WATER QUALITY SURVEY
OF
THE BERRYVILLE STP EFFLUENT
ON FREEMAN BRANCH AND OSAGE CREEK
JUNE 18, 1992

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INTRODUCTION

A water quality investigation was conducted on Freeman Branch, the receiving stream of the Berryville municipal wastewater treatment facility, and also on Osage Creek, the receiving stream of the Freeman Branch discharge, in order to determine the level of impact this discharge is having on the water quality and aquatic inhabitants of the receiving streams. This stream survey had a dual purpose--to address concerns of the Arkansas Game and Fish Commission regarding diseased and/or deformed fish in Osage Creek in the vicinity of the STP discharge, and also to determine if any enhancement of water quality could be ascertained due to the upgraded Berryville wastewater treatment facility. This investigation was conducted on August 26-28, 1991. A preliminary survey was completed on August 21 for the purpose of determining stream accessibility and potential station locations.

GENERAL DISCUSSION

I. Waterway Description

Osage Creek has its origin near the town of Compton in the northern edge of Newton County. It flows in a northwest direction across Carroll County and joins the Kings River approximately four miles northwest of Berryville. Osage Creek drains about 150 square miles at the Freeman Branch confluence and 164 square miles at its mouth. Freeman Branch is a small intermittent stream, draining approximately three square miles. The Berryville STP effluent discharges into Mill Branch, which flows 0.1 miles prior to discharging to Freeman Branch, which flows 0.6 miles to Osage Creek. The stream gradient for these small tributary streams is on the order of 60 feet/mile, while the stream gradient for Osage Creek at the Freeman Branch confluence is in the 10-15 feet/mile range. The substrate composition of both streams consisted predominantly of bedrock, boulders, rubble and gravel. The pool/riffle ratio in the study area of Osage Creek was approximately 4 to 1, while Freeman Branch was closer to 2 to 1, due to the higher stream gradient. There is an abundance of habitat cover available to both aquatic invertebrates and fish in Freeman Branch and Osage Creek. At the time of the survey, stream flow in Freeman Branch was measured at 2.3 cfs (cubic feet per second), while the Osage Creek flow above the Freeman Branch confluence was 6 cfs.

II. Previous Studies

In October of 1981, the consulting firm of Brown and Caldwell was hired to conduct a water quality investigation for the purpose of determining the impact of the Berryville STP on the water quality of the receiving stream and to project future effluent limitations that would maintain the water quality standards in existence at that time. At the time of this survey, the Berryville wastewater treatment facility consisted of a two-stage trickling filter and was discharging a 1.16 MGD (million gallons per day) volume effluent containing 40 mg/l BOD5, 36 mg/l TSS, and 39 mg/l NH3N. Their dissolved oxygen analysis in Freeman Branch over a 24 hour sampling period revealed concentrations of 8 mg/l below the STP outfall to 3.7 mg/l at the mouth of this stream. This indicated a deficit of over 4 mg/l taking place within the 0.6 mile stream reach. Stream temperatures ranged from 20 degrees Centigrade at the outfall to 15 degrees at the mouth. Their conclusions also stated Freeman Branch was of noticeably poor quality, with septic organic sludge deposits present in significant amounts. They also recorded the presence of a noticeable "mixing zone" in Osage Creek below the confluence of Freeman Branch. Their recommendations were that an upgrade or replacement of the existing treatment facility would be necessary to achieve maintenance of the existing water quality standards of the receiving stream.

An April 4, 1991 survey of Osage Creek at Berryville was conducted by Martin Maner, a regional ADPC&E engineer, in response to Game and Fish Commission concerns of possible diseased fish in this stream vicinity. This investigation was to determine if there were any unknown dischargers entering Osage Creek, or possible water quality conditions conducive to causing fish diseases in this portion of the stream. The survey consisted of floating the stream from Freeman Branch confluence to the Kings River, making visual observations and performing a dissolved oxygen profile. This report concluded that there were no apparent adverse water quality conditions in this portion of Osage Creek.

III. Land Use

Approximately 35 percent of the Osage Creek watershed has been converted to agricultural uses--predominantly pasturelands for cattle grazing. Much of the upper watershed is still forested, but in the lower portion where the terrain is less steep, there is an abundance of cleared land adjacent to the stream. Poultry production houses are scattered throughout the watershed, as well as a few confined swine operations. The waste products from these activities are periodically applied to pasturelands. A small amount of acreage has been converted to urban usage, with the largest area in and around Berryville.

IV. Geology

Osage Creek and its tributaries lie within the Springfield Plateau of the Ozark Highlands ecoregion. The geology of the upper portion of the Osage Creek basin is characterized by the Atoka Formation, Bloyd Shale, and the Prairie Grove member of the Hale Formation. The remainder of the watershed, including the survey area, is characterized by the dolomitic limestones of the Cotter and Jefferson City Dolomites. This is an area of karst geology and contains some subsurface fractures and springs, but not to the extent of the surrounding areas of Boone Formation, which contain innumerable solutionally enlarged fractures, cave systems, sinkholes and springs.

V. Water Quality Standards And Beneficial Uses

Osage Creek, which drains a 150 mi^2 watershed above the Berryville vicinity, is classified as an Ozark Highlands large watershed perennial fishery, and as such, has an applicable dissolved oxygen standard of 6 mg/l, with a 1 mg/l diurnal fluctuation being allowed for no longer than 8 hours in a 24 hour period when the stream temperature exceeds 22 degrees Centigrade. At stream temperatures of 22 degrees C. or less, the 6 mg/l standard generally applies. The exception to this is during the March through May time frame when the stream temperature is 10 degrees or less, and the stream flow exceeds 15 cfs. At these conditions, the dissolved oxygen standard is 6.5 mg/l. The Freeman Branch tributary would normally be classified as a small watershed seasonal fishery; however, due to the volume of the wastewater discharge from the Berryville facility, the next higher watershed category applies. A mid-size perennial fishery has an applicable dissolved oxygen standard of 5 mg/l at stream temperatures exceeding 22 degrees C., with the diurnal fluctuation allowed. At temperatures of 22 degrees or less, a 5 mg/l standard, without fluctuation, applies.

Designated beneficial uses of these streams consist of primary and secondary contact recreation-which includes wading, canoeing, fishing, and swimming-as well as a source of water for domestic, industrial and agricultural uses.

DATA ACQUISITION

During the afternoon of August 26, 1991, the survey crew arrived at the Osage Creek survey site, completed stream flow measurements and installed continuous dissolved oxygen meters above and below the Freeman Branch confluence. On August 27, 1991, Osage Creek was sampled for macroinvertebrate and fish species and numbers above the mouth of Freeman Branch, in Freeman Branch, and downstream of the Freeman Branch confluence. Grab samples for water quality determinations were collected on August 28 and returned to the central

laboratory for analysis.

