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Pre-Project Water Quality of Watershed Streams in the Demonstration Erosion Control (DEC) Project in the Yazoo Basin of Mississippi: 1985-1987

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Submitted to the DEC Task Force

by

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Pre-Project Water Quality of Watershed Streams in the Demonstration Erosion Control (DEC) Project in the Yazoo Basin of Mississippi:1985-1987[1] [2]

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ABSTRACT

Two bluffline hill land streams and selected tributaries were sampled weekly over a two year period to establish physical, biological and chemical water quality cycles. This research was part of pre-construction documentation and evaluation of a watershed scale comprehensive land treatment and channel stability program designed to demonstrate the effectiveness of upland conservation practices and stream management modifications (Demonstration Erosion Control [DEC] Project in the Yazoo Basin). These streams, which have serious land and channel erosion problems, provided an opportunity (i) to document current prominent limnological and water quality cycles over time in mixed cover agrarian watershed streams and (ii) to acquire the pre-project information necessary to evaluate the effectiveness of watershed conservation and stabilization measures. Significant physical and chemical differences for pH, dissolved oxygen, dissolved solids and conductivity, and phosphorus and nitrogen were noted between creeks and between sites within each creek. In spite of differences in land use, temperature and suspended solids were not significantly different in the two creeks. Otoucalofa Creek site #1 was significantly higher than all other sites in phosphorus and nitrogen because it contained drainage from Water Valley, Mississippi and the town's sewage lagoon effluent. Resulting nutrient stimulation of phytoplankton attracted large numbers of forage fish in the reach of creek downstream of Water Valley, and these fish were, in turn, heavily

INTRODUCTION

Instream suspended sediment and bedload materials are, by volume, the largest pollutants in the U. S. (Fowler and Heady, 1981). Water erosion removes 1.5 to 2 billion tons of U.S. topsoil each year. The Mississippi River alone carries 331 million tons of topsoil to the Gulf of Mexico annually (Brown, 1984). Sediments from agricultural lands are major contributors and create concern for several reasons: (i) they indicate the loss of valuable topsoil necessary to agricultural productivity; (ii) they degrade downstream water resources and carry nutrients and chemical pollutants which adversely affect water quality and aquatic life; and (iii) in many cases, they deposit and accumulate in streams and lakes, creating habitat degradation and contamination, navigational difficulties, and shortening productive reservoir life. Watersheds with channel instability have additional difficulties including undercutting of stream banks, headcuts, clogging from vegetation associated with bank failure, and loss of adjoining land and riparian habitat.

In response to critical erosion problems on land and in stream channels of hill lands and piedmont regions across the U.S., Congress, in 1984, directed the U.S. Army Corps of Engineers and the USDA Soil Conservation Service to establish six demonstration watersheds in a region of continuing erosion where a systematic watershed soil conservation, channel stability, and flood control program could be developed and tested.

STUDY AREA AND METHODOLOGY

Watershed Descriptions and Sampling Sites

The loess hills of northern Mississippi were chosen for the Demonstration Erosion Control project because they have a history of large scale erosional sequences with massive gully formation in the uplands and large soil losses (as much as 200+ tons/ac/yr) from agricultural lands. Since streams have little or no bed controls and the hill land region ends in an abrupt bluffline at the Mississippi River alluvial delta, channels become deeply incised, cutting through soil and subsoil into underlying sands and gravels. These unstable channels are prone to meander, causing bank caving and loss of adjoining land.

Six watersheds in the Yazoo River drainage were chosen for the demonstration project (Fig. 1). Two of the streams empty into U.S. Army Corps of Engineers flood control reservoirs, and others enter rivers draining the loess hills. The watersheds vary in size but are all of mixed cover and land use. Table 1 lists watershed areas and cover composition.

After an initial exploratory period at the beginning of the study, seven sites were selected for weekly sampling on Otoucalofa Creek (Fig. 2). Two of these sites sampled rural tributaries and a third monitored Town Creek, a tributary draining the municipality of Water Valley, Mississippi. Eight sites were selected on Long Creek and its tributaries (Fig. 3).

In addition to weekly sampling, storm flows were sampled seasonally on Otoucalofa Creek.

Otoucalofa Creek is a third order stream that flows 37 km east to west in Calhoun, Lafayette, and Yalobusha counties before flowing into the Yocona River within the upper reaches of Enid Reservoir. Otoucalofa Creek varies in channel morphology from shallow iron stone or clay sill riffle-pool sequences in its headwaters to an open channel with a bottom composed of moving sand waves and seasonal silt deposits at its confluence with the Yocona River. Several channel reaches (approximately 64 percent of the stream) have been subjected to some degree of channelization during the past 10-20 years. As indicated in Table 1, most of the watershed is in pasture or some form of forest succession.

Long Creek in Panola County, Mississippi, also a third order stream, flows 29 km east to west and cuts through the loess hills bluffline where it empties into the Yocona River at the edge of the Mississippi River alluvial delta. The lower portion of the main stem of Long Creek has also been previously channelized.

