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LITTLE DEEP FORK TMDL SUPPORT AND BMP IMPLEMENTATION

OCC Task 66
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1.0 INTRODUCTION

1.1 HISTORY

In 1989, the Indian Nation Council of Governments (INCOG) conducted an intensive water quality survey of Little Deep Fork Creek and selected tributaries to assess impacts of two municipal wastewater treatment plants (WWTP) discharging into the system. Data was used to calibrate predictive models and develop appropriate waste load allocations (WLA) for each WWTP (located at Bristow and Depew, OK) as a precursor to upcoming National Pollutant Discharge Elimination System (NPDES) permit renewal (INCOG, 1989).

During data review, significantly high dissolved oxygen (DO) maximums were found to occur at the control site immediately upstream of the Depew WWTP input tributary; similar results were found in subsequent DO sampling in 1994. Increase in DO percent saturation as well as fecal coliform were also discovered above the Bristow WWTP discharge. Because there are no point sources (PS) above these sites, agricultural nonpoint sources (NPS) appeared the likely cause for these occurrences. As a result, EPA stipulated approval of the final report only upon conducting a Phased Total Maximum Daily Load (TMDL) study of suspect reaches.

To this end, INCOG established a monitoring plan and data quality objectives for the first phase of the TMDL. The main objective of this process was to identify and characterize all pollution (PS and NPS) contributing to the excessive diurnal DO swings and develop Best Management Practices (BMP) to reduce magnitude of suspected NPS pollution. Resultant funds received by INCOG were designated for the completion of Phase I and for modeling to develop the final WLAs, leaving several tasks to be covered by other agencies and workplans

1.2 PROJECT BACKGROUND

1.2.1 Project Site

The Upper Little Deep Fork Creek basin is in the southwest corner of the northeast quadrant of Oklahoma (Figure 1). It covers approximately 39,500 ha (97,500 acres) and lies almost entirely in Creek County, with the western 2000 ha (5,000 acres) stretching into neighboring Lincoln County. Flowing generally east, the Little Deep Fork Creek merges with the Deep Fork River, a tributary of the North Canadian River. Major industrial activities in the basin include oil/gas exploration and agriculture, comprising hay, grazed cattle, and small grain production. In general, the basin is approximately 40% forest and 55% grasslands, with the remaining 5% urban or other (OSU BAE, 1999).

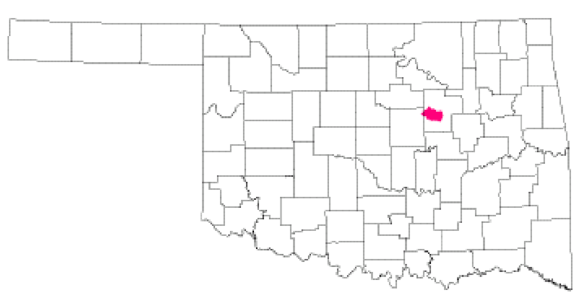

Figure 1. Upper Little Deep Fork Creek Watershed

Little Deep Fork Creek (WBID#: OK520700060010) is listed as high priority on the State's 303(d) list with pesticides, nutrients, siltation, salinity, and organic enrichment/dissolved oxygen as causes. Sources for this stream are listed as storm sewers, surface runoff, petroleum activities, wastewater, non-irrigated crop production, specialty crops, pastureland, and range land. The 319 water quality assessment gives similar causes and sources for the evaluated assessment of fully supporting but threatened for the beneficial use of warm water aquatic community (WWAC); suspended solids, phosphorus, chlordane, and turbidity are cited as pollutants of concern. The downstream reach of the Bristow discharge and the Depew tributary comprise the only difference in beneficial use designation, both being listed as Habitat Limited Aquatic Community (HLAC).

The Little Deep Fork (hereafter referenced as LDF) watershed has had significant modification through the construction of floodwater retention structures as part of a 1957 PL 566 Watershed Workplan (Figure 2). Presence of these structures has had a significant impact on system hydrology and posed a difficulty in modeling parameter dynamics through the watershed. Extensive areas of uncontrolled land lie adjacent to the third and fourth order segments of the stream system. Cattle have complete access to the streambed in many areas of the watershed.

1.2.2 Project Overview

As part of a collaborative effort, the Oklahoma Conservation Commission (OCC) received 319(h) funding to assess the extent and impact(s) of NPS pollution (specifically nutrients and sediment) in the Upper Little Deep Fork Creek basin. Specifically, this project had two objectives: (1) provide support for implementation of the TMDL by targeting/implementing best managements practices (BMPs) for reducing nutrients and sediment to the creek, and (2) achieve improvements in water quality to avoid violation of standards upon addition of effluent from the WWTPs. In fulfillment of the first two workplan tasks, a cooperative agreement between OCC and INCOG and a project advisory group were established in early 1996. Upon final approval of the QAPP, data collection and major project activities began in September 1997.

The geographical domain of the project extended from the headwaters of LDF, downstream to the section road between sections 9 and 10 of Township 15 North, Range 9 East, approximately 1/8 mile downstream of the confluence of Sand Creek and LDF. The segment of stream between the town of Depew and a previously identified section road was the primary concern for the WLAs and the TMDL to protect water quality. Thus, identification of NPS problems and demonstration of BMP's encompassed the watershed above this section road. Reference collections were made on selected streams within the area, and final reference stream selection occurred upon reconnaissance of streams within Creek, Lincoln, Okfuskee, and Okmulgee Counties, Oklahoma.

Precursory investigations within the watershed and reconnaissance along the creek in selected areas showed significant livestock impacts to the stream. The stream was found to be a major loafing area for cattle and often their sole water source. Cow pats (fecal matter) of one per square meter over a 300meter stream segment was observed by OCC field investigators. Initial observations revealed limited areas of cropland within the watershed generally located in the bottomlands. Some oil waste land also was discovered and became a point of concern. Several

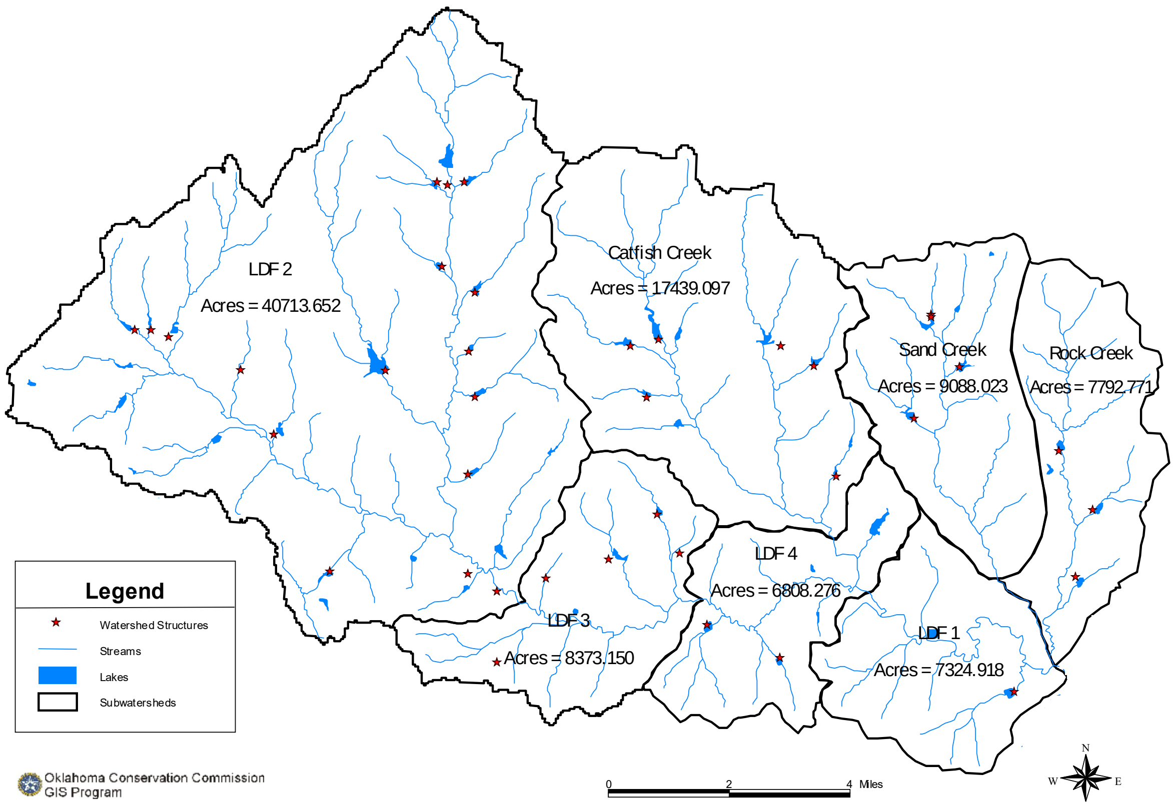

Figure 2. Little Deep Fork Creek Watershed, Project Subwatersheds, and NRCS Flood Control Structures.

of these highly eroded sites were found within the watershed; one site upstream of Bristow was found adjacent to the stream.

In light of these findings and in order to assess the NPS problems in support of the TMDL, initial data objectives involved four principle areas: (1) What was the current condition of LDF?, (2) What were the NPS contributions within the watershed significantly affecting water quality?, (3) What was the effect of the cattle activity?, and (4) What were achievable goals for water quality, habitat, and the aquatic community of LDF (gleaned from the reference stream database). Upon achievement of these objectives (i.e., delineation of problematic NPS sources), education programs and implementation of appropriate BMPs would be undertaken to improve water quality and potentially create the necessary "buffer" for the WWTP effluent.

Although, the project proceeded largely in fulfillment of exact workplan tasks, some "instream" amendments were necessary as incoming data was examined. One of the greatest areas of focus in the hypothesized NPS perturbations was the excessive DO swings above the PS discharges. Upon cursory examination, results of the OSU Biosystems and Agricultural Engineering (OSUBAE) model (discussed later) indicated less than expected NPS loading from the watershed. The focus thus turned to instream vs. watershed phenomenon as the factor inflating primary productivity and causing the high DO maximums. The result was an inclusion of a sediment oxygen demand study and diminution of the cattle impact assessment as outlined in the workplan.

2.0 MATERIALS AND METHODS

2.1 NPS LOAD CHARACTERIZATION

2.1.1 Land Use

To facilitate identification of potential NPS contributions, accurate and up to date land use data was paramount. The most recent land use database available at the outset of the project was from 1985, far too outdated for a good assessment. As a result, an intensive, ground based survey of the watershed began in the spring of 1996. Aerial photographs (1:660) were purchased to facilitate this effort. Each of the 148 plus sections within the project boundary were physically walked and mapped according to OCC SOP, no. 46. All land was placed into one of nine broad categories: forest land, grass land, crop land, erosional features, structures, and water bodies. Land use was further defined and quantified within these categories based on the percentage of bare soil observed. This task was completed in January 1997. Completed maps were digitized into the OCC Geographic Information System (GIS) to facilitate identification of potentially high NPS contributions and allow for BMP targeting.

As a subset of land use and effort toward BMP prioritization, an attempt was made to conduct a cattle census within the LDF watershed during the spring of 1996. A physical field count proved to be impractical due to the dynamic nature of the local operations (e.g., cattle sold/acquired, pastures rotated). Considering these obstacles, a county plat map was used to establish a list of all significant landowners (>20 ac) within the watershed. Once generated, this list was used to conduct a search of the most recent tax records. To account for bias due to inaccurate records or unreported holdings, personal interviews were conducted with approximately twenty percent of the relevant landowners.

To further prioritize landowners for BMPs, Mark Moseley (Grazing Land Specialist, Natural Resource Conservation Service) and Kent Barnes (Livestock Specialist,OSU Coop. Extension Service) were consulted regarding appropriate stocking rates for the project region. Both agreed that maximum density for optimum conditions and management would be one cow calf unit per eight acres. Maximum density for unimproved pasture with low intensity management would be one unit per twenty acres. Based on these recommendations a simple spreadsheet was developed to calculate stocking rates and determine areas of high intensity production in the watershed.

2.1.2 Soil Sampling and Watershed Modeling

Upon delineation of current landuse activities, soil samples were collected throughout the watershed from summer 1996 through spring 1997. In general, the basin was divided into one square mile grids and at least one composite sample comprising 25, 1x2 inch cores was collected from a field within each grid. Samples were collected in proportion to the percentage of land use type. Approximately 150 composite samples were collected initially, but due to similar magnitudes of forest and range land soil phosphorous levels, 20 additional composite samples were obtained from forested areas to improve data variability and mean estimates. Sampling procedures followed OSUCES recommendations for the collection of representative samples

(Marshall, 1998). General sampling locations were recorded and digitized in the OCC GIS database.

Oklahoma State University was contracted to quantify the major nonpoint source loads from the LDF watershed. Dr Dan Storm (OSUBAE) was responsible for development of a model to accomplish the task. Specifically, the Soil and Water Assessment Tool SWAT (Arnold et al., 1996; Srinivasan et al., 1996) interfaced with GRASS (CERL, 1988) was used to estimate runoff, sediment loading, and phosphorus loading (see output 400.6, *Estimating NPS Phosphorus and Sediment Loading to the Upper Little Deep Fork Watershed* for specific methodology). The model incorporated the updated land use and soil fertility data generated by OCC, as well as soil types, slopes, and local weather data. Modal outputs (NPS loading estimates) were used in the overall stream model and for targeting implementation efforts.

2.1.3 Habitat Assessment

A significant portion of the NPS contribution to the LDF was expected to come from direct cattle access to the stream. These activities were hypothesized to make an impact in nutrients (fecal matter, bank erosion), siltation (bank erosion), and habitat alteration. In the spring of 1997, an extensive instream and riparian habitat assessment was conducted to document the impacts from cattle and pinpoint eroding stream banks and other problem areas. The assessment began at the lower project boundary and progressed upstream encompassing the entire length of LDF and all named tributaries. Data was recorded every 50 meters and included the following primary parameters: stream depth, width, substrate composition, habitat type, fish cover, canopy cover, percent bank erosion and riparian width/condition. Data was digitized into the OCC GIS system and used as a screening tool to target areas for implementation. All assessments were conducted in accordance with procedures outlined in the OCC Habitat Assessment SOP, no. 39 and were completed in June 1997.

2.2 WATERSHED MONITORING

2.2.1 Water Sampling

Low-flow water sampling efforts began in September 1997, comprising a monthly frequency for the five study sites (LDF1 – LD4, and Catfish Creek) and quarterly for the four reference streams (Adams, Brown, Salt, and Sand Creeks) (Figure 3). All sampling and measurement activities followed procedures outlined in the appropriate OCC SOP (nos. 1, 8, 9, 10, 12, 14, 15, 18, 24, and 32). In-situ measurements included the following parameters: temperature, dissolved oxygen, pH, specific conductance, alkalinity, turbidity, and instantaneous discharge. Water samples were submitted to the Oklahoma City County Health Department (OCCHD) Lab for analysis of the following parameters: nitrate, nitrite, total Kjeldahl nitrogen, total phosphorus, sulfate, chloride, hardness and total suspended solids.

High flow/runoff samples also were collected as they occurred following procedures outlined in OCC SOP, no. 2. A total of nine events were collected between January 98 and March 99. Modifications to the high flow procedures were necessary for LDF1 due to lack of a bridge from which to sample. Several attempts were made to construct a cable/pulley system, but these efforts were repeatedly washed out. Therefore, high flow discharge at the site was estimated by

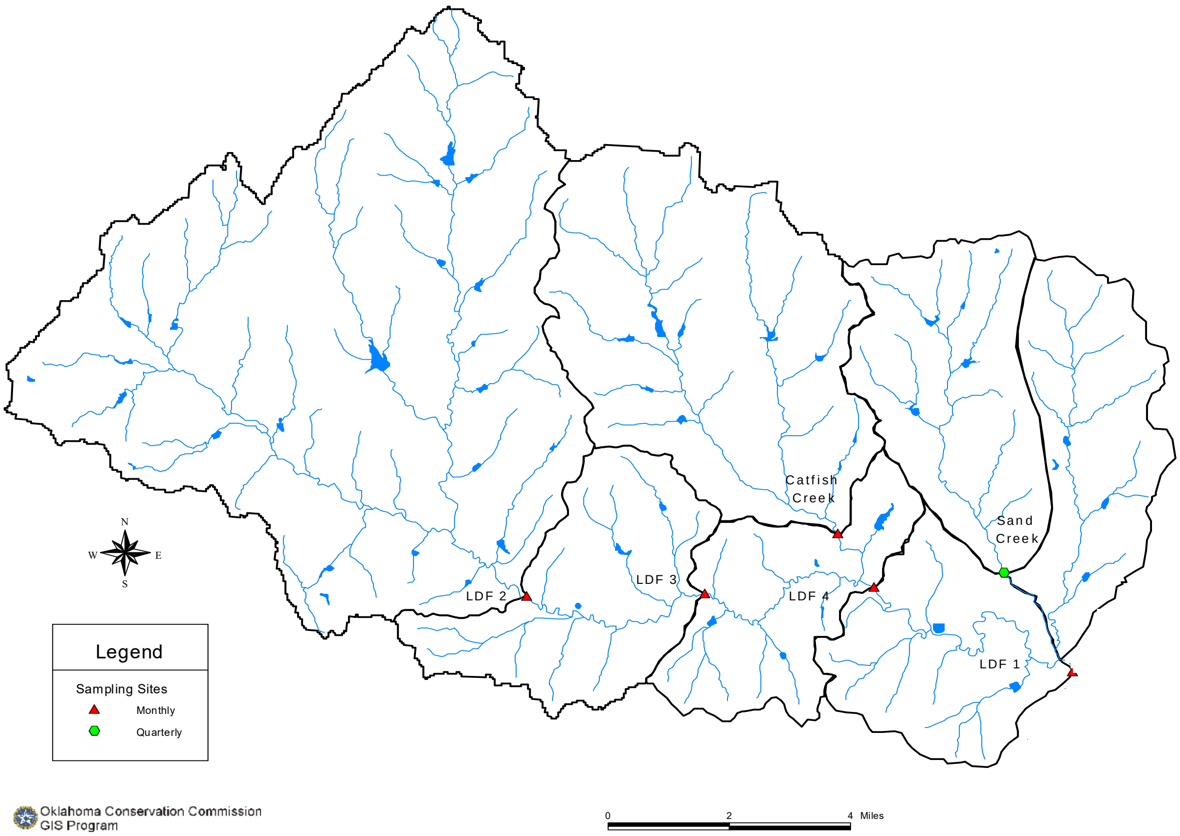

Figure 3. LDF Watershed Monitoring Sites.

surveying and calculating the cross sectional area, recording the stage, and multiplying by a determined velocity (elapsed time of a semi submersible object).

