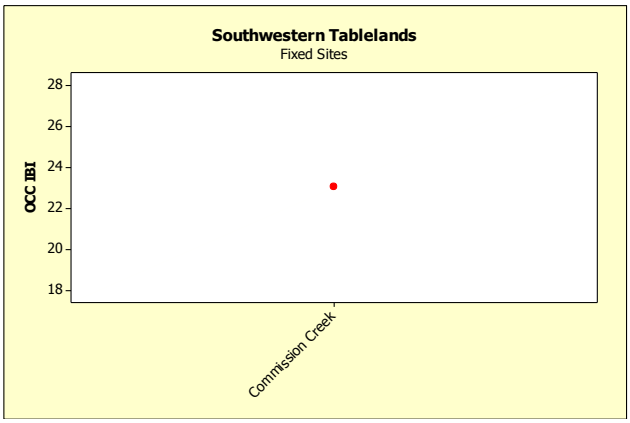



**Figure 7. IBI score (fish) for each probabilistic site plotted by ecoregion. Solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.**

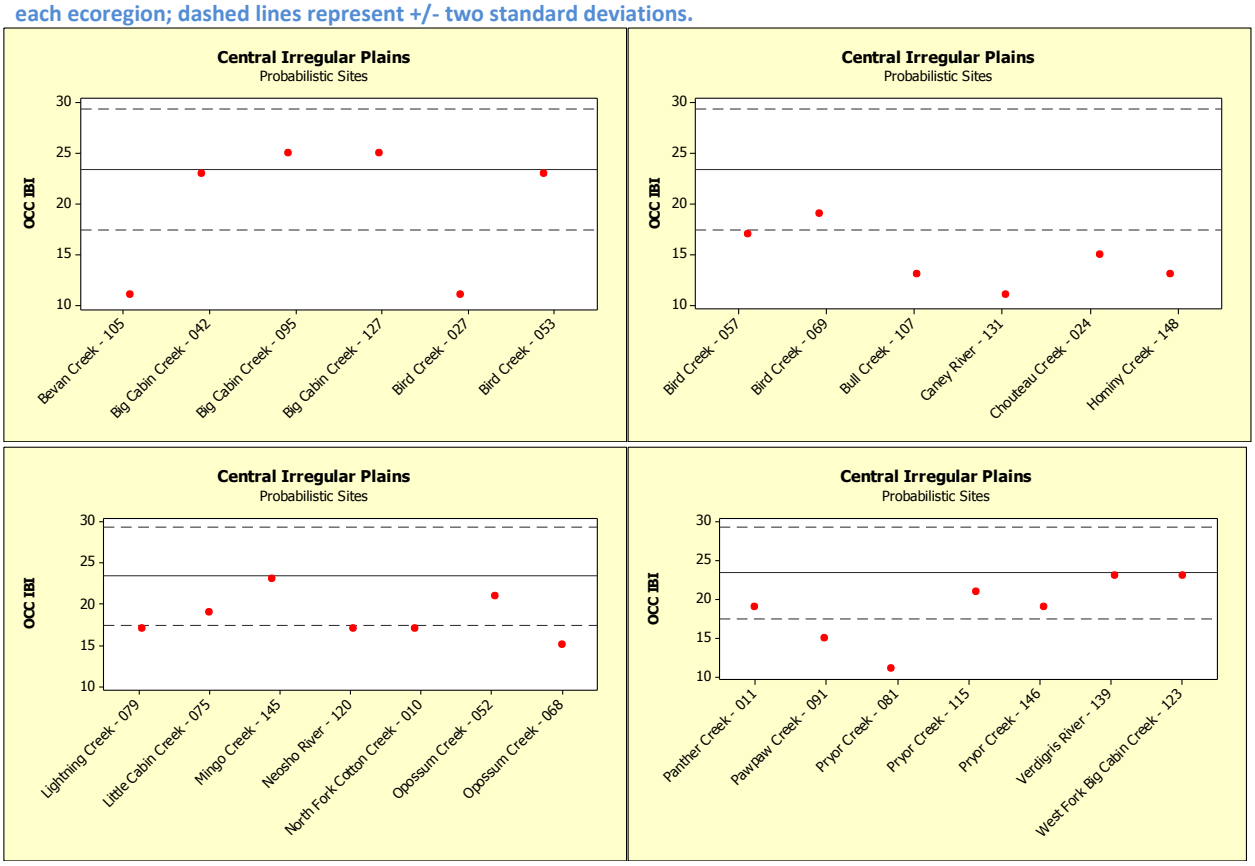
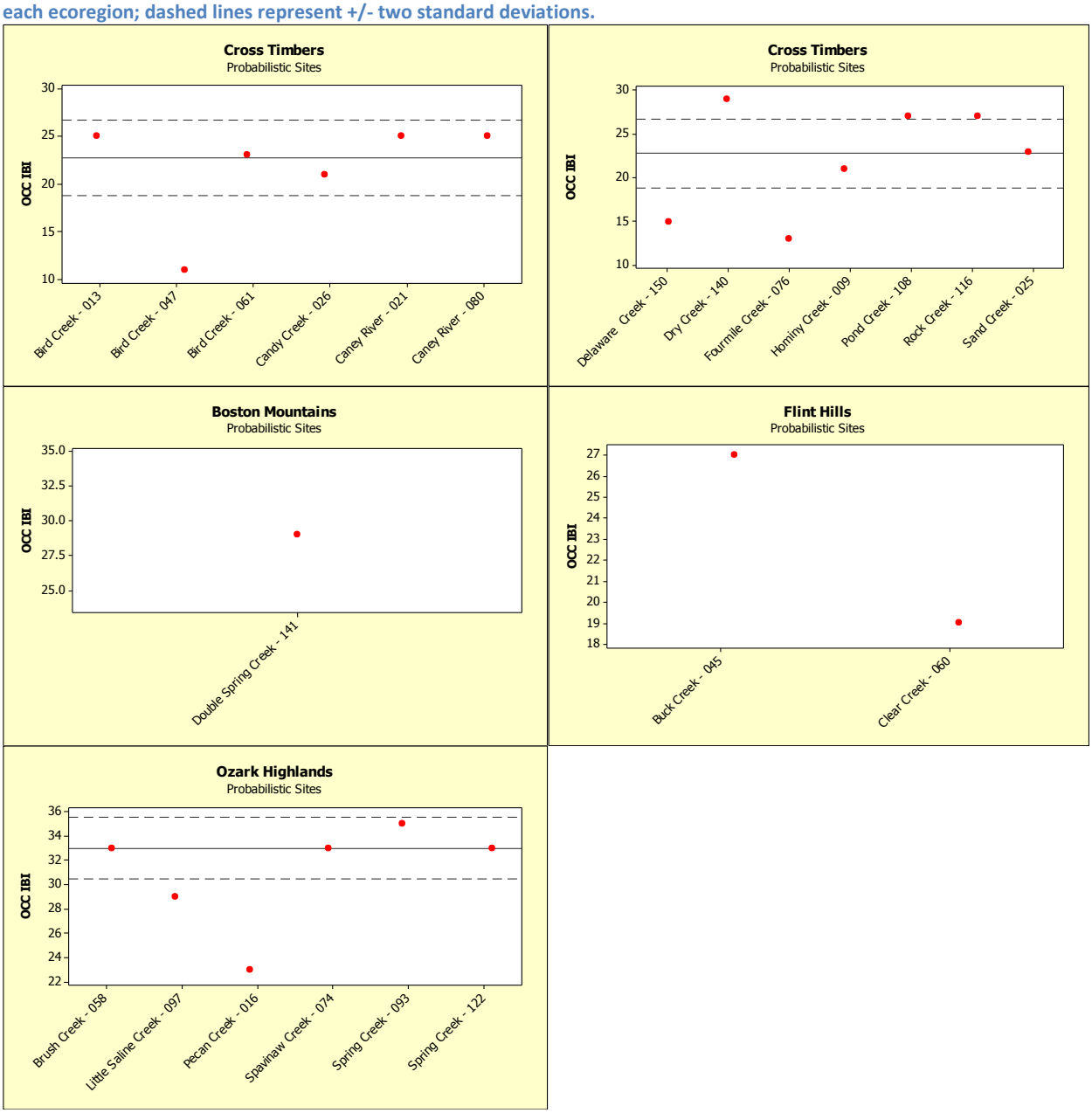


**Figure 7 (cont.) IBI score (fish) for each probabilistic site by ecoregion. solid lines indicate the mean value of high quality sites in each ecoregion; dashed lines represent +/- two standard deviations.**




Forty percent of the probabilistic sites and 33% of the fixed sites had significantly lower IBI scores than the high quality sites, as indicated by an IBI score below the bottom dashed line in Figures 6 and 7 (the sites without good high quality reference conditions were not used in this comparison). These sites were rated "good," "fair," or "poor" using the OCC IBI method (Tables 19 – 21). Conditions have been quite dry during this monitoring cycle, so it is possible that this contributed to low fish scores relative to the high quality site scores, which were collected in previous years. There tended to be more variability among the probabilistic sites than among the fixed sites. This could be an artifact of the selection process for the fixed sites; only sites with consistent flow have been maintained as part of the regular rotation, while probabilistic sites were included if there was water present at the time of the initial visit.

Table 21 shows a comparison between fish data collected in cycle 1 (2001 or 2002), cycle 2 (2006 or 2007), and cycle 3 (2011 or 2012) of the rotating basin project in order to examine whether biological conditions have improved, worsened, or remained the same at a particular site. 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 the rotating basin cycle 3 collection, not to a change in the high quality sites. The fish community remained in the same condition for nine of the 27 sites with IBI scores to be compared. Seven streams had worse fish community conditions in cycle 3 relative to cycle 2, while eleven streams had improved fish communities.

**Table 21. Comparison of fish data from previous projects to Rotating Basin Year 1, Cycle 3 (2011-2012).**

| Site Name | WBID | Year | Total Individuals | Total Species | # Darter Spp. | # Sunfish Spp. | # Intolerant Spp. | Proportion Tolerant Individuals | Proportion Insect. Cyprinid Individuals | Proportion Lithophylic Spawners | Total Score | IBI | Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | 2001 | 886 | 28 | 1 | 7 | 4 | 0.26 | 0.04 | 0.39 | 23 | 0.88 | good |
| Big Creek | OK121510-03-0010D | 2006 | 242 | 24 | 1 | 10 | 3 | 0.62 | 0.07 | 0.13 | 21 | 0.81 | good |
| Big Creek | OK121510-03-0010D | 2011 | 389 | 21 | 0 | 6 | 2 | 0.47 | 0.27 | 0.38 | 25 | 1.07 | excellent |
| Bird Creek | OK121300-02-0010C | 2001 | 2146 | 24 | 3 | 7 | 4 | 0.83 | 0.75 | 0.13 | 23 | 1.00 | excellent |
| Bird Creek | OK121300-02-0010C | 2006 | 784 | 18 | 2 | 6 | 3 | 0.55 | 0.04 | 0.40 | 27 | 1.17 | excellent |
| Bird Creek | OK121300-02-0010C | 2011 | 1221 | 17 | 2 | 5 | 4 | 0.95 | 0.02 | 0.04 | 23 | 1.01 | excellent |
| Buck Creek | OK121400-03-0170C | 2001 | 671 | 29 | 4 | 6 | 7 | 0.24 | 0.10 | 0.36 | 25 | 0.93 | good |
| Buck Creek | OK121400-03-0170C | 2006 | 619 | 29 | 3 | 6 | 8 | 0.40 | 0.30 | 0.45 | 29 | 1.07 | excellent |
| Buck Creek | OK121400-03-0170C | 2011 | 395 | 17 | 1 | 4 | 5 | 0.58 | 0.34 | 0.30 | 25 | 1.10 | excellent |
| Buggy Creek | OK520610-02-0120C | 2001 | 948 | 13 | 0 | 3 | 1 | 0.85 | 0.15 | 0.00 | 19 | 0.86 | good |
| Buggy Creek | OK520610-02-0120C | 2006 | 234 | 12 | 0 | 4 | 0 | 0.96 | 0.04 | 0.00 | 15 | 0.68 | fair |
| Buggy Creek | OK520610-02-0120C | 2011 | 1321 | 9 | 0 | 3 | 1 | 0.70 | 0.30 | 0.00 | 23 | 1.05 | excellent |
| Bull Creek | OK121500-02-0090D | 2001 | 671 | 25 | 2 | 8 | 3 | 0.66 | 0.00 | 0.13 | 19 | 0.73 | fair |
| Bull Creek | OK121500-02-0090D | 2006 | 395 | 23 | 0 | 10 | 0 | 0.74 | 0.25 | 0.76 | 15 | 0.58 | poor |
| Bull Creek | OK121500-02-0090D | 2011 | 467 | 20 | 0 | 8 | 1 | 0.95 | 0.00 | 0.02 | 19 | 0.81 | good |
| California Creek | OK121510-02-0050C | 2001 | 971 | 24 | 2 | 6 | 4 | 0.40 | 0.02 | 0.49 | 23 | 0.88 | good |
| California Creek | OK121510-02-0050C | 2006 | 168 | 27 | 1 | 8 | 2 | 0.66 | 0.10 | 0.20 | 23 | 0.88 | good |
| California Creek | OK121510-02-0050C | 2011 | 504 | 19 | 0 | 5 | 3 | 0.68 | 0.10 | 0.28 | 23 | 0.98 | excellent |
| Chouteau Creek | OK121600-01-0430M | 2001 | 351 | 23 | 0 | 8 | 1 | 0.41 | 0.03 | 0.04 | 17 | 0.65 | fair |
| Chouteau Creek | OK121600-01-0430M | 2006 | 232 | 14 | 0 | 8 | 1 | 0.93 | 0.00 | 0.02 | 15 | 0.58 | poor |
| Chouteau Creek | OK121600-01-0430P | 2011 | 340 | 21 | 0 | 8 | 1 | 0.86 | 0.03 | 0.07 | 19 | 0.81 | good |
| Commission Creek | OK520620-05-0160C | 2001 | 117 | 10 | 0 | 4 | 1 | 0.57 | 0.43 | 0.00 | 21 | 0.88 | good |
| Commission Creek | OK520620-05-0160C | 2006 | 339 | 7 | 0 | 2 | 1 | 0.27 | 0.73 | 0.00 | 23 | 0.96 | excellent |
| Commission Creek | OK520620-05-0160C | 2011 | 475 | 7 | 0 | 2 | 1 | 0.27 | 0.73 | 0.00 | 23 | 1.00 | excellent |
| Curl Creek | OK121400-01-0270G | 2001 | | | | | | | | | 19 | 0.73 | fair |
| Curl Creek | OK121400-01-0270C | 2006 | 383 | 14 | 1 | 7 | 0 | 0.98 | 0.00 | 0.26 | 15 | 0.58 | poor |
| Curl Creek | OK121400-01-0270C | 2011 | 247 | 17 | 0 | 8 | 1 | 0.91 | 0.02 | 0.06 | 17 | 0.73 | fair |
| Deer Creek | OK520620-06-0010F | 2001 | 3451 | 21 | 0 | 6 | 2 | 0.90 | 0.19 | 0.00 | 19 | 0.86 | good |