Both creeks have sufficient gradient so that there are no stagnant pools although riffle-pool sequences are common features. The creeks are bordered by some riparian vegetation for the majority of their lengths. In its lowest reach Long Creek becomes wider and, thus, shallower than Otoucalofa Creek. It also has almost no shading vegetation in this

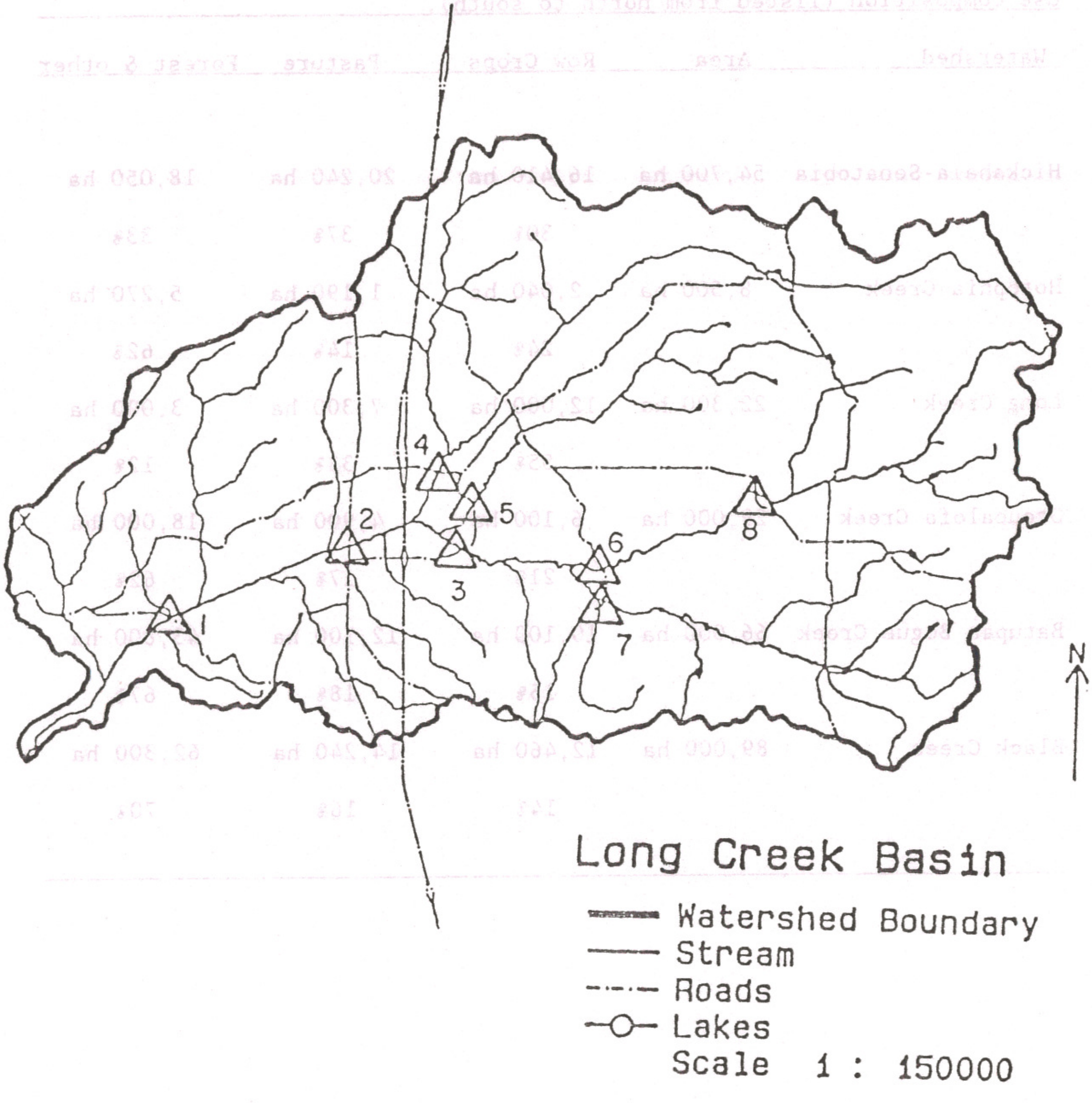


Figure 3. Map of Long Creek, including weekly water quality sampling sites.

reach. Because both creeks transverse land forms with little or no channel bed controls, they are deeply incised into the landscape with 2 to 4 m banks that are near vertical in many reaches. Prominent bed features in Otoucalofa Creek include the iron indurated sandstone and clay sills in the upper reaches and sand bottom in lower portions. The prominent bed feature in Long Creek and its tributaries is unconsolidated gravel and sand.

Sample Collection and Analysis

Temperature, conductivity, dissolved oxygen, and pH were measured in situ by pre-calibrated electronic water quality meter. Total solids, suspended solids, and dissolved solids were analyzed by standard methods as were nutrients and coliforms (APHA, 1975; USEPA, 1974). Pesticide and heavy metal samples from storm flow were analyzed by the Soil-Plant Analysis Laboratory, Northeast Louisiana University, Monroe, Louisiana by standard gas chromatography and atomic absorption spectrophotometry procedures (USEPA, 1971).

Storm samples were collected seasonally at Otoucalofa Creek Site # 1 (Fig. 2) below Water Valley, Mississippi. Storms were sampled in the upper third of the water column. Analysis of several events revealed that samples taken at one hour intervals through the peak of a storm hydrograph supplied the needed sediment, nutrient, and pesticide information to assess storm water quality.

Analysis of variance and Duncan's multiple range tests (Steel and Torrie, 1980) were used to test for significant differences between years, creeks

RESULTS AND DISCUSSION

Physical parameters

Physical, chemical, and biological data were treated by creek, by site and by year grouping (i.e., consecutive 12 month periods). Means and ranges for physical parameters grouped by creek and by year are listed in Table 2. Means and ranges for each site for the two years of the study are listed for Otoucalofa Creek in Table 3 and for Long Creek in Table 4.