Monthly water sampling was suspended after March 1999 as efforts focused on assimilating and interpreting the data. A report of the findings of the OSUBAE model indicated relatively lowlevels of nutrient and sediment loading. A cursory study of the water quality data appeared to support this finding. After further study and a brief literature review, a new opinion developed regarding the source of the DO swings. Spikes in primary productivity driving the DO swings seemed to be driven by autochthonous rather than allochthonous inputs. Thus, it was determined that remaining monitoring efforts should focus on isolation and diagnosis of this phenomenon (sediment oxygen demand and nutrient flux). Although planned diurnal oxygen profiles were carried out at three sites on 8/18/99 (LDF2, LDF3, and Kelly Bros. Ranch) and two sites on 8/31/99 (LDF at State Highway 48 and LDF at Oil lease site), the cattle impact assessment was aborted in lieu of a sediment oxygen demand study to investigate its contribution to system metabolism.

To this end, an informal sediment oxygen demand study was planned and conducted on 8/31/99 in conjunction with the diurnal study. Plexiglass sampling devices were constructed, allowing discrete sampling/monitoring of specific sites in the streambed. For control, one was constructed with a closed bottom to eliminate interface with the sediment. Water samples were collected from the water column, and then the devices were installed in the stream within areas of upwelling from the hyporheaic zone. Dissolved oxygen was read and recorded every hour for the following 24 hr period, upon which additional water samples were collected from the devices. Samples were submitted to the OCCHD Lab and analyzed for the entire nutrient series to determine if sediments were contributing or consuming nutrients.

An attempt was also made to isolate and quantify the impact of shallow ground water on the system. Ground water seeps were excavated at LDF 2 and LDF @ State Highway 48 on 11/29/99. Samples were collected from the seeps at both sites the following day. For control, samples were also collected from the water column. All samples were submitted to the OCCHD Lab and analyzed for the entire nutrient series.

2.2.2 Biological Monitoring

2.2.2a Fish

Bioassessment sampling was initiated in the summer of 1997. Fish were collected from a total of nine sites including four on LDF Creek, Catfish Creek, and four reference streams (Table 1). Fish collections were made via backpack electrofishing and seining methods according to procedures outlined in OCC SOP, nos. 35 and 39. All unidentifiable individuals were preserved and sent to a professional taxonomist for identification. All data was entered into the OCC WQ database and queried for analysis. A modified version of Karr's Index of Biotic Integrity (adapted from Plafkin et al. 1989) was used to score and compare the health of the fish community between sample and reference sites. Modifications included the use of the number of minnow species as opposed to the number of sucker species in metric 4, and the proportion of Mosquito fish and Red Shiner as opposed to the proportion of Green Sunfish in metric 6.

2.2.2b Macroinvertebrates

Macroinvertebrates were collected from a total of nine sites from Sep 1997 through Feb 1999 (Table 2) according to procedures outlined in OCC SOP, nos. 29, 30, 31, and 36. Aquatic invertebrates were collected from rocky riffles, streamside vegetation, and woody debris as present at each sampling site. Efforts were made to obtain collections from all sites during both

Table 1. Fish Collection Event Data. (*Reference Site)

Site Name	WBID	Legal	Sample Date
Little Deep Fork (1)	OK520700-06-0010H	se/ne/ne 9 15n 9e	30-Sep-97
Little Deep Fork (2)	OK520700-06-0010P	ne/ne/ne 1 15n 7e	15-Sep-97
Little Deep Fork (3)	OK520700-06-0010M	¾ 15n 8e	15-Sep-97
Little Deep Fork (4)	OK520700-06-0010J	sw/se/se 36 16n 8e	19-Sep-97
Catfish Creek	OK520700-06-0140G	25/36 16n 8e	16-Sep-97
Adams Creek*	OK520700-02-0080P	32 15n 12e -- 5 14n 12e	26-Sep-97
Browns Creek*	OK520700-06-0050L	24/19 15n 10e	22-Sep-97
Salt Creek*	OK520700-02-0150G	se 34 15n 11e	30-Sep-97
Sand Creek*	OK520700-06-0110G	29/32 16n 9e	16-Sep-97

Table 2. Macroinvertebrate Collection Event Data (*Reference Sites)

Site Name	WBID	Legal	Sample Date	SampleType (Riff, Veg, Woody)
Little Deep Fork (1)	OK520700-06-0010H	se/ne/ne 9 15n 9e	08-Sep-97	R,W
Little Deep Fork (1)	OK520700-06-0010H	se/ne/ne 9 15n 9e	09-Feb-98	R,W
Little Deep Fork (1)	OK520700-06-0010H	se/ne/ne 9 15n 9e	25-Jun-98	R,W
Little Deep Fork (1)	OK520700-06-0010H	se/ne/ne 9 15n 9e	17-Feb-99	R,W
Little Deep Fork (2)	OK520700-06-0010P	ne/ne/ne 1 15n 7e	08-Sep-97	R,V
Little Deep Fork (2)	OK520700-06-0010P	ne/ne/ne 1 15n 7e	09-Feb-98	R,W
Little Deep Fork (2)	OK520700-06-0010P	ne/ne/ne 1 15n 7e	28-Jul-98	R,W
Little Deep Fork (2)	OK520700-06-0010P	ne/ne/ne 1 15n 7e	17-Feb-99	R,W
Little Deep Fork (3)	OK520700-06-0010M	3/4 15n 8e	08-Sep-97	V,W
Little Deep Fork (3)	OK520700-06-0010M	3/4 15n 8e	09-Feb-98	W
Little Deep Fork (3)	OK520700-06-0010M	3/4 15n 8e	23-Jun-98	W
Little Deep Fork (3)	OK520700-06-0010M	3/4 15n 8e	17-Feb-99	V,W
Little Deep Fork (4)	OK520700-06-0010J	sw/se/se 36 16n 8e	08-Sep-97	R,V,W
Little Deep Fork (4)	OK520700-06-0010J	sw/se/se 36 16n 8e	09-Feb-98	R,V
Little Deep Fork (4)	OK520700-06-0010J	sw/se/se 36 16n 8e	25-Jun-98	R
Little Deep Fork (4)	OK520700-06-0010J	sw/se/se 36 16n 8e	16-Feb-99	R,V,W
Catfish Creek	OK520700-06-0140G	25/36 16n 8e	08-Sep-97	R,V,W
Catfish Creek	OK520700-06-0140G	25/36 16n 8e	09-Feb-98	R,W
Catfish Creek	OK520700-06-0140G	25/36 16n 8e	25-Jun-98	R,V
Catfish Creek	OK520700-06-0140G	25/36 16n 8e	10-Feb-99	R
Catfish Creek	OK520700-06-0140G	25/36 16n 8e	17-Feb-99	R,W
Adams Creek*	OK520700-02-0080P	32 15n 12e -- 5 14n 12e	05-Feb-98	R,V,W
Adams Creek*	OK520700-02-0080P	32 15n 12e -- 5 14n 12e	24-Feb-99	R,V
Browns Creek*	OK520700-06-0050L	24/19 15n 10e	06-Feb-98	R,W
Browns Creek*	OK520700-06-0050L	24/19 15n 10e	18-Feb-99	R
Salt Creek*	OK520700-02-0150G	se 34 15n 11e	05-Feb-98	R,W
Salt Creek*	OK520700-02-0150G	se 34 15n 11e	18-Feb-99	R,W
Sand Creek*	OK520700-06-0110G	29/32 16n 9e	09-Feb-98	R
Sand Creek*	OK520700-06-0110G	29/32 16n 9e	16-Feb-99	R,V

the summer and winter index periods. Unfortunately, low or nonexistent flow was encountered during both summer collection periods at all the reference sites, thus prohibiting collections. Preserved samples were picked in the laboratory, and the picked subsamples sent to a professional taxonomist for identification. All data was entered into the OCC WQ database and queried for analysis. Data was prepared and entered into a spreadsheet for metric calculations and subsequent bioassessment determination (modified version of Plafkin et al 1989).

Bioassessment analyses were restricted to riffle samples to limit variability inherent in sampling differing substrates. In the case where no riffle samples were procured (e.g., LDF3), reference stream data was used to calculate a factor allowing conversion from a vegetation or woody sample to a riffle sample. Because no summer index collections were made for the reference sites, alternate reference sites within the same ecoregion and most proximal to study sites were chosen for comparison.

2.2.2c Periphyton

The periphyton community was sampled to estimate stream primary productivity. To accomplish this, periphytometers were employed in accordance with procedures outlined in OCC SOP, no. 6. Upon retrieval, rods were scraped, filtered and processed as per OCC SOP, no. 50. Samples were stored upright in the freezer until their submittal to the OCCHD Lab for chlorophyll a and phaeophytin analyses. The workplan called for three summer sets and three winter sets per year. Several attempts were made to deploy periphytometers beginning in December of 1997. However, these efforts yielded no data as extended periods of elevated flows either washed samplers away or scoured them beyond use. The first and only successful winter deployment for the period occurred in February 1998. Summer collections went more smoothly as three sets were successfully deployed and retrieved in 1998. Only two winter sets were successfully retrieved in 1999, again due to elevated flows.

2.2.2d Diurnal DO Profiles

According to the work plan, diurnal dissolved oxygen profiles were to have been conducted each summer. However, final approval of the QAPP was not granted until September 1997. This left a very brief window of opportunity and a number of tasks to be completed during the remainder of the summer season. Thus, there was physically not enough time to complete the task that first summer. A diurnal profile was scheduled for July 1998. However, extreme heat and dry conditions left the two uppermost sites without flow, only intermittent pools remained. A cattle impact assessment had also been scheduled at this time. After consulting with Phil Moershel (QA Officer OCC) and Richard Smith (INCOG), it was determined that current conditions were not representative of the system and that information gleaned from these studies could be misleading. As a result, both projects were postponed, until such time that conditions were felt to be appropriate. Conditions remained unchanged throughout the remainder of the summer.

2.3 STREAM MODELING FOR LOAD AND WASTE LOAD ALLOCATIONS

A primary result of the 1989 INCOG study was the calibration and application of a QUAL2EU computer model to develop waste load allocations for the Depew and Bristow WWTPs. EPA stipulated acceptance of the model's results, however, only upon conducting the phased TMDL study to better account for NPS loadings and the potential effect of their reduction upon BMP implementation. Therefore, a key task of this project was to furnish INCOG with a complete characterization and estimation of NPS loadings to be incorporated in the model. New allocations for both WWTPs would then be developed by assuming a significant decrease in nonpoint source loadings due to implementation of BMPs. INCOG Output 200.4, *Little Deep Fork Creek TMDL Creek County, Oklahoma—Final Report* (FY-93 104 (b)(3) X996184-01) details the fulfillment of this task.

2.4 WATERSHED EDUCATION

In February 2001, the OCC contracted with the OSUCES to target communities and land owner groups within the LDF watershed for several educational/organizational meetings and activities. The overall purpose of the project was three-fold: (1) increase awareness of watershed residents and decision makers concerning pertinent water quality problems, (2) educate the same concerning the impact individual actions, relevant laws, and public policy alternatives can have on water quality, (3) promote volunteer action and seek implementation of BMPs. Numerous tasks were undertaken to accomplish these goals including various workshops, seminars, educational brochures, volunteer monitoring programs, and other activities. The reader is referenced to the project's final report (Appendix A) for a complete address of specific activities and results (Appendix A).

2.5 BMP DEMONSTRATION

Because of the anticipated NPS contributions and subsequent impacts on the LDF, one of the primary goals of this project was to accurately target areas for BMP implementation. To accomplish this task, digitized data from the land use inventory and instream habitat survey were composited and queried using GIS software. Demonstration sites targeted areas optimally blending highest nonpoint source impacts with greatest improvement potential(s) to the stream. A citizens advisory group was formed to facilitate implementation of demonstration BMPs.

The BMPs employed entailed both structural and cultural practices as outlined in the Agricultural NPS Management Plan. Structural BMPs included livestock exclusion and off stream livestock watering in critical areas. Because of close proximity of cropland to streams, farm operators were targeted for implementation of cultural BMPs for nutrient and sediment controls. Riparian area reestablishment measures were implemented where appropriate. Cost of BMP implementation was subsidized through cost share funding by the United States Department of Agriculture (USDA), Farm Services Agency (formerly Agricultural and Stabilization Conservation Service), Oklahoma Energy Resources Board (OERB) (oil and gas field related activities), and the OCC. Additional support included technical services provided by the NRCS in accomplishing certain project activities (e.g., pond surveying).

3.0 RESULTS AND DISCUSSION

3.1 LAND USE AND HABITAT ASSESSMENT

To fulfill land use survey requirements, a total of 101,929 acres were walked, mapped, and placed in one of twenty-nine specific categories (Figure 4). Notable broad categories and their corresponding areas included the following uses: grassland, 57,267 ac; forest-land 38,730 ac; farmsteads, 2,832 ac; surface water, 1,763 ac; crop land, 232 ac; and erosion 169 ac. Land use was further defined based on the percentage of bare soil observed (Table 3). The remaining percentages unaccounted for in the table include cropland, urban, oilfield, and other landuses.

Table 3. Percent Bare Soil of Dominant Land Use Types in the LDF Watershed.

Land Use Category	Percent Bare Soil	Percent of Watershed
Poor Condition Grassland	5 – 20	18
Fair Condition Grassland	1 – 5	25
Good Condition Grassland	0 – 1	8.6
Heavily Used Forest	>5	12.5
Moderately Used Forest	1 – 5	20
Stable Forest	0 - 1	5.5

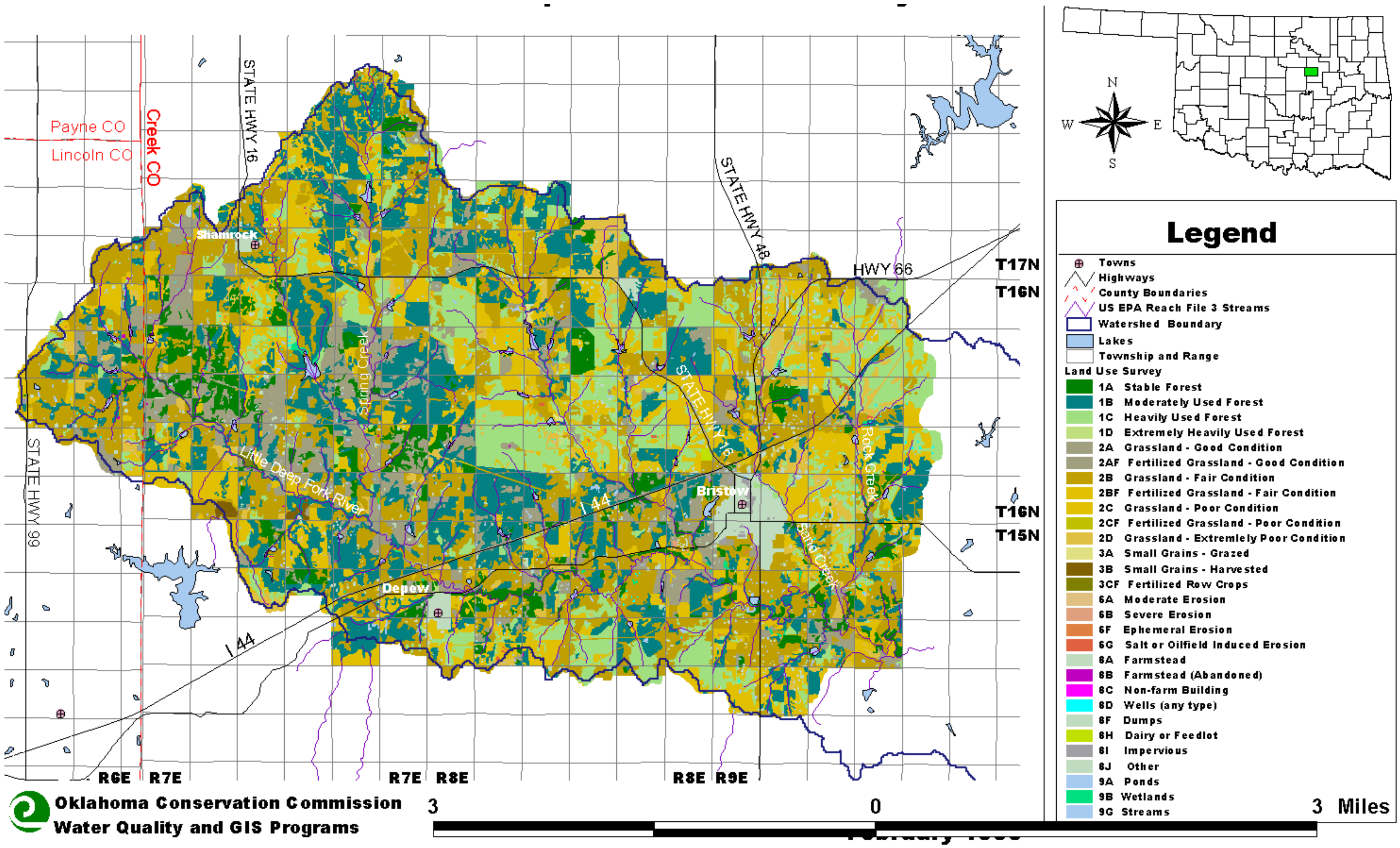

Figure 4. Oklahoma Conservation Commission Land Use Survey, Little Deep Fork Watershed, 1996/1997.

