TMDL INVESTIGATION OF WATER QUALITY IMPAIRMENTS TO TOWNBRANCH, MCKISIK, AND LITTLE SUGAR CREEKS, BENTON COUNTY, ARKANSAS

ARKANSAS DEPARTMENT OF ENVIRONMENTAL QUALITY

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

TMDL INVESTIGATION OF WATER QUALITY IMPAIRMENTS TO TOWN BRANCH, MCKISIC, AND LITTLE SUGAR CREEKS BENTON COUNTY, ARKANSAS

INTRODUCTION

A TMDL, or total maximum daily load, is a tool for implementing State water quality standards and is based on the relationships between sources of pollution and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a waterbody, thus providing the basis for use of water quality-based controls necessary to meet water quality standards. The TMDL process is established by Section 303(d) of the Clean Water Act and by EPA's Water Quality Planning and Management Regulations (40 CFR 130.7(b). The primary steps in the process are: (1) identification of water quality limited waterbodies, (2) a priority ranking and targeting of these waters for TMDL activities, and (3) the development of a TMDL.

Town Branch and Little Sugar Creeks have been on the 303(d) list for several years, with a high priority ranking (primarily due to excessive nutrients), but an intensive investigation was deferred until 1996 due to prior commitments. The TMDL survey of Town Branch, McKisic, and Little Sugar Creeks was conducted during August 12-14, 1996. Point source dischargers within this drainage basin include the Bentonville wastewater treatment plant effluent into Town Branch Creek and two Bella Vista wastewater treatment discharges to Little Sugar Creek. The first of the Bella Vista discharges is located just below the Bella Vista Lake spillway; the second facility is further downstream, approximately 0.5 miles from the Missouri state line. The survey consisted of an evaluation of stream conditions in all three waterways and was accomplished through characterization of water quality above and below the effluent discharges, physical habitat identification, flow measurements, and evaluation of macroinvertebrate and fish community structure.

HISTORICAL DATA

Waterway Description

Town Branch Creek has its origin in and around the urban area of Bentonville and flows north-northwest through wooded slopes and pasturelands approximately two miles to its confluence with McKisic Creek. Approximately 400 yards above the confluence, the Town

Branch base flow goes underground for 200-300 yards. Recent road construction activities (blasting)on U.S. Highway 71 greatly magnified the "losing stream" condition in this stream reach. Town Branch re-emerges about 100 yards prior to entering McKisic Creek. Town Branch Creek has a drainage area of about seven square miles at its mouth. The origin of McKisic Creek is within the city limits of Centerton. This stream flows northeast approximately 10 miles prior to the Town Branch Creek confluence. McKisic Creek also has been determined to be a losing stream, with critical season sub-surface flow occuring approximately 2.5 miles downstream of Centerton. This stream drains a 22.3 square mile watershed at its confluence with Little Sugar Creek.

The headwaters of Little Sugar Creek arise near the northwest portion of Beaver Reservoir at the Lost Bridge Village community. This stream drainage is in a westerly direction until the McKisic Creek confluence, where it turns in a northwesterly direction through the Bella Vista development where it crosses the Missouri state line. Little Sugar Creek has a drainage area of 63 square miles above McKisic Creek and a total drainage area of 118 square miles at the state line. Stream slopes range from 40 feet/mile for Town Branch Creek, 15-20 feet/mile for McKisic Creek, to 15 feet/mile for upper Little Sugar Creek above McKisic Creek. Below Bella Vista Lake, the Little Sugar stream slope is approximately 10 feet/mile to the state line.

There are three permitted municipal dischargers to the Little Sugar Creek watershed. Bentonville, operating under NPDES # AR0022403, discharges into Town Branch Creek 2.2 miles above its confluence with McKisic Creek. This facility has a design flow of 4.0 MGD (million gallons per day). Average discharge volume ranges from 2.5 to 3.0 MGD. Village Wastewater, Inc. operates two wastewater treatment facilities on Little Sugar Creek. The first facility (AR0034266) has a design flow of 0.07 MGD and is located approximately one mile downstream of the McKisic Creek confluence, just below the Bella Vista Lake spillway. The second treatment facility (AR0034258) is about six miles further downstream and approximately 0.7 miles from the state line. The design flow of this treatment plant is 0.4 MGD.

In addition to these point source discharges, potential non-point source pollutants can impact these streams which drain watersheds dominated by agricultural and urban activities. Town Branch Creek above the Bentonville STP flows through a developed area of homes and businesses. Below the STP the watershed is composed primarily of pastureland with wooded borders adjacent to the stream. The McKisic Creek watershed in the headwaters area just north of Centerton is primarily grass/pasture lands. This is combined with urban runoff potential as the stream flows through Centerton. The

middle portion of the watershed northeast of Centerton is comprised mainly of forested lands, while the lower portion of the watershed is a mixture of forestlands and pasture, with urban impacts near the Town Branch Creek confluence and downstream to the confluence with Little Sugar Creek. The watershed of Little Sugar Creek consists of a mix of forest and pasture lands, with the stream dissecting a flat corridor dominated by pasture lands. Of the 85,548 acres in the Little Sugar Creek watershed, approximately 33% consists of grasslands. Agricultural activities, in addition to hay production, consist primarily of dairy farming, poultry operations, and to a lesser extent, confined swine facilities. Approximately 31% of the watershed remains forested, while urban development accounts for 28% of the remaining acreage.

Previous Studies

There are two ambient water quality monitoring stations within the study area. ARK 01, located on Little Sugar Creek at the Highway 71 bridge at the state line, has been inactive since 1983. The other station, ARK 56, is located on Town Branch Creek at the same site as survey station TBC 04. Five years of data were evaluated from this active station, while 15 years of data were examined from ARK01, to determine any parameter trends. The evaluation of the data from these two monitoring stations will be discussed in the results section of this report. Discharge monitoring reports (DMR's) from the permitted facilities were examined to determine the extent of permit violations. No violations were recorded at the Bentonville facility during the 1991-95 time frame. The Bella Vista facility at Bella Vista Lake had only one fecal coliform violation during the same time period, while the Bella Vista North facility reported numerous BOD5 and TSS violations during 1991, with no additional violations the remainder of the time period evaluated.

The earliest comprehensive study of the Little Sugar Creek watershed was conducted by ADPC&E as a part of an intensive survey of planning segment 3-J. This survey was conducted during the summer of 1978, and consisted of identification and sampling of industrial discharges to municipal treatment facilities, sampling of the municipal facilities and all streams within the segment potentially impacted by these discharges. Of the 36 stream stations established, five were located in the Little Sugar Creek watershed. Two stations were located on McKisic Creek, above and below Town Branch, and three sites were on Little Sugar Creek-one above McKisic Creek, one near Bella Vista Lake and one at the state line. The conclusions of this study stated that Little Sugar Creek was being impacted by elevated nutrients, resulting in increased algae and a slightly impacted macroinvertebrate community at the

state line station.

During July 8-10, 1980, personnel from the ADPC&E water division conducted a wasteload assimilative capacity study on Town Branch Creek in order to assess the impact of the Bentonville wastewater treatment facility. This study concluded that this stream was being severely impacted from the STP, resulting in low dissolved oxygen concentrations, excessive algae and very high BOD and nutrients. It recommended tertiary treatment of the Bentonville wastewater in order to maintain the water quality standards of the receiving stream.

In 1992, concerns from water quality personnel from Missouri led to a literature search in order to quantify the nutrient loading to Little Sugar Creek. This study identified both point source loads (municipal wastewater discharges) and non-point contributions such as watershed runoff from pasturelands receiving applications of animal wastes. Other sources identified included intermittent discharges from fertilized watershed lakes (seven lakes totaling 991 surface acres)and runoff from numerous fertilized golf courses along the stream corridor. This study provided a current estimate of the total watershed load (at the state line) of nitrogen and phosphorus in pounds per day.

Current Study of the Little Sugar Creek Basin

Data Acquisition

The TMDL investigation of the Little Sugar Creek basin was initiated on August 12, 1996, with the selection of water quality sampling stations and installation of two continuous dissolved oxygen meters in Little Sugar Creek upstream and downstream of point source dischargers. On August 13, macroinvertebrates and fish were collected at Town Branch Creek below the Bentonville STP discharge (TBC 04), McKisic Creek above the Town Branch Creek confluence (MCK 01), Little Sugar Creek above the McKisic Creek confluence (LSC 01), and Little Sugar Creek downstream of the Village Wastewater North STP discharge (LSC 07). Physical habitat assessments were performed in conjunction with the biological sampling at these sites. The water quality stations were sampled for fecal coliform bacteria on this date. August 14 activities included sampling for water chemistry analyses, in-situ measurements of dissolved oxygen, temperature and pH, and flow measurements at selected stations. The survey was completed by removal of the continuous dissolved oxygen meters and transportation of the samples to the central laboratory for analysis.

Parameters

Analyses performed in the central laboratory included chlorides, total organic carbon (TOC), carbonaceous biochemical oxygen demand ($CBOD_5$), total suspended solids (TSS), total dissolved solids (TDS), ammonia nitrogen (NH_3N), nitrate nitrogen (NO_3N), orthophosphorus and total phosphorus. The following metals were analyzed in both total recoverable and dissolved forms: Aluminum (Al), Boron (B), Barium (Ba), Beryllium (Be), Calcium (Ca), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Potassium (K), Magnesium (Mg), Manganese (Mn), Sodium (Na), Nickel (Ni), Lead (Pb), Vanadium (V), and Zinc (Zn).