Temperature

All organisms have limits of temperature in which they may operate and survive. These limits result from both the internal thermal and chemical dynamics of an organism and the role that temperature plays on external environmental factors such as dissolved oxygen concentrations. Generally, if changes in temperature occur over a long period of time, acclimation is possible and only abrupt changes prove fatal. In southern streams vegetative canopy buffers extreme temperatures that result from solar radiation; thus, temperature follows a gradual annual cycle of change to which endemic aquatic organisms have become adapted. Temperature followed typical annual cycles of highs in summer months and lows in winter in both streams. No significant differences in mean annual temperature were observed for either Otoucalofa or Long Creeks, nor were Otoucalofa and Long Creeks different from one another.

Table 3. Means and ranges of physical parameters for Otoucalofa Creek by collection site over the two year observation period.

Site #	Parameter	Otoucalofa Creek		
		Lower Limit	Mean	Upper Limit
1	Temperature(°C)	1.8	17.8	28.3
2		5.5	18.2	27.3
3		0.5	17.3	28.0
4		0.5	17.3	27.7
5		0.4	17.2	29.0
6		2.8	16.4	28.2
7		1.3	16.6	27.0
1	Conductivity * (mhos/cm^1)	12.0	49.4	99.0
2		32.0	75.0	126.0
3		10.0	37.3	67.0
4		12.0	36.5	69.0
5		13.0	40.3	76.0
6		14.0	58.2	119.0
7		13.0	53.4	192.0
1	Dissolved Oxygen(mg/L)	6.0	8.8	16.0
2		0.4	8.8	14.4
3		5.7	8.8	15.6
4		6.2	8.9	16.0
5		6.0	9.0	16.0
6		6.1	8.8	13.4
7		3.7	8.5	16.8
1	pH	5.1	6.2	7.4
2		5.2	6.0	7.2
3		4.5	6.1	7.6
4		5.0	6.1	7.6
5		5.0	6.1	7.4
6		5.2	6.1	7.4
7		5.2	6.0	7.8
1	Total Solids(mg/L) *	50.	157.5	1479.
2		51.	79.8	238.
3		48.	145.0	1207.
4		50.	138.3	1281.
5		51.	124.3	1886.
6		55.	99.1	614.
7		56.	104.1	1131.
1	Dissolved Solids(mg/L)*	31.	53.7	112.
2		40.	66.2	88.
3		37.	49.4	77.
4		27.	47.8	82.
5		35.	49.9	83.
6		40.	64.7	92.
7		35.	61.4	113.
1	Suspended Solids(mg/L)*	0.	103.7	1424.
2		0.	13.6	165.
3		0.	95.7	1153.
4		0.	90.5	1231.
5		0.	74.5	1845.
6		0.	34.5	568.
7		0.	42.5	1082.

* Significant differences between sites within Otoucalofa Creek.

Analysis of site to site means revealed no differences in temperature on either creek over the two year sample period. Upper temperature ranges were between 3.4 and 2.4 °C greater in Long Creek than Otoucalofa Creek, but the extremes observed in either creek were not biologically limiting to southern stream flora or fauna. Solubility of dissolved oxygen at 31.6 °C is 7.3 mg/L which is well above the lower limit of 4 mg/L needed for maintaining life in warmwater streams.

Although temperature in southern streams is usually considered to be somewhat influenced by solar input, no creek to creek differences were observed. This is noteworthy since Otoucalofa Creek watershed is 62% forest land compared to 12% forest on Long Creek and, Otoucalofa Creek might be expected to have lower temperatures from shading of vegetative canopy. Mean temperature trends were evidently influenced more by the earth's ambient temperature and subsurface lateral exchange than by direct solar input.

Dissolved Oxygen

Because oxygen is an essential ingredient in metabolism of all organisms utilizing aerobic respiration, its concentration, distribution and dynamics in aquatic systems defines the behavior and distribution of most aquatic life. Factors influencing dissolved oxygen concentration and, thus, influencing aquatic organisms include altitude, temperature, salinity, and chemical and biological oxygen demand.

