Oklahoma Conservation Commission/
Water Quality Programs

FY 1993 106 - Task 215
Southeastern Oklahoma Multiple Basin Study (SOMBS)

Report prepared by
W. Schad Meldrum

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1. Introduction

FY 1991 106 - Task 215 Southeastern Oklahoma Multiple Basin Study

The degradation of water quality in several southeastern Oklahoma streams has been documented by several different agencies in the Section 31 9 Assessment Report. In general, stream waters in the area have historically been of very high quality supporting a wide diversity of aquatic life and attracting tourists. Water quality degradation is most evident by decreased water clarity and occasional fish kills. It is suspected that the degradation is due to increased agricultural activities. Although within the state southeastern Oklahoma streams still offer some of the highest quality recreational waters, continued degradation will almost certainly impact beneficial uses including aquatic life, recreational, water supply, and aesthetics.

1.1. Objectives

The objectives of this study were to: 1. assess non-point pollution sources in the watersheds of five major streams in the area- the Clear and Muddy Boggy Rivers, Blue River, Pennington Creek, and Mill Creek; 2. establish baseline data for area streams in order to fill the state wide data gap on small stream water quality; and 3. select twenty sites in the area for inclusion in biological assessment studies across the state.

1.2. Historical

The five streams of concern are the Clear and Muddy Boggy Rivers, Blue River, Pennington Creek, and Mill Creek. The Blue River, Pennington Creek, and Mill Creek are historically of very high water quality. Muddy Boggy has had a long-standing water quality problem. Obvious problems in the area streams are sediment loading in all steams and dissolved oxygen fluctuations which have resulted in fish kills in streams with typically very high water quality. The source of these problems is likely due to increased agricultural activity with poor protection from fields, deforestation and subsequent stream bank erosion, and the establishment of confined poultry operations. Quantification of the magnitude of the water quality degradation as well as the impact of increased agricultural activity will be difficult due to the limited amount of background information on area streams. The primary goal of this project was to establish baseline data for the area.

2. Sampling Protocol

2.1. Site Selection Criteria

Sites were selected in the watersheds of five major southeastern Oklahoma streams which feed the Red River- the Clear and Muddy Boggy Rivers, Blue River, Pennington Creek, and Mill Creek. Sites were selected in three additional watersheds feeding the

Red River- Whitegrass Creek, Island Bayou, and Big Sandy (near Tishomingo).
Seventy-two sites were originally selected for sampling based on established site selection criteria for this project.

Sites were selected based on the following criteria:

1. Sites were located on streams with perennial flow near the outlet of the subwatershed.
2. Additional sites were selected, within subwatersheds of sufficient size and on stream locations with perennial flow, to represent the variety of conditions in the area:

   -sites were located on streams flowing through different land use and land form areas at the outlet of each different area.

   -sites were selected to represent all typical land uses including forest, pasture, managed pasture, row crops, small grains, eroded pasture, and urban areas.

   -sites were also selected to represent streams and stream areas with varying water and substrate quality, including clear, turbid, and enriched waters and sand, clay, silt, organic and rock substrates.

Although there are more than eight subwatersheds of the Red River in the area, streams in only the eight subwatersheds previously identified met the selection criteria of having perennial flow.

Originally the workplan called for 80 sampling sites; 72 were selected. However the sites were reduced to thirty-nine following the third quarterly sampling run. This was necessary due to logistical factors of effectively collecting runoff samples over such a wide area. Sites were selected for elimination based on the redundancy of stream and watershed conditions. The remaining 39 stream sites best represent the full range of local conditions.

Table 2.1 and 2.2 give the complete SOMBS sampling site list plus site descriptions. The percentage area of the eight major subwatersheds of the Red River assessed in the SOMBS project area by the 39 sites selected is given in Table 2.3. There are five sets of sites that are located upstream/downstream of each other. Those sites are: Delaware Creek near Bromide and near Olney; Caney Boggy Creek near Non and near Parker; Whitegrass Creek near Bennington and near New Oberlin; and Mill Creek near Mill Creek and southwest of Ravia. The Blue River has sites near Fittstown, at Diamond Spring Bridge, and at Milburn with a site near Connerville on the a Little Blue tributary entering the Blue River between the sites near Fittstown and at Diamond Spring Bridge

TABLE 2.1: SOMBS Sampling Site List

Site Description	County	Water Body ID#	Legal Description	GIS Cat. #	SOMBS Reference Streams*
Big Sandy Creek nr Citra	Hughes	OK410400060260G	S bound, S35, T4N, R9E	3	--
Big Sandy Creek nr Tish.	Johnston	OK310800010090G	S bound, S2, T4S, R6E	28	--
Blue River at Diamond Spr. Br.	Johnston	OK410600020010M	S bound, S6, T2S, R7E	19	--
Blue River at Milburn	Johnston	OK410600070010G	E bound, S34, T3S, R7E	29	--
Blue River nr Fittstown	Pontotoc	OK410600020010T	S bound, S17, T1N, R6E	9	NRS
Bois D Arc Creek nr Fittstown	Pontotoc	OK410400040110G	S bound, S7, T2N, R7E	10	NRS
Caney Boggy Creek nr Non	Hughes	OK410400060120T	SW 1/4, S33, T4N, R11 E	6	NRS
Caney Boggy Creek nr Parker	Coal	OK410400060120G	NW 1/4, S18, T3N, R11E	7	--
Caney Creek at Coalgate	Coal	OK410400060020G	E bound, S14, T1N, R10E	15	--
Caney Creek nr Bentley	Atoka	OK410400020200G	SW corner, S21, T4S, R12E	31	--
Caney Creek nr Caney	Atoka	OK410400030070G	N bound, S10, T4S, R10E	32	--
Chickasaw Creek nr Stringtown	Atoka	OK410400050420G	S l/2, S22, T1S, R12E	22	PRS
Clear Boggy Ur nr Union Valley	Pontotoc	OK410400040010T	S bound, S30, T3N, R7E	8	NRS
Coal Creek nr Tupelo	Coal	OK410400030520G	E bound, S4, T1N, R8E	16	--
Delaware Creek nr Bromide	Johnston	OK410400030240T	E bound, S18, T2S, R8E	24	--
Delaware Creek nr Olney	Atoka	OK410400030240G	E bound, S5, T2S, R9E	25	--
Goose Creek nr Tupelo	Coal	OK410400030490G	NE 1/4, S16, T1N, R8E	21	--
Island Bayou near Albany	Bryan	OK410700000040G	SE corner, S17, T8S, R11E	38	NRS
Leader Cr Blw Owl Cr nr Tupelo	Coal	OK410400030370B	S bound, S17, T1N, R9E	14	ORS
Little Blue Cr nr Connerville	Johnston	OK410600020090G	S bound, S19, T1S, R7E	20	ORS
McGee Creek at Redden	Atoka	OK410400070010M	S bound, S33, T1N, R14E	13	PRS
Mill Creek at Harden City	Pontotoc	OK410400040090G	E bound, S30, T2N, R7E	11	PRS
Mill Creek near Mill Creek	Johnston	OK310800010190T	SW 1/4, S2, T2S, R4E	17	NRS
Mill Creek Southwest of Ravia	Johnston	OK310800010190G	SE l/4, S6, T4S, R5E	39	--
Mineral Bayou at Armstrong	Bryan	OK410600010300G	SW 1/4, S10, T6S, R9E	33	NRS
Muddy Boggy Creek nr Steedman	Pontotoc	OK410400060010T	NW 1/4, S24, T4N, R8E	1	--
North Boggy Cr nr Wardville	Atoka	OK410400080010T	n.c., S12, T2N, R12E	5	--
Panther Creek nr Gerty	Hughes	OK410400060240G	S bound, S25, T4N, R9E	4	PRS
Pennington Ur at Reagan	Johnston	OK310800010120M	SE 1/4, S30, T2S, R6E	23	--
Salt Creek nr Boggy Depot	Atoka	OK410400030100G	E bound, S24, T3S, R9E	30	--
Sandy Creek at Boggy Depot	Atoka	OK410400030160G	E bound, S12, T3S, R9E	27	ORS
Sandy Creek nr Wapanucka	Johnston	OK410400030160T	NW 1/4, S1, T3S, R8E	26	ORS
Sheep Creek nr Harden City	Pontotoc	OK410400040070G	N bound, S34, T2N, R7E	12	PRS
Sincere Creek nr Steedman	Pontotoc	OK410400060290G	E bound, S27, T4N, R8E	2	--
Spring Creek nr Connerville	Johnston	OK310800010160G	S bound, S30, T1S, R6E	18	PRS
Sugar Creek nr Soper	Choctaw	OK410400010200G	S bound, S33, T5S, R15E	37	PRS
Sulphur Creek nr Bennington	Bryan	OK410600010030G	NE 1/4, S16, T7S, R12E	34	--
Whitegrass Cr nr Bennington	Bryan	OK410400010210T	E bound, S36, T6S, R12E	35	PRS
Whitegrass Cr nr New Oberlin	Choctaw/Bryan	OK410400010210G	E bound, S25, T7S, R13E	36	--

This table lists the 39 water sampling sites. Of those 39 sites, 19 were chosen as sites on reference streams for bioassessment sampling. In addition the county in which the site exists, the water body identification number, the legal description, and the GIS category number are listed.
*Reference Stream Designations: Positive Reference Stream (PRS), Negative Reference Stream (NRS), and Other Reference Stream (ORS).

TABLE 2.2: SOMBS Sampling Sites Listed By Major Subwatershed

Subwatershed	Site Description	Sampler Identified Geology	SCS Major Land Resource Area* Primary	Secondary
Big Sandy Cr.	Big Sandy Creek nr Tish.	granite	Grand Prairie	W. Cross timber
Blue River	Blue River at Diamond Spr. Br	limestone spring fed	Grand Prairie	
	Blue River at Milburn		Grand Prairie	
	Blue River nr Fittstown		Grand Prairie	
	Little Blue Cr nr Connerville	limestone spring fed	Grand Prairie	
	Mineral Bayou at Armstrong		Grand Prairie	
	Sulphur Creek nr Bennington		Grand Prairie	W. Coastal Plain
Clear Boggy	Bois D Arc Creek nr Fittstown	limestone spring fed	W. Ark. Valley & Ridges	
	Caney Creek nr Bentley		W. Coastal Plain	
	Caney Creek nr Caney		W. Coastal Plain	
	Clear Boggy Cr nr Union Valley		W. Ark. Valley & Ridges	
	Coal Creek nr Tupelo		W. Ark. Valley & Ridges	
	Delaware Creek nr Bromide	limestone spring fed	Grand Prairie	
	Delaware Creek nr Olney		Grand Prairie	
	Goose Creek nr Tupelo	limestone spring fed	W. Ark. Valley & Ridges	
	Leader Cr Blw Owl Cr nr Tupelo		W. Ark. Valley & Ridges	
	Mill Creek at Harden City	limestone spring fed	W. Ark. Valley & Ridges	
	Salt Creek nr Boggy Depot		Grand Prairie	
	Sandy Creek at Boggy Depot	granite sand	Grand Prairie	
	Sandy Creek nr Wapanucka	granite outcrop	Grand Prairie	
	Sheep Creek nr Harden City	limestone sping fed	W. Ark. Valley & Ridges	
Island Bayou	Island Bayou near Albany		Grand Prairie	W. Coastal Plain
Mill Creek	Mill Creek near Mill Creek		Grand Prairie	
	Mill Creek Southwest of Ravia		Grand Prairie	
Muddy Boggy	North Boggy Cr nr Wardville		W. Ark. Valley & Ridges	
	Big Sandy Creek nr Citra		W. Ark. Valley & Ridges	
	Caney Boggy Creek nr non		W. Ark. Valley & Ridges	
	Caney Boggy Creek nr Parker		W. Ark. Valley & Ridges	
	Caney Creek at Coalgate		W. Ark. Valley & Ridges	
	Chickasaw Creek nr Stringtown		Ouachita Mtns.	
	McGee Creek at Redden		Ouachita Mtns.	
	Muddy Boggy Creek nr Steedman		W. Ark. Valley & Ridges	
	Panther Creek nr Gerty		W. Ark. Valley & Ridges	
	Sincere Creek nr Steedman		W. Ark. Valley & Ridges	
	Sugar Creek nr Soper	some limestone spring fed	Grand Prairie	
Pennington Cr.	Pennington Cr at Reagan	limestone spring fed	Grand Prairie	
	Spring Creek nr Connerville	limestone spring fed	Grand Prairie	
Whitegrass Cr.	Whitegrass Cr. nr Pennington		W. Coastal Plain	
	Whitegrass Cr nr New Oberlin		W. Coastal Plain	

This table lists the 39 water-sampling sites by subwatershed. In addition the sampler identification of geology and the SCS major land resources areas are listed.
*Based on the EPA defined Ecoregions (1994 revision) all the SOMBS sampling site watersheds fall within the Central Oklahoma/ Texas Plains except Chickasaw Cr. near Stringtown and McGee Cr. near Steedman which falls in the Ouachita Mtns.

TABLE 2.3: Percent Of Major Subwatershed Assessed

Total SOMBS

Red River Major Subwatershed	Watershed Within Major Subwatershed Size (acres)	Percent Of Major Subwatershed (acres)	Subwatershed Assessed
Big Sandy Cr.	16573	15933	96%
Blue River	435541	162424	37%
Clear Boggy	640597	270851	42%
Island Bayou	96006	86406	90%
Mill Cr.	61651	60371	98%
Muddy Boggy	919283	239506	26%
Pennington Cr-.	65030	38943	60%
Whitegrass Cr.	71053	26903	38%

This table shows the percentage area assessed by the SOMBS sampling sites for each of the eight major subwatersheds of the Red River in the SOMBS project area.