VI. Parameters

In addition to the biological samples, these streams were sampled for dissolved oxygen, temperature, pH, flow, chlorides, total organic carbon, biochemical oxygen demand (BOD), total suspended solids, total dissolved solids, ammonia nitrogen, nitrite + nitrate nitrogen, orthophosphate, and total phosphate.

VII. Collection, Preservation And Measurements

Stream samples were collected, preserved, and analyzed according to the 16th Edition of Standard Methods for Examination of Water and Wastewater. Analysis was conducted under ADPC&E's existing Quality Assurance Program. Dissolved oxygen and stream temperature during sample collection were measured by a Y.S.I. Model 57 portable dissolved oxygen meter, which was calibrated by a Winkler titration prior to use. Two Model 56 continuous dissolved oxygen meters were used to determine diurnal variation in the dissolved oxygen concentration in Osage Creek above the Freeman Branch confluence and in Osage Creek downstream of the mixing zone below the Freeman Branch discharge. Stream pH was analyzed by an Orion SA 230 portable pH meter, which was calibrated using buffer solutions of pH 4 and 7. Stream flow was measured using a Marsh-McBirney Model 201 meter by obtaining a representative number of velocities and depths across suitable stream locations. Flows were taken in Osage Creek above and below Freeman Branch, and also in Freeman Branch. Macroinvertebrate samples were collected at the same three locations, using an indestructible Turtox benthos net. An attempt was made to sample all types of habitat. The fish community was sampled by use of a Honda backpack AC generator. Riffle areas were sampled by driving the fish into a seine, while the fish in the pools were collected by electroshocking favorable habitat areas.

VIII. Station Description

A total of four water chemistry stations were established on Osage Creek, and one station in Freeman Branch. These stations were selected for the purpose of determining any impacts from non-point source contaminants, as well as determination of any impact from the Berryville STP effluent on Freeman Branch and Osage Creek. Stations were spaced in order to determine any dissolved oxygen sag due to the effluent load on Osage Creek. The station descriptions are as follows:

Station 1. Osage Creek 200 yards above the Freeman Branch confluence

Station 2. Osage Creek 30 yards below Freeman Branch

Station 3. Osage Creek 800 yards below Freeman Branch

Station 4. Osage Creek two miles below Freeman Branch

Station 5. Freeman Branch 50 yards above Osage Creek

Three stations were sampled for macroinvertebrates and fishes. These communities were analyzed on an upstream/downstream basis, as well as the identification of the aquatic inhabitants of Freeman Branch, for determination of any adverse impacts on population diversity and density. Figures 1 and 2 provide the locations of water sampling stations, as well as areas sampled for aquatic life.

DATA RESULTS

IX. Dissolved Oxygen

The dissolved oxygen profile was evaluated two times during the survey of Osage Creek. During the preliminary investigation the dissolved oxygen concentrations were around 90% saturation in the upper stations (including Freeman Branch), and 83% saturation at the downstream station two miles below Freeman Branch. This D.O. profile was conducted during the late morning hours from 10:00 A.M. to 12:00 P.M. Stream temperatures ranged from 21 to 22 degrees Centigrade. The second profile was taken during the water chemistry sampling effort on August 28. The saturation values were substantially lower during this sample, averaging 70 to 75% at the upper stations, and dropping to 64% at the lower downstream station. Stream temperatures were in the 23-24 degree range, with the D.O. sampling conducted between 8:00 A.M. and 10:00 A.M. Weather conditions had an effect on the dissolved oxygen saturation values. The August 21 profile was conducted under a cloud cover, and the area had cloud cover and a light rainfall the previous day also. The August 28 profile followed a relatively clear day, as was the condition during this D.O. profile. This situation results in greater photosynthetic activity during the daylight hours, with the dissolved oxygen concentration fluctuation peaking in late afternoon, and falling to its lowest value during the time just prior to sunrise. This phenomenon is commonly associated with an increase in nutrients to the stream, thereby enhancing algal productivity. The watershed runoff from the previous week's rainfall undoubtedly resulted in a nutrient increase in Osage Creek. Two continuous dissolved oxygen meters were placed in Osage Creek at Station 1 upstream of Freeman Branch, and between Stations 2 and 3, below Freeman Branch, in order to determine the extent of the

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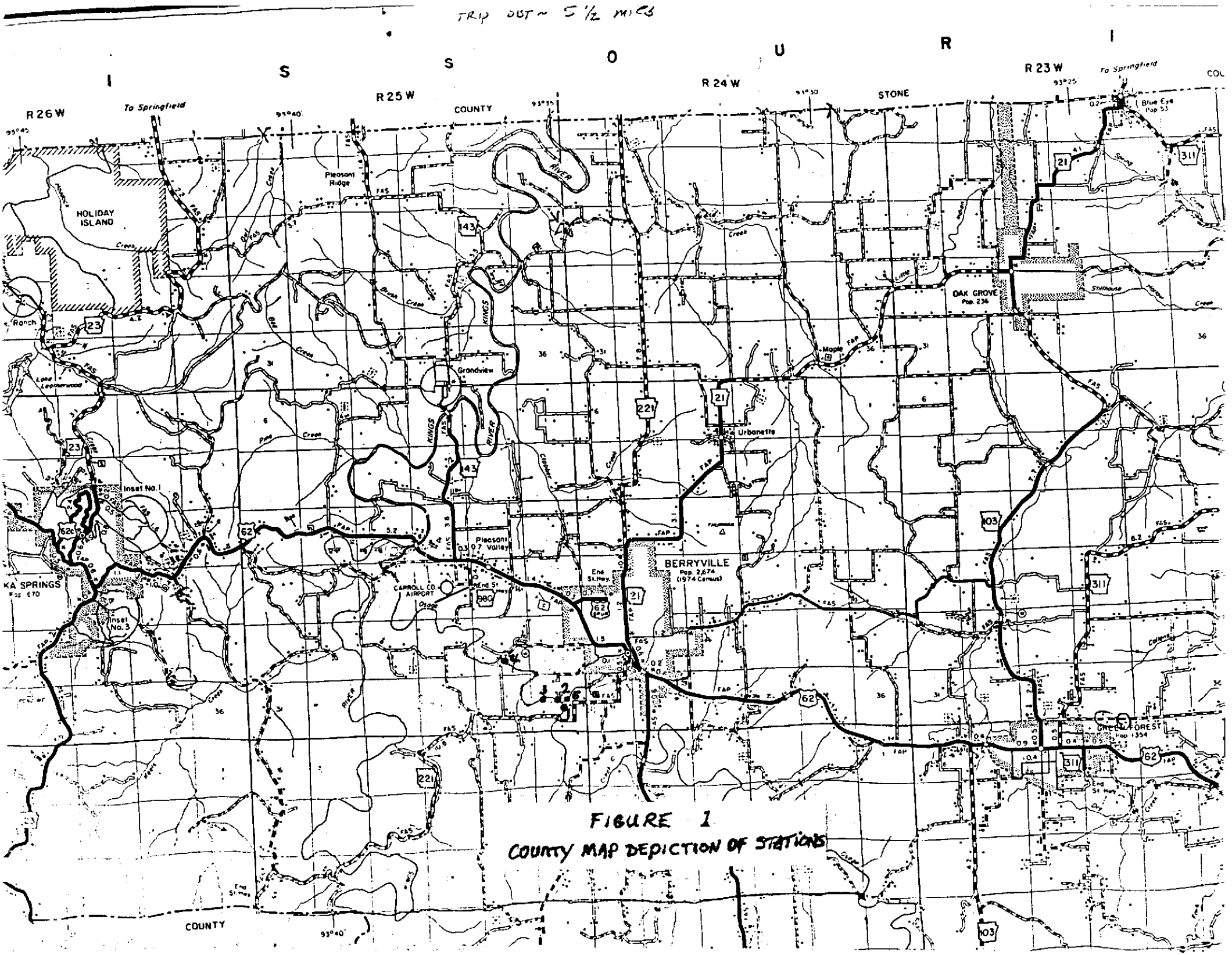