The first step toward assessing major nonpoint source potentials was to note land use types proximal to the streams. Intuitively, perturbing land use activities within the stream bed or floodplain would exert the greatest effect(s) on the stream and constitute the highest priority for targeting BMP implementation. The inventory data was queried using Arc View GIS, and a map was produced showing the land use types within 100 m of LDF tributaries. A similar map showing selected land use types was particularly useful (Figure 5).

Optimal assessment of nonpoint sources in the LDF watershed was obtained upon overlay of specific information from the extensive and intensive habitat assessments (HA). HA data was analyzed and several key parameters were selected that were believed to contribute most to nutrient and sediment NPS loads. These included reaches that contained significant magnitude of the following: eroding stream bank, cattle pat density, cow trails leading to stream, floodplain with little or no riparian vegetation, and segments with a shallow maximum depth. Width and depth data were specifically useful to INCOG for re-calibration of the TMDL model hydraulics.

The specific habitat variables chosen for targeting criteria were selected for several reasons. Of most importance, reaches possessing large areas of eroding stream bank contribute sediment and its associated nutrients/organic matter directly to the stream, thereby exacerbating the dissolved oxygen problem. Cattle pats in the streambed also contribute directly to nutrient/organic input thereby necessitating inclusion of reaches possessing them. Cow trails were targeted because they effectively short-circuit the filtering capacity of the riparian vegetation. A healthy unbroken riparian corridor is the last line of defense in stopping unwanted pollutants from upland and floodplain areas. For this same reason, OCC targeted any reach of stream where the riparian corridor was less than a designated width on either side.

Because the initial concern driving this project was low nighttime dissolved oxygen levels and wide diurnal fluctuations immediately above the towns of Bristow and Depew, stream depth also was considered to be a critical factor. Sediment oxygen demand exerts an increasingly larger influence as streams shallow. Streams that have filled with sediment due to erosion can be improved by practices that restore and protect eroding banks and reestablish riparian vegetation. An intact riparian corridor will trap sediment moving as bedload during floods, allowing pools and the stream in general to deepen.

Targeting and implementing BMPs in areas impacted by these factors should lead to improved stream health, less sediment oxygen demand, and much less oxygen demand relative to the volume of water in the stream. Therefore, specific selection criteria were formulated and GIS maps developed to view the following conditions: (1) stream segments with eroding banks greater than 20% (Appendix B-1), 2) stream segments with cow flop density of 2 counts per every 100 meter HA cross-section (Appendix B-1), 3) stream segments with two or more cattle trails per 100 meter HA segment (Appendix B-2); and 4) stream segments with a depth ≥ 0.1 meters (Appendix B-2). Queries were run in ArcView GIS to select for all locations that had at least three of these four key parameters (Figure 6). The highlighted areas indicate locations in the watershed having the greatest potential to contribute nonpoint sources. Reaches of limited to no stream riparian corridor were also mapped (Appendix B-3).

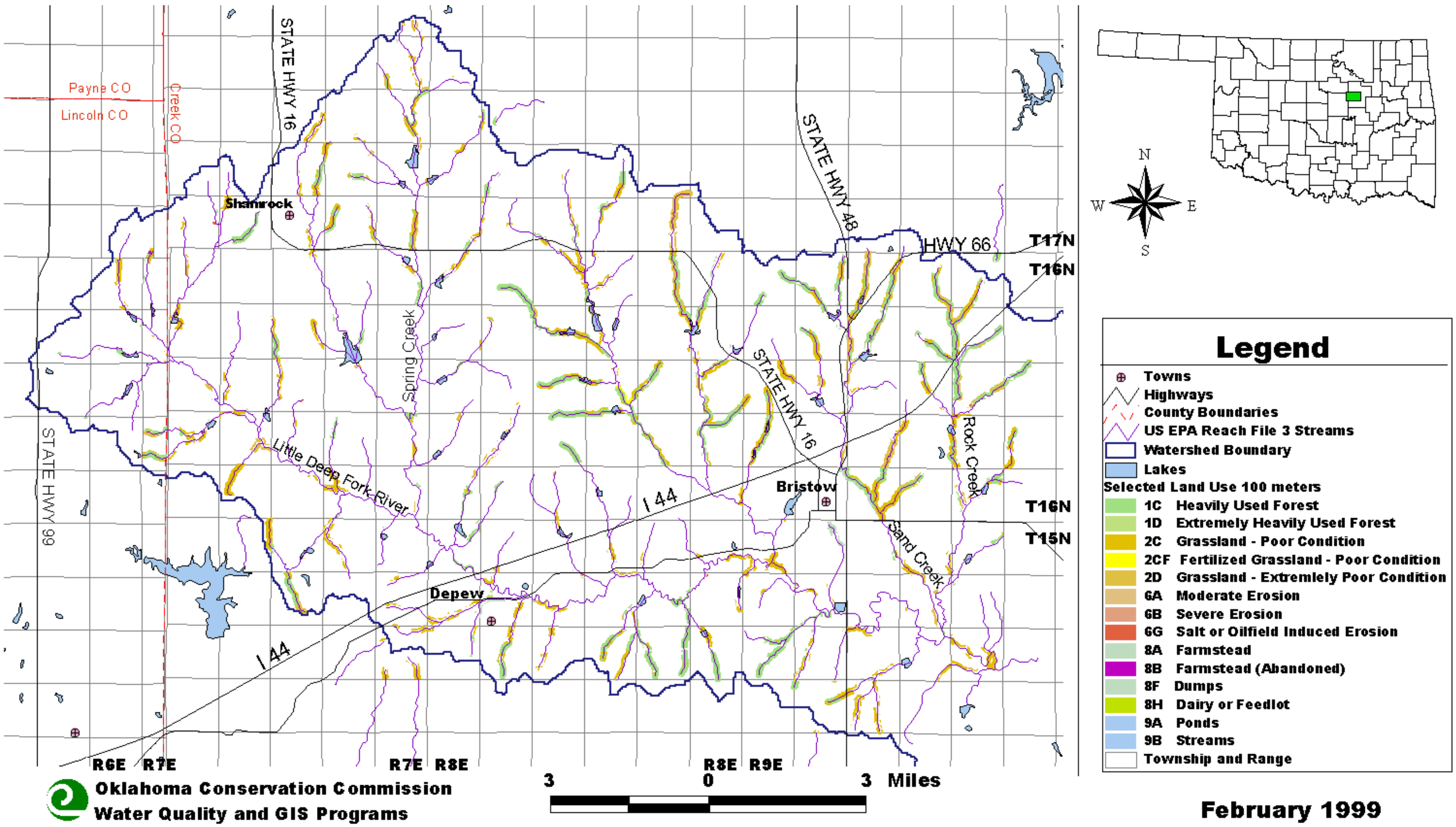

Figure 5. Selected Land Use Within 100 m of LDF Tributaries.

Little Deep Fork--Reaches Containing 3 of the 4 Impairment Categories

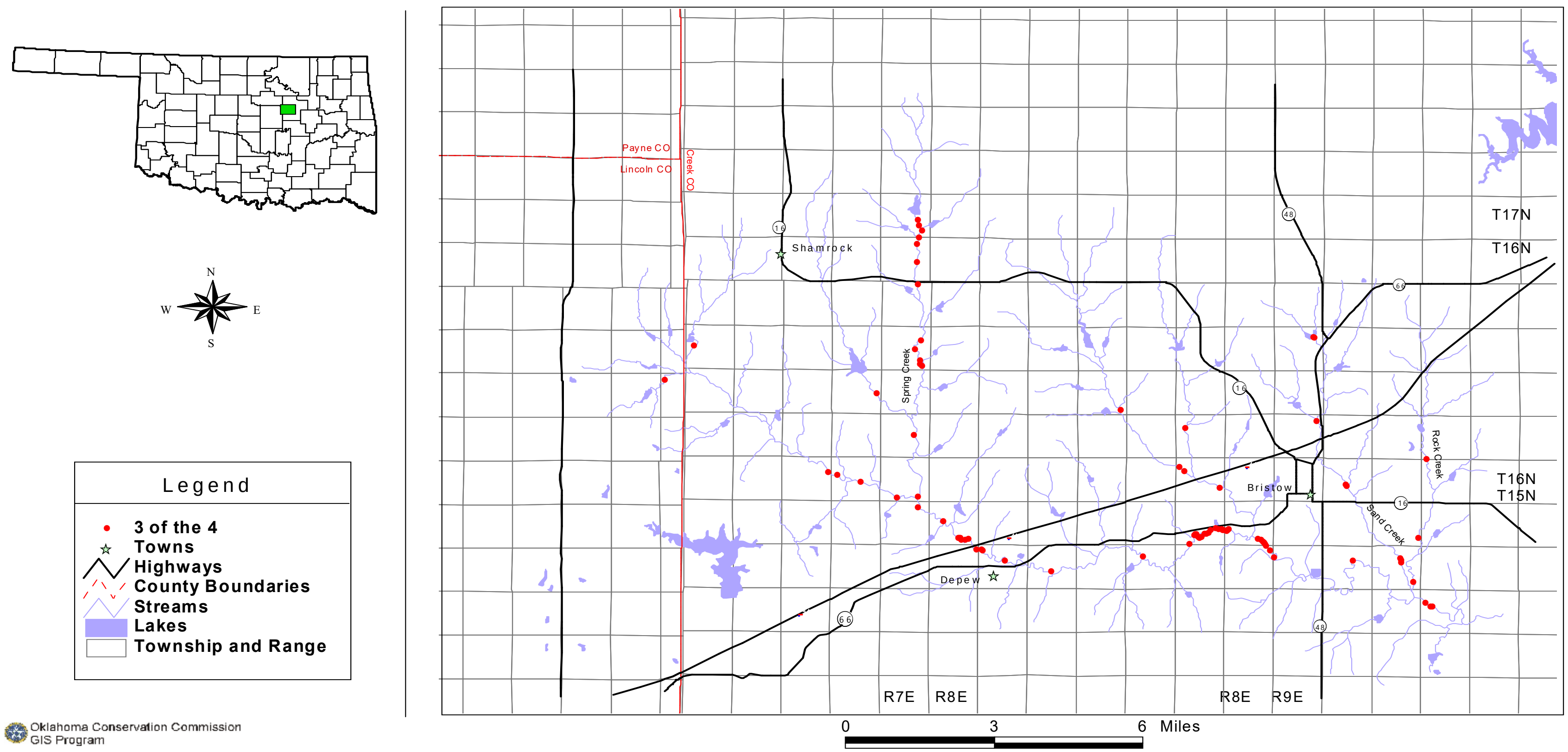

Figure 6. GIS Map Showing LDF Watershed Reaches Possessing Three of the Four Impairment Criteria.

3.2 CATTLE CENSUS

One hundred and thirteen landowners were surveyed as part of the cattle census. Landowner holdings accounted for a total of 9,215 ac, which supported 2,096 head. This yielded a mean stocking rate of 0.28 head per acre. Because tax records did not differentiate between cows and calves, direct comparison to Barnes and Moseley's recommended maximum stocking rate could not be made. Since cattle operations in this area are predominantly cow/calf oriented, a reasonable conversion might be to divide the 2,096 total by two, assuming a one to one adult to young ratio. Applying this adjustment, the new mean stocking rate is 0.14 units/acre, slightly greater than the recommended rate of 0.125 units/acre. Based on this value, approximately 17 percent of the landowners exceeded the recommended stocking rate. The maximum recorded stocking rate was 0.91 units/acre. Fifty-two percent of the landowners reported having no cattle at all.

3.3 WATERSHED SOILS

Soil samples were collected from each of 148 sections within the project area in proportion to land use type. The exception to this was forest land use, which was assumed to have relatively uniform soil nutrient levels. The soil samples were collected from the summer of 1996 through the spring of 1997. A soils data summary may be referenced below (Table 4).

The soils are in three general associations: (1) sandy soils of the forested areas, (2) dark soils of the prairies, and (3) soils of the bottom lands. Each association is dominated by soils that developed from similar or related parent materials, have some characteristics in common, and contain many small areas that belong to one of the other two associations (SCS, 1959; 1970). Most of the soils within the basin are from the Darnell and Stephenville series. The Darnell series are very shallow, acid soils developed over reddish sandstones and are used mainly for

Table 4. Little Deep Fork Watershed Soil Sample Results, 1996/1997.

Land Use	N	Mean pH	Mean NO_3	NO_3 Range	Mean P (p205)	P (p205) Range
Poor Condition Grassland	45	5.7	8.9	1 – 19	32	8 – 108
Fair Condition Grassland	40	5.8	10.1	1 – 32	30.6	13 – 62
Good Condition Grassland	42	5.7	10.1	1 – 44	31.8	17 – 71
Unmanaged Grassland	4	6.9	13.3	4 – 27	22.5	13 – 28
Heavily Used Forest	10	5.6	9.1	2 – 36	40.1	23 – 57
Moderately Used Forest	10	5.2	13.4	2 – 31	37	25 – 55
Stable Forest	10	5.3	7.8	1 – 19	36.6	26 – 47

woodland pasture. The Stephenville series are medium deep soils, which are slightly acidic and occur over soft, reddish sandstone. Sandstone outcrops are common in both series (SCS, 1959; 1970).

3.4 WATERSHED MODELING

Using the updated land use/land cover and soils data, the OSUBAE employed the SWAT (interfaced with GRASS) model to evaluate the NPS pollution potential of the LDF basin. In general, the model was calibrated using the OCC data, and sediment and phosphorus loads were calculated for a thirty year simulation based on extracted weather data from OKEMAH 1 weather statistics. Average annual concentrations and loading estimates were determined for each parameter according to modeled subbasins (Table 5, below) and land use categories. A two year daily modeling also was run in an attempt to compare model output (derived from daily weather inputs for the period) to OCC water quality monitoring results. For an in depth review, see output 400.6, *Estimating NPS Phosphorus and Sediment Loading to the Upper Little Deep Fork Watershed*.

Table 5. Estimated Average Annual Estimates of Sediment and Phosphorus Loads in the LDF Basin Based on a 30-Year SWAT Simulation (adapted from OSUBAE, 1999).

OSU BASIN	OCC Basin Eqvlnc*	AREA (acres)	RAIN (in)	RUNOFF (in)	SEDMNT (tons/ac)	SEDMNT P (lbs/ac)	SOL P (lbs/ac)	TOT P (lbs/ac)	SEDMNT (mg/l)	SEDMNT P (mg/l)	SOL P (mg/l)	TOT P (mg/l)
1A - 1C	LDF2	42130.6	36.4	2.8	0.36	0.15	0.07	0.22	0.76	0.24	0.12	0.36
3	Catfish	17815.9	35.6	2.3	0.12	0.05	0.07	0.12	0.26	0.13	0.13	0.26
2	LDF3	7338.9	34.4	2.6	0.17	0.07	0.07	0.14	1.06	0.16	0.12	0.28
4	LDF4	5757.4	34.5	2.6	0.29	0.12	0.07	0.20	1.68	0.23	0.11	0.34
5	LDF1	24438.2	36.7	3.5	0.54	0.24	0.06	0.30	0.31	0.33	0.09	0.42
Basin Avg.		97481.0	36.1	2.8	0.34	0.15	0.07	0.21	0.81	0.24	0.11	0.36
*rough app.												

3.5 STREAM WATER QUALITY AND NUTRIENT LOADING ESTIMATES

Water quality monitoring began in September 1997 and continued through March 1999. A total of nineteen monthly low flow events were sampled for LDF1 – LDF4 and Catfish Creek. Reference sites were sampled quarterly through the period, totaling seven events per site. High flow events were also sampled throughout the monitoring period. A total of nine events were collected for LDF2 and Catfish Creek, and eight for LDF1. Upon receipt of analysis results, all data was assimilated into the OCC relational database, collated in a spreadsheet by site, and basic statistics generated (Tables 6 through 14). Water quality data was shared with both OSU and INCOG in fulfillment of workplan tasks.