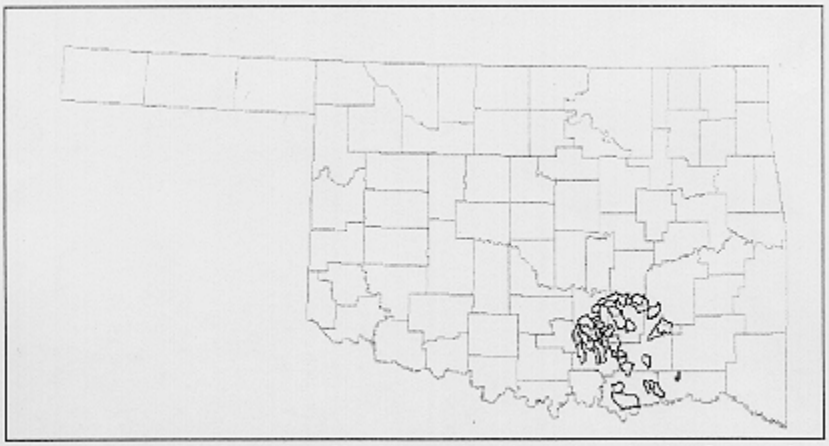

Figure 1: SOMBS Sampling Site Watershed Locations in the State of Oklahoma

2.2. Sample Collection and Analysis

A detailed description of sampling protocol can be found in the project workplan and quality assurance project plan. Samples were collected and field equipment was operated and maintained according to the procedures documented in the Oklahoma Conservation Commission Water Quality Standard Operating Procedures (SOP)

document. Both baseflow and high flow samples were collected by the method of grab sampling.

The project workplan required base flow samples be taken quarterly and high flow samples twice annually. Seven baseflow samples and four high flow samples were collected from September 1991 to August 1993. The quarterly base flow sample to have taken place approximately in January of 1 993 could not be collected throughout the quarter due to flows not representative of base flow conditions. High flow collections were made in December 1991, May 1992, April 1993, and May 1993.

Water quality parameters were measured *in situ* or by the contracted laboratory from samples for mineral components, nutrients, and basic chemical parameters. *In situ* measurements include dissolved oxygen, conductivity, pH, and temperature. These *in situ* measurements were not made during high flow events. Samples were analyzed by OCC/Water Quality field personnel for turbidity and alkalinity the day of collection. All other parameters were measured by the laboratory at the US Geological Survey (USGS). Mineral analysis included chloride, sulfate, total suspended solids, and hardness. Nutrient analysis included nitrate/nitrite, Total Kjeldahl Nitrogen (TKN), and total phosphorus.

2.3. Other Analyses

Geographic Information Systems (GIS) analyses were also conducted. A land survey was conducted to identify and map areas of potential non-point pollution sources (ex. roadside erosion, gullies, overgrazed pastures, strip mining areas, etc). This survey information was digitized on the GIS. This data along with existing land use, soils, slopes, and other available relevant data was used for GIS analyses of the watershed conditions above each sampling site.

3. Data Analysis and Discussion

Exceptional circumstances were noted by samplers at Coal Creek near Tupelo on 8/4/93. The building of a bridge near this site resulted in conditions in the stream which were not representative of normal base flow conditions as reflected in the lab analysis particularly for

suspended sediment. For this reason the Coal Creek site data will be analyzed independently of the data from this date.

3.1. Summation of Data By Sampling Site

See Tables 3.1 through 3.5

3.1.1. Mineral Constituents

Chloride

Average base flow chloride values ranged from a minimum of 4.8 mg/l to a maximum of 234.6 mg/l among the 39 sampling sites. The average for the SOMBS project area was 30.8 mg/l. The distribution for average chloride values for the 39 sites was: 11 sites less than 10 mg/l, 11 between 10-20 mg/l, 10 between 20-50 mg/l, 5 between 50-100 mg/l, and 2 greater than 100 mg/l. Chloride values in the study area are relatively low compared to other streams in the state. Average chloride concentrations were highly variable in the project area in comparison with other parameters. This high variability may be due to a wide range of geologic conditions in the region.

On average high flow chloride concentrations decreased to 47% of base flow concentrations. This decrease may be the result of dilution. Four streams sites— Bois D'Arc Creek near Fittstown, Mill Creek at Harden City, Sheep Creek near Harden City, and Mill Creek near Mill Creek— had slightly higher concentrations of chloride during high flow than base flow. This increase may be the result of geological conditions combined with land use activities since these streams are spatially related. In the area of these four streams there is a concentration of quarries and oil fields.

Sulfate

Average base flow sulfate values ranged from a minimum of 4.9 mg/l in Spring Creek near Connerville to a maximum of 99.7 mg/l in Island Bayou near Albany. The average value for the 39 sites in the project area was 25.0 mg/l. Sulfate values were distributed as follows: 11 sites less than 13 mg/l, 11 between 13-25 mg/l, 1 5 between 25-50 mg/l, and 2 above 50 mg/l. Sulfate was one of the more highly variable chemical constituents measured between sampling dates. However, average sulfate values among sites were much less variable.

As with chloride concentrations, sulfate concentrations were decreased by half on average during high flow events possibly due to dilution. Only three sites- Bois D'Arc near Fittstown, Spring Creek near Connerville, and Little Blue Creek near Connerville-

TABLE 3.1: Average Base Flow Values By SOMBS Sampling Site

Subwatershed	Site Description	TEMP	D.O.	TURB	TSS	PH	ALK.	NOx	TKN	TOT. P	COND	HARD.	CI	SO4	TN:TP
Big Sandy Cr.	Big Sandy Creek nr Tish.	20.2	93.4%	4	10	7.9	146	0.07	0.68	0.08	387	179	15.8	36.2	10
Blue River	Blue River at Diamond Spr. Br	18.8	98.0%	10	12	8.1	295	0.29	0.23	0.02	566	260	11.5	24.9	26
	Blue River at Milburn	18.8	100.0%	10	17	8.2	249	0.22	0.32	0.02	480	237	6.0	8.7	23
	Blue River nr Fittstown	18.4	97.3%	8	11	8.2	324	0.66	0.20	0.04	590	293	7.0	13.6	20
	Little Blue Cr nr Connerville	18.8	98.3%	6	8	8.3	292	0.40	0.20	0.02	569	280	5.1	6.9	36
	Mineral Bayou at Armstrong	20.3	81.8%	30	23	7.7	146	0.16	0.37	0.04	396	169	19.2	34.0	12
	Sulphur Creek nr Bennington	18.7	82.1%	13	19	7.7	163	0.11	0.30	0.02	445	186	26.0	26.8	21
Clear Boggy	Bois D Arc Creek nr Fittstown	19.0	76.2%	54	24	7.8	171	0.46	0.53	0.14	390	191	9.5	16.3	7
	Caney Creek nr Bentley	19.2	65.9%	27	27	7.3	87	0.08	0.47	0.04	334	121	25.1	35.4	14
	Caney Creek nr Caney	19.6	79.1%	15	15	7.7	150	0.06	0.47	0.03	498	176	37.8	25.4	16
	Clear Boggy Cr nr Union Valley	18.1	89.0%	12	15	7.9	250	0.09	0.32	0.04	616	268	14.8	46.9	8
	Coal Creek nr Tupelo	18.3	81.1%	10	11	7.9	233	0.05	0.35	0.03	606	289	29.3	23.5	14
	Delaware Creek nr Bromide	19.1	95.8%	8	19	8.2	232	0.06	0.35	0.04	892	277	89.3	19.0	9
	Delaware Creek nr Olney	19.3	111.7%	19	26	8.0	210	0.05	0.40	0.06	730	267	68.7	25.7	8
	Goose Creek nr Tupelo	19.6	76.0%	16	23	7.9	188	0.07	0.51	0.06	405	209	8.0	12.4	7
	Leader Cr Blw Owl Cr nr Tupelo	23.4	94.2%	55	41	7.6	111	0.08	0.71	0.07	361	95	22.5	21.9	12
	Mill Creek at Harden City	19.1	92.8%	6	11	8.2	266	0.53	0.25	0.01	571	279	18.0	34.7	67
	Salt Creek nr Boggy Depot	20.7	87.4%	18	22	7.7	105	0.08	0.41	0.02	724	190	125.0	47.4	22
	Sandy Creek at Boggy Depot	21.4	87.9%	11	12	7.8	109	0.08	0.33	0.04	323	104	17.0	18.1	10
	Sandy Creek nr Wapanucka	21.3	102.9%	9	5	7.9	93	0.07	0.48	0.02	311	90	51.7	9.3	24
	Sheep Creek nr Harden City	19.8	83.1%	12	13	8.2	207	0.08	0.36	0.03	449	228	21.0	11.5	17
Island Bayou	Island Bayou near Albany	18.6	71.6%	67	79	7.4	185	0.18	0.84	0.10	771	216	44.2	99.7	11
Mill Cr.	Mill Creek near Mill Creek	18.6	91.5%	10	18	8.2	256	0.13	0.45	0.04	501	240	7.3	8.4	15
	Mill Creek Southwest of Ravia	19.6	82.6%	23	22	8.0	192	0.11	0.37	0.04	403	196	7.1	10.1	14
Muddy Boggy	North Boggy Cr nr Wardville	19.8	80.1%	92	26	7.0	56	0.05	0.72	0.09	196	97	50.8	21.2	9
	Big Sandy Creek nr Clara	18.1	89.1%	20	19	7.8	129	0.11	0.38	0.02	351	125	18.1	29.9	21
	Caney Boggy Creek nr non	17.8	79.5%	40	24	7.1	47	0.06	0.54	0.04	217	83	10.8	21.2	14
	Caney Boggy Creek nr Parker	20.1	82.5%	43	33	7.5	84	0.11	0.61	0.08	273	83	14.6	25.4	13
	Caney Creek at Coalgate	20.2	88.2%	56	21	7.5	91	0.06	2.28	0.26	407	107	21.7	38.2	9
	Chickasaw Creek nr Stringtown	20.5	82.7%	25	13	7.3	42	0.12	0.23	0.03	144	48	9.6	21.8	14
	McGee Creek at Redden	19.7	75.8%	27	15	7.0	33	0.05	0.37	0.03	121	41	9.4	12.4	14
	Muddy Boggy Creek nr Steedman	18.6	94.8%	15	22	8.2	202	0.06	0.35	0.04	1228	302	234.6	55.6	11
	Panther Creek nr Gerty	16.3	93.2%	13	8	7.6	54	0.26	0.30	0.01	186	64	13.0	26.0	39
	Sincere Creek nr Steedman	17.4	69.5%	22	31	7.8	190	0.06	0.61	0.05	546	219	64.6	44.1	11
	Sugar Creek nr Soper	20.0	90.1%	10	15	8.0	119	0.06	0.28	0.02	284	138	15.0	12.0	23
Pennington Cr.	Pennington Cr at Reagan	19.0	95.7%	7	12	8.2	278	0.28	0.23	0.02	524	296	6.9	6.4	31
	Spring Creek nr Connerville	18.8	94.3%	4	5	7.9	312	0.07	0.35	0.02	561	328	4.8	4.9	25
Whitegrass Cr.	Whitegrass Cr nr Bennington	19.4	77.5%	8	14	7.8	153	0.06	0.25	0.02	418	152	21.6	26.0	14
	Whitegrass Cr nr New Oberlin	19.7	74.2%	44	41	7.5	96	0.06	0.40	0.04	298	100	24.5	16.8	13
	Average	19.3	86.3%	22	20	7.8	168	0.14	0.46	0.05	466	186	30.9	25.1	186
	Coeff of Var.	6	13	68	64	4	46	97	73	94	46	45	134	69	45
	Maximum Average Value	23.4	111.7%	92	79	8.3	324	0.85	2.28	0.26	1228	328	234.6	99.7	328
	First Quartile (25th Percentile)	18.7	79.3%	10	12	7.6	101	0.06	0.30	0.02	328	106	9.5	12.4	11
	Median (50th Percentile)	19.2	87.9%	15	18	7.8	163	0.09	0.37	0.04	418	190	18.0	21.9	14
	Third Quartile (75th Percentile)	19.9	94.2%	27	24	8.0	233	0.14	0.50	0.05	570	268	27.7	31.9	21
	Minimum Average Value	16	0.6	4	5	7	33	0	0	0	121	41	5	5	41

This table shows the average of seven baseflow measurements for each of 39 sites. Shading is used to represent identify the quartile divisions for each parameter (best- no shade; middle- partial shade; and worst- ful shade). PARAMETER UNITS: TEMP (C); TURB (NTU); COND (US/CM @ 25C); D.O. (% Sat.); ALK. (MG/L AS CACO3); TSS (MG/L); NOx = NO2 + NO3 (MG/L AS N); TKN (MG/L AS N); TOT. P (MG/L AS P); HARD. (MG/L AS CACO3); CI (MG/L); SO4 (MG/L); TN:TP (RATIO OF TOTAL NITROGEN TO TOTAL PHOSPHORUS BY WEIGHT, PHOSPHORUS LIMITED > 7 > NITROGEN LIMITED).