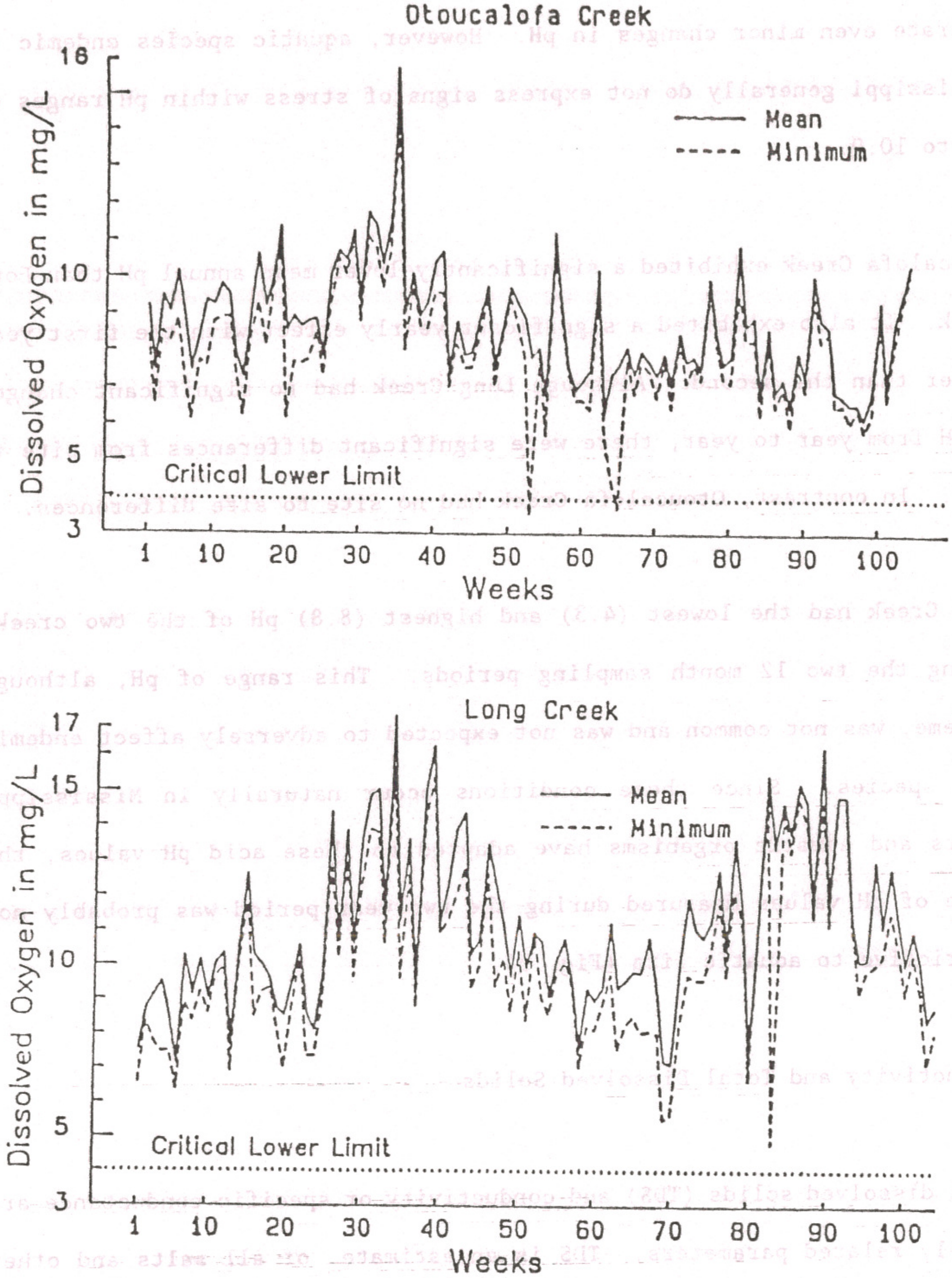


Figure 4. Weekly dissolved oxygen concentrations for Otoucalofa and Long Creeks.

the concentration of TDS the lower the resistance to electric current and, therefore, the higher the conductivity. Measurements of this resistance can be used as and index of TDS content (Cole, 1975). Since only a portion of TDS is composed of ionic materials, conductivity may or may not be closely correlated to TDS.

Long Creek had significantly greater annual mean TDS than Otoucalofa Creek, but neither creek had any year to year differences. Otoucalofa site 2 on Town Creek, a major tributary which drained Water Valley, Mississippi, had significantly greater mean total dissolved solids than other sites. Long Creek exhibited site to site differences in TDS, but these differences followed no discernible spacial pattern.

As might be expected because of TDS concentrations, Long Creek had significantly greater annual mean conductivities than Otoucalofa Creek. Both streams exhibited site to site differences which followed the same patterns as TDS.

Since freshwater fish constantly take up water because of the strong osmotic gradient in which they live, they must also expel vast quantities of water while retaining essential ions. When ambient concentrations of dissolved materials are drastically altered, fish die because they cannot maintain an osmotic balance. United States Environmental Protection Agency (1973) regulations state that total dissolved materials should not be changed to the point that characteristic populations of aquatic organisms are significantly altered. Mace (1953) and Rounsefell and Everhart (1953) established an upper tolerance concentration for TDS at 5,000 to 10,000 mg/L. However, the optimum concentration of TDS fish population health and diversity was reported to be between 169 and 400 mg/L (Hart et al. 1945). TDS never exceeded these optimal concentrations in either of the two streams (Fig. 6).

Total Solids and Suspended Solids

Total and suspended solids concentration and composition are largely determined by soil structure, drainage patterns, land use, rainfall and subsequent runoff, and channel erosion. Total solids and its major component, suspended solids, may adversely affect aquatic organisms in a number of ways. Mechanical abrasion can damage delicate organisms or tissues (eg. fish gills) of heartier organisms. As suspended solids settle, the blanketing effect of deposition can kill sessile organisms and may kill or damage fish eggs and larval fishes. The organic portion of total solids can also effect the chemical characteristics of water by contributing to oxygen depletion. Since the inorganic fraction of total and suspended solids often has large irregularly shaped surfaces that carry electrostatic charges, these particles act as carriers for toxic pollutants such as pesticides (USEPA, 1973).

Mean annual total solids were significantly greater in Long Creek than in Otoucalofa Creek; however, no significant difference was found between the creeks for suspended solids. Neither creek demonstrated significantly greater concentrations for either total solids or suspended solids in period 1 versus period 2. No site to site differences were found in total or suspended solid concentrations for Long or Otoucalofa Creeks.

