OKLAHOMA CONSERVATION
COMMISSION

# FY 1991 104 (b)(3)
# LITTLE RIVER BASIN STUDY

1995

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# INTRODUCTION

The purpose of the FY 1991 104 (b)(3) Little River Basin Study was to assess NPS contributions from individual watersheds, evaluate the overall water quality in the Little River Basin, and provide data to assist in the identification reference conditions. This information was combined with a land use inventory to identify potential contributing sources of pollution and help prioritize watersheds in the basin. Together this information was used to select high priority areas where implementation programs would prove useful in improving water quality. This project has been funded for an additional 3 years and will include fish, macro-invertebrate, base flow water quality sampling, flow measurement, and habitat assessments. Therefore, this report is only an interim report and presents only preliminary results.

Historically, streams in the Little River Basin have been of very high quality, primarily due to the low intensity of land uses, and have been a significant factor in attracting tourism. As land uses in the area and tourism have increased, the identification of water quality problems has increased.

In Oklahoma's Section 319 Assessment Report, water quality degradation was identified in the Little River, its tributaries, and in impounded areas of the river. Unusually low pH values have been reported on several occasions which were low enough to impact fisheries. With a relative lack of point source discharges, nonpoint sources (NPS) appear to be a major contributing factor to this problem.

Excessive algal growths have also been reported in Pine Creek Reservoir, Oklahoma and Millwood Reservoir, Arkansas which have impaired their aesthetic, recreational, and fishery uses. The cause of the excessive algal growth has not been identified but is likely influenced by NPS nutrient contributions.

High levels of turbidity have been observed in the Little River, Millwood Reservoir, and Pine Creek Reservoir. The cause of this turbidity is probably both organic and inorganic in nature. Since not all of the turbidity in these waters can be attributed to algal growth, NPS runoff from rural and forestry roads, and silviculture appear to be contributing factors.

# MATERIALS AND METHODS

Field data collection was performed according to procedures outlined in the OCC standard operating procedures (SOP) document. Grab samples were collected at 74 watershed sites on a quarterly basis with the addition of two high flow samples collected from each site. During drier periods of the year some streams had no flow and sampling was not possible at these sites. A map identifying the location of the Little River Basin is attached (Appendix A). Base flow and high flow samples were analyzed for total phosphorous, Kjeldahl nitrogen, nitrate, nitrite, fluoride, sulfate, hardness, chloride, and suspended solids in the laboratory. Conductivity was measured *in situ* by OCC staff in both base flow and high flow samples. Alkalinity, turbidity, temperature, dissolved oxygen, and pH were measured *in situ* by OCC staff (Table 1) on base flow samples only. Kjeldahl nitrogen, nitrate, and nitrite values were combined to determine total nitrogen.

**Table 1. Watershed Sampling Schedule.**

| Parameter | Frequency | Container | Preservative |
|---|---|---|---|
| Total Phosphorous | quarterly* | plastic | $H_2SO_4$ |
| Kjeldahl Nitrogen | " | " | " |
| Nitrate | " | " | " |
| Nitrite | " | " | " |
| Suspended Solids | " | " | ice |
| Sulfate | " | " | " |
| Chloride | " | " | " |
| Flouride | " | " | " |
| Hardness | " | " | " |
| Alkalinity** | " | " | " |
| Turbidity** | " | " | " |
| Temperature** | " | *in situ* | none |
| Conductivity | " | " | " |
| Dissolved Oxygen** | " | " | " |
| pH** | " | " | " |

* Quarterly sampling augmented with 2 high flow sample collections.
** Not collected during high flow events.

# RESULTS

## LAND USE

These watersheds represent a wide variety of land uses including agriculture, silviculture, confined animal operations, and urban areas. In the Little River Basin, silviculture is the primary industry. Over 80% of the study area is composed of forest land. The land use in each sub-watershed can be found in Appendix B.