TABLE 3.2: Coefficient of Variation For Base Flow Measurements

Subwatershed	Site Description	TEMP	D.O.	TURB	TSS	PH	ALK.	NOx	TKN	TOT. P	COND	HARD.	CI	SO4
Big Sandy Cr.	Big Sandy Creek nr Tish.	42	9	114	90	4	21	51	105	91	27	41	41	83
Blue River	Blue River at Diamond Spr. Br	32	14	86	38	2	8	49	32	50	3	22	133	173
	Blue River at Milburn	37	7	29	17	4	3	59	56	77	4	22	19	31
	Blue River nr Fittstown	35	7	22	33	1	14	28	0	37	3	15	22	24
	Little Blue Cr nr Connerville	29	9	42	45	2	12	21	0	45	4	28	37	92
	Mineral Bayou at Armstrong	36	13	133	38	1	33	89	34	56	25	23	18	26
	Sulphur Creek nr Bennington	38	12	96	66	2	21	100	52	32	18	19	31	50
Clear Boggy	Bois D Arc Creek nr Fittstown	40	23	177	117	2	32	208	48	114	29	32	25	52
	Caney Creek nr Bentley	36	32	33	32	7	32	49	25	40	13	14	19	26
	Caney Creek nr Caney	41	20	35	75	3	40	39	56	64	36	43	65	76
	Clear Boggy Cr nr Union Valley	39	9	54	42	2	12	36	28	44	13	13	23	40
	Coal Creek nr Tupelo	34	15	160	1959	2	23	64	21	49	20	15	40	39
	Delaware Creek nr Bromide	38	14	61	72	3	12	27	46	105	39	27	108	44
	Delaware Creek nr Olney	40	39	42	85	1	26	13	35	38	40	24	71	49
	Goose Creek nr Tupelo	30	19	61	42	2	24	39	41	40	25	24	43	89
	Leader Cr Blw Owl Cr nr Tupelo	22	48	43	51	3	54	33	29	45	48	51	77	67
	Mill Creek at Harden City	31	10	36	54	5	5	11	31	32	4	9	28	152
	Salt Creek nr Boggy Depot	38	10	70	44	3	13	50	27	45	48	24	69	50
	Sandy Creek at Boggy Depot	39	10	182	74	4	29	58	36	70	22	33	52	72
	Sandy Creek nr Wapanucka	42	7	96	69	5	84	71	19	85	55	28	80	112
	Sheep Creek nr Harden City	37	12	37	71	3	6	43	39	75	20	9	28	68
Island Bayou	Island Bayou near Albany	41	23	114	105	3	42	96	22	70	37	43	64	31
Mill Cr.	Mill Creek near Mill Creek	37	11	45	54	2	24	65	49	48	15	19	22	67
	Mill Creek Southwest of Ravia	38	26	68	52	3	10	75	46	59	9	9	16	51
Muddy Boggy	North Boggy Cr nr Wardville	39	42	91	65	3	52	2	17	49	52	86	158	85
	Big Sandy Creek nr Citra	48	12	70	67	3	64	33	41	32	50	56	29	55
	Caney Boggy Creek nr non	42	24	63	71	4	33	24	22	64	67	37	23	46
	Caney Boggy Creek nr Parker	44	20	48	37	2	57	65	39	51	50	55	66	72
	Caney Creek at Coalgate	40	10	63	87	6	80	35	141	160	83	62	76	103
	Chickasaw Creek nr Stringtown	42	16	59	63	3	41	128	20	31	16	27	17	19
	McGee Creek at Redden	42	22	46	56	4	43	0	37	36	34	33	48	72
	Muddy Boggy Creek nr Steedman	50	8	70	69	5	15	11	33	47	24	19	38	15
	Panther Creek nr Gerty	55	12	58	101	3	25	59	36	51	12	10	9	61
	Sincere Creek nr Steedman	43	25	62	63	5	40	20	43	46	39	32	45	35
	Sugar Creek nr Soper	40	19	65	28	5	8	19	52	51	10	17	48	60
Pennington Cr.	Pennington Cr at Reagan	28	11	32	51	1	2	18	20	28	8	6	107	29
	Spring Creek nr Connerville	33	21	69	104	2	7	29	96	66	15	7	29	61
Whitegrass Cr.	Whitegrass Cr nr Bennington	34	17	105	61	3	19	30	20	67	17	32	44	35
	Whitegrass Cr nr New Oberlin	42	18	39	45	4	34	22	20	51	22	37	37	21
	Average Coefficient of Variation	38	17	72	110	3	28	48	39	57	27	28	49	59

This table shows the coefficient of variation for base flow measurements. The coefficient of variation is calculated as the standard deviation of the base flow measurements x 100 / average of the base flow measurements for each site. PARAMETER UNITS: TEMP (C); TURB (NTU); COND (US/CM @ 25C); D.O. (% Sat.); ALK. (MG/L AS CACO3); TSS (MG/L); NOx=NO2 + NO3 (MG/L AS N); TKN (MG/L AS N); TOT. P (MG/L AS P); HARD. (MG/L AS CAO3); CI (MG/L); SO4 (MG/L)

TABLE 3.3: Percentage Rank of Average Base Flow Values By SOMBS Sampling Site

Subwatershed	Site Description	TEMP	D.O.	TURB	TSS	PH	ALK.	NOx	TKN	TOT. P	HARD.	COND	CL	SO4
Big Sandy Cr.	Big Sandy Creek nr Tish.	81%	71%	2%	10%	52%	42%	34%	89%	84%	44%	34%	44%	84%
Blue River	Blue River at Diamond Spr. Br	31%	89%	34%	29%	76%	94%	89%	5%	15%	73%	71%	31%	55%
	Blue River at Milburn	28%	94%	23%	47%	89%	78%	81%	28%	26%	66%	57%	2%	10%
	Blue River nr Fittstown	15%	86%	13%	18%	97%	100%	100%	0%	65%	92%	78%	10%	28%
	Little Blue Cr nr Connerville	31%	92%	7%	7%	100%	92%	92%	0%	7%	81%	73%	5%	2%
	Mineral Bayou at Armstrong	36%	31%	78%	71%	31%	39%	76%	47%	63%	35%	39%	55%	76%
	Sulphur Creek nr Bennington	26%	34%	44%	52%	34%	50%	55%	21%	15%	47%	52%	73%	71%
Clear Boggy	Bois D Arc Creek nr Fittstown	39%	18%	69%	76%	42%	52%	84%	78%	97%	52%	36%	23%	31%
	Caney Creek nr Bentley	50%	2%	76%	84%	10%	15%	42%	68%	52%	28%	26%	71%	81%
	Caney Creek nr Caney	97%	23%	52%	39%	28%	44%	28%	68%	44%	42%	60%	78%	60%
	Clear Boggy Cr nr Union Valley	7%	55%	42%	44%	63%	81%	97%	28%	65%	86%	84%	39%	92%
	Coal Creek nr Tupelo	13%	28%	31%	13%	60%	76%	7%	34%	39%	68%	81%	76%	52%
	Delaware Creek nr Bromide	47%	84%	15%	55%	78%	73%	26%	94%	66%	76%	97%	84%	39%
	Delaware Creek nr Olney	52%	100%	60%	86%	71%	71%	5%	57%	76%	84%	92%	92%	68%
	Grasse Creek nr Tupelo	60%	15%	55%	73%	55%	57%	31%	76%	89%	57%	44%	18%	23%
	Leader Cr Blw Owl Cr nr Tupelo	100%	73%	92%	94%	23%	31%	47%	92%	84%	15%	31%	65%	50%
	Mill Creek at Harden City	44%	65%	5%	13%	92%	86%	97%	13%	0%	78%	76%	50%	76%
	Salt Creek nr Boggy Depot	92%	47%	57%	68%	36%	25%	55%	63%	23%	50%	89%	97%	94%
	Sandy Creek at Boggy Depot	97%	50%	36%	23%	47%	28%	44%	21%	52%	23%	23%	47%	36%
	Sandy Creek nr Wapanucka	94%	97%	21%	0%	57%	21%	39%	73%	26%	13%	21%	86%	13%
	Sheep Creek nr Harden City	68%	44%	39%	26%	86%	68%	50%	42%	36%	65%	55%	57%	18%
Island Bayou	Island Bayou near Albany	21%	7%	97%	100%	13%	55%	76%	97%	94%	60%	94%	81%	100%
Mill Cr.	Mill Creek near Mill Creek	18%	63%	26%	50%	84%	84%	73%	63%	60%	71%	63%	15%	7%
	Mill Creek Southwest of Reva	73%	39%	68%	63%	73%	63%	68%	47%	47%	55%	42%	13%	15%
Muddy Boggy	North Boggy Cr nr Wardville	68%	0%	100%	81%	0%	10%	2%	94%	92%	18%	7%	84%	42%
	Big Sandy Creek nr Clra	7%	57%	63%	57%	50%	36%	63%	55%	26%	31%	28%	52%	73%
	Caney Boggy Creek nr non	5%	26%	81%	78%	5%	5%	23%	81%	73%	5%	10%	28%	44%
	Caney Boggy Creek nr Parker	78%	36%	84%	92%	15%	13%	60%	84%	78%	10%	13%	36%	57%
	Caney Creek at Coalgate	81%	52%	94%	60%	18%	15%	52%	100%	100%	26%	47%	63%	86%
	Chickasaw Creek nr Stringtown	89%	42%	71%	31%	7%	2%	71%	5%	34%	2%	2%	26%	47%
	McGee Creek at Redden	65%	13%	73%	36%	2%	0%	0%	52%	42%	0%	0%	21%	26%
	Muddy Boggy Creek nr Steedman	23%	78%	50%	65%	94%	65%	10%	42%	52%	97%	100%	100%	97%
	Panther Creek nr Gerty	0%	68%	47%	5%	26%	7%	34%	21%	2%	7%	5%	34%	65%
	Sincere Creek nr Steedman	2%	5%	65%	89%	44%	60%	18%	84%	81%	63%	86%	89%	89%
	Sugar Creek nr Soper	76%	60%	28%	42%	68%	34%	13%	13%	5%	34%	15%	42%	21%
Pennington Cr.	Pennington Cr at Reagan	39%	81%	10%	21%	78%	89%	36%	5%	7%	34%	65%	7%	5%
	Spring Creek nr Connerville	31%	76%	0%	2%	68%	97%	36%	34%	7%	100%	68%	0%	0%
Whitegrass Cr.	Whitegrass Cr nr Bennington	55%	21%	18%	34%	39%	47%	15%	13%	21%	36%	50%	60%	63%
	Whitegrass Cr nr New Oberlin	63%	10%	86%	97%	18%	23%	21%	57%	50%	21%	18%	68%	34%

This table shows the percentage rank the average of seven baseflow measurements for each of 39 sites.

TABLE 3.4: Maximum and Minumum Base Flow Values Summarized By Major Subwatershed

Subwatershed	Site Description	MAX TURB	MAX TSS	MAX PH	MIN PH	MIN D.O.	MAX NOx	MAX TKN	MAX TOT. P
Big Sandy Cr.	Big Sandy Creek nr Tish.	15	28	8.2	7.3	6.0	0.14	2.1	0.20
Blue River	Blue River at Diamond Spr. Br	30	17	8.2	7.8	6.5	0.47	0.4	0.03
	Blue River at Millburn	13	21	8.5	7.6	7.2	0.39	0.7	0.06
	Blue River nr Fittstown	11	16	8.4	8.1	7.2	0.93	0.2	0.06
	Little Blue Cr nr Connerville	11	13	8.5	8.0	7.1	0.50	0.2	0.03
	Mineral Bayou at Armstrong	120	35	7.8	7.5	6.0	0.40	0.6	0.09
	Sulphur Creek nr Bennington	37	42	7.8	7.5	5.5	0.34	0.6	0.03
Clear Boggy	Bois D Arc Creek nr Fittstown	290	92	8.0	7.5	3.4	2.80	0.9	0.50
	Caney Creek nr Bentley	40	38	8.0	6.4	2.7	0.14	0.7	0.06
	Caney Creek nr Caney	20	31	8.0	7.3	3.9	0.12	1.1	0.08
	Clear Boggy Cr nr Union Valley	24	27	8.2	7.6	7.4	0.15	0.4	0.07
	Coal Creek nr Tupelo	55	598	8.3	7.7	4.5	0.15	0.4	0.05
	Delaware Creek nr Bromide	16	42	8.4	7.8	7.0	0.09	0.6	0.14
	Delaware Creek nr Olney	28	84	8.1	7.8	8.0	0.07	0.7	0.09
	Goose Creek nr Tupelo	30	38	8.2	7.7	4.9	0.12	0.9	0.11
	Leader Cr Blw Owl Cr nr Tupelo	100	74	7.9	7.1	4.9	0.13	1.0	0.12
	Mill Creek at Harden City	10	19	8.6	7.3	6.8	0.61	0.4	0.02
	Salt Creek nr Boggy Depot	39	36	8.0	7.3	5.7	0.18	0.6	0.04
	Sandy Creek at Boggy Depot	58	31	8.3	7.3	5.9	0.16	0.5	0.10
	Sandy Creek nr Wapanucka	26	9	8.5	7.3	8.3	0.19	0.6	0.06
	Sheep Creek nr Harden City	17	31	8.6	7.9	5.3	0.14	0.6	0.07
Island Bayou	Island Bayou near Albany	220	238	7.7	7.1	4.2	0.50	1.0	0.22
Mill Cr.	Mill Creek near Mill Creek	16	35	8.4	8.0	6.4	0.29	0.7	0.07
	Mill Creek Southwest of Ravia	55	41	8.3	7.7	3.2	0.29	0.7	0.07
Muddy Boggy	North Boggy Cr nr Wardville	290	55	7.5	6.7	0.9	0.05	0.9	0.17
	Big Sandy Creek nr Citra	48	39	8.2	7.5	6.6	0.17	0.7	0.03
	Caney Boggy Creek nr non	96	56	7.4	6.6	5.1	0.09	0.7	0.11
	Caney Boggy Creek nr Parker	85	51	7.7	7.2	5.1	0.23	1.0	0.10
	Caney Creek at Coalgate	110	56	8.4	7.1	6.6	0.12	8.7	1.10
	Chickasaw Creek nr Stringtown	47	25	7.5	6.9	5.2	0.47	0.3	0.04
	McGee Creek at Redden	44	29	7.5	6.7	4.4	0.05	0.6	0.05
	Muddy Boggy Creek nr Steedman	34	53	9.2	7.7	7.2	0.07	0.6	0.08
	Panther Creek nr Gerty	36	26	8.0	7.1	7.8	0.49	0.5	0.03
	Sincere Creek nr Steedman	44	57	8.6	7.2	4.5	0.08	1.2	0.12
	Sugar Creek nr Soper	23	21	8.5	7.3	6.3	0.08	0.6	0.03
Pennington Cr.	Pennington Cr at Reagan	10	18	8.3	8.0	6.7	0.35	0.3	0.02
	Spring Creek nr Connerville	11	14	8.2	7.7	4.4	0.11	1.1	0.04
Whitegrass Cr.	Whitegrass Cr nr Bennington	27	31	8.0	7.4	4.8	0.10	0.3	0.05
	Whitegrass Cr nr New Oberlin	66	74	7.8	7.0	5.4	0.08	0.5	0.06