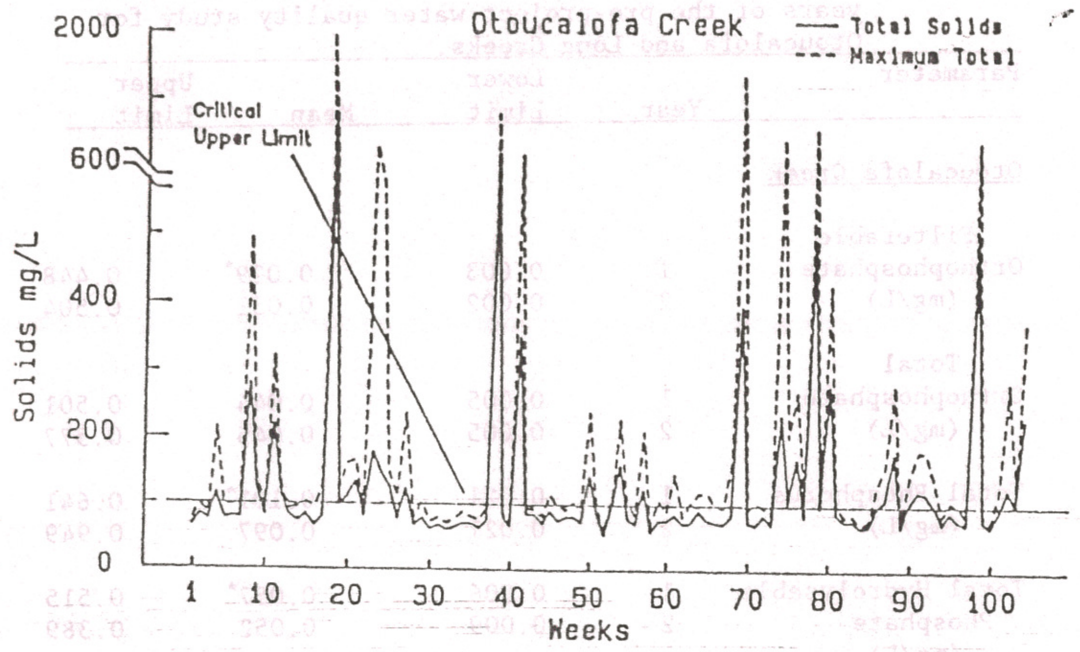
Standards of maximum total and suspended solids concentration for warm water fish production have not been established; however, 80 to 100 mg/L is generally accepted as the maximum concentration for optimal growth. Although mean concentrations of total solids slightly exceeded this 80 to 100 mg/L limit, no visible signs of stress were noted in captured fish. However, if concentrations as high as those experienced during storm events were sustained over longer periods, detrimental effects on fish and other aquatic fauna would be expected (Fig. 7).

Chemical parameters

Means and ranges for chemical parameters grouped by creek and by year are listed in Table 5. Means and ranges for each site for the two years of the study are listed for Otoucalofa Creek in Table 6 and for Long Creek in Table 7.

Phosphorus

Because it is a component of ATP (adenosine triphosphate) as well as other complex organic molecules such as nucleotides, phosphorus is necessary to all life. Although it is not rare, phosphorus is much scarcer than other organic building blocks such as oxygen, carbon, hydrogen and nitrogen and is rapidly taken up by aquatic organisms. It is usually a limiting nutrient for primary productivity and, consequently, fish production



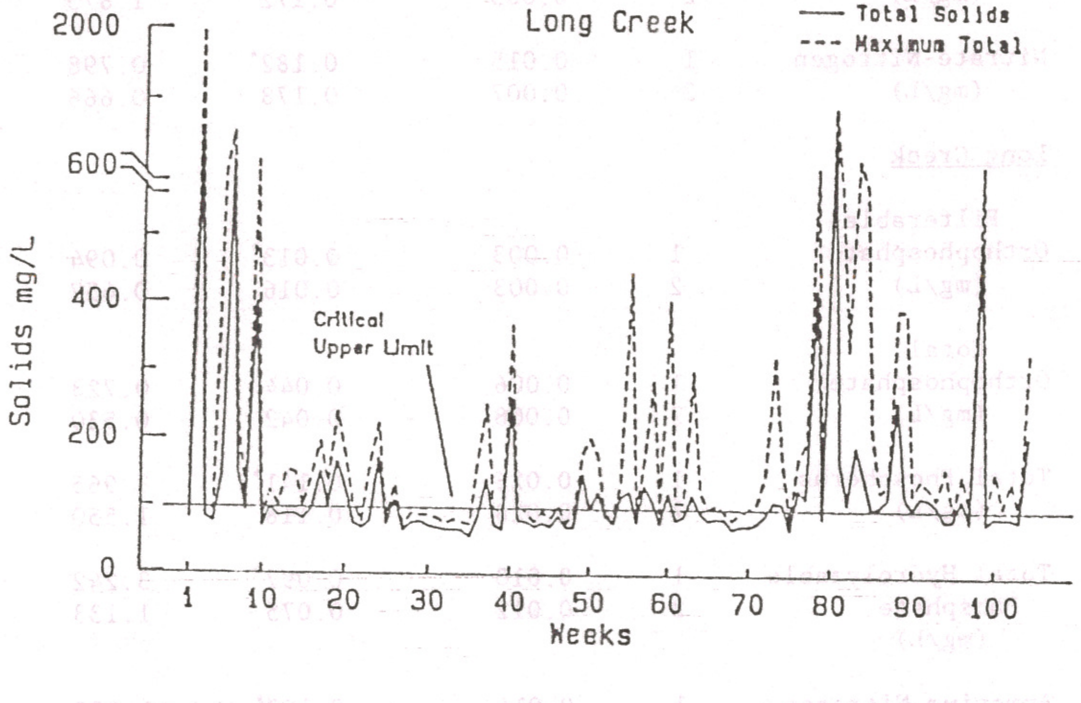


Figure 7. Weekly and critical total solids concentrations for Otoucalofa and Long Creeks.

Table 6. Means and ranges of chemical parameters for Otoucalofa Creek by collection site over the two year observation period.