| Site Name | WBID | Year | Total Individuals | Total Species | # Darter Spp. | # Sunfish Spp. | # Intolerant Spp. | Proportion Tolerant Individuals | Proportion Insect. Cyprinid Individuals | Proportion Lithophylic Spawners | Total Score | IBI | Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Deer Creek | OK520620-06-0010F | 2006 | 3632 | 15 | 0 | 3 | 1 | 0.88 | 0.12 | 0.00 | 21 | 0.95 | excellent |
| Deer Creek | OK520620-06-0010F | 2011 | 2342 | 20 | 0 | 5 | 1 | 0.94 | 0.07 | 0.00 | 21 | 0.95 | excellent |
| Delaware Creek | OK121300-01-0150H | 2001 | 261 | 26 | 1 | 9 | 3 | 0.49 | 0.03 | 0.11 | 21 | 0.91 | good |
| Delaware Creek | OK121300-01-0150H | 2006 | 131 | 22 | 2 | 9 | 3 | 0.84 | 0.05 | 0.05 | 23 | 1.00 | excellent |
| Delaware Creek | OK121300-01-0150H | 2011 | 152 | 16 | 1 | 6 | 1 | 0.87 | 0.00 | 0.05 | 19 | 0.81 | good |
| Dog Creek | OK121500-02-0360D | 2002 | 537 | 25 | 3 | 7 | 3 | 0.87 | 0.00 | 0.04 | 19 | 0.73 | fair |
| Dog Creek | OK121500-02-0360D | 2006 | 214 | 16 | 1 | 6 | 1 | 0.92 | 0.02 | 0.03 | 19 | 0.73 | fair |
| Dog Creek | OK121500-04-0010M | 2011 | 90 | 7 | 0 | 4 | 0 | 0.98 | 0.00 | 0.00 | 9 | 0.38 | very Poor |
| Fivemile Creek | OK121600-07-0110G | 2001 | 1557 | 24 | 2 | 6 | 9 | 0.13 | 0.39 | 0.85 | 29 | 0.88 | good |
| Fivemile Creek | OK121600-07-0110G | 2006 | 704 | 20 | 3 | 6 | 11 | 0.05 | 0.43 | 0.95 | 33 | 1.00 | excellent |
| Fivemile Creek | OK121600-07-0110G | 2011 | 500 | 21 | 4 | 7 | 13 | 0.06 | 0.43 | 0.94 | 33 | 1.00 | excellent |
| Fourteenmile Creek | OK121600-01-0100G | 2001 | 2690 | 31 | 5 | 8 | 16 | 0.11 | 0.34 | 0.89 | 27 | 0.82 | good |
| Fourteenmile Creek | OK121600-01-0100G | 2006 | 726 | 20 | 3 | 7 | 11 | 0.10 | 0.40 | 0.90 | 33 | 1.00 | excellent |
| Fourteenmile Creek | OK121600-01-0100G | 2011 | 490 | 26 | 6 | 6 | 13 | 0.38 | 0.21 | 0.60 | 29 | 0.88 | good |
| Hackberry Creek | OK520620-04-0050D | 2001 | 265 | 6 | 0 | 1 | 1 | 0.76 | 0.48 | 0.00 | 17 | 0.77 | good |
| Hackberry Creek | OK520620-04-0050D | 2007 | 288 | 9 | 0 | 2 | 0 | 0.89 | 0.10 | 0.00 | 11 | 0.50 | poor |
| Hackberry Creek | OK520620-04-0050D | 2011 | 250 | 12 | 0 | 2 | 0 | 0.99 | 0.01 | 0.00 | 13 | 0.59 | poor |
| Hogshooter Creek | OK121400-01-0300D | 2001 | 210 | 12 | 1 | 4 | 3 | 0.69 | 0.02 | 0.29 | 17 | 0.65 | fair |
| Hogshooter Creek | OK121400-01-0300D | 2006 | 294 | 14 | 1 | 4 | 1 | 0.89 | 0.02 | 0.04 | 15 | 0.58 | poor |
| Hogshooter Creek | OK121400-01-0300G | 2011 | 814 | 21 | 2 | 7 | 4 | 0.59 | 0.02 | 0.38 | 27 | 1.15 | excellent |
| Hominy Creek | OK121300-04-0280G | 2001 | 802 | 18 | 1 | 6 | 1 | 0.71 | 0.62 | 0.26 | 19 | 0.83 | good |
| Hominy Creek | OK121300-04-0280G | 2006 | 316 | 20 | 2 | 4 | 2 | 0.70 | 0.08 | 0.21 | 23 | 1.00 | excellent |
| Hominy Creek | OK121300-04-0280G | 2011 | 777 | 18 | 0 | 6 | 1 | 0.80 | 0.10 | 0.16 | 19 | 0.84 | good |
| Little Cabin Creek | OK121600-06-0080C | 2001 | 348 | 25 | 3 | 8 | 4 | 0.52 | 0.11 | 0.14 | 23 | 0.88 | good |
| Little Cabin Creek | OK121600-06-0080C | 2006 | 167 | 21 | 2 | 8 | 3 | 0.75 | 0.05 | 0.13 | 21 | 0.81 | good |
| Little Cabin Creek | OK121600-06-0080C | 2011 | 421 | 22 | 3 | 6 | 3 | 0.86 | 0.01 | 0.07 | 23 | 0.98 | excellent |
| Little Horse Creek | OK121600-03-0190A | 2001 | 428 | 22 | 2 | 5 | 10 | 0.10 | 0.47 | 0.88 | 31 | 1.19 | excellent |
| Little Horse Creek | OK121600-03-0190A | 2006 | 40 | 10 | 1 | 5 | 2 | 0.85 | 0.00 | 0.05 | 19 | 0.73 | fair |
| Little Horse Creek | OK121600-03-0190A | 2011 | 716 | 21 | 2 | 7 | 1 | 0.56 | 0.00 | 0.41 | 23 | 0.98 | excellent |
| Lone Creek | OK520620-03-0020C | 2001 | 858 | 13 | 0 | 2 | 2 | 0.76 | 0.24 | 0.00 | 19 | 0.86 | good |
| Lone Creek | OK520620-03-0020C | 2006 | 625 | 8 | 0 | 0 | 1 | 0.65 | 0.35 | 0.00 | 17 | 0.77 | good |
| Lone Creek | OK520620-03-0020C | 2011 | 628 | 11 | 0 | 4 | 1 | 0.87 | 0.13 | 0.00 | 21 | 0.95 | excellent |
| Pryor Creek: Hwy 20 | OK121610-00-0050D | 2001 | 467 | 27 | 1 | 7 | 4 | 0.64 | 0.04 | 0.27 | 23 | 0.88 | good |
| Pryor Creek: Hwy 20 | OK121610-00-0050D | 2006 | 306 | 18 | 1 | 7 | 2 | 0.81 | 0.02 | 0.14 | 21 | 0.81 | good |
| Pryor Creek: Hwy 20 | OK121610-00-0050D | 2011 | 457 | 16 | 2 | 6 | 3 | 0.87 | 0.00 | 0.12 | 21 | 0.90 | good |
| Ranger Creek | OK121600-01-0060D | 2001 | 552 | 17 | 1 | 6 | 3 | 0.39 | 0.16 | 0.53 | 21 | 0.64 | fair |

| Site Name | WBID | Year | Total Individuals | Total Species | # Darter Spp. | # Sunfish Spp. | # Intolerant Spp. | Proportion Tolerant Individuals | Proportion Insect. Cyprinid Individuals | Proportion Lithophylic Spawners | Total Score | IBI | Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ranger Creek | OK121600-01-0060D | 2006 | 200 | 18 | 1 | 6 | 3 | 0.48 | 0.20 | 0.50 | 23 | 0.70 | fair |
| Ranger Creek | OK121600-01-0060D | 2011 | 640 | 21 | 2 | 7 | 5 | 0.72 | 0.14 | 0.20 | 23 | 0.70 | fair |
| Sand Creek | OK121400-04-0010F | 2001 | 378 | 21 | 1 | 7 | 4 | 0.40 | 0.15 | 0.28 | 21 | 0.91 | good |
| Sand Creek | OK121400-04-0010F | 2006 | 601 | 27 | 2 | 8 | 5 | 0.84 | 0.01 | 0.11 | 23 | 1.00 | excellent |
| Sand Creek | OK121400-04-0010F | 2011 | 434 | 18 | 0 | 6 | 3 | 0.96 | 0.01 | 0.01 | 23 | 1.01 | excellent |
| Sycamore Creek | OK121600-03-0510D | 2001 | 1261 | 26 | 2 | 8 | 13 | 0.06 | 0.52 | 0.93 | 31 | 0.94 | excellent |
| Sycamore Creek | OK121600-03-0510D | 2006 | 649 | 24 | 3 | 9 | 10 | 0.14 | 0.40 | 0.85 | 31 | 0.94 | excellent |
| Sycamore Creek | OK121600-03-0510D | 2011 | 390 | 22 | 3 | 9 | 11 | 0.26 | 0.29 | 0.67 | 29 | 0.88 | good |
| Tar Creek | OK121600-04-0060D | 2001 | 160 | 16 | 0 | 5 | 0 | 0.74 | 0.09 | 0.03 | 15 | 0.58 | poor |
| Tar Creek | OK121600-04-0060D | 2006 | 10 | 6 | 0 | 2 | 0 | 0.80 | 0.00 | 0.20 | 11 | 0.42 | very poor |
| Tar Creek | OK121600-04-0060D | 2011 | 498 | 16 | 0 | 6 | 1 | 0.88 | 0.00 | 0.08 | 19 | 0.81 | good |
| Trail Creek | OK520620-02-0090G | 2001 | 845 | 12 | 1 | 2 | 1 | 0.93 | 0.07 | 0.00 | 19 | 0.86 | good |
| Trail Creek | OK520620-02-0090G | 2006 | 269 | 8 | 0 | 2 | 1 | 0.51 | 0.49 | 0.00 | 21 | 0.95 | excellent |
| Trail Creek | OK520620-02-0090G | 2011 | 1023 | 6 | 0 | 0 | 1 | 0.77 | 0.23 | 0.00 | 17 | 0.77 | fair |
| Walnut Creek | OK520610-03-0010C | 2001 | | | | | | | | | 21 | 0.95 | excellent |
| Walnut Creek | OK520610-03-0010F | 2006 | 1496 | 11 | 0 | 4 | 0 | 0.61 | 0.39 | 0.00 | 17 | 0.77 | good |
| Walnut Creek | OK520610-03-0010F | 2011 | 1106 | 15 | 0 | 6 | 0 | 0.94 | 0.08 | 0.00 | 15 | 0.68 | fair |

### 3.2.3 Macroinvertebrate Collections

The complete macroinvertebrate dataset, including species and numbers captured per site, can be found in Appendix C. Macroinvertebrates were collected for most sites at least once during the project period; however, seven sites lacked sufficient flowing water for the entire rotation cycle due to drought and have no macroinvertebrate data for this rotation. Lack of flow during the collection periods prevented the collection of four total samples for some sites.