FIGURE 1

COUNTY MAP DEPICTION OF STATIONS

FIGURE 2

TOPOGRAPHIC DEPICTION OF FISH & MACROINVERTEBRATE COLLECTION SITES

diurnal fluctuation over a 48 hour period. Figures 3 and 4 show the dissolved oxygen fluctuation at these two stations during the August 26-28 survey. The upstream station had a diurnal fluctuation of approximately 2 mg/l, while the lower station had a fluctuation of 4 mg/l. Both these values are within the range of fluctuations recorded in the ecoregion study of the Ozark Highlands. Diurnal fluctuations of this magnitude generally reflect the land use patterns of this ecoregion--the predominance of pasturelands, poultry and swine production, and subsequent land application of waste products from these activities. The increase in the diurnal fluctuation at the lower station is probably due in part to the positioning of the continuous dissolved oxygen meter. The meter at this location was in a long, wide pool in which the stream velocity was decreased, allowing a greater potential for algal activity. The upstream meter was located in a much narrower, shorter pool with a quicker flow-through time. However, there are also indications that nutrient enrichment from the STP discharge has increased periphyton production which increases dissolved oxygen during daylight and decreases dissolved oxygen during the nighttime.

X. pH And Temperature

Stream pH values measured during this survey were typical for streams in the Ozark Highlands ecoregion. The values ranged from 7.8 upstream to 7.6 at the lowest downstream station. The 1984 ecoregion evaluation indicated a summertime average pH of 7.6 for all size watersheds studied. Likewise, the stream temperatures were similar to those values measured in the ecoregion study. The cool summer temperatures are a reflection of the karst geology of this region that produces numerous springs in the watershed.

XI. Flow

According to USGS data from 1951 to 1963, Osage Creek at Berryville has a Q7-10 of 0.1 cfs. Stream flows are typically much higher than that value during the summer months. During Martin Maner's April, 1991 survey, flows were estimated at 75 to 100 cfs. This is consistent with springtime flows measured in the 1984 ecoregion survey of similar size streams. Long Creek, at a 184 square mile watershed, had a 183 cfs flow on 5-1-85. War Eagle Creek, with a 263 mile watershed, had a 5-13-86 flow of 102 cfs. Summer flows are also consistent with ecoregion data. Long Creek had a flow of 9.5 cfs on August 28, 1984. Osage Creek above Freeman Branch had a 6 cfs flow on August 27, 1991. The Freeman Branch flow was measured at 2.3 cfs, which consisted almost entirely of Berryville's wastewater discharge.