This table shows the maximum and minimum measured base flow values for various parameters at each of the 39 sites. PARAMETER UNITS: TURB (NTU); D.O. (MG/L); ALK. (MG/L AS CACO3); TSS (MG/L); NOx = NO2 + NO3 (MG/L AS N); TKN (MG/L AS N); TOT. P (MG/L AS P)

TABLE 3.5: Average High Flow Values By SOMBS Sampling Site

Subwatershed	Site Description	TSS	NOx	TKN	TOT. P	HARD.	Cl	SO4
Big Sandy Cr.	Big Sandy Creek nr Tish.	56	0.07	0.65	0.10	76	6.8	12.2
Blue River	Blue River at Diamond Spr. Br	262	0.26	0.85	0.17	145	4.2	6.8
	Blue River at Milburn	437	0.28	1.05	0.18	111	4.2	6.1
	Blue River nr Fittstown	257	0.39	0.68	0.14	172	5.8	8.6
	Little Blue Cr nr Connerville	144	0.25	0.73	0.24	173	4.6	7.5
	Mineral Bayou at Armstrong	349	0.23	0.85	0.16	70	6.8	11.5
	Sulphur Creek nr Bennington	173	0.11	0.68	0.10	68	8.1	9.4
Clear Boggy	Bois D Arc Creek nr Fittstown	59	0.16	0.73	0.15	157	9.3	19.0
	Caney Creek nr Bentley	177	0.09	0.68	0.09	55	7.7	9.4
	Caney Creek nr Caney	439	0.14	0.57	0.10	89	7.4	6.7
	Clear Boggy Cr nr Union Valley	267	0.15	0.70	0.21	141	8.5	21.8
	Coal Creek nr Tupelo	134	0.07	0.60	0.20	134	13.5	7.5
	Delaware Creek nr Bromide	164	0.08	0.55	0.17	164	10.7	11.4
	Delaware Creek nr Olney	231	0.18	0.83	0.26	96	6.8	8.6
	Goose Creek nr Tupelo	88	0.10	0.77	0.23	80	4.3	7.9
	Leader Cr Blw Owl Cr nr Tupelo	370	0.14	0.90	0.15	32	6.8	7.5
	Mill Creek at Harden City	43	0.26	0.38	0.08	210	19.0	9.8
	Salt Creek nr Boggy Depot	489	0.20	0.85	0.09	61	10.8	8.7
	Sandy Creek at Boggy Depot	166	0.15	0.98	0.20	40	6.3	7.2
	Sandy Creek nr Wapanucka	19	0.13	0.80	0.13	30	5.4	6.4
	Sheep Creek nr Harden City	169	0.12	0.50	0.07	140	27.0	6.9
Island Bayou	Island Bayou near Albany	599	0.52	1.05	0.20	64	6.1	36.4
Mill Cr.	Mill Creek near Mill Creek	81	0.22	0.95	0.34	155	8.3	6.9
	Mill Creek Southwest of Ravia	55	0.16	0.87	0.12	143	5.9	8.0
Muddy Boggy	North Boggy Cr nr Wardville	152	0.07	0.60	0.07	23	5.3	10.2
	Big Sandy Creek nr Citra	277	0.12	0.68	0.08	37	5.9	11.0
	Caney Boggy Creek nr non	242	0.10	0.95	0.12	32	5.0	8.3
	Caney Boggy Creek nr Parker	447	0.14	0.73	0.12	24	5.0	8.2
	Caney Creek at Coalgate	210	0.12	0.78	0.09	46	6.2	9.3
	Chickasaw Creek nr Stringtown	57	0.06	0.45	0.09	22	5.1	11.0
	McGee Creek at Redden	68	0.05	0.45	0.07	16	4.2	7.3
	Muddy Boggy Creek nr Steedman	649	0.12	0.53	0.09	84	27.0	14.0
	Panther Creek nr Gerty	57	0.14	0.78	0.07	31	6.2	12.3
	Sincere Creek nr Steedman	245	0.08	0.75	0.14	48	6.4	12.0
	Sugar Creek nr Soper	82	0.20	0.68	0.12	104	7.0	9.6
Pennington Cr.	Pennington Cr at Reagan	13	0.25	0.85	0.14	231	3.5	5.7
	Spring Creek nr Connerville	13	0.10	0.43	0.04	237	3.4	6.2
Whitegrass Cr.	Whitegrass Cr nr Bennington	67	0.08	0.60	0.09	73	8.8	11.1
	Whitegrass Cr nr New Oberlin	227	0.14	0.83	0.11	34	7.0	7.2
	Average	206	0.16	0.72	0.14	93	8.0	10.1
	Maximum Average Value	649	0.52	1.05	0.34	237	27.0	36.4
	First Quartile (25th Percentile)	58	0.10	0.60	0.09	38	5.2	7.3
	Median (50th Percentile)	169	0.14	0.73	0.12	76	6.4	8.6
	Third Quartile (75th Percentile)	264	0.20	0.85	0.17	142	8.2	11.1
	Minimum Average Value	13	0.05	0.38	0.04	16	3.4	5.7

This table shows the average of four high flow measurements for each of 39 sites. PARAMETER UNITS: TSS (MG/L); NOx = NO2 + NO3 (MG/L AS N); TKN (MG/L AS N); TOT. P (MG/L AS P); HARD. (MG/L AS CAO3); Cl (MG/L); SO4 (MG/L)

had elevated high flow sulfate concentrations. High flow sulfate concentrations at the two sites near Connerville were near average for the all sites in the project area while base flow values were very much below average. Streams in this area have been identified as primarily spring fed (Table 2.2). However, high flow sulfate concentrations

at Bois D'Arc were much higher than average for the project area. This increase may be due to pollutant sources in the watershed.

Specific Conductance

Average base flow specific conductance values ranged from 121 uS/cm to 1228 uS/cm. The average for the project area was 466 uS/cm. Average values were distributed as follows: ten sites below 325 uS/cm, ten between 325-425 uS/cm, eight between 575-900 uS/cm, and one above 1225 uS/cm. This again shows wide range of geologic conditions in the region.

Specific conductance was not measured during high flow sampling.

Dissolved Oxygen

Average base flow dissolved oxygen (DO) values ranged from 60% saturation at North Boggy near Wardville to 112% saturation at Delaware Creek near Olney. The average for the project area was 86% saturation. State water quality standards require that the DO be at least 6.0 mg/l for the season between 4/1 and 6/15 and 5.0 mg/l the remainder of the year. No baseflow measurements were taken in any year between 4/1 and 6/15.

Generally DO is greatest during daylight hours due to photosynthetic production. However, in highly productive creeks a high daytime DO concentration may be an indication of depleted concentrations during nighttime hours due to respiration (consumptive metabolism). Usually creeks are not measured during the early morning hours due to time constraints. However many times low DO concentrations were measured during the daylight hours during this project. These low DO concentrations were likely due to high COD or BOD inputs to the stream or water inputs low in DO to the stream near the site. If these is a large COD or BOD in these streams the potential exists for very low DO concentrations during the nighttime.

The beneficial use standard dissolved oxygen criteria of 5.0 mg/l was violated at least once during the seven base flow measurements at 13 of the 39 sites (33%). The DO standard was violated two of the seven sampling times at Caney Creek near Bentley and three of the seven times at North Boggy near Wardville. A DO concentration of 0.9 mg/l was measured at North Boggy near Wardville; concentrations below 2.0 mg/l almost always result in fish kills where fish are present.

Dissolved oxygen was not measured for high flow events.

Total Suspended Solids

Average baseflow total suspended solids (TSS) values ranged from 4.5 mg/l at Spring Creek near Connerville to 79 mg/l at Island Bayou near Albany. The average for all sites was 19 mg/l. Increased sediment can cause degradation to habitat thus having a negative impact on aquatic life and stream health.

It is likely that suspended sediment may enter the streams during high flow events as a result of poor land use practices within watersheds and activities which destabilize stream banks. High flow values for total suspended solids for the project area were increased on average by more than 10x over base flow concentrations and were highly variable among sites. Although baseflow TSS for Muddy Boggy Creek near Steedman were only slightly above average for the project area, high flow values were more than 30x higher averaging 649 mg/l. Pennington Creek at Reagan had a lower than average baseflow TSS and a high flow value only 10% higher at 13 mg/l indicating stable watershed and stream banks.

As a result of bridge construction on Coal Creek near Tupelo the baseflow TSS concentration was increased from 11 mg/l on average to 598 mg/l on 8/4/94. This demonstrates the dramatic effect of destabilized stream banks due to activities in the riparian zone.

Turbidity

Average base flow turbidity for all sites in the project area was 23 NTU ranging between a minimum average of 4.3 NTU and a maximum average of 92 NTU. According to beneficial use water quality standards base flow turbidity should not exceed 50 NTU. Several streams exceeded this criteria for average turbidity: North Boggy near Wardville (92 NTU), Island Bayou near Albany (67 NTU), Caney Creek at Coalgate (56 NTU), Leader Creek below Owl Creek near Tupelo (55 NTU), and Bois D'Arc Creek near Fittstown (54 NTU). In addition to these five sites seven other sites exceeded the turbidity standard at least once during the seven baseflow measurements. In contrast thirteen sites averaged turbidities 10 NTU or less.

Turbidity was not measured during high flow events.

Hydrogen Ion Concentration (pH)

Average hydrogen ion concentrations ranged from a pH of 7.0 to 8.3. The average for all sites was 7.8. A pH value of 9.2 was recorded on 4/28/93 at Muddy Boggy Creek near Steedman, violating water quality criteria. The beneficial use standards state that pH values should be between 6.5 and 9.0 in waters designated for fish and wildlife propagation. At no time at any site was the minimum pH criteria exceeded. No measurements of pH were made during high flow sampling.

3.1.2. Nutrients

Nitrate/Nitrite

Average baseflow values for nitrate/nitrite were relatively low compared to other areas in the state. The average nitrate/nitrite value for all sites in the study area was 0.14 mg/l (as N) ranging from a minimum of less than detectable (< 0.05 mg/l) to a maximum of 0.65 mg/l (as N). No site in the project area had an average value or a single

individual measurement above 1 mg/l (as N) except one. A nitrate/nitrite concentration of 2.8 mg/l (as N) was measured at Bois D'Arc Creek near Fittstown on August 3, 1993. This may be the result of accumulation and concentration of nutrients in the stream due to livestock during summer low flow periods.

Average nitrate/nitrite high flow concentrations for the project area were 47% higher than base flow values. Ten sites had lower concentrations of nitrate/nitrite in high flows on average than baseflows. Seven sites had concentrations greater than 2x the base flow concentration, two of which were more than 3x greater.

Total Kieldahl Nitrogen

Average base flow Total Kjeldahl Nitrogen values (TKN) were relatively low in the project area. Average TKN values ranged from a minimum of 0.20 mg/l to a maximum of 2.3 mg/l with an overall average of 0.46 mg/l.

High flow values were 93% higher than base flow concentrations for the project area for TKN. Only two sites had TKN concentrations below base flow values.

Nitrate/Nitrite vs. TKN

Some general trends were apparent between high flow and baseflow concentrations of nitrate/nitrite and TKN. Sites with lower concentrations of nitrate/nitrite during high flow events had above average baseflow concentrations of nitrate/nitrite. Average base flow concentration for these sites was 0.32 mg/l, which is more than double the average for the project area while nitrate/nitrite was 31% lower than baseflow on average during high flows. In addition lower high flow concentrations of nitrate/nitrite were usually combined with increased concentrations of TKN over base flow; where nitrate/nitrite concentrations decreased during high flow TKN increased an average of 157% of base flow for the same sites (1.7x higher than the average TKN increase for all 39 sites).