Collection, Preservation, and Measurements

Stream samples were collected, preserved, and analyzed according to the 18th edition of Standard Methods for Examination of Water and Wastewater. Analyses were conducted under ADPC&E's existing Quality Assurance Program. In-situ dissolved oxygen and temperatures were measured with an Orion Model 840 portable meter, which was calibrated before, during and after use according to the manufacturers instructions. Stream pH was measured with an Orion Model 230A portable meter, which was calibrated with buffer solutions of pH 4, 7, and 10. Stream flow was measured with a Marsh-McBirney Model 2000 Flow Mate velocity meter by obtaining a representative number of depths and velocities across a relatively uniform segment of stream channel. Macroinvertebrates were collected with a Turtox Indestructible benthos net by agitating favorable riffle habitats for a total of five minutes per sample site. Organisms were picked in the field and preserved in 70% ethyl alcohol for transport to the laboratory. Sampling activities were performed in accordance with established protocol for rapid bioassessments. The fish community was sampled with a Smith-Root Model 15-A POW DC backpack electrofisher. Riffle species were collected by shocking in a downstream direction, driving the fish into a seine. Pool inhabitants were collected by electroshocking favorable habitat areas and removing stunned fish with dip nets. Fish samples were preserved in 10% formalin solution for laboratory identification. Large specimens were identified, counted, and returned to the stream.

Station Description

A total of five water chemistry stations were established on Town Branch Creek, with two stations on McKisic Creek, and six stations on Little Sugar Creek. These stations were selected for the purpose of determining any impacts from non-point source

contaminants, as well as assessing the impacts of the Bentonville, Village Wastewater, Inc. and Village Wastewater North STP effluents on Town Branch, McKisic and Little Sugar Creeks. Stations were spaced in order to determine any dissolved oxygen sag due to the effluent loading on the receiving streams. The station descriptions are as follows:

Station TBC 01. Town Branch Creek 200 yards above Bentonville STP discharge

Station TBC 02E. Bentonville STP outfall

Station TBC 03. Town Branch Creek 100 yards below STP outfall

Station TBC 04. Town Branch Creek approximately 1.5 miles below the STP discharge (same location as ambient monitoring station ARK 56)

Station TBC 05. Town Branch Creek just above McKisic Creek confluence

Station MCK 01. McKisic Creek 30 yards above Town Branch Creek

Station MCK 02. McKisic at County Road 40 bridge approximately 600 yards below Town Branch Creek confluence

Station LSC 01. Little Sugar Creek at County Road 40 bridge approximately 600 yards above McKisic Creek confluence

Station LSC 02. Little Sugar Creek at Bella Vista Lake spillway

Station LSC 03E. Village Wastewater, Inc. STP just below Bella Vista Lake spillway (no discharge during survey)

Station LSC 04. Little Sugar Creek approximately 100 yards below Village Wastewater, Inc. STP

Station LSC 05. Little Sugar Creek 50 yards above the Village Wastewater North STP discharge

Station LSC 06E. Village Wastewater North STP effluent

Station LSC 07. Little Sugar Creek approximately 400 yards below Village Wastewater North STP, near state line

Figures 1 and 2 provide a vicinity map and a schematic depicting the locations of water sampling stations, as well as areas sampled for aquatic life.

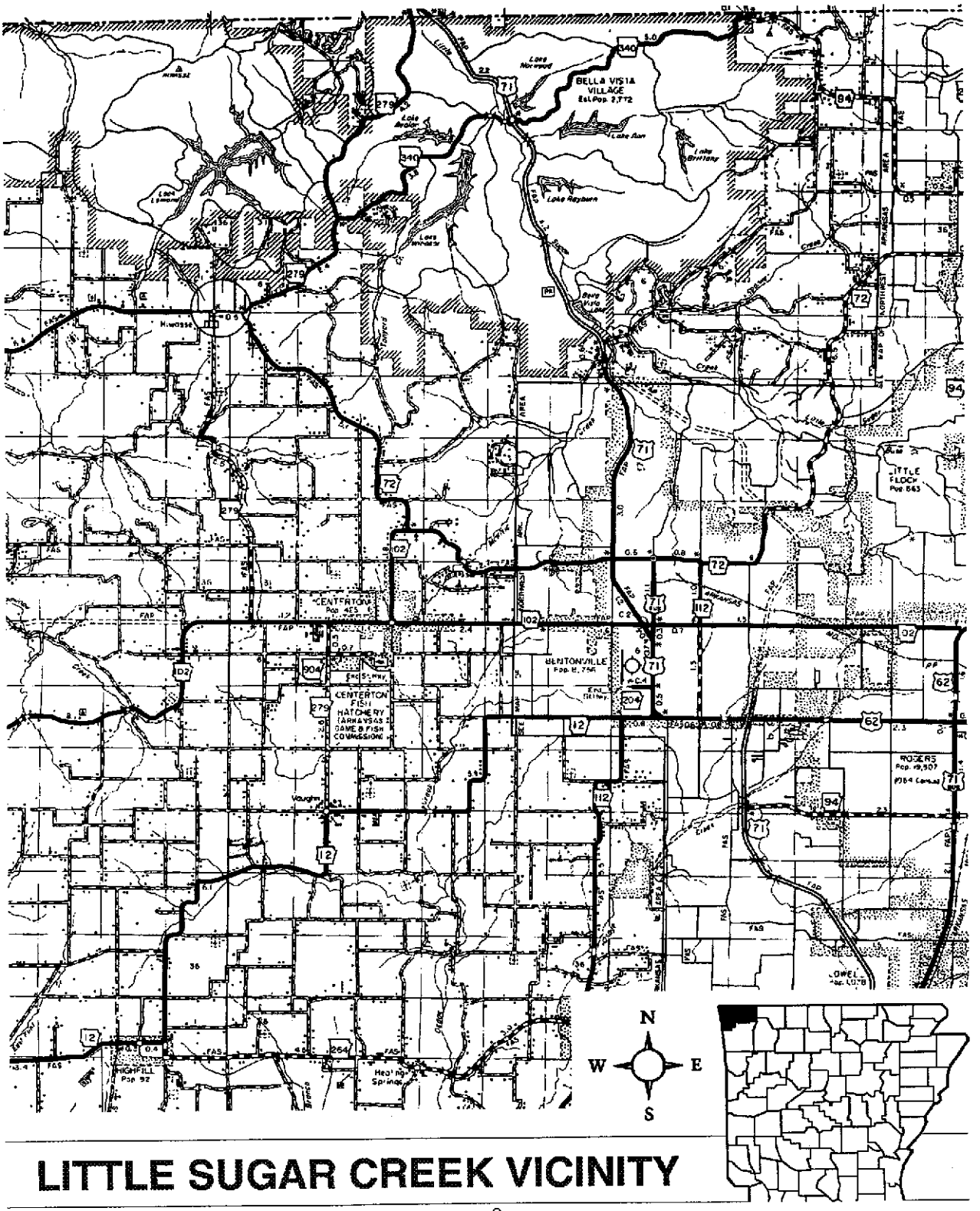
WATER QUALITY RESULTS

Dissolved Oxygen and Temperature

The dissolved oxygen profile was evaluated on the morning of August 14 during the water chemistry sampling activities. The saturation value of the upper Town Branch Creek station was 85% at 8:40 A.M. This headwaters site had only 0.22 cfs stream flow which consisted primarily of spring water. The Bentonville STP effluent volume was 4.25 cfs at 100% saturation. At TBC 03 approximately 100 yards below the outfall, the dissolved oxygen saturation had dropped to 81%, and further declined to 64% at TBC 04 at 9:25 A.M., resulting in a dissolved oxygen deficit of 3.2 mg/l at this site. Since the water samples were collected on a clear day during a time period where photosynthetic activity was producing oxygen, it is likely greater oxygen deficits will occur during periods of cloudy weather. The effect of photosynthetic activity was obvious at TBC 05, where the saturation value was 124% at the 10:00 A.M. sample time. Upstream McKisic Creek (MCK 01) had a dissolved oxygen saturation identical to TBC 01. This site, having a flow of 2.1 cfs, was also spring water dominated. Water temperatures were identical at both upstream locations, measured at 18^{0}C during this sampling event. The upper Little Sugar Creek site (LSC 01) was similar in temperature and dissolved oxygen saturation to TBC 01 and MCK 01, again reflecting spring water influence. Saturation values remained in the 85% range to the vicinity of the golf courses, where the site below this area, LSC 05, had a dissolved oxygen saturation of 78%. The Village Wastewater North effluent had a saturation value of 75%, with an instream decline to 67% being observed at LSC 07. The dissolved oxygen deficit at this lower site had increased to 2.9 mg/l, demonstrating the impact of nutrient load on the diurnal pattern of dissolved oxygen of the stream.