## QUALITY ASSURANCE (QA)

Nine sets of samples were analyzed to determine the quality of the data. QA was performed on chloride, hardness, nitrate, sulfate, kjeldahl nitrogen, phosphate, and total phosphorous. All QA data collected during the study is listed in Appendix C.

Duplicate samples were analyzed to determine precision of the data. The mean percent differences between the duplicates were 1% for chloride (sd=2%), 18% for hardness (sd=41%), 25% for nitrate (sd=45%), 5% for sulfate (sd=9%), 12% for kjeldahl nitrogen (sd=35%), 0% for ortho-phosphate (sd=0%), and 29% for total phosphorous (sd=32%). Standard Methods (Clesceri 1989) suggest that percent difference not exceed 25%. Only total phosphorous exceeds this suggested value. Only 15% of the percent differences exceeded the suggested value. These generally occurred in samples with low concentrations (at or below the method detection limit). Overall, the precision of the data was sufficient to meet the data quality objectives.

Spiked samples were analyzed to determine the percent recoveries and accuracy of the data. Percent recoveries were determined by dividing the observed by the expected concentrations of spiked samples. The mean percent recoveries were 182% for chloride (sd=62%), 109% for hardness (sd=29%), 83% for nitrate (sd=62%), 96% for sulfate (sd=28%), 85% for kjeldahl nitrogen (sd=34%), 72% for ortho-phosphate (sd=0%), and 84% for total phosphorous (sd=34%). Standard Methods (Clesceri 1989) suggests a percent recovery between 80-120%. Chloride and ortho-phosphate do not comply with this suggested criteria. The cause for the high percent recoveries of chloride was investigated. It was found that the hardness spike and the sulfate spike contained chloride. The hardness spike, which should have been 100% calcium carbonate, was made up of 50% calcium carbonate and 50% calcium chloride. The hardness spike provided approximately 8650 mg/l chloride. The sulfate spike contained 900 mg/l chloride from an unknown source. The combination of these two sources of Cl resulted in the high observed percent recovery. Overall, the accuracy of the data was sufficient to meet the data quality objectives.

A total of 486 samples were collected during the study. Due to budget constraints, the workplan was altered after several sampling runs eliminating 31 sample sites, leaving 43 sites. Therefore, the total number of samples collected was less than the amount originally planned for. No samples were rejected. In some cases, certain parameters of a QA sample exceeded the recommended percent differences or recoveries; however, as a whole the QA sample was valid. Thus, all samples were considered valid.

## STREAM ASSESSMENT

The Little River Basin study examined streams in the Ouachita Mountains and Central Oklahoma-Texas Plains Ecoregions. The predominant soils are the Ultisols and Inceptisols which are nutrient poor, highly susceptible to acidification, and have low base saturation (Kress et al. 1990). Waters are generally nutrient poor, have low alkalinities, and have low buffering capacities. This area of Oklahoma is susceptible to impacts by acid atmospheric deposition (Kress et al. 1988).

Most streams in the Ouachita Mountain Ecoregion would be classified as cool water aquatic communities by the Oklahoma water quality standards. These streams have stoneflies and darters, and the larger streams have smallmouth bass. However, all the streams are not listed in the Water Quality Standards. Unlisted streams are considered Warm Water Aquatic Communities by the Standards until a "Use Attainability Analysis" can be made by the Oklahoma Water Resources Board. Therefore in this document, the unlisted streams are considered in both contexts (as Warm and Cool Water Aquatic Communities). The standards include significantly more stringent dissolved oxygen and turbidity standards for Cool Water Aquatic Communities. Base flow data can be found in Appendix D and storm flow data can be found in Appendix E.