Parameter	Site	Lower Limit	Mean	Upper Limit
Filterable Orthophosphate (mg/L)	1	0.034	0.194*	0.577
	2	0.008	0.025	0.219
	3	0.008	0.024	0.232
	4	0.006	0.020	0.152
	5	0.006	0.015	0.085
	6	0.006	0.017	0.222
	7	0.006	0.013	0.144
Total Orthophosphate (mg/L)	1	0.006	0.147*	0.504
	2	0.003	0.018	0.195
	3	0.002	0.008	0.044
	4	0.002	0.007	0.018
	5	0.002	0.006	0.012
	6	0.003	0.010	0.147
	7	0.003	0.007	0.035
Total Phosphorus (mg/L)	1	0.079	0.282*	0.949
	2	0.021	0.061	0.433
	3	0.029	0.084	0.580
	4	0.028	0.059	0.620
	5	0.026	0.069	0.600
	6	0.021	0.060	0.463
	7	0.024	0.059	0.565
Total Hydrolyzable Phosphate (mg/L)	1	0.024	0.087*	0.543
	2	0.006	0.037	0.214
	3	0.019	0.060	0.348
	4	0.014	0.059	0.468
	5	0.009	0.054	0.515
	6	0.013	0.044	0.241
	7	0.013	0.046	0.421
Ammonium-Nitrogen (mg/L)	1	0.071	0.674*	2.646
	2	0.004	0.131	0.942
	3	0.014	0.101	0.586
	4	0.012	0.107	0.600
	5	0.006	0.114	0.594
	6	0.002	0.130	1.875
	7	0.006	0.121	1.110
Nitrate-Nitrogen (mg/L)	1	0.007	0.223*	0.644
	2	0.140	0.582	0.798
	3	0.031	0.111	0.323
	4	0.025	0.095	0.373
	5	0.019	0.072	0.638
	6	0.009	0.047	0.183
	7	0.012	0.075	0.472

* Significant differences between sites between Otoucalofa Creek.

Dorosoma cepedianum). These fish were heavily exploited by largemouth bass (Micropterus salmoides) and channel catfish (Ictalurus punctatus), two important game fishes (Knight and Cooper, 1987C). As a result of this readily available food source, largemouth bass growth was estimated at a rate of over 0.45 kg/year. This growth rate is comparable to rates sought in carefully managed fertilized farm ponds (Davies, 1981, personal communication) and more than twice the 0.24 kg/year average for southeastern waters (Carlander, 1977).

Nitrogen - Because of its high solubility in water, nitrogen, although necessary for all life, is not usually limiting in freshwater. Nitrogen, generally measured in water as ammonium-nitrogen or nitrate-nitrogen, may enter an aquatic system via rainfall, air-water interface, runoff or as a waste product. Nitrate-nitrogen and ammonium-nitrogen are not usually found in concentrations toxic to aquatic organisms (Hunnan et al., 1981). However, they can contribute to excessive phytoplankton production which eventually leads to oxygen depletion.

Otoucalofa Creek had a significantly greater mean concentration of nitrate-nitrogen and ammonium-nitrogen than Long Creek (Table 6). Otoucalofa Creek's nitrogen output was relatively high and constant since the major source was the Water Valley sewage treatment facility. Ammonium-nitrogen was statistically higher during sampling year 1 on Otoucalofa Creek and nitrate-nitrogen was greater during sampling year 2 on Long Creek. No other yearly effects were noted.

between land use and coliform counts. While contributions from different watershed components are difficult to characterize, coliform sources and sinks also remain a problem in our quest for clean water.

Means of indicator bacteria densities by year period and by site for Otoucalofa (Table 8) and Long (Table 9) Creeks indicated that warm-blooded animal contamination is a major pollution problem in these small streams draining mixed cover watersheds. The concentration of life at Water Valley was a major source of contamination in Otoucalofa Creek. Long Creek exhibited a more consistent pattern of warm-blooded animal contamination.

Contamination levels in both streams exceeded contemporary water quality criteria for primary contact (swimming or bathing) at all sites during most of each year of the study. Criteria are generally given as 240 organisms per 100 ml for TC and 200 organisms per 100 ml for FC (Harms et al., 1975). Monitoring actual contamination sources is difficult in mixed cover watersheds since total coliform enumeration is general in nature and several streptococci are ubiquitous in soil and aquatic environments (Faust, 1982; Kibbey et al., 1978). The best data application for monitoring sources of contamination may be fecal coliform (FC):fecal streptococci (FS) ratios over time. FC/FS ratios of less than 1.0 generally indicate warmblooded animal pollution while ratios of 4.0 or more suggest domestic waste (Geldreich, 1976; Baxter-Potter and Gilliland, 1988). Mean FC/FS ratios were less than 1.0 for Otoucalofa Creek during the first year of the study although

Table 9. Mean bacteria densities by collection site for Long Creek for the two year sampling period.

Site#	Year	Minimum density	Mean density	Maximum density
Total Coliform				
1	1	0	538	5800
	2	0	601	2860
2	1	0	641	4400
	2	20	524	2640
3	1	0	1281	15200
	2	0	469	2480
4	1	0	1035	6800
	2	0	1009	7600
5	1	0	324	3295
	2	0	607	3220
6	1	0	435	3030
	2	0	1131	5370
7	1	0	626	5200
	2	0	698	4830
8	1	0	585	3200
	2	0	598	3370
Fecal Coliform				
1	1	0	987	13800
	2	0	562	1770
2	1	0	1794	1122
	2	0	661	2740
3	1	0	1122	6600
	2	0	661	2740
4	1	0	758	6400
	2	0	1264	8230
5	1	0	428	4320
	2	0	626	6090
6	1	10	869	10500
	2	0	961	6310
7	1	0	931	11000
	2	0	841	6800
8	1	0	563	3800
	2	0	645	4650
Fecal Streptococci				
1	1	0	3584	36000
	2	0	751	4920
2	1	0	3650	33640
	2	20	889	8060
3	1	0	4515	39640
	2	0	887	510
4	1	0	3898	37210
	2	20	1117	5370
5	1	0	2081	22090
	2	0	749	7760
6	1	0	2099	10700
	2	0	588	3130
7	1	5	4120	31360
	2	0	748	358
8	1	0	2163	11560
	2	20	881	4750

