Small Watershed Rotating Basin Monitoring Program

Basin Group 5: Lower Red River Basin

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1.0 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 implementation plans to correct identified problems. In addition, each state's NPS agency is tasked with the identification of all programs which are actively planning or enforcing NPS controls. Cooperation between local, regional, and interstate entities can magnify the impact of efforts to reduce NPS pollution. The state NPS agency can then report on total program status regarding efforts to address NPS impacts and improve water quality. The Oklahoma Conservation Commission (OCC) is assigned as the NPS Program technical lead by Oklahoma state statute and therefore must monitor to determine the occurrence, nature, and extent of NPS impacts to state waters. Robust and meaningful assessment of the state's water quality is the foundation for meeting the long-term goals of the Oklahoma NPS program and water quality management in general.

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

To complement the fixed site monitoring, the OCC added a probabilistic component to the Rotating Basin Monitoring Program for Cycle 2 in 2008. This addition to the Rotating Basin Program provided a statistically qualified assessment of water quality conditions throughout the project basin. To accomplish this, sites were randomly selected from all waters of interest in a target area (i.e., basin unit), and the monitoring results were used to estimate water quality conditions in the larger area with known confidence (USGAO 2004). Analysis of the probabilistic component indicated that data collected from the fixed sites accurately represents the stream quality of the basin. Therefore, probabilistic sites have not been monitored in Cycle 5. The fixed sites monitored in Cycle 5 are shown in Figure 1.

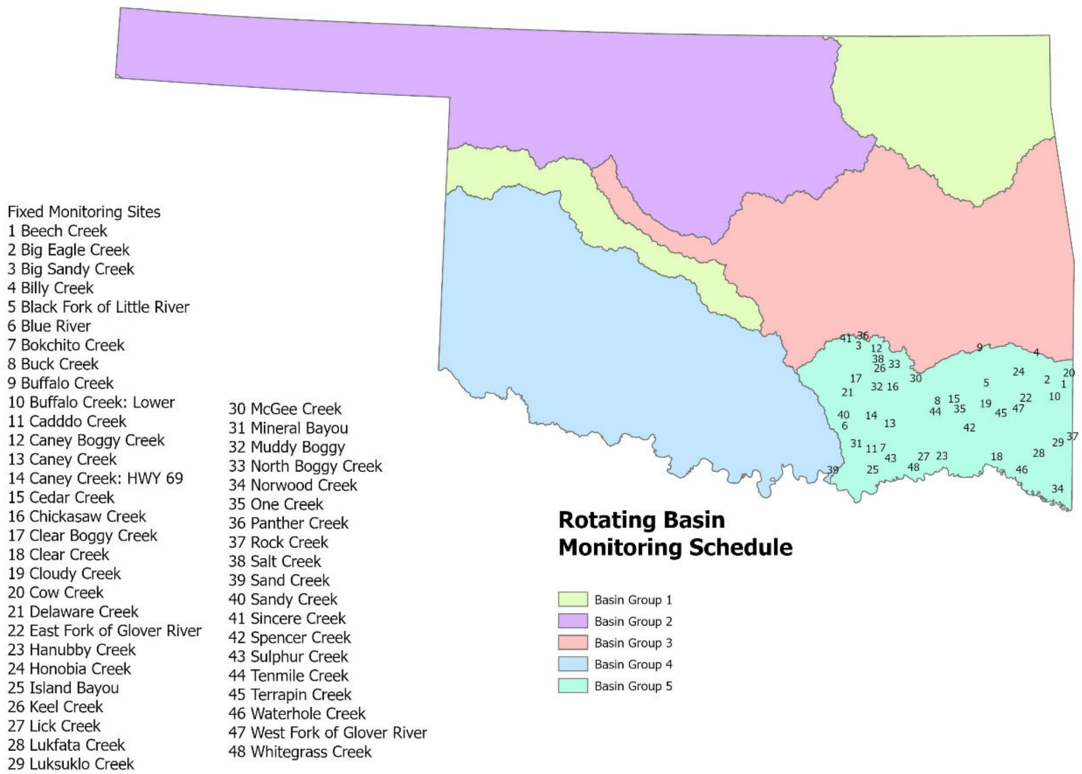

Figure 1. Monitoring sites in "Basin Group 5- Lower Red River" for the fourth cycle of the Small Watershed Rotating Basin Monitoring Program.

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*. Stages two through four are conditional and are completed as needed based on ambient monitoring results and project demands. 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 beneficial uses due to NPS or NPS plus point source (PS) pollution?
2. Which waterbodies show elevated or increasing levels of NPS or NPS plus point source pollutants, which may threaten water quality?
3. What are the sources and magnitude of pollution loading within threatened or impaired waterbodies?
4. Which land uses or changes in land use are sources or potential sources for pollutants causing beneficial use impairment?

In its entirety, OCC's Rotating Basin Monitoring Program provides an assessment of water quality, watershed condition, and support status for selected streams statewide, which is necessary for planning, implementation, and eventual evaluation of mitigation efforts. The statewide ambient monitoring program has allowed a comprehensive approach for the identification of nonpoint source (NPS) affected waters, as well as the identification of high-quality streams. Results from this effort are used to assist the state in producing the 305(b) and 303(d) lists which are required by the EPA to assess beneficial use support for waterbodies biannually.

This report discusses the results of the *ambient* (routine physical, chemical, and biological sampling) and *diagnostic* (special parameter sampling) stages of the fourth cycle of the Rotating Basin program in the Lower Red River Basin (see Figure 1). *Implementation* and *success* monitoring are typically accomplished through priority watershed projects and reported on separately 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.

2.0 MATERIALS AND METHODS

2.1 GENERAL

Sampling stations were selected to effectively represent streams of the Lower Red River Basin. Candidate streams were selected from sub-watersheds within the basin located entirely within the state of Oklahoma and having perennial water. Watersheds that did not have perennial water or were within 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 as a Rotating

Basin site, if the external monitoring met the project data quality objectives. For most sub-watersheds, the OCC monitoring site was located near the outflow of the primary stream but far enough upstream to limit backwater (surface and alluvial) effects of the waterbody to which it drained. For larger sub-watersheds, 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 land use different from most other streams being monitored in that region or sub-watershed.

Reconnaissance of all potential sites within the Lower Red River Basin was accomplished prior to the first round of monitoring in 2005, and sites which did not meet the sampling criteria were removed from the project. Forty-two sites were monitored during the first rotating basin cycle, from 2005-2007. Forty-one were monitored in the second cycle from June 2010-May 2012. Thirty-eight sites were monitored during the third cycle from June 2015-May 2017. The fourth cycle of monitoring in these basins occurred from June 2020-June 2022. There were 48 fixed sites during this cycle of monitoring (Table 1).

The sites monitored in the Lower Red River basin occur in five level-three ecoregions: The Arkansas Valley (AV), Cross Timbers (CT), East Central Texas Plains (ECTP), Ouachita Mountains (OM), and South Central Plains (SCP). Two sites had a heavy influence from a bordering ecoregion (i.e., the sites are very close to the ecoregion border and have water originating in the other ecoregions), so they were grouped with the influencing ecoregions when compared to reference conditions: Delaware Creek (located in CT but influenced by the "Arbuckle Uplift") and Luksuklo Creek (located in SCP but influenced by the Ouachita Mountains). These changes are indicated by the "modified ecoregion" column in Table 1.

Table 1. Site list for Rotating Basin Monitoring Program: Basin Group 5 (Lower Red River Basin), Cycle 4. WBID is a unique waterbody identifier for each monitoring site. Ecoregions include Arbuckle Uplift (Arbuckle), Arkansas Valley (AV), Cross Timbers (CT), East Central Texas Plains (ECTP), Ouachita Mountains (OM), and South Central Plains (SCP). The modified ecoregion is a representation, not only of the location of the sampling point, but the entirety of the watershed that influences the stream.

Site Name	WBID	Latitude	Longitude	County	Ecoregion	Modified Ecoregion
Beech Creek	OK410210-06-0320G	34.48682	-94.53915	McCurtain	OM	OM
Big Eagle Creek	OK410210-06-0160I	34.4899	-94.6842	McCurtain	OM	OM
Big Sandy Creek	OK410400-06-0260G	34.76694444	-96.331	Hughes	AV	AV
Billy Creek	OK410310-02-0070C	34.6822	-94.7759	LeFlore	OM	OM
Black Fork of Little River	OK410210-03-0020C	34.4729	-95.2171	Pushmataha	OM	OM
Blue River	OK410600-02-0010F	34.197016	-96.447669	Johnston	CT	CT
Bokchito Creek	OK410600-01-0090G	34.013636	-96.122527	Bryan	SCP	SCP
Buck Creek	OK410300-03-0420C	34.3394	-95.6417	Pushmataha	OM	OM
Buffalo Creek	OK410310-03-0030N	34.7229	-95.2695	Latimer	OM	OM
Buffalo Creek: Lower	OK410210-06-0020G	34.36953	-94.62245	McCurtain	OM	OM
Caddo Creek	OK410600-01-0140J	34.005428	-96.193227	Bryan	SCP	SCP

Site Name	WBID	Latitude	Longitude	County	Ecoregion	Modified Ecoregion
Caney Boggy Creek	OK410400-06-0120G	34.71815	-96.175718	Coal	AV	AV
Caney Creek	OK410400-02-0200G	34.186	-96.0581	Atoka	SCP	SCP
Caney Creek: HWY 69	OK410400-03-0020C	34.242793	-96.2186	Atoka	SCP	SCP
Cedar Creek	OK410300-03-0020M	34.33125	-95.4777	Pushmataha	OM	OM
Chickasaw Creek	OK410400-05-0420G	34.4475	-96.033	Atoka	OM	OM
Clear Boggy Creek	OK410400-03-0230K	34.5055	-96.3542	Coal/Pontotoc	AV	AV
Clear Creek	OK410100-01-0480N	33.94674	-95.1313	McCurtain	SCP	SCP
Cloudy Creek	OK410210-02-0300C	34.3247	-95.2234	Pushmataha	OM	OM
Cow Creek	OK410210-06-0350G	34.5068	-94.4939	McCurtain	OM	OM
Delaware Creek	OK410400-03-0240M	34.407	-96.4244	Johnston	CT	Arbuckle
East Fork of Glover River	OK410210-09-0010G	34.3557	-94.8721	McCurtain	OM	OM
Hanubby Creek	OK410400-01-0080G	33.95386111	-95.605	Choctaw	SCP	SCP
Honobia Creek	OK410210-03-0150H	34.548	-94.9329	LeFlore	OM	OM
Island Bayou	OK410700-00-0040J	33.857108	-96.204817	Bryan	ECTP	ECTP
Keel Creek	OK410400-06-0100D	34.60771	-96.14482	Coal	AV	AV
Lick Creek	OK410400-01-0130E	33.950326	-95.764558	Choctaw	SCP	SCP
Lukfata Creek	OK410210-07-0010G	33.96817	-94.76617	McCurtain	SCP	SCP
Luksuklo Creek	OK410210-04-0020G	34.04255556	-94.597	McCurtain	SCP	OM
McGee Creek	OK410400-07-0010L	34.5066	-95.8305	Atoka	OM	OM
Mineral Bayou	OK410600-01-0300G	34.043917	-96.347146	Bryan	SCP	SCP
Muddy Boggy	OK410400-05-0270M	34.447505	-96.170159	Atoka	AV	AV
North Boggy Creek	OK410400-08-0010E	34.6078	-96.0172	Atoka	AV	AV
Norwood Creek	OK410100-01-0050H	33.7133	-94.6075	McCurtain	SCP	SCP
One Creek	OK410300-03-0060F	34.3168	-95.4699	Pushmataha	OM	OM
Panther Creek	OK410400-06-0240G	34.78133333	-96.313	Hughes	AV	AV
Rock Creek	OK410200-03-0010G	34.08407	-94.49043	McCurtain	OM	OM
Salt Creek	OK410400-06-0090G	34.63663889	-96.16077778	Coal	AV	AV
Sand Creek	OK410700-00-0260G	33.853	-96.5499	Bryan	ECTP	ECTP
Sandy Creek	OK410600-02-0020G	34.21688	-96.45925	Johnston	SCP	SCP
Sincere Creek	OK410400-06-0290G	34.78938889	-96.44138889	Pontotoc	AV	AV
Spencer Creek	OK410300-02-0140F	34.155669	-95.364998	Choctaw	SCP	SCP
Sulphur Creek	OK410600-01-0030G	33.94658	-96.04985	Bryan	SCP	SCP
Tenmile Creek	OK410300-03-0270C	34.29913	-95.66118	Pushmataha	OM	OM
Terrapin Creek	OK410210-02-0150H	34.25603	-95.08927	Pushmataha	OM	OM
Waterhole Creek	OK410100-01-0340D	33.853	-94.91352	McCurtain	SCP	SCP
West Fork of Glover River	OK410210-09-0070C	34.3144	-94.9374	McCurtain	OM	OM

Site Name	WBID	Latitude	Longitude	County	Ecoregion	Modified Ecoregion
Whitegrass Creek	OK410400-01-0210G	33.88108	-95.85132	Choctaw	SCP	SCP

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 (OCC 2020), the Oklahoma Secretary of Energy & Environment (OSEE), and EPA Region VI in Dallas. All sampling and measurement activities of OCC Water Quality staff followed procedures outlined in the appropriate OCC Standard Operating Procedure (OCC 2022). Water quality chemical analyses were conducted by the Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) laboratory.

All data were compiled and entered into an Access database for later analysis. Upon retrieval, data were proofed and quality assured, and the descriptive statistics were generated for each parameter using the statistical software package *Minitab V. 17*.

2.2 WATER QUALITY MONITORING

Starting in June 2020 and completing in June 2022, 48 sites were monitored for physical and chemical parameters on five-week intervals (usually 20 total sampling events per site). This sampling frequency exceeds state data requirements for beneficial use assessment and meets a sample number necessary to provide a 90% level of confidence for principal water quality data (specifically phosphorus, a critical NPS concern) as determined from EPA's DEFT software (USEPA 2001). 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 2022).

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 (OCC 2020). Samples were submitted to the ODAFF Laboratory for analysis of the following parameters: nitrate (NO_3), orthophosphate (PO_4), total phosphorus (TP), total Kjeldahl nitrogen (TKN), ammonia (NH_3; May 1 - September 30 only), 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 and TKN for each sample. Available nitrogen was calculated by summing the values of ammonia and nitrate. Due to high chloride levels in Basin 5 the reporting limits for nitrite (NO_2) were adjusted to levels that were orders of magnitude higher than those typically observed in stream samples, and therefore excluded from total nitrogen and available nitrogen calculations. Nitrite values are generally below detection and exclusion has minimal impact on total nitrogen calculations. In addition, *in-situ* water quality parameters were measured at each sampling location and included the following: water temperature, dissolved oxygen, pH, conductivity, alkalinity, hardness, turbidity, and instantaneous discharge.

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

2.3 BIOLOGICAL MONITORING

2.3.1 Habitat Assessment

In the summer of 2020, OCC staff began conducting instream and riparian habitat assessments at sites concurrent with fish collections (described in Section 2.3.2); any sites not sampled in 2020 were sampled in the summer of 2021. All assessments were conducted in accordance with procedures outlined in the OCC Habitat Assessment SOP (OCC 2022). The OCC's habitat assessment adheres to a modified version of the EPA Rapid Bioassessment Protocols (RBP) (Barbour et al., 1999; 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 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 composition, stable cover, canopy, depth, and velocity. Macro-scale assesses the channel morphology and sediment deposits, among other parameters. The third category looks at the riparian zone quality, width, and structure (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 calculations completed in Microsoft® *Access* ®. 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. The habitat score was then obtained as the sum of habitat components, and then divided by the average habitat score of the reference sites from the same ecoregion to determine the percent of reference score.

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 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 stressed by the higher water temperature, 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 **streamside cover** category is representative of a large part of the energy and food input that 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.

Additional habitat measurements (Fines% and Riparian Condition), not included in the original OCC habitat assessment score were calculated and utilized in analyses for this report (Section 2.4), because of their potential importance in influencing healthy stream biotic communities.