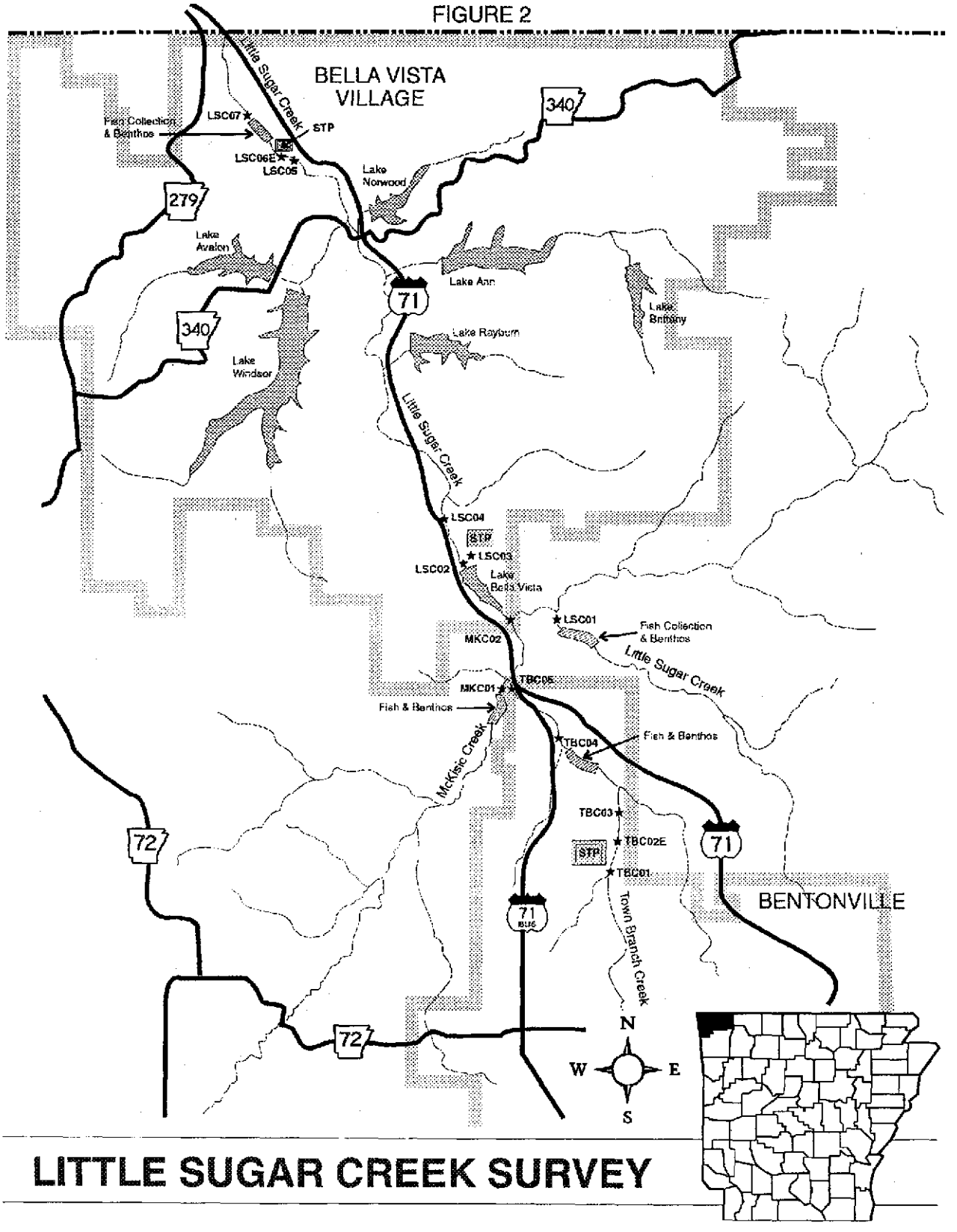
In order to assess the oxygen fluctuation patterns, Hydrolab Recorder multi-parameter meters were installed in Little Sugar Creek at the upstream site (LSC 01) and at the farthest downstream location (LSC 07). Both dissolved oxygen and temperature diurnal fluctuation was recorded for a 48 hour period. Data was recorded at five minute intervals. As can be seen in Figures 3 and 4, the dissolved oxygen diurnal fluctuation at LSC 01 is approximately 4 mg/l, with a concentration range from less than 7 to 11 mg/l for the first 24 hour period. The second 24 hour period followed a similar pattern. Contrasting patterns are seen in the LSC 07 profile. A diurnal dissolved oxygen variation of over 7 mg/l was recorded in the first 24 hour period, followed by a fluctuation of 5 mg/l during the second 24 hour time frame.

FIGURE 1



LITTLE SUGAR CREEK VICINITY

FIGURE 2



LITTLE SUGAR CREEK SURVEY

Figure 3

LSC01

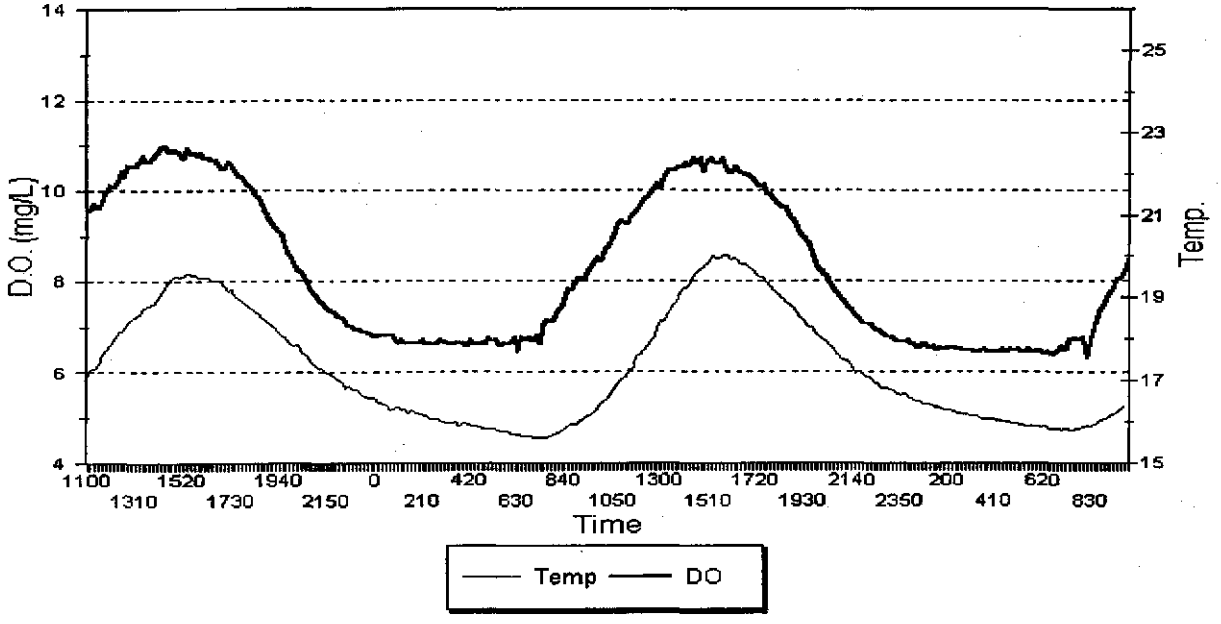
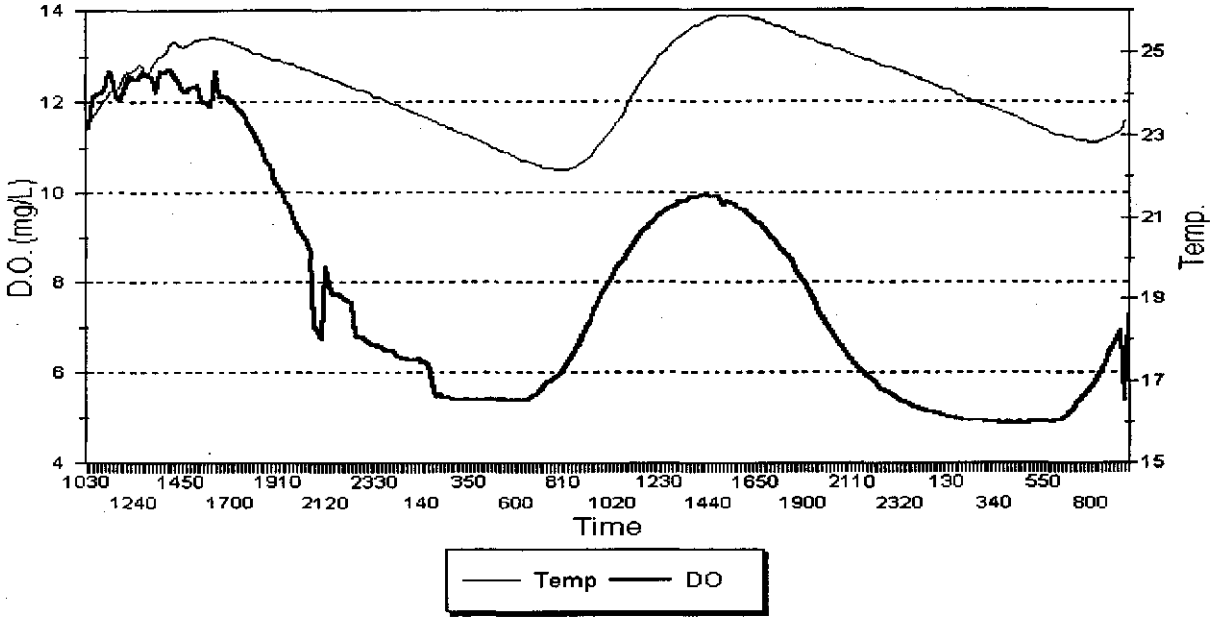


Figure 4

LSC07



The larger diurnal fluctuation reflects increased algal activity at the lower site which was a direct result of increased nutrient loading along the stream. Stream temperature fluctuation was of similar magnitude at both locations, however the near 20°C maximum at LSC 01 was noticeably different than the 26°C maximum at LSC 07. This increase is due to a combination of the addition of the elevated temperature of the effluent discharges, as well as a decrease in stream canopy along the developed lower stream reaches. Increased stream temperature also enhances algal growth. Table 1 provides a summary of the diurnal dissolved oxygen and temperature data generated from the Hydrolab Recorders.