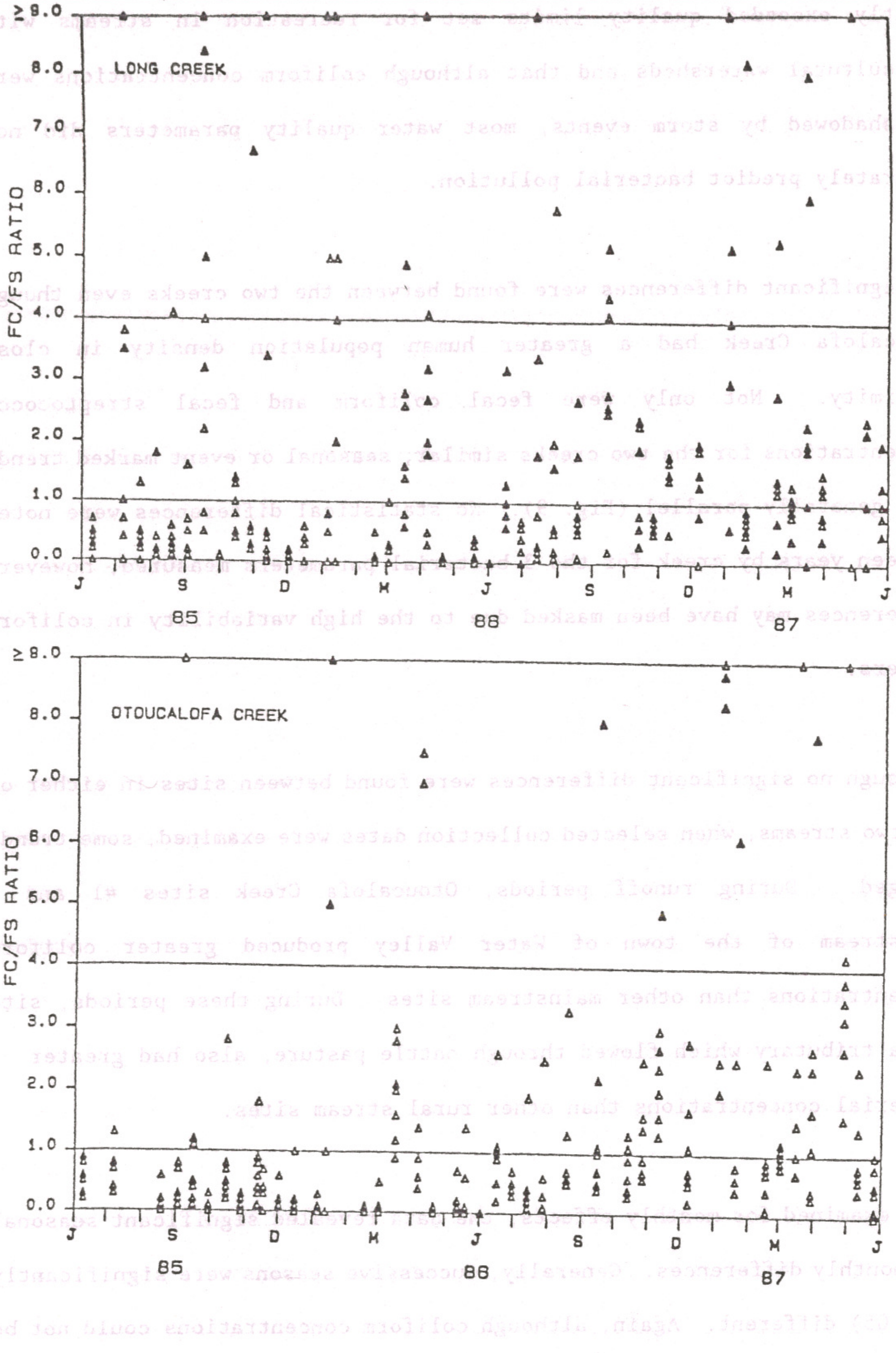


Figure 8. Fecal coliform - fecal streptococci ratios for Long and Otoucalofa Creeks.