(12) The **Fines%** component is included because excessive fine sediment is considered the top nonpoint source pollutant in stream ecosystems (Waters, 1995). The distribution of substrate composition samples attributed to the silt and unconsolidated clay category were compared to that of reference sites using a binomial test. The binomial test was conducted as described for water-quality parameters in Section 2.4.1, where a success rate ≥ 0.75 scored a 1 and a success rate < 0.75 and ≥ 0.5 scored 0.5. A success rate < 0.5 scored a 0.

(13) The **Riparian Condition** was not expected to be regionally variable, so it was not compared to reference streams like the other habitat metrics. Instead, we calculated the percent of the riparian transects that were evaluated as poor condition, or that had no riparian area to be evaluated. This percentage was subtracted from 1 so that the best condition a riparian area could achieve was 1 and the worst condition was 0.

2.3.2 Fish

Fish collections were completed in the summer of 2020 or 2021 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 (2022). 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.

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. Threatened, endangered, rare and out of range 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* (ODEQ 2022a). In addition, each site was assessed using OCC's modified RBP method, which is a modified version of Karr's Index of Biotic Integrity (IBI) (adapted from Plafkin et al., 1989). 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. High quality sites were determined by identifying the sites among all sampling locations that scored the highest for a composite scoring regime (OCC 2005). The modified RBP 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 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 to spawn; hence, these fish are sensitive to siltation. This metric allows separation of excellent streams from moderate quality streams.

For each of these seven metrics, a score of 5, 3, or 1 was assigned (Table 2), and these scores were summed to get a total IBI score (35 point maximum) for each site. For all "proportion" metrics, the score was based on the actual metric. For all non–proportion metrics, the score was determined by dividing the monitoring site's metric by the average high-quality site metric of the same ecoregion. Each monitoring site's total score was then compared to average high-quality site total score in that ecoregion and given an integrity rating (as established and suggested by the EPA RBP; see Table 3, below.

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

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

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

% Comparison to the Reference Score	Integrity Class	Characteristics
90 – 100 %	Excellent	Comparable to pristine conditions, exceptional species assemblage
78 – 89%	Good	Decreased species richness, especially intolerant species
62 – 77%	Fair	Intolerant and sensitive species rare or absent
42 – 61%	Poor	Top carnivores and many expected species absent or rare; omnivores and tolerant species dominant
0 – 41%	Very Poor	Few species and individuals present; tolerant species dominant; diseased fish frequent

2.3.3 Macroinvertebrates (Bugs)

Collection of macroinvertebrates was attempted at all sites during both winter and summer index periods from June 2020 through March 2022 according to procedures outlined in the OCC SOP (2022). Index periods represent seasons of relative community stability that afford opportunity for meaningful site comparisons. For Oklahoma, the summer index occurs from June 1 to September 15; the winter index occurs from January 1 to March 15. Macroinvertebrate were only collected when flowing water was 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, 1-m^2 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 five 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 habitat 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 (EPT), the mayflies, stoneflies, and caddisflies, 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 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 for each season-specific sample type (e.g., summer riffle, winter vegetation, summer woody) for each site were calculated in R Statistical Software (version 4.1.1, R Core Team, 2021) and compared to the average respective metric of high-quality streams in the ecoregion. High-quality sites were determined by identifying the sites among all sampling locations that scored the highest for a composite scoring regime (OCC 2005). A Bioassessment score was calculated similarly to the IBI score for fish. For each site, scores of 6, 4, 2, or 0 were assigned for each metric (according to the criteria in Table 4, below) and then summed to get a total Bioassessment score for each site, with a maximum of 36 points. For taxa richness and EPT taxa richness, the percentages used to assign scores was obtained by dividing each monitoring site metric by the average high-quality site metric in a particular ecoregion. For the HBI metric, the high-quality site value was divided by the monitoring site value (high-quality site metric / monitoring site metric). For the remaining metrics, the score was based on the actual values obtained instead of being relative to the high quality-site metric. Each monitoring site's total score was then compared to the average high-quality sites' total score (in that ecoregion) and classified according to the condition gradient outlined in Table 5 (adapted from Plafkin et al., 1989).

Table 4. Bioassessment scoring criteria for macroinvertebrates

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

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

Table 5. Bioassessment score interpretation for macroinvertebrates

% Comparison to the Reference Score	Biological Condition	Characteristics
≥80%	Non-Impaired	Comparable to the best situation expected within the ecoregion. Balanced trophic and community structure for stream size.
52-79%	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.
20-51%	Moderately Impaired	Fewer species due to the loss of most intolerant forms. Reduction in EPT index.
≤19%	Severely Impaired	Few species present. If high densities of organisms occur, they are dominated by 1 or 2 taxa.

2.4 DATA ANALYSIS

2.4.1 Stream Scores

To assess current (cycle 4: 2020-2022) stream condition, streams were assigned a score ranging from 0 to 100% for water chemistry parameters, as well as habitat and biota (fish and bugs). To avoid redundancy in site scores, a subset of water chemistry parameters was included in the analysis: three nutrient parameters (PO_4, Total Nitrogen [TN], NH_3), two salt parameters (Cl, SO_4), pH, DO% saturation and turbidity. Raw data results for other metrics are available in Appendix A.1, and descriptive statistics in appendix A.3.

For each site, each water quality metric assessed was compared to the distribution of that metric at high-quality reference sites (reference sites) from the same ecoregion (OCC 2005) using binomial statistical tests. We considered sample results from each water-quality metric within each site independently. For most water-quality metrics (except pH and DO% saturation), a sample result falling below the 75th percentile of reference site distribution for the same metric was considered a success. Using binomial tests in R Statistical Software, we tested the null hypothesis that the success rate of a metric within a site was ≥ 0.75, then we tested for a success rate of ≥ 0.50 using an α = 0.05. If we determined that the success rate of a metric was at least 0.75, the stream was given a score of 1 for that metric (similar to reference), and if the success rate was < 0.75 but ≥ 0.50, we assigned the stream a score of 0.5 for the metric (moderate deviation from reference). If the success rate was < 0.50 we assigned the stream a score of 0 for the metric (high deviation from reference).

Unlike the other metrics, optimal values for pH and DO% saturation are in the middle of their range and have established ecological thresholds, beyond which biota exhibit physiological stress. Therefore, two binomial tests were needed to evaluate each metric at each threshold. Because there were multiple thresholds for each metric, we used a single success rate of 95%. At the highest threshold for DO% saturation, a success meant that a measurement fell between 80% and 130% and at the secondary threshold a measurement was successful when it fell between 50% and 150%. Similarly, the highest threshold for pH was 6.5 – 9 and the secondary threshold was 5.5 – 10. Because the metrics had upper and lower limits, a two-tailed test was required at each threshold. This was achieved via two binomial tests at limits of each threshold range (two tests per threshold evaluation). We combined the probabilities (i.e., P (≥80%) ∩ P (≤130%)) and compared the resulting P-value to α=0.025 which was obtained via the Bonferroni correction. Streams with 95% success rate within the highest thresholds received the best possible score of 1. Streams not meeting the highest threshold but with a 95% success rate within the secondary threshold received an intermediate score of 0.5. Streams not meeting the success rate at either threshold received a score of 0, indicating a high potential for ecological degradation.

The water-quality score of a stream was based on the average score of all metrics, so that a score of 1 indicated that a site exhibited no observed deviation from reference site conditions for all metrics and a score of 0 indicated a site was most degraded compared to reference sites for all metrics.

Habitat assessment scores (original habitat scores) were calculated as percent of reference condition as outlined in sections 2.3.1. Additionally, to generate site scores for this analysis, the habitat score included two additional variables not utilized during our habitat assessment protocol. Percent fines (Fines%) and riparian condition have been demonstrated to have significant impacts on the quality of stream habitat (Waters, 1995; Pusey *et al.*, 2005). To attain the habitat score, the original habitat score was first divided by the average habitat score of the reference sites from the same ecoregion to determine the percent of reference score. To calculate the modified habitat score, we multiplied the percent reference score by 11 to weight it for the 11 components then added the additional habitat components (Fines% and Riparian Condition) and divided by 13 (11 original components + 2 new components).

Like habitat, fish and macroinvertebrate scores are also calculated as percent of reference condition as outlined in section 2.3.2. Therefore, habitat, fish, and macroinvertebrate scores greater than 100% are possible. Habitat, fish, and macroinvertebrate scores that exceeded 100% were reduced to 100% to maintain a 0 to 100% distribution for all parameters (i.e., water chemistry, habitat, fish, and macroinvertebrates).

Overall site score was then calculated by averaging water chemistry, fish, macroinvertebrate, and habitat scores. Sites with scores $\geq$ 0.9 were assigned an 'A', sites < 0.9 and ≥ 0.8 were assigned a 'B'. Sites < 0.8 and ≥ 0.7 were assigned a 'C', sites <0.7 and ≥ 0.6 were assigned a 'D', and sites < 0.6 were assigned an F.

2.4.2 Trends Analysis

To assess long-term trends in water-quality parameter values in streams that have been monitored for at least 3 cycles since 2001, we used generalized linear mixed models (GLMM) built with the R package "lme4" (R Statistical Software version 1.1-27; Bates, et al., 2021). Model output was used to identify improvement or decline in stream condition. GLMM was utilized to allow for a random slope for monitoring cycle and a random intercept for each site, so that the trend could be evaluated independently at each stream with consideration for natural variability within streams in the monitored population. We further controlled variability associated with season and flow within sites by including two variables for month (i.e., using sine and cosine variables to accommodate the cyclical nature of month) and stream stage (e.g., low flow, base flow, elevated flow) respectively. We then evaluated the estimated random-slope coefficient of each site and determined coefficients that were 2 SE > 0 to be increasing, those with coefficient 2 SE < 0 deceasing, and all others stable. Decreasing nutrients, salts and turbidities were considered improving, whereas increases in those parameters was considered a degrading condition. Conversely, decreasing pH and DO% saturation was considered degrading.

Additionally, we assessed the long-term trends in the fish IBI scores for sites that have been assessed in at least 3 monitoring cycles. As with chemistry parameters, we used a GLMM to estimate a random intercept and slope for each site. Previous research has indicated that fish score may be heavily influenced by the cumulative rainfall from the year leading up to the sampling event. For that reason, we included recent annual precipitation (within 1 year prior to sampling event) near each site as a covariate to correct for the influence of weather. Sites were matched to the nearest MESONET (mesonet.org, accessed 7/31/2023) weather station via the "join attributes to nearest" tool in QGIS (vers. 3.32.0, qgis.org, accessed 7/31/2023) to approximate recent annual precipitation. At each site, the daily rainfall of the nearest MESONET from the 365 days prior to the sample event were summed to determine recent rainfall accumulation.

2.4.3 Relative Risk Assessment

The relative risk posed to stream biota resulting from physico-chemical degradation was assessed using the methods in the National Rivers and Streams Assessment 2013 – 2014 Technical Report (USEPA, 2020).

First monitoring sites were split into two categories based on the average of fish and bug biotic scores; "Intact" or "not-poor" biotic communities were those with average scores of a B or greater (≥ 0.8), and all other sites were considered "sub-optimal" or "poor" (< 0.8). Physico-chemical degradation was then calculated for the following stressor groups at every site:

- nutrients = TN, AN, TP and OP;
- salts = conductivity, chloride, sulfate and total dissolved solids;
- acid = pH and alkalinity;
- DO = percent DO saturation;
- fine sediment = turbidity, total suspended sediment and percent fine substrate;
- riparian condition = percent poor or absent riparian area;
- habitat = habitat percent reference score.

If any metric within a stressor group scored a 0 (see Section 2.4.1), the stressor was considered "poor". The relative risk of each stressor was estimated as:

$$\widehat{RR} = \frac{\Pr(B = P|S = P)}{\Pr(B = P|S = NP)}$$

Where relative risk ($\widehat{RR}$) is equal to the probability that a biotic score (B) is poor (P) given the stressor (S) is poor, divided by the probability that a biotic score is poor given the stressor is not poor (NP). The resulting value indicated the relative risk to biota posed by each categorical impairment. A value $\leq$ 1 indicated no risk, whereas a value > 1 indicated potential risk with higher values indicating greater risk.

2.4.4 Watershed Assessment

To investigate potential sources of NPS pollution for streams showing beneficial use impairment, relevant data layers were explored using ArcMap 10.1 Geographic Information System (GIS) software. Data explored included the 2019 USGS National Land Cover Dataset (NLCD), oil and gas wells, confined animal feeding operations, national pollution discharge elimination system permit holders, total retention sites, biosolid land application sites and other data layers. The NLCD was explored to determine percent occurrence of particular land-use types such as bare rock/sand/clay, vegetation (separated into several categories, both natural and agricultural), open water, and residential/commercial/industrial uses (divided into several categories). Change in land-use was calculated between NLCD 2006 (~ first rotation in Basin 5) and NLCD 2019 (just prior to the fourth rotation) for each watershed to inform a qualitative assessment of potential land-use impacts on stream trends. Change in permitted land-use from 2016 to 2019 was calculated and qualitatively reviewed to evaluate potential impacts to water chemistry warranting further evaluation. To examine the effects of point source versus non-point source pollution on the parameters at the monitoring sites, one-way ANOVAs were performed comparing sites with the permitted discharge to sites with no permitted discharge. Finally, because oil and gas wells showed the most change in permitted use since 2017 (Table 15) and are a potential source of elevated salinity, we used Spearman's rank correlation to compare the salt stressor category (Section 2.4.3) to the change in oil and gas wells.

To further understand the relationship between changes in landuse and the relative risk to biota we used multinomial linear models in R statistical software, where the ordinal water-quality scores (i.e., 0, 0.5 and 1) obtained in the previous analysis (Section 2.4.1) were used as the response variable. Each site location was linked to a National Hydrography Dataset (NHD) Plus (usgs.gov/national-hydrography/nhdplus-high-resolution, accessed 7/31/2023) COMID. The COMID was used to join NLCD data from StreamCat (www.epa.gov/national-aquatic-resource-surveys/streamcat-dataset, accessed 7/31/2023) where NLCD data were derived for 100-m buffers around the stream segment at each the catchment and watershed scale. The NLCD year nearest the beginning of the first and fourth monitoring cycles for Basin 5 was used for each stream (*i.e.*, Cycle 1 = NLCD 2006 and Cycle 4 = NLCD 2019). For each site, the NLCD metrics from 2019 were subtracted from those from NLCD 2006 to obtain the amount of change that has occurred during the four monitoring cycles. The percent open water, hay/pasture and crop cover were retained as separate features, however, columns that represented different levels of development were summed to create a development category. Finally, barren ground, grassland, scrub/shrub and the various forest metrics were combined to create an undeveloped category. Each water-quality metric in the phyisco-chemical stressor categories that was identified as a potential risk by the relative risk assessment was regressed against the various NLCD change features. With an intercept-only model used as a null model, an information criterion approach was used to determine if a landuse feature was potentially contributing to degradation of water-quality metrics (Johnson and Omland, 2004). If the addition of a landuse feature resulted in a drop in AIC value by more than 2 points compared to the null model, we considered a potential relationship between that landuse feature and stream impairment. We calculated Nagelkerke's pseudo R^2 value to evaluate the goodness-of-fit of the best model. Pearson's correlation was used to determine the relationship among landuse changes over time.

2.4.5 Beneficial Use Determination

Appendix E presents the state's 2022 Integrated Report beneficial use determinations for Basin 5 sites. In this report we present updated, draft evaluations of fish, bug and bacteria criteria which will be submitted to ODEQ for final assimilation into the state's 2024 Integrated Report as a component of a complete beneficial use determination for Basin 5 data collected between 2020 and 2022. Bacteria and fish are assessed following *Oklahoma Administrative Code 252, Chapter 740: Implementation of Oklahoma's Water Quality Standards, Subchapter 15: Use Support Assessment Protocols* (ODEQ 2022a). Fish communities in ecoregions not promulgated in rule or assessed with an undetermined USAP result, as well as macroinvertebrate communities are evaluated following the state's *Continuing Planning Process, Integrated Water Quality Report Listing Methodology* (Oklahoma Department of Environmental Quality, 2012).