Tables 22 and 23 present 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 22. Macroinvertebrate metric values determined for each fixed monitoring site, averaged per season and habitat. NI = non-impaired, SI = slightly impaired, MI = moderately impaired, SvI = severely impaired.**

| Site Name | WBID | # of Samples | Sample Type | Winter or Summer | Total Species | EPT Taxa | Percent EPT | HBI | Percent Dominant 2 taxa | Shannon Diversity | Total Points | % of Reference | Condition | Average Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | 2 | Riffle | W | 11 | 2.5 | 0.05 | 6.23 | 0.76 | 1.32 | 11 | 0.40 | MI | MI |
| Bird Creek | OK121300-02-0010C | 2 | Riffle | S | 13 | 5.5 | 0.24 | 4.90 | 0.64 | 1.72 | 17 | 0.72 | SI | NI |
| | | 2 | Riffle | W | 21 | 7.5 | 0.35 | 5.24 | 0.35 | 2.50 | 28 | 0.94 | NI | |
| | | 1 | Sveg | W | 20 | 5 | 0.12 | 6.27 | 0.46 | 2.34 | 18 | 0.81 | NI | |
| | | 2 | Woody | S | 9 | 2 | 0.44 | 5.17 | 0.68 | 1.42 | 14 | 0.56 | SI | |
| | | 1 | Woody | W | 21 | 6 | 0.44 | 5.23 | 0.40 | 2.46 | 28 | 1.07 | NI | |
| Buck Creek | OK121400-03-0170C | 2 | Riffle | W | 9.5 | 2.5 | 0.27 | 5.01 | 0.68 | 1.54 | 12 | 0.50 | MI | MI |
| Buggy Creek | OK520610-02-0120C | 1 | Sveg | S | 14 | 4 | 0.32 | 6.83 | 0.55 | 2.00 | 22 | 1.07 | NI | NI |
| | | 1 | Sveg | W | 10 | 1 | 0.06 | 6.50 | 0.62 | 1.70 | 14 | 0.82 | NI | |
| | | 1 | Woody | W | 8 | 1 | 0.08 | 6.13 | 0.55 | 1.80 | 12 | 0.82 | NI | |
| Chouteau Creek | OK121600-01-0430P | 1 | Riffle | W | 9 | 2 | 0.08 | 5.98 | 0.77 | 1.29 | 8 | 0.33 | MI | MI |
| Commission Creek | OK520620-05-0160C | 1 | Riffle | S | 18 | 7 | 0.30 | 3.20 | 0.52 | 2.09 | 20 | 0.94 | NI | NI |
| | | 1 | Sveg | S | 19 | 4 | 0.64 | 5.02 | 0.52 | 2.30 | 20 | 0.88 | NI | |
| | | 2 | Sveg | W | 15 | 4 | 0.53 | 4.61 | 0.57 | 1.80 | 18 | 0.77 | SI | |
| Deer Creek | OK520620-06-0010F | 1 | Sveg | S | 14 | 6 | 0.47 | 5.56 | 0.55 | 1.98 | 26 | 1.07 | NI | NI |
| | | 2 | Sveg | W | 14 | 2.5 | 0.11 | 6.76 | 0.57 | 1.90 | 16 | 1.00 | NI | |
| | | 1 | Woody | S | 15 | 6 | 0.55 | 5.31 | 0.48 | 2.07 | 26 | 1.00 | NI | |
| | | 2 | Woody | W | 12 | 2 | 0.26 | 6.05 | 0.70 | 1.59 | 15 | 0.86 | NI | |
| Delaware Creek | OK121300-01-0150H | 1 | Riffle | W | 16 | 6 | 0.19 | 5.88 | 0.57 | 1.93 | 22 | 0.93 | NI | NI |
| Fivemile Creek | OK121600-07-0110G | 2 | Riffle | S | 16 | 6.5 | 0.32 | 5.24 | 0.55 | 1.96 | 21 | 0.78 | SI | SI |
| | | 2 | Riffle | W | 15 | 7.5 | 0.28 | 4.96 | 0.56 | 1.85 | 16 | 0.50 | MI | |
| Fourteenmile Creek | OK121600-01-0100G | 2 | Riffle | S | 18 | 9 | 0.54 | 4.85 | 0.40 | 2.33 | 27 | 1.00 | NI | NI |
| | | 2 | Riffle | W | 23 | 11 | 0.48 | 5.43 | 0.32 | 2.64 | 28 | 0.82 | NI | |
| Hominy Creek | OK121300-04-0280G | 2 | Riffle | S | 20 | 8.5 | 0.42 | 5.36 | 0.39 | 2.49 | 27 | 1.00 | NI | SI |
| | | 2 | Riffle | W | 22 | 6.5 | 0.28 | 5.55 | 0.53 | 2.24 | 21 | 0.81 | NI | |
| | | 1 | Woody | W | 9 | 2 | 0.02 | 6.12 | 0.86 | 1.03 | 10 | 0.33 | MI | |
| Lightning Creek | OK121500-01-0130N | 1 | Riffle | S | 10 | 2 | 0.10 | 4.25 | 0.76 | 1.23 | 12 | 0.44 | MI | SI |
| | | 2 | Riffle | W | 12 | 4.5 | 0.19 | 5.63 | 0.69 | 1.50 | 18 | 0.70 | SI | |
| Little Cabin Creek | OK121600-06-0080C | 2 | Riffle | W | 18 | 4 | 0.21 | 6.46 | 0.38 | 2.41 | 23 | 0.87 | NI | NI |
| Little Horse Creek | OK121600-03-0190A | 2 | Riffle | W | 6.5 | 1.5 | 0.04 | 7.95 | 0.79 | 1.20 | 7 | 0.17 | SvI | SvI |
| Lone Creek | OK520620-03-0020C | 1 | Sveg | S | 17 | 4 | 0.40 | 6.13 | 0.50 | 2.10 | 22 | 1.07 | NI | SI |
| | | 1 | Sveg | W | 3 | 0 | 0.00 | 5.98 | 0.99 | 0.31 | 6 | 0.27 | MI | |
| Pryor Creek | OK121610-00-0050D | 2 | Riffle | S | 11 | 2.5 | 0.02 | 5.51 | 0.65 | 1.58 | 11 | 0.47 | MI | SI |
| | | 2 | Riffle | W | 17 | 4 | 0.29 | 5.39 | 0.54 | 2.02 | 20 | 0.80 | NI | |
| Ranger Creek | OK121600-01-0060D | 1 | Riffle | S | 12 | 4 | 0.13 | 6.65 | 0.74 | 1.37 | 10 | 0.31 | MI | MI |

| Site Name | WBID | # of Samples | Sample Type | Winter or Summer | Total Species | EPT Taxa | Percent EPT | HBI | Percent Dominant 2 taxa | Shannon Diversity | Total Points | % of Reference | Condition | Average Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2 | Riffle | W | 19 | 6.5 | 0.27 | 5.35 | 0.63 | 1.93 | 18 | 0.63 | SI | |
| Sand Creek | OK121400-04-0010F | 2 | Riffle | S | 12 | 5 | 0.11 | 4.56 | 0.74 | 1.41 | 10 | 0.44 | MI | MI |
| | | 2 | Riffle | W | 16 | 3 | 0.06 | 6.78 | 0.39 | 2.34 | 15 | 0.56 | SI | |
| | | 1 | Woody | S | 11 | 4 | 0.32 | 5.78 | 0.64 | 1.66 | 18 | 0.69 | SI | |
| | | 1 | Woody | W | 10 | 1 | 0.01 | 6.95 | 0.81 | 1.37 | 10 | 0.27 | MI | |
| Sycamore Creek | OK121600-03-0510D | 2 | Riffle | S | 19 | 9 | 0.36 | 4.90 | 0.50 | 2.17 | 25 | 0.94 | NI | SI |
| | | 2 | Riffle | W | 17 | 9 | 0.67 | 5.00 | 0.48 | 2.21 | 22 | 0.71 | SI | |
| | | 1 | Sveg | W | 13 | 3 | 0.07 | 6.37 | 0.65 | 1.75 | 12 | 0.38 | MI | |
| Tar Creek | OK121600-04-0060D | 2 | Riffle | S | 12 | 2.5 | 0.05 | 5.32 | 0.65 | 1.65 | 13 | 0.53 | SI | SI |
| | | 1 | Riffle | W | 12 | 5 | 0.18 | 6.12 | 0.48 | 2.12 | 20 | 0.80 | NI | |
| Trail Creek | OK520620-02-0090G | 1 | Sveg | S | 13 | 3 | 0.49 | 5.75 | 0.53 | 2.01 | 18 | 1.00 | NI | SI |
| | | 2 | Sveg | W | 9.5 | 1 | 0.04 | 6.26 | 0.81 | 1.03 | 10 | 0.50 | SI | |
| Walnut Creek | OK520610-03-0010F | 2 | Sveg | S | 16 | 6 | 0.23 | 6.54 | 0.57 | 2.03 | 22 | 0.90 | NI | SI |
| | | 2 | Sveg | W | 9 | 1 | 0.07 | 6.83 | 0.74 | 1.45 | 12 | 0.64 | SI | |
| | | 1 | Woody | W | 8 | 1 | 0.05 | 7.44 | 0.78 | 1.24 | 10 | 0.45 | MI | |
| Willow Creek | OK520610-01-0080H | 2 | Sveg | S | 15 | 3.5 | 0.22 | 6.91 | 0.51 | 2.06 | 18 | 0.90 | NI | NI |
| | | 1 | Sveg | W | 13 | 3 | 0.12 | 6.54 | 0.57 | 1.88 | 18 | 1.27 | NI | |
| | | 1 | Woody | W | 9 | 2 | 0.02 | 6.64 | 0.79 | 1.34 | 10 | 0.55 | SI | |

Most fixed sites had either non-impaired or slightly impaired macroinvertebrate communities overall (when averaging the scores across sample types). The following sites were moderately impaired overall: Big, Buck, Choteau, Ranger, and Sand Creeks. Little Horse Creek was severely impaired. Results for the fixed sites indicate had non-impaired macroinvertebrate communities in 35% of the sites, slightly impaired communities in 39% of the sites, moderately impaired communities in 22% of the sites, and severely impaired communities in 4% of the sites.

The overall results for the probabilistic sites are shown in Table 23. Most of the probabilistic sites were scored using only one macroinvertebrate collection. Most of the sixteen sites indicated non-impaired (50%) or slightly impaired communities (37%). Two sites (13%) indicated moderately impaired macroinvertebrate communities: Lightning and Panther Creeks. None of the probabilistic sites indicated severely impaired communities, though collections were not made in many sites because of the drought.

**Table 23. Macroinvertebrate metric values determined for each probabilistic monitoring site, averaged per season and habitat. NI = non-impaired, SI = slightly impaired, MI = moderately impaired.**