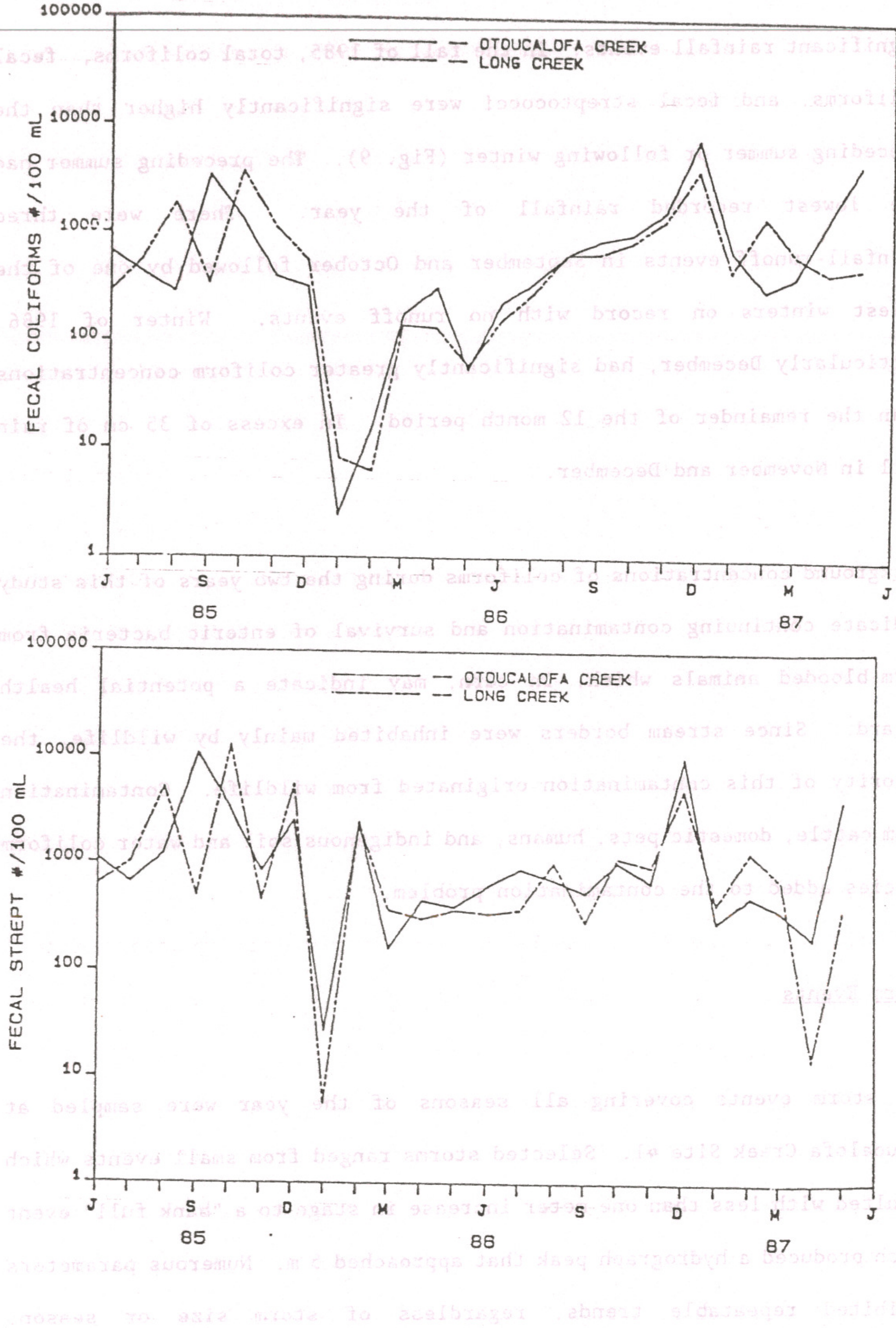


Figure 9. Monthly fecal coliform and fecal streptococci counts (#/100 mL) for Long and Otoucalofa Creeks.

percent from dilution. No significant changes were noted in dissolved oxygen or pH. Measurable concentrations of several residual pesticides were routinely encountered in samples taken on the rising portion of storm hydrographs. These pesticides, including DDT, DDD, DDE, heptachlor, lindane and dieldrin, which were used in farming practices before being banned in the 1970's, generally appeared in concentrations of less than 1.0 micrograms per kilogram (ppb) and never approached harmful levels. Arsenic and mercury, two metals used in herbicides and seed treatments, also appeared routinely in storm flows. Arsenic and mercury concentrations peaked between 5 and 15 micrograms per kilogram (ppb) in storm flows. The routine presence of residual pesticides and metals in storm events indicates that runoff from agricultural lands continues to make a measurable contribution to Otoucalofa Creek.

Storm event sampling highlighted the importance of ground cover in prevention of erosion. The greatest concentration of total solids (suspended plus dissolved solids), 3879 mg/L (ppm), was during a medium-sized storm with a maximum gauge height of 231 cm (90.9 in) on 4/23/85. During this period of year land preparation for planting exposed freshly tilled soil with no cover to prevent raindrop splatter and runoff. Total solids concentrations during this storm exceeded storms of twice the magnitude sampled during other seasons. Visual comparison indicated that the suspended sediment load carried by Otoucalofa Creek during storm events was only a small fraction of the total storm load carried by the creek. Typically, as water receded

SUMMARY

A study of two bluffline streams over a two year period established physical and chemical water quality cycles and compared the two streams, one of which passed through Water Valley, Mississippi. In spite of land use differences bordering the creeks, temperature and suspended solids were not significantly different in the creeks. Phosphorus and nitrogen concentrations at Otoucalofa Creek Site #1 were significantly higher than all other sites in either creek because it captured the nutrient rich drainage from Water Valley and also the town's sewage lagoon effluent. Biologically, the resulting nutrient stimulation of phytoplankton attracted large numbers of forage fish which were, in turn, heavily exploited by game fish. No physical or nutrient parameter measured during normal flow conditions was found detrimental to aquatic life.

Coliform indicators showed that contamination levels in both creeks exceeded clean water standards for primary contact. Although Otoucalofa Creek had a greater human population in close proximity, there were no significant differences in contamination levels between the two creeks. Statistical seasonal differences in coliforms were generated by the presence or absence of rainfall. Background concentrations indicated continuing contamination and survival of coliforms from warm-blooded animals.

Storm flows flushed measurable concentrations of residual pesticides as well as arsenic and mercury from agricultural lands. Suspended sediment concentrations from storm related runoff produced peak concentrations of

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