3.0 RESULTS

All chemical and physical water quality data collected for the project are included in Appendix A.1; Appendix A.2 contains bacteria data. Descriptive statistics for water quality parameters are presented by site in Appendix A.3. Fish data are presented in Appendix B. Macroinvertebrate data are presented in Appendix C.1. Appendix C.2 includes the complete Basin 4 rotation 4 macroinvertebrate dataset, because a portion of the samples were not processed in time for the 2022 Basin 4 cycle 4 Report.

Table 6 displays the geometric mean of *E. coli* bacteria samples for each site over the two-year monitoring period. Caney Creek: HWY 69 and Island Bayou are highlighted in yellow and are designated Secondary Body Contact Recreation (SBRC), which allows for a higher bacteria concentration (geometric mean of 630 colonies /100 ml). All other sites are designated Primary Body Contract Recreation (PBCR). Big Sandy Creek, Billy Creek, Buffalo Creek, Caney Creek, Clear Creek, East Fork of Glover River, Keel Creek, Lick Creek, Lukfata Creek, Luksuklo Creek, One Creek, Panther Creek, Salt Creek, Sulphur Creek, Tenmile Creek, Waterhole Creek and Whitegrass Creek do not meet the *E. coli* standard. 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 (ODEQ 2022a).

Table 6. Geometric mean of bacteria values for Basin 5 (Lower Red River Basin) monitoring sites, 2020-2022. An asterisk (*) indicates that the stream does not meet state standards for E. coli. Those highlighted in yellow have secondary body contact recreation (SBCR) designation, allowing for higher bacteria concentrations.

Site Name	WBID	E.coli	
Beech Creek	OK410210-06-0320G	19.61	
Big Eagle Creek	OK410210-06-0160I	88.46	
Big Sandy Creek	OK410400-06-0260G	465.85	*
Billy Creek	OK410310-02-0070C	441.33	*
Black Fork of Little River	OK410210-03-0020C	111.41	
Blue River	OK410600-02-0010F	51.40	
Bokchito Creek	OK410600-01-0090G	12.71	
Buck Creek	OK410300-03-0420C	62.26	
Buffalo Creek	OK410310-03-0030N	168.78	*
Buffalo Creek: Lower	OK410210-06-0020G	29.1	
Caddo Creek	OK410600-01-0140J	40.69	
Caney Boggy Creek	OK410400-06-0120G	109.34	
Caney Creek	OK410400-02-0200G	174.64	*
Caney Creek: HWY 69	OK410400-03-0020C	64.31	
Cedar Creek	OK410300-03-0020M	114.66	
Chickasaw Creek	OK410400-05-0420G	20.07	
Clear Boggy Creek	OK410400-03-0230K	113.48	
Clear Creek	OK410100-01-0480N	277.96	*
Cloudy Creek	OK410210-02-0300C	77.59	

Site Name	WBID	E.coli	
Island Bayou	OK410700-00-0040J	173.06	
Keel Creek	OK410400-06-0100D	175.16	*
Lick Creek	OK410400-01-0130E	338.7	*
Lukfata Creek	OK410210-07-0010G	268.02	*
Luksuklo Creek	OK410210-04-0020G	152.23	*
McGee Creek	OK410400-07-0010L	58.93	
Mineral Bayou	OK410600-01-0300G	54.92	
Muddy Boggy	OK410400-05-0270M	71.78	
North Boggy Creek	OK410400-08-0010E	53.74	
Norwood Creek	OK410100-01-0050H	86.96	
One Creek	OK410300-03-0060F	202.1	*
Panther Creek	OK410400-06-0240G	169.17	*
Rock Creek	OK410200-03-0010G	62.72	
Salt Creek	OK410400-06-0090G	457.6	*
Sand Creek	OK410700-00-0260G	85.76	
Sandy Creek	OK410600-02-0020G	124.8	
Sincere Creek	OK410400-06-0290G	120.39	
Spencer Creek	OK410300-02-0140F	83.2	
Sulphur Creek	OK410600-01-0030G	202.95	*

Site Name	WBID	E.coli	
Cow Creek	OK410210-06-0350G	39.73	
Delaware Creek	OK410400-03-0240M	89.71	
East Fork of Glover River	OK410210-09-0010G	150.92	*
Hanubby Creek	OK410400-01-0080G	137.91	*
Honobia Creek	OK410210-03-0150H	22.5	

Site Name	WBID	E.coli	
Tenmile Creek	OK410300-03-0270C	178.48	*
Terrapin Creek	OK410210-02-0150H	39.47	
Waterhole Creek	OK410100-01-0340D	316.93	*
West Fork of Glover River	OK410210-09-0070C	66.86	
Whitegrass Creek	OK410400-01-0210G	295.62	*

3.1 SITE SCORES AND TRENDS

3.1.1 Water Chemistry Scores and Trends

Water quality was assessed at 48 sites across 6 ecoregions. Most of the sites were located within the Ouachita Mountain Ecoregion (n = 19), followed by the South Central Plains accounting for 16 sites, and the Arkansas Valley with 9 sites. Two sites were located in the East Central Texas Plains, and the Arbuckle Uplift and Cross Timbers each accounted for a single site. Because there are no water-quality reference criteria in the Arbuckle Uplift or East Central Texas Plains, the site in the Arbuckle uplift was assessed as a Cross Timbers site and sites in the East Central Texas Plains were assessed with the South Central Plains.

Water chemistry scores across the basin ranged from 0.35 at Tenmile Creek to 0.96 at Lukfata Creek and Blue River, the only Cross Timbers stream (Table 7). In the Ouachita Mountains 53% of sites scored a ‘B’ or an ’A’. The Arkansas Valley had the worst water quality with 89% of sites receiving an ‘F’, and the highest scoring site (North Boggy Creek) receiving a 0.62 . Overall, most sites in the Basin scored an F (38%) followed by B (25%). Dissolved oxygen percent saturation was the most commonly degraded metric with 79% of sites deviating from reference condition (0 or 0.5 metric score); Salt metrics were also commonly degraded with over 50% of sites receiving a 0 for at least one salt metric.

Basin-wide there were 25 streams with at least 3 cycles of monitoring data, for which trends could be calculated. Metrics associated with salts showed the most change with 8 and 9 sites showing significant trends toward degradation (*i.e.,* increasing concentration) and 9 and 7 sites trending toward improvement for Chloride and Sulfate respectively (Table 8). Nutrients showed the least change with all sites being stable for TP and OP and only one site trending toward degradation for AN.

Table 7. Score for each site for each water quality parameter. A score of 1 indicated that 75% of measurements of the parameter were within the 75th percentile of the parameter values for high-quality reference sites within the same ecoregion. A score of 0.5 indicated that less than 75% but at least 50% of measurements were below the 75th percentile of reference, and a score of 0 was given when more than half of the measurements were outside the 75th percentile of reference. The score column in the far right is the average of the water quality scores. A score of 1 indicates that a site was identical to reference conditions.

Site Name	WBID	Modified Ecoregion	TP	PO_4	TN	Available Nitrogen	Chloride	Sulfate	TDS	Conductivity	pH	Alkalinity	DO% Saturated	Turbidity	TSS	Overall
Beech Creek	OK410210-06-0320G	OM	1	1	1	1	1	1	1	1	1	1	1	1	0	0.92
Big Eagle Creek	OK410210-06-0160I	OM	1	1	1	1	1	1	1	1	0.5	1	1	1	0	0.88
Big Sandy Creek	OK410400-06-0260G	AV	1	0	0.5	0	0.5	1	0	0.5	1	1	0.5	0.5	1	0.58
Billy Creek	OK410310-02-0070C	OM	1	1	1	1	1	1	0.5	1	1	1	0.5	0.5	0	0.81
Black Fork of Little River	OK410210-03-0020C	OM	1	1	1	1	1	1	1	1	0.5	1	0.5	0.5	0	0.81
Blue River	OK410600-02-0010F	CT	1	0.5	1	1	1	1	1	1	1	1	1	1	1	0.96
Bokchito Creek	OK410600-01-0090G	SCP	1	1	1	1	1	0	0	0	1	1	0.5	1	1	0.73
Buck Creek	OK410300-03-0420C	OM	0.5	1	0.5	1	0.5	0.5	0	0.5	1	1	0.5	0.5	0	0.58
Buffalo Creek	OK410310-03-0030N	OM	0.5	1	1	1	1	0.5	0.5	0.5	1	1	0.5	0.5	0	0.69
Buffalo Creek: Lower	OK410210-06-0020G	OM	0.5	1	1	1	1	1	1	1	1	1	1	1	0	0.88
Caddo Creek: Hwy 70	OK410600-01-0140J	SCP	1	1	1	1	0.5	0	0	0	1	1	0.5	1	1	0.69
Caney Boggy Creek	OK410400-06-0120G	AV	0.5	0	0.5	1	0	1	0	0.5	1	1	0	0.5	1	0.54
Caney Creek	OK410400-02-0200G	SCP	0.5	0.5	0.5	1	0	0	0	0	1	1	0	0	0.5	0.38
Caney Creek: HWY 69	OK410400-03-0020C	SCP	0.5	0.5	1	1	0	0	0	0	1	1	0.5	1	1	0.58
Cedar Creek	OK410300-03-0020M	OM	0.5	1	0.5	1	1	1	0.5	0.5	1	1	0.5	0.5	0	0.69
Chickasaw Creek	OK410400-05-0420G	OM	0.5	1	0.5	1	0.5	0	0	0	1	1	0	0.5	0	0.46
Clear Boggy Creek	OK410400-03-0230K	AV	0.5	0	0.5	0.5	0	1	0.5	0	1	1	0.5	0.5	0.5	0.50
Clear Creek	OK410100-01-0480N	SCP	1	0.5	1	1	1	1	1	1	1	1	0.5	0.5	1	0.88
Cloudy Creek	OK410210-02-0300C	OM	0.5	1	1	1	0.5	1	0.5	0.5	0.5	1	0.5	0.5	0	0.65
Cow Creek	OK410210-06-0350G	OM	1	1	1	1	1	1	1	1	1	1	0.5	1	0	0.88
Delaware Creek	OK410400-03-0240M	Arbuckle	1	0.5	1	1	0.5	0	0	0.5	1	1	0.5	1	1	0.69
East Fork of Glover River	OK410210-09-0010G	OM	1	1	1	1	1	1	1	1	0.5	1	1	0.5	0	0.85

Site Name	WBID	Modified Ecoregion	TP	PO_4	TN	Available Nitrogen	Chloride	Sulfate	TDS	Conductivity	pH	Alkalinity	DO% Saturated	Turbidity	TSS	Overall
Hanubby Creek	OK410400-01-0080G	SCP	1	1	1	1	0.5	0	0	0	1	1	0.5	0.5	1	0.65
Honobia Creek	OK410210-03-0150H	OM	1	1	1	1	1	1	1	1	0.5	1	1	1	0	0.88
Island Bayou	OK410700-00-0040J	ECTP	0	0	0.5	0	1	0	0.5	1	1	1	0.5	0.5	1	0.54
Keel Creek	OK410400-06-0100D	AV	0	0	0	1	0.5	0.5	0	0.5	1	1	0	0.5	1	0.46
Lick Creek	OK410400-01-0130E	SCP	0.5	0.5	0.5	1	0.5	0	0	0.5	1	1	0	0.5	0.5	0.50
Lukfata Creek	OK410210-07-0010G	SCP	1	1	1	1	1	1	1	1	1	1	0.5	1	1	0.96
Luksuklo Creek	OK410210-04-0020G	SCP	1	1	1	1	1	1	1	1	1	0.5	0.5	1	1	0.92
McGee Creek	OK410400-07-0010L	OM	0	0.5	0.5	1	0.5	0	0	0	1	1	0.5	0.5	0	0.42
Mineral Bayou	OK410600-01-0300G	SCP	1	0.5	1	1	0.5	0	0	0	1	1	0.5	0.5	1	0.62
Muddy Boggy	OK410400-05-0270M	AV	0.5	0	0	0.5	0	0.5	0	0.5	1	1	0.5	0	0.5	0.38
North Boggy Creek	OK410400-08-0010E	AV	0.5	0	0	1	0.5	1	0	1	1	1	0.5	0.5	1	0.62
Norwood Creek	OK410100-01-0050H	SCP	0	0	0.5	1	0.5	0.5	0.5	0.5	1	1	0	0	0.5	0.46
One Creek	OK410300-03-0060F	OM	0	1	0.5	1	1	1	0	0.5	1	1	1	0.5	0	0.65
Panther Creek	OK410400-06-0240G	AV	1	0.5	0	0	0	0.5	0	0.5	1	1	0.5	1	1	0.54
Rock Creek	OK410200-03-0010G	OM	1	1	1	1	1	1	1	1	1	1	1	1	0	0.92
Salt Creek	OK410400-06-0090G	AV	0	0	0	1	0.5	1	0	0.5	1	1	0	0.5	1	0.50
Sand Creek	OK410700-00-0260G	ECTP	1	1	0.5	0	1	1	1	1	1	1	0.5	1	1	0.85
Sandy Creek	OK410600-02-0020G	SCP	1	1	1	1	0.5	0.5	0.5	0.5	1	1	0.5	1	1	0.81
Sincere Creek	OK410400-06-0290G	AV	0.5	0	0	1	0	1	0	0.5	1	1	0.5	0.5	1	0.54
Spencer Creek	OK410300-02-0140F	SCP	1	1	1	1	1	1	1	1	0.5	0	0.5	1	1	0.85
Sulphur Creek	OK410600-01-0030G	SCP	1	1	1	1	0	0	0	0	1	1	1	0.5	1	0.65
Tenmile Creek	OK410300-03-0270C	OM	0	0	0	1	0.5	0.5	0	0	1	1	0	0.5	0	0.35
Terrapin Creek	OK410210-02-0150H	OM	1	1	1	1	1	1	1	1	0.5	1	1	0.5	0	0.85
Waterhole Creek	OK410100-01-0340D	SCP	0.5	0.5	0.5	1	0.5	0.5	0.5	0.5	1	1	0	0.5	0.5	0.58
West Fork of Glover River	OK410210-09-0070C	OM	0.5	0.5	1	1	1	1	1	1	0.5	1	0.5	0.5	0	0.73
Whitegrass Creek	OK410400-01-0210G	SCP	1	1	1	1	0	0	0	0.5	1	1	0.5	0.5	1	0.65

Table 8. Directional trend for sites that have been monitored for 3 or more cycles since the beginning of the Rotating Basin Monitoring Program. For nutrient (PO_4, TN, NH_3), salt (Cl, SO_4) and turbidity parameter; a score of 1 was given when a significant increasing slope was detected indicating a ‘degrading’ trend, whereas a score of -1 was assigned to significantly decreasing slopes indicating an ‘improving’ condition. For DO% saturation and pH increasing values were considered improving and decreasing values were considered declining. The final column provides a ratio in improving to degrading parameters at a given site.