Total Phosphorus

Average total phosphorus values ranged from a minimum of less than detectable (<0.01 mg/l as P) to a maximum of 0.26 mg/l as P. The average for all sites was 0.05 mg/l as P. Recommended phosphorus concentrations should be less than 0.05 mg/l as P to maintain in-stream quality and less than 0.02 mg/l if there is downstream loading to a waterbody of concern. Average total phosphorus values were distributed as follows: 13

sites less than 0.02 mg/l as P, 16 between 0.02-0.05 mg/l, and 6 between 0.05- 0.09 mg/l. Three sites, Bois D'Arc near Fittstown, North Boggy near Wardville, and Island Bayou near Albany averaged above 0.09 mg/l total phosphorus. The site located at Caney Creek at Coalgate had a very high average total phosphorus of 0.26 mg/I.

The Island Bayou watershed contains a wastewater effluent to the stream as well as greater than 10% cropland (Table 3.1 1), which may result in elevated phosphorus levels. In Caney Creek at Coalgate and Bois D'Arc Creek near Fittstown phosphorus values

were highly elevated in August 1993 over other sampling dates. The elevated total phosphorus value measured in Bios D' Arc in August of 1993 is consistent with the high nitrate value measured on this date as discussed earlier. The high phosphorus value measured in August 1993 also corresponds with a high TKN value on this date (8.7 mg/l) and elevated chloride and sulfate. There may have been some discharge from an upstream waste treatment lagoon, which would account for the elevated parameters on this date.

3.2. Summation of Data By Major Subwatershed

See Table 3.6 and 3.7

Chloride, Sulfate, Hardness, and Conductivity

There is a strong positive correlation between chloride and sulfate concentrations within the eight subwatersheds of the Red River studied. Among major subwatershed chloride values ranged from 5.9 mg/l to 44.2 mg/l and sulfate from 5.6 mg/l to 99.7 mg/l. Chloride and sulfate concentration were highest in Island Bayou and Muddy Boggy Creek and lowest in Pennington Creek and Mill Creek. Chloride concentrations were highly variable within the Muddy Boggy Creek and Clear Boggy Creek subwatersheds. This variability may be due to the size of these subwatersheds and range of geological conditions as compared to other subwatersheds. Also old oil production sites concentrated in certain areas of these two watersheds may contribute to the high variability. Sulfate concentrations were less variable within each subwatershed as compared to chloride.

Hardness and conductivity were much less variable than chloride and sulfate among subwatersheds. Hardness ranged from 117 mg/l to 312 mg/l. Conductivity ranged from 358 uS/cm to 771 uS/cm. The variability of hardness and conductivity was low within each subwatershed except for Muddy Boggy Creek and to a lesser extent Clear Boggy. This again may be the result of watershed size and range of geologic and land use conditions. The variability of hardness and conductivity within the Muddy and Clear Boggy Creeks was much less than the variability of chloride and sulfate within these same watersheds.

TABLE 3.6: Base Flow Values Summarized By Major Subwatershed

Subwatershed		D.O.	TURB	TSS	PH	ALK.	NOx	TKN	TOT. P	COND	HARD.	CI	SO4	n
Big Sandy Cr.	Average	93.4%	4	10	7.9	146	0.07	0.68	0.08	387	179	15.8	36.2	n=1
	Coeff. of Var.	-	-	-	-	-	-	-	-	-	-	-	-	
Blue River	Average	93.0%	13	15	8.0	245	0.30	0.27	0.03	508	238	12.3	19.0	n=6
	Coeff. of Var.	9	70	36	3	30	65	25	43	16	21	70	59	
Clear Boggy	Average	87.4%	19	19	7.8	172	0.13	0.42	0.05	515	202	38.2	24.9	n=14
	Coeff. of Var.	14	83	49	3	36	117	28	68	35	38	89	49	
Island Bayou	Average	71.6%	67	79	7.4	185	0.18	0.84	0.10	771	216	44.2	99.7	n=1
	Coeff. of Var.	-	-	-	-	-	-	-	-	-	-	-	-	
Mill Cr.	Average	87.1%	16	20	8.1	224	0.12	0.41	0.04	452	218	7.2	9.3	n=2
	Coeff. of Var.	7	57	12	1	20	10	14	9	15	14	2	13	
Muddy Boggy	Average	82.3%	33	21	7.5	95	0.09	0.61	0.06	366	117	42.0	28.0	n=11
	Coeff. of Var.	13	74	37	5	62	66	95	119	87	68	158	48	
Pennington Cr.	Average	95.0%	5	8	8.0	295	0.17	0.29	0.02	542	312	5.9	5.6	n=2
	Coeff. of Var.	1	30	60	2	8	84	28	0	5	7	25	20	
Whitegrass Cr.	Average	76.0%	26	28	7.6	125	0.06	0.33	0.03	358	126	23.0	21.4	n=2
	Coeff. of Var.	4	97	68	2	33	1	33	36	24	29	9	30	

This table shows the average of seven base flow measurements for each of the 8 subwatersheds. The coefficient of variation is caluculated from the averages for each sampling site. PARAMETER UNITS: TEMP (C); TURB (NTU); COND (US/CM @ 25C); D.O. (% Sat.); ALK. (MG/L AS CACO3); TSS (MG/L); NOx = NO2 + NO3 (MG/L AS N); TKN (MG/L AS NI; TOT. P (MG/L AS PI; HARD. (MG/L AS CAO3); CI (MG/L); SO4 (MG/L)

TABLE 3.7: High Flow Values Summarized By Major Subwatershed

Subwatershed		TSS	NOx	TKN	TOT. P	HARD.	CI	SO4	n
Big Sandy Cr.	Average	56	0.07	0.65	0.10	76	6.8	12.2	n=1
	Coeff. of Var.	-	-	-	-	-	-	-	
Blue River	Average	270	0.25	0.80	0.16	123	5.6	8.3	n=6
	Coeff. of Var.	41	36	18	29	39	28	24	
Clear Boggy	Average	201	0.14	0.70	0.15	102	10.2	9.9	n=14
	Coeff. of Var.	72	37	24	41	55	60	47	
Island Bayou	Average	599	0.52	1.05	0.20	64	6.1	36.4	n=1
	Coeff. of Var.	-	-	-	-	-	-	-	
Mill Cr.	Average	68	0.19	0.91	0.23	149	7.1	7.5	n=2
	Coeff. of Var.	27	25	6	68	6	24	11	
Muddy Boggy	Average	226	0.11	0.67	0.10	42	7.6	10.3	n=11
	Coeff. of Var.	82	39	23	25	65	86	20	
Pennington Cr.	Average	13	0.18	0.64	0.09	234	3.5	5.9	n=2
	Coeff. of Var.	1	59	47	79	2	2	5	
Whitegrass Cr.	Average	147	0.11	0.71	0.10	53	7.9	9.2	n=2
	Coeff. of Var.	77	41	22	20	52	17	30	

This table shows the average of four high flow measurements for each of the 8 subwatersheds. The coefficient of variation is caluculated from the averages for each sampling site. PARAMETER UNITS: TEMP (C); TURB (NTU); COND (US/CM @ 25C); D.O. (% Sat.); ALK. (MG/L AS CACO3); TSS (MG/L); NOx=NO2 + NO3 (MG/L AS N); TKN (MG/L AS N); TOT. P (MG/L AS P); HARD. (MG/L AS CAO3); CI (MG/L); SO4 (MG/L); n= number of streams in the watershed.

Total Suspended Solids and Turbidity

A relationship exists between TSS and turbidity among the major subwatersheds. Pennington Creek had the lowest TSS (8 mg/1) and turbidity (5 NTU) and island Bayou had the highest TSS (79 mg/1) and turbidity (67 NTU). As expected, a positive correlation was observed between increased TSS and increased turbidity. Increased turbidity had a detrimental effect on water quality. Increased TSS can destroy habitat impacting aquatic life of a stream and thus recreational use.

Nutrients

Total Kjeldahl Nitrogen (TKN) was highest in Island Bayou, Big Sandy Creek, and Muddy Boggy Creek and lowest in Pennington Creek and the Blue River. However, nitrate/nitrite was highest in the Blue River, Island Bayou, and Pennington Creek and lowest in Whitegrass Creek, Big Sandy Creek, and Muddy Boggy Creek. Total phosphorus was highest in Island Bayou and Big Sandy Creek and lowest in Pennington Creek and the Blue River. The subwatersheds are listed in order below according to the respective nutrient concentration:

TKN (lowest to highest)	Nitrate/nitrite (highest to lowest)	TP (lowest to highest)
Blue River	Blue River	Pennington Cr.
Pennington Cr.	Island Bayou	Blue River
Whitegrass Cr.	Pennington Cr.	Whitegrass Cr.
Mill Cr.	Clear Boggy	Mill Cr.
Clear Boggy	Mill Cr.	Clear Boggy
Muddy Boggy	Muddy Boggy	Muddy Boggy
Big Sandy Cr.	Big Sandy Cr.	Big Sandy Cr.
Island Bayou	Whitegrass Cr.	Island Bayou

There is an apparent relationship in the concentration of nutrients among subwatersheds. Based on the relative concentrations of phosphorus and nitrogen, phosphorus is most likely the limiting nutrient in all subwatersheds (see Table 3.1). (Wetzel, Robert G. *Limnology*. Saunders College Publishing, 1983, p. 285). Generally where phosphorus is the limiting nutrient, increased phosphorus usually correlates with increased primary productivity in streams. The increased productivity results in a decrease in nitrate/nitrite, as nitrogen is these forms are readily utilized, and an increase in TKN, usually correlating with increased biomass.

This relationship is most evident in Big Sandy Creek and Muddy Boggy Creek subwatersheds. Where little phosphorus is available, nitrate/nitrite concentrations are relatively high for the region and TKN low as in the Blue River and Pennington Creek.

Two creeks Island Bayou and Whitegrass Creek do not follow this trend. Whitegrass

Creek is relatively low in both nitrate/nitrite and total phosphorus but high in TKN; Island Bayou is relatively high in all three nutrient parameters. This may be the result of inputs of TKN to the creeks- Island Bayou is known to have sewage inputs.

3.3. Summation of Data By SCS Major Land Resource Area

See Table 3.8 and 3.9

SOMBS site watersheds were divided based on the EPA defined Ecoregions and SCS defined Major Land Resource Areas. The SOMBS area is covered by two EPA defined ecoregions: Central Oklahoma/Texas Plains Ecoregion and the Ouachita Mountains Ecoregion. All SOMBS sites watersheds fall within the EPA defined Central Oklahoma/Texas Plains Ecoregion except Chickasaw Cr. near Stringtown and McGee Cr. near Redman which fall in the Ouachita Mountains Ecoregion. The SOMBS area is covered by four SCS defined Major Land Resource Areas (MLRA): Grand Prairie, W. Arkansas and Ridges, W. Coastal Plain, and Ouachita Mountains. The SCS Ouachita Mountains MLRA corresponds directly with the EPA Ouachita Mountains Ecoregion. The EPA Central Oklahoma/Texas Plains Ecoregion is divided into three MLRA by SCS. Therefore the site data will be organized and analyzed by SCS MLRA's (see Table 2.2).

Analysis of the data by dominant SCS defined Major Land Resource Area for each watershed revealed some trends. The major land resource areas ranked in the same order for average pH, conductivity, alkalinity, and hardness (from highest to lowest): Grand Prairie; W. Arkansas Valley and Ridges; W. Coastal Plain; and Ouachita Mountains. Average chloride and sulfate were lowest in the Ouachita Mountain area and similar in the other three land resource areas. Average total suspended solids was low for both the Grand Prairie area and the Ouachita Mountains. Average turbidity was lowest in the Grand Prairie area and similar in the other three areas. Nutrients had no trends among the Major Land Resource Areas.

Some parameters were highly variable within some Major Land Resource Areas. Both chloride and sulfate were highly variable in the Grand Prairie area and W. Arkansas area. Both turbidity and total suspended solids were highly variable in the Grand Prairie area. This variability may be the result of various land uses in the watersheds within these areas.

Two types of dominant geology were identified by samplers within two of the Major Land Resource Areas- the Grand Prairie area and W. Arkansas Valley and Ridges area. Streams originating from limestone-dominated areas were identified in both the Grand Prairie area and W. Arkansas Valley and Ridges area. Streams originating from granite-dominated areas were identified only in the Grand Prairie area. Analysis of the data by the dominant geology within the two Land Resource Areas reveals some trends (see Table 3.9).