| Site Name | WBID | # of Samples | Sample Type | Winter or Summer | Total Species | EPT Taxa | Percent EPT | HBI | Percent Dominant 2 taxa | Shannon Diversity | Total Points | % of Reference | Condition |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Cabin Creek - 042 | NEOGRD-042 | 1 | Riffle | S | 16 | 3 | 0.08 | 4.73 | 0.61 | 1.88 | 14 | 0.56 | SI |
| Bird Creek - 013 | NEOGRD-013 | 1 | Riffle | S | 11 | 4 | 0.17 | 4.51 | 0.69 | 1.59 | 12 | 0.56 | SI |
| Bird Creek - 069 | NEOGRD-069 | 1 | Sveg | S | 23 | 6 | 0.27 | 6.05 | 0.31 | 2.71 | 28 | 1.00 | NI |
| | | 1 | Woody | S | 15 | 8 | 0.12 | 6.32 | 0.72 | 1.67 | 22 | 0.80 | NI |
| Brush Creek - 058 | NEOGRD-058 | 1 | Woody | S | 24 | 11 | 0.44 | 4.96 | 0.45 | 2.46 | 26 | 1.00 | NI |
| Double Spring Creek - 141 | NEOGRD-141 | 1 | Riffle | S | 16 | 6 | 0.63 | 6.26 | 0.62 | 1.90 | 18 | 0.81 | NI |
| Lightning Creek - 079 | NEOGRD-079 | 1 | Riffle | S | 14 | 3 | 0.07 | 7.05 | 0.77 | 1.27 | 12 | 0.31 | MI |
| | | 1 | Woody | S | 10 | 2 | 0.03 | 7.22 | 0.71 | 1.40 | 10 | 0.33 | MI |
| Little Saline Creek - 097 | NEOGRD-097 | 1 | Woody | S | 23 | 11 | 0.50 | 3.65 | 0.41 | 2.56 | 26 | 1.06 | NI |
| Mingo Creek - 145 | NEOGRD-145 | 1 | Riffle | S | 20 | 5 | 0.07 | 5.62 | 0.41 | 2.44 | 16 | 0.69 | SI |
| Panther Creek - 011 | NEOGRD-011 | 1 | Riffle | S | 12 | 2 | 0.12 | 6.37 | 0.68 | 1.56 | 14 | 0.50 | MI |
| | | 1 | Woody | S | 8 | 2 | 0.08 | 7.21 | 0.81 | 1.02 | 8 | 0.20 | MI |
| Pecan Creek - 016 | NEOGRD-016 | 1 | Riffle | S | 14 | 5 | 0.15 | 4.85 | 0.69 | 1.58 | 14 | 0.56 | SI |
| | | 1 | Sveg | S | 14 | 3 | 0.05 | 6.62 | 0.58 | 1.88 | 12 | 0.56 | SI |
| Pryor Creek - 146 | NEOGRD-146 | 1 | Riffle | S | 18 | 7 | 0.41 | 5.71 | 0.55 | 2.14 | 26 | 1.00 | NI |
| Rock Creek - 116 | NEOGRD-116 | 1 | Riffle | S | 14 | 4 | 0.35 | 4.88 | 0.47 | 2.21 | 18 | 0.81 | NI |
| Spavinaw Creek - 074 | NEOGRD-074 | 1 | Riffle | S | 14 | 7 | 0.42 | 4.06 | 0.47 | 2.12 | 22 | 0.88 | NI |
| | | 1 | Woody | S | 17 | 6 | 0.31 | 5.25 | 0.45 | 2.22 | 24 | 0.94 | NI |
| Spring Creek - 093 | NEOGRD-093 | 1 | Woody | S | 18 | 7 | 0.38 | 5.04 | 0.57 | 2.14 | 26 | 1.00 | NI |
| Spring Creek - 122 | NEOGRD-122 | 1 | Riffle | S | 16 | 6 | 0.51 | 4.03 | 0.65 | 1.95 | 22 | 0.81 | NI |
| | | 1 | Sveg | S | 16 | 4 | 0.51 | 4.59 | 0.47 | 2.25 | 16 | 0.75 | SI |
| Verdigris River - 139 | NEOGRD-139 | 1 | Riffle | S | 12 | 5 | 0.49 | 5.97 | 0.40 | 2.18 | 20 | 0.75 | SI |

Poor macroinvertebrate scores could indicate water quality problems; however, it is possible that the macroinvertebrate collection was not taken at a time which would best represent the community there (i.e., drought influences). Hence, the macroinvertebrate scores should be examined in conjunction with habitat and fish scores to better represent the general health of the stream.

### 3.2.4 Overall Biological Assessment

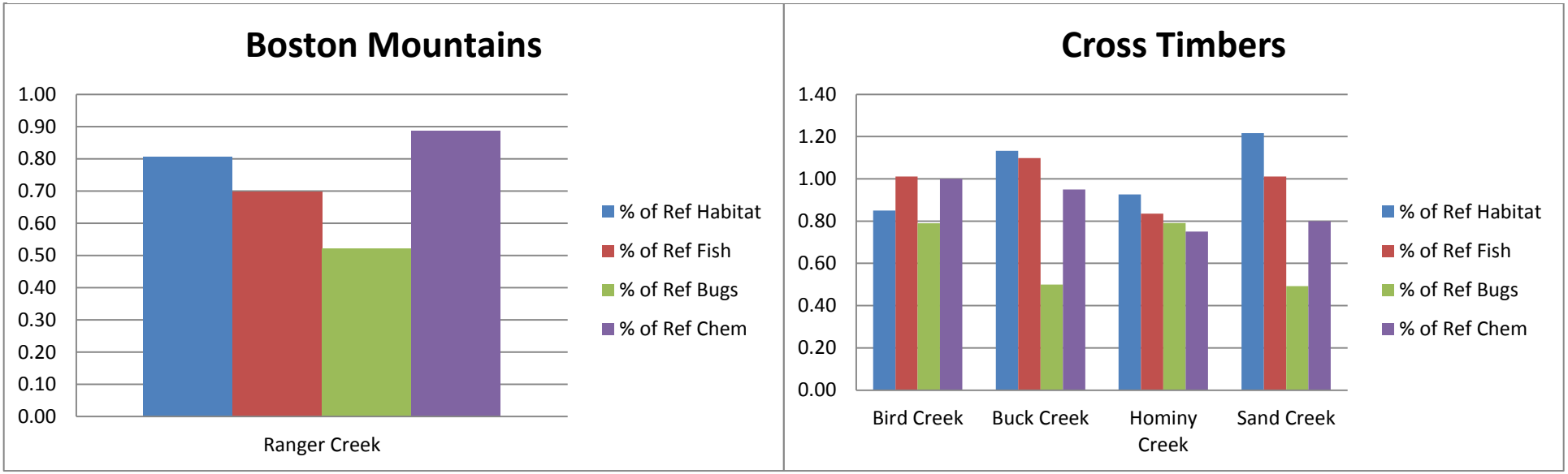
In order to synthesize the biological findings into a meaningful representation of the overall quality of each site, the biological assessments were compared with the habitat and water chemistry results. For the fixed sites, a water quality score was computed similarly to the other index scores by comparing 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, macroinvertebrate, and water quality scores (relative to the mean of high quality sites in the respective ecoregions) were examined in concert with one another (Figure 8). The water quality index score was calculated for the probabilistic sites, but often only a single sample was obtained; Figure 9 shows the habitat, fish, and macroinvertebrate scores for each site relative to the average score of high quality sites in that ecoregion.

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 could indicate habitat impairments despite good water quality.

Many of the sites sampled during this rotation have macroinvertebrate collections that indicate poorer conditions than the rest of the parameters, and most of the probabilistic sites did not have macroinvertebrate collections at all since flowing water is required for collections. This clearly reflects the drought conditions during the period of the rotation.

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. Scores may have been skewed lower during this sampling period relative to the reference sampling period due to the drought.

**Figure 8. Comparison of habitat, fish, macroinvertebrate, and chemistry scores for fixed sites relative to the average high quality site in each ecoregion.**



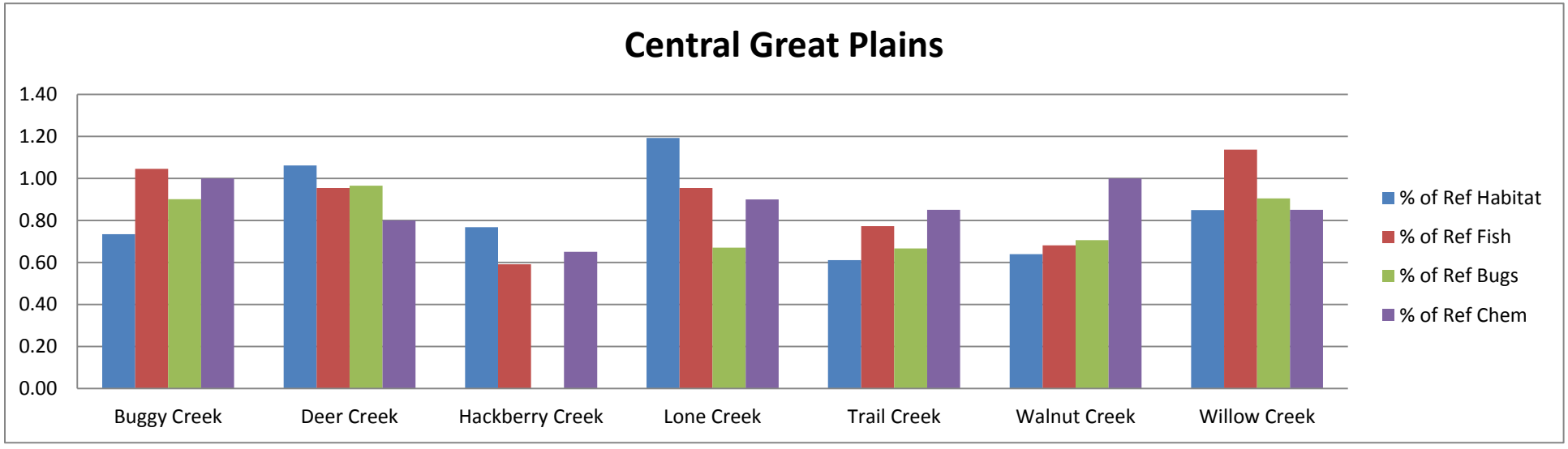
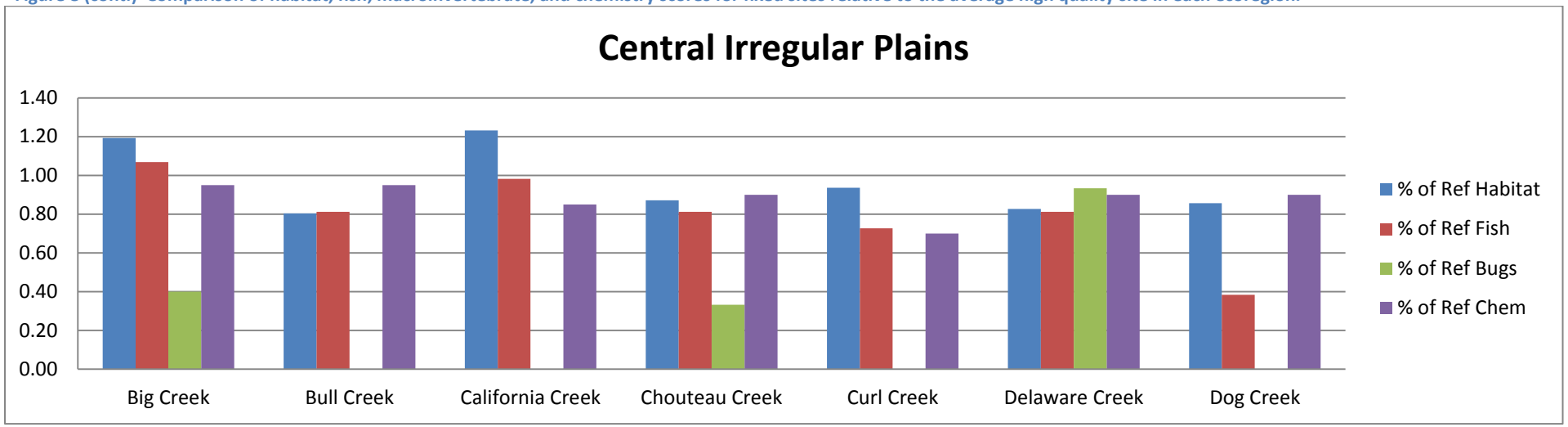



**Figure 8 (cont.) Comparison of habitat, fish, macroinvertebrate, and chemistry scores for fixed sites relative to the average high quality site in each ecoregion.**



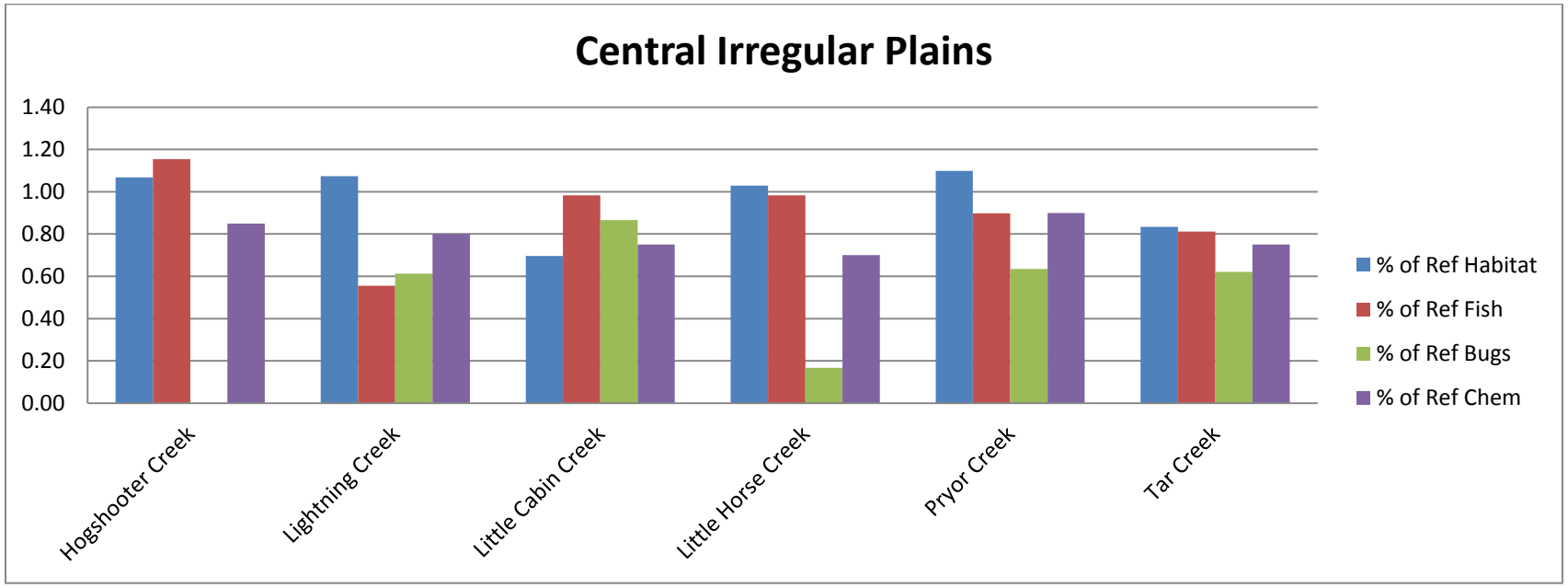



Figure 8 (cont.) Comparison of habitat, fish, macroinvertebrate, and chemistry scores for fixed sites relative to the average high quality site in each ecoregion.