Site Name	WBID	Modified Ecoregion	TP	OP	TN	Available N	Chloride	Sulfate	TDS	Conductivity	pH	Alkalinity	DO% Saturation	Turbidity	TSS	I to D ratio
Beech Creek	OK410210-06-0320G	OM	0	0	-1	0	-1	-1	-1	-1	0	0	0	-1	0	6:0
Billy Creek	OK410310-02-0070C	OM	0	0	0	0	-1	1	0	-1	-1	0	0	0	0	3:1
Black Fork of Little River	OK410210-03-0020C	OM	0	0	-1	0	-1	1	1	-1	-1	0	0	1	0	4:3
Bokchito Creek	OK410600-01-0090G	SCP	0	0	0	0	0	0	0	1	1	0	0	-1	0	1:2
Buck Creek	OK410300-03-0420C	OM	0	0	0	0	0	-1	0	0	0	0	0	1	1	1:2
Buffalo Creek: Lower	OK410210-06-0020G	OM	0	0	0	0	-1	0	0	0	0	0	0	0	0	1:0
Caney Boggy Creek	OK410400-06-0120G	AV	0	0	1	0	0	1	1	0	0	0	0	0	0	0:3
Caney Creek	OK410400-02-0200G	SCP	0	0	1	0	1	0	0	0	0	0	0	0	0	0:2
Caney Creek: Hwy 69	OK410400-03-0020C	SCP	0	0	0	0	1	0	0	0	0	0	0	0	0	0:1
Cedar Creek	OK410300-03-0020M	OM	0	0	0	0	0	-1	0	-1	0	0	0	1	0	2:1
Cloudy Creek	OK410210-02-0300C	OM	0	0	0	0	-1	-1	0	-1	-1	0	0	1	0	4:1
Cow Creek	OK410210-06-0350G	OM	0	0	-1	0	-1	-1	-1	-1	0	0	0	0	0	4:0
Delaware Creek	OK410400-03-0240M	Arbuckle	0	0	0	0	1	0	1	1	1	0	0	-1	0	1:4
East Fork of Glover River	OK410210-09-0010G	OM	0	0	0	0	-1	0	1	-1	-1	0	0	0	0	3:1
Lukfata Creek	OK410210-07-0010G	SCP	0	0	0	0	0	0	-1	0	0	0	0	1	1	1:2
Mineral Bayou	OK410600-01-0300G	SCP	0	0	0	0	1	1	0	1	1	0	0	0	-1	1:4
Norwood Creek	OK410100-01-0050H	SCP	0	0	1	0	1	-1	-1	0	0	0	0	0	0	2:2
One Creek	OK410300-03-0060F	OM	0	0	0	0	-1	0	0	-1	0	0	0	1	0	2:1
Rock Creek	OK410200-03-0010G	OM	0	0	0	0	-1	-1	0	-1	-1	0	0	0	0	4:0
Sand Creek	OK410700-00-0260G	ECTP	0	0	1	1	1	1	1	1	0	0	0	0	0	0:6
Sandy Creek	OK410600-02-0020G	SCP	0	0	0	0	0	1	-1	1	0	0	0	-1	0	2:2
Sulphur Creek	OK410600-01-0030G	SCP	0	0	-1	0	1	1	0	1	1	0	0	-1	-1	3:4

Site Name	WBID	Modified Ecoregion	TP	OP	TN	Available N	Chloride	Sulfate	TDS	Conductivity	pH	Alkalinity	DO% Saturation	Turbidity	TSS	I to D ratio
Tenmile Creek	OK410300-03-0270C	OM	0	0	1	0	0	0	1	0	0	0	0	1	1	0:4
Waterhole Creek	OK410100-01-0340D	SCP	0	0	1	0	0	1	0	0	0	0	0	1	1	0:4
Whitegrass Creek	OK410400-01-0210G	SCP	0	0	0	0	1	1	0	1	0	0	0	-1	-1	2:3

3.1.2 Habitat Scores

Habitat scores ranged from 44% (Waterhole and McGee creeks) to more than 100% in 6 streams that were in better condition than the average reference conditions (Table 9). The Ouachita Mountains ecoregion had the highest scores on average (90%), followed by the Cross Timbers (89%), Arbuckle Uplift (87%), Arkansas Valley (77%) and South Central Plains (70%). Streams in the highest scoring ecoregions benefited from forest land cover and rocky soils that are less prone to erosion than the two worst scoring ecoregions which occur in the loamy valleys surrounding the Ouachita and Arbuckle mountains.

Table 9. Habitat scores for Basin 5 (Lower Red River Basin) sites. The score for each habitat component is listed, the 'Total Points' and 'Original Score' columns refer to the original habitat scoring metrics based on the 11 original components and subsequent comparison to ecoregion reference. The 'Fines%' and 'Riparian Condition' scores are listed, and the 'Final Score' indicates the weighted average of all 13 habitat components. Sites in the East Central Texas Plain (Island Bayou and Sand Creek) have no reference habitat score and therefore are listed as NC (no criteria) for all measurements that require reference comparison (e.g., Original Score)

Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow (average Base flow)	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points	Original Score	Fines%	Riparian Condition	Final Score
Beech Creek	OK410210-06-0320G	17.8	11.9	8.3	10	10.3	10.5	6.7	1.6	10	5.7	9.8	102.6	86%	1	0.9	88%
Big Eagle Creek	OK410210-06-0160I	19.1	17.9	19.1	3.2	11.4	16.7	0.7	2.9	10	9	9.7	119.7	101%	1	0.9	100%
Big Sandy Creek	OK410400-06-0260G	3.3	2	9.9	19.9	0	11.2	0.5	4	5.1	3.8	8.87	68.57	66%	1	0.98	71%
Billy Creek	OK410310-02-0070C	17.4	13.2	17.7	18.9	13.3	2	2.8	3.1	8.9	8.3	9.1	114.7	97%	0	0.7	87%
Black Fork of Little River	OK410210-03-0020C	18.5	16.6	14.4	17.7	9	15	9.9	2	10	6.9	9.4	129.4	109%	1	0.83	106%
Blue River	OK410600-02-0010F	3	1.4	20.2	10.4	0	20	1.8	1.5	6.1	3.2	7.2	74.8	89%	0.5	0.63	84%
Bokchito Creek	OK410600-01-0090G	9.3	10.2	17.2	11.9	14.7	3.6	0.5	2.9	6.5	6.8	9.9	93.5	76%	1	1	80%
Buck Creek	OK410300-03-0420C	6.2	13.7	13.6	5.5	9	9.5	0.4	0.5	9.1	8.3	9.5	85.3	72%	0	0.95	68%
Buffalo Creek	OK410310-03-0030N	12.6	15.7	14	8.7	2.2	7.8	8.7	1.3	10	8.8	10	99.8	84%	0.5	1	83%
Buffalo Creek: Lower	OK410210-06-0020G	13.6	17	18.2	6.1	15.2	19	0.4	0.1	10	7.6	9.6	116.8	98%	1	0.85	97%
Caddo Creek	OK410600-01-0140J	6.3	13.2	14.6	3.4	2.2	4.3	16.5	0.1	8.7	8.7	10	88	71%	1	0	68%
Caney Boggy Creek	OK410400-06-0120G	10.2	7.4	14.2	18.7	9	6.3	1	2.1	2.5	3.3	9.8	84.5	81%	0	0.95	76%
Caney Creek	OK410400-02-0200G	4.5	4.9	14.2	19.9	0	5	13.7	5.4	7.1	5.9	7	87.6	71%	0	0.23	62%
Caney Creek: Hwy 69	OK410400-03-0020C	4.2	0.4	0	19.6	4.1	7.2	4.2	1.4	5.3	3.2	9.3	58.9	48%	1	0.9	55%

Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow (average Base flow)	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points	Original Score	Fines%	Riparian Condition	Final Score
Cedar Creek	OK410300-03-0020M	19.4	15.9	18.5	19.6	12.4	11.5	0.7	8.8	10	9.3	9.5	135.6	114%	0.5	0.95	108%
Chickasaw Creek	OK410400-05-0420G	8.7	12.1	14.6	4.5	15.6	5	11.1	0.3	7.4	7.5	10	96.8	82%	1	0.88	83%
Clear Creek	OK410100-01-0480N	7.9	10.9	14	14.2	15.2	16.3	1.8	1.7	8.4	8.8	9.9	109.1	88%	1	0.95	90%
Cloudy Creek	OK410210-02-0300C	19.6	19	14.6	6.3	16.3	10.3	0.4	1.1	9	4.5	9.3	110.4	93%	1	0.53	90%
Cow Creek	OK410210-06-0350G	18.5	14.2	1.4	18.1	9	10.8	2.3	0.4	8.6	7.5	9.3	100.1	84%	1	1	87%
Delaware Creek	OK410400-03-0240M	4.4	2.1	14.6	19.9	4.1	13.1	8.7	2	7.9	6.6	9	92.4	87%	1	0.85	88%
East Fork of Glover River	OK410210-09-0010G	14.8	9.8	19.3	9.7	11.4	14.9	0.4	0	10	10	10	110.3	93%	1	1	94%
Hanubby Creek	OK410400-01-0080G	3.5	1.9	15	19.2	0	2	4.2	1.3	6.6	5.4	9.1	68.2	55%	0.5	0.58	55%
Honobia Creek	OK410210-03-0150H	19.6	16.6	18.2	4.9	15.2	14.8	12.3	0.9	10	9.3	9.6	131.4	111%	1	1	109%
Island Bayou	OK410700-00-0040J	5.6	2	14.6	15	0	10.8	13.7	1.3	4.8	2.3	6	76.1	NC	NC	NC	NC
Keel Creek	OK410400-06-0100D	10.2	5.8	14.2	19.7	2.2	3.2	0.4	4.5	8.5	8.5	8.5	85.7	82%	0	0.98	77%
Lick Creek	OK410400-01-0130E	11.7	4.5	17.8	19.9	0	7.6	2.3	6.8	8	8.8	9.5	96.9	79%	0	1	74%
Lukfata Creek	OK410210-07-0010G	12.5	11.2	13.4	19.5	4.1	16.6	5	1.8	6.9	4	6	101	82%	1	0.55	81%
Luksuklo Creek	OK410210-04-0020G	16	14.4	20.2	19.7	14.1	2.4	1	2.4	8.1	7.2	8.9	114.4	96%	1	0.5	93%
McGee Creek	OK410400-07-0010L	7.9	6.1	13.5	1.8	4.1	9.6	0.5	2.8	5.5	7	3.3	62.1	52%	0	0	44%
Mineral Bayou	OK410600-01-0300G	4.9	3.9	9	18.3	5.9	10	0.4	6.8	8.8	8	9.7	85.7	69%	0.5	0.95	70%
Muddy Boggy	OK410400-05-0270M	6.2	8	13.4	1.7	10.3	11.3	0.4	1.2	7.4	7.4	9.4	76.7	74%	0	0.98	70%
North Boggy Creek	OK410400-08-0010E	9.4	9.4	18.7	12.1	4.1	4.8	2.8	0.8	5.5	3.6	8.8	80	77%	1	0.98	80%
Norwood Creek	OK410100-01-0050H	5.1	4.4	19.6	19.8	4.1	5.6	4.2	0.6	8.2	9.1	9.5	90.2	73%	0	0.93	69%
One Creek	OK410300-03-0060F	11	14.1	20.2	15.3	10.3	8.1	0.4	1.7	8.7	8.7	9.8	108.3	91%	0.5	0.95	88%
Panther Creek	OK410400-06-0240G	4.5	6.6	3.5	19.3	11.4	5.7	0.4	3.1	7.3	6.7	10	78.5	76%	1	1	79%
Rock Creek	OK410200-03-0010G	16.3	12.2	15.9	19.9	14.7	11.2	1.4	1.5	10	9.7	10	122.8	103%	1	0.95	103%
Salt Creek	OK410400-06-0090G	13.8	4.3	13.6	19.7	4.1	5	2.3	4.1	4.7	4.5	9.5	85.6	82%	0	1	77%
Sand Creek	OK410700-00-0260G	7.1	8.5	17.2	10.6	11.4	11.6	0.4	0.8	7.6	7.2	9.3	91.7	NC	NC	NC	NC
Sandy Creek	OK410600-02-0020G	3.8	2.8	0	10.2	0	4.2	0.4	1.8	9.8	7.7	9.7	50.4	41%	1	0.95	50%

Site Name	WBID	Instream Cover	Pool Bottom Substrate	Pool Variability	Canopy Cover Shading	Presence of Rocky Runs or Riffles	Flow (average Base flow)	Channel Alteration	Channel Sinuosity	Bank Stability	Bank Vegetation Stability	Streamside Cover	Total Points	Original Score	Fines%	Riparian Condition	Final Score
Sincere Creek	OK410400-06-0290G	5.1	2.7	19.1	17.2	2.2	5	0.4	0.1	7.3	8.8	8.9	76.6	74%	0.5	0.9	73%
Spencer Creek	OK410300-02-0140F	13.6	8.6	20.2	20	2.2	3.4	5	0.6	9.5	7.8	9.4	100.3	81%	1	0.95	84%
Sulphur Creek	OK410600-01-0030G	3.2	3.1	19.6	19.8	4.1	7.1	0.4	6.8	8.6	7.3	9.13	89.13	72%	0.5	0.78	71%
Tenmile Creek	OK410300-03-0270C	15.5	8	14	20	13.3	7.5	3.5	1.1	3.3	3.5	9.7	99.4	84%	0	0.6	75%
Terrapin Creek	OK410210-02-0150H	19.6	17	20	14.3	7.5	13.6	16.5	2.8	10	5.8	9.7	136.8	115%	1	1	113%
Waterhole Creek	OK410100-01-0340D	6.5	3.5	4.1	18.1	4.1	0.5	0.4	0.9	6	7.6	6.3	58	47%	0	0.53	44%
West Fork of Glover River	OK410210-09-0070C	19.2	16.5	17.2	18	16.1	16.2	11.1	0.5	9.9	8.7	9.9	143.3	121%	1	1	117%
Whitegrass Creek	OK410400-01-0210G	4.7	3.5	15	19.7	0	12.3	7.7	0.7	6.3	5.2	6.8	81.9	66%	0	0.7	62%

3.1.3 Fish Scores

Fish scores were generally in good condition across the basin (Table 10). The worst evaluation assigned to any streams was fair and only three sites received that designation. Six sites had good fish condition, whereas 40 sites had excellent fish assemblages. Additionally, trends were assessed at 24 sites and each site was found to have stable fish community over the past 20 years.

Table 10. Results from fish assemblage assessments in Basin 5 (Lower Red River Basin) Cycle 4. Site information includes the name of the site, waterbody ID, Ecoregion and the aquatic community type (FWP: WWAC = warm water, CWAC = cool water, and HLAC = habitat limited). FWP with an '*' were assessed as WWAC due to missing reference criteria. The metrics used to determine the OK Conservation Commission scores are provided along with the resulting score (IBI (OCC)), the percentage of the score compared to high-quality reference sites (Percent Reference) and the interpretation of that score (Interpretation (OCC)). Additionally, the USAP score, and its interpretation are provided (IBI (USAP), Interpretation (USAP)). Finally, a value for the long-term trend is provided for sites that have been monitored for at least 3 cycles. All trends assessed were stable, while NA indicates that the stream was not assessed for trend.