TABLE 3.8: Average Base Flow Values By SCS Major Land Resource Area

SCS Major Land Resource Area		D.O.	TURB	TSS	PH	ALK.	NOx	TKN	TOT. P	COND	HARD.	CL	SO4	n
Grand Prairie	Average	92.4%	15	19	7.9	206	0.17	0.38	0.04	525	220	29.1	22.9	n=18
	Coeff. of Var.	10	101	87	3	37	90	43	62	32	31	117	99	
W. Ark. Valley & Ridges	Average	83.3%	31	21	7.7	152	0.14	0.59	0.07	460	176	36.7	28.6	n=15
	Coeff. of Var.	12	80	43	5	49	107	83	97	57	51	155	45	
W. Coastal Plain	Average	74.3%	24	24	7.6	122	0.06	0.40	0.03	387	137	27.2	25.9	n=4
	Coeff. of Var.	8	66	51	2	29	14	26	23	23	25	26	29	
Ouachita Mountains	Average	79.3%	26	14	7.1	37	0.09	0.30	0.03	132	45	9.5	17.1	n=2
	Coeff. of Var.	6	6	8	2	16	59	32	13	12	11	2	39	

This table shows the average base flow value and coefficient of variation by SCS defined Major Land Resource Area. PARAMETER UNITS: TEMP (C); TURB (NTU); COND (US/CM @ 25C); D.O. (% Sat.); ALK. (MG/L AS CACO3); TSS (MG/L); NOx=NO2 + NO3 (MG/L AS N); TKN (MG/L AS N); TOT. P (MG/L AS P); HARD. (MG/L AS CAO3); CI (MG/L); SO4 (MG/L)

TABLE 3.9: Average Base Flow Values For SCS Major Land Resource Area By Sampler Identified Dominant Geology

Major Land Resource Area		D.O.	TURB	TSS	PH	ALK.	NOx	TKN	TOT. P	COND	HARD.	CL	SO4	n
Grand Prairie-typical	Average	89.5%	22	26	7.9	203	0.19	0.41	0.04	560	224	34.2	30.6	n=9
	Coeff. of Var.	13	85	76	4	32	95	44	56	28	20	117	95	
Grand Prairie-limestone	Average	95.4%	7	12	8.1	255	0.19	0.29	0.02	568	263	22.1	12.2	n=6
	Coeff. of Var.	3	31	43	2	28	77	23	51	34	25	150	67	
Grand Prairie-granite	Average	94.8%	6	9	7.9	116	0.07	0.49	0.05	340	124	28.1	21.2	n=3
	Coeff. of Var.	8	41	44	1	23	6	39	59	12	38	73	65	
W. Ark. Valley & Ridges-typical	Average	83.8%	34	23	7.6	132	0.09	0.65	0.07	463	157	45.0	32.2	n=11
	Coeff. of Var.	13	76	43	5	57	64	88	104	68	61	145	37	
W. Ark. Valley & Ridges-limestone	Average	82.0%	22	18	8.0	208	0.28	0.41	0.06	454	227	14.1	18.7	n=4
	Coeff. of Var.	10	101	40	3	20	86	32	89	18	17	45	58	

This table shows the average base flow value and coefficient of variation for the SCS Major Land Resource Areas by dominant geology as identified by SOMBS samplers. PARAMETER UNITS: TEMP (C); TURB (NTU); COND (US/CM @ 25C); D.O. (% Sat.); ALK. (MG/L AS CACO3); TSS (MG/L); NOx=NO2 + NO3 (MG/L AS N); TKN (MG/L AS N); TOT. P (MG/L AS P); HARD. (MG/L AS CAO3); CI (MG/L); SO4 (MG/L)

Streams originating from limestone and granite areas had lower average turbidity, total suspended solids, chloride, and sulfate compared to all other areas within the Grand Prairie area and W. Arkansas Valley and Ridges area. The pH was higher on average for

streams originating from limestone areas for both Major Land Resource Areas. Alkalinity was higher in limestone areas of both Major Land Resource Areas and lower for granite areas in the Grand Prairie (no granite areas were identified in the W. Arkansas Valley and Ridge area). Hardness was lower in granite areas and slightly higher in limestone areas.

3.4. Seasonal Trends

Table 3.10 gives values for all 39 SOMBS sites averaged by date to show possible seasonal trends. The least variable of all parameters measured by date were hardness and alkalinity while turbidity and chloride were highly variable. In general most parameters were consistent through the various dates measured. However on two sampling dates in October of 1992 and August of 1993 several parameters were elevated over average values. These elevated parameters include conductivity, hardness, chloride, and sulfate. These parameters were elevated at the end of the summer months, historically the driest part of the year, when rainfall amounts are below normal. The resulting decrease in water levels in the creeks appears to have affected the concentration of the conservative chemical constituents. Creeks which did not show elevated values for these parameters during the dry season were identified by samplers as being predominantly spring-fed rather than runoff-fed.

TABLE 3.10: Average Base Flow Values By Sampling Date

MONTH	TURB	TSS	ALK.	NOx	TKN	TOT. P	COND	HARD.	CI	SO4
Sep-91	33.3	18.3	155	0.18	0.54	0.05	390	163	33.0	14.3
Jan-92	34.2	20.3	133	0.14	0.36	0.05	322	159	15.4	20.3
Apr-92	14.5	27.5	112	0.06	0.30	0.03	355	154	23.4	26.5
Jul-92	17.4	18.2	151	0.14	0.39	0.03	356	151	21.0	17.1
Oct-92	10.5	15.5	186	0.09	0.34	0.04	581	224	46.7	34.2
Apr-93	13.8	10.2	143	0.09	0.30	0.02	366	162	18.5	20.9
Aug-93	22.1	32.0	188	0.20	0.57	0.07	571	202	46.2	28.8
Coeff. of Var.	42	33	17	36	26	37	24	15	41	28

This table shows the average base flow values for all 39 sites by sampling date. PARAMETER UNITS: TURB (NTU); COND (US/CM @ 25C); ALK. (MG/L AS CACO3); TSS (MG/L); NOx=NO2 + NO3 (MG/L AS N); TKN (MG/L AS N); TOT. P (MG/L AS P); HARD. (MG/L AS CAO3); CI (MG/L); SO4 (MG/L)

3.5. Selection of Bioassessment Sites

Nineteen sites in the area were identified for bioassessment. These nineteen sites were selected based on the data collected during this project. With limited current data

and little or no background data a comprehensive determination of reference conditions is not yet possible. A crude version of the methodology for selecting reference streams by ranking streams according to certain parameters was used to select these bioassessment sites. Mainly, sites were ranked based on nutrient parameters. Bioassessment sites were selected to fit one of three categories of reference streams: positive, negative, and other. A listing of 19 bioassessment sites among the 39 sampling sites for the project area is given in Table 2.1. The reference category is also given for each bioassessment site. Some bioassessment on these sites has already been conducted by OCC/WQ; continued bioassessement will depend on available funds.

3.6. Land Use, Non-point Source Inventory, and Geographic Information Systems (GIS)

A Geographic Information System was used for the spatial analysis of land use and non-point pollutant source inventory data. The land use data was obtained from SCS surveys by county. The SCS survey data in the GIS systems is in a resolution of 10-acre cells. Table 3.11 shows the SCS land survey by SOMBS watershed; the survey data shows only the type of land use for each area.

The SOMBS area is dominated by rangeland in the west, pasture land in the central region, and forest land in the east. This land use data corresponds with the SCS Major Land Resources areas. Only Island Bayou and Sandy Creek near Wapanucka had greater than 10% of the watershed in cropland. No trends were evident in the data analysis based on the SCS land use GIS data.

This SCS land use data is of only limited GIS value to water quality since the resolution is much less than desired and the survey is dated by many years thus not showing the current land usage for agriculture in the area. In addition, the survey does not provide an indication of the condition of vegetation in the different land use types. Conditions of poor soil cover due to overgrazing, farming, and erosion, as well as nutrient sources from fertilizer application and various confined animal areas are important to water quality analysis. OCC Water Quality has begun conducting land use surveys to fill in these land use/condition data gaps on other projects and plans to continue with future projects.

A non-point pollution source inventory was conducted as part of this project. The inventory was conducted over the entire SOMBS project area, covering 10 counties. Sites and areas were marked on USGS 7.5" topoquad maps and later digitized into the GIS system. The following sources were identified within the area as determined from GIS analysis:

TABLE 3.11: SCS Land Use Data By SOMBS Watershed

Site Name	Total Watershed Acreage	Landuse As Percentage Of Total Watershed Area							
		Rangeland	Pastureland	Cropland	Forest Land	Water	Urban and Builtup Land	Quarries and Gravel Pits (>5 ac) and Strip Mines	Oil and Gas Production
Big Sandy Creek nr Citra	22625	43.33%	4.64%		52.04%				
Big Sandy Creek nr Tish.	15933	75.74%	20.04%	0.50%	0.62%	1.24%	1.55%	0.31%	
Blue River at Diamond Spr. Br	41790	86.65%	9.44%	0.85%	0.33%	0.02%	0.73%		
Blue River at Milburn	32172	80.80%	14.10%	1.47%	2.03%	0.31%	1.32%		
Blue River nr Fittstown	35711	65.71%	26.18%	5.62%		0.39%	1.61%	0.53%	
Bois D Arc Creek nr Fittstown	8905	83.68%	12.65%	2.77%		0.78%	0.11%		
Caney Boggy Creek nr non	22545	26.09%	8.70%	4.35%	60.87%				
Caney Boggy Creek nr Parker	22325	40.28%	22.42%	1.15%	35.97%	0.04%	0.04%	0.09%	
Caney Creek at Coalgate	21893	53.14%	12.78%	0.05%	29.84%	2.93%	1.17%	0.14%	
Caney Creek nr Bentley	19046	3.68%	70.99%	1.25%	24.08%				
Caney Creek nr Caney	28505	30.89%	36.96%	4.13%	25.80%	0.97%	2.08%	0.07%	
Chickasaw Creek nr Stringtown	22644	18.03%	7.94%		46.75%		0.04%	0.17%	
Clear Boggy Cr nr Union Valley	14421	48.12%	20.70%	9.86%		0.75%	22.69%		
Coal Creek nr Tupelo	11851	66.64%	29.19%	0.87%	2.92%		0.50%		0.08%
Delaware Creek nr Bromide	18108	73.25%	16.32%	2.57%	6.39%	0.76%	0.71%		
Delaware Creek nr Olney	38231	28.72%	46.54%	7.78%	13.83%	0.75%	2.09%	0.28%	
Goose Creek nr Tupelo	14679	43.97%	36.09%	0.74%	18.11%	0.94%	0.13%		
Island Bayou near Albany	86406	0.63%	77.42%	11.29%	8.80%	0.30%	1.83%		
Leader Cr Blw Owl Cr nr Tupelo	59245	32.65%	54.87%	0.52%	10.33%	0.75%	0.90%		
Little Blue Cr nr Connerville	12019	84.05%	11.43%	1.15%	0.68%	0.16%	2.38%	0.16%	
McGee Creek at Redden	35444	27.75%	3.74%		50.92%	0.06%			
Mill Creek at Harden City	7571	86.55%	8.09%	2.87%		0.39%	1.96%		0.26%
Mill Creek near Mill Creek	29514	56.73%	28.53%	6.30%	6.16%	1.27%	0.40%	0.60%	
Mill Creek southwest of Ravia	30658	85.68%	4.61%	0.90%	6.41%	0.45%	1.44%	0.51%	
Mineral Bayou at Armstrong	24799	1.75%	69.43%	1.95%	8.05%	0.08%	21.36%		
Muddy Boggy Creek nr Steedman	30087	64.36%	28.75%	1.87%		0.43%	4.47%		0.16%
North Boggy Cr nr Wardville	26554	25.86%	33.63%		39.42%	0.26%	0.73%		
Panther Creek nr Gerty	10783	54.55%			36.36%		9.09%		
Pennington Cr at Reagan	33902	95.34%	1.92%	0.50%	1.31%	0.44%	0.50%		
Salt Creek nr Boggy Depot	14915	15.04%	57.52%	5.37%	20.94%	0.46%		0.66%	
Sandy Creek at Boggy Depot	15834	6.55%	54.43%	4.62%	33.77%	0.12%	0.50%		
Sandy Creek nr Wapanucka	7670	39.43%	31.19%	20.10%	7.47%	0.39%	1.42%		
Sheep Creek nr Harden City	11671	89.68%	6.74%	0.58%		0.93%	1.00%	0.75%	0.42%
Sincere Creek nr Steedman	17406	68.82%	28.51%	1.19%		0.45%	1.02%		0.11%
Spring Creek nr Connerville	5041	97.84%	0.78%	0.20%	0.78%	0.20%	0.20%		
Sugar Creek nr Soper	6600	2.91%	71.95%	3.78%	21.37%				
Sulphur Creek nr Bennington	15933	5.09%	72.64%	4.96%	15.82%		1.49%		
Whitegrass Cr nr Bennington	9093	10.33%	70.22%	1.63%	17.83%				
Whitegrass Cr nr New Oberlin	17810	1.00%	61.66%	4.55%	32.74%	0.06%			
Avegarge	23111	46.75%	30.10%	3.02%	16.38%	0.44%	2.19%	0.11%	0.03%

This table shows the SCS land use data for each watershed based on the categroization of 10 acre size tracks. Watersheds extend from the sampling site up to the upper reaches of the watershed or to the boundary of the watershed of another sampling site.