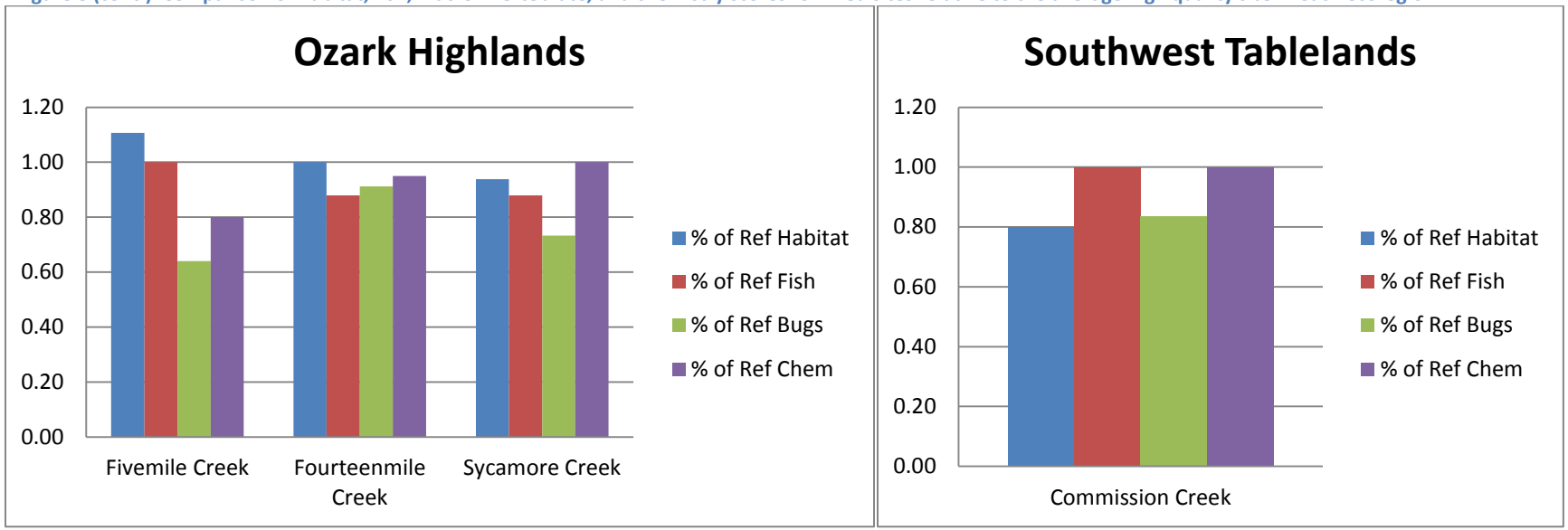



Figure 9. Comparison of habitat, fish, macroinvertebrate and chemistry scores for probabilistic sites relative to the average high quality sites in each ecoregion.

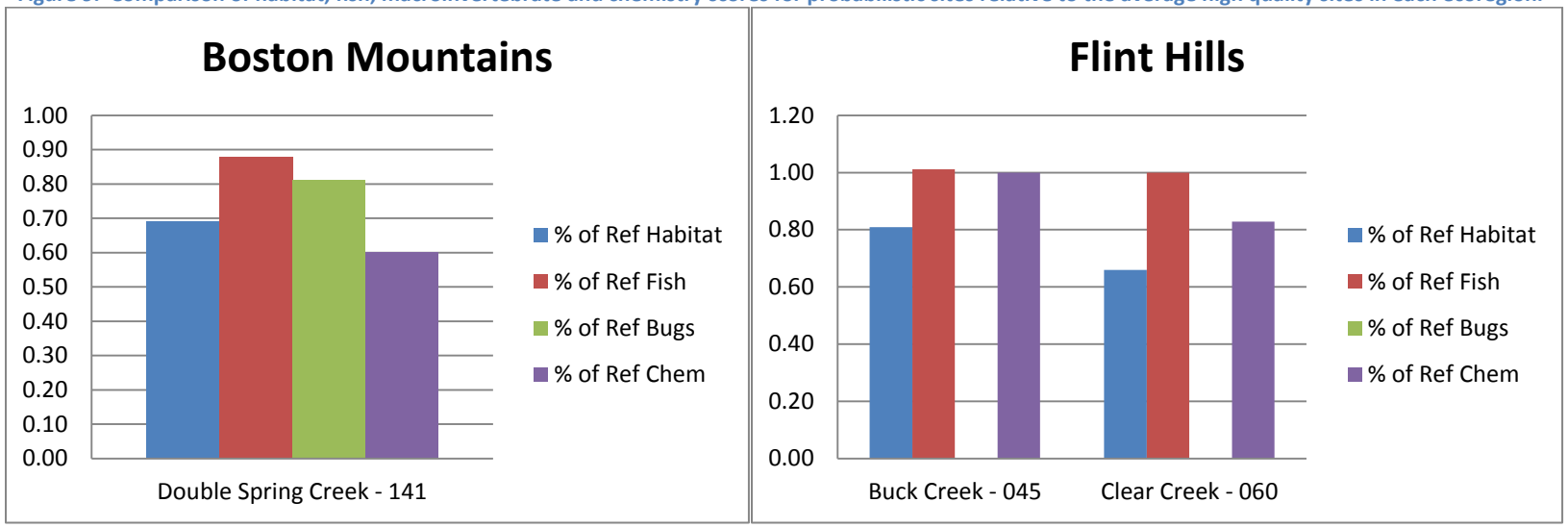
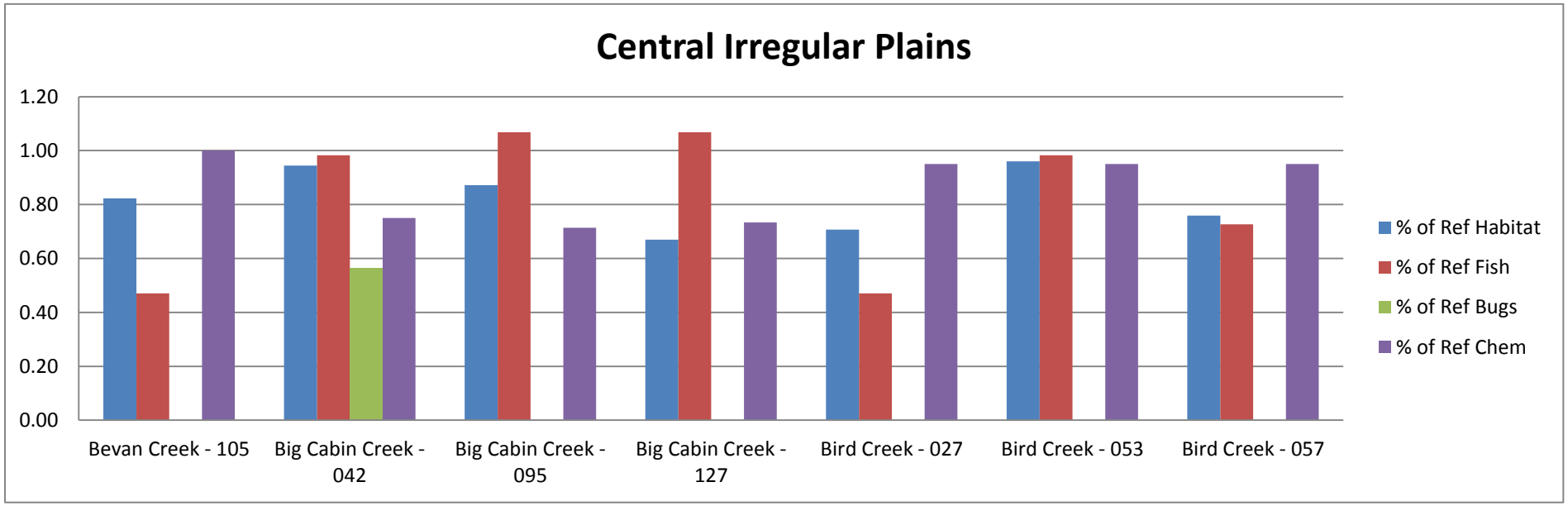


**Figure (9 cont.) Comparison of habitat, fish, macroinvertebrate and chemistry scores for probabilistic sites relative to the average high quality sites in each ecoregion.**



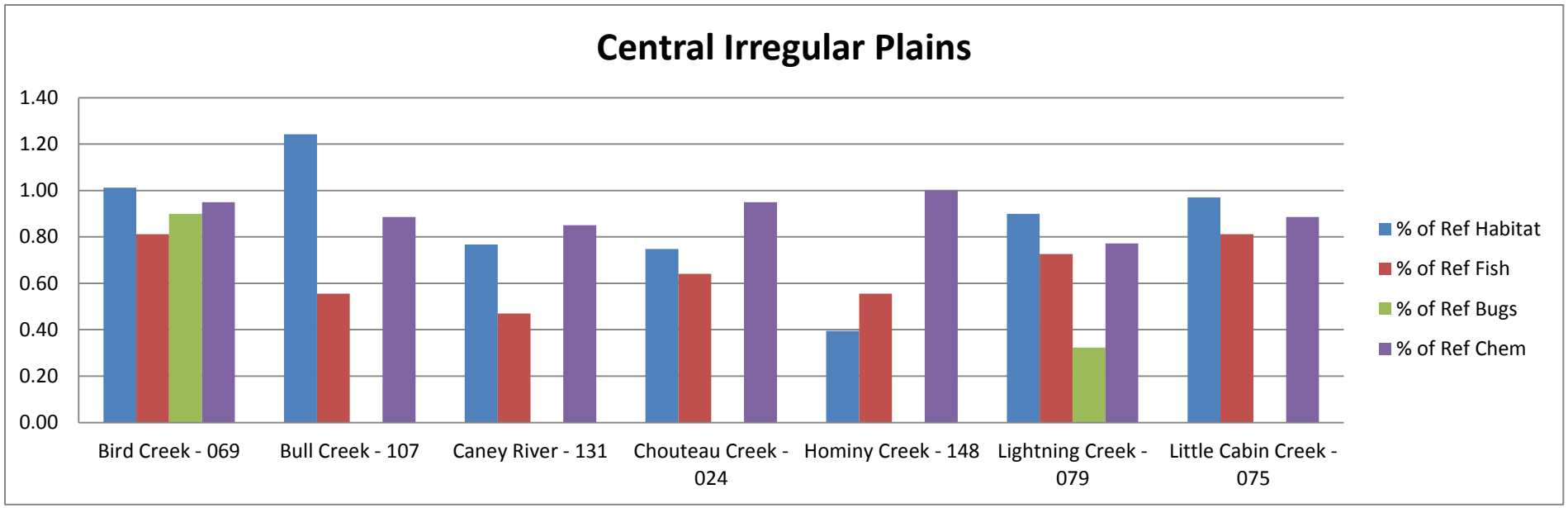
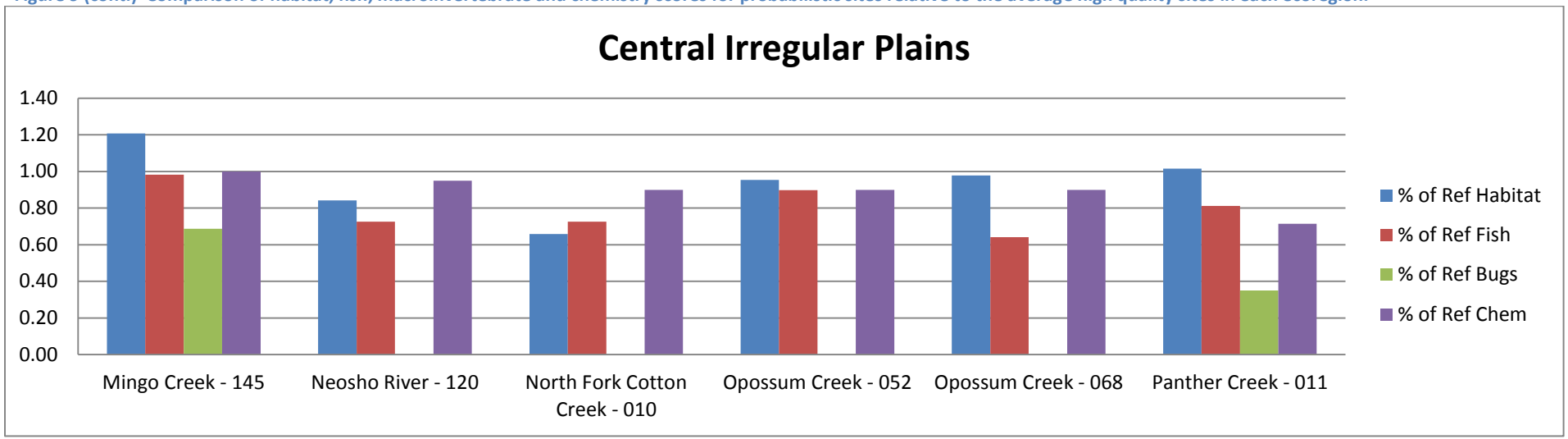