Site Name	WBID	Modified Ecoregion	FWP	Total Individuals	Total Species	Sensitive Benthic	Sunfish Species	Intolerant Species	Percent Tolerant	Percent Insectivore	Percent Lithophilic	IBI (OCC)	Percent Reference	Interpretation (OCC)	IBI (USAP)	Interpretation (USAP)	Trend
Beech Creek	OK410210-06-0320G	OM	CWAC*	986	18	8	3	11	29%	35%	61%	27	96%	Excellent	39	Supporting	Stable
Big Eagle Creek	OK410210-06-0160I	OM	CWAC*	1099	23	6	6	9	25%	42%	51%	31	111%	Excellent	41	Supporting	NA
Big Sandy Creek	OK410400-06-0260G	AV	WWAC	293	24	5	9	5	86%	5%	6%	21	78%	Good	33	Undetermined	NA
Billy Creek	OK410310-02-0070C	OM	WWAC	1464	24	7	6	5	26%	47%	45%	31	118%	Excellent	37	Supporting	Stable
Black Fork of Little River	OK410210-03-0020C	OM	CWAC*	942	26	7	6	7	33%	47%	31%	29	104%	Excellent	37	Supporting	Stable
Blue River	OK410600-02-0010F	SCP	WWAC	1732	28	7	8	8	21%	64%	14%	29	116%	Excellent	33	Undetermined	NA
Bokchito Creek	OK410600-01-0090G	SCP	WWAC	971	23	5	6	3	44%	26%	45%	29	116%	Excellent	37	Supporting	Stable
Buck Creek	OK410300-03-0420C	OM	WWAC	1115	34	8	7	10	39%	25%	54%	29	110%	Excellent	35	Supporting	Stable
Buffalo Creek	OK410310-03-0030N	OM	WWAC	1179	29	7	7	6	15%	9%	79%	29	110%	Excellent	37	Supporting	NA
Buffalo Creek: Lower	OK410210-06-0020G	OM	CWAC*	1549	23	7	6	8	24%	54%	42%	33	118%	Excellent	37	Supporting	Stable
Caddo Creek	OK410600-01-0140J	SCP	WWAC	482	30	6	8	4	42%	18%	21%	25	100%	Excellent	37	Supporting	NA
Caney Boggy Creek	OK410400-06-0120G	AV	WWAC	1035	27	7	7	8	49%	6%	46%	27	100%	Excellent	39	Supporting	Stable
Caney Creek	OK410400-02-0200G	SCP	WWAC	507	27	3	11	6	72%	1%	1%	23	92%	Excellent	35	Supporting	Stable
Caney Creek: HWY 69	OK410400-03-0020C	SCP	WWAC	472	22	6	8	6	46%	41%	12%	25	100%	Excellent	31	Undetermined	Stable

Site Name	WBID	Modified Ecoregion	FWP	Total Individuals	Total Species	Sensitive Benthic	Sunfish Species	Intolerant Species	Percent Tolerant	Percent Insectivore	Percent Lithophilic	IBI (OCC)	Percent Reference	Interpretation (OCC)	IBI (USAP)	Interpretation (USAP)	Trend
Cedar Creek	OK410300-03-0020M	OM	CWAC*	1224	29	7	8	9	51%	11%	41%	27	96%	Excellent	37	Supporting	Stable
Chickasaw Creek	OK410400-05-0420G	OM	WWAC	746	25	5	7	5	45%	30%	35%	27	103%	Excellent	37	Supporting	NA
Clear Creek	OK410100-01-0480N	SCP	WWAC	716	26	9	7	8	31%	2%	46%	27	108%	Excellent	41	Supporting	NA
Cloudy Creek	OK410210-02-0300C	OM	CWAC*	2226	25	6	6	7	40%	7%	53%	27	96%	Excellent	33	Undetermined	Stable
Cow Creek	OK410210-06-0350G	OM	CWAC*	1225	15	6	2	7	18%	23%	78%	29	104%	Excellent	37	Supporting	Stable
Delaware Creek	OK410400-03-0240M	SCP	WWAC	1117	32	11	9	8	40%	43%	25%	27	108%	Excellent	39	Supporting	Stable
East Fork of Glover River	OK410210-09-0010G	OM	CWAC*	2461	21	5	5	9	24%	32%	62%	31	111%	Excellent	39	Supporting	Stable
Hanubby Creek	OK410400-01-0080G	SCP	WWAC	1206	38	9	9	9	70%	13%	17%	23	92%	Excellent	37	Supporting	NA
Honobia Creek	OK410210-03-0150H	OM	WWAC	672	12	2	3	4	30%	12%	69%	25	95%	Excellent	33	Undetermined	NA
Island Bayou	OK410700-00-0040J	SCP	WWAC	1158	31	7	8	6	45%	43%	4%	25	100%	Excellent	33	Undetermined	NA
Keel Creek: Hwy 31	OK410400-06-0100D	AV	WWAC	732	27	3	10	5	73%	9%	16%	21	78%	Good	35	Supporting	NA
Lick Creek	OK410400-01-0130E	SCP	WWAC	439	25	4	9	7	69%	2%	9%	23	92%	Excellent	37	Supporting	NA
Lukfata Creek	OK410210-07-0010G	OM	CWAC*	888	38	11	11	16	41%	11%	21%	25	89%	Good	41	Supporting	Stable
Luksuklo Creek	OK410210-04-0020G	SCP	WWAC	993	32	7	9	12	39%	24%	40%	29	116%	Excellent	43	Supporting	NA
McGee Creek	OK410400-07-0010L	OM	WWAC	912	24	6	8	3	57%	18%	40%	25	95%	Excellent	31	Undetermined	NA
Mineral Bayou	OK410600-01-0300G	SCP	WWAC	710	23	6	7	3	36%	23%	38%	29	116%	Excellent	33	Undetermined	NA
Mineral Bayou	OK410600-01-0300G	SCP	WWAC	710	21	6	6	4	37%	37%	24%	27	108%	Excellent	33	Undetermined	NA
Muddy Boggy	OK410400-05-0270M	AV	WWAC	1494	26	7	4	9	79%	11%	10%	21	78%	Good	33	Undetermined	NA
North Boggy Creek	OK410400-08-0010E	AV	WWAC	1240	27	4	9	4	34%	0%	50%	25	93%	Excellent	37	Supporting	NA
Norwood Creek	OK410100-01-0050H	SCP	WWAC	779	38	6	10	14	65%	8%	6%	23	92%	Excellent	25	Undetermined	Stable
One Creek	OK410300-03-0060F	OM	WWAC	1545	34	10	7	12	44%	14%	48%	27	103%	Excellent	41	Supporting	Stable
Panther Creek	OK410400-06-0240G	AV	WWAC	374	19	5	7	3	77%	12%	10%	19	70%	Fair	35	Supporting	NA
Rock Creek	OK410200-03-0010G	OM	CWAC*	1834	30	8	8	14	19%	43%	58%	31	111%	Excellent	35	Supporting	Stable
Salt Creek	OK410400-06-0090G	AV	WWAC	184	17	3	6	5	74%	7%	19%	23	85%	Good	31	Undetermined	NA
Sand Creek	OK410700-00-0260G	SCP	WWAC	1619	28	6	9	3	61%	11%	27%	25	100%	Excellent	35	Supporting	NA
Sandy Creek	OK410600-02-0020G	CT	WWAC	774	23	7	8	4	30%	57%	8%	27	119%	Excellent	31	Supporting	Stable

Site Name	WBID	Modified Ecoregion	FWP	Total Individuals	Total Species	Sensitive Benthic	Sunfish Species	Intolerant Species	Percent Tolerant	Percent Insectivore	Percent Lithophilic	IBI (OCC)	Percent Reference	Interpretation (OCC)	IBI (USAP)	Interpretation (USAP)	Trend
Sandy Creek	OK410600-02-0020G	CT	WWAC	774	17	4	6	2	37%	48%	14%	27	119%	Excellent	31	Supporting	Stable
Sincere Creek	OK410400-06-0290G	AV	WWAC	653	18	3	8	2	72%	5%	17%	19	70%	Fair	31	Undetermined	NA
Spencer Creek	OK410300-02-0140F	SCP	WWAC	359	24	8	5	9	49%	9%	32%	25	100%	Excellent	39	Supporting	NA
Sulphur Creek	OK410600-01-0030G	SCP	WWAC	373	22	4	6	3	37%	58%	2%	27	108%	Excellent	31	Undetermined	Stable
Tenmile Creek	OK410300-03-0270C	OM	WWAC	836	24	6	5	6	22%	18%	69%	29	110%	Excellent	37	Supporting	Stable
Terrapin Creek	OK410210-02-0150H	OM	CWAC*	1778	11	3	3	4	16%	34%	64%	23	82%	Good	31	Undetermined	NA
Waterhole Creek	OK410100-01-0340D	SCP	WWAC	1170	40	9	14	14	69%	5%	5%	23	92%	Excellent	35	Supporting	Stable
West Fork of Glover River	OK410210-09-0070C	OM	CWAC*	801	20	5	7	7	59%	14%	29%	25	76%	Fair	33	Undetermined	NA
Whitegrass Creek	OK410400-01-0210G	SCP	WWAC	868	27	6	8	8	51%	20%	7%	25	100%	Excellent	37	Supporting	Stable

3.1.4 Macroinvertebrate Scores

Macroinvertebrate assemblages across the Lower Red River Basin were mostly in good condition (Table 11). There were no sites in the basin designated moderately impaired or severely impaired. Twenty-seven of the 43 sites evaluated were considered not impaired, and 16 site were deemed slightly impaired. Twenty-one sites have been sampled in at least 3 monitoring cycles and were evaluated for long-term trends. Of those, 13 sites were deemed stable, 6 were increasing, and only two were observed to be declining.

Table 11. Results from macroinvertebrate assemblage assessments in Basin 5 (Lower River Basins) Cycle 4. Site information includes the name of the site, waterbody ID and the Ecoregion. The metrics used to determine the OK Conservation Commission scores are provided along with the resulting score (IBI Score), the percentage of the score compared to high-quality reference sites (Percent Reference) and the interpretation of that score (Interpretation) which can be not impaired (NI), slightly impaired (SI), moderately impaired (MI) or severely impaired (SVI). When reference criteria were not available for a site, it was designated NC. Finally, an assessment of the long-term trend is provided for sites that have been monitored for at least 3 cycles. Trends may be Improving (Increase), Degrading (Decrease), unchanging (Stable), or not assessed (NA).

Site Name	WBID	Modified Ecoregion	Season	Habitat	Taxa Richness	Modified HBI	EPT%	EPT Taxa	Dom 2 Taxa	Shannon Weaver	IBI Score	Percent Reference	Mean score	Interpretation	Trend
Beech Creek	OK410210-06-0320G	OM	Summer	Riffle	23	4.44	55%	11	25%	2.77	26	93%			
Beech Creek	OK410210-06-0320G	OM	Summer	Riffle	14	4.19	36%	7	45%	2.20	24	86%	89%	NI	Increase
Big Eagle Creek	OK410210-06-0160I	OM	Summer	Riffle	13	5.13	31%	7	55%	2.01	24	86%			
Big Eagle Creek	OK410210-06-0160I	OM	Summer	Riffle	19	4.85	53%	10	51%	2.20	26	93%	89%	NI	NA
Big Sandy Creek	OK410400-06-0260G	AV	Summer	Riffle	13	4.97	14%	5	56%	1.86	20	71%			
Big Sandy Creek	OK410400-06-0260G	AV	Winter	Riffle	13	3.04	73%	4	70%	1.46	22	85%			
Big Sandy Creek	OK410400-06-0260G	AV	Summer	Riffle	10	4.48	57%	3	75%	1.26	20	77%			
Big Sandy Creek	OK410400-06-0260G	AV	Winter	Riffle	13	2.74	85%	4	83%	1.31	22	85%	79%	SI	NA
Billy Creek	OK410310-02-0070C	OM	Summer	Riffle	18	4.98	56%	10	44%	2.32	26	93%			
Billy Creek	OK410310-02-0070C	OM	Winter	Riffle	17	5.22	15%	7	47%	2.26	20	77%			
Billy Creek	OK410310-02-0070C	OM	Summer	Riffle	15	5.84	7%	4	51%	2.02	16	57%			
Billy Creek	OK410310-02-0070C	OM	Winter	Riffle	20	4.45	38%	11	56%	2.19	26	100%	82%	NI	Stable
Black Fork of Little River	OK410210-03-0020C	OM	Summer	Riffle	12	3.89	14%	4	72%	1.60	18	64%			

Site Name	WBID	Modified Ecoregion	Season	Habitat	Taxa Richness	Modified HBI	EPT%	EPT Taxa	Dom 2 Taxa	Shannon Weaver	IBI Score	Percent Reference	Mean score	Interpretation	Trend
Black Fork of Little River	OK410210-03-0020C	OM	Winter	Riffle	20	4.56	40%	11	35%	2.53	28	108%			
Black Fork of Little River	OK410210-03-0020C	OM	Summer	Riffle	18	4.04	41%	7	41%	2.44	26	93%			
Black Fork of Little River	OK410210-03-0020C	OM	Summer	Woody	18	4.07	26%	7	53%	2.11	22	100%	91%	NI	Stable
Blue River	OK410600-02-0010F	CT	Winter	Woody	22	5.46	15%	7	43%	2.53	18	82%			
Blue River	OK410600-02-0010F	CT	Summer	Woody	23	5.17	42%	12	37%	2.60	22	85%			
Blue River	OK410600-02-0010F	CT	Winter	Woody	9	6.44	12%	4	72%	1.57	20	91%	86%	NI	NA
Bokchito Creek	OK410600-01-0090G	SCP	Summer	Riffle	13	4.40	53%	5	64%	1.70	24	92%			
Bokchito Creek	OK410600-01-0090G	SCP	Winter	Riffle	21	5.68	11%	3	48%	2.32	22	92%			
Bokchito Creek	OK410600-01-0090G	SCP	Summer	Riffle	16	4.55	21%	4	56%	1.98	24	92%			
Bokchito Creek	OK410600-01-0090G	SCP	Winter	Riffle	4	6.03	0%	0	98%	0.68	6	25%	75%	SI	Stable
Buck Creek	OK410300-03-0420C	OM	Summer	Riffle	17	4.62	69%	10	41%	2.25	26	93%			
Buck Creek	OK410300-03-0420C	OM	Summer	Riffle	20	4.20	63%	10	40%	2.38	26	93%			
Buck Creek	OK410300-03-0420C	OM	Winter	Riffle	25	5.03	55%	10	30%	2.76	28	108%	98%	NI	Stable
Buffalo Creek	OK410310-03-0030N	OM	Summer	Riffle	15	5.60	22%	5	49%	2.14	20	71%			
Buffalo Creek	OK410310-03-0030N	OM	Winter	Riffle	12	5.99	38%	8	70%	1.64	20	77%			
Buffalo Creek	OK410310-03-0030N	OM	Summer	Riffle	11	4.73	43%	3	58%	1.73	22	79%			
Buffalo Creek	OK410310-03-0030N	OM	Winter	Riffle	18	4.24	72%	9	54%	2.10	26	100%	82%	NI	NA
Buffalo Creek: Lower	OK410210-06-0020G	OM	Summer	Riffle	18	4.65	53%	9	44%	2.36	26	93%			
Buffalo Creek: Lower	OK410210-06-0020G	OM	Summer	Riffle	21	5.26	22%	8	46%	2.38	24	86%	89%	NI	Increase
Caney Boggy Creek	OK410400-06-0120G	AV	Summer	Riffle	14	4.32	19%	5	55%	2.09	22	85%			
Caney Boggy Creek	OK410400-06-0120G	AV	Winter	Riffle	10	5.61	35%	3	61%	1.84	22	85%			
Caney Boggy Creek	OK410400-06-0120G	AV	Summer	Riffle	6	4.23	13%	1	92%	0.63	14	54%			
Caney Boggy Creek	OK410400-06-0120G	AV	Winter	Riffle	12	5.98	4%	5	75%	1.50	14	54%	69%	SI	Stable
Caney Creek: HWY 69	OK410400-03-0020C	SCP	Summer	Riffle	15	4.90	40%	6	51%	2.12	26	100%			
Caney Creek: HWY 69	OK410400-03-0020C	SCP	Winter	Riffle	15	5.88	38%	3	45%	2.10	26	108%	104%	NI	Stable

Site Name	WBID	Modified Ecoregion	Season	Habitat	Taxa Richness	Modified HBI	EPT%	EPT Taxa	Dom 2 Taxa	Shannon Weaver	IBI Score	Percent Reference	Mean score	Interpretation	Trend
Cedar Creek	OK410300-03-0020M	OM	Summer	Riffle	18	4.85	22%	7	55%	2.16	24	86%	86%	NI	Stable
Chickasaw Creek	OK410400-05-0420G	OM	Summer	Riffle	12	4.80	41%	4	61%	1.75	22	79%			
Chickasaw Creek	OK410400-05-0420G	OM	Winter	Riffle	18	5.63	16%	6	34%	2.47	22	85%			
Chickasaw Creek	OK410400-05-0420G	OM	Summer	Riffle	12	4.08	69%	5	83%	1.24	20	71%			
Chickasaw Creek	OK410400-05-0420G	OM	Winter	Riffle	9	4.77	31%	3	82%	1.26	20	77%	78%	SI	NA
Clear Creek	OK410100-01-0480N	SCP	Summer	Riffle	15	4.94	25%	6	41%	2.24	24	92%			
Clear Creek	OK410100-01-0480N	SCP	Winter	Riffle	12	4.46	28%	4	62%	1.76	22	92%			
Clear Creek	OK410100-01-0480N	SCP	Summer	Riffle	16	5.17	12%	7	48%	2.14	22	85%			
Clear Creek	OK410100-01-0480N	SCP	Winter	Riffle	22	4.64	39%	11	37%	2.65	22	92%			
Clear Creek	OK410100-01-0480N	SCP	Winter	Riffle	13	4.65	47%	7	38%	2.24	22	92%	90%	NI	NA
Cloudy Creek	OK410210-02-0300C	OM	Summer	Riffle	16	5.48	11%	4	40%	2.33	20	71%			
Cloudy Creek	OK410210-02-0300C	OM	Summer	Riffle	11	4.53	58%	4	67%	1.60	22	79%	75%	SI	Increase
Cow Creek	OK410210-06-0350G	OM	Summer	Riffle	21	4.52	56%	8	41%	2.43	26	93%	93%	NI	Increase
Delaware Creek	OK410400-03-0240M	Arbuckle	Summer	Woody	12	6.79	13%	3	75%	1.55	NC	NC	NC		
Delaware Creek	OK410400-03-0240M	Arbuckle	Winter	Woody	11	6.76	1%	1	60%	1.78	14	54%			
Delaware Creek	OK410400-03-0240M	Arbuckle	Summer	Woody	11	6.54	23%	5	60%	1.82	NC	NC	54%	SI	Stable
East Fork of Glover River	OK410210-09-0010G	OM	Summer	Riffle	14	4.18	51%	6	38%	2.28	24	86%			
East Fork of Glover River	OK410210-09-0010G	OM	Summer	Riffle	17	4.15	38%	6	43%	2.27	26	93%	89%	NI	Stable
Hanubby Creek	OK410400-01-0080G	SCP	Summer	Riffle	12	4.13	86%	5	79%	1.31	22	85%			
Hanubby Creek	OK410400-01-0080G	SCP	Winter	Woody	11	5.88	24%	4	40%	2.11	24	92%	88%	NI	NA
Honobia Creek	OK410210-03-0150H	OM	Summer	Riffle	17	3.96	36%	7	41%	2.34	26	93%			
Honobia Creek	OK410210-03-0150H	OM	Winter	Riffle	26	5.26	31%	13	42%	2.58	26	100%			
Honobia Creek	OK410210-03-0150H	OM	Summer	Riffle	19	4.96	36%	8	34%	2.54	28	100%	98%	NI	NA
Island Bayou	OK410700-00-0040J	ECTP	Summer	Riffle	12	4.65	45%	7	55%	1.83	NC	NC			
Island Bayou	OK410700-00-0040J	ECTP	Summer	Riffle	14	4.47	73%	5	57%	1.95	NC	NC			