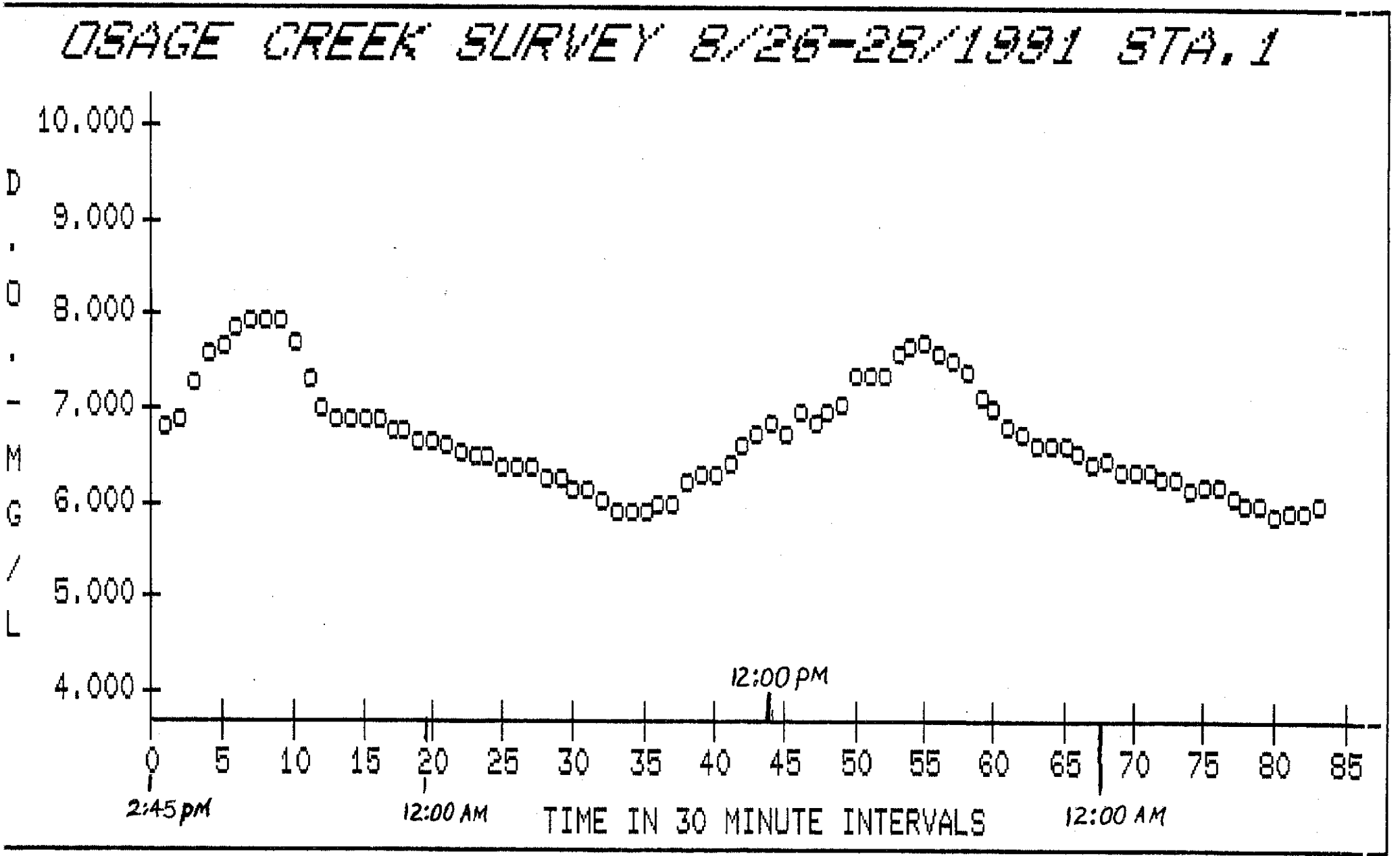

FIGURE 3 - DISSOLVED OXYGEN CONCENTRATION PROFILE: UPSTREAM

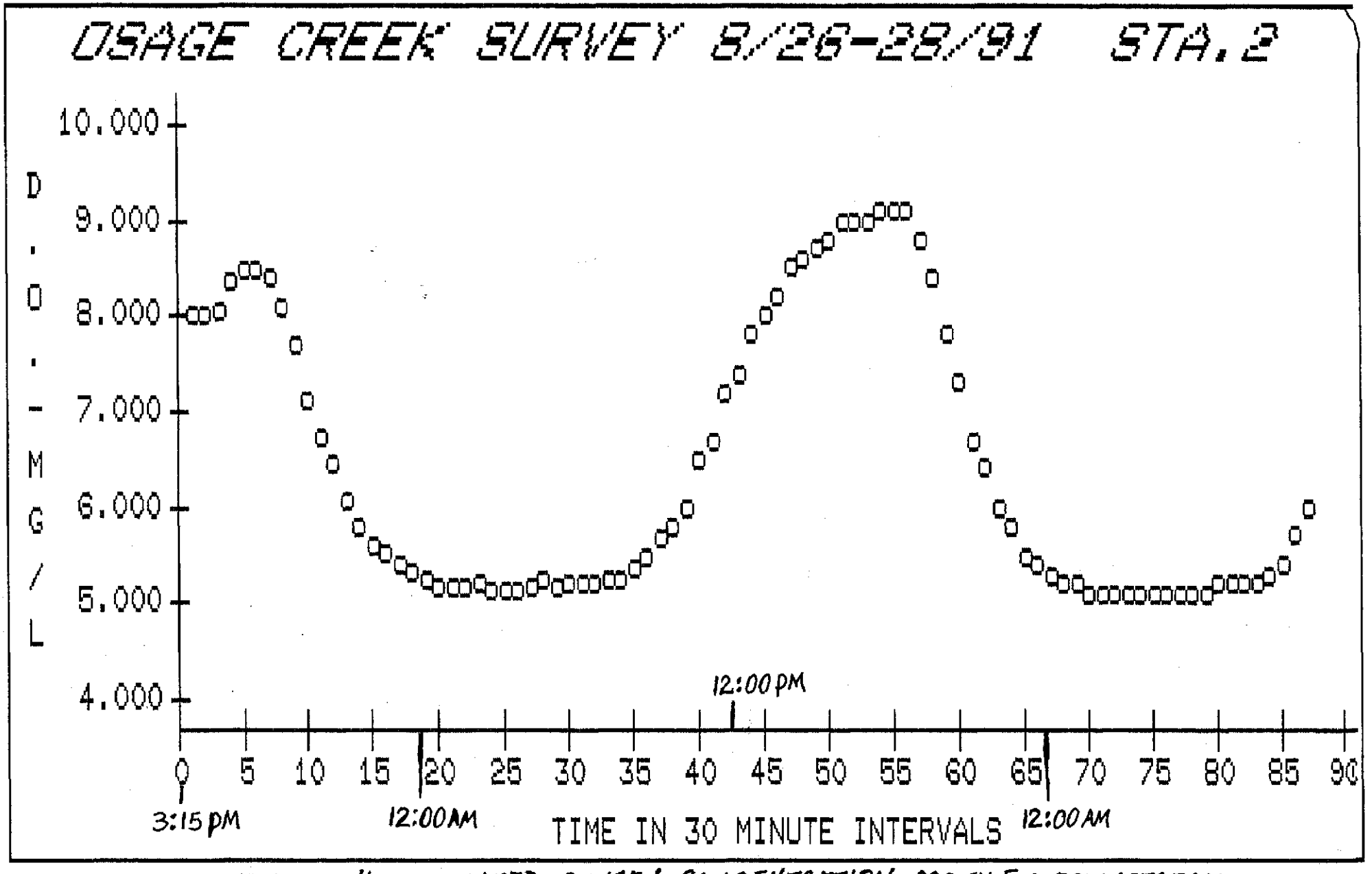

FIGURE 4 - DISSOLVED OXYGEN CONCENTRATION PROFILE : DOWNSTREAM

XII. Chlorides And Total Dissolved Solids

ADPC&E's on-going water monitoring network has established two stations on Osage Creek--one just above the Berryville STP effluent (at the highway bridge just above Station 1), and one approximately five miles below this discharge. The 1990 biennial Water Quality Inventory Report (305-b) summarized two years of monthly samples from these two sites. The mean value for chlorides at the upstream station was 3.6 mg/l, while the mean value for the downstream site was 8.8 mg/l. Recent data analyses to be included in the 1992 305-b report indicate that the downstream values are close to the 20 mg/l range, with the July 1991 sample measuring 54 mg/l. This value is similar to the chloride concentrations found in the August 28, 1991 samples. The upstream sample had a chloride value of 4.8 mg/l, stations 2,3, and 4 had values of 53, 55, and 53 mg/l, respectively, while station 5 (Freeman Branch) had a chloride concentration of 167 mg/l. Total dissolved solids from the 305-b data base follow a similar pattern, from an upstream level of 140 mg/l to a downstream mean concentration of 163 mg/l (1990 data). The 1992 data again show a major increase downstream from the 1990 values, with total dissolved solids concentrations exceeding 200 mg/l. The August 28 data show similar increases from the upstream station to the downstream locations--154 mg/l up to over 370 mg/l. Although sulfates were not analyzed from the August 28, 1991 samples, similar increases are noted from the 305-b data base; with a major increase seen within the last two years at the downstream water quality monitoring station.