**Figure 9 (cont.) Comparison of habitat, fish, macroinvertebrate and chemistry scores for probabilistic sites relative to the average high quality sites in each ecoregion.**



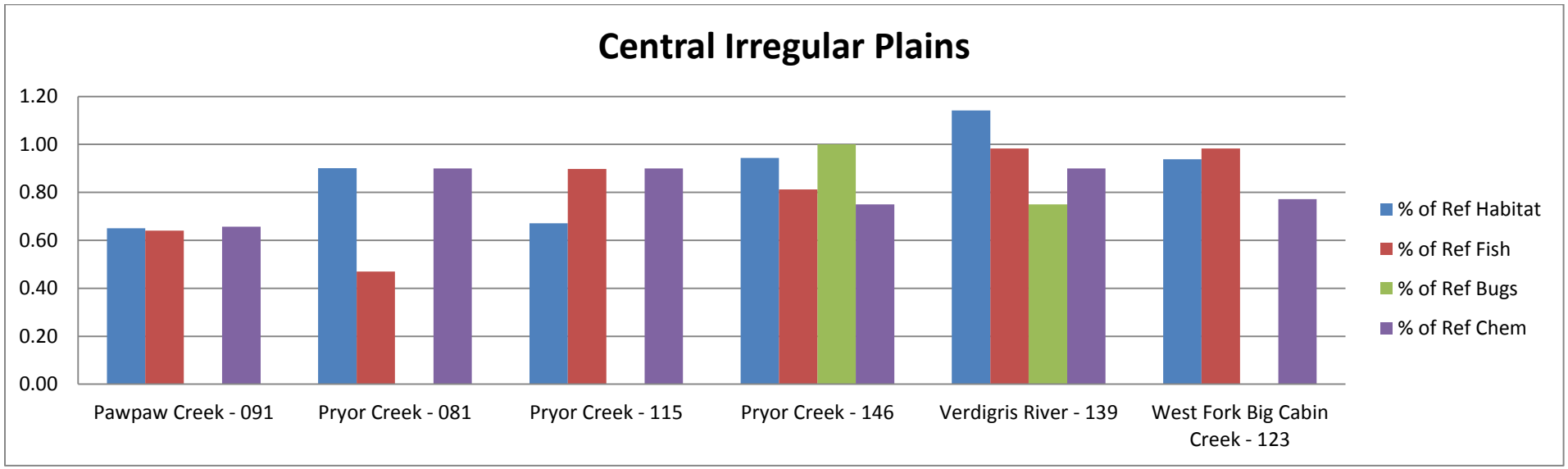
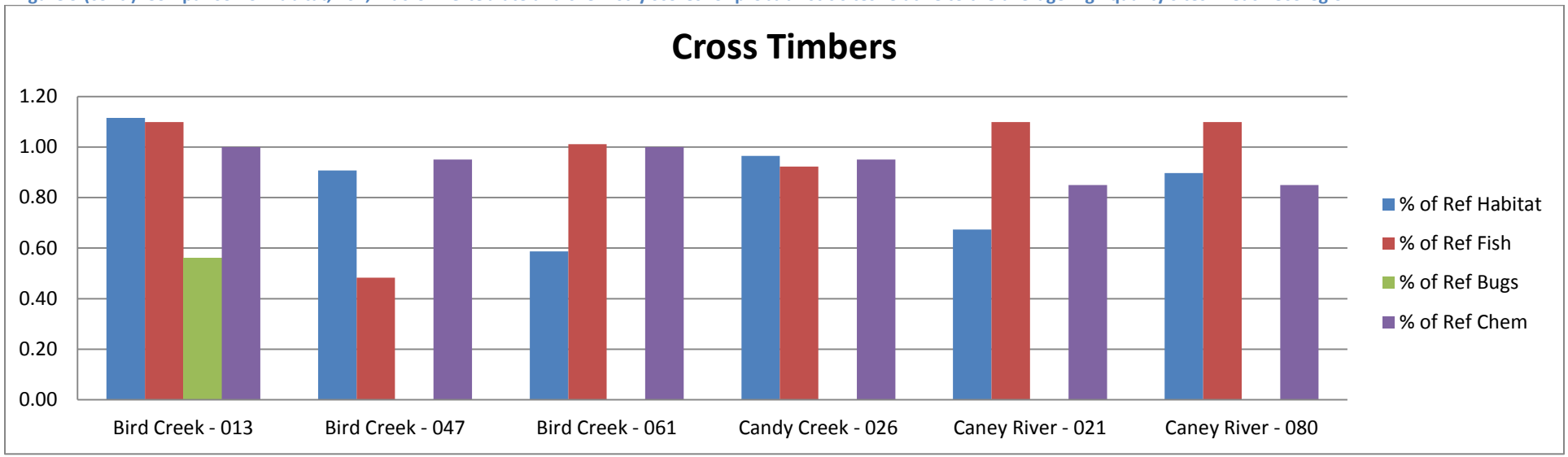



**Figure 9 (cont.) Comparison of habitat, fish, macroinvertebrate and chemistry scores for probabilistic sites relative to the average high quality sites in each ecoregion.**



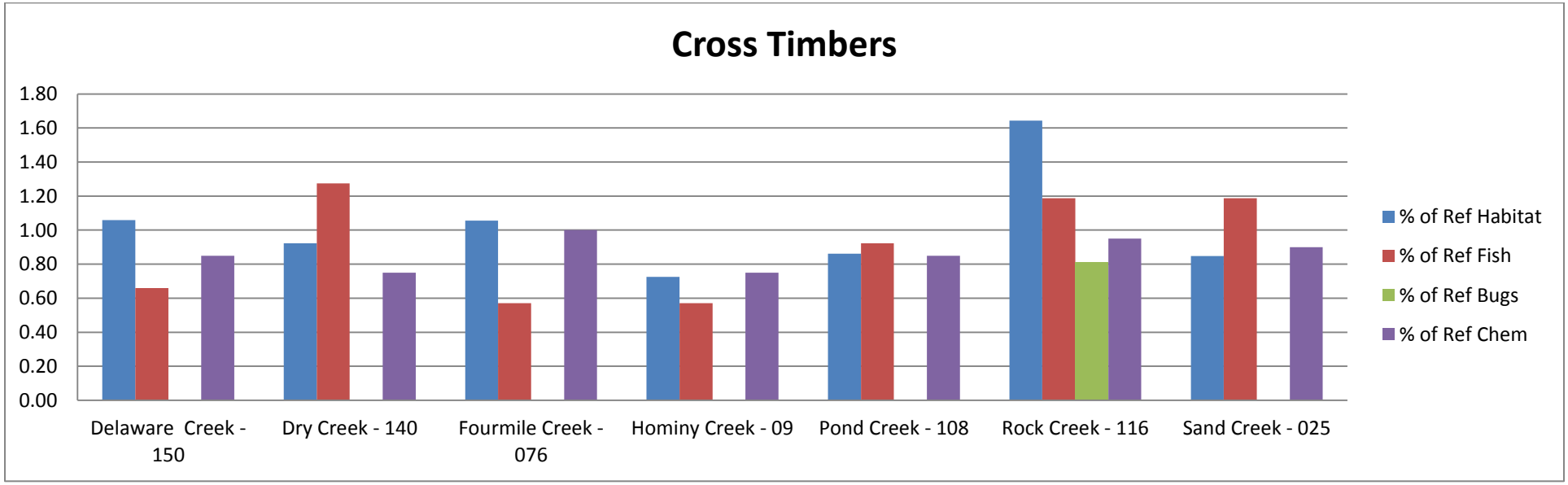
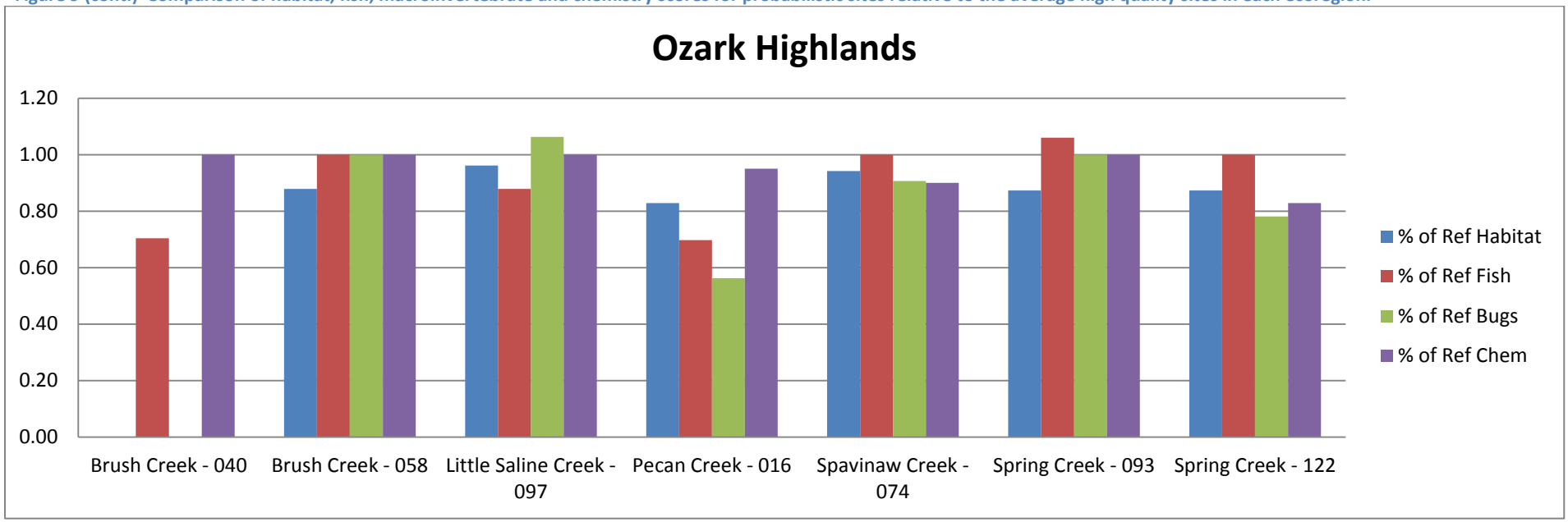



**Figure 9 (cont.) Comparison of habitat, fish, macroinvertebrate and chemistry scores for probabilistic sites relative to the average high quality sites in each ecoregion.**



## 3.3 WATERSHED ASSESSMENT

Table 24 shows the landuse upstream of each monitoring site as obtained through GIS using the 2006 National Land Cover Data set produced by the Multi-Resolution Land Characterization (MRLC) consortium. Approximately 7% of the land in the Neosho-Grand and Upper Canadian basins is cultivated crops, 22% is deciduous forest, 34% is grassland, and another 35% is pasture. There is very little development in the area (4%). Table 25 presents the types and number of permitted activities that occur in the watershed upstream of each site. Three fixed sites had no permitted activities in the watershed: Fivemile, Little Horse, and Sycamore Creeks.

Ten sites had national pollution discharge elimination systems (NPDES) in the watershed. Past analysis has indicated that sites with a major NPDES upstream have significantly higher nutrient concentrations than those with minor or no NPDES facilities. However, sites with permits were slightly more likely to have higher flows during this time of drought, an advantage which can improve the likelihood of the biological community surviving.

Two sites have consistently high nutrient levels: Deer Creek and Hackberry Creek. In the Deer Creek watershed, landuse is 61% cultivated crops, there are two confined animal feeding operations, four total retention lagoons, and three NPDES permits, and the City of Weatherford has land application permits. Landuse at Hackberry Creek is 54% grasslands and 37% shrub/scrub. It is possible that management practices are contributing nutrients. Lightning Creek appears to have good habitat and water chemistry but the biological collections do not reflect the same quality. Perhaps the thirteen NPDES permits for coal mining are affecting the aquatic community. Many of the sites in the Central Irregular Plains ecoregion were affected by drought so that macroinvertebrates were not able to be collected. Three sites (Big, Choteau, and Little Horse Creeks) had poor macroinvertebrate collections even though the fish, habitat, and water chemistry all appear healthy. These three sites are probably reflecting the drought conditions. Dog Creek had a poor fish collection, and landuse in the watershed includes land application and NPDES permits.