Table 1- Diel D.O. and Temperature Summary

Station ID	Sample Date 1996	Dissolved Oxygen (mg/L)			Temperature (°C)		
		Max	Min	M.D.F.*	Max	Min	M.D.F.
LSC01	8/12-13	11.0	6.4	4.6	19.6	15.6	4.0
	8/13-14	10.7	6.4	4.3	20.0	15.8	4.2
LSC07	8/12-13	12.7	5.4	7.3	25.4	22.1	3.3
	8/13-14	10.0	4.9	5.1	25.9	22.9	3.0

*Maximum Daily Fluctuation

Stream pH

Stream pH values measured during this survey were typical for streams in the Ozark Highlands ecoregion. The values ranged from 7.4 to 7.8 at the three background sample stations. At the time of the survey the Bentonville effluent had a pH of 6.9 which was reflected in the downstream Town Branch Creek values of 7.2, 7.3 and 7.4 for the successive downstream sites. The McKisic and Little Sugar Creek values were all in the mid-to-high 7 range, with the exception of LSC 02 and LSC 04 sites, with pH values of 8.4 and 8.5, respectively. These values reflect the pH of Bella Vista Lake since LSC 02 is located just below the spillway, and LSC 04 is a few hundred yards below 02. Further downstream at LSC 05 the pH was 7.5, and a value of 7.7 was measured at LSC 07. The samples were collected in the morning, and based on other field work in this ecoregion, a small pH increase takes place in the afternoon hours. The rise in pH is associated with the photosynthetic

activity during this time frame. The initial ecoregion study produced an average pH of 7.6 for all size watersheds studied.

Flow

Stream flow measurements were performed in conjunction with the water sampling event in order to accurately calculate pollutant loading in the streams. Flows were measured at three sites in the Town Branch Creek drainage. Upstream flow (TBC 01) was measured at 0.22 cfs. It was joined by 4.2 cfs of effluent flow. At TBC 03, below the STP, the flow was measured at 3.9 cfs. A few hundred yards downstream of TBC 04, this stream loses its flow entirely for a distance of approximately 300 yards. It then re-emerges about 200 yards above its confluence with McKisic Creek. Stream flow was also measured at TBC 05 (located just above McKisic Creek), primarily for the purpose of determining the volume lost to groundwater. A flow of 2.5 cfs was recorded at this location. Upstream McKisic Creek had a flow of 2.1 cfs and upper Little Sugar Creek was measured at 5.45 cfs during the survey. According to USGS data, Little Sugar Creek at the state line has a Q7-10 in excess of 10 cfs. This survey recorded a stream flow of 13.1 cfs in the lower reach (at LSC 05). Although USGS data indicates a Q 7-10 flow of zero for the tributary streams, previous surveys have recorded similar flow patterns to those measured during this investigation.

Chlorides, Sulfates, And Total Dissolved Solids

ADPC&E's routine water monitoring network has one active station and one inactive station in the survey area. ARK 56 is located at the TBC 04 site on Town Branch Creek. This is the active site, established in 1991 for the purpose of monitoring the effects of the Bentonville STP effluent on the water quality of the receiving streams. The inactive site, ARK 01, was established at the Highway 71 bridge at the state line. A 15 year period of data exists for this location. It was discontinued in 1983.

The 1996 biennial Water Quality Inventory Report (305-b) summarized two years of monthly samples from ARK 56. The mean value for chlorides at this station was 33.8 mg/l, with a range from 8 mg/l to 56 mg/l. The 1983 ecoregion data indicates a "background" level of 8 mg/l for chlorides for small watershed streams. The 1996 survey sample collected at this station had a concentration of 48.6 mg/l. In contrast, the upstream Town Branch Creek station (TBC 01) had a concentration of 9.4 mg/l. The Bentonville STP sample had a concentration of 74.2 mg/l. This was an eight-fold increase over background concentrations.

Sulfate concentrations for the two year period (1996 305b) ranged from 11 to 59 mg/l, with a mean of 37.8. The survey data listed a concentration of 55.2 mg/l, while the background and effluent concentrations were 17.9 and 74.2 mg/l, respectively. Smaller increases were noted in total dissolved solids. A range from 154 to 411 mg/l was listed in the 305b two year summary, with a concentration of 370 mg/l recorded during the survey. Background TDS concentrations were higher at all three streams than the ecoregion data, which indicated an average value of 161 mg/l for all Ozark Highland watersheds studied. One possible explanation for this is that the main channel of Little Sugar Creek dissects surface limestone outcroppings of Clifty Limestone formation for much of its distance. The data from LSC 07 indicates that the chlorides, sulfates and total dissolved solids have returned to near background concentrations. Figures 5 and 6 provide a graphical representation of the minerals data generated by this survey. All water quality data from the survey can be found in Appendix 1.

Figure 5

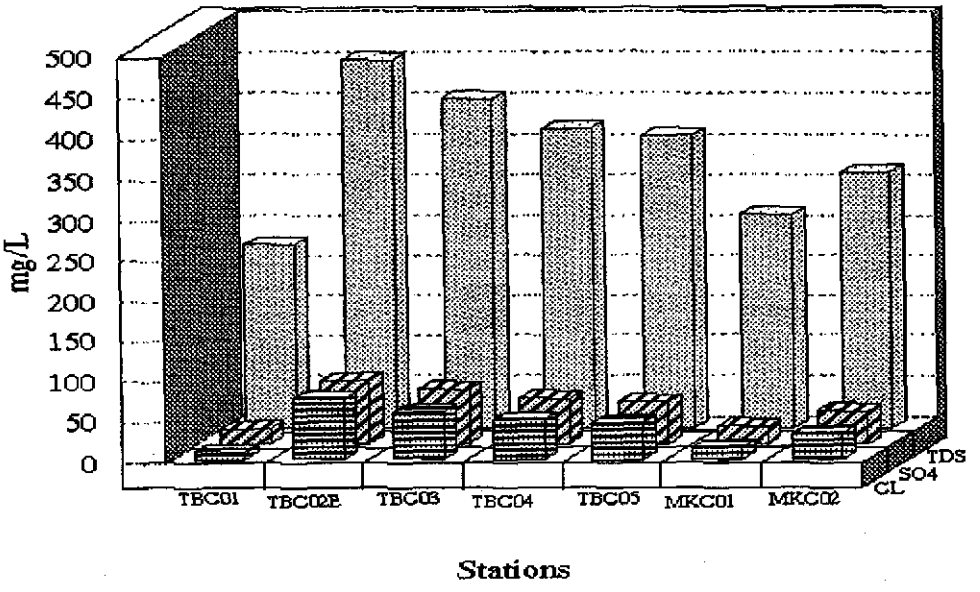
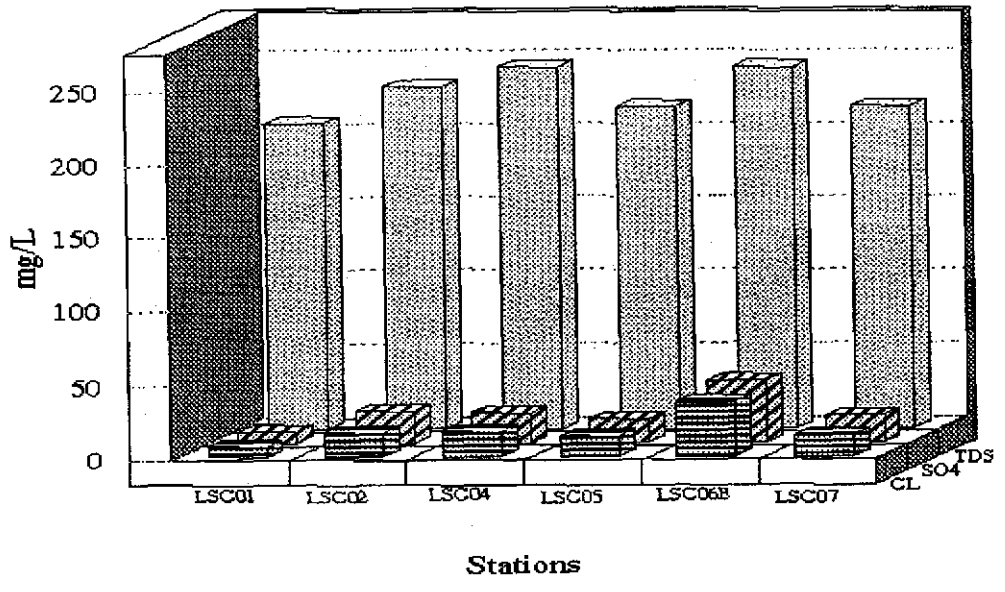


Figure 6



BOD, TSS, And Nutrients

There have been major reductions in in-stream concentrations of BOD, TSS, and NH_3N since the Bentonville wastewater treatment facility improvements in the mid-1980's. The initial wasteload assimilative capacity study, conducted in 1980, recorded effluent BOD_5 concentrations of 50 mg/l, TSS values over 30 mg/l and NH_3N concentrations over 20 mg/l. Total phosphorus levels of near 20 mg/l were also being discharged during that survey. At the ARK 56 site BOD's were still near 30 mg/l, TSS's over 20 mg/l, NH_3N values of 15 mg/l, and total phosphorus concentrations of 10 mg/l.

An analysis of the 1991-1996 Bentonville DMR data shows a maximum BOD_5 of 14.9 mg/l and an average of 4.2 mg/l. Effluent TSS concentrations decreased to an average of 4.6 mg/l, with a maximum recorded value of 36 mg/l. Ammonia nitrogen decreased to an average of 0.56 mg/l, with a high of 10.8 mg/l. Phosphorus is not currently a permitted parameter, and although no DMR data is available, an analysis of the data from ARK 56 for the last five years shows several total phosphorus values exceeding 6 mg/l, with a maximum of 12.8 mg/l. The five year record of BOD data from this station shows a range of 0.1 to 3.7, with a mean of 1.1 mg/l. Ammonia nitrogen ranged from 0.05 to 0.32, with a mean of 0.09 mg/l. A TSS range of 1 to 391 was recorded, with a mean value of 12.5 mg/l. This TSS mean can be misleading since the TSS concentrations exceeded 4 mg/l only four times in 60 samples, with concentrations of 13, 22, 28, and 391 mg/l occuring. These higher values likely were due to storm events.