XIII. BOD, TSS, And Nutrients

As noted earlier, the Brown and Caldwell 1982 report recorded five day BOD's averaging 40 mg/l, total suspended solids of 36 mg/l, and ammonia nitrogen values averaging 39 mg/l during their survey period. Based on the effluent requirements determined by this initial study and subsequent stream modeling, a new wastewater treatment facility was constructed for Berryville. This new facility-an oxidation ditch system-went into operation in the mid-1980's. The treatment efficiency of the new plant has resulted in a dramatic reduction in BOD, TSS, and NH3N loading on Freeman Branch and Osage Creek. An analysis of a recent 12 month period of DMR's (discharge monitoring reports) showed an average five day BOD of 3 mg/l at the STP effluent pipe. The TSS concentration for this same time period was 5 mg/l, while the NH3N concentration averaged .36 mg/l. None of stream station sampled during the August 28, 1991 survey had five day BOD values higher than 1.2 mg/l. The 1.2 mg/l sample was taken at the upstream station, while the lowest value (.6 mg/l) was from Freeman Branch. Similarly, the TSS values were lowest in Freeman Branch and highest at the upstream and lowest downstream station (13 and 14 mg/l, respectively). Ammonia nitrogen concentrations were basically the same at all

stations sampled. Nitrate plus nitrite nitrogen, which are products of the oxidation of ammonia nitrogen, did show an increase from the upstream to the downstream stations, and the increase can be attributed to the STP effluent. This parameter rose from 0.03 mg/l at station 1 to 0.45 mg/l at station 2, which represents a fifteen-fold increase. The Freeman Branch sample had a concentration of 1.4 mg/l. Also, the ortho and total phosphate concentrations showed a four to five-fold increase from the upstream to downstream stations, again due to the STP effluent. Although the nitrates and phosphates from the Berryville treatment facility result in multi-fold increases in these nutrients in and below the Freeman Branch confluence with Osage Creek, these values are relatively low in comparison with other advanced treatement systems in the state. This nutrient increase, however, serves as a catalyst to enhance algal growth and thereby create more severe fluctuations in the dissolved oxygen concentration in the receiving streams. Appendix A presents the analyses of the water chemistry samples taken during this survey.

XIV. Macroinvertebrates

A total of three sampling stations were established for this survey. One station was located on Osage Creek above the Freeman Branch confluence, in the vicinity of the upstream water sampling location. The other Osage Creek station was below Freeman Branch in the stream stretch between water sampling stations 2 and 3. It was assumed that the Freeman Branch discharge was completely mixed with Osage Creek at this point. The third station was above the mouth of Freeman Branch. These three stations were sampled with a Turtox indestructible benthos net for a total of ten minutes at each site. All available habitat types were sampled at each area. The samples were picked on-site and preserved in 70% ethanol for laboratory identification. The benthic species lists generated from this survey are included as Appendix B.

The data analysis of the macroinvertebrate inhabitants consisted of an abbreviated use of the Biometric Scoring System in which the various characteristics (metrics) of the benthic community are assigned a score based on criteria that define a relative change between communities upstream and downstream from a pollutant source. Biometrics evaluated included Dominants in Common (DIC), Common Taxa Index (CTI), Quantitative Similarity Index (QSI), Taxa Richness, and Functional Group Percent Similarity (FGPS). The application of these biometrics relating to community structure and diversity all fell within the minimal to no impairment categories. There was a decrease in taxa from upstream to downstream (52 versus 43), and also a decrease in total number of specimens (1024 versus 774). Specimen counts were elevated due to high numbers of single species of snails

(Elimia), clams (Corbicula), and damselfly naiads (Coenagrion) at both stations. These three taxa comprised 45% of the upstream numbers and 52% of the downstream specimens. One pollution intolerant sideswimmer species, Hyalella azteca, was abundant in the upstream sample and missing from the downstream location. This might suggest the presence of a comtaminant that affects this organism specifically, entering Osage Creek via the Freeman Branch drainage. The diversity indices calculated for these two stations also indicates a minimal impairment, with a value of 4.12 upstream compared to 3.85 below the Freeman Branch confluence.

The macroinvertebrate community in Freeman Branch appears to be severely impacted both quantitatively and qualitatively. Only eight taxa were collected at this site, and a total of 49 specimens. Two damselfly species comprised over 50% of the total specimen count. The diversity index for this sample was 2.41. The subtle changes occuring in the benthic community assemblage in Osage Creek upstream of Freeman Branch to the downstream location might become obvious changes in the absence of upstream dilution flow. This supposition is borne out by the impaired state of the Freeman Branch benthic community.

XV. Fish Community

Fish communities were sampled in Osage Creek above the confluence of Freeman Branch (Osage A), in Osage Creek below the confluence of Freeman Branch (Osage B), and in Freeman Branch from its mouth to several hundred yards upstream, as shown in Figure 2. Appendix C lists the species collected at each site and the relative abundance for each species. The relative abundance value is based on the numerical abundance of the species relative to the habitat and the typical abundance of the species. A value from one to four is assigned to the adult and the sub-adult segment of each species population. The maximum relative abundance value for any species is eight.

Fish community samples from Osage A and Osage B contained 32 species each, and the total relative abundance value from Osage B was slightly higher than Osage A. Similarity indices of these two communities based on the number of common species and the similarity of the species relative abundance values were 87.5% and 82.7% respectively. A value of 100% indicates identical communities. It is therefore concluded that the fish communities of Osage Creek above and below Freeman Branch are very similar. The few differences shown are likely related to slight differences in the habitats collected above and below the Freeman Branch confluence. One noticeable difference in these communities which may be related to nutrient enrichment of Osage Creek below Freeman Branch is the substantial difference in the abundance of the

Ozark Minnow and the Bluntnose Minnow above and below Freeman Branch. The relative abundance value of the Ozark Minnow was 4.5 above Freeman Branch and 8.0 below. The number of individuals collected was 12 above and 296 below. Also, the Bluntnose Minnow had a relative abundance value of 1.0 above and 6.0 below the confluence of Freeman Branch with Osage Creek. The number of individuals collected was 1 above and 35 below. Both these species are primary feeders, with planktonic and periphytic algae and diatoms comprising their primary diet.

The fish community of Freeman Branch contained 17 species. This could be considered species rich for a stream of its size; however, the abundance of all species except the Stoneroller and the Duskystripe Shiner was very low. This indicates that the stream supports a fish community with a substantially reduced biomass. This reduction is not a result of limited habitat, but is likely a result of a limited food source. The relatively large number of species with low number of individuals in Freeman Branch reflects migrants from Osage Creek and a low resident population of fishes in Freeman Branch. The species list and relative abundances of fishes from these three collection sites are included as Appendix C.

CONCLUSIONS

A review of the water chemistry analyses in terms of permitted constituents in the Berryville wastewater effluent discharge indicates an excellent removal efficiency for BOD, TSS, and NH3N, with values of 0.6, 4.5, and 0.13 mg/l, respectively, at the Freeman Branch confluence with Osage Creek. Even an evaluation of the same constituents from an upstream/downstream comparison indicates a slight reduction in concentrations of these parameters downstream of Freeman Branch. If the review ended with these parameters, it would seem evident that there were no adverse impacts on water quality from this wastewater discharge; however, a review of the non-permitted wastewater constituents-chlorides, nitrates, phosphates-indicates that a change in water quality is occuring due to the wastewater influence. A ten-fold increase in chloride concentration, a fifteen-fold increase in nitrate concentration, and a five-fold increase in phosphate concentration from the upstream Osage Creek station to the downstream location lends credence to the assumption that subtle adverse impacts are occuring in this stream due to the STP effluent. These assumptions are borne out in the analyses of the benthic and fish communities collected above and below the Freeman Branch confluence, as well as by the diurnal dissolved oxygen concentrations measured at these two stations.