Five streams in the study area receive permitted discharges (Table 2). In addition to those listed, Broken Bow Waste Disposal Landfill lies in the headwaters of Coon Creek. The Werhauser sawmill in Wright City has a NPDES permit which expired in 1979. In addition, Beaver's Bend State Park is a potential discharger to the Mountain Fork River. Due to the lack of point sources, NPS pollution appears to be the cause of most water quality degradation in the basin.

| PERMITTED DISCHARGERS | RECEIVING STREAM |
|---|---|
| Broken Bow Public Works | Yanubbee |
| Holly Creek Fryers-Broken Bow | Little River |
| City of Idabell | Mud Creek |
| Wright City | Horse Head Creek |
| Mountain Fork Water Supply | Mountain Fork River |

## Turbidity

Turbidity was measured in base flow samples only, because the water quality criteria for turbidity applies to only base flow samples. Turbidity ranged from 0.5-100 NTU and averaged 15.5 NTU (s=13.1, n=326). The Oklahoma Water Quality Standards state that the turbidity of Cool Water Aquatic Communities should not exceed 10 NTU and other surface waters should not exceed 50 NTU. Only 34% of the samples contained turbidities of less than 10 NTU. Ninety-seven percent of the samples contained turbidities of less than 50 NTU. The majority of the samples (89%) contained turbidities of less than 25 NTU.

The mean base flow turbidities of only four streams (Hurricane Creek, Rock Creek, Turkey Creek, and West Fork Glover River) exceeded 25 NTU (Oklahoma's Water Quality Standard for lake turbidity). Forest land is the predominant land use in the watersheds of these streams. Land use in the Hurricane Creek watershed (6,385 acres) is predominately composed of forest (5891 acres) and pasture (484 acres) with only small acreage (10 acres) of urban ranchettes. Land use in the Rock Creek (at Smithville) watershed (13,640 acres) is predominately made up of forest (12,711 acres) and pasture (909 acres) with small acreage (10 acres) of confined feeding operations. Land use in the Turkey Creek watershed (10,566 acres) is predominately composed of forest (6759 acres), pasture (2619 acres), and 1188 acres in Arkansas (land use unknown). Land use in the West Fork Glover River (at Battiest) watershed (22,150 acres) is predominately composed of forest (20,795 acres) and pasture (1,355 acres).

## Dissolved Oxygen

Dissolved oxygen was measured in base flow samples only. Dissolved oxygen concentrations ranged from 1.2-15.0 mg/l in base flow samples. The Oklahoma Water Quality Standards state that dissolved oxygen concentrations should not fall below 6.0 mg/l for Cool Water Aquatic Communities or 5.0 mg/l for Warm Water Aquatic Communities at any time. However, because of natural diurnal dissolved oxygen fluctuations, a 1.0 mg/l dissolved oxygen deficit is allowed for not more than eight hours during any twenty-four hour period (OWRB 1992). Only 6% of the base flow samples contained dissolved oxygen concentrations of less than 5.0 mg/l and only 12% contained concentrations of less than 6.0 mg/l. Only 17 streams contained dissolved oxygen concentrations of less than 5.0 mg/l. However, dissolved oxygen criteria varies depending on time of year. Individual dissolved oxygen violations are discussed in a following section (Dissolved Oxygen Violations).

## pH

The pH was measured in base flow samples only. The pH ranged from 4.7-10.7 in base flow samples. Oklahoma's Water Quality Standards state that pH should fall between 6.5 and 9.0. Sixty-eight percent of the samples were compliant with this criteria. However, 32% of the samples contained pH values of less than 6.5 and were in violation of the Oklahoma Water

Quality Standards.

The pH of the following 12 streams averaged less than 6.5:

| | |
|---|---|
| Little River near Ludlow | Mountain Fork River (lower) at narrows |
| Buffalo Creek (upper) | West Fork Glover River at Battiest |
| Honobia Creek at Honobia | East Boktuklo Creek near Smithville |
| Cucumber Creek near Octavia | Terrapin Creek (middle) near Ringold |
| Boktuklo Creek near Smithville | Watson Creek near Nashoba |
| Glover River near Bethel | Leslie's Creek near Octavia |

These streams are located in the Ouachita Mountain Ecoregion. The watersheds of these streams are composed almost entirely (96.4%) of forest land. The pH of Terrapin Creek (middle) near Ringold was less than 6.5 in all samples during the study. Fifty-one of the streams contained pH values of less than 6.5 at least once during the study. The lowest pH value measured during the study was 4.7 (Pine Creek at Rufe). The pH in Black Fork Creek near Nashoba exceeded 9.0 once.