Considering that the impetus behind the phased TMDL was concern for the cause of the dissolved oxygen swings, it was necessary to investigate the rates of nutrient loading within the watershed. Water quality data were composited by site, and basic statistics were rendered summarizing results for all observations during the sampling period. Nutrient concentration means were used along with mean flow to calculate the average loads at each site. For comparative purpose and

Table 6. Base Flow Water Quality Data Statistics for Adams Creek, Sep. 1997 - March 1999,.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	6.62	7.20	241.46	14.87	13.93	56.71	31.57	9.33	75.86	10.04	0.04	0.155	0.003	0.417
median	9.61	7.06	262.70	12.60	11.80	55.00	30.00	9.99	76.00	7.50	0.04	0.150	0.003	0.430
high	11.01	8.41	297.40	25.80	25.00	85.00	49.00	22.10	98.00	24.00	0.08	0.230	0.006	0.708
low	1.12	6.83	166.30	4.40	6.21	38.00	16.00	-1.00	55.00	5.50	0.02	0.103	0.002	0.180
std	4.60	0.55	51.42	9.61	7.03	15.99	10.45	9.86	16.09	6.50	0.02	0.044	0.002	0.184
n	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Table 7. Base Flow Water Quality Data Statistics for Browns Creek, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	7.12	7.20	240.43	14.27	19.12	65.71	27.14	19.26	77.71	17.07	0.05	0.154	0.005	0.474
median	9.83	7.08	224.50	12.30	16.80	68.00	22.00	25.30	72.00	11.00	0.05	0.128	0.004	0.459
high	11.62	8.28	341.00	25.00	31.50	107.00	44.00	43.40	114.00	60.00	0.06	0.296	0.012	0.640
low	1.71	6.87	127.50	4.40	4.32	33.00	16.00	-2.00	52.00	4.00	0.03	0.070	0.001	0.380
Std	4.74	0.49	86.87	9.34	8.92	32.26	10.96	17.35	25.10	19.26	0.01	0.078	0.004	0.089
n	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Table 8. Base Flow Water Quality Data Statistics for Salt Creek, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	6.41	7.38	1066.71	14.07	22.23	145.14	227.57	46.60	207.71	25.00	0.07	0.548	0.003	0.572
median	7.87	7.36	900.00	13.20	20.60	128.00	166.00	35.40	172.00	19.50	0.07	0.365	0.002	0.530
high	10.57	8.14	1968.00	25.80	34.30	199.00	480.00	131.00	364.00	62.00	0.09	1.300	0.005	0.950
low	1.19	7.06	333.00	3.70	11.80	106.00	100.00	-1.00	24.00	14.00	0.03	0.230	0.001	0.290
Std	4.10	0.35	579.80	9.69	7.80	39.02	143.26	41.30	119.61	16.78	0.02	0.381	0.001	0.253
n	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Table 9. Base Flow Water Quality Data Statistics for Sand Creek, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
Mean	9.24	7.51	582.14	14.89	20.01	116.43	95.29	16.46	167.86	10.00	0.05	0.681	0.009	0.403
median	10.42	7.34	638.00	13.70	19.10	118.00	103.00	17.70	178.00	9.50	0.05	0.660	0.010	0.400
High	12.58	8.09	882.00	24.20	37.30	181.00	150.00	22.90	240.00	17.00	0.07	1.150	0.014	0.520
Low	5.15	7.16	253.00	5.80	5.60	43.00	38.00	2.00	75.00	5.50	0.03	0.300	0.003	0.310
Std	3.08	0.36	200.19	8.40	11.24	49.63	36.36	7.10	55.22	3.85	0.02	0.266	0.004	0.075
n	7	7	7	7	7	7	7	7	7	7	7	7	7	7

Table 10. Base Flow Water Quality Data Statistics for LDF1, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
Mean	9.75	7.86	715.83	14.64	29.40	118.63	132.29	34.50	182.44	22.43	0.11	0.991	0.013	0.611
median	9.68	7.76	603.00	12.20	28.00	124.00	113.00	25.00	182.00	22.10	0.09	0.861	0.006	0.525
High	13.30	8.81	1756.00	31.50	59.70	161.00	340.00	194.00	280.00	59.70	0.38	3.000	0.070	1.550
Low	5.25	7.26	122.00	2.00	7.23	66.00	45.00	-2.00	110.00	7.00	0.04	0.130	0.002	0.340
Std	2.47	0.45	383.73	9.34	15.09	28.60	75.88	41.93	47.06	13.49	0.08	0.720	0.017	0.316
n	19	19	19	19	19	19	18	18	18	18	18	18	18	18

Table 11. Base Flow Water Quality Data Statistics for LDF2, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	9.48	7.71	401.11	15.05	37.62	144.21	69.72	8.53	166.72	25.04	0.06	0.250	0.007	0.497
median	9.98	7.77	358.30	13.50	22.60	137.00	48.95	0.04	158.00	20.00	0.05	0.257	0.004	0.470
High	14.70	8.64	732.00	30.10	268.00	280.00	445.00	83.60	376.00	172.00	0.28	0.522	0.024	1.340
Low	1.05	6.80	207.00	4.20	6.62	84.00	20.00	-2.00	96.00	6.00	0.02	0.040	0.002	0.240
Std	3.17	0.39	127.27	8.72	57.81	46.40	94.47	20.01	59.70	38.76	0.06	0.124	0.006	0.255
n	19	19	19	19	19	19	18	18	18	17	17	17	17	17

Table 12. Base Flow Water Quality Data Statistics for LDF3, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	10.26	7.92	401.46	15.78	25.39	137.79	49.94	3.33	162.61	17.68	0.06	0.252	0.006	0.504
median	9.93	7.81	424.50	14.60	21.30	150.00	48.00	-1.00	169.00	13.75	0.06	0.214	0.004	0.470
High	14.46	9.28	527.00	33.30	57.50	178.00	75.00	18.10	308.00	58.80	0.09	0.680	0.016	0.940
Low	5.22	7.28	208.00	3.60	5.30	62.00	24.00	-2.00	90.00	2.00	0.03	0.060	0.001	0.200
Std	2.33	0.50	86.57	9.52	17.18	33.10	12.37	7.05	46.02	14.64	0.02	0.155	0.004	0.198
n	19	19	19	19	19	19	18	18	18	18	18	18	18	18

Table 13. Base Flow Water Quality Data Statistics for LDF4, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	9.57	7.76	636.53	14.68	26.51	123.79	122.87	2.70	177.58	17.59	0.06	0.423	0.004	0.440
median	10.30	7.71	525.00	12.20	25.50	120.00	85.00	-1.00	168.00	17.50	0.06	0.327	0.004	0.420
High	13.66	8.74	1660.00	28.90	57.00	179.00	450.00	16.70	320.00	39.50	0.09	1.160	0.016	0.790
Low	4.47	7.01	223.20	2.60	7.61	45.00	41.00	-2.00	85.00	5.00	0.02	0.060	-0.001	0.230
Std	2.70	0.36	369.66	9.38	14.77	35.23	104.82	6.96	57.15	9.24	0.02	0.279	0.003	0.155
n	19	19	19	19	19	19	19	19	19	19	19	18	19	19

Table 14. Base Flow Water Quality Data Statistics for Catfish Creek, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	9.83	7.57	1224.34	14.25	39.07	91.42	261.84	0.31	212.42	14.66	0.05	0.749	0.006	0.409
median	10.28	7.48	972.00	14.00	37.40	95.00	198.00	-1.00	188.00	14.50	0.05	0.620	0.005	0.360
High	13.45	8.38	4554.00	29.90	219.50	118.00	1100.00	11.60	560.00	34.50	0.09	2.790	0.027	0.680
Low	4.64	6.91	306.00	1.70	2.25	57.00	57.00	-2.00	104.00	1.20	0.02	0.040	0.002	0.230
Std	2.54	0.35	1012.75	8.76	47.44	17.80	236.08	4.03	104.16	9.05	0.02	0.613	0.005	0.120
n	19	19	19	19	19	19	19	19	19	19	19	19	19	19

Table 15. High Flow Water Quality Data Statistics for Catfish Creek, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	---	---	---	---	---	---	27.11	-1.78	57.00	498.33	0.50	0.358	0.007	1.412
median	---	---	---	---	---	---	18.50	-2.00	56.00	440.00	0.43	0.300	0.004	1.380
high	---	---	---	---	---	---	78.30	-1.00	110.00	1098.00	0.98	0.841	0.019	2.130
low	---	---	---	---	---	---	10.50	-2.00	34.00	150.00	0.25	0.083	0.003	1.000
std	---	---	---	---	---	---	21.03	0.44	23.09	292.83	0.26	0.249	0.005	0.400
n	---	---	---	---	---	---	9	9	9	9	9	9	9	9

Table 16. High Flow Water Quality Data Statistics for LDF1, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	---	---	---	---	---	---	41.86	-1.88	73.38	1048.38	0.62	0.445	0.007	1.855
median	---	---	---	---	---	---	27.50	-2.00	60.00	780.00	0.72	0.378	0.006	1.545
high	---	---	---	---	---	---	165.00	-1.00	193.00	3272.00	1.07	0.879	0.013	3.070
low	---	---	---	---	---	---	8.50	-2.00	28.00	64.00	0.09	0.137	0.004	0.720
std	---	---	---	---	---	---	51.50	0.35	52.13	1019.02	0.32	0.267	0.003	0.847
n	---	---	---	---	---	---	8	8	8	8	8	8	8	8

Table 17. High Flow Water Quality Data Statistics for LDF2, Sep. 1997 - March 1999.

Statistic	DO (mg/l)	pH	Cond (uS/cm)	Temp C	Turb (NTU)	Alk (mg/l)	Chloride (mg/l)	Sulfate (mg/l)	TotHrd (mg/l)	TSS (mg/l)	TotP (mg/l)	Nitrate (mg/l)	Nitrite (mg/l)	TKN (mg/l)
mean	---	---	---	---	---	---	26.23	-1.78	137.11	419.44	0.37	0.348	0.006	1.444
median	---	---	---	---	---	---	20.00	-2.00	60.00	288.00	0.31	0.320	0.005	1.290
high	---	---	---	---	---	---	55.00	-1.00	750.00	909.00	0.64	0.875	0.010	2.470
low	---	---	---	---	---	---	7.00	-2.00	26.00	196.00	0.23	0.130	0.003	1.000
std	---	---	---	---	---	---	16.77	0.44	230.75	258.82	0.14	0.228	0.003	0.499
n	---	---	---	---	---	---	9	9	9	9	9	9	9	9

possible BMP targeting , basin relative loads were developed by isolating each basin's load (i.e., subtracting of any upstream basin cumulative loads, if applicable) and dividing by the associated acreage.

Although this approach can prove useful, the reader is cautioned to realize that results were derived for low flow conditions, which could be significantly biased by activities or pertinent phenomenon (e.g., cattle pat density) proximal to sampling sites. Given this occurrence, nutrient concentrations would be higher than the true basin average, resulting in inflated basin loading estimates. Also, because high flow events contribute most of the loading, calculation of basin loads for this purpose alone must include high flow data. However, because the DO swings occurred during summertime, low flow conditions, focus on low flow loadings was more applicable.

Results of the loading estimates show an expected general increase in both nutrients (TP and TN minus ammonia) with downstream progression (Table 18). Intuitively, highest loads were observed at the watershed's terminal station, LDF1. By subtracting preceding basin loads where relevant, basin specific contributions appeared highest for LDF1 and LDF4 for both nutrients. Given similar nutrient dynamics (e.g., processing, sequestering) for all basins, these basins are contributing a relatively higher percentage of the total low flow load and would likely be good targets for BMP implementation.

Key water quality parameters do not appear to exhibit significant differences among stations, although some general trends may be inferred. Of particular significance, DO concentrations appeared similar among sample stations but collectively higher than those for reference sites (Figure 7). Depauperate riparian cover and significant number of excessively shallow reaches in sample basins could explain elevated primary productivity (and thus higher DOs) over reference sites. A general downstream increase in pH would also result as available carbon was used (Figure 8). Alkalinity exhibited a general decrease with downstream stations (Figure 9), while temperature showed no significant differences or trend among stations or reference sites (Figure 10). With the exception of Catfish and LDF2, turbidity showed a slight increase with downstream progression and overall was higher for sample sites (Figure 11).

Table 18. Total Phosphorus and Total Nitrogen Loading Calculations for LDF and Reference Sites.

SITE	AREA (acres)	MEAN FLOW (cfs)	MEAN TP (mg/l)	MEAN TN (no NH4) (mg/l)	TP, Cumulative Load (lbs/yr)	TP, Relative Areal Load (lbs/ac/yr)	TN, Cumulative Load (lbs/yr)	TN, Relative Areal Load (lbs/ac/yr)
LDF2	40713	13.64	0.060	0.754	1608.01	0.039	20207.298	0.496
Catfish	17439	4.33	0.050	1.164	425.38	0.024	9902.923	0.568
LDF3	8373	14.27	0.060	0.762	1682.28	0.009	21364.930	0.138
LDF4	6808	27.52	0.060	0.867	3244.31	0.229	46880.266	3.748
LDF1	15118	40.43	0.110	1.615	8738.14	0.352	128291.772	5.146
Sand*	9088	1.68	0.050	1.093	165.04	0.018	3607.879	0.397

*reference site

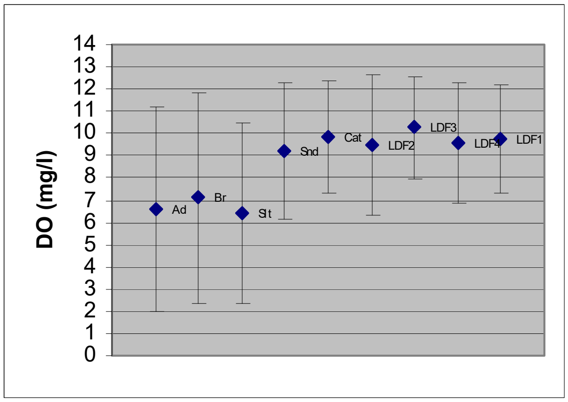

Figure 7. DO Concentration (+/-stdev) for LDF Watershed and Reference Sites.

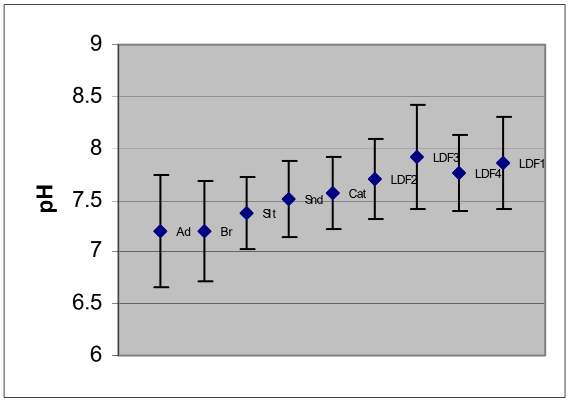

Figure 8. pH (+/- stdev) for LDF Watershed and Reference Sites.

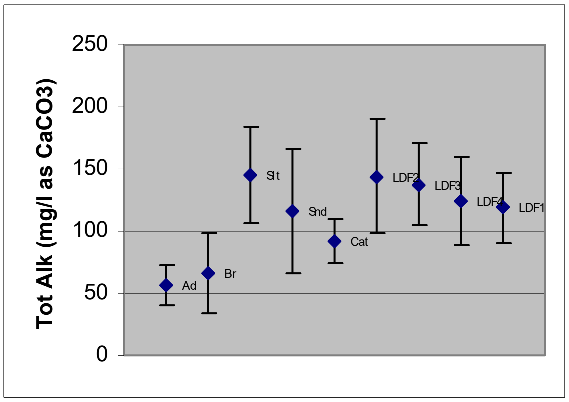

Figure 9. Total Alkalinity (+/- stdev) for LDF Watershed and Reference Sites.

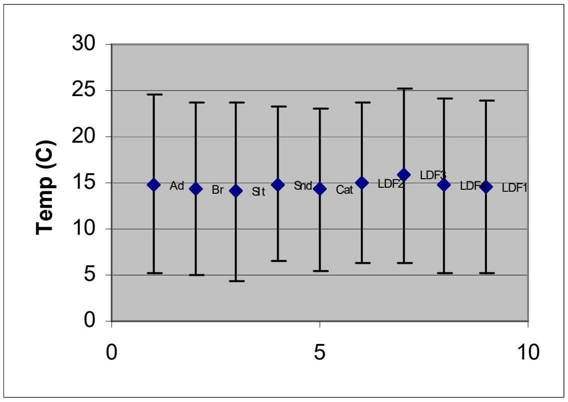

Figure 10. Temperature (+/- stdev) for LDF Watershed and Reference Sites.

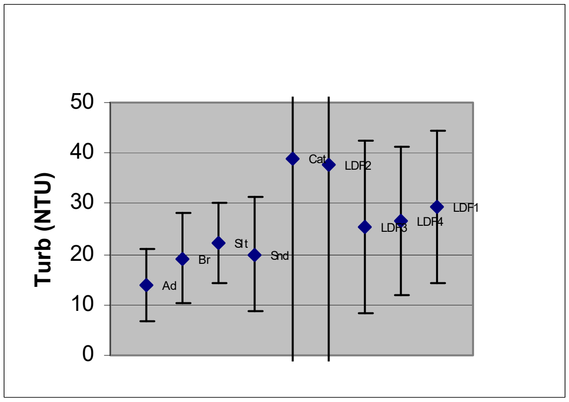

Figure 11. Turbidity (+/- stdev) for LDF Watershed and Reference Sties.

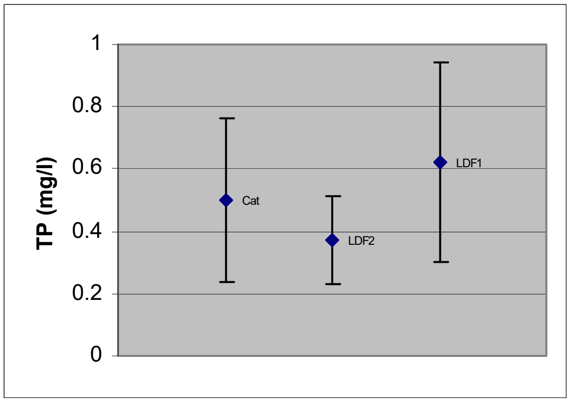

Figure 12. High Flow Total Phosphorus Concs. for Collected Stations.

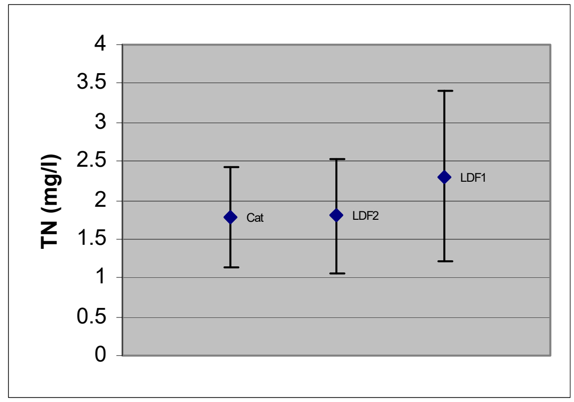

Figure 13. High Flow Total Nitrogen Concs. for Collected Stations.