The permitted parameter nutrient data generated by the 1996 survey was lower than the DMR and ARK 56 averages noted above. The effluent BOD, TSS, and NH_3N concentrations were 1.4, 3.5, and 0.09 mg/l, respectively. These values represent a very efficient treatment of these pollutants, however, the unpermitted nutrients of nitrate nitrogen and phosphorus were being discharged at levels that warrant concern. The effluent NO_3N during the survey was 19.2 mg/l, and still had a concentration of 11.3 mg/l at the ARK 56 (TBC 04) site. During this survey all stream flow in Town Branch went underground a short distance downstream of TBC 04. Due to the karst geology of the region, a potential threat to drinking water supplies exists due to nitrate nitrogen contamination.

The other unpermitted nutrient of concern is phosphorus. During the survey, an effluent concentration of almost 12 mg/l total phosphorus was recorded and an instream concentration of near 10 mg/l was found at TBC 03 and 6 mg/l at TBC 04. The background concentration of phosphorus in Town Branch (TBC 01) was 0.105 mg/l. Thus the Bentonville effluent produced a 95 fold increase in the

instream concentration of phosphorus at the time of the survey. With the dilution provided by McKisic Creek, the phosphorus concentration at MKC 02, below Town Branch, was 3.62 mg/l, and with the Little Sugar Creek dilution, phosphorus was 1.1 mg/l at LSC 02. With the presence of 2.5 mg/l NO_3N at this site, ample nutrients were present for algae production. These nutrients continued to be assimilated as the flow approached the state line where concentrations of NO_3N was 1.5 mg/l and phosphorus was 0.57 mg/l at station LSC 05. In addition, Village Wastewater North, Inc. contributed 5.2 mg/l of phosphorus, 1.05 mg/l of nitrate nitrogen and 7.5 mg/l ammonia nitrogen. The resulting concentration of nutrients at LSC 07 was below detection level for NH_3N, 1.4 mg/l NO_3N, and 0.55 mg/l total phosphorus during the survey. These phosphorus values represent an 8.5 fold increase over background concentrations in Little Sugar Creek.

Nutrient loading to the Little Sugar Creek drainage basin is dominated by point source discharges during the low-flow season. In Town Branch Creek background nutrient loads during the survey consisted of 2.1 pounds/day NO_3N, less than 0.06 pounds of NH_3N and 0.13 pounds/day of phosphorus. The Bentonville wastewater discharge contributed 439.6 pounds/day of NO_3N, 2.04 pounds of NH_3N, and 281.6 pounds of phosphorus per day to the receiving streams. McKisic Creek contributions, above Town Branch, included 40.5 pounds of NO_3N, less than 0.5 pounds NH_3N, and 14.6 pounds/day phosphorus. Little Sugar Creek loadings above the influence of the point sources consisted of 46.4 pounds of NO_3N, less than 1.47 pounds NH_3N and 1.9 pounds/day phosphorus. Village Wastewater North, Inc. contributed an additional 2.2 pounds of NO_3N, 15.7 pounds of NH_3N, and 10.9 pounds/day phosphorus to the stream. During low flow conditions, point source contributions of NO_3N comprised 80% of the total measured input, while total phosphorus was 94% of the total input. The total nutrient load leaving the state via Little Sugar Creek during the 1996 survey was 101 pounds/day of nitrate nitrogen, less than 3.6 pounds/day ammonia nitrogen and 40 pounds/day total phosphorus. Approximately 81% of the nitrate nitrogen and 87% of the total phosphorus was being removed from the Little Sugar Creek water column prior to leaving the state. Figures 7 and 8 provide the nutrient concentrations analyzed from the survey stations, and Figure 9 depicts the nutrient loading at selected sites.

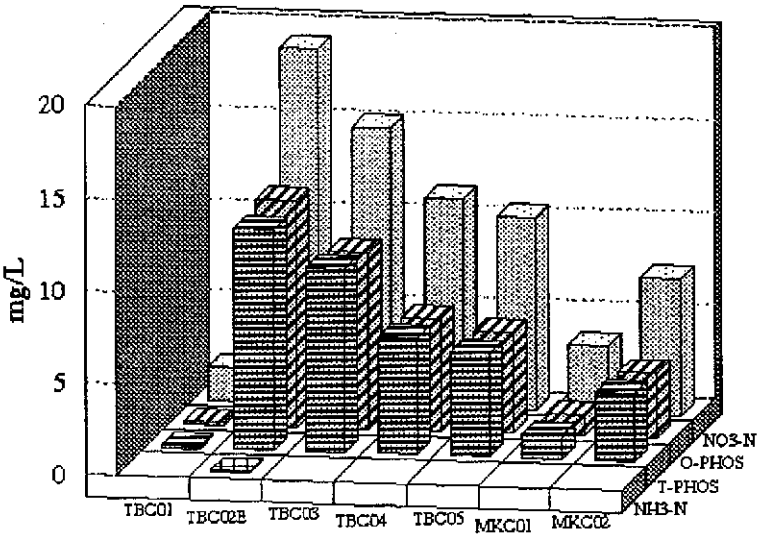
Dissolved Metals

A total of 18 dissolved metals were analyzed from each of the survey sites. Of these, seven metals had a ten to twenty-fold increase in Town Branch Creek below the Bentonville municipal

Figure 7

TOWN BRANCH & McKISIC CREEKS

Nutrients

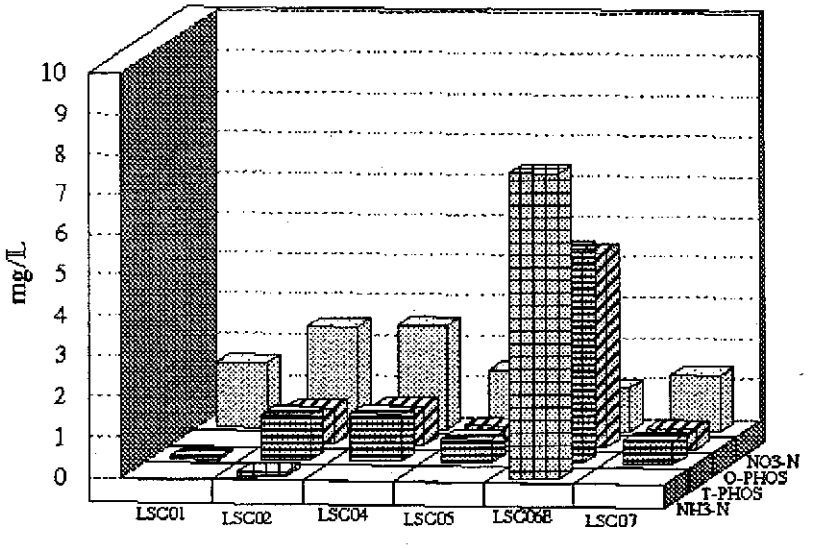


Stations

Figure 8

LITTLE SUGAR CREEK

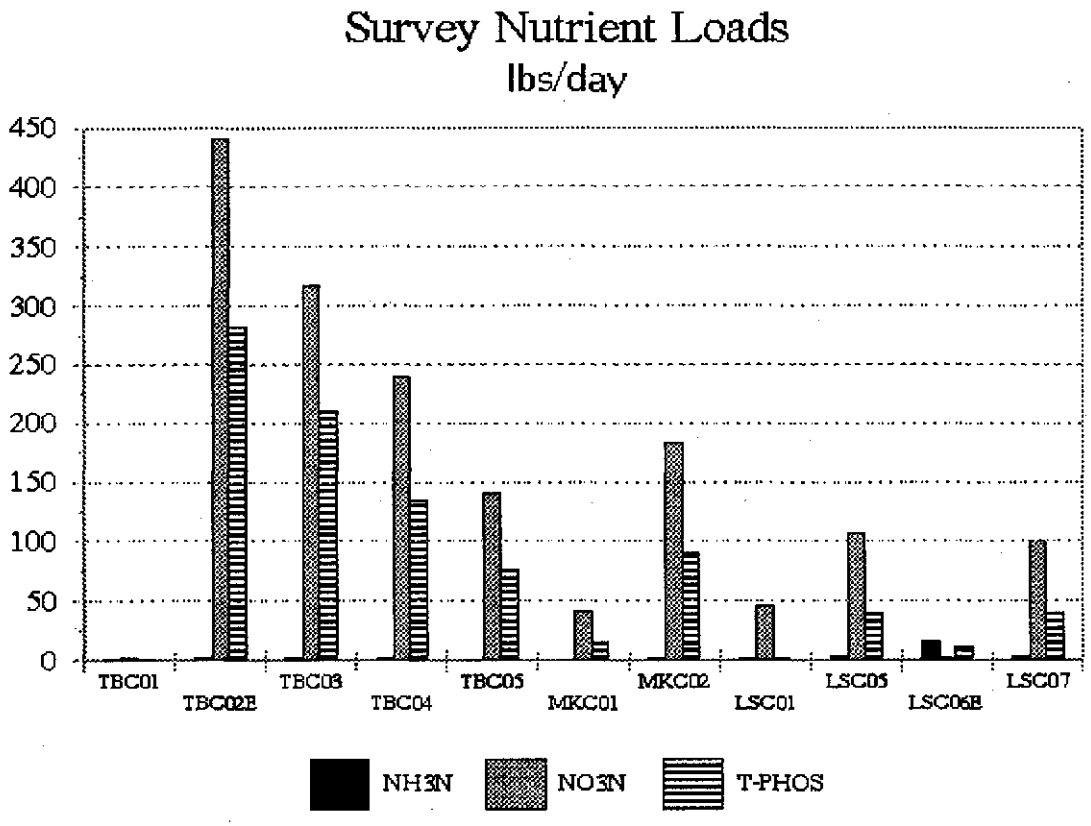
Nutrients



Stations

effluent discharge from upstream values. Although increases in various metals concentrations are common below many municipal wastewater discharges, the concentration of copper in the effluent was 19.2 ug/l. At downstream sites, it was 13.9 at TBC 03 and 15.5 at TBC 04. The chronic aquatic life toxicity standard of copper at the hardness values associated with the Ozark Highlands ecoregion is 15.9 ug/l. This is based on a four day average concentration so further sampling would be necessary to determine if the water quality standards are being violated due to the Bentonville wastewater effluent discharge. It is also notable that the concentrations of cadmium, cobalt, copper, nickel and zinc increased at TBC 04 over TBC 03 values. Some of these increases were substantial. The cause is not known. It could be a slug effect from the Bentonville treatment plant effluent or an unknown discharger.