**Alkalinity**

Alkalinity, which was measured in base flow samples only, was extremely low. These waters have low buffering capacities and are more susceptible to acid rain. Alkalinities ranged from 2-77 mg/l $CaCO_3$ in base flow samples. Alkalinities are low in the Little River Basin. Alkalinity was less than 75 mg/l $CaCO_3$ in 99.8% of the samples. A majority of the samples (91%) contained alkalinities of less than 25 mg/l $CaCO_3$. The average alkalinities of only the following nine streams were greater than 25 mg/l $CaCO_3$:

| | |
|---|---|
| Buck Creek near Shinewell | Yashoo Creek near Broken Bow |
| Holly Creek near Idabell | Yanubbee Creek below Coon Creek |
| Cedar Creek near Glover | Mud Creek near Haworth |
| Horse Head Creek at Wright City | Lukfata Creek near Idabell |
| Colbert Creek near Glover | |

Excluding Cedar Creek, these streams are located in Central Oklahoma-Texas Plains Ecoregion. The streams in the Ouachita Mountains Ecoregion generally contained average alkalinities of less than 25 mg/l. Cedar Creek arises and flows through an area of metamorphic and igneous rock atypical to the Ouachita Mountain Ecoregion.

**Hardness**

Hardness measurements indicate that the water is classified as soft (hardness < 60 mg/l). At only Lukfata Creek was the water considered moderately hard (hardness 61-120 mg/l).

**Sulfate, Chloride, and Fluoride**

Sulfate was not present in significant quantities. However, the sulfate concentration in Mud

Creek (20 mg/l) was significantly higher than levels found in other nearby streams. Excluding Mud Creek concentrations, sulfate concentrations ranged from 1.6-7.7 mg/l and averaged 3.3 mg/l. Fluoride concentrations were at or below the detection limit. Chloride was also not present in significant quantities. However, the Mud Creek chloride concentration (11 mg/l) was higher than those found in other streams in the area. In addition, the Yanubbee Creek chloride concentration (6.8 mg/l) was slightly higher than those found in other area streams. Excluding Mud and Yanubbee Creek which receive effluent from a publicly owned treatment works (POTW), chloride concentrations ranged from 1-4.2 mg/l and averaged 2.1 mg/l.

**Conductivity**

Conductivity was measured in both base and storm flow samples. Conductivities in this region are low. Of all the samples collected, 95% contained conductivities of less than 150 uS/cm while 77% contained conductivities of less than 50 uS/cm.

Conductivity ranged from 15-389 uS/cm in base flow samples. Ninety-four percent of the base flow samples contained conductivities of less than 150 uS/cm. A majority of the base flow samples (76%) contained conductivities of less than 50 uS/cm. Excluding Cedar Creek, the average conductivities of streams in the Ouachita Mountains Ecoregion were less than 65 uS/cm. As mentioned before, Cedar Creek arises from an area of metamorphic and igneous rock atypical to the Ouachita Mountain Ecoregion. Excluding Mud Creek, which receives POTW effluent from the City of Idabell, average conductivities of streams in the Central Oklahoma-Texas Plains Ecoregion were less than 160 uS/cm. The average conductivity in Mud Creek was significantly higher (245 uS/cm).

Conductivity ranged from 16-267 uS/cm in storm flow samples. Ninety-eight percent of the storm flow samples contained conductivities of less than 150 uS/cm. A majority of the storm flow samples (81%) contained conductivities of less than 50 uS/cm. Mean storm flow conductivities in streams in the Ouachita Mountains Ecoregion were less than 60 uS/cm. Three streams (Mud, Lukfata, and Buck Creeks) contained storm flow conductivities greater than 100 uS/cm.