TABLE 3.12: OCC/WQ Land Survey Data From GIS For SOMBS Watersheds

Site Name	Overgrazing (acre)	Stripped Soil and Gravel Pits (acre)	Gullies (acre)	Roadside Erosion (km)	Roadside Herbicides (km)	Confinement (acre)	Reclaimed Strip Pit (acre)	Roadside Dump (number)	Oil Well Areas (number)	Poultry Production (number)
Big Sandy Creek nr Citra										
Big Sandy Creek nr Tish.										
Blue River at Diamond Spr. Br										
Blue River at Milburn										
Blue River nr Fittstown				0.22						
Bois D Arc Creek nr Fittstown				0.20						
Caney Boggy Creek nr non										
Caney Boggy Creek nr Parker	54.24		2.62	3.91	46.63					
Caney Creek at Coalgate	9.76	0.05	16.33	2.94	1.65					
Caney Creek nr Bentley			8.03	4.96				1		
Caney Creek nr Caney				3.43		8.92				
Chickasaw Creek nr Stringtown				1.16						
Clear Boggy Cr nr Union Valley				0.46						
Coal Creek nr Tupelo				0.56					2	
Delaware Creek nr Bromide	1049.79	139.59	5.12	1.87						
Delaware Creek nr Olney	1232.42	109.94	16.11	3.17		0.05		5		
Goose Creek nr Tupelo	106.67	649.41		0.44						
Island Bayou near Albany				0.85				2		
Leader Cr Blw Owl Cr nr Tupelo			36.42	12.14				3		
Little Blue Cr nr Connerville	16.04		6.57	0.03				1		
McGee Creek at Redden		3.93		0.72				1		
Mill Creek at Harden City				0.16						
Mill Creek near Mill Creek		128.17	71.19	0.22						
Mill Creek Southwest of Ravia		27.21	38.89	0.26						
Mineral Bayou at Armstrong			4.03	0.20						
Muddy Boggy Creek nr Steedman				1.46						
North Boggy Cr nr Wardville										
Panther Creek nr Gerty										
Pennington Cr at Reagan										
Salt Creek nr Boggy Depot		118.51	1.28	1.68			3.66	1		
Sandy Creek at Boggy Depot		3.63	5.93	1.88				1		
Sandy Creek nr Wapanucka			8.08	1.33				2		
Sheep Creek nr Harden City				0.22						
Sincere Creek nr Steedman				0.78						
Spring Creek nr Connerville										
Sugar Creek nr Soper				1.21						
Sulphur Creek nr Bennington				2.64				2		
Whitegrass Cr nr Bennington				2.08						
Whitegrass Cr nr New Oberlin										

This table shows the non-point pollution source GIS data by watershed for the SOMBS sites based on the land survey conducted by Water Quality. Data computed from a GIS raster resolution of 10 sq.meter.

Roadside Erosion ..... 209 km
Reclaimed Strip Pit ..... 75 acres
Roadside Herbicides . . .. 533 km
Roadside Dumps ..... 121 sites
Gullies ..... 534 acres
Overgrazing ..... 4880 acres
Poultry Production . . .. 5 houses on 4 sites

Oil Fields ..... 7 sites
Confinement ..... 9 acres
Mining..... 13 acres
Strip Soil and Gravel Pits .... 1615 acres
Dairy ..... 1 operation

Table 3.12 contains the non-point pollutant source inventory within each of the 39 SOMBS site watersheds. This inventory was a basis for a more complete land survey/ non-point source inventory currently used by OCC Water Quality.

Permitted wastewater discharges, as reported by the Oklahoma Department of Environmental Quality, were located on the GIS for the SOMBS project area. The following sites had permitted waste water discharges within their watersheds: Island Bayou near Albany, Mill Cr. southwest of Ravia, Delaware Cr. near Olney, and Chickasaw Cr. near Stringtown.

3.7. Aquatic Life Use Support Status of SOMBS Streams

Table 3.13 gives the "aquatic life use" support status based on DO, pH, and turbidity criteria as detailed in the 1994 305(b) Oklahoma Water Quality Report to Congress for each of the 39 SOMBS sites. The “aquatic life use” support status is also based on additional parameters, including habitat or community modification, point and non-point source impacts, toxicants, siltation, and nuisance biota- which were not measured as part of this study. No parameters were measured to assess the "swimming use" of these water bodies. Currently OCC/WQ is conducting biological assessments on streams selected for assessment as part of this study. Additional data (biological, fecal coliform, etc.) may further expand the list of stream with less than supporting status.

TABLE 3.13: Aquatic Life Support Status of SOMBS Streams Based On 1994 305(b) Oklahoma Water Quality Report to Congress Criteria**

Subwatershed	Site Description	Support Status*	Problem Parameter
Big Sandy Cr.	Big Sandy Creek nr Tish.	fully supporting	
Blue River	Blue River at Diamond Spr. Br	fully supporting	
	Blue River at Milburn	fully supporting	
	Blue River nr Fittstown	fully supporting	
	Little Blue Cr nr Connerville	fully supporting	
	Mineral Bayou at Armstrong	not supporting	turbidity
	Sulphur Creek nr Bennington	fully supporting	
Clear Boggy	Bois D Arc Creek nr Fittstown	not supporting	turbidity, DO
	Caney Creek nr Bentley	not supporting	turbidity, DO
	Caney Creek nr Caney	partially supporting	DO
	Clear Boggy Cr nr Union Valley	fully supporting	
	Coal Creek nr Tupelo	partially supporting	DO
	Delaware Creek nr Bromide	fully supporting	
	Delaware Creek nr Olney	fully supporting but threatened	turbidity
	Goose Creek nr Tupelo	partially supporting	DO
	Leader Cr Blw Owl Cr nr Tupelo	not supporting	turbidity, DO
	Mill Creek at Harden City	fully supporting	
	Salt Creek nr Boggy Depot	fully supporting	
	Sandy Creek at Boggy Depot	fully supporting	
	Sandy Creek nr Wapanucka	fully supporting	
	Sheep Creek nr Harden City	fully supporting	
Island Bayou	Island Bayou near Albany	not supporting	turbidity, DO
Mill Cr.	Mill Creek near Mill Creek	fully supporting	
	Mill Creek Southwest of Ravia	partially supporting	DO, turbidity peaks
Muddy Boggy	North Boggy Cr nr Wardville	not supporting	turbidity, DO
	Big Sandy Creek nr Citra	fully supporting	
	Caney Boggy Creek nr non	not supporting	turbidity
	Caney Boggy Creek nr Parker	not supporting	turbidity
	Caney Creek at Coalgate	not supporting	turbidity
	Chickasaw Creek nr Stringtown	partially supporting	turbidity
	McGee Creek at Redden	not supporting	turbidity, DO
	Muddy Boggy Creek nr Steedman	partially supporting	pH
	Panther Creek nr Gerty	fully supporting	
	Sincere Creek nr Steedman	partially supporting	DO, turbidity
	Sugar Creek nr Soper	fully supporting	
Pennington Cr.	Pennington Cr at Reagan	fully supporting	
	Spring Creek nr Connerville	partially supporting	DO
Whitegrass Cr.	Whitegrass Cr nr Bennington	partially supporting	DO
	Whitegrass Cr nr New Oberlin	not supporting	turbidity

This table gives the "aquatic life use" support status based on DO, pH, and turbidity criteria as detailed in the 1994 305(b) Oklahoma Water Quality Report to Congress for each of the 39 SOMBS sites.

*The "aquatic life use" support status is also based on additional parameters- including habitat or community modification, point and non-point source impacts, toxicants, siltation, and nuisance biota- which were not measured as part of this study.

**No parameters were measured to assess the "swimming use" of these water bodies.

3.8. Annual Loading Estimates

An attempt was made to estimate the annual loading for selected parameters for each of the thirty-nine SOMBS watersheds. The necessary components are annual average concentration and annual average flow (volume/time). Baseflow and high flow concentrations are measured separately because concentrations can vary widely between

baseflow and high flow. Average concentration has been determined from the quarterly baseflow and semi-annual high flow measurements. It is assumed that these average concentrations are representative of a yearly average for each watershed.

In addition the average time spent annually at baseflow and high flow must be known. Since flow was not measured as part of this study, average flow at baseflow and average flow at high flow must be estimated. The estimate was based on flow measurements at USGS gauging stations (Heimann, David C., R. L. Tortorelli. *Statistical Summaries of Streamflow Records in Oklahoma and Parts of Arkansas, Missouri, and Texas Through 1984.* USGS, Oklahoma City, OK, 1988.) and the USGS estimation of annual runoff *(USGS).* Three USGS gauging stations in the area were used: Blue River at Milburn, Blue River near Blue, Muddy Boggy near Farris, and Clear Boggy near Caney. From the USGS Duration Table Of Daily Mean Flow For Period of Record 1943-63 average flow and duration at base flow and high flow could be calculated. From this total yearly flow could be calculated at the USGS stations. The yearly flow at each SOMBS site was estimated by the area fraction of the SOMBS site watershed to USGS gauging station watershed and weighted according to the USGS average runoff estimate for each area. From the average annual estimated volume and measured concentrations at baseflow and high flow, the annual loading, normalized to the size of each watershed, could be calculated . It must be assumed, for simple calculation purposes, that concentrations in the stream are the result of loading directly from the land and that each parameter is conservative once in the stream- it is not altered or taken up. This conservative behavior method does not account for seasonal and annual flow variations which affect concentrations-, evaporation, transpiration, water usage, etc.(Linsley, R. K., M. A. Kohler, and J. L. H. Paulhus. *Hydrology for Engineers-Second Edition.* McGraw-Hill, Inc., 1975.)

Table 3.14 shows the average flow estimate and the estimated annual loading for each watershed. The relative loading from each watershed coincides with the stream water quality based on concentration alone; possible sources of loading to the stream are discussed for watersheds with poor water quality in earlier sections. Some SOMBS site watersheds have negative loadings; these are sites where there was an upstream and downstream site where concentrations decreased between the two sites. This demonstrates that the estimation of flow for all sites may not be accurate or that the assumption that all water quality parameters are conservative does not hold true. We know that elements are not conservative in the stream are not conservative, especially the

TABLE 3.14: Annual Loading Estimate By SOMBS Site Watershed

Subwatershed	Site Description	ACRES	EST Runoff	Ave. Base Flow Est.	Ave. High Flow Est.	Annual Loading (kg/hectare/yr) TSS	NOx	TKN	TOT. P	HARD.	CL	SO4
Big Sandy Cr.	Big Sandy Creek nr Tish.	15933	6	4	58	16.32	0.12	1.13	0.13	296.66	25.86	60.14
Blue River	Blue River at Diamond Spr. Br	41790	6	32	216	20.52	-0.08	0.40	0.00	331.12	25.33	58.78
	Blue River at Milburn	32172	7	71	478	100.69	0.81	1.90	0.13	1078.79	-2.15	-23.38
	Blue River nr Pittstown	35711	6	13	86	16.63	0.95	0.29	0.06	430.01	10.25	19.79
	Little Blue Cr nr Connerville	12019	6	4	29	12.23	0.59	0.29	0.02	411.56	7.48	8.70
	Mineral Bayou at Armstrong	24799	9	9	136	57.88	0.38	0.91	0.10	420.81	47.72	84.70
	Sulphur Creek nr Bennington	15933	9	6	87	46.81	0.28	0.75	0.06	463.64	84.74	66.73
Clear Boggy	Bois D Arc Creek nr Pittstown	8905	6	2	40	44.17	0.84	0.96	0.25	345.61	17.23	29.62
	Caney Creek nr Bentley	19046	12	7	164	93.79	0.27	1.65	0.13	421.05	87.80	123.72
	Caney Creek nr Caney	28505	9	8	184	40.03	0.16	1.23	0.09	462.08	98.40	86.60
	Clear Boggy Cr nr Union Valley	14421	6	3	62	26.94	0.15	0.55	0.06	503.56	25.47	81.81
	Coal Creek nr Tupelo	11851	7	2	55	19.86	0.10	0.66	0.05	547.29	55.49	44.45
	Delaware Creek nr Bromide	18106	7	4	91	39.29	0.12	0.71	0.09	563.58	181.98	39.67
	Delaware Creek nr Olney	38231	7	12	293	65.44	0.10	0.86	0.13	594.60	113.93	81.73
	Goose Creek nr Tupelo	14576	7	3	68	44.32	0.12	0.97	0.15	394.52	15.08	23.37
	Leader Cr Blw Owl Cr nr Tupelo	59245	7	12	287	79.97	0.16	1.40	0.13	187.45	44.48	43.02
	Mill Creek at Harden City	7571	7	1	35	19.86	1.00	0.47	0.02	526.93	34.05	65.65
	Salt Creek nr Boggy Depot	14915	8	4	85	51.22	0.20	0.96	0.05	441.33	291.01	110.42
	Sandy Creek at Boggy Depot	15834	8	4	91	27.60	0.16	0.70	0.09	242.12	39.58	42.14
	Sandy Creek nr Wapanucka	7670	7	2	38	9.17	0.15	0.98	0.05	183.92	106.34	18.97
	Sheep Creek nr Harden City	11871	7	2	55	24.05	0.15	0.68	0.05	432.08	39.72	21.83
Island Bayou	Island Bayou near Albany	96408	9	24	557	206.38	0.47	2.20	0.25	565.72	115.76	261.12
Mill Cr.	Mill Creek near Mill Creek	29514	6	7	71	22.89	0.17	0.57	0.05	302.55	9.22	10.56
	Mill Creek Southwest of Ravia	30658	6	15	146	31.10	0.12	0.36	0.04	194.19	8.63	14.94
Muddy Boggy	North Boggy Cr nr Wardville	26554	11	6	150	74.13	0.14	2.03	0.25	274.00	144.00	59.98
	Big Sandy Creek nr Citra	22625	7	3	80	34.86	0.19	0.69	0.04	225.62	32.71	53.93
	Caney Boggy Creek nr non	22545	8	3	92	50.33	0.12	1.12	0.09	129.46	22.15	43.72
	Caney Boggy Creek nr Parker	22325	8	7	182	84.66	0.31	1.41	0.14	211.79	37.97	60.92
	Caney Creek at Coalgate	21893	8	3	89	42.86	0.17	4.70	0.54	221.15	44.64	78.84
	Chickasaw Creek nr Stringtown	22644	11	5	126	37.77	0.34	0.66	0.07	136.93	27.25	61.86
	McGee Creek at Redden	35444	13	9	234	49.74	0.17	1.24	0.10	137.76	31.33	41.81
	Muddy Boggy Creek nr Steedman	30087	5	3	76	27.78	0.07	0.46	0.05	388.72	302.07	71.56
	Panther Creek nr Gerty	10783	7	1	38	13.65	0.46	0.54	0.03	114.61	23.44	46.97
	Sincere Creek nr Steedman	17405	5	2	46	41.53	0.08	0.83	0.06	295.74	87.31	59.89
	Sugar Creek nr Soper	6800	13	2	45	51.34	0.19	0.95	0.05	462.61	50.22	40.18
Pennington Cr.	Pennington Cr at Reagan	33902	6	8	123	19.26	0.46	0.39	0.03	490.86	11.50	10.85
	Spring Creek nr Connerville	5041	6	1	18	7.75	0.12	0.58	0.03	545.19	8.02	8.06
Whitegrass Cr.	Whitegrass Cr nr Bennington	9083	13	2	60	47.99	0.19	0.84	0.07	507.25	72.27	86.98
	Whitegrass Cr nr New Oberlin	17610	13	7	177	182.86	0.20	1.60	0.15	247.63	87.02	40.65
	Average					48.29	0.28	1.02	0.10	377.73	62.67	53.83
	Maximum Average Value					206.38	1.00	4.70	0.54	1078.79	302.07	261.12
	First Quartile (25th Percentile)					21.70	0.12	0.57	0.05	233.87	22.79	26.50
	Median (50th Percentile)					40.03	0.17	0.84	0.08	394.52	39.58	46.97
	Third Quartile (75th Percentile)					51.28	0.33	1.18	0.13	477.26	87.16	66.13
	Minimum Average Value					7.75	-0.08	0.29	0.00	114.61	-2.15	-23.38