Dissolved oxygen concentrations at the upstream station ranged from a minimum of around 6 mg/l to a maximum of 8 mg/l, while at the downstream location the minimum was just

below 5 mg/l, with a maximum concentration of 9 mg/l. This diurnal fluctuation of over 4 mg/l indicates the presence of substantial algae populations at the downstream site; a situation that is enhanced by a nutrient influx. The benthic community underwent subtle changes from the upstream station to the downstream in that the diversity index decreased, and a pollution intolerant species (Hyalella azteca), present in the upstream sample in abundance, was not found at the downstream site. The fish communities, although quite similar at both sites, also indicated changes due to a nutrient influx in that two primary feeder species, the Ozark Minnow and the Bluntnose Minnow, were few in number at the upper station and quite abundant at the downstream site. The primary food source of these species is planktonic and periphytic algae and diatoms.

An isolated evaluation of individual components of this study might not indicate a stream impairment in Osage Creek. However, chlorides, total dissolved solids and probably sulfates exceed water quality standards. The benthic communities are quite similar, though differences are present, and the fish inhabitants are also very similar in composition, with the differences mentioned above. However, the cumulative changes in all components of the study from the upstream site on Osage Creek to the downstream Osage Creek site reveal a stream impact is occuring due to nutrient enrichment from the wastewater discharge from the Berryville STP. In contrast, a significant impairment is evident in Freeman Branch. This impairment appears to be of a toxilogical nature as reflected by the severe reduction in the macroinvertebrate community and the limited fish numbers. The toxic compounds apparently occur frequently, but are broken down or substantially diluted by Osage Creek. Water quality data indicate that ammonia is no longer the likely cause of toxicity. Although not measured in the survey, chlorine is strongly suspected as the toxic agent.

RECOMMENDATIONS

It is recommended that the City of Berryville begin immediately planning for modification of their STP discharge to include effluent dechlorination. Additionally, investigations should be made to identify the source of elevated chlorides, total dissolved solids, and sulfates in preparation for meeting discharge limits of these constituents in their next permit renewal.

APPENDIX A

ARKANSAS DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY

TO: Bob Singleton

FROM: Dick Cassat

DATE: September 18, 1991

SUBJECT: Osage Creek Samples

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The August 28, 1991, Osage Creek and Freeman Branch samples have been analyzed. The results are below.

#1 Osage Creek above Berryville (Freeman Branch)
#2 Osage Creek below Berryville (Freeman Branch)
#3 Osage Creek ½ mile below Freeman Branch
#4 Osage Creek 2 miles below Freeman Branch
#5 Freeman Branch

	#1	#2	#3	#4	#5
Chloride (mg/l)	4.8	53.4	55.0	53.0	167
Total Organic Carbon (mg/l)	6.3	7.0	8.3	6.7	8.0
Field Dissolved Oxygen (mg/l)	6.4	6.2	6.1	5.4	6.7
BOD (mg/l)	1.2	0.9	0.9	1.1	0.6
Field pH	7.84	7.77	7.70	7.64	7.87
Total Suspended Solids (mg/l)	13	10	9	14	4.5
Total Dissolved Solids (mg/l)	154	380	398	372	217
Ammonia as Nitrogen (mg/l)	0.17	0.15	0.14	0.15	0.13
Nitrate+Nitrite-N (mg/l)	0.03	0.45	0.51	1.04	1.40
Orthophosphate as P (mg/l)	0.04	0.18	0.24	0.28	0.82
Total Phosphate as P (mg/l)	0.06	0.29	0.32	0.36	0.93

APPENDIX B

Benthic Bioassessment
Station # WHI0068
Osage Cr AB Berryville AR
Eco Reg.# OZHI
Segment # 4K
Sample Date 91-08-27
Sample Time 0000
Sampling technique employed 10MAAH
Printed on 19-FEB-1992

# of Taxa = 52 # of organisms = 1032 Biotic score = 0
% Annelida = 0.5
# Ephemeroptera taxa = 10 % Ephemeroptera = 17.9
# Trichoptera taxa = 4 % Trichoptera = 1.0
# Coleoptera taxa = 11 % Coleoptera = 9.6
# Chironomidae taxa = 3 % Chironomidae = 1.1

Diversity index = 4.1267767

Group summary

SH= 11 CO= 3 SC= 242 PR= 419 GC= 225 FC= 132

SH%= 1 CO%= 0 SC%= 23 PR%= 40 GC%= 21 FC%= 12

Bio #	Name			Gr	Count	%
18020408004	DAMSELFLY NAIAD	Chromagrio		PR	240	23.3
19050404001001	CLAM	Corbicula	flueminia	FC	115	11.1
19030215999	SNAIL	Elimia		SC	105	10.2
18010201001001	SIDESWIMMER	Hyalella	azteca	GC	103	10.0
18020502002	MAYFLY NYMPH	Tricorytho		GC	51	4.9
18021215005	BEETLE, ELMID, LARVA	Dubiraphia		SC	39	3.8
18020802001001	HELLGRAMMITE	Corydalus	cornutus	PR	38	3.7
18020510007	MAYFLY NYMPH	Stenonema		SC	38	3.7
18020510007024	MAYFLY NYMPH	Stenonema	luteum	SC	38	3.7
18050103001	WATER MITE	Lebertia		PR	34	3.3
1802120900300001	BEETLE, WATER SCAVEN	Berosus-la		PR	29	2.8
18020408003	DAMSELFLY NAIAD	Argia		PR	25	2.4
18021215005002	BEETLE, ELMID,ADULT	Dubiraphia	quadrinota	GC	15	1.5
18020511005	MAYFLY NYMPH	Isonychia		FC	15	1.5
18020508002	MAYFLY NYMPH	Baetis		GC	14	1.4
18020501004	MAYFLY NYMPH	Hexagenia		GC	11	1.1
18020410002	DRAGONFLY NAIAD	Macromia		PR	9	0.9
18020801001	ALDERFLY LARVA	Sialis		PR	9	0.9
18020503002	MAYFLY NYMPH	Caenis		GC	8	0.8
19030215001	SNAIL	Pleurocera		SC	8	0.8
18020404003001	DRAGONFLY NAIAD	Basiaeschn	janata	PR	7	0.7
18020405018	DRAGONFLY NAIAD	Libellula		PR	7	0.7
180211158	BLOODWORM	Chironomin		PR	6	0.6
18010302003	CRAYFISH	Orconectes		SH	6	0.6
18021217002	BEETLE, RIFFLE, LARV	Ectopria		SC	5	0.5
18020501002004	MAYFLY NYMPH	Ephemera	simulans	GC	5	0.5
18020708006	CADDISFLY LARVA	Triaenodes		SH	5	0.5
18020503001	MAYFLY NYMPH	Brachycerc		GC	4	0.4
18020614001	BUG, WATER TREADER	Mesovelia		PR	4	0.4
1802121501200102	BEETLE, ADULT ELMID	Macronychu	glabratus	GC	4	0.4