**Total Suspended Solids (TSS)**

Total suspended solids (TSS) were measured in both base and high flow samples. Numerical criteria for TSS do not exist. Twenty percent of all the samples collected contained TSS concentrations of less than 1 mg/l. Sixty-nine percent of all the samples contained TSS concentrations of less than 10 mg/l. Ninety-eight percent of all the samples contained TSS concentrations of less than 100 mg/l. Naturally, TSS were substantially greater during storm flow than during base flow.

Total suspended solids (TSS) ranged from 0.5-68.0 mg/l in base flow samples. Twenty-three percent of the base flow samples contained TSS concentrations less than 1 mg/l and were representative of good conditions. Thirty-six percent of the base flow samples contained TSS concentrations between 1-5 mg/l and were representative of intermediate conditions. Twenty-two percent of the base flow samples contained TSS concentrations between 5-10 mg/l and were representative of bad conditions. Nineteen percent of the base flow samples contained TSS concentrations greater than 10 mg/l and likely represented areas where anthropogenic disturbance has occurred. TSS concentrations in base flow samples were not dependent on ecoregion. Five streams (Holly Creek near Idabell, Beech Creek, Hurricane Creek, Pine Creek at Rufe, and Big Eagle Creek near Smithville) contained mean base flow TSS concentrations of greater than 10 mg/l and were likely impacted by anthropogenic activity.

Total suspended solids (TSS) ranged from 0.5-1070 mg/l in storm flow samples. Only 2% of the storm flow samples contained TSS concentrations of less than 1 mg/l. Thirty-nine percent of the storm flow samples contained TSS concentrations of less than 10 mg/l. Eighty-one percent of the samples contained TSS concentrations of less than 50 mg/l. Mean TSS concentrations during storm events were greater than 100 mg/l in the following 6 streams:

| | |
|---|---|
| Cane Creek near Cheatham, Ark. | Silver Creek near Battiest |
| Coon Creek near Bethel | Caney Creek above S.H. 41 near Cross Roads |
| Luksuklo Creek near Eagletown | West Fork Glover River at Battiest |

**Total Nitrogen (TN)**

Total nitrogen (TN) was calculated from the addition of kjeldahl nitrogen (TKN), nitrite, and nitrate for both base and storm flow samples. Total nitrogen concentrations in the Little River basin were low. Of all the samples collected, 93% contained nitrogen concentrations of less than 1 mg/l. Most of the samples (74%) contained TN concentrations of less than 0.5 mg/l.

Total nitrogen concentrations ranged from 0.1-7.7 mg/l in base flow samples. Ninety-six percent of the base flow samples contained total nitrogen concentrations of less than 1 mg/l. A majority of the samples (84%) contained TN concentrations of less than 0.5 mg/l. Streams in the Ouachita Mountain Ecoregion contained average TN concentrations of less than 0.5 mg/l. Only four streams (Mud Creek, Buck Creek, Yanubbee Creek, and Holly Creek near Idabell) contained average TN concentrations of greater than 1 mg/l. Mud Creek and Yanubbee Creek receive POTW effluent from the Cities of Idabell and Broken Bow, respectively. Both Buck Creek and Holly Creek contain a larger percent pasture than most of the streams in the study area. The Buck Creek watershed is composed primarily of forest (6,049 acres) and pasture land (2,343 acres); however, it also contains 40 acres of confined feeding operations. The Holly Creek watershed is also composed primarily of forest (2,709 acres) and pasture land (4,933 acres). However, the Holly Creek watershed also contains 49 acres of confined feeding operations and 208 acres of urban land. In addition, Holly Creek flows through a large marsh above the sampling site. Therefore, this stream has many characteristics of a wetland including lower dissolved oxygen and higher nutrients.