Site Name	WBID	Modified Ecoregion	Season	Habitat	Taxa Richness	Modified HBI	EPT%	EPT Taxa	Dom 2 Taxa	Shannon Weaver	IBI Score	Percent Reference	Mean score	Interpretation	Trend
Island Bayou	OK410700-00-0040J	ECTP	Summer	Woody	14	4.93	41%	4	33%	2.32	NC	NC	NC	NC	NA
Keel Creek	OK410400-06-0100D	AV	Summer	Riffle	13	6.81	22%	4	54%	1.92	18	69%			
Keel Creek	OK410400-06-0100D	AV	Winter	Riffle	10	6.13	2%	2	87%	1.24	12	46%			
Keel Creek	OK410400-06-0100D	AV	Summer	Riffle	11	5.83	6%	3	67%	1.57	16	62%			
Keel Creek	OK410400-06-0100D	AV	Winter	Riffle	6	6.00	2%	1	93%	0.80	10	38%	54%	SI	NA
Lick Creek	OK410400-01-0130E	SCP	Summer	Riffle	6	4.04	23%	3	80%	1.16	16	62%			
Lick Creek	OK410400-01-0130E	SCP	Winter	Riffle	11	5.82	5%	3	84%	0.97	16	67%	64%	SI	NA
Lukfata Creek	OK410210-07-0010G	SCP	Summer	Riffle	18	4.27	65%	7	65%	1.81	26	100%			
Lukfata Creek	OK410210-07-0010G	SCP	Winter	Riffle	16	4.76	36%	5	43%	2.25	26	108%			
Lukfata Creek	OK410210-07-0010G	SCP	Summer	Vegetation	12	5.46	31%	5	78%	1.45	22	79%	96%	NI	Stable
Luksuklo Creek	OK410210-04-0020G	OM	Summer	Riffle	19	4.02	34%	9	37%	2.51	28	100%			
Luksuklo Creek	OK410210-04-0020G	OM	Summer	Riffle	15	4.32	30%	5	34%	2.30	24	86%	93%	NI	NA
McGee Creek	OK410400-07-0010L	OM	Winter	Riffle	21	4.73	51%	10	50%	2.24	26	100%			
McGee Creek	OK410400-07-0010L	OM	Summer	Riffle	19	4.60	32%	7	49%	2.28	26	93%			
McGee Creek	OK410400-07-0010L	OM	Winter	Riffle	12	5.06	25%	8	77%	1.35	18	69%	87%	NI	NA
Mineral Bayou	OK410600-01-0300G	SCP	Summer	Riffle	13	4.48	36%	5	65%	1.67	24	92%			
Mineral Bayou	OK410600-01-0300G	SCP	Winter	Riffle	17	5.88	12%	4	59%	1.93	22	92%			
Mineral Bayou	OK410600-01-0300G	SCP	Summer	Riffle	13	4.68	52%	5	59%	1.88	24	92%			
Mineral Bayou	OK410600-01-0300G	SCP	Winter	Riffle	14	5.72	4%	3	71%	1.62	20	83%	90%	NI	Stable
Muddy Boggy	OK410400-05-0270M	AV	Winter	Riffle	13	5.97	6%	3	57%	1.90	18	69%			
Muddy Boggy	OK410400-05-0270M	AV	Summer	Woody	15	4.68	18%	6	54%	2.09	20	77%	73%	SI	NA
North Boggy Creek	OK410400-08-0010E	AV	Summer	Riffle	19	5.38	25%	7	43%	2.42	22	85%			
North Boggy Creek	OK410400-08-0010E	AV	Winter	Riffle	16	5.86	13%	4	55%	2.11	22	85%			
North Boggy Creek	OK410400-08-0010E	AV	Summer	Riffle	16	5.03	25%	4	63%	1.86	24	92%			
North Boggy Creek	OK410400-08-0010E	AV	Winter	Riffle	11	6.01	5%	4	80%	1.30	14	54%	79%	SI	NA

Site Name	WBID	Modified Ecoregion	Season	Habitat	Taxa Richness	Modified HBI	EPT%	EPT Taxa	Dom 2 Taxa	Shannon Weaver	IBI Score	Percent Reference	Mean score	Interpretation	Trend
Norwood Creek	OK410100-01-0050H	SCP	Summer	Riffle	11	5.28	15%	4	68%	1.50	20	77%			
Norwood Creek	OK410100-01-0050H	SCP	Summer	Riffle	9	4.16	4%	1	93%	0.82	14	54%			
Norwood Creek	OK410100-01-0050H	SCP	Winter	Riffle	12	5.29	7%	4	72%	1.63	18	75%	69%	SI	NA
One Creek	OK410300-03-0060F	OM	Summer	Riffle	21	4.86	27%	8	62%	2.12	24	86%			
One Creek	OK410300-03-0060F	OM	Summer	Riffle	20	4.99	31%	7	30%	2.68	28	100%			
One Creek	OK410300-03-0060F	OM	Winter	Riffle	22	4.81	33%	10	43%	2.49	26	100%	95%	NI	Stable
Panther Creek	OK410400-06-0240G	AV	Summer	Riffle	16	5.36	16%	4	38%	2.37	20	77%			
Panther Creek	OK410400-06-0240G	AV	Winter	Riffle	16	5.29	26%	5	60%	1.90	24	92%			
Panther Creek	OK410400-06-0240G	AV	Summer	Riffle	13	4.93	22%	5	61%	1.81	22	85%			
Panther Creek	OK410400-06-0240G	AV	Winter	Riffle	17	3.83	73%	7	48%	2.18	26	100%	88%	NI	NA
Rock Creek	OK410200-03-0010G	OM	Summer	Riffle	16	4.13	27%	8	54%	2.03	22	79%			
Rock Creek	OK410200-03-0010G	OM	Winter	Riffle	22	3.76	29%	9	53%	2.19	24	92%			
Rock Creek	OK410200-03-0010G	OM	Summer	Riffle	22	3.93	34%	11	44%	2.41	24	86%	86%	NI	Increase
Salt Creek	OK410400-06-0090G	AV	Winter	Riffle	7	6.01	0%	0	98%	0.74	6	23%			
Salt Creek	OK410400-06-0090G	AV	Summer	Woody	14	5.63	15%	5	75%	1.66	22	85%			
Salt Creek	OK410400-06-0090G	AV	Summer	Woody	13	5.79	2%	1	62%	1.88	20	77%	62%	SI	NA
Sand Creek	OK410700-00-0260G	ECTP	Summer	Riffle	17	4.37	60%	8	52%	2.12	NC	NC			
Sand Creek	OK410700-00-0260G	ECTP	Winter	Riffle	15	5.23	44%	4	52%	2.03	NC	NC			
Sand Creek	OK410700-00-0260G	ECTP	Winter	Riffle	12	5.99	8%	4	67%	1.71	NC	NC	NC	NC	NA
Sandy Creek	OK410600-02-0020G	SCP	Summer	Riffle	21	4.72	55%	10	23%	2.77	22	85%			
Sandy Creek	OK410600-02-0020G	SCP	Winter	Riffle	20	4.69	59%	8	32%	2.54	24	100%	92%	NI	Increase
Sincere Creek	OK410400-06-0290G	AV	Winter	Riffle	14	5.45	19%	5	43%	2.16	22	85%			
Sincere Creek	OK410400-06-0290G	AV	Summer	Riffle	15	5.09	14%	5	61%	1.82	20	77%			
Sincere Creek	OK410400-06-0290G	AV	Winter	Riffle	7	6.33	0%	0	88%	1.08	6	23%	62%	SI	NA
Spencer Creek	OK410300-02-0140F	SCP	Winter	Riffle	17	4.23	18%	7	68%	1.69	20	83%			

Site Name	WBID	Modified Ecoregion	Season	Habitat	Taxa Richness	Modified HBI	EPT%	EPT Taxa	Dom 2 Taxa	Shannon Weaver	IBI Score	Percent Reference	Mean score	Interpretation	Trend
Spencer Creek	OK410300-02-0140F	SCP	Winter	Riffle	16	5.77	17%	4	45%	2.13	22	92%	88%	NI	NA
Sulphur Creek	OK410600-01-0030G	SCP	Summer	Riffle	12	4.08	65%	5	57%	2.01	24	92%			
Sulphur Creek	OK410600-01-0030G	SCP	Winter	Riffle	15	6.42	23%	5	58%	1.96	24	100%	96%	NI	NA
Tenmile Creek	OK410300-03-0270C	OM	Summer	Riffle	10	6.06	3%	2	79%	1.40	12	43%			
Tenmile Creek	OK410300-03-0270C	OM	Summer	Riffle	8	4.41	14%	3	79%	1.31	14	50%			
Tenmile Creek	OK410300-03-0270C	OM	Winter	Riffle	13	5.41	5%	4	76%	1.54	18	69%	54%	SI	Stable
Terrapin Creek	OK410210-02-0150H	OM	Summer	Riffle	16	4.79	49%	7	55%	2.06	24	86%			
Terrapin Creek	OK410210-02-0150H	OM	Summer	Riffle	23	4.75	42%	9	32%	2.58	28	100%	93%	NI	NA
Waterhole Creek	OK410100-01-0340D	SCP	Summer	Riffle	9	5.33	8%	2	65%	1.63	16	62%	62%	SI	Decline
West Fork of Glover River	OK410210-09-0070C	OM	Summer	Riffle	25	5.32	43%	11	36%	2.63	26	93%			
West Fork of Glover River	OK410210-09-0070C	OM	Summer	Vegetation	14	4.72	35%	5	66%	1.73	26	100%	96%	NI	NA
Whitegrass Creek	OK410400-01-0210G	SCP	Summer	Riffle	10	4.45	5%	2	67%	1.61	16	62%			
Whitegrass Creek	OK410400-01-0210G	SCP	Winter	Riffle	8	4.81	1%	1	84%	1.15	14	58%	60%	SI	Decline

Table 12. Scores from each assessment (WQ, fish, bugs, and habitat) are averaged to provide an overall score (Final) for each stream. Final scores are converted to letter grades: ≥90= A, <90 B ≥80, <80 C ≥70, <70 D ≥60, <60=F. Sites listed as NA were not assessed as a result of incomplete data, whereas sites listed as NC did not have reference criteria for evaluation. Detailed assessments for the water quality (WQ), fish, bugs, and habitat scores can be found in the previous tables.

Site Name	WBID	Modified Ecoregion	WQ	Fish	Bugs	Habitat	Overall	Grade
Beech Creek	OK410210-06-0320G	OM	0.92	0.96	0.89	0.88	0.91	A
Big Eagle Creek	OK410210-06-0160I	OM	0.88	1.00	0.89	1.00	0.94	A
Big Sandy Creek	OK410400-06-0260G	AV	0.58	0.78	0.79	0.71	0.71	C
Billy Creek	OK410310-02-0070C	OM	0.81	1.00	0.82	0.87	0.87	B
Black Fork of Little River	OK410210-03-0020C	OM	0.81	1.00	0.91	1.00	0.93	A
Blue River	OK410600-02-0010F	CT	0.96	1.00	0.86	0.84	0.91	A
Bokchito Creek	OK410600-01-0090G	SCP	0.73	1.00	0.75	0.80	0.82	B
Buck Creek	OK410300-03-0420C	OM	0.58	1.00	0.98	0.68	0.81	B
Buffalo Creek	OK410310-03-0030N	OM	0.69	1.00	0.82	0.83	0.83	B
Buffalo Creek: Lower	OK410210-06-0020G	OM	0.88	1.00	0.89	0.97	0.94	A
Caddo Creek: Hwy 70	OK410600-01-0140J	SCP	0.69	1.00	NA	0.68	0.79	C
Caney Boggy Creek	OK410400-06-0120G	AV	0.54	1.00	0.69	0.76	0.75	C
Caney Creek	OK410400-02-0200G	SCP	0.38	0.92	NA	0.62	0.64	D
Caney Creek: HWY 69	OK410400-03-0020C	SCP	0.58	1.00	1.00	0.55	0.78	C
Cedar Creek	OK410300-03-0020M	OM	0.69	0.96	0.86	1.00	0.88	B
Chickasaw Creek	OK410400-05-0420G	OM	0.46	1.00	0.78	0.83	0.77	C
Clear Boggy Creek	OK410400-03-0230K	AV	0.50	1.00	NA	NA	0.75	C
Clear Creek	OK410100-01-0480N	SCP	0.88	1.00	0.90	0.90	0.92	A
Cloudy Creek	OK410210-02-0300C	OM	0.65	0.96	0.75	0.90	0.82	B
Cow Creek	OK410210-06-0350G	OM	0.88	1.00	0.93	0.87	0.92	A
Delaware Creek	OK410400-03-0240M	Arbuckle	0.69	1.00	NC	0.88	0.86	B
East Fork of Glover River	OK410210-09-0010G	OM	0.85	1.00	0.89	0.94	0.92	A
Hanubby Creek	OK410400-01-0080G	SCP	0.65	0.92	0.88	0.55	0.75	C
Honobia Creek	OK410210-03-0150H	OM	0.88	0.95	0.98	1.00	0.95	A
Island Bayou	OK410700-00-0040J	ECTP	0.54	1.00	NC	NC	0.77	C
Keel Creek	OK410400-06-0100D	AV	0.46	0.78	0.54	0.77	0.64	D
Lick Creek	OK410400-01-0130E	SCP	0.50	0.92	0.64	0.74	0.70	C
Lukfata Creek	OK410210-07-0010G	SCP	0.96	0.89	0.96	0.81	0.91	A
Luksuklo Creek	OK410210-04-0020G	SCP	0.92	1.00	0.93	0.93	0.95	A
McGee Creek	OK410400-07-0010L	OM	0.42	0.95	0.87	0.44	0.67	D
Mineral Bayou	OK410600-01-0300G	SCP	0.62	1.00	0.90	0.70	0.80	B
Muddy Boggy	OK410400-05-0270M	AV	0.38	0.78	0.73	0.70	0.65	D
North Boggy Creek	OK410400-08-0010E	AV	0.62	0.93	0.79	0.80	0.78	C
Norwood Creek	OK410100-01-0050H	SCP	0.46	0.92	0.69	0.69	0.69	D

Site Name	WBID	Modified Ecoregion	WQ	Fish	Bugs	Habitat	Overall	Grade
One Creek	OK410300-03-0060F	OM	0.65	1.00	0.95	0.88	0.87	B
Panther Creek	OK410400-06-0240G	AV	0.54	0.70	0.88	0.79	0.73	C
Rock Creek	OK410200-03-0010G	OM	0.92	1.00	0.86	1.00	0.94	A
Salt Creek	OK410400-06-0090G	AV	0.50	0.85	0.62	0.77	0.69	D
Sand Creek	OK410700-00-0260G	ECTP	0.85	1.00	NC	NC	0.92	A
Sandy Creek	OK410600-02-0020G	SCP	0.81	1.00	0.92	0.50	0.81	B
Sincere Creek	OK410400-06-0290G	AV	0.54	0.70	0.62	0.73	0.65	D
Spencer Creek	OK410300-02-0140F	SCP	0.85	1.00	0.88	0.84	0.89	B
Sulphur Creek	OK410600-01-0030G	SCP	0.65	1.00	0.96	0.71	0.83	B
Tenmile Creek	OK410300-03-0270C	OM	0.35	1.00	0.54	0.75	0.66	D
Terrapin Creek	OK410210-02-0150H	OM	0.85	0.82	0.93	1.00	0.90	A
Waterhole Creek	OK410100-01-0340D	SCP	0.58	0.92	0.62	0.44	0.64	D
West Fork of Glover River	OK410210-09-0070C	OM	0.73	0.76	0.96	1.00	0.86	B
Whitegrass Creek	OK410400-01-0210G	SCP	0.65	1.00	0.60	0.62	0.72	C

3.2 POTENTIAL IMPAIRMENT SOURCES

3.2.1 Relative Risk Assessment

In the relative risk assessment, Dissolved Oxygen was identified as the most likely cause of impaired biota, followed by nutrients and habitat with Fines% and Riparian Condition metrics included (Table 13). Because fish assemblages were generally in good condition, degraded biotic scores were mostly due to poor macroinvertebrate scores. Nutrient and DO impairment may be connected because, high nutrient concentrations lead to eutrophication, resulting in low dissolved oxygen levels over night. Extremely low DO can result in the extirpation of biota, especially those that are intolerant to low DO, resulting in the low macroinvertebrate scores observed.