19031002004	SNAIL	Lymnaea		SC	3	0.3
18020718006003	CADDISFLY LARVA	Polycentro	cinereus	PR	3	0.3
18021115	BLOODWORM	Chironomid		CO	3	0.3
1802120900300002	BEETLE, WATER SCAVEN	Berosus		GC	2	0.2
17010101017	AQUATIC EARTHWORM	Branchiura		GC	2	0.2
18021115018	BLOODWORM	Clinotanyp		PR	2	0.2
18020403002002	DRAGONFLY NAIAD	Dromogomph	spinosus	PR	2	0.2
17010102	AQUATIC EARTHWORM	Naididae		GC	2	0.2
18020610004	BUG, POND SKATER	Trepobates		PR	2	0.2
8021215020	RIFFLE BEETLE, ADULT	Stenelmis	adult	GC	2	0.2
18020704002	CADDISFLY LARVA	Cheumatops		FC	1	0.1
1802121500200102	BEETLE, ELMID ADULT	Ancyronyx	variegata	GC	1	0.1
18020409003	DRAGONFLY NAIAD	Epicorduli		PR	1	0.1
18020510007003	MAYFLY NYMPH	Stenonema	femoratum	SC	1	0.1
1802121501200101	BEETLE, ELMID, LARVA	Macronychu	glabratus	SC	1	0.1
18021001003	AQUATIC CATERPILLAR	Parargyrac		SC	1	0.1
17010202	AQUATIC EARTHWORM	Lumbriculi		GC	1	0.1
18021217004	WATER PENNY	Psephenus		SC	1	0.1
18020611001	BUG, BR SHD WATERSTR	Rhagovelia		PR	1	0.1
18021215020	BEETLE, ELMID, LARVA	Stenelmis		SC	1	0.1
18021213001	BEETLE	Cyphon		SC	1	0.1
18020702001999	CADDISFLY LARVA	Chimarra		FC	1	0.1

Benthic Bioassessment
Station # WHI0069
Osage Cr BL Berryville AR
Eco Reg.# OZHI
Segment # 4K
Sample Date 91-08-27
Sample Time 0000
Sampling technique employed 10MAAH
Printed on 19-FEB-1992

# of Taxa = 43 # of organisms = 774 Biotic score = 0
% Annelida = 0.6
# Ephemeroptera taxa = 8 % Ephemeroptera = 21.3
# Trichoptera taxa = 2 % Trichoptera = 0.5
# Coleoptera taxa = 9 % Coleoptera = 8.5
# Chironomidae taxa = 4 % Chironomidae = 7.1

Diversity index = 3.8436511

Group summary

SH= 3 CO= 15 SC= 151 PR= 238 GC= 206 FC= 161

SH%= 0 CO%= 1 SC%= 19 PR%= 30 GC%= 26 FC%= 20

Bio #	Name		Gr	Count	%
18020408004	DAMSELFLY NAIAD	Chromagrio	PR	170	22.0
19050404001001	CLAM	Corbicula flueminia	FC	135	17.4
19030215999	SNAIL	Elimia	SC	98	12.7
18020502002	MAYFLY NYMPH	Tricorytho	GC	82	10.6
18021215005002	BEETLE, ELMID,ADULT	Dubiraphia quadrinota	GC	40	5.2
18021115016	BLOODWORM	Chironomus	GC	28	3.6
18020503002	MAYFLY NYMPH	Caenis	GC	25	3.2
18020511005	MAYFLY NYMPH	Isonychia	FC	23	3.0
19031003003	LIMPET	Ferrissia	SC	17	2.2
18020408003	DAMSELFLY NAIAD	Argia	PR	16	2.1
18020802001001	HELLGRAMMITE	Corydalus cornutus	PR	16	2.1
18021115	BLOODWORM	Chironomid	CO	15	1.9
18020510007024	MAYFLY NYMPH	Stenonema luteum	SC	12	1.6
18021115018	BLOODWORM	Clinotanyp	PR	11	1.4
18020501004	MAYFLY NYMPH	Hexagenia	GC	9	1.2
18020508002	MAYFLY NYMPH	Baetis	GC	8	1.0
18021209003000001	BEETLE, WATER SCAVEN	Berosus-la	PR	7	0.9
18021215005	BEETLE, ELMID, LARVA	Dubiraphia	SC	5	0.6
17010202	AQUATIC EARTHWORM	Lumbriculi	GC	5	0.6
18020510007	MAYFLY NYMPH	Stenonema	SC	5	0.6
18021215012001002	BEETLE, ADULT ELMID	Macronychu glabratus	GC	4	0.5
18021215020	BEETLE, ELMID, LARVA	Stenelmis	SC	4	0.5
18020704002	CADDISFLY LARVA	Cheumatops	FC	3	0.4
18010302003	CRAYFISH	Orconectes	SH	3	0.4
18050103001	WATER MITE	Lebertia	PR	3	0.4
19031002004	SNAIL	Lymnaea	SC	3	0.4
18020610004	BUG, POND SKATER	Trepobates	PR	3	0.4
8021215020	RIFFLE BEETLE, ADULT	Stenelmis adult	GC	3	0.4
18020404003001	DRAGONFLY NAIAD	Basiaeschn janata	PR	2	0.3
18020403002002	DRAGONFLY NAIAD	Dromogomph spinosus	PR	2	0.3
18021214002000002	BEETLE, DRYOPID	Helichus	SC	2	0.3

18020411002	DAMSELFLY NAIAD	Hetaerina		PR	2	0.3
19031005002	SNAIL	Physa		SC	2	0.3
18021217004	WATER PENNY	Psephenus		SC	2	0.3
1802121500200102	BEETLE, ELMID ADULT	Ancyronyx	variegata	GC	1	0.1
18021115026	BLOODWORM	Cryptochir		PR	1	0.1
18021217002	BEETLE, RIFFLE, LARV	Ectopria		SC	1	0.1
18020508004	MAYFLY NYMPH	Centroptil		GC	1	0.1
18020403006001	DRAGONFLY NAIAD	Hagenius	brevistylu	PR	1	0.1
18021114001	BITING MIDGE LARVA	Bezzia		PR	1	0.1
18020410002	DRAGONFLY NAIAD	Macromia		PR	1	0.1
18020718006003	CADDISFLY LARVA	Polycentro	cinereus	PR	1	0.1
18021118001	HORSEFLY LARVA	Tabanus		PR	1	0.1

Benthic Bioassessment
Station # WHI0092
Freeman Branch below Berryville STP
Eco Reg.# OZHI
Segment # 4K
Sample Date 91-08-26
Sample Time 0000
Sampling technique employed 10MAAA
Printed on 19-FEB-1992

# of Taxa = 8 # of organisms = 49 Biotic score = 0

		% Annelida =	0.0
# Ephemeroptera taxa =	2	% Ephemeroptera =	4.1
# Trichoptera taxa =	1	% Trichoptera =	12.2
# Coleoptera taxa =	0	% Coleoptera =	0.0
# Chironomidae taxa =	1	% Chironomidae =	2.0