Total nitrogen concentrations ranged from 0.1-4.0 mg/l in storm flow samples. Ninety-nine percent of the storm flow samples contained total nitrogen concentrations of less than 2 mg/l. A majority of the storm flow samples (86%) contained TN concentrations of less than 1 mg/l. Total nitrogen concentrations were higher in storm flow samples than base flow samples; however, the storm flow TN concentrations were not extremely high. Only the following eight streams contained mean TN concentrations of greater than 1 mg/l during storm events:

| | |
|---|---|
| Mud Creek near Haworth | Buck Creek near Shinewell |
| Brushy Creek at Cloudy | Turkey Creek near Ringold |
| Lukfata Creek near Idabell | Holly Creek near Idabell |
| Boktuklo Creek at Golden | Rock Creek at Smithville |

Mud Creek contained the highest mean storm flow TN concentration of 2.7 mg/l. This is significantly higher than concentrations found in the other streams sampled. Mud Creek receives effluent from the City of Idabell POTW. NPS pollution appears to be the likely cause of the higher TN concentrations in the remaining streams, due to the lack of point sources in their watersheds. Confined feeding operations are located in the watersheds of Mud Creek, Buck Creek, Lukfata Creek, Holly Creek, Boktuklo Creek, and Rock Creek.

**Total Phosphorous (TP)**

Total phosphorous (TP) concentrations were measured in both storm and base flow samples. The Environmental Protection Agency suggests that TP concentrations not exceed 0.05 mg/l in any stream at the point where it enters a reservoir, and should not exceed 0.10 mg/l in streams not discharging directly into a lake (EPA 1986). Of all the samples, 92% contained TP concentrations of less than 0.10 mg/l. Most of the samples (78%) contained TP concentrations of less than 0.05 mg/l. Only 8% of all the samples (base and storm flow) contained TP concentrations which exceeded the suggested EPA criteria (0.10 mg/l).

Total phosphorous concentrations ranged from below detection (<0.01 mg/l) to 1.4 mg/l in base flow samples. Ninety-six percent of base flow samples contained TP concentrations of less than 0.10 mg/l. Most of the samples (87%) contained TP concentrations of less than 0.05 mg/l. Only 4% of the base flow samples exceeded the criteria suggested by EPA (0.10 mg/l).

The mean TP concentrations of only four streams (Mud Creek, Yanubbee Creek, Holly Creek near Idabell, and Buck Creek) exceeded 0.10 mg/l during base flow conditions. Mud Creek and Yanubbee Creek receive waste water discharges. There are no known waste water discharges into Holly Creek or Buck Creek; therefore, the source of the elevated TP concentrations must originate from NPS pollution. The Holly Creek watershed is composed primarily of forest (2,709 acres) and pasture land (4,933 acres); however, it also contains 49 acres of confined feeding operations and 208 acres of urban land. In addition, the Holly Creek sampling site is located below a large marsh and the water quality retains many characteristics of wetland water quality including higher nutrient and lower dissolved oxygen concentrations. Forty acres of confined feeding operations are present in the Buck Creek watershed. Mud Creek near Haworth contained the highest TP concentrations. The lowest TP concentration measured in Mud Creek was 0.18 mg/l. Mean TP concentrations during base flow conditions were less than 0.05 mg/l in the remaining 70 streams. Mean TP concentrations in streams in the Ouachita Mountains Ecoregion were 0.04 mg/l or less.

Total phosphorous concentrations ranged from below detection (<0.01) to 1.6 mg/l in storm flow samples. Eighty-three percent of the storm flow samples contained TP concentrations of less than 0.10 mg/l. A majority of the high flow samples (59%) contained TP concentrations of less than 0.05 mg/l. Only 17% of the storm flow samples exceeded the criteria suggested by EPA (0.10 mg/l). Mean TP concentrations during storm flow exceeded 0.10 mg/l in only the following nine streams:

- Mud Creek near Haworth
- Lukfata Creek near Idabell
- Cypress Creek at Wright City
- Big Eagle Creek near Smithville
- Horse Head Creek at Wright City
- Boktuklo Creek at Golden
- Holly Creek near Idabell
- Yanubbee Creek below Coon Creek
- Turkey Creek near Ringold

Mud, Yanubbee, and Horse Head Creeks receive effluent from the Cities of Idabell, Broken Bow, and Wright City, respectively. NPS pollution appears to be the likely cause of the higher TP concentrations in the remaining streams, due to the lack of point sources in their watersheds. Confined feeding operations are located in the watersheds of Mud Creek, Boktuklo Creek, Lukfata Creek, Holly Creek, Yanubbee Creek, and Big Eagle Creek.