As expected, nutrient concentrations were significantly greater for high flow events. Although concentration variability was not significantly different among stations, general trends appear to follow expectations. Mean total phosphorus was five to ten times greater than low flow concentrations, exhibiting a general increase with downstream station (Figure 12, above). Mean total nitrogen (less ammonia) was only 1.5 – 2 times greater than low flow values and followed a similar trend (Figure 13, above).

On August 31, 1999, the OCC engaged in a cursory sediment oxygen demand SOD study to investigate the benthic metabolism of selected sites. Although it was not a workplan task, periphyton (discussed later), water quality, and modeling results appeared to indicate that the magnitude of water column productivity or its potential was not sufficient to contribute to the DO swings observed by INCOG. Instead, it was hypothesized that benthic algal assemblages might play a greater role in the process, especially during the significantly low flow of summertime conditions. Two sites were monitored, resulting in four samples per site: initial water column, final water column, test (in-situ chamber allowing interface with sediments), and control (in-situ chamber prohibiting interface with sediments). Once a significant "crash" or reduction in DO was observed, samples were collected from the chamber and analyzed to infer whether sediments were contributing or consuming nutrients.

Similar trends were seen in DO between sampling sites (Figure 14). In both cases, DO means were highest for test samples, medial for controls, and lowest in the water column. For test site A, DO was most variable and exhibited the highest magnitude of all samples; a result which would be expected for significant benthic algal activity. Nutrient analyses also revealed similar trends between sites, but differences were not as marked (Figures 15 and 16). Results show test samples possessing slightly greater TP concentrations than controls for both sites. Although differences may appear slight, one must consider that results were elaborated from a one liter chamber over a six square inch area. Any difference between test and control samples, if truly present, must be considered in light of elaboration to total stream area. In the case of dissolved oxygen and TP, potential for significant system wide impact appears likely.

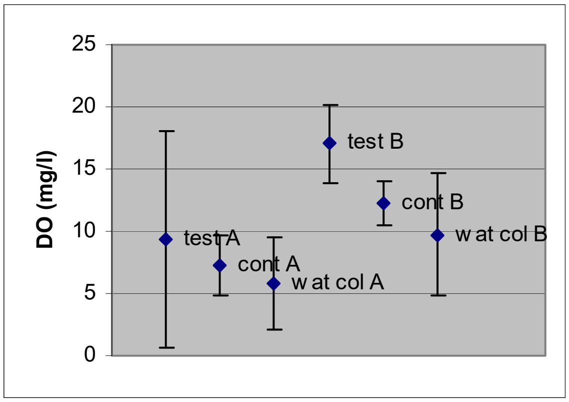

Figure 14. DO Results for Test, Control, and Water Column Sampling for Two LDF Sites.

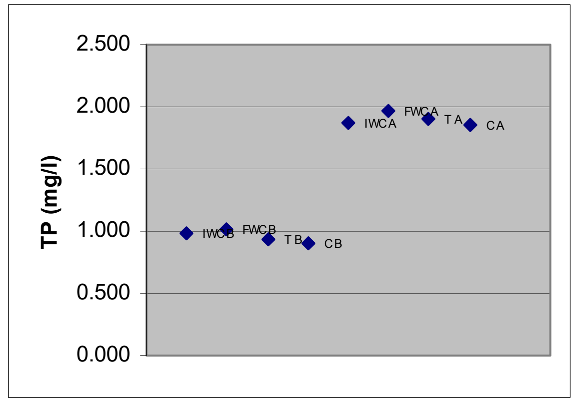

Figure 15. TP Results for Test, Control, and Water Column Samples for Two LDF Sites.

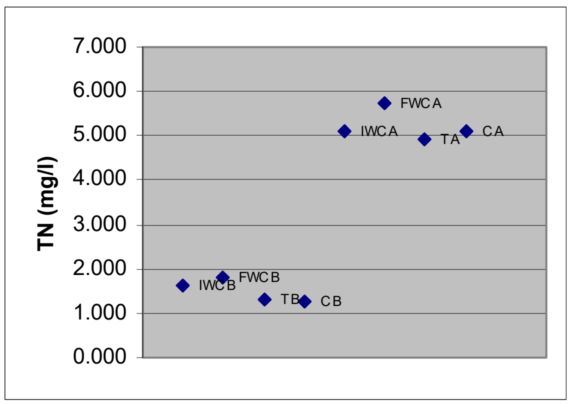

Figure 16. TN Results for Test, Control, and Water Column Samples for Two LDF Sites.

Two groundwater seeps also were collected to determine their contribution to the system. One grab sample was collected at each seep and the corresponding stream water column to assess impact potential. Results for the LDF 2 Seep exhibit a marked difference from the water column in sulfate and nutrient concentrations (Table 19). Total phosphorus and total nitrogen concentrations were eight and four fold instream concentrations, respectively. These results indicate that seep water input could potentially affect stream loads for select items.

Table 19. Select Water Quality Analytes for Two LDF Seeps (test) and Associated Water Columns (control).

SiteName	Cl (mg/l)	SO4 (mg/l)	TotHrd (mg/l)	TP (mg/l)	oP (mg/l)	NH3 (mg/L)	NO3 (mg/l)	NO2 (mg/l)	TKN (mg/l)	TN (mg/l)
LDF2 - wat col	96.00	2.60	256.00	0.031	0.004	0.021	0.062	0.001	0.460	0.544
LDF2 seep	9.00	266.00	220.00	0.237	0.002	0.025	0.510	0.002	1.570	2.107
LDF @ SH48 - wat col	212.00	114.00	276.00	0.756	0.552	0.021	1.190	0.084	1.270	2.565
LDF @ SH48 - seep	76.00	35.60	476.00	0.035	0.001	0.015	0.033	0.001	0.210	0.259

Due to limited summer flow and a late start in 1997, diurnal sampling results were limited significantly. Four events were achieved in August 1999 at the following sites: LDF2, LDF3, LDF at Kelly Bro (upstream of Bristow WWTP discharge), and LDF at SH 48 (immediately downstream of discharge). DO "swings" for all upstream sites exhibited an approximate average of 5 mg/l (Figures 17 – 19). While this is at the upper range of what would be expected for nonimpacted streams (Dan Butler, pers. comm.), it did not reach the magnitude of that reported in the INCOG study. However, as expected, DO showed a much broader range at the SH 48 site (Figure 20).

3.6 BIOLOGICAL MONITORING

3.6.1 Instream Habitat

A necessary foundation of any healthy biological community is quality habitat. Instream habitat assessments were conducted for all study and reference sites from September through October 1997. All data was entered into the OCC relational database and compiled and queried for scoring metrics. Although results revealed relatively acceptable habitat scores for all sites, mean total score was higher for reference (103.2) than study (86.9) sites (Table 20).

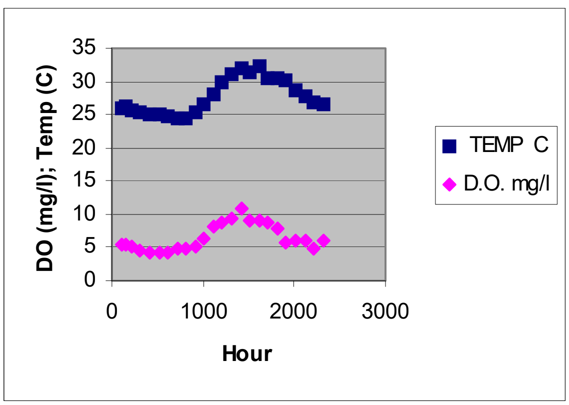

Figure 17. Diurnal DO profile for LDF2, 18 AUG 99.

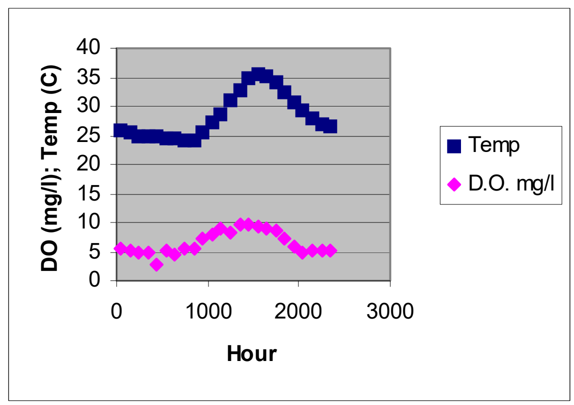

Figure 18. Dirunal DO profile for LDF3, 18 AUF 99.

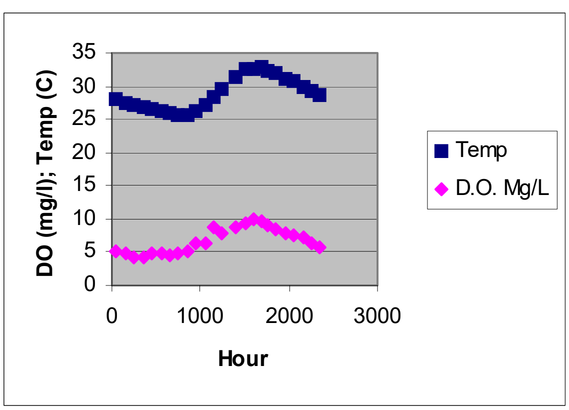

Figure 19. Diurnal DO profile for LDF at Kelly Bro., 18 AUG 99.

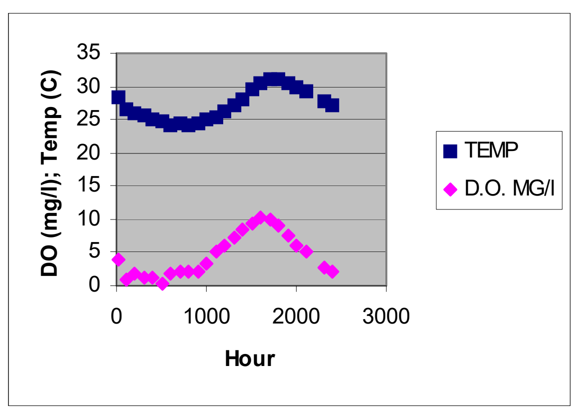

Figure 20. Diurnal DO profile for LDF at SH48, 31 AUG 99.

Table 20. Instream Habitat Assessment Metric Scores for LDF Study and Reference Sites.

SiteName	IS Cover	PlBotSub	PlVar	Can. Cov./ Shadng	Rocky Runs/Riffs	Flow	Chnl Altrtn	Sinu	Bnk Stab	Bnk Veg	StmSd Cvr	Total
LDF2	3.0	1.9	14.3	19.3	3.8	17.9	11.5	1.6	7.9	0.9	3.9	**86.0**
Catfish Creek	3.2	2.5	9.9	17.4	4.1	19.9	15.1	0.4	6.1	5.5	10.0	**94.1**
LDF3	1.4	2.2	16.7	20.0	0.0	17.4	12.9	1.6	9.3	2.3	7.2	**90.9**
LDF4	1.9	2.9	13.6	12.9	0.0	20.0	16.5	1.1	7.9	0.9	4.0	**81.7**
LDF1	1.4	2.5	16.3	3.8	0.0	20.0	15.1	1.1	8.5	3.8	9.1	**81.6**
Sand*	1.4	4.2	17.2	18.7	0.0	6.0	16.5	0.6	8.1	5.5	9.9	**88.1**
Adams*	10.3	9.9	17.2	20.0	4.1	12.1	16.5	7.3	10.0	7.5	6.6	**121.5**
Browns*	9.0	10.8	16.6	18.8	5.9	7.7	16.5	2.4	8.2	6.2	9.7	**111.8**
Salt*	6.2	5.0	20.0	16.9	4.1	5.7	9.9	3.7	7.4	3.7	8.7	**91.3**
*ref. sites												

In cursory review, a few habitat parameters appear to account for most of this difference. Pooled mean scores of reference *instream cover* and *pool bottom substrate* are three-fold those of LDF study sites; reference stream *rocky runs/riffles* is two-fold. Given the relatively large influence of these parameters in determining fish assemblages, one might expect a reflection of their differences in fish collections.

3.6.2 Fish

Fish were collected from each of the project sites in September 1997. Upon receipt of sample identifications, all data was entered into the OCC relational database and queried for selected results and IBI metric calculations (Table 21). As a group, study sites exhibited lower IBI scores than reference sites, but exceptional differences between them were not apparent. Since fish community structure tends to be especially sensitive to differences in habitat, one must consider IBI results in light of habitat variability among sites.

As discussed above, study sites differed as a whole from reference sites mostly in *instream cover, pool bottom substrate,* and *rocky runs/riffles*. If habitat differences really do exist, one should see this reflected in the fish collections. As a whole, centrarchids are generally pool species requiring good instream structure and sound bottom substrate. Any shifts in these habitat variables between sites should be reflected in collections (assuming equivalent water quality). Such differences appeared to exist, with study sites exhibiting a mean relative abundance of centrarchids of 46 percent and reference sites 57 percent. Although highest total species for study sites were recorded at LDF2 and LDF1, mean total species for study and reference site groupings were not that different (16 and 16.5, respectively). Since the proportion of Omnivores tends to increase with deteriorating physical and/or chemical habitat, this metric was isolated to establish further differences in overall community health. The mean proportion of Omnivores from the four reference streams is 11 percent, while that for the study sites is 35 percent.

Assuming equivalent water quality among sites, differences in sound fish collections should be due to differential habitat. As discussed previously, general water quality is not significantly

Table 21. IBI Scores and Sample Composition by Trophic Level and Tolerance Proportions of Age 1+ Fish for LDF Study and Reference Collections.

Site	Total Collected	Percent Herbivores	Percent Insectivores	Percent Omnivores	Percent Piscivores	Percent Tolerant	Percent Mod. Tolerant	Percent Mod. Intolerant	Total Species	Modified IBI
LDF2	399		60	36	4	54	27	8	20	**34**
Catfish	190		73	24	3	56	35	9	13	**34**
LDF3	254		70	26	3	45	52	3	14	**30**
LDF4	124		49	45	6	54	40	6	15	**32**
LDF1	236		50	47	3	68	27	5	18	**31**
Sand*	333		66	30	4	50	49	1	13	**42**
Adams*	186	15	67	6	11	26	52	15	16	**34**
Browns*	351	9	81	5	5	26	58	16	16	**42**
Salt*	227		93	3	4	46	50	4	21	**46**
*reference sites										

different among study and reference sites. Although some parameters appeared to show a trend with downstream progression, none were corrected for time. Apparent downstream increases/decreases in variables such as DO and pH could be more a function of disparate sample times than true site differences. The mean IBI score for reference streams is 41, while that for the study sites is 32. In light of the previous discussion, it would appear any difference between the two groups should be attributed to habitat.

3.6.3 Macroinvertebrates

Macroinvertebrate collections were completed from September 1997 through February 1999 to assess the physical and chemical water quality of LDF and reference sites. All sampling was done at base flow conditions to avoid sampling habitat scoured during high flow events. All three generalized habitat types (riffle, woody, vegetation) were sampled according to occurrence. Only woody samples were collected throughout sampling duration for LDF3 during winter periods. Although woody samples tend to be variable and unreliable, the results.were converted to riffle via a woody-to-riffle conversion factor derived from pooled reference data to investigate the sites collections. Unfortunately, no summer collections were achieved for reference sites throughout the sampling period due to no flow. A brief effort to find an alternate reference site yielded two summer collections from Lagoon Creek (29 JUL 99 and 11 JUL 00). Data from these collections were pooled and used in derivation of index metrics for summer LDF collections.

Seven community attributes were used to score (Table 22) the condition of the benthic invertebrate community. They include the following metrics:

(1) Number of Taxa refers to the total number of taxonomically different types of animals in the sample. As is the case with the fish, this number rises with increasing water or habitat quality. Taxa Richness is scored as a ratio of the study site to the reference site x 100 (PLAFKIN ET AL. 1989).

Table 22: Modified Biological Condition Scoring Criteria

Metrics	***6***	***4***	***2***	***0***
Taxa Richness**	>80	60-80	40-60	<40
Modified HBI* (**)	>85	70-85	50-70	<50
EPT/EPT + Chironomini**	>75	50-75	25-50	<25
EPT/Total (Density)***	>30	30 & >20	<=20 & >10	<=10
EPT Taxa (Index)**	>90	80-90	70-80	<70
Dominants to Total**	<20	20-30	30-40	>40
Shannon-Weaver***	>=3.5	<3.5&>=2.5	<2.5&>=1.5	<1.5

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

(2) The Modified Hilsenhoff Biotic Index is a measure of the invertebrate community's tolerance to organic pollution. It ranges between 0 and 10 with 0 being the most pollution sensitive. The index used in the RBP Manual is based on the pollution tolerance of invertebrates from the upper Midwest. The Index used here is calculated the same way, but uses tolerance values of North Carolina invertebrates. The Modified HBI is a ratio of the reference site to the study site x 100 (PLAFKIN ET AL. 1989).

(3) Percent EPT of EPT and Chironomids is a further isolation of EPT relative abundance corrected for Chironomini. Chironomids are a member of the Dipteran family Chironomidae or midges. Many members of this family are pollution tolerant, and they can build up to high numbers as animals that prey on them begin to disappear due to the effects of pollution. EPT/EPT + Chironomidae- is scored as a ratio of the study site to the reference site x100 (PLAFKIN ET AL. 1989).