Diversity index = 2.4117835

Group summary

SH= 7 PR= 34 GC= 2 FC= 6

SH%= 14 PR%= 69 GC%= 4 FC%= 12

Bio #	Name		Gr	Count	%
18020411001	DAMSELFLY NAIAD	Calopteryx	PR	20	40.8
18020408003	DAMSELFLY NAIAD	Argia	PR	8	16.3
18020704002	CADDISFLY LARVA	Cheumatops	FC	6	12.2
18020802001001	HELLGRAMMITE	Corydalus cornutus	PR	6	12.2
18010302003	CRAYFISH	Orconectes	SH	6	12.2
18020508002	MAYFLY NYMPH	Baetis	GC	1	2.0
18020503002	MAYFLY NYMPH	Caenis	GC	1	2.0
18021115087998	BLOODWORM	Polypedilu	SH	1	2.0

Benthic Community Comparision

Stations: WHI0068 Osage Cr AB Berryville AR
Sample Date 91-08-27
Sample Time 0000
Sampling technique employed 10MAAH
WHI0069 Osage Cr BL Berryville AR
Sample Date 91-08-27
Sample Time 0000
Sampling technique employed 10MAAH

Printed on 20-FEB-1992

Qual. Similarity Index = 66.
Dominants in Common = 4
Taxa in Common = 33
Common Taxa Index = 0.63
Pro. Judgement Score = 4

		WHI0068	WHI0069
# of Taxa	=	52	43
# of organisms	=	1032	774
# Ephemeroptera taxa	=	10	8
# Trichoptera taxa	=	4	2
# Coleoptera taxa	=	11	9
# Chironomidae taxa	=	3	4
Annelida cnt/%	=	5/ 0.5	5/ 0.6
Ephemeroptera cnt/%	=	185/ 17.9	165/ 21.3
Trichoptera cnt/%	=	10/ 1.0	4/ 0.5
Coleoptera cnt/%	=	99/ 9.6	66/ 8.5
Chironomidae cnt/%	=	11/ 1.1	55/ 7.1
Biotic score	=	0	0

Taxa @ WHI0068 but not @ WHI0069

SIDESWIMMER	Hyalella	azteca	103	10.0
ALDERFLY LARVA	Sialis		9	0.9
SNAIL	Pleurocera		8	0.8
DRAGONFLY NAIAD	Libellula		7	0.7
BLOODWORM	Chironominae		6	0.6
CADDISFLY LARVA	Triaenodes		5	0.5
MAYFLY NYMPH	Ephemera	simulans	5	0.5
MAYFLY NYMPH	Brachycercus		4	0.4
BUG, WATER TREADER	Mesovelia		4	0.4
AQUATIC EARTHWORM	Naididae		2	0.2
BEETLE, WATER SCAVEN	Berosus		2	0.2
AQUATIC EARTHWORM	Branchiura		2	0.2
AQUATIC CATERPILLAR	Parargyractis		1	0.1
BEETLE, ELMID, LARVA	Macronychus	glabratus	1	0.1
MAYFLY NYMPH	Stenonema	femoratum	1	0.1
BEETLE	Cyphon		1	0.1
DRAGONFLY NAIAD	Epicordulia		1	0.1
BUG, BR SHD WATERSTR	Rhagovelia		1	0.1
CADDISFLY LARVA	Chimarra		1	0.1

Taxa @ WHI0069 but not @ WHI0068				
BLOODWORM	Chironomus		28	3.6
LIMPET	Ferrissia		17	2.2
DAMSELFLY NAIAD	Hetaerina		2	0.3
SNAIL	Physa		2	0.3
BEETLE, DRYOPID	Helichus		2	0.3
MAYFLY NYMPH	Centroptilum		1	0.1
BITING MIDGE LARVA	Bezzia		1	0.1
HORSEFLY LARVA	Tabanus		1	0.1
BLOODWORM	Cryptochironomus		1	0.1
DRAGONFLY NAIAD	Hagenius	brevistylus	1	0.1

APPENDIX C

RELATIVE ABUNDANCE VALUE OF FISHES FROM OSAGE CR. AND FREEMAN BRANCH

SPECIES		OSAGE-A	OSAGE-B	FREEMAN
Micropterus punctulatus	Spotted bass	8.0	6.5	
*Etheostoma zonale	Banded darter	8.0	8.0	
*Etheostoma blennioides	Greenside darter	8.0	6.0	1.0
*Notropis pilsbryi	Duskystripe shiner	8.0	8.0	8.0
*Etheostoma caeruleum	Rainbow darter	8.0	8.0	5.0
Campostoma oligolepis	Largescale stoneroller	8.0	8.0	8.0
*Noturus albater	Ozark madtom	6.0	8.0	
Lepomis megalotis	Longear	6.0	7.0	2.0
*Moxostoma duquesnei	Black redhorse	5.5	6.5	
Percina caprodes	Logperch	5.0	5.0	
*Notropis whipplei	Steelcolor shiner	5.0	3.5	1.0
*Hypentelium nigricans	Northern hogsucker	5.0	7.0	
Notropis nubilus	Ozark minnow	4.5	8.0	3.5
Lepomis macrochirus	Bluegill	4.5	3.0	
*Ambloplites constellatus	Ozark bass	4.0	2.0	2.0
Lepomis cyanellus	Green sunfish	4.0	4.0	4.0
*Etheostoma euzonum	Arkansas saddled darter	4.0	5.0	
*Fundulus catenatus	Northern studfish	4.0		2.0
Ictalurus punctatus	Channel catfish	3.5	2.5	
Cyprinus carpio	Carp	3.5		
Dorosoma cepedianum	Gizzard shad	3.0	1.5	
*Micropterus dolomieui	Smallmouth bass	3.0	1.0	
Micropterus salmoides	Largemouth bass	3.0	3.0	
*Etheostoma juliae	Yoke darter	3.0	1.0	
Moxostoma erythrurum	Golden redhorse	3.0	6.5	
*Noturus exilis	Slender madtom	2.0	3.0	4.0
*Hybopsis dissimilis	Streamline chub	2.0	2.0	
Pylodictis olivaris	Flathead catfish	2.0		
Notropis chrysocephalus	Striped shiner	2.0	3.0	2.0
Fundulus olivaceus	Blackspotted topminnow	1.5	3.0	
Pimephales notatus	Bluntnose minnow	1.0	6.0	2.0
*Notropis boops	Bigeye shiner	1.0		
Etheostoma spectabile	Orangethroat darter			1.0
*Hybopsis amblops	Bigeye chub		6.0	3.5
Ictalurus natalis	Yellow bullhead		1.0	2.0
*Cottus carolinae	Banded sculpin		4.0	2.0
*Notropis telescopus	Telescope shiner		1.0	
	TOTAL RELATIVE ABUNDANCE VALUE	139.0	148.0	53.0
	TOTAL SPECIES	32.0	32.0	17.0

* SENSITIVE SPECIES