In the Cross Timbers ecoregion, all of the fixed sites had enough water to perform macroinvertebrate collections, though most of the probabilistic sites had no collections. Buck and Sand Creeks are similar to those mentioned above; the macroinvertebrate collection does not match the quality of the other parameters. In the Ozark Highlands ecoregion, Fivemile and Pecan Creeks fall in the same situation, and neither creek has landuse or permitted activities that would be expected to negatively affect the water quality. Of all of the probabilistic sites, Bird Creek has the most human impact, with multiple landfills, NPDES permits (many waste water treatment outfalls), more than 2500 oil/gas wells, land application permits, and public water intakes. Despite this, the one of four sites that had a macroinvertebrate collection indicated that it was healthy. Fish were collected from all four sites and only the site farthest downstream showed signs of impact.

The effects of the drought make it hard to accurately explain the results seen in this cycle of the Rotating Basin Project. Habitat assessments are not likely to be representative of normal conditions in this area. Many fixed sites did not have the complete cycle of two summer and two winter macroinvertebrate collections; many probabilistic sites did not have a collection at all. It appears that some watersheds

with NPDES permits did not have enough natural flow to “dilute” the effects of the discharges. In other watersheds, the discharges may have kept the creek flowing. Sites in this basin will be resampled starting in 2016, and it will be important to examine results under what will hopefully be more representative climatic conditions.

**Table 24. Watershed landuse for each fixed and probabilistic 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 | Evergreen Forest | Grasslands/Herbaceous | Mixed Forest | Open Water | Pasture/Hay | Shrub/Scrub | Woody Wetlands | Total Acres |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | | 2% | 13% | | | | 3% | | 27% | | | 55% | | | 95,101 |
| Bird Creek | OK121300-02-0010C | | | 28% | | 1% | | | | 64% | | 2% | 3% | 1% | | 236,720 |
| Buck Creek | OK121400-03-0170C | | | 7% | | | | 3% | | 82% | | | 8% | | | 41,105 |
| Buggy Creek | OK520610-02-0120C | | 27% | 5% | | 1% | | 4% | 8% | 54% | | | | | | 60,796 |
| Bull Creek | OK121500-02-0090D | | 11% | 6% | | 1% | | 4% | | 19% | | | 58% | | | 30,201 |
| California Creek | OK121510-02-0050C | | 2% | 7% | | | | 3% | | 41% | | | 47% | | | 37,049 |
| Chouteau Creek | OK121600-01-0430P | | 3% | 18% | | | | 3% | | 29% | | 1% | 46% | | | 19,506 |
| Commission Creek | OK520620-05-0160C | | 3% | | | | | 2% | | 56% | 1% | | | 39% | | 15,535 |
| Curl Creek | OK121400-01-0270C | | | 12% | | | | 4% | | 41% | | | 42% | | | 29,539 |
| Deer Creek | OK520620-06-0010F | | 61% | 1% | | 1% | | 5% | 2% | 29% | | | | | | 202,733 |
| Delaware Creek | OK121300-01-0150H | | | 58% | | | | 4% | | 21% | | | 17% | | | 29,033 |
| Dog Creek | OK121500-04-0010M | | | 48% | | | | 7% | | 18% | | | 26% | | | 25,650 |
| Fivemile Creek | OK121600-07-0110G | | 1% | 50% | | 1% | | 7% | | 1% | | | 36% | 2% | | 18,894 |
| Fourteenmile Creek | OK121600-01-0100G | | | 32% | | | | 4% | | 2% | | | 62% | | | 41,726 |
| Hackberry Creek | OK520620-04-0050D | | 5% | | | | | 3% | | 54% | | | | 37% | | 62,113 |
| Hogshooter Creek | OK121400-01-0300D | | | 12% | | | | 7% | | 29% | | 1% | 51% | | | 27,184 |
| Hominy Creek | OK121300-04-0280G | | 1% | 22% | | | | 3% | | 72% | | | 1% | | | 45,789 |
| Lightning Creek | OK121510-01-0130N | | | 17% | | | | 6% | | 28% | | | 49% | | | 23,288 |
| Little Cabin Creek | OK121600-06-0080C | | 9% | 8% | | 1% | | 4% | | 5% | | | 71% | | | 86,459 |
| Little Horse Creek | OK121600-03-0190A | | 11% | 3% | | 2% | | 2% | | 1% | | | 77% | 1% | | 10,685 |
| Lone Creek | OK520620-03-0020C | | 2% | | | | | 4% | 23% | 67% | | | | 4% | | 17,879 |
| Pryor Creek: Hwy 20 | OK121610-00-0050D | | 3% | 20% | | 1% | | 6% | | 14% | | | 55% | | | 127,551 |

| Site Name | WBID | Barren Land (Rock/Sand/Clay) | Cultivated Crops | Deciduous Forest | Developed, High Intensity | Developed, Low Intensity | Developed, Medium Intensity | Developed, Open space | Evergreen Forest | Grasslands/Herbaceous | Mixed Forest | Open Water | Pasture/Hay | Shrub/Scrub | Woody Wetlands | Total Acres |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ranger Creek | OK121600-01-0060D | | | 29% | | 1% | | 6% | | 2% | | | 61% | | | 21,531 |
| Red Creek | OK520620-03-0110F | | 3% | | | | | 1% | | 46% | 6% | | | 43% | | 8,172 |
| Sand Creek | OK121400-04-0010F | | 1% | 35% | | | | 5% | | 48% | | | 11% | | | 145,705 |
| Sycamore Creek | OK121600-03-0510D | | | 32% | | | | 4% | | 1% | | | 62% | | | 29,033 |
| Tar Creek | OK121600-04-0060D | 6% | 40% | 4% | 1% | 11% | 3% | 7% | | | | 1% | 25% | | 2% | 27,485 |
| Trail Creek | OK520620-02-0090G | | 13% | 1% | | | | 5% | 13% | 66% | 2% | | | | | 28,785 |
| Walnut Creek | OK520610-03-0010F | | 16% | 16% | | 1% | | 6% | | 56% | | 1% | 5% | | | 128,980 |
| Willow Creek | OK520610-01-0080H | | 22% | 7% | | 1% | | 4% | | 3% | | 1% | 35% | | | 13,406 |
| Bevan Creek - 105 | NEOGRD-105 | | 2% | 12% | | 1% | | 4% | | 15% | | | 36% | | | 4,449 |
| Big Cabin Creek - 042 | NEOGRD-042 | | 5% | 11% | | 1% | | 5% | | 13% | | | 64% | | | 247,302 |
| Big Cabin Creek - 095 | NEOGRD-095 | | 5% | 15% | | | | 4% | | 18% | | | 58% | | | 58,079 |
| Big Cabin Creek - 127 | NEOGRD-127 | | 5% | 16% | | | | 4% | | 23% | | 1% | 51% | | | 37,508 |
| Bird Creek - 013 | NEOGRD-013 | | 1% | 23% | | 1% | | 5% | | 64% | | 1% | 5% | | | 201,869 |
| Bird Creek - 027 | NEOGRD-027 | | 1% | 32% | | 1% | | 5% | | 49% | | 2% | 9% | | | 785,875 |
| Bird Creek - 047 | NEOGRD-047 | | 1% | 7% | | | | 3% | | 81% | | 2% | 6% | | | 58,885 |
| Bird Creek - 053 | NEOGRD-053 | | 1% | 30% | | | | 5% | | 53% | | 1% | 9% | | | 459,811 |
| Bird Creek - 057 | NEOGRD-057 | | 1% | 29% | | 1% | | 5% | | 56% | | 1% | 7% | | | 303,982 |
| Bird Creek - 061 | NEOGRD-061 | | 1% | 29% | | | | 5% | | 59% | | 1% | 5% | | | 269,085 |
| Bird Creek - 069 | NEOGRD-069 | | 1% | 32% | | | | 5% | | 50% | | 2% | 9% | | | 767,251 |
| Brush Creek - 040 | NEOGRD-040 | | | 45% | | | | 3% | 1% | 4% | | | 46% | | | 21,176 |
| Brush Creek - 058 | NEOGRD-058 | | | 44% | | | | 3% | 1% | 3% | | | 48% | | | 19,740 |
| Buck Creek - 045 | NEOGRD-045 | | | 2% | | | | 3% | | 87% | | | 7% | | | 26,685 |
| Bull Creek - 107 | NEOGRD-107 | | 4% | 4% | 2% | 5% | 2% | 10% | | 10% | | 1% | 63% | | | 9,533 |

| Site Name | WBID | Barren Land (Rock/Sand/Clay) | Cultivated Crops | Deciduous Forest | Developed, High Intensity | Developed, Low Intensity | Developed, Medium Intensity | Developed, Open space | Evergreen Forest | Grasslands/Herbaceous | Mixed Forest | Open Water | Pasture/Hay | Shrub/Scrub | Woody Wetlands | Total Acres |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Candy Creek - 026 | NEOGRD-026 | | | 34% | | | | 4% | | 58% | | | 4% | | | 13,521 |
| Caney River - 021 | NEOGRD-021 | | 2% | 14% | | | | 3% | | 72% | | | 9% | | | 55,830 |
| Caney River - 080 | NEOGRD-080 | | 2% | 14% | | | | 3% | | 71% | | | 9% | | | 56,035 |
| Caney River - 131 | NEOGRD-131 | | 4% | 21% | | | | 5% | | 44% | | 3% | 22% | | | 307,486 |
| Chouteau Creek - 024 | NEOGRD-024 | | 6% | 17% | | | | 5% | | 23% | | 1% | 48% | | | 40,043 |
| Clear Creek - 060 | NEOGRD-060 | | 1% | 1% | | | | 5% | | 91% | | 1% | 1% | | | 15,654 |
| Delaware Creek - 150 | NEOGRD-150 | | | 75% | | | | 4% | | 19% | | | 1% | | | 4,469 |
| Double Spring Creek - 141 | NEOGRD-141 | | | 25% | | 1% | | 5% | | 1% | | | 68% | | | 21,798 |
| Dry Creek - 140 | NEOGRD-140 | | | 13% | | | | 4% | | 73% | | | 9% | | | 8,069 |
| Fourmile Creek - 076 | NEOGRD-076 | | | 31% | | | | 6% | | 61% | | | 1% | | | 6,471 |
| Hominy Creek - 009 | NEOGRD-009 | | 1% | 22% | | | | 3% | | 73% | | | 1% | | | 38,651 |
| Hominy Creek - 148 | NEOGRD-148 | | 1% | 33% | | | | 4% | | 49% | | 4% | 7% | | | 264,889 |
| Lightning Creek - 079 | NEOGRD-079 | | | 17% | | | | 6% | | 28% | | | 49% | | | 23,288 |
| Little Cabin Creek - 075 | NEOGRD-075 | | 8% | 8% | | 1% | | 4% | | 6% | | | 73% | | | 65,417 |
| Little Saline Creek - 097 | NEOGRD-097 | | 1% | 50% | | | | 3% | | 7% | | | 36% | 3% | | 12,429 |
| Mingo Creek - 145 | NEOGRD-145 | | | 5% | 16% | 29% | 18% | 14% | | 11% | | | 6% | | | 37,274 |
| Neosho River - 120 | NEOGRD-120 | | 23% | 10% | | | | 4% | | 3% | | 1% | 56% | | 3% | 81,255 |
| North Fork Cotton Creek - 010 | NEOGRD-010 | | 7% | 15% | | | | 5% | | 21% | | | 52% | | | 11,909 |
| Opossum Creek - 052 | NEOGRD-052 | | 6% | 21% | | | | 4% | | 20% | | | 49% | | | 23,469 |
| Opossum Creek - 068 | NEOGRD-068 | | 3% | 26% | | | | 4% | | 23% | 1% | | 43% | | | 10,954 |
| Panther Creek - 011 | NEOGRD-011 | | 4% | 29% | | | | 4% | | 26% | | 1% | 36% | | | 2,198 |
| Pawpaw Creek - 091 | NEOGRD-091 | | 3% | 14% | | | | 4% | | 19% | | | 60% | | | 146,090 |
| Pecan Creek - 016 | NEOGRD-016 | | | 12% | | 2% | 1% | 10% | | | | | 74% | | | 5,390 |

| Site Name | WBID | Barren Land (Rock/Sand/Clay) | Cultivated Crops | Deciduous Forest | Developed, High Intensity | Developed, Low Intensity | Developed, Medium Intensity | Developed, Open space | Evergreen Forest | Grasslands/Herbaceous | Mixed Forest | Open Water | Pasture/Hay | Shrub/Scrub | Woody Wetlands | Total Acres |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pond Creek - 108 | NEOGRD-108 | | | 24% | | | | 4% | | 63% | | | 9% | | | 31,532 |
| Pryor Creek - 081 | NEOGRD-081 | | 3% | 22% | | 1% | | 5% | | 14% | | | 55% | | | 106,752 |
| Pryor Creek - 115 | NEOGRD-115 | | 1% | 26% | | | | 4% | | 17% | | | 52% | | | 12,355 |
| Pryor Creek - 146 | NEOGRD-146 | | 4% | 20% | | 1% | | 6% | | 14% | | | 54% | | | 158,188 |
| Rock Creek - 116 | NEOGRD-116 | | | 45% | | | | 5% | | 69% | | 1% | 10% | | | 16,566 |
| Sand Creek - 025 | NEOGRD-025 | | 1% | 35% | | | | 15% | | 48% | | | 12% | | | 135,724 |
| Spavinaw Creek - 074 | NEOGRD-074 | | | 40% | | 1% | | 4% | 1% | 3% | | | 50% | | | 102,365 |
| Spring Creek - 093 | NEOGRD-093 | | | 43% | | 1% | | 4% | 1% | 3% | | | 47% | | | 52,184 |
| Spring Creek - 122 | NEOGRD-122 | | | 32% | | 1% | | 6% | | 4% | | | 55% | 1% | | 25,877 |
| Verdigris River - 139 | NEOGRD-139 | | 6% | 12% | | 1% | | 4% | | 28% | | 1% | 48% | | | 126,738 |
| West Fork Big Cabin Creek - 123 | NEOGRD-123 | | 2% | 11% | | | | 3% | | 24% | | 1% | 58% | | | 27,641 |