(4) Percent EPT is a measure of how many individuals in the sample are members of the EPT group. This metric helps to separate high quality streams from those of moderately high quality. The highest quality streams will have many individuals of many different taxa of EPT. As conditions deteriorate, animals will begin to die or to drift downstream. At this point, the community will still have many taxa of EPT, but there will be fewer individuals. EPT/Total (density) is scored as a percent of contribution (PLAFKIN ET AL. 1989).

(5) The EPT Index is the number of different taxa from the orders Ephemeroptera, Plecoptera, and Trichoptera, the mayflies, stoneflies, and caddisflies respectively. With few exceptions, these insects are more sensitive to pollution than any other groups. As a stream deteriorates in quality, members of this group will be the first to disappear. This is a robust metric that allows discrimination between all but the worst of streams. EPT Taxa (Index) is scored as a ratio of the study site to the reference site x100 (PLAFKIN ET AL. 1989).

(6) Percent Dominant Taxa is the percentage of the collection composed of the most common taxa. As more and more species are excluded by increasing pollution, the remaining ones can

build up to larger numbers due to the unused resources left by the excluded animals. This metric helps to separate the high quality from the moderate quality streams. The Dominants to Total is scored as a percent contribution (PLAFKIN ET AL. 1989).

(7) The Shannon-Weaver Species Diversity Index measures the evenness of the species distribution. It increases as more and more taxa are found in the collection and as individual taxa become less dominant. This metric increases with increasing biotic quality. Shannon-Weaver is scored directly with numerical guidance in the EPA RBP (PLAFKIN ET AL. 1989).

Because riffle samples tend to produce the most reliable results and generally reflect the community adequately (PLAFKIN ET AL. 1989), only riffle samples were analyzed to investigate macroinvertebrate community impact. A total of two winter samples were collected for all reference and study sites, except Catfish, which yielded three. Average reference metrics were derived from pooled reference data minus two samples (Salt-2/5/98 and Adams-2/24/98), which did not adequately reflect reference conditions. Samples were averaged for each site, and metric scores derived and compared to the reference mean score (Table 23).

Table 23. Metrics for Winter Macroinvertebrate Collections, Sep 1997 through Feb 1999.

METRIC	LDF2 WINTER AVERAGE	LDF2 WINTER SCORES	CATFISH WINTER AVERAGE	CATFISH WINTER SCORES	LDF3 WINTER AVERAGE*	LDF3 WINTER SCORES
Number of taxa	12	**4**	13	**6**	18	**6**
Modified Hilsenhoff biotic index	6.08	**6**	6.90	**6**	6.05	**6**
EPT/EPT + Chronomini	0.74	**6**	0.69	**6**	0.73	**6**
EPT/total	0.16	**2**	0.28	**4**	0.16	**2**
EPT taxa	2.00	**0**	3.33	**4**	7.00	**6**
Dominants/total	0.54	**0**	0.32	**2**	0.34	**2**
Shannon-Weaver diversity index	2.19	**2**	2.64	**4**	3.63	**6**
TOTALS		**20**		**32**		**34**
PERCENT OF REFERENCE		**67**		**107**		**113**

METRIC	LDF4 WINTER AVERAGE	LDF4 WINTER SCORES	LDF1 WINTER AVERAGE	LDF1 WINTER SCORES	REFERENCE WINTER AVERAGE	REFERENCE WINTER SCORES
Number of taxa	14	**6**	14	**6**	15	**6**
Modified Hilsenhoff biotic index	5.75	**6**	6.65	**6**	6.17	**6**
EPT/EPT + Chronomini	0.73	**6**	0.75	**6**	0.65	**6**
EPT/total	0.35	**6**	0.13	**2**	0.14	**2**
EPT taxa	4.50	**6**	3.50	**4**	4.17	**6**
Dominants/total	0.33	**2**	0.36	**2**	0.43	**0**
Shannon-Weaver diversity index	3.07	**4**	2.97	**4**	2.66	**4**
TOTALS		**36**		**30**		**30**
PERCENT OF REFERENCE		**120**		**100**		

Table 24. Metrics for Summer Macroinvertebrate Collections, Sep 1997 through Feb 1999.

METRIC	LDF2 SUMMER AVERAGE	LDF2 SUMMER SCORES	CATFISH SUMMER AVERAGE	CATFISH SUMMER SCORES	LDF4 SUMMER AVERAGE	LDF4 SUMMER SCORES
Number of taxa	12	**6**	19	**6**	20	**6**
Modified Hilsenhoff biotic index	4.91	**6**	5.11	**6**	4.99	**6**
EPT/EPT + Chronomini	0.71	**6**	0.83	**6**	0.74	**6**
EPT/total	0.16	**2**	0.31	**6**	0.36	**6**
EPT taxa	3.50	**4**	6.50	**6**	8.50	**6**
Dominants/total	0.49	**0**	0.20	**6**	0.27	**4**
Shannon-Weaver diversity index	2.11	**2**	3.66	**6**	3.52	**6**
TOTALS		**26**		**42**		**40**
PERCENT OF REFERENCE		**87**		**140**		**133**
METRIC	**LDF1 SUMMER AVERAGE**	**LDF1 SUMMER SCORES**	**LAGOON CK SUMMER AVERAGE**	**LAGOON CK SUMMER SCORES**		
Number of taxa	15	**6**	13	**6**		
Modified Hilsenhoff biotic index	5.58	**6**	5.95	**6**		
EPT/EPT + Chronomini	0.68	**6**	0.33	**6**		
EPT/total	0.36	**6**	0.10	**0**		
EPT taxa	6.50	**6**	4.00	**6**		
Dominants/total	0.27	**4**	0.34	**2**		
Shannon-Weaver diversity index	3.16	**4**	2.82	**4**		
TOTALS		**38**		**30**		
PERCENT OF REFERENCE		**127**				

A total of two summer collections were achieved and used in metric derivation for each site, including the reference site (Lagoon Creek). Metrics were derived and analyzed using the same methodology for winter samples described above. Unfortunately the reference pool is severely restricted, consisting of only two samples. Results may be found above (Table 24).

Similar results were observed for both winter and summer collections. In both cases, study sites exhibited higher total scores than reference sites with the exception of LDF2, which showed lower scores for both periods. Although the general data set was not robust, results appear to indicate that study sites, collectively, do not differ significantly from the reference sites. Given riffle habitat similarity among stations, this could suggest similar water quality between study and reference sites.

3.6.4 Periphyton

The summer periphyton data from 1998 and 1999 indicated poor colonization of the glass rod periphytometers. Chlorophyll-a data averaged for all study sites for both summers resulted in only 0.52 ug/cm^2 (Std. Dev. = 0.76) with a maximum value of 2.19 ug/cm^2. Reference streams averaged 0.53 ug/cm^2 (Std. Dev. = 0.40) with a maximum value of 1.61 ug/cm^2. Barbour et al. (1999) addresses target densities of chlorophyll-a from periphytometers that indicate nutrient enrichment. A level of >10 ug chl-a/cm^2 represents nuisance levels, indicating nutrient or organic enrichment. Mean benthic chlorophyll equal to 2 ug/cm^2 defines the oligotrophic - mesotrophic boundary. Because concurrent mean water column chlorophyll was near detection limits for all sites (0.0168 ug/l and 0.0065 ug/l \ for study and reference sites, respectively), low flow stream productivity for the study basin appears dominated by periphyton and streambed algal communities. Results of the 1994 INCOG WQ study also support these findings.

3.7 WATERSHED EDUCATION

Throughout most of 2001, The OSUCES conducted a watershed wide education project under contract with the OCC in fulfillment of task seven requirements. The project addressed specific educational needs of urban communities in Bristow and Depew and rural areas of the LDF watershed. Programs were presented to a broad audience who well represented a variety of needs in the watershed area. The project fulfilled six basic tasks: (1) organization and monthly meeting of an educational steering committee, (2) conducting of Home*A*Syst Assessment meetings with volunteers, (3) organization and implementation of riparian workshops, field trips, and 4-H programs, (4) organization of a private domestic waste seminar, including well-water and other issues, (5) organization of a Sediment Control workshop for developers and city officials, (6) production of a final report. For a complete coverage of project activities and results, please reference the final report, *Little Deep Fork Watershed NPS Education Project, Bristow and Depew, Creek County, Oklahoma.* (Appendix A).

3.8 DEMONSTRATION OF BEST MANAGEMENT PRACTICES (BMP)

Conservation planners for BMP implementation utilized a matrix system and habitat survey to pin point their priorities and develop farm plans. One of the most valuable results of the extensive habitat survey and land use ranking was the development of a GIS based decision matrix for targeting implementation areas. Different GIS queries used by the matrix included cow trails & pats, little or no riparian zones, eroded banks, and reaches of excessively shallow and minimally deep water. Results of the “3 out of 4” GIS query allowed pinpointing of the most problematic non-point source (NPS) potentials. Priority zones of greatest nonpoint pollution influence along the LDF at these sites were ranked a high priority; those near and outside the sites were given medium and low priority, respectively. Utilizing this targeting mechanism a ranking for individual cooperators was developed which helped focus efforts within the highest priority zone.

As a step toward enrollment, a public meeting was advertised and held at the Creek County Conservation District. Details of the cost share program, including eligibility requirements and a list of possible BMPs, were relayed to prospective participants. The list of BMPs was approved for the demonstration area by the watershed advisory group/ Creek County Conservation District Board and included the following:

1. Riparian Area Management/ Establishment
    - Incentive Payments
    - Off-Site Watering

- Vegetative Establishment
- Fencing

2. Buffer – Filter Strip Establishment
    - Incentive Payments
    - Vegetative Establishment
    - Fencing

3. Stream Bank Stabilization (not to exceed 160 ac. drainage)
    - Fencing
    - Vegetative Establishment
    - Special Management Practices

4. Rural Waste Systems
    - Septic System
    - Rock Reed System
    - Perc Test
    - Lagoon

5. Animal Waste Systems
    - Lagoons
    - Composters
    - Stack-Out Houses

6. Pasture Establishment/ Management
    - Pasture Planting (Erosion Control)
    - Fertilization/ Lime
    - Watering Facilities
    - Fencing (Rotational Grazing System)

7. Heavy Use Area (Establishing Feeding Areas)
    - Grading & Shaping
    - Geo-textile
    - Geo-cell
    - Rock

8. Sedimentation/ Water Quality Special Practices
    - Designed To Meet NRCS Specifications
    - Concurred By The Local Conservation District
    - Approved By OCC/WQ Representative
    - Cost Share Specifications

Conservation planners and landowners selected specific BMPs from the list that met the landowner's need, and the landowners agreed to exact cost share/responsibility details pertaining to them as described in Appendix C. Landowners then signed a performance agreement, maintenance agreement, and an agreement with the local conservation district, which obligated funding for BMPs on the ground.

The majority of the landowner response came from the priority zones, which facilitated the targeting for implementation on five priority areas revealed by the decision matrix. Attempts were made to contact these landowners in hopes to solicit participation. In this effort, one of the two longest reaches of riparian influence proved a viable option for implementation, and an agreement was signed and implemented. In summary, this reach was fenced (5,190 linear feet) and livestock were excluded from grazing. Several offsite watering facilities were planned and designed by NRCS for the area, one was constructed with draw down tower, discharge pipe, and anti seep baffles, another was funded by a landowner himself and designed by NRCS as a large pond that served as a wetlands, erosion control structure and water supply, and still another pond is planned for the future utilizing EQUIP funds. Cattle will be excluded and the riparian area maintained to foster natural growth, stabilize streambanks, and support water quality improvements. Although the area was priority two of the five, this landowner turned out to be ideal because he is independently wealthy, eager to cooperate, and interested in purchasing the other longest riparian reach (currently the priority one area). This purchase would give the project almost two miles of continuous riparian corridor with the same landowner on both sides of the creek. As a result, implementation efforts have an excellent potential of perpetuity, growing in both magnitude and scope.

In addition to the targeted areas many other cooperators implemented BMPs throughout the rest of the demonstration area. Numerous cost share (state match) activities occurred throughout the duration of the project as various BMPs were implemented in the watershed. Creek County contracted with fifty-three different cooperators to implement BMPs, which comprised twenty-six offsite watering/erosion control installations and thirty revegetation/ erosion control efforts, totaling $162,222 in both state and landowner matching funds. Applicable Lincoln County activities included eighteen different cooperators installing nine offsite watering/ erosion control practices, one pond cleanout practice, and eight revegetation/ erosion control practices, which totaled $46,464 in state cost share and landowner matching funds.

In addition, the Oklahoma Energy Resources Board (OERB) completed several restoration projects involving abandoned oil/gas wells within or near the LDF watershed. These abandoned oil scarred and eroding sites have been restored to productivity at no cost to landowners. Oklahoma's oil and natural gas producers and royalty owners are voluntarily funding and helping landowners stabilize their land and bring it back to productivity, whether for agriculture or recreational use. All of these projects are related to past exploration and/ or production activities, and are orphaned or abandoned as determined by the Oklahoma Corporation Commission without a responsible party (operator) still in business that currently or previously operated the site. More specifically the project area of influence was riddled with numerous old abandoned oil and gas sites. During the six years of this project two hundred and twenty-seven of these sites were addressed. The remediation efforts involved site restoration, debris removal, grading & shaping, revegetation, diversion structures (ponds & terraces), and pit closures. The sum of these industry funded activities totaled $582,234.

Future funding to support continued interest in the demonstration area is being sought. The local County Conservation Districts have already received additional state cost share funds to assist eligible landowners, and EQIP funding from the U.S. Department of Agriculture is still available in the watershed area. Also the OERB plans to continue funding contract work in the demonstration area. Another partner, often overlooked, is the local County Commissioners who maintain county roads and bridges. The local Conservation District made an effort in this project to coordinate with the County Commissioners and plans to continue with the effort. In the future additional 319(h) funds or minigrant funds will be solicited if necessary. Currently a special request is being submitted to utilize the left over 319(h) funds from this project in an extended proposal for the LDF in an FY2001 grant.

4.0 CONCLUSIONS

This study was initiated in light of concern for identification and quantification of NPS pollutants (sediment and nutrients) from the LDF watershed. A cursory scope of this work seems to indicate that a large proportion of the nutrient loading to this system must be occurring during high flow events. This appears to be the case for several reasons (1) a rather intensive land use survey of the watershed failed to isolate any significant potential sources, (2) extensive soil sampling indicated that overall soil fertility in the watershed was very low, (3) thirty year simulation modeling did not reveal significantly high annualized basin contributions for either nutrient, and (4) biological data appear to support only difference in habitat, not water quality between study and reference sites. An additional consideration evolved during the study that also appears a possible explanation. Internal loading from the sediments themselves appeared evident base on a sediment oxygen demand study, which revealed high demand from the sediments and some contribution of phosphorus to the water column.

If we look at internal loading as a symptom and not the problem, then the most probable source of the problem is the hydrology of the stream itself. Thirty-nine flood control structures have been built upstream of the lower project boundary in the last 40 years. By design, these structures act to impede the stream's ability to cleanse itself by depositing accumulated organic matter onto the flood plain. Instead, this organic matter is covered over by sediments as flood events wane. It is then attacked by oxygen consuming bacteria during the decomposition process. Eventually, it will be re-suspended by the next event and nutrients will be leached into the water column, stimulating robust algae populations and exacerbating diurnal DO swings.

By all indications, any problem the Little Deep Fork system has with severe dissolved oxygen swings is not due to its gross enrichment, but rather to its grossly entrenched stream channel. As you move downstream the channel becomes progressively wider and due to erosion has progressively less canopy. The resulting combination of very warm, shallow, and relatively transparent water appears the perfect scenario for excessive DO swings, even given a moderate amount of nutrients.

Regardless of the validity of this particular diagnosis, the impetus of our findings suggested that our implementation efforts should be concentrated in the LDF (1) and (4) basins, and that at least some consideration should be given to urban/social practices. Sound implementation and demonstration activities were intitiated in key locations in these areas and are proving to have growth potential long after this project.