This table shows the estimated annual loading for each of the SOMBS site watersheds. The watershed areas given are for the watershed up to an upstream watershed in the cases where there were upstream and down stream sites. Some loadings are negative where there was an upstream and down stream site; this resulted from the fact that all or more of the loading of a certain parameter at the down stream site could be accounted for at the upstream site. (See section 3.8) PARAMETER UNITS: TSS (MG/SQ.M/YR); NOx=NO2 + NO3 (MG/SQ.M/YR AS N); TKN (MG/SQ.M/YR AS N); TOT. P (MG/SQ.M/YR AS P); HARD. (MG/SQ.M/YR AS CAO3); CSQ.M/YR (MG/SQ.M/YR); SO4 (MG/SQ.M/YR)

nutrients, thus to more accurately determine loading intensive mathematical modeling- beyond the scope of this study- would be required. However, although inaccurate, these estimated loadings provide a means for comparison of watersheds.

3.9. Estimated Level Of Impact On Stream Water Quality

Table 3.15 shows the estimated level of impact for all 39 SOMBS sampling sites. The "overall weighted percent rank" was calculated using a weight factor, based on estimated level of importance, for each of the measured parameters to determine an overall stream rank. These weights were applied to the percent rank for each parameter (Table 3.3), summed, and ranked to produce an overall stream rank. Parameters were weighted as follows:

Parameter	Weight Factor
turbidity	2
dissolved oxygen	10
conductivity	1
pH	5
TSS	7
Nitrate/Nitrite	6
TKN	4
Total Phosphorus	8
Hardness	1
Chloride	1
Sulfate	2

The overall weighted percent rank was divided into levels of impact based on the following division:

Percent Rank	Level of Impact
< 10%	"unimpacted"
10% - 25%	"slightly unimpacted"
25% - 50%	"slightly impacted"
50% - 75%	"impacted"
75% - 90%	"very impacted"
> 90%	"highly impacted"

TABLE 3.15: Estimated Level Of Impact

Subwatershed	Site Description	Overall Weighted Percent Rank*	Level of Impact
Big Sandy Cr.	Big Sandy Creek nr Tish.	44%	impacted
Blue River	Blue River at Diamond Spr. Br	18%	slightly unimpacted
	Blue River at Milburn	15%	slightly unimpacted
	Blue River nr Fittstown	23%	slightly unimpacted
	Little Blue Cr nr Connerville	2%	unimpacted
	Mineral Bayou at Armstrong	81%	very impacted
	Sulphur Creek nr Bennington	52%	slightly impacted
Clear Boggy	Bois D Arc Creek nr Fittstown	94%	highly impacted
	Caney Creek nr Bentley	89%	very impacted
	Caney Creek nr Caney	65%	slightly impacted
	Clear Boggy Cr nr Union Valley	60%	slightly impacted
	Coal Creek nr Tupelo	36%	impacted
	Delaware Creek nr Bromide	42%	impacted
	Delaware Creek nr Olney	57%	slightly impacted
	Goose Creek nr Tupelo	78%	very impacted
	Leader Cr Blw Owl Cr nr Tupelo	73%	slightly impacted
	Mill Creek at Harden City	21%	slightly unimpacted
	Salt Creek nr Boggy Depot	68%	slightly impacted
	Sandy Creek at Boggy Depot	26%	impacted
	Sandy Creek nr Wapanucka	10%	unimpacted
	Sheep Creek nr Harden City	39%	impacted
Island Bayou	Island Bayou near Albany	100%	highly impacted
Mill Cr.	Mill Creek near Mill Creek	50%	impacted
	Mill Creek southwest of Ravia	63%	slightly impacted
Muddy Boggy	North Boggy Cr nr Wardville	92%	highly impacted
	Big Sandy Creek nr Citra	47%	impacted
	Caney Boggy Creek nr non	71%	slightly impacted
	Caney Boggy Creek nr Parker	84%	very impacted
	Caney Creek at Coalgate	86%	very impacted
	Chickasaw Creek nr Stringtown	31%	impacted
	McGee Creek at Redden	34%	impacted
	Muddy Boggy Creek nr Steedman	55%	slightly impacted
	Panther Creek nr Gerty	13%	slightly unimpacted
	Sincere Creek nr Steedman	97%	highly impacted
	Sugar Creek nr Soper	7%	unimpacted
Pennington Cr.	Pennington Cr at Reagan	5%	unimpacted
	Spring Creek nr Connerville	0%	unimpacted
Whitegrass Cr.	Whitegrass Cr nr Bennington	28%	impacted
	Whitegrass Cr nr New Oberlin	76%	very impacted

This table shows the overall weighted percentage for each of 39 sites.

*Overall weighted percent calculation and level of impact estimation are described in Section 3.9

Based on the overall percent ranking the five most impacted streams are, in order: Island Bayou near Albany, Bois D' Arc Creek near Fittstown, Sincere Creek near Steedman, North Boggy Creek near Wardville, and Caney Creek near Bentley. The least impacted streams are, in order: Spring Creek near Connerville, Little Blue Creek near Connerville,

Sandy Creek near Wapanucka, Sugar Creek near Soper, and Pennington Creek at Reagan.

The streams with the least and most estimated impact in the two dominant SCS Major Land Resource Areas (Table 2.2) covering the SOMBS area respectively are Spring Creek near Connerville and Island Bayou near Albany for the Grand Prairie MLRA and Panther Creek near Gerty and Bois D' Arc Creek near Fittstown for the West Arkansas Valley and Ridges MLRA. Too few SOMBS stream sites were covered by both the Western Coastal Plain MLRA and Ouachita Mountains MLRA to determine a usable most and least impacted stream.

At almost all streams where there was an upstream/downstream site the estimated level of impact increased. Estimated impact increased slightly between SOMBS sites in Delaware Creek, Mill Creek, and Caney Boggy Creek. There was a larger increase between sites on Whitegrass Creek. In all of these creeks there is no obvious source for the increased impact between the upstream watershed and the downstream watershed. As described earlier, the SCS land use inventory does not show the extent to which conservation practices are used in each watershed which could be an important factor in controlling the impact of different land uses on water quality. Estimated impact was found to decrease moving downstream in the Blue River.

3.10. Land Use Versus Water Quality Impact

An attempt was made to determine the degree of correlation between land use (Table 3.1 1) and the estimated level of impact to water quality (Table 3.1 5). The results showed absolutely no correlation between the two for the SOMBS watersheds. The SCS land use inventory shows the relative level of land use in a watershed. The type of land use can be used to estimate the relative potential to contribute to the degradation of water quality. The land use survey collected by the Oklahoma Conservation Commission as part of this study provides an assessment of selected potential point and non-point sources in the watershed. Many factors which affect water quality could not be assessed without detailed models- for example, the extent to which land use practices to control non-point source pollution are used in the watersheds. Therefore, the qualitative affect of various non-point sources on water quality both for selected measured parameters and for estimated stream impact as a whole could not be determined.

4. Data Quality Assurance/ Quality Control

All QA data collected during the study is contained in the report Summary of Quality Assurance Results for Water Quality Sampling Conducted by The Oklahoma Conservation Commission for

the Years 1991. 1992, and 1993. This report is available from the Oklahoma Conservation Commission, Water Quality.

Eleven sets of samples were analyzed to determine the quality of the data. QA analysis was performed on chloride, hardness, nitrate, sulfate, Kjeldahl nitrogen, and total phosphorous. Duplicate samples were analyzed to determine precision of the data (Table 4.1). Standard Methods suggest that percent difference not exceed 25% (Clesceri, Lenore S., A. E. Greenberg, R. R. Trussell, eds. 1 989. Standard Methods for the Examination of Water and Wastewater. American Public Health Association, Washington, D.C., p. 1-8.) The average percent differences of all the parameters complied with this suggested criteria. However, the percent differences of three total phosphorous QA samples, one total Kjeldahl nitrogen QA sample, and one nitrate QA sample exceeded the suggested criteria. These generally occurred in samples with low concentrations (at or below the method detection limit). Overall, the precision of the data was sufficient to meet the data quality objectives.

TABLE 4.1 Average percent differences and recoveries calculated from QA samples. Coefficients of variation for each parameter are in parentheses.

Parameter	Average % Difference	Average % Recovery
Total Phosphorous	25 (107)	101 (11)
Total Kjeldahl Nitrogen	19 (172)	100 (23)
Sulfate	6 (98)	121 (30)
Nitrate-nitrogen	7 (166)	97 (6)
Hardness	1 (120)	97 (4)
Chloride	2 (148)	140 (20)

Spiked samples were analyzed to determine the percent recoveries and accuracy of the data. Percent recoveries were determined by dividing the observed by the expected concentrations of spiked samples. Standard Methods suggests a percent recovery between 80-120%. Average percent recoveries of chloride and sulfate did not comply with this suggested criterion. All chloride QA samples, three sulfate QA samples, and one total Kjeldahl nitrogen QA sample did not comply with the suggested range of acceptable recoveries. The cause of the high percent recoveries of chloride was investigated. It was found that the hardness and sulfate spike contained chloride. The hardness spike, which

should have been 100% calcium carbonate, was made up of 50% calcium carbonate and 50% calcium chloride, thus providing approximately 8650 mg/l chloride. In addition, the sulfate spike contained 900 mg/l chloride. The combination of these two sources of chloride resulted in the high observed percent recoveries. Overall, the accuracy of the data was sufficient to meet the data quality objectives.

No samples were rejected. In some cases, certain parameters of a QA sample exceeded the recommended percent differences or recoveries; however, as a whole the QA sample was valid. Thus, all samples were considered valid. A total of seven base flow samples and four high flow samples were collected during the study at each site. However, the workplan stated that eight base flow samples were to be collected. Therefore, the data is 88 percent complete. This is within the acceptable limit of data completeness (75%) set forth in the QAPP.

5. Conclusions

Overall, the project objectives were successfully completed. The data gathered during this project provides important baseline data for the SOMBS area. From the data gathered, bioassessment sites have been selected for water quality and habitat study.

Data was gathered and entered into a Geographic Information System for analysis to show the capabilities of GIS for future projects.

The data shows that streams in the SOMBS project area are highly variable in their water quality. This variability among the thirty-nine sites is likely due to the size of the project area which covered a wide range of geologies and land uses. Both geology and, to a lesser extent, land use are generally similar within SCS defined Major Land Resource Areas. Other factors which affected water quality in the area were the extent to which the stream is fed by ground water inputs, or runoff, and direct wastewater inputs.

Many streams in the area are of poor water quality due to problems of dissolved oxygen, suspended solids, and turbidity. With a third of the area streams violating the dissolved oxygen standard on at least one sampling date, the stream biota may have already been adversely affected in many areas. Problems due to turbidity and total suspended solids are highly variable among areas of similar geology, which suggests that improper land management may be a major factor. The Blue River, which has historically been of superior water quality, had a disproportionate increase in suspended solids in the head waters of the river during high flow events compared to other area streams. This could over time negatively alter habitat down stream impacting aquatic life including the important sport fish population of this stream. A habitat assessment on selective streams is needed to monitor habitat degradation.

Some streams with sediment and dissolved oxygen problems also contain high levels of nutrients, most importantly total phosphorus. These streams were found to have the poorest water quality in the area. The worst of the thirty-nine sites sampled were: Island Bayou near Albany, Sincere Creek near Steedman, Bois D'Arc Creek near Fittstown, North Boggy near Wardville, and Caney Creek near Bentley.

The best streams in the area were: Spring Creek near Connerville and Pennington Creek at Reagan- both in the Pennington Creek subwatershed; Sandy Creek near Wapanucka; Sugar Creek near Soper; and Little Blue Creek near Connerville.