Table 13. Relative Risk Score for Sites in Basin 5 (Lower Red River Basin), Cycle 4.

Stressor	Relative Risk Score
Nutrients	3.00
Salts	1.55
Acid	0
Dissolved Oxygen	3.90
Fine Sediment	0.94
Riparian Condition	0.44
Habitat	2.25

3.2.2 Watershed Assessment

Table 14 shows the changes in land-use upstream of each monitoring site calculated from the 2006 USGS National Land Cover Dataset (NLCD) in Geographic Information Systems (GIS) in cycle 1 and the 2019 NLCD for cycle 4. The watershed sizes and land uses vary widely, with Panther Creek having the smallest watershed area, 0.4 km^2, while the Muddy Boggy watershed includes more than 133 km^2.

We evaluated the relationship between landuse change and percent saturated dissolved oxygen (DO%), total nitrogen (TN), available nitrogen (AN), total phosphorus (TP) and orthophosphate (OP). The percent of land lost to open water at the catchment level was the only statistically meaningful model observed (ΔAIC = 3.60). As more land was converted to open water, a stream was 52% (13 – 78% 95% CI) more likely to have degraded DO%, although the model was weak (pseudo $R^2 = 0.14$). Similarly, change in open water at the watershed scale was the best predictor for TN and AN impairment (ΔAIC = 8.40 & 5.41, respectively). As more land was converted to open water, TN was 89% (50 – 98%) and AN was 80% (26 – 98%) more likely to be degraded. The models were better than the DO% model but still weak in explanatory power ($R^2 = 0.24$ TN & $R^2 = 0.25$ AN). There were no informative predictors of TP or OP. The Pearson's correlation analysis indicated that undeveloped land was the most likely landuse type to be lost to open water (ρ = -0.29 catchment scale & ρ = -0.59 watershed scale) during our monitoring program. Additionally, open water was strongly correlated with low intensity urban development at the watershed scale (ρ = 0.74). Low intensity urban development commonly replaced open urban development and may be interpreted as suburban development (ρ = -0.72). Ponds are often created in the development of suburban areas, and the increase in impervious surfaces promotes more runoff and pooling resulting in an increase in open water areas in the watershed. The removal of vegetation and the increase in runoff associated with development may be sources of increased nutrients in streams. More detailed analyses of the types of land-use change within the developed land classes, may reveal landscape patterns that help elucidate potential sources of nutrient enrichment in the region.

Table 15 presents the types and number of permitted activities (e.g., Concentrated Animal Feeding Operations [CAFOs], landfills, National Pollution Discharge Elimination System [NPDES] permits) that occur upstream of each site. Ten sites had no permitted activity in the watershed in this basin: Beech Creek, Buffalo Creek: Lower, Cedar Creek, Cloudy Creek, Cow Creek, East Fork of Glover River, Lukfata Creek, Luksuklo Creek, Rock Creek, and Terrapin Creek. Increases in oil and gas activities within a watershed was correlated with poorer salt scores (ρ = -0.33).

Nine sites had NPDES in the watershed. To examine the effects of point source versus non-point source pollution on the parameters at the monitoring sites, one-way ANOVAs were performed comparing sites with the permitted discharge to sites with no permitted discharge. Table 16 shows the results: Several parameters showed significant difference between sites with a NPDES vs. without. Nutrients (orthophosphorous, TP, nitrate, TN, Available N, TKN) and salts (TDS, TSS, and Chloride) were significantly lower in watersheds with no NPDES permits. Though, increases in NPDES permits in a watershed since 2016 did not reveal any consistent patterns in nutrient trends.

3.2.3 Designated Use Support Assessment

2022 Integrated Report assessments for basin 5 sites are presented in Appendix E. A list of parameters for which a stream is listed can be found in Appendix D, along with information regarding TMDL development status. The updated draft designated use attainment status for bacteria and biological conditions for basin 5 sites based on OCC data alone are presented in Table 17. The draft designated use assessments and the causes and potential source(s) (if known) of any impairments will be submitted to ODEQ for the 2024 Integrated Report, and may be integrated with external datasets during assessments. Island Bayou is the only stream monitored in Basin 5 in full attainment of its designated uses.

Table 14. Percent change in watershed land use for Basin 5 (Lower Red River Basin) monitoring sites based on the Land Cover Dataset that coincided with Cycle 1 (NLCD; USGS 2006) and the most recent NLCD (USGS 2019). Each site is given a unique waterbody identifier (WBID). Positive values indicate an increase in area of the land cover type, while negative values indicate a decrease.

Site Name	WBID	Area (KM^2)	Open Water (%)	Urban, Open (%)	Urban, Low (%)	Urban, Medium (%)	Urban, High (%)	Barren Land (%)	Deciduous Forest (%)	Conifer Forest (%)	Mixed Forest (%)	Shrubland (%)	Grassland (%)	Hay/Pasture (%)	Cropland (%)	Woody Wetland (%)	Herbaceous Wetland (%)
Beech Creek	OK410210-06-0320G	16.05	-0.10	-0.02	0.01	0.02	0.00	0.00	2.64	0.45	0.41	-1.91	-1.56	0.06	0.00	0.00	0.00
Big Eagle Creek	OK410210-06-0160I	52.66	-0.06	-0.02	0.00	0.02	0.00	0.00	-1.06	-0.81	0.28	3.39	-1.71	-0.04	0.00	0.00	0.00
Big Sandy Creek	OK410400-06-0260G	21.86	0.09	-0.07	0.03	0.08	0.02	0.00	3.73	-0.06	0.02	0.23	-4.09	0.03	0.00	0.00	0.00
Billy Creek	OK410310-02-0070C	11.44	-0.05	-0.04	-0.02	0.04	0.02	0.00	-1.38	-1.56	-0.46	1.44	1.71	0.29	0.00	0.00	0.00
Black Fork of Little River	OK410210-03-0020C	33.62	-0.02	-0.01	0.00	0.01	0.00	0.02	-0.50	0.15	0.38	-0.41	0.41	-0.03	0.00	0.01	-0.01
Blue River	OK410600-02-0010F	116.75	0.46	-0.06	0.02	0.06	0.01	-0.02	2.05	-0.01	0.01	1.22	-3.93	0.02	0.16	0.00	0.01
Bokchito Creek	OK410600-01-0090G	7.95	0.08	-0.20	0.10	0.17	0.00	0.00	3.07	0.00	0.03	5.48	-9.28	0.57	0.00	0.00	-0.01
Buck Creek	OK410300-03-0420C	55.25	-0.02	-0.01	0.00	0.02	0.01	0.00	2.69	0.70	2.22	-3.39	-1.90	-0.31	0.00	0.02	-0.01
Buffalo Creek	OK410310-03-0030N	31.50	0.02	-0.04	0.00	0.07	0.01	0.00	0.63	0.82	1.95	-2.84	-0.37	-0.24	0.00	0.00	0.00
Buffalo Creek: Lower	OK410210-06-0020G	34.11	-0.23	-0.03	0.03	0.04	0.00	0.03	-3.21	-5.05	-0.77	5.18	3.85	0.16	0.00	0.00	0.01
Caddo Creek	OK410600-01-0140J	8.96	0.01	-0.06	0.09	0.06	0.00	0.00	0.59	-0.01	-0.04	3.39	-4.39	0.35	0.00	0.01	-0.01
Caney Boggy Creek	OK410400-06-0120G	59.22	0.55	-0.18	0.12	0.25	0.12	0.01	-0.55	-0.08	0.03	2.49	-2.72	-0.02	0.00	0.00	-0.01
Caney Creek	OK410400-02-0200G	7.72	0.03	-0.08	0.02	0.06	0.00	0.00	4.20	0.00	0.01	3.88	-9.12	1.21	0.00	0.00	-0.22
Caney Creek: HWY 69	OK410400-03-0020C	12.27	0.32	-0.07	0.02	0.04	0.01	0.09	1.31	0.00	0.00	0.81	-2.49	0.18	0.00	0.01	-0.23
Cedar Creek	OK410300-03-0020M	34.62	0.02	-0.02	-0.01	0.04	0.00	0.00	-1.99	-1.55	-0.48	3.27	0.65	0.10	0.00	-0.02	0.00
Chickasaw Creek	OK410400-05-0420G	16.42	0.00	-0.04	0.01	0.05	0.01	-0.01	0.25	-0.41	0.36	0.60	-0.78	-0.04	0.00	0.00	0.00
Clear Boggy Creek	OK410400-03-0230K	244.61	0.19	-0.06	0.04	0.10	0.02	0.01	1.93	0.00	0.00	1.18	-3.58	0.14	0.05	0.00	-0.02
Clear Creek	OK410100-01-0480N	11.40	-0.01	-0.02	0.03	0.06	0.00	0.06	0.73	0.88	-0.09	0.13	-0.69	-1.10	0.00	0.13	-0.11
Cloudy Creek	OK410210-02-0300C	21.87	0.00	-0.02	0.01	0.02	0.00	0.00	-0.74	5.89	0.53	-0.06	-5.53	-0.09	0.00	-0.02	0.01
Cow Creek	OK410210-06-0350G	7.42	-0.21	0.00	0.00	0.00	0.00	0.00	1.14	-0.63	-0.10	-1.82	1.61	0.00	0.00	0.00	0.00

Site Name	WBID	Area (KM²)	Open Water (%)	Urban, Open (%)	Urban, Low (%)	Urban, Medium (%)	Urban, High (%)	Barren Land (%)	Deciduous Forest (%)	Conifer Forest (%)	Mixed Forest (%)	Shrubland (%)	Grassland (%)	Hay/Pasture (%)	Cropland (%)	Woody Wetland (%)	Herbaceous Wetland (%)
Delaware Creek	OK410400-03-0240M	13.57	0.11	-0.04	0.02	0.01	0.01	0.00	3.07	0.00	0.00	0.40	-3.53	0.03	0.00	0.00	-0.09
East Fork of Glover River	OK410210-09-0010G	17.34	-0.04	0.06	0.02	0.01	0.00	0.00	-0.92	-1.72	-0.46	6.63	-3.51	-0.06	0.00	0.00	-0.01
Hanubby Creek	OK410400-01-0080G	5.80	0.11	-0.03	0.00	0.03	0.00	0.00	-2.61	0.03	0.29	3.10	-1.71	0.88	0.00	-0.06	-0.05
Honobia Creek	OK410210-03-0150H	26.58	-0.13	0.00	-0.01	0.00	0.00	0.00	0.30	1.88	0.49	-2.20	-0.35	0.00	0.00	0.00	0.02
Island Bayou	OK410700-00-0040J	30.17	0.13	-0.08	0.08	0.22	0.04	-0.18	0.88	-0.02	-0.65	1.64	-2.65	0.15	0.18	-0.02	0.28
Keel Creek	OK410400-06-0100D	13.76	0.29	-0.14	0.05	0.18	0.08	0.00	3.78	0.00	0.00	2.77	-6.87	-0.14	0.00	0.00	0.00
Lick Creek	OK410400-01-0130E	14.18	0.00	-0.05	0.03	0.06	0.00	0.00	-4.73	0.04	-0.14	4.56	-1.78	0.95	0.00	0.03	1.04
Lukfata Creek	OK410210-07-0010G	12.15	0.00	-0.09	-0.02	0.08	0.03	0.04	-1.73	-3.40	-0.89	5.35	0.40	0.22	0.00	-0.01	0.01
Luksuklo Creek	OK410210-04-0020G	4.98	0.27	0.00	0.04	0.02	0.00	0.40	-1.32	-0.33	-1.81	3.91	0.09	-1.28	0.00	0.65	-0.63
McGee Creek	OK410400-07-0010L	41.44	0.04	-0.01	0.00	0.02	0.01	0.00	7.23	0.23	0.99	-0.55	-7.87	-0.09	0.00	-0.04	0.04
Mineral Bayou	OK410600-01-0300G	10.65	0.04	-0.09	0.06	1.25	0.38	-0.03	1.20	-0.03	0.09	0.90	-3.80	0.02	0.00	0.01	0.01
Muddy Boggy	OK410400-05-0270M	330.75	0.49	-0.12	0.06	0.15	0.05	0.01	2.01	-0.11	0.02	2.05	-4.66	0.03	0.00	0.00	0.01
North Boggy Creek	OK410400-08-0010E	55.07	0.15	-0.08	-0.01	0.11	0.04	0.00	3.98	0.00	0.00	2.74	-7.12	0.19	0.00	0.00	-0.01
Norwood Creek	OK410100-01-0050H	31.09	0.32	-0.01	0.03	0.06	0.00	0.03	-1.53	-3.26	-0.35	4.20	0.61	0.04	0.00	0.75	-0.90
One Creek	OK410300-03-0060F	14.80	-0.19	-0.04	0.01	0.04	0.00	0.00	0.23	4.94	2.07	-5.24	-1.80	-0.02	0.00	0.00	0.00
Panther Creek	OK410400-06-0240G	0.40	2.72	-0.23	0.23	0.00	0.00	0.00	-2.27	0.00	0.00	0.00	-0.45	0.00	0.00	0.00	0.00
Rock Creek	OK410200-03-0010G	13.77	-0.02	-0.02	0.01	0.01	0.00	0.00	-3.68	-1.51	-4.79	8.02	1.87	0.11	0.00	0.00	-0.01
Salt Creek	OK410400-06-0090G	19.58	0.37	-0.09	0.04	0.11	0.04	0.01	1.52	0.00	0.00	1.09	-3.01	-0.09	0.00	-0.02	0.02
Sand Creek	OK410700-00-0260G	7.44	0.13	-0.02	0.05	0.01	0.00	-2.88	0.69	0.00	0.00	0.91	1.14	-0.08	0.00	0.00	0.06
Sandy Creek	OK410600-02-0020G	11.75	0.13	-0.05	0.01	0.06	0.00	0.00	2.93	0.00	0.04	1.36	-4.69	0.05	0.00	0.00	0.17
Sincere Creek	OK410400-06-0290G	18.28	0.12	-0.08	0.03	0.05	0.00	0.00	3.48	0.00	0.00	1.07	-4.63	-0.01	0.00	0.00	-0.03
Spencer Creek	OK410300-02-0140F	6.24	0.01	-0.09	0.10	0.10	0.01	0.00	-3.07	-0.48	0.68	2.19	0.75	-0.13	0.00	0.00	-0.09
Sulphur Creek	OK410600-01-0030G	10.64	0.08	-0.07	-0.02	0.11	0.02	0.00	3.09	0.00	0.05	1.76	-4.91	-0.11	0.00	0.00	-0.01