## Violation of Water Quality Standards

Water quality violations in the Little River Basin are summarized in Tables 3-5 and discussed below.

### Turbidity Violations

The number of turbidity violations exceeded the numbers of all other violations. However, only three samples contained turbidities which exceeded Warm Water Aquatic Community criteria. These samples were collected from Turkey, Coon, and Hurricane Creeks. The type of aquatic communities in these streams has not been designated; therefore, only Warm Water Aquatic Community criteria applies. However, Coon and Hurricane Creeks should likely be classified as Cool Water Aquatic Communities.

Table 3

Table 4

Table 5

On average, unlisted streams and streams listed as Cool Water Aquatic Communities violated the Cool Water Aquatic Community turbidity criteria (>10 NTU) three times during the study. Holly Creek and Roosevelt Creek, which are unlisted streams, violated the Cool Water Aquatic Community criteria six times each during the study. These streams are located in the Ouachita Mountains and likely contain cool water aquatic communities. The following eight cool water streams violated the turbidity standard five times during the study:

| | |
|---|---|
| Glover River near Bethel | West Fork Glover River near Battiest |
| East Fork Glover River | West Fork Glover River at Battiest |
| Rock Creek at Smithville | Big Eagle Creek near Smithville |
| Buffalo Creek near Watson | Mountain Fork River above Ward Creek |

In addition to those above, seven unlisted streams (Pine, Caney, East, Silver, Sixmile, Mine, and Dry Creeks) violated the Cool Water Aquatic Community turbidity criteria five times during the study. Excluding Pine Creek near Rufe, the streams are located in the Ouachita Mountains and are likely Cool Water Aquatic Communities.

Turbidity is dependent on, among other things, the watershed's geology. The Ouachita Mountains are formed primarily of mud stones (sedimentary rock). Runoff from the weathering of these rocks and the kaolin clays cause the turbidities found in the Ouachita Mountain Ecoregion. The low turbidities of streams, such as Cedar Creek, Big Hudson Creek, and Horse Head Creek, are due to the metamorphic rock and the minimal land use in their watersheds.

### Dissolved Oxygen Violations

Dissolved oxygen (D.O.) criteria were violated the fewest number of times. The following streams violated D.O. criteria two or more times during the study:

| | |
|---|---|
| Yashoo Creek | Jack Creek |
| Lukfata Creek | West Fork Glover River at Battiest |
| Yanubbee Creek | Beech Creek |
| Holly Creek near Idabell | Pine Creek at Rufe |

Holly, Yashoo, and Lukfata Creeks have both urban areas and CAFOs. Yanubbee Creek receives a permitted discharge, and has both urban areas and CAFOs in its watershed. Jack Creek and West Fork Glover River at Battiest are composed primarily of forest and pasture.

### pH Violations

The occurrence of low pH in the Little River Basin was widespread. Thirty-two percent of the base flow samples contained pH values of less than 6.5. Fifty-one of the streams assessed contained pH values which violated the Oklahoma Water Quality Standard for pH.