5.0 LITERATURE CITED

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APPENDIX A

Little Deep Fork Watershed NPS Education Project

Bristow and Depew, Creek County, Oklahoma

Final Report

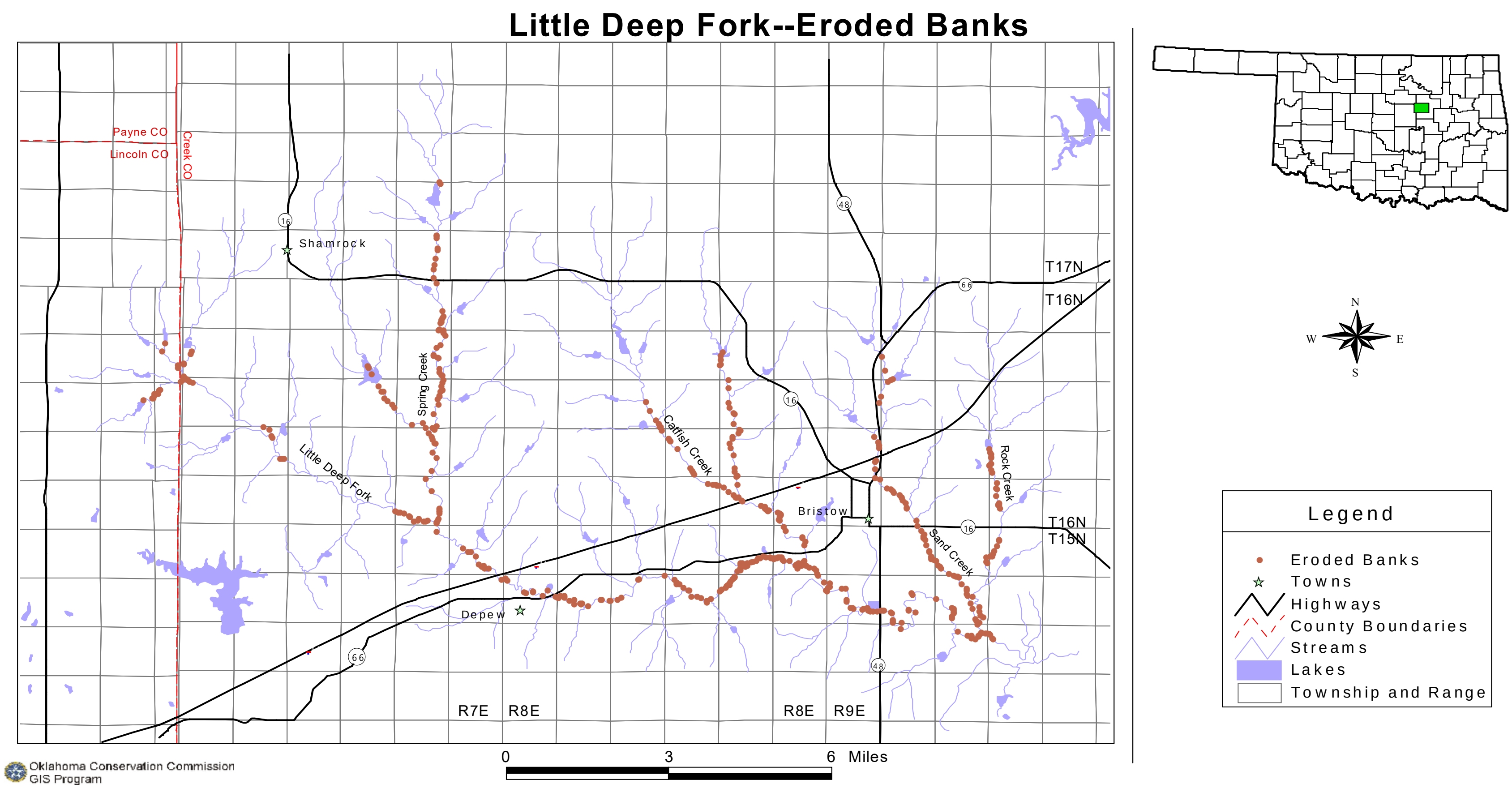
Appendix A. ***Little Deep Fork Watershed NPS Education Project, Bristow and Depew, Creek County, Oklahoma. OSUCES Project Report, September 2001.***

See File: ***LDF Final Report Education***

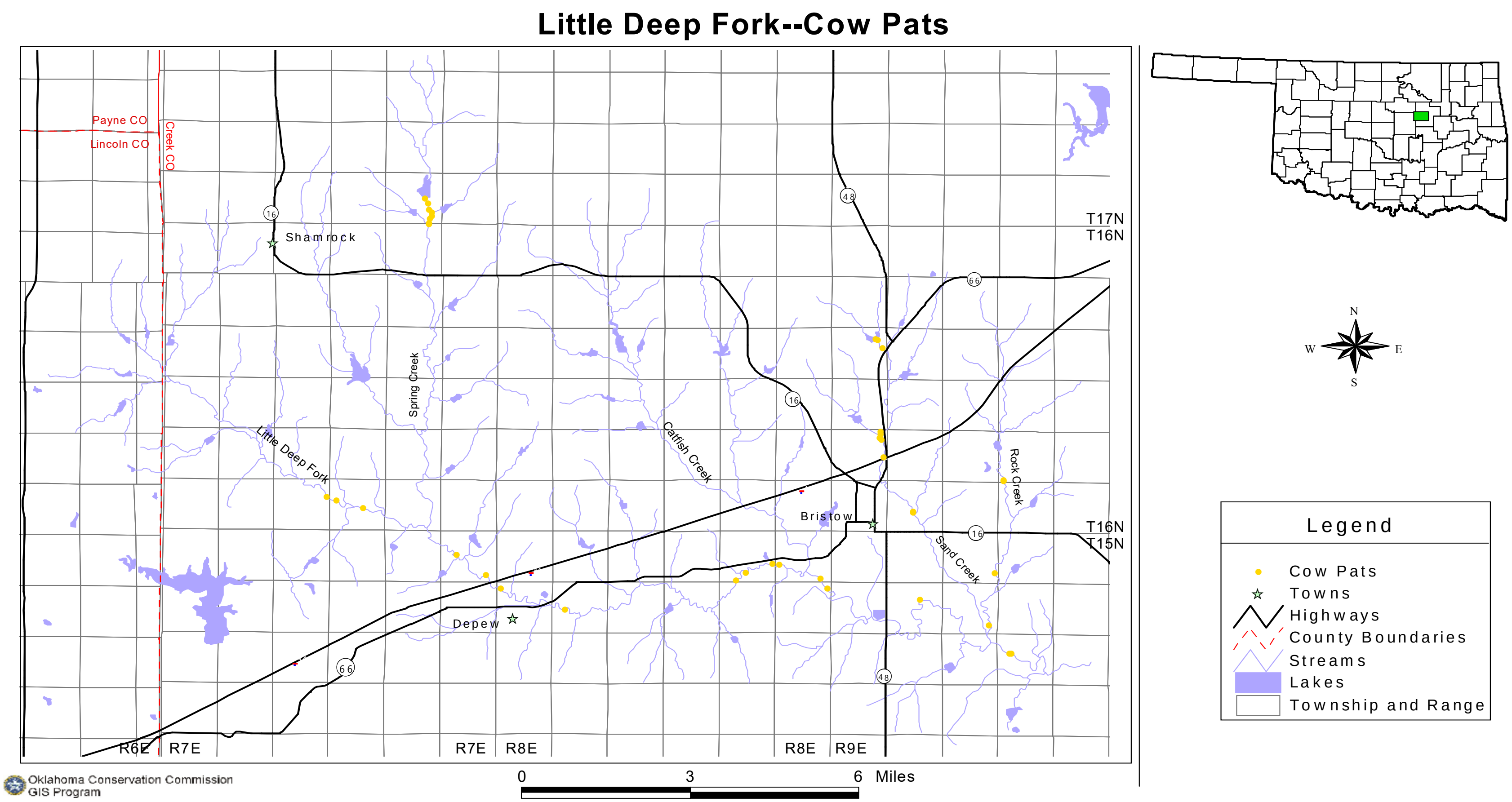
APPENDIX B

GIS Maps of Selected HA Data for Determining NPS Sources

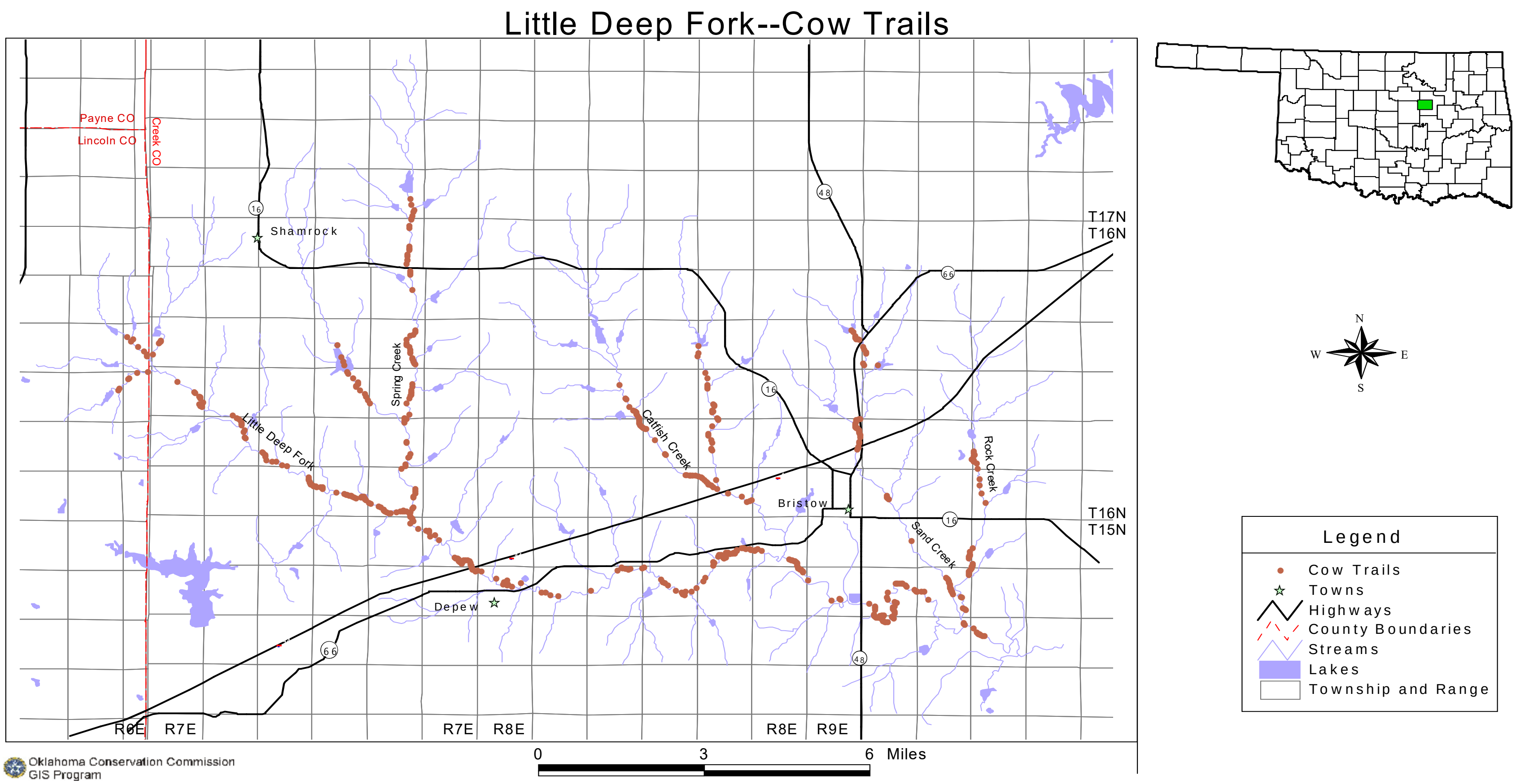
Appendix B-1. GIS Map Showing Occurrence of Excessively Eroded Banks in LDF Watershed Reaches.



Appendix B-2. GIS Map Showing Cow Pat Occurrence in LDF Watershed Reaches.

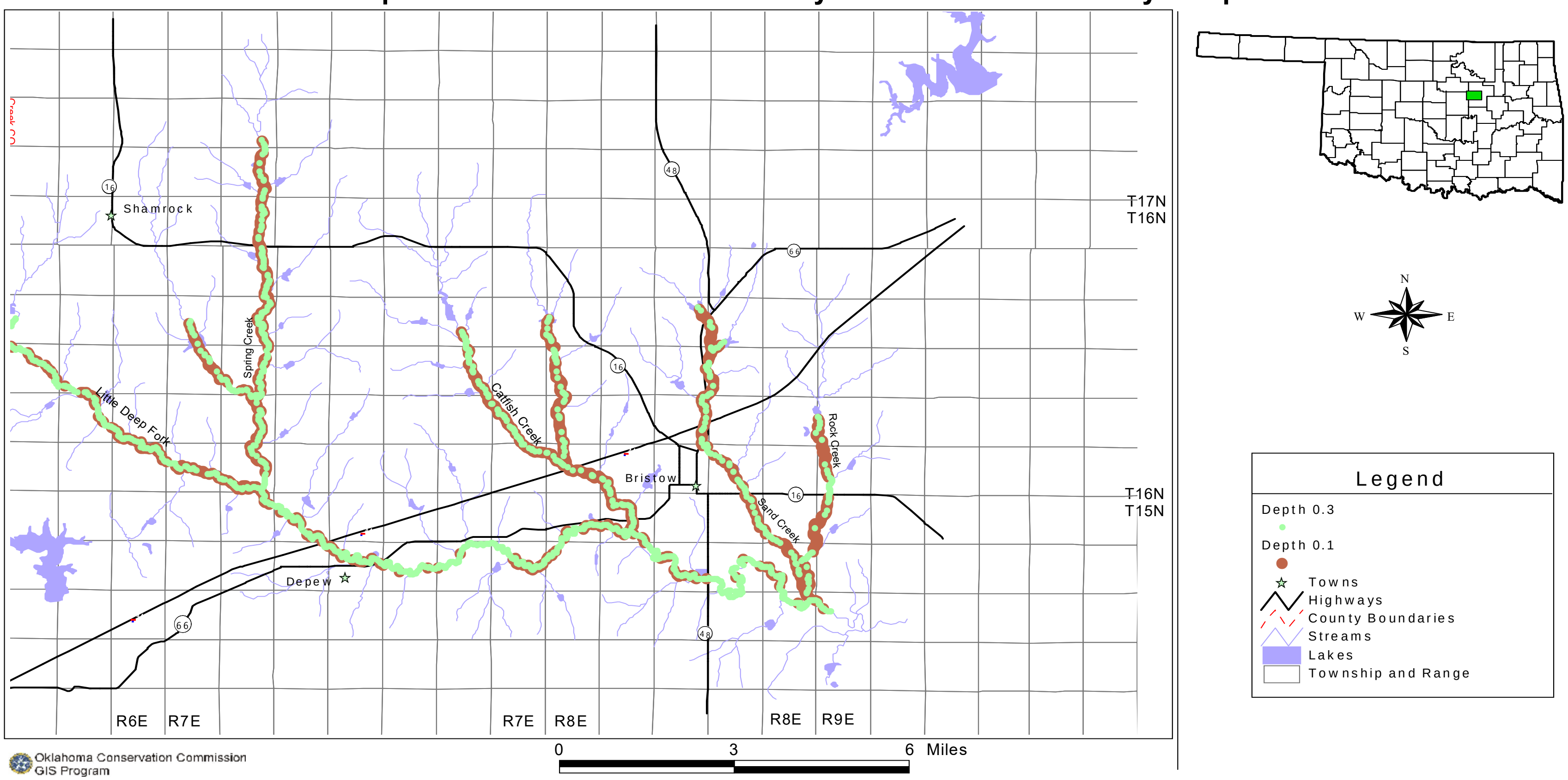


Appendix B-3. GIS Map Showing Cow Trail Occurrence in LDF Watershed Reaches.



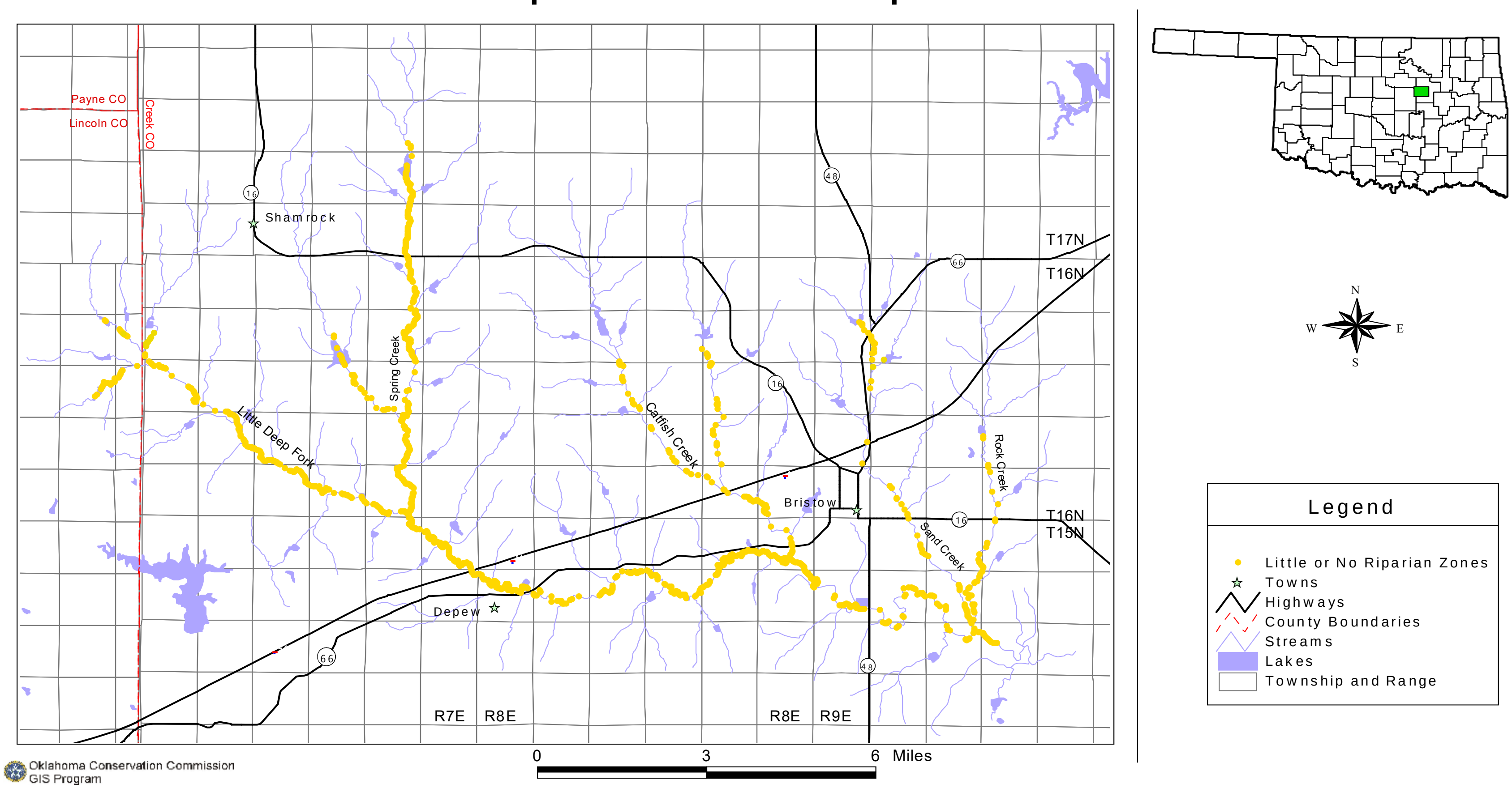
Appendix B-4. GIS Map Showing Occurrence of Excessively Shallow and Minimally Deep LDF Watershed Reaches.