Site Name	WBID	Area (KM²)	Open Water (%)	Urban, Open (%)	Urban, Low (%)	Urban, Medium (%)	Urban, High (%)	Barren Land (%)	Deciduous Forest (%)	Conifer Forest (%)	Mixed Forest (%)	Shrubland (%)	Grassland (%)	Hay/Pasture (%)	Cropland (%)	Woody Wetland (%)	Herbaceous Wetland (%)
Tenmile Creek	OK410300-03-0270C	38.61	0.09	-0.02	0.01	0.02	0.00	0.00	2.27	0.21	0.56	1.04	-3.18	-1.00	0.00	-0.03	0.04
Terrapin Creek	OK410210-02-0150H	16.96	-0.02	-0.03	0.01	0.02	0.00	0.00	-2.67	-8.44	-2.55	11.07	2.62	0.00	0.00	0.02	-0.03
Waterhole Creek	OK410100-01-0340D	20.01	0.06	-0.13	0.05	0.13	0.00	0.02	0.02	0.40	-0.01	1.03	-1.80	0.13	0.09	0.09	-0.10
West Fork of Glover River	OK410210-09-0070C	32.44	-0.21	-0.05	0.02	0.04	0.01	0.00	-0.69	-5.65	-0.31	6.60	0.00	0.16	0.00	0.06	0.05
Whitegrass Creek	OK410400-01-0210G	27.17	0.07	-0.05	0.02	0.06	0.00	-0.02	2.53	0.05	0.00	2.00	-4.93	0.36	0.02	0.05	-0.14

Table 15. Permitted land use for each Group 5 (Lower Red River Basin) monitoring site watershed as of 2022 and change in permitted land use since the completion of Cycle 3 in 2017. Each site is given a unique identifier (WBID)

Site Name	WBID	# CAFO	CAFO Change	# Landfill	Landfill Change	# Permitted Discharge	Discharge Change	# O & G Wells	OG Change	# Total Retention Lagoon	Lagoon Change	# Land Application	Land Application Change	# Public Water Intakes	Intakes Change
Beech Creek	OK410210-06-0320G														
Big Eagle Creek	OK410210-06-0160I							1	1						
Big Sandy Creek	OK410400-06-0260G	5	n/a					185	n/a					6	n/a
Billy Creek	OK410310-02-0070C							1							
Black Fork of Little River	OK410210-03-0020C							3	3					2	2
Blue River: Egypt Rd.	OK410600-02-0010F					34	n/a	43	n/a	5	n/a	1	n/a	33	n/a
Bokchito Creek	OK410600-01-0090G							2	2					4	4
Buck Creek	OK410300-03-0420C							153	92						
Buffalo Creek	OK410310-03-0030N							39	22						
Buffalo Creek: Lower	OK410210-06-0020G														
Caddo Creek: Hwy 70	OK410600-01-0140J							3	n/a	1	n/a			6	n/a
Caney Boggy Creek: Lower	OK410400-06-0120G	3						485	104						
Caney Creek	OK410400-02-0200G							8	8	2					
Caney Creek: HWY 69	OK410400-03-0020C					8	8	8	4					2	2
Cedar Creek: East of Finley	OK410300-03-0020M														
Chickasaw Creek	OK410400-05-0420G							20	n/a						
Clear Boggy Creek	OK410400-03-0230K		-1	2		25	22	4451	3011			3		8	8
Clear Creek	OK410100-01-0480N							3	n/a						
Cloudy Creek	OK410210-02-0300C														
Cow Creek	OK410210-06-0350G														

Site Name	WBID	# CAFO	CAFO Change	# Landfill	Landfill Change	# Permitted Discharge	Discharge Change	# O & G Wells	OG Change	# Total Retention Lagoon	Lagoon Change	# Land Application	Land Application Change	# Public Water Intakes	Intakes Change
Delaware Creek	OK410400-03-0240M	1				5	4	32	32					7	7
East Fork of Glover River	OK410210-09-0010G		-1												
Hanubby Creek	OK410400-01-0080G							4	n/a					1	n/a
Honobia Creek	OK410210-03-0150H							3	3						
Island Bayou	OK410700-00-0040J					16	14	21	19					12	12
Keel Creek: Hwy 31	OK410400-06-0100D							75	n/a						
Lick Creek: N4080	OK410400-01-0130E							5	n/a					4	n/a
Lukfata Creek	OK410210-07-0010G														
Luksuklo Creek	OK410210-04-0020G														
McGee Creek	OK410400-07-0010L							124	70						
Mineral Bayou	OK410600-01-0300G			2		21	20	42	28	1				1	
Muddy Boggy: E1770	OK410400-05-0270M	11	n/a			25	n/a	3806	n/a	1	n/a			29	n/a
North Boggy Creek	OK410400-08-0010E					1	1	258	112						
Norwood Creek	OK410100-01-0050H					7	7	7	7						
One Creek	OK410300-03-0060F							2	2						
Panther Creek	OK410400-06-0240G	2	n/a					69	n/a					12	n/a
Rock Creek	OK410200-03-0010G														
Salt Creek	OK410400-06-0090G							232	n/a						
Sand Creek	OK410700-00-0260G							9	8						
Sandy Creek	OK410600-02-0020G	1						3	3	1				3	3
Sincere Creek	OK410400-06-0290G							147	n/a						
Spencer Creek: N4310	OK410300-02-0140F							1	n/a						
Sulphur Creek	OK410600-01-0030G							4	4	1				6	6

Site Name	WBID	# CAFO	CAFO Change	# Landfill	Landfill Change	# Permitted Discharge	Discharge Change	# O & G Wells	OG Change	# Total Retention Lagoon	Lagoon Change	# Land Application	Land Application Change	# Public Water Intakes	Intakes Change
Tenmile Creek: HWY 2	OK410300-03-0270C							40	28						
Terrapin Creek: Lower	OK410210-02-0150H														
Waterhole Creek	OK410100-01-0340D							23	23						
West Fork of Glover River	OK410210-09-0070C		1					2	2						
Whitegrass Creek: Lower	OK410400-01-0210G							12	12						

Table 16. Comparisons of site chemistry at rotating Basin 5 (Lower Red River Basin) monitoring sites with and without National Pollution Discharge Elimination System (NPDES) permits based on one-way ANOVAs. Comparisons where p-values were less than 0.05 were considered significantly different.

Parameter	NPDES Permit	Sample Size (N)	Mean	Standard Deviation	p Value	Result
Alkalinity	NO	751	63.39	63.48	<0.001	Lower
	YES	174	149.34	77.01		
Conductivity	NO	742	174.28	169.26	<0.001	Lower
	YES	171	402.1	220.3		
DO	NO	663	7.959	2.794	0.084	No significant difference
	YES	124	7.486	2.784		
DO % Sat	NO	663	80.03	20.92	0.018	Higher
	YES	124	75.19	20.32		
Hardness	NO	754	87.52	80.02	<0.001	Lower
	YES	173	194.45	85.88		
pH	NO	723	7.1465	0.5122	<0.001	Lower
	YES	167	7.6912	0.495		
Water Temp	NO	747	16.949	7.99	0.644	No significant difference
	YES	171	17.262	7.927		
Turbidity	NO	782	26.57	63.23	0.004	Lower
	YES	160	43.64	86.87		
Ammonia	NO	188	0.033	0.079	0.062	No significant difference
	YES	47	0.148	0.823		
Chloride	NO	740	11.42	13.48	<0.001	Lower
	YES	174	33.58	38.42		
TDS	NO	741	132.62	102.02	<0.001	Lower
	YES	174	261.28	118.21		
TKN	NO	742	0.4496	0.3313	<0.001	Lower
	YES	174	0.6728	0.6639		
Nitrate	NO	741	0.1265	0.2465	<0.001	Lower
	YES	174	0.2346	0.6409		
Ortho P	NO	742	0.0238	0.0326	<0.001	Lower
	YES	174	0.0975	0.2163		
TP	NO	742	0.0533	0.0571	<0.001	Lower
	YES	174	0.1404	0.2355		
Sulfate	NO	741	39.39	219.96	0.415	No significant difference
	YES	174	25.79	19.93		
TSS	NO	741	17	48.4	0.019	Lower
	YES	174	28.57	88.66		
Available N	NO	742	0.0135	0.2525	<0.001	Lower

Parameter	NPDES Permit	Sample Size (N)	Mean	Standard Deviation	p Value	Result
	YES	174	0.2746	0.8078		
TN	NO	742	0.5759	0.4276	<0.001	Lower
	YES	174	0.9074	1.0624		

Table 17. Draft Designated Use Attainment Status for bacteria and biological conditions for rotating basin monitoring sites in Basin 5 (Lower Red River Basin). Each site was assigned a unique waterbody identifier (WBID).

Site Name	WBID	E. coli Assessment	Fish Assessment	Bug Assessment
Beech Creek	OK410210-06-0320G	Attaining	Attaining	Insufficient Data
Big Eagle Creek	OK410210-06-0160I	Attaining	Attaining	Insufficient Data
Big Sandy Creek	OK410400-06-0260G	Not Attaining	Undetermined	Insufficient Data
Billy Creek	OK410310-02-0070C	Not Attaining	Attaining	Undetermined
Black Fork of Little River	OK410210-03-0020C	Attaining	Attaining	Undetermined
Blue River	OK410600-02-0010F	Attaining	Attaining	Insufficient Data
Bokchito Creek	OK410600-01-0090G	Attaining	Attaining	Undetermined
Buck Creek	OK410300-03-0420C	Attaining	Attaining	Insufficient Data
Buffalo Creek	OK410310-03-0030N	Not Attaining	Attaining	Insufficient Data
Buffalo Creek: Lower	OK410210-06-0020G	Attaining	Attaining	Insufficient Data
Caddo Creek	OK410600-01-0140J	Attaining	Attaining	No Data
Caney Boggy Creek	OK410400-06-0120G	Attaining	Attaining	Insufficient Data
Caney Creek	OK410400-02-0200G	Not Attaining	Attaining	Insufficient Data
Caney Creek: HWY 69	OK410400-03-0020C	Attaining	Attaining	Insufficient Data
Cedar Creek	OK410300-03-0020M	Attaining	Attaining	Insufficient Data
Chickasaw Creek	OK410400-05-0420G	Attaining	Attaining	Insufficient Data
Clear Boggy Creek	OK410400-03-0230K	Attaining	Attaining	Insufficient Data
Clear Creek	OK410100-01-0480N	Not Attaining	Attaining	Attaining
Cloudy Creek	OK410210-02-0300C	Attaining	Attaining	Attaining
Cow Creek	OK410210-06-0350G	Attaining	Attaining	Insufficient Data
Delaware Creek	OK410400-03-0240M	Attaining	Attaining	Not Attaining
East Fork of Glover River	OK410210-09-0010G	Not Attaining	Attaining	Insufficient Data
Hanubby Creek	OK410400-01-0080G	Attaining	Attaining	Insufficient Data

Site Name	WBID	E. coli Assessment	Fish Assessment	Bug Assessment
Honobia Creek	OK410210-03-0150H	Attaining	Attaining	Attaining
Island Bayou	OK410700-00-0040J	Attaining	No Criteria	No Criteria
Keel Creek	OK410400-06-0100D	Not Attaining	Attaining	Not Attaining
Lick Creek	OK410400-01-0130E	Not Attaining	Attaining	Insufficient Data
Lukfata Creek	OK410210-07-0010G	Not Attaining	Attaining	Attaining
Luksuklo Creek	OK410210-04-0020G	Not Attaining	Attaining	Insufficient Data
McGee Creek	OK410400-07-0010L	Attaining	Attaining	Insufficient Data
Mineral Bayou	OK410600-01-0300G	Attaining	Attaining	Undetermined
Muddy Boggy	OK410400-05-0270M	Attaining	Undetermined	Insufficient Data
North Boggy Creek	OK410400-08-0010E	Attaining	Attaining	Insufficient Data
Norwood Creek	OK410100-01-0050H	Attaining	Attaining	Insufficient Data
One Creek	OK410300-03-0060F	Not Attaining	Attaining	Insufficient Data
Panther Creek	OK410400-06-0240G	Not Attaining	Undetermined	Insufficient Data
Rock Creek	OK410200-03-0010G	Attaining	Attaining	Insufficient Data
Salt Creek	OK410400-06-0090G	Not Attaining	Attaining	Insufficient Data
Sand Creek	OK410700-00-0260G	Attaining	No Criteria	No Criteria
Sandy Creek	OK410600-02-0020G	Attaining	Attaining	Insufficient Data
Sincere Creek	OK410400-06-0290G	Attaining	Undetermined	Insufficient Data
Spencer Creek	OK410300-02-0140F	Attaining	Attaining	Insufficient Data
Sulphur Creek	OK410600-01-0030G	Not Attaining	Attaining	Insufficient Data
Tenmile Creek	OK410300-03-0270C	Not Attaining	Attaining	Not Attaining
Terrapin Creek	OK410210-02-0150H	Attaining	Attaining	Insufficient Data
Waterhole Creek	OK410100-01-0340D	Not Attaining	Attaining	Insufficient Data
West Fork of Glover River	OK410210-09-0070C	Attaining	Attaining	Insufficient Data
Whitegrass Creek	OK410400-01-0210G	Not Attaining	Attaining	Insufficient Data

4.0 SUMMARY

Overall, streams in the Lower Red River Basin are in good condition with over half of the streams receiving a letter grade of A or B. Additionally, water chemistry and fish communities within the region are generally stable. No stream exhibited a declining fish community and no individual water chemistry parameter exhibited consistent declines across the basin. However, while trends at the highest quality streams tended to be stable or improving, Sulphur, Sand, Mineral Bayou and Delaware Creeks declined for salt metrics. Given the excellent biological communities at these streams and the potential for salts to degrade biota, these streams appear to be at risk of further degradation. Other watersheds with generally poor and declining water chemistry, co-occurring with excellent biotic communities include Tenmile Creek, Buck Creek, Caney Boggy Creek, and Caney Creek: HWY 69. Additional monitoring and analyses within these watersheds may be necessary to determine the sources of water chemistry degradation, and help prevent further declines in stream condition.

Twelve streams in the Basin received an overall score of a 'C', another nine streams received an overall score of ‘D’, and no stream received an overall score of ‘F’. The low scores were primarily driven by poor water chemistry and habitat scores. All ‘D’ streams exhibited degraded salt metrics, nitrogen metrics, and phosphorous metrics. Furthermore, only one of these streams had an average macroinvertebrate IBI score above 0.8. However, the excellent fish scores at some ‘D’ sites may be due to the higher mobility of fish than macroinvertebrates (e.g., McGee Creek, Norwood Creek, and Waterhole Creek). We found several landscape-scale changes that may be contributing to stream quality degradation. Conversion of undeveloped land-cover to surface water, potentially associated with suburban development, was correlated with an increase in nutrient concentrations, as well as degradation of instream DO conditions. Furthermore, increases in oil and gas activities within a watershed was correlated with poorer salt scores. However, all correlations were weak to moderate. Contrarily, most streams with an overall ‘A’ score had little to no permitted activity within its watershed, with the exception of the Blue River (34 permitted discharges and 43 oil and gas wells). Given the importance of nutrient and salts in predicting biotic communities in the region, it will be critical to refine analyses to aid in the identification of landscape sources of chemical degradation. Additional landscape analyses may help predict why some regional streams are in poor condition and help better tailor conservation practices to address impairments.

Low dissolved oxygen continues to be prevalent throughout this basin, however at all sites with sufficient data to calculate trends, DO% Saturation is stable. This is most likely due to the fact that these systems, particularly those in McCurtain, LeFlore, and Pushmataha Counties, naturally tend toward sluggish, organically enriched conditions which promote high biological demand. Fish communities have developed under these naturally occurring conditions and are well adapted to the significantly lower DO trends. However, according to the relative risk assessment low DO is the most likely cause of impaired macroinvertebrate communities. We are currently reassessing our reference criteria to better understand where DO is low as a result of natural conditions verses anthropogenic stressors.

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