Figure 9



AQUATIC MACROINVERTEBRATES

Methods

Aquatic macroinvertebrates were collected using modified protocols set forth in Plafkin et al. (1989). These protocols call for habitat sampling for five minutes. During the five minute collections, all available habitats within a riffle are sampled to collect the maximum number of taxa from the greatest number of niches. Collections were made with an aquatic macroinvertebrate dip net and preserved in 70% ethanol.

In the lab, all organisms, organic and inorganic material were placed in a dissecting pan. A 10 cm (4 in.) ring was placed in the pan to delimit a subsample and all organisms were removed from the ring until the ring was depleted of organisms. This process was continued until 100 organisms were removed. In cases where additional organisms remained in the ring after removal of 100 organisms, the additional organisms were placed in the subsample to reduce biasing the sample. In instances of ≤100 organisms, the entire sample was used to derive scores.

RBA scores from multi-metric analyses are derived for each site. Each site's score is compared to the reference site score to determine percent comparable estimate (%CE) which determines the impairment status. Impairment categories are found in Table 2.

Scores are based on five metrics. Taxa richness (TR), compares the number of taxa at each site, which is important to show diversity of the community. Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa abundances relate to the number of "intolerant" organisms. The Hilsenhoff Biotic Index (HBI), shows the tolerance level of the entire community to organic pollution in the water. The Community Loss Index (CLI) relates to the number of organisms found at the reference site but not at other sites.

This form of rapid bioassessment (RBA) includes biological and physical evaluations from each site. Physical evaluations are necessary to ensure that each site can physically support the community structure found at the reference or "least impacted" site. Physical parameters are scored and scores are compared back to the reference. A percent CE (Table 3) is calculated to determine comparability of stations to the reference.

Table 2. Percent comparable estimate categories to determine impairment.

Biological Condition	%CE	Attributes
No significant impairment	>83%	Comparable to reference
Slight impairment	54-79%	Community structure less than reference. Taxa Richness lower and tolerant forms are more prevalent.
Moderate Impairment	21-50%	Obvious decline in community structure with loss of intolerant forms. EPT index reduced.
Severe Impairment	< 20%	Community dominated by 1 or 2 taxa, few taxa present.

Table 3. Percent comparable estimates for physical assessments.

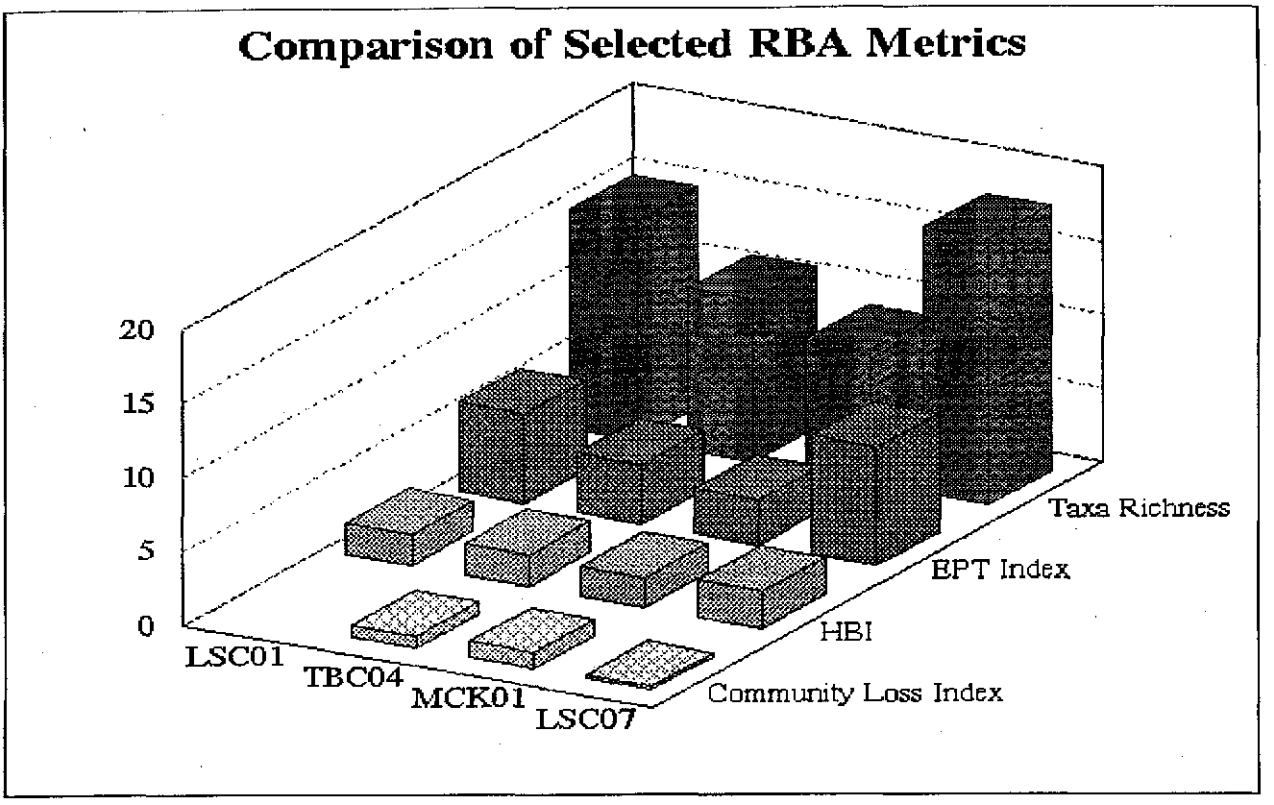
Assessment Category	%CE
Comparable to Reference	≥90%
Supporting	75-88%
Partially Supporting	60-73%
Non-Supporting	≤58%

Results

Rapid bioassessment scores for sites compared to LSC 01 as the reference show slight impairment at TBC 04 (58%), moderate impairment at MKC01 (50%), and no significant impairment at LSC 07 (92%) (Table 4). Physical habitat scores from all sites showed good comparability to the reference site (>90%).

The Town Branch Creek (TBC 04) and McKisic Creek (MKC 01) sites were impaired based on TR, EPT index and CLI (Figure 10). Chemical data revealed lower D.O. values, higher water temperatures, higher minerals and nutrients, and dissolved metals values near toxic levels at TBC 04 compared to LSC 01. Dissolved oxygen and temperature values in the ground water dominated MKC 01 were similar to LSC 01. Other water quality parameters were also

Figure 10



slightly elevated in McKisic Creek. The lower Little Sugar site similar, although nutrients were notably elevated and minerals(LSC 07) showed no significant impairment when compared to LSC 01. An additional three taxa, including two Ephemeropterans, were collected at LSC 07 that were not collected at LSC 01 (Table 4). Water temperature, flow and the diel D.O. pattern were notably different between the two sites. Nitrate values were similar, but total phosphorus remained higher at LSC 07.

Discussion

Rapid bioassessments are not designed to be exhaustive surveys to determine qualitative or quantitative community structure of aquatic macroinvertebrates. It is a tool to determine if problems are occurring in a stream and determine if future intensive surveys are necessary.

While impairments were indicated in two of the sites (TBC 04 and MKC 01), stream flow may have been the limiting factor in McKisic Creek. Stream flow is responsible for maintaining the aquatic environment for organisms that live there (Plafkin et al., 1989). Flows less than 5.0 cubic feet per second (cfs) tend to limit the

number of taxa found at these sites, while flows greater than 5.0 cfs supported the most taxa. The complete taxa list generated during this survey is included as Appendix 2.

Table 4. Metrics from selected stream sites in Little Sugar, Mckisic and Town Branch Creeks.

Metric	Location			
	LSC01	TBC04	MKC01	LSC07
% Dominant Taxa	59	54	85	46
Taxa Richness	15	11	9	18
EPT Index	6	4	3	8
HBI	2.1	2.1	2.0	2.5
CLI	*	0.8	1.1	0.2
Biological %CE	*	58	50	92
Physical %CE	*	95	96	91

*= Reference site

FISH COMMUNITY SURVEY

In August 1996 personnel from the Department performed fish community surveys at the stations listed below:

Station Description

LSC01 Little Sugar Creek at county road 40 bridge, east of Ford Springs. Approximately 51 mi^2 watershed. Benton County. (Secs. 17 &20, T20N, R30W)

LSC07 Little Sugar Creek upstream from US Hwy 71B bridge, 1/2 mile, near the Missouri state line. 118 mi^2 watershed. Benton county. (Secs. 15 & 16, T21N, R31W)

TBC04 Town Branch below Bentonville STP discharge at low water bridge. Approximately 3 mi^2 watershed. Benton County. (Secs. 12 & 13, T20N, R30W)

MKC01 M^{c}Kisic Creek upstream from US Hwy 71B bridge, above Town Branch confluence. Approximately 22 mi^2 watershed. Benton County. (Secs. 20, T20N, R30W)

Methodology

A Smith-Root model 15-B backpack electrofishing device with pulsed DC current was used to collect fish from all sites. The device was used in the shallow pools and along the pool edges while wading upstream and dipping the stunned fishes from the water with dip nets. The riffles were collected by posting a twenty foot seine near the toe of the riffle and while working the electrofisher in a downstream direction through the riffle, the bottom substrate was overturned and the fish were herded into the seine or washed in by the current.