**Table 25. Permitted landuse for each fixed and probabilistic site.**

| Site Name | WBID | # CAFO | # Landfill | # NPDES Permits | # O&G Wells | # Total Retention Lagoon | # Land Application | # Public Water Intakes | # Storage Disposal |
|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | | | | 388 | | | | |
| Bird Creek | OK121300-02-0010C | | | 5 | 7694 | | | 2 | |
| Buck Creek | OK121400-03-0170C | | | | 1 | | | | |
| Buggy Creek | OK520610-02-0120C | 2 | | 2 | 202 | | | | |
| Bull Creek | OK121500-02-0090D | | | | 245 | | | | |
| California Creek | OK121510-02-0050C | | | | 1371 | | 1 | | |
| Chouteau Creek | OK121600-01-0430P | | | | 81 | | | | |
| Commission Creek | OK520620-05-0160C | | | | 112 | | | | |
| Curl Creek | OK121400-01-0270C | | | | 1267 | | | | |
| Deer Creek | OK520620-06-0010F | 2 | | 3 | 490 | 4 | 3 | | |
| Delaware Creek | OK121300-01-0150H | | | 1 | 13 | | 2 | | |
| Dog Creek | OK121500-04-0010M | | | 1 | 181 | | 1 | | |
| Fivemile Creek | OK121600-07-0110G | | | | | | | | |
| Fourteenmile Creek | OK121600-01-0100G | | | | 3 | | | | |
| Hackberry Creek | OK520620-04-0050D | | | | 754 | | | | |
| Hogshooter Creek | OK121400-01-0300D | | | | 1411 | | | | |
| Hominy Creek | OK121300-04-0280G | | | | 1907 | | | | |
| Lightning Creek | OK121510-01-0130N | | | 13 | 67 | | | | |
| Little Cabin Creek | OK121600-06-0080C | 1 | | 6 | 66 | | | | |
| Little Horse Creek | OK121600-03-0190A | | | | | | | | |
| Lone Creek | OK520620-03-0020C | | | | 132 | | | | |
| Pryor Creek | OK121610-00-0050D | | | 3 | 600 | | 1 | | |
| Ranger Creek | OK121600-01-0060D | | | | 14 | 1 | | | |
| Red Creek | OK520620-03-0110F | | | | 18 | | | | |
| Sand Creek | OK121400-04-0010F | | 1 | | | | | | |
| Sycamore Creek | OK121600-03-0510D | | | | | | | | |
| Tar Creek | OK121600-04-0060D | | | 6 | | | | | |
| Trail Creek | OK520620-02-0090G | | | | 73 | | | | |
| Walnut Creek | OK520610-03-0010F | 1 | | 2 | 492 | | | 11 | |
| Willow Creek | OK520610-01-0080H | | | | 21 | | | | |
| Bevan Creek - 105 | NEOGRD-105 | | | | 51 | | | | |
| Big Cabin Creek - 042 | NEOGRD-042 | 1 | | 19 | 522 | | 1 | | |
| Big Cabin Creek - 095 | NEOGRD-095 | | | | 174 | | | | |
| Big Cabin Creek - 127 | NEOGRD-127 | | | | 159 | | | | |
| Bird Creek - 013 | NEOGRD-013 | | | 5 | | | | 1 | |
| Bird Creek - 027 | NEOGRD-027 | | 2 | 22 | 2352 | 1 | 43 | 6 | |
| Bird Creek - 047 | NEOGRD-047 | | | | | | | 1 | |
| Bird Creek - 053 | NEOGRD-053 | | 1 | 8 | 1059 | | 15 | 3 | |
| Bird Creek - 057 | NEOGRD-057 | | | 8 | 468 | | 12 | 3 | |
| Bird Creek - 061 | NEOGRD-061 | | | 7 | 21 | | | 3 | |
| Bird Creek - 069 | NEOGRD-069 | | 2 | 18 | 2062 | 1 | 35 | 6 | |
| Brush Creek - 040 | NEOGRD-040 | | | 1 | 1 | | | | |
| Brush Creek - 058 | NEOGRD-058 | | | 1 | 1 | | | | |
| Buck Creek - 045 | NEOGRD-045 | | | | 1 | | | | |
| Bull Creek - 107 | NEOGRD-107 | | | 3 | 1 | | 1 | | |
| Candy Creek - 026 | NEOGRD-026 | | | | | | | | |

| Site Name | WBID | # CAFO | # Landfill | # NPDES Permits | # O&G Wells | # Total Retention Lagoon | # Land Application | # Public Water Intakes | # Storage Disposal |
|---|---|---|---|---|---|---|---|---|---|
| Caney River - 021 | NEOGRD-021 | | | | 1 | | | | |
| Caney River - 080 | NEOGRD-080 | | | | 1 | | | | |
| Caney River - 131 | NEOGRD-131 | | | 1 | 4726 | 2 | 14 | 3 | |
| Chouteau Creek - 024 | NEOGRD-024 | | | | 110 | | | | |
| Clear Creek - 060 | NEOGRD-060 | | | | | | | | |
| Delaware Creek - 150 | NEOGRD-150 | | | | | | | | |
| Double Spring Creek - 141 | NEOGRD-141 | | | 1 | 10 | | 1 | 1 | |
| Dry Creek - 140 | NEOGRD-140 | | | | | | | | |
| Fourmile Creek - 076 | NEOGRD-076 | | | | | | | | |
| Hominy Creek - 009 | NEOGRD-009 | | | | | | | | |
| Hominy Creek - 148 | NEOGRD-148 | | | 7 | 267 | | 9 | 3 | |
| Lightning Creek - 079 | NEOGRD-079 | | | | | | | | |
| Little Cabin Creek - 075 | NEOGRD-075 | 1 | | 3 | 56 | | | | |
| Little Saline Creek - 097 | NEOGRD-097 | | | 14 | 1 | | | | |
| Mingo Creek - 145 | NEOGRD-145 | | | | 302 | 3 | 1 | | 3 |
| Neosho River - 120 | NEOGRD-120 | | | | 22 | | | | |

| Site Name | WBID | # CAFO | # Landfill | # NPDES Permits | # O&G Wells | # Total Retention Lagoon | # Land Application | # Public Water Intakes | # Storage Disposal |
|---|---|---|---|---|---|---|---|---|---|
| North Fork Cotton Creek - 010 | NEOGRD-010 | | | | 400 | | | | |
| Opossum Creek - 052 | NEOGRD-052 | | | | 566 | | | | |
| Opossum Creek - 068 | NEOGRD-068 | | | | 168 | | | | |
| Panther Creek - 011 | NEOGRD-011 | | | | 6 | | | | |
| Pawpaw Creek - 091 | NEOGRD-091 | | | 10 | 453 | | | | |
| Pecan Creek - 016 | NEOGRD-016 | | | | | 1 | | | |
| Pond Creek - 108 | NEOGRD-108 | | | | | | | | |
| Pryor Creek - 081 | NEOGRD-081 | | | 2 | 549 | | | | |
| Pryor Creek - 115 | NEOGRD-115 | | | | 45 | | | | |
| Pryor Creek - 146 | NEOGRD-146 | | | 4 | 719 | 3 | 3 | | |
| Rock Creek - 116 | NEOGRD-116 | | | | | | | | |
| Sand Creek - 025 | NEOGRD-025 | | | | | | | | |
| Spavinaw Creek - 074 | NEOGRD-074 | | | | | 1 | | | |
| Spring Creek - 093 | NEOGRD-093 | 1 | | | 6 | 2 | | | |
| Spring Creek - 122 | NEOGRD-122 | | | | 2 | 2 | | | |
| Verdigris River - 139 | NEOGRD-139 | | | 1 | 1618 | | 1 | 1 | |
| West Fork Big Cabin Creek - 123 | NEOGRD-123 | | | 5 | 24 | | | | |

## 3.4 DESIGNATED USE SUPPORT ASSESSMENT

The designated uses assessed for the monitoring sites are presented below, along with the current attainment status of each use based on the 2012 Integrated Report. The causes and potential source(s) (if known) of any impairments are available in the State's Integrated Report, available from the Department of Environmental Quality (http://www.deq.state.ok.us/wqdnew/305b_303d/index.html).

**Table 26. Designated use support assessment. F = fully supporting, N = not supporting, I = insufficient information, X = use not assessed.**

| Site Name | WBID | Cool Water Aquatic Community | Warm Water Aquatic Community | Habitat Limited Aquatic Community | Primary Body Contact (Recreation) | Secondary Body Contact (Recreation) | Aesthetics | Agriculture | Fish Consumption | Public/Private Water Supply | Emergency Water Supply | High Quality Water | Outstanding Resource Waters | Sensitive Water Supply |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Big Creek | OK121510-03-0010D | | N | | N | | F | F | X | I | | | | |
| Bird Creek | OK121300-02-0010C | | F | | N | | F | F | X | I | | | | |
| Buck Creek | OK121400-03-0170C | | N | | N | | I | F | X | I | | | | |
| Buggy Creek | OK520610-02-0120C | | F | | N | | F | F | X | | F | | | |
| Bull Creek | OK121500-02-0090D | | N | | N | | F | F | X | | | | | |
| California Creek | OK121510-02-0050C | | N | | N | | F | F | X | I | | | | |
| Chouteau Creek | OK121600-01-0430P | | X | | X | | X | X | X | | | | | |
| Commission Creek | OK520620-05-0160C | | F | | N | | I | F | X | I | | | | |
| Curl Creek | OK121400-01-0270C | | N | | N | | F | F | X | | | | | |
| Deer Creek | OK520620-06-0010F | | F | | N | | I | F | X | F | | | | |
| Delaware Creek | OK121300-01-0150H | | N | | N | | F | N | X | I | | | | |
| Dog Creek | OK121500-04-0010M | | N | | I | | I | I | X | I | | | | X |
| Fivemile Creek | OK121600-07-0110G | N | | | N | | F | F | F | F | | | | |
| Fourteenmile Creek | OK121600-01-0100G | F | | | N | | F | F | F | F | | F | | |
| Hackberry Creek | OK520620-04-0050D | | F | | N | | I | N | X | I | | | | |
| Hogshooter Creek | OK121400-01-0300D | | N | | N | | F | | X | | | | | |
| Hominy Creek | OK121300-04-0280G | | F | | N | | I | N | X | I | | | | X |
| Lightning Creek | OK121510-01-0130N | | I | | N | | I | N | X | I | | | | |
| Little Cabin Creek | OK121600-06-0080C | | N | | N | | F | N | X | | | | | |
| Little Horse Creek | OK121600-03-0190A | | N | | N | | I | F | X | | | | | |
| Lone Creek | OK520620-03-0020C | | F | | N | | F | N | X | I | | | | |
| Pryor Creek | OK121610-00-0050D | | N | | N | | I | F | X | I | | | | |
| Ranger Creek | OK121600-01-0060D | | N | | N | | F | F | X | X | | | | |
| Red Creek | OK520620-03-0110F | | F | | N | | I | N | X | I | | | | |
| Sand Creek | OK121400-04-0010F | | F | | N | | I | F | X | I | | | | |
| Sycamore Creek | OK121600-03-0510D | N | | | N | | I | F | X | I | | | | |
| Tar Creek | OK121600-04-0060D | | | N | | N | | | X | | | | | |
| Trail Creek | OK520620-02-0090G | | | F | N | X | F | N | X | | F | | | |

| Site Name | WBID | Cool Water Aquatic Community | Warm Water Aquatic Community | Habitat Limited Aquatic Community | Primary Body Contact (Recreation) | Secondary Body Contact (Recreation) | Aesthetics | Agriculture | Fish Consumption | Public/Private Water Supply | Emergency Water Supply | High Quality Water | Outstanding Resource Waters | Sensitive Water Supply |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Walnut Creek | OK520610-03-0010F | | F | | N | | I | F | X | | | | | |
| Willow Creek | OK520610-01-0080H | | N | | N | | F | F | X | | | | | |

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# APPENDICES