Little Deep Fork--Reaches of Excessively Shallow and Minimally Deep Water



Appendix B-5. GIS Map Showing LDF Watershed Reaches Possessing Little or No Riparian Zone.

Little Deep Fork--Little or No Riparian Zones



APPENDIX C

Minutes from the LDF Cost Share Program Public Meeting

Appendix C. Minutes from the LDF Cost Share Program Public Meeting.

Attachment #1

Little Deepfork TMDL
Cost Share Program

Best management practices that were selected by our landowners at the public meeting include; Riparian area management / establishment and streambsnk stabilization.

Under riparian area management we would like to offer a 50 $/ acre /year, incentive payment for total exclusion of livestock. Cooperators would also have to agree to not cut hay for the duration of the agreement to receive this price. 45$ /acre /year would be offered to those cooperators who wished to continue cutting hay. We would recommend a 4 year period of agreement for the incentive program. Off site watering would need to be offered to cooperators who relocated their livestock, this could include but is not limited to ponds. Fencing of ponds would be preferred and highly recommended, which will necessitate installation of freeze proof tanks. The recommended cost share rate would be 75% of average cost. Fencing would obviously be required, to protect the riparian area, the recommended cost share rate would again be 75% of average cost. Use of electric fence would be allowed in situations deemed practical. Under stream bank stabilization, where fencing, dirt work and vegetative plantings would be required the previously mentioned cost share rate would be recommended. Only projects containing 160 acres or less drainage will be considered for streambank stabilization. Cooperators will be solely responsible for maintenance of any installed practices.

APPENDIX D

Fish Collections for LDF Study and Reference Sites

Appendix D. Fish Collections for LDF Study and Reference Sites.

Site Name	SMPLID	Sh Time (sec)	Sn Time (sec)	CSh	RS	CSn	RSn	Family	VernName	Species
LDF2	11958	4262	80		1			Lepisosteidae	Spotted gar	Lepisosteus oculatus
LDF2	11958	4262	80	38		64		Cyprinidae	Red shiner	Cyprinella lutrensis
LDF2	11958	4262	80		5		1	Cyprinidae	Common carp	Cyprinus carpio
LDF2	11958	4262	80	10				Cyprinidae	Suckermouth minnow	Phenacobius mirabilis
LDF2	11958	4262	80	16		11		Cyprinidae	Bullhead minnow	Pimephales vigilax
LDF2	11958	4262	80		1			Catostomidae	Smallmouth buffalo	Ictiobus bubalus
LDF2	11958	4262	80	1				Ictaluridae	Yellow bullhead	Ameiurus natalis
LDF2	11958	4262	80		3	1		Ictaluridae	Channel catfish	Ictalurus punctatus
LDF2	11958	4262	80	13				Ictaluridae	Freckeled madtom	Noturus nocturnus
LDF2	11958	4262	80	1				Ictaluridae	Flathead catfish	Pylodictis olivaris
LDF2	11958	4262	80	19		36		Poeciliidae	Mosquitofish	Gambusia affinis
LDF2	11958	4262	80	26	5	3	3	Centrarchidae	Green sunfish	Lepomis cyanellus
LDF2	11958	4262	80	1				Centrarchidae	Orangespotted sunfish	Lepomis humilis
LDF2	11958	4262	80	13		14		Centrarchidae	Bluegill sunfish	Lepomis macrochirus
LDF2	11958	4262	80	46	5	27	2	Centrarchidae	Longear sunfish	Lepomis megalotis
LDF2	11958	4262	80			4		Centrarchidae	Redear sunfish	Lepomis microlophus
LDF2	11958	4262	80	7	4	11		Centrarchidae	Spotted bass	Micropterus punctulatus
LDF2	11958	4262	80	4	1			Centrarchidae	Largemouth bass	Micropterus salmoides
LDF2	11958	4262	80	1				Centrarchidae	White crappie	Pomoxis annularis
LDF2	11958	4262	80		1			Sciaenidae	Freshwater drum	Aplodinotus grunniens
Catfish	11876	2820	75	11		26		Cyprinidae	Red shiner	Cyprinella lutrensis
Catfish	11876	2820	75	17		17		Cyprinidae	Sand shiner	Notropis stramineus
Catfish	11876	2820	75	8				Cyprinidae	Suckermouth minnow	Phenacobius mirabilis
Catfish	11876	2820	75	5		4		Cyprinidae	Bullhead minnow	Pimephales vigilax
Catfish	11876	2820	75		1			Catostomidae	Black buffalo	Ictiobus niger
Catfish	11876	2820	75	9				Ictaluridae	Yellow bullhead	Ameiurus natalis
Catfish	11876	2820	75	7				Ictaluridae	Freckeled madtom	Noturus nocturnus
Catfish	11876	2820	75	5		8		Poeciliidae	Mosquitofish	Gambusia affinis
Catfish	11876	2820	75	35	1	1		Centrarchidae	Green sunfish	Lepomis cyanellus
Catfish	11876	2820	75					Centrarchidae	Orangespotted sunfish	Lepomis humilis
Catfish	11876	2820	75	2		7		Centrarchidae	Bluegill sunfish	Lepomis macrochirus
Catfish	11876	2820	75	17		4		Centrarchidae	Longear sunfish	Lepomis megalotis
Catfish	11876	2820	75	2		1		Centrarchidae	Spotted bass	Micropterus punctulatus
Catfish	11876	2820	75	2				Centrarchidae	Largemouth bass	Micropterus salmoides
LDF3	11959	3650	100			57		Cyprinidae	Red shiner	Cyprinella lutrensis
LDF3	11959	3650	100			1		Cyprinidae	Bullhead minnow	Pimephales vigilax
LDF3	11959	3650	100			7		Catostomidae	River carpsucker	Carpiodes carpio
LDF3	11959	3650	100	3				Ictaluridae	Yellow bullhead	Ameiurus natalis

LDF3	11959	3650	100	2				Ictaluridae	Freckeled madtom	Noturus nocturnus
LDF3	11959	3650	100	1				Ictaluridae	Flathead catfish	Pylodictis olivaris
LDF3	11959	3650	100	3		29		Poeciliidae	Mosquitofish	Gambusia affinis
LDF3	11959	3650	100	6		2		Centrarchidae	Green sunfish	Lepomis cyanellus
LDF3	11959	3650	100	1		2		Centrarchidae	Orangespotted sunfish	Lepomis humilis
LDF3	11959	3650	100	8		8		Centrarchidae	Bluegill sunfish	Lepomis macrochirus
LDF3	11959	3650	100	69		41		Centrarchidae	Longear sunfish	Lepomis megalotis
LDF3	11959	3650	100			1		Centrarchidae	Redear sunfish	Lepomis microlophus
LDF3	11959	3650	100	5	1	6		Centrarchidae	Spotted bass	Micropterus punctulatus
LDF3	11959	3650	100	1				Centrarchidae	Largemouth bass	Micropterus salmoides
LDF4	11960	4428	120	4		38		Cyprinidae	Red shiner	Cyprinella lutrensis
LDF4	11960	4428	120		3			Cyprinidae	Common carp	Cyprinus carpio
LDF4	11960	4428	120	7				Cyprinidae	Suckermouth minnow	Phenacobius mirabilis
LDF4	11960	4428	120	5		6		Cyprinidae	Bullhead minnow	Pimephales vigilax
LDF4	11960	4428	120	1				Ictaluridae	Yellow bullhead	Ameiurus natalis
LDF4	11960	4428	120	1	1		1	Ictaluridae	Channel catfish	Ictalurus punctatus
LDF4	11960	4428	120		2			Ictaluridae	Flathead catfish	Pylodictis olivaris
LDF4	11960	4428	120	4				Poeciliidae	Mosquitofish	Gambusia affinis
LDF4	11960	4428	120	2				Centrarchidae	Green sunfish	Lepomis cyanellus
LDF4	11960	4428	120	1		2		Centrarchidae	Orangespotted sunfish	Lepomis humilis
LDF4	11960	4428	120	13				Centrarchidae	Bluegill sunfish	Lepomis macrochirus
LDF4	11960	4428	120	15		15		Centrarchidae	Longear sunfish	Lepomis megalotis
LDF4	11960	4428	120	1				Centrarchidae	Redear sunfish	Lepomis microlophus
LDF4	11960	4428	120			1		Centrarchidae	Spotted bass	Micropterus punctulatus
LDF4	11960	4428	120	1				Centrarchidae	Largemouth bass	Micropterus salmoides
LDF1	11957	4110	90			1	1	Clupeidae	Gizzard shad	Dorosoma cepedianum
LDF1	11957	4110	90			18		Cyprinidae	Red shiner	Cyprinella lutrensis
LDF1	11957	4110	90		3		2	Cyprinidae	Common carp	Cyprinus carpio
LDF1	11957	4110	90	4				Cyprinidae	Suckermouth minnow	Phenacobius mirabilis
LDF1	11957	4110	90	10		69		Cyprinidae	Bullhead minnow	Pimephales vigilax
LDF1	11957	4110	90		1	2		Catostomidae	River carpsucker	Carpiodes carpio
LDF1	11957	4110	90				1	Catostomidae	Smallmouth buffalo	Ictiobus bubalus
LDF1	11957	4110	90		1			Ictaluridae	Channel catfish	Ictalurus punctatus
LDF1	11957	4110	90	1		1		Ictaluridae	Freckeled madtom	Noturus nocturnus
LDF1	11957	4110	90	6		1		Poeciliidae	Mosquitofish	Gambusia affinis
LDF1	11957	4110	90	2				Centrarchidae	Green sunfish	Lepomis cyanellus
LDF1	11957	4110	90	1		40		Centrarchidae	Orangespotted sunfish	Lepomis humilis
LDF1	11957	4110	90	11		10		Centrarchidae	Bluegill sunfish	Lepomis macrochirus
LDF1	11957	4110	90	14		16		Centrarchidae	Longear sunfish	Lepomis megalotis
LDF1	11957	4110	90			9		Centrarchidae	Redear sunfish	Lepomis microlophus
LDF1	11957	4110	90	2		3		Centrarchidae	Spotted bass	Micropterus punctulatus
LDF1	11957	4110	90			1		Centrarchidae	White crappie	Pomoxis annularis
LDF1	11957	4110	90			1		Percidae	Slenderhead darter	Percina phoxocephala

LDF1	11957	4110	90	1				SEE COMMENTS	SEE COMMENTS	SEE COMMENTS
Sand	12043	4624	75	10		29		Cyprinidae	Red shiner	Cyprinella lutrensis
Sand	12043	4624	75		1		3	Cyprinidae	Common carp	Cyprinus carpio
Sand	12043	4624	75	1				Cyprinidae	Golden shiner	Notemigonus crysoleucas
Sand	12043	4624	75	1		1		Cyprinidae	Suckermouth minnow	Phenacobius mirabilis
Sand	12043	4624	75	21		31		Cyprinidae	Bullhead minnow	Pimephales vigilax
Sand	12043	4624	75				1	Catostomidae	River carpsucker	Carpiodes carpio
Sand	12043	4624	75	1				Ictaluridae	Black bullhead	Ameiurus melas
Sand	12043	4624	75		2			Ictaluridae	Yellow bullhead	Ameiurus natalis
Sand	12043	4624	75				1	Ictaluridae	Channel catfish	Ictalurus punctatus
Sand	12043	4624	75	11		16		Poeciliidae	Mosquitofish	Gambusia affinis
Sand	12043	4624	75	32	2		2	Centrarchidae	Green sunfish	Lepomis cyanellus
Sand	12043	4624	75	3				Centrarchidae	Warmouth sunfish	Lepomis gulosus
Sand	12043	4624	75	19		14		Centrarchidae	Bluegill sunfish	Lepomis macrochirus
Sand	12043	4624	75	82		36		Centrarchidae	Longear sunfish	Lepomis megalotis
Sand	12043	4624	75	1	1	1		Centrarchidae	Spotted bass	Micropterus punctulatus
Sand	12043	4624	75	3	1	2	1	Centrarchidae	Largemouth bass	Micropterus salmoides
Sand	12043	4624	75		1	1		Centrarchidae	White crappie	Pomoxis annularis
Adams	11837	3965	80	26				Cyprinidae	Central stoneroller	Campostoma anomalum
Adams	11837	3965	80		11			Cyprinidae	Common carp	Cyprinus carpio
Adams	11837	3965	80	1		1		Cyprinidae	Golden shiner	Notemigonus crysoleucas
Adams	11837	3965	80	4				Cyprinidae	Bluntnose minnow	Pimephales notatus
Adams	11837	3965	80	2	1			Ictaluridae	Yellow bullhead	Ameiurus natalis
Adams	11837	3965	80	3		1		Fundulidae	Blackstripe topminnow	Fundulus notatus
Adams	11837	3965	80	15		1		Poeciliidae	Mosquitofish	Gambusia affinis
Adams	11837	3965	80			6		Atherinidae	Brook silverside	Labidesthes sicculus
Adams	11837	3965	80	11				Centrarchidae	Green sunfish	Lepomis cyanellus
Adams	11837	3965	80	16				Centrarchidae	Warmouth sunfish	Lepomis gulosus
Adams	11837	3965	80	9		1		Centrarchidae	Orangespotted sunfish	Lepomis humilis
Adams	11837	3965	80	35		2		Centrarchidae	Bluegill sunfish	Lepomis macrochirus
Adams	11837	3965	80	30		1		Centrarchidae	Longear sunfish	Lepomis megalotis
Adams	11837	3965	80	2				Centrarchidae	Largemouth bass	Micropterus salmoides
Adams	11837	3965	80		1			Centrarchidae	White crappie	Pomoxis annularis
Adams	11837	3965	80	1				Percidae	Redfin darter	Etheostoma whipplei
Adams	11837	3965	80	10		4		SEE COMMENTS	SEE COMMENTS	SEE COMMENTS
Browns	11863	3951	90	29		3		Cyprinidae	Central stoneroller	Campostoma anomalum
Browns	11863	3951	90	1		1		Cyprinidae	Red shiner	Cyprinella lutrensis
Browns	11863	3951	90	7		13		Cyprinidae	Redfin shiner	Lythrurus umbratilis
Browns	11863	3951	90	11		3		Cyprinidae	Bluntnose minnow	Pimephales notatus
Browns	11863	3951	90		2			Catostomidae	Smallmouth buffalo	Ictiobus bubalus
Browns	11863	3951	90	2	4			Ictaluridae	Yellow bullhead	Ameiurus natalis

Browns	11863	3951	90	52		14		Poeciliidae	Mosquitofish	Gambusia affinis
Browns	11863	3951	90	8				Centrarchidae	Green sunfish	Lepomis cyanellus
Browns	11863	3951	90	14	2			Centrarchidae	Warmouth sunfish	Lepomis gulosus
Browns	11863	3951	90	42		27		Centrarchidae	Bluegill sunfish	Lepomis macrochirus
Browns	11863	3951	90	79	1	18		Centrarchidae	Longear sunfish	Lepomis megalotis
Browns	11863	3951	90			1		Centrarchidae	Largemouth bass	Micropterus salmoides
Browns	11863	3951	90	1		10		Centrarchidae	White crappie	Pomoxis annularis
Browns	11863	3951	90			1		Centrarchidae	Black crappie	Pomoxis nigromaculatus
Browns	11863	3951	90	4				Percidae	Redfin darter	Etheostoma whipplei
Browns	11863	3951	90	1				Percidae	Logperch	Percina caprodes
Salt	12039	3610	90	3				Clupeidae	Gizzard shad	Dorosoma cepedianum
Salt	12039	3610	90			3		Cyprinidae	Red shiner	Cyprinella lutrensis
Salt	12039	3610	90	1		3		Cyprinidae	Redfin shiner	Lythrurus umbratilis
Salt	12039	3610	90	1				Cyprinidae	Suckermouth minnow	Phenacobius mirabilis
Salt	12039	3610	90	1				Cyprinidae	Bullhead minnow	Pimephales vigilax
Salt	12039	3610	90	1				Ictaluridae	Black bullhead	Ameiurus melas
Salt	12039	3610	90	2				Ictaluridae	Yellow bullhead	Ameiurus natalis
Salt	12039	3610	90			1		Fundulidae	Blackstripe topminnow	Fundulus notatus
Salt	12039	3610	90	67		5		Poeciliidae	Mosquitofish	Gambusia affinis
Salt	12039	3610	90	12		13		Atherinidae	Brook silverside	Labidesthes sicculus
Salt	12039	3610	90	15		3		Centrarchidae	Green sunfish	Lepomis cyanellus
Salt	12039	3610	90	2				Centrarchidae	Warmouth sunfish	Lepomis gulosus
Salt	12039	3610	90	5		6		Centrarchidae	Bluegill sunfish	Lepomis macrochirus
Salt	12039	3610	90	47		16		Centrarchidae	Longear sunfish	Lepomis megalotis
Salt	12039	3610	90	1				Centrarchidae	Redear sunfish	Lepomis microlophus
Salt	12039	3610	90	4		1		Centrarchidae	Largemouth bass	Micropterus salmoides
Salt	12039	3610	90	1		6		Centrarchidae	White crappie	Pomoxis annularis
Salt	12039	3610	90	1		1		Centrarchidae	Black crappie	Pomoxis nigromaculatus
Salt	12039	3610	90	1		2		Percidae	Bluntnose darter	Etheostoma chlorosomum
Salt	12039	3610	90	1				Percidae	Slough darter	Etheostoma gracile
Salt	12039	3610	90			1		Percidae	Redfin darter	Etheostoma whipplei