Fish were collected from all available habitat within the sample area until a fully representative sample of the species in the area was thought to have been obtained. Larger specimens were field identified and released. The smaller specimens and those unidentifiable in the field were preserved in a ten percent (10%) formalin solution and returned to the lab for identification.

Results

Fish community samples were collected at all stations on August 12th and 13th, 1996. They were evaluated by comparing different metrics and basic community structures. The samples collected at LSC 01 and MKC 01 were used as reference sites for comparison to the site located below the wastewater treatment facility, TBC 04. There was not a reference site established for the site located near the state line on Little Sugar Creek, LSC 07. Ecoregion data from the least-disturbed Ozark Highlands ecoregion sites on Flint Creek, 19 mi^2 watershed, and South Fork Spavinaw Creek, 18 mi^2 watershed, were also used in the data comparisons.

There were 14 species of fish collected from Little Sugar Creek (LSC 01) above the confluence of M^{c}Kisic Creek and Town Branch; 24 species at the furthest downstream Little Sugar Creek site (LSC 07); 10 species from Town Branch below the STP outfall (TBC 04); and 12 species from M^{c}Kisic Creek (MKC 01). Appendix 3 contains a list of species collected from each site, the number of specimens per species collected, and the percent community composition of each species. Table 5 compares the fish family composition between sampling stations, percent and total sensitive, key and primary

trophic levels species; and it provides the Shannon-Wiener diversity index (log base 2) for each sample. Table 6 shows similarity indices between sample sites based on number of species and the relative abundance of the species.

The fish communities in McKisic Creek, MKC 01, and upper Little Sugar Creek, LSC 01, were quite similar according to the similarity indices, percent sensitive individuals, percent key individuals and their respective diversity indices. However, their community structures and trophic level compositions were somewhat different. The Cyprinids comprised approximately 60% of the community in McKisic Creek and only 37% at the upper Little Sugar Creek site, although the species composition was the same. The largest community structure differences between these two sites were the Cottids, 42% at LSC 01 and 31% at MKC 01, and the orangethroat darter, 12% at LSC 01 and 2% at MKC 01. Substrate and/or water temperature could be the reason for this difference between these two communities. There was also a noticeable difference in the number of individuals comprising the primary trophic feeding level between these two sites. Twenty percent of the community at LSC 01 were primary feeders compared to 30% at MKC 01. This is perhaps indicating that there is more periphytic activity in McKisic Creek than upper Little Sugar Creek. Both nitrates and phosphorus were noticeably elevated in McKisic Creek over upper Little Sugar Creek.

The ecoregion reference streams were somewhat similar to LSC 01 and MKC 01; however, both reference streams had a much smaller Cottid population. Similar to LSC 01 and MKC 01, the ecoregion sites were dominated by the Cyprinid community and had a similar composition of primary feeders. Both study sites had a similar percentage of sensitive species as Flint Creek, but somewhat less than South Fork Spavinaw Creek. The LSC 01 site had a similar percent composition of key individuals as the ecoregion sites; however MKC 01 percent key individuals was slightly lower. In overall comparison the study site reference streams were quite similar to the ecoregion reference stream sites. However, the site located below the Bentonville waste water treatment facility, TBC 04, had a much different community structure than either of the LSC 01 and MKC 01 reference communities. Cyprinids dominated the community at TBC 04, comprising over 70% of the population, while Cottids comprised less than 12% of the community. Sensitive individuals comprised less than 36% of the community as compared to over 60% in the reference streams. Key individuals comprised less than 5% of the community as compared to 24% or more at the reference sites. Also, the diversity index at TBC 04 was somewhat lower than the reference sites. Most of the community difference was in the primary trophic level species. The stoneroller and southern redbelly dace

TABLE 5

COMMUNITY STRUCTURE (as percent total community)						
Family	LSC01	LSC07	TBC04	MKC01	Flint Creek	S.F. Spavinaw
Cyprinidae	37.46	36.63	71.37	59.63	66.40	46.20
Catostomidae	4.30	1.89	1.28	2.41	1.20	0.20
Ictaluridae	0.00	28.05	0.43	0.00	6.10	9.60
Centrarchidae	0.86	15.26	5.56	5.21	6.10	1.00
Percidae	15.55	14.03	9.83	1.87	10.70	26.80
Cottidae	41.84	4.07	11.54	30.88	5.56	16.13
Total Species Collected	14	24	10	12	21	13
No. Sensitive Species	7	12	5	5	11	9
No. Sensitive Individuals	798	791	84	475	433	893
% Sensitive Individuals	68.6	57.5	35.9	63.5	28.32	80.45
No. Primary TFL	228	298	159	229	616	297
% Primary TFL	19.6	21.7	67.9	30.6	15.7	26.75
No. Key Individuals	328	736	11	179	511	286
% Key Individuals	28.2	53.5	4.7	23.9	33.42	25.77
Diversity Index	2.60	3.31	2.18	2.61	3.12	3.01

TABLE 6

FISH COMMUNITY SIMILARITY INDICES		
Sample Sites	Species Similarity	Relative Abundance Similarity
LSC01/LSC07	0.631	0.574
LSC01/TBC04	0.750	0.616
LSC01/MKC01	0.846	0.774
TBC04/MKC01	0.727	0.689

accounted for almost 68% of the TBC 04 community compared to 31% at MKC 01 and 20% at LSC 01. These factors indicate that there is nutrient enrichment occurring at TBC 04 along with some additional alterations in other water quality parameters. Other factors indicating differences in fish community structure at TBC 04 were

the relative abundance similarity indices which show a very low level of comparability between Town Branch and the reference streams.

The fish community at the LSC 07 site, Little Sugar Creek near the state line, was well distributed as illustrated by its diversity index of 3.31. Its Cyprinid and Percid community percentages were similar to LSC01 and Flint Creek, but it had a larger Ictalurid community, with slender madtoms comprising 28% of the community. There were fewer daces and Cottids at LSC 07 indicating less ground water influence and more dominance by warmer surface runoff. There were seven species of sunfish and six percid species collected at LSC 07 which reflects a high degree of diversity and stability in this community. In addition, there was a high percentage of key individuals collected at LSC07 indicating its similarity to typical ecoregion stream communities. The wastewater treatment facilities do not seem to be having any effect on the fish community at this site.

Conclusions

The fish communities in the Little Sugar Creek and M^{c}Kisic Creek reference sites were quite similar in structure to the Ozark Highland Ecoregion fish communities in Flint Creek and South Fork Spavinaw Creek. The fish community of Town Branch below the Bentonville wastewater treatment facility had similar species composition to the four communities listed above, but the fish family composition within the community was quite different. The primary feeders dominate the community indicating nutrient enrichment is occurring. Only one species of sunfish was present. This was the green sunfish which tends to be more pollution tolerant than other sunfishes. Additionally, the percentage of sensitive species was small. In contrast, the point source discharges do not seem to be having adverse effects on the fish community in Little Sugar Creek at the state line. That community is very diverse and supports very good populations of sensitive and key species, including a large population of slender madtom. It also supports a diverse Centrarchid community, including numerous smallmouth bass and shadow bass, and a very diverse Percid community.

SUMMARY AND RECOMMENDATIONS

While visable evidence of gross pollution was not encountered in the streams evaluated during this TMDL study, the data generated indicated subtle changes are occuring due to the influx of nutrients from the Little Sugar Creek watershed. Excessive nutrients are implicated in the obvious change in the diurnal

dissolved oxygen fluctuations from the upstream (LSC 01) to downstream (LSC 07) sites. Evidence of instream nutrients was seen in the wide range of oxygen saturation values in Town Branch Creek above and below the Bentonville sanitary wastewater discharge. The prolific growth of emergent vegetation in McKisic Creek in the fish survey area can also be attributed to elevated instream nutrients.

The evidence is readily verified by the nutrient data analyzed from samples collected during the survey. Large increases in nitrates and phosphorus in Town Branch Creek below the STP provided ample nutrients to generate wide fluctuations in oxygen saturation values, resulting from photosynthetic and respiratory activities of algae and periphyton. Nitrate concentrations at the upstream McKisic Creek site (MKC 01) that were two times higher than upstream Town Branch and Little Sugar Creek sites, and phosphorus concentrations over 10 times higher, produced the macrophytic growth in the stream channel. The suspected source of nutrients at this site is from groundwater recharge from the subsurface Town Branch Creek flow. The confluence of this stream flow and additional nutrient inputs downstream also produced the unusually large diurnal dissolved oxygen variation at the downstream Little Sugar Creek site. Although slight and moderate impairment status were assigned to the TBC 04 and MKC 01 macroinvertebrate communities, respectively, when compared to LSC 01, it was concluded that the differences were related to a lower stream flow at the MKC 01 site. However, an increase in primary feeders in the fish communities at these two sites was attributed to an increase in algae and periphytic growth.

Since the survey was conducted in a low flow season, with little input from non-point source watershed activities, recommendations for nutrient control will apply to point source discharges to these streams. Based on the high NO3N and phosphorus concentrations reported from ambient monitoring station ARK 56 (TBC 04), and also Bentonville STP effluent concentrations of 19.2 mg/l NO3N and 12.3 mg/l of orthophosphorus analyzed from the survey, control measures are necessary for this facility. Because Town Branch Creek has been verified to be a losing stream, permit limits for nitrate nitrogen will be required, as will a monitoring and reporting of total phosphorus. Plans should be developed for phosphorus control at the Bentonville STP. In addition, the existing permit will be modified to include $CBOD_5$/TSS limits of 10/15, as per the Dept. losing stream policy. The treatment facility needs to identify the source or sources of the elevated metals in the wastewater. Copper was being discharged at toxic levels during the survey. In order to comply with the recommendations, changes in pre-treatment requirements for industrial contributors to the city treatment facility may need to be addressed.