The following 10 streams violated the pH criteria three or more times during the study:

| | |
|---|---|
| Terrapin Creek (middle) | Little River near Ludlow |
| West Fork Glover River at Battiest | Big Eagle Creek near Octavia |
| Cucumber Creek | Silver Creek |
| East Boktuklo Creek | Honobia Creek |
| Watson Creek | East Creek |

Low pH values were likely caused by a combination of factors. Rainfall in the Little River Basin generally contains pH values of less than 5.0 and is considered acidic (NADP 1991, Kress 1988). Soils in the basin have low cation exchange capacities and do not remove $H^+$ ions from water passing through them (Kress et al. 1988). Thus, the soils do not neutralize the acidic rainfall. In addition, the waters in the basin are soft and have a low buffering capacity to acidity. It is likely that even if the rainfall pH was greater than 5.6 (the average pH of rainfall), the stream water pH would still be less than 6.5 due to the low buffering capacity of the soils and water.

**Nutrient Violations**

Although nutrient loading from the basin was not substantial, several streams contained high concentrations of nitrogen and phosphorous. Mud Creek and Yanubbee Creek, which exceeded the suggested criteria for TP (>0.05 mg/l) eight times during the study, were the most frequent violators. As discussed previously, both receive permitted discharges and have confined feeding operations within their watersheds. In addition, Silver Creek, Holly Creek near Idabell, Lukfata Creek, Boktuklo Creek, Buck Creek, and Pine Creek violated the suggested criteria three or more times during the study. Holly Creek, Boktuklo Creek, Buck Creek, Pine Creek, and Lukfata Creek also have confined feeding operations in their watersheds. However, confined feeding operations are located in 23 of the watersheds in the study area. Nearly half of these streams do not appear to be impacted by excessive nutrient input. The source of the nutrients in the impacted streams should be identified and BMPs be applied.

## CONCLUSIONS

In conclusion, current activities in the Little River Basin in Oklahoma are not supplying considerable amounts of NPS pollutants to Millwood Reservoir. However, bed load was not measured. Bed load resulting from past road building and other silviculture activities could be causing the observed degradation of Millwood Reservoir, but no quantitative data exists to support this.

### IMPACTED STREAMS

The streams most impacted by turbidity and TSS were Hurricane Creek, Pine Creek, Big Eagle Creek, Silver Creek, Coon Creek, Caney Creek, and the West Fork Glover River.

The streams most impacted by pH were Terrapin Creek (middle), Little River near Ludlow, West Fork Glover River, Cucumber Creek, East Boktuklo Creek, Honobia Creek, and Watson Creek.

The streams most impacted by nutrient input were Mud Creek, Yanubbee Creek, Holly Creek near Idabell, Buck Creek, Boktuklo Creek at Golden, Lukfata Creek near Idabell, and Turkey Creek. Mud Creek and Yanubbee Creek were impacted primarily by the permitted point source discharges from the Cities of Idabell and Broken Bow. All of the streams listed above, except Turkey Creek, are known to contain CAFOs in their watersheds.

The streams most impacted by dissolved oxygen deficits were Yashoo Creek, Jack Creek, Lukfata Creek, West Fork Glover River, Yanubbee Creek, Beech Creek, Holly Creek near Idabell, and Pine Creek.

### BEST STREAMS

The two best streams were Robinson and Big Hudson Creeks. In addition to these, the following ten streams were also in excellent condition:

| | |
|---|---|
| Colbert Creek | Rock Creek near Ludlow |
| West Terrapin Creek | Carter Creek |
| Boktuklo Creek | Little Rock Creek |
| Harris Creek | Rocky Creek |
| Pine Creek near Bethel | Rock Creek near Ultima Thule |

Currently, additional base flow sampling is being conducted on 42 streams in the Little River Basin. Flow and biological communities, including macroinvertebrates and fish, are also being monitored.

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## APPENDIX A

## LOCATION OF LITTLE RIVER BASIN

# APPENDIX B

# LAND USE IN LITTLE RIVER BASIN

# APPENDIX C

# QA DATA - LITTLE RIVER BASIN STUDY

# APPENDIX D

# BASE FLOW DATA - LITTLE RIVER BASIN STUDY

# APPENDIX E

# STORM FLOW DATA - LITTLE RIVER BASIN STUDY