Appendix 1. WATER QUALITY--AUGUST 14, 1996

Bentonville/Bella Vista Survey													
Station ID	LSC01	MKC01	TBC01	TBC02E	TBC03	TBC04	TBC05	MKC02	LSC02	LSC04	LSC05	LSC06E	LSC07
FLOW (cfs)	5.45	2.1	0.22	4.25	3.92	3.92	2.5	4.6			13.1	0.4	13.5
D.O. (mg/L)	8.1	8.1	8.7	8.2	7.1	5.7	10.9	7.8	8.6	7.5	6.7	6.3	5.8
pH (S.U.)	7.4	7.6	7.8	6.9	7.2	7.3	7.4	7.5	8.4	8.5	7.5	7.2	7.7
Water Temp (C)	16.8	17.9	18.1	26.1	23.6	21.5	21.8	19.9	22.2	22.8	23	25.2	23.3
CBOD (mg/L)	0.2	0.1	0.2	1.41	0.84	0.2	0.1	0.3	2.39	2.57	0.6	0.9	0.6
NH3-N (mg/L)	<0.05	<0.05	<0.05	0.09	<0.05	<0.05	<0.05	<0.05	0.1	<0.05	<0.05	7.54	<0.05
CL (mg/L)	7.2	14.7	9.4	74.2	57.8	48.6	44.4	31.1	15.9	17.1	13.6	36.2	13.9
NO3-N (mg/L)	1.6	3.6	1.8	19.2	15	11.3	10.4	7.4	2.5	2.5	1.5	1.051	1.387
O-PHOS (mg/L)	<0.03	1.17	0.12	12.3	9.56	6.07	5.47	3.47	0.88	0.96	0.48	4.78	0.47
T-PHOS (mg/L)	0.07	1.29	0.11	11.98	9.96	6.32	5.61	3.62	1.1	1.14	0.57	5.24	0.55
SO4 (mg/L)	7.5	21.2	17.9	76.9	66	55.2	51.7	38.8	21.2	20.1	15.6	41.4	17.9
TOC (mg/L)	1.2	2.3	2.1	13.1	10.2	5.4	5	3.5	4.7	4.2	1.8	10.6	1.8
TSS (mg/L)	<1.0	17	2	3.5	2	1	3.5	2.5	22	22	3.5	4.5	3.5
TDS (mg/L)	207	265	228	454	407	370	362	317	232	245	218	245	218
Hardness (mg/L)	169	194	182	100	123	142	147	169	155	161	155	86	154
Fecal Coliform Counts													
No./100 ml	96	NA	96	9	NA	60	31	46	27	14	3	183	3
Dissolved Metals													
Al (ug/L)	<16.0	<16.0	<16.0	25.7	<16.0	<16.0	<16.0	<16.0	16.7	<16.0	<16.0	27.8	<16.0
B (ug/L)	9.2	37.8	20.8	202	160.7	137.8	124.4	83.3	34.3	44.7	31.8	164.9	34.5
Ba (ug/L)	49.6	50.1	61.4	<4.0	13.9	32.8	33.1	40.4	40.9	37.5	43.8	6.1	44.9
Be (ug/L)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Ca (mg/L)	68	74.2	67.9	35.6	44.9	53.9	55.3	63.8	69.2	60.8	59.1	29	58.5
Cd (ug/L)	<0.5	<0.5	<0.5	<0.5	<0.5	1	0.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Co (ug/L)	<3.0	<3.0	<3.0	3.1	3.1	13.1	10.2	7.1	3.6	<3.0	<3.0	<3.0	<3.0
Cr (ug/L)	<1.0	<1.0	1.2	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Cu (ug/L)	<2.0	2.4	<2.0	17.9	13.9	15.5	12.8	7.8	<2.0	<2.0	<2.0	<2.0	<2.0
Fe (ug/L)	<1.8	43.7	5.4	1020	782	316	206	102	35.1	18.7	<1.8	27.4	1.9
K (mg/L)	1	2.3	1.3	16.2	12.2	8.8	8.5	5.1	2.4	2.3	1.8	8.2	1.9
Mg (mg/L)	1.5	2	2.3	2.4	2.4	2.3	2.3	2.2	1.8	1.9	2	2.8	2.1
Mn (ug/L)	6.5	7.2	2.4	43.8	52.7	33.4	7	11.5	17.9	20.5	7.9	13.8	10.3
Na (mg/L)	3.8	15.8	7.5	84.7	67.1	56.1	51.5	34.6	15.2	19.4	14	37.5	12.6
Ni (ug/L)	<5.0	5.9	<5.0	<5.0	<5.0	16.2	14.6	9.1	<5.0	5.2	<5.0	<5.0	5.2
Pb (ug/L)	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
V (ug/L)	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0
Zn (ug/L)	<2.0	19.3	6.1	95.9	76.6	114	88.1	51.8	13.7	15.1	7.6	22.9	6.9

Appendix 2. Aquatic macroinvertebrate taxa from selected Little Sugar, McKisic and Town Branch Creek sites.

				LSC01	TBC04	MKC01	LSC07
HBI	FEEDING GROUP	EPT	Taxa	#Coll	#Coll	#Coll	#Coll
2	COL	N	*Gammarus*	177	2	224	1
3	COL	N	*Orconectes*	3	3	1	7
3	COL	Y	*Baetis*	18	10		1
2	COL	Y	*Isonychia*				12
2	SCR	Y	*Stenacron*		55		5
3	SCR	N	*Stenonema*	14	3	11	70
1	COL	Y	*Paraleptophlebia*				3
2	COL	Y	*Tricorythodes*	1			1
2	COL	Y	*Caenis*			19	3
3	PRE	N	*Argia*		3		
2	PRE	Y	*Acroneuria*	7		1	5
3	COL	Y	*Cheumatopsyche*	20	10	5	1
2	COL	Y	*Chimarra*	3	5		
2	SCR	Y	*Helicopsyche*	3			
2	SCR	N	*Ectopria*			1	
2	SCR	N	*Psephenus*		6	1	37
3	COL	N	*Dubiraphia*	2	1		1
2.5	COL	N	*Narpus (A)*				1
2	SCR	N	*Optioservus (L)*	24			2
2.5	SCR	N	*Ordobrevia*		4		
2.5	SCR	N	*Ordobrevia (A)*				1
2.5	SCR	N	*Stenelmis (A)*	1			1
2.5	SCR	N	*Stenelmis (L)*	21			1
2	SHR	N	*Tipula*	1			
3	COL	N	*Prosimulium*			1	
3	COL	N	*Simulium*		1		
4.5	PRE	N	Chironomidae	4			
			TOTAL	299	103	264	153

Appendix 3

LITTLE SUGAR CREEK FISH COMMUNITY									
		LSC01		LSC07		TBC04		MKC01	
SCIENTIFIC NAME	COMMON NAME	Num	% Com	Num	% Com	Num	% Com	Num	% Com
Cyprinidae	Minnows								
Campostoma anomalum	Stoneroller	158	13.57	246	17.88	124	52.99	166	22.19
Luxilus cardinalis	Cardinal shiner	177	15.21	155	11.26	2	0.85	165	22.06
Nocomis asper	Redspot chub			51	3.71				
Notropis nubilus	Ozark minnow	32	2.75	52	3.78			6	0.80
Notropis rubellus	Rosyface shiner	4	0.34					4	0.53
Phoxinus erythrogaster	Southern redbelly dace	38	3.26			38	16.24	57	7.62
Semotilus atromaculatus	Creek chub	27	2.32			3	1.28	48	6.42
Catostomidae	Suckers								
Catostomus commersoni	White sucker	38	3.26	4	0.29	3	1.28	18	2.41
Hypentelium nigricans	Northern hogsucker	12	1.03	17	1.24				
Moxostoma duquesnei	Black redhorse			4	0.29				
Moxostoma erythrurum	Golden redhorse			1	0.07				
Ictaluridae	Catfishes								
Ameiurus melas	Black bullhead					1	0.43		
Noturus exilus	Slender madtom			386	28.05				
Poeciliidae	Livebearers								
Gambusia affinis	Mosquitofish			1	0.07				
Centrarchidae	Sunfishes								
Ambloplites rupestris	Rock bass			22	1.60				
Lepomis cyanellus	Green sunfish	2	0.17	17	1.24	13	5.56	3	0.40
Lepomis macrochirus	Bluegill sunfish	7	0.60	112	8.14			35	4.68
Lepomis megalotis	Longear sunfish	1	0.09	21	1.53				
Lepomis microlophus	Redear sunfish			7	0.51				
Micropterus dolomieui	Smallmouth bass			30	2.18				
Micropterus salmoides	Largemouth bass			1	0.07			1	0.13
Percidae	Perches								
Etheostoma blenniodes	Greenside darter			3	0.22				
Etheostoma flabellare	Fantail darter	42	3.61	3	0.22	14	5.98		
Etheostoma punctulatum	Stippled darter			19	1.38				
Etheostoma spectabile	Orangethroat darter	139	11.94	126	9.16	9	3.85	14	1.87
Etheostoma zonale	Banded darter			41	2.98				
Percina caprodes	Logperch			1	0.07				
Cottidae	Sculpins								
Cottus carolinae	Banded sculpin	487	41.84	56	4.07	27	11.54	231	30.88
	Number of Species	14		24		10		12	
	Number of Specimens	1164		1376		234		748	
	Effort (sec)	4979		3148					
	Catch Ratio	0.23		0.44					