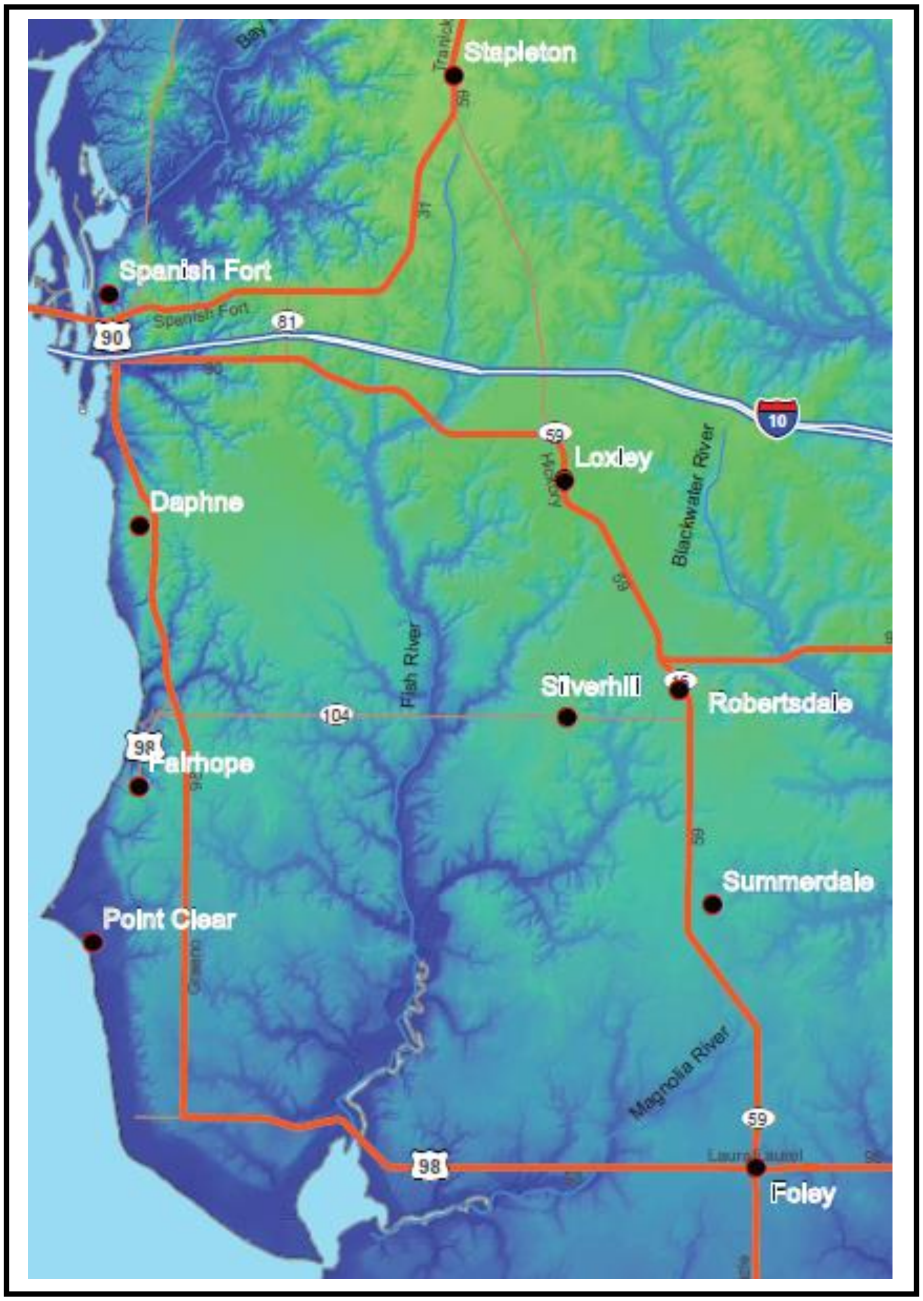
PRE-RESTORATION ANALYSIS OF DISCHARGE, SEDIMENT TRANSPORT RATES, WATER QUALITY, AND LAND-USE IMPACTS INTHE FISH RIVER WATERSHED, BALDWIN COUNTY, ALABAMA



Mobile Bay National Estuary Program

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By

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INTRODUCTION

Quality of life issues are of utmost importance to the citizens of Mobile and Baldwin Counties. These issues include sustainability of a coastal environment characterized by a moderate climate, diverse wildlife, and dominated by abundant marine and fresh-water resources. Alabama's coastal environment creates attractive places for population and economic growth, which threatens the quality and sustainability of the environment. When activities related to population and economic growth are combined with highly erodible soils and cyclonic storms that produce high intensity rainfall events, deleterious water-quality and biological habitat impacts can be severe. Previous investigations of sediment transport and general water quality have shown dramatic increases in sediment loading and loss of biological habitat in streams downstream from areas affected by rapid runoff and resulting erosion from particular types of land uses. Other areas are virtually unimpacted by land-use change and are characterized by natural landscapes dominated by forests and wetlands. Results of these investigations are valuable in quantifying impacts so that limited regulatory and remedial resources may be focused to remediate problem areas or to preserve relatively pristine watersheds.

The purpose of this investigation is to assess general hydrogeologic and water quality conditions and to estimate sediment transport rates for Fish River and its tributaries. These data will be used to quantify water quality impacts and to support development of a watershed management plan, designed to preserve, protect, and restore the Fish River watershed.

ACKNOWLEDGMENTS

Ms. Roberta Swann, Director; Ms. Amy Newbold, Deputy Director; and Mr. Tom Herder, Watershed Protection Coordinator, Mobile Bay National Estuary Program, provided administrative and coordination assistance for the project; Mr. Bruce Bradley, President, Polyengineering, Inc., provided administrative assistance; Mr. Emery Baya, Senior Vice President (retired), Mr. Michael Eubanks, and Mr. John Carlton, Senior Scientists, Thompson Engineering, provided coordination for the watershed management plan. Mr. Tony Darling, Riviera Utilities, provided bacterial analyses for the project.

PROJECT AREA

The Fish River watershed covers 98,112 acres (153.3 square miles (mi^2) (US Geological Survey (USGS), 2016) in western Baldwin County (fig. 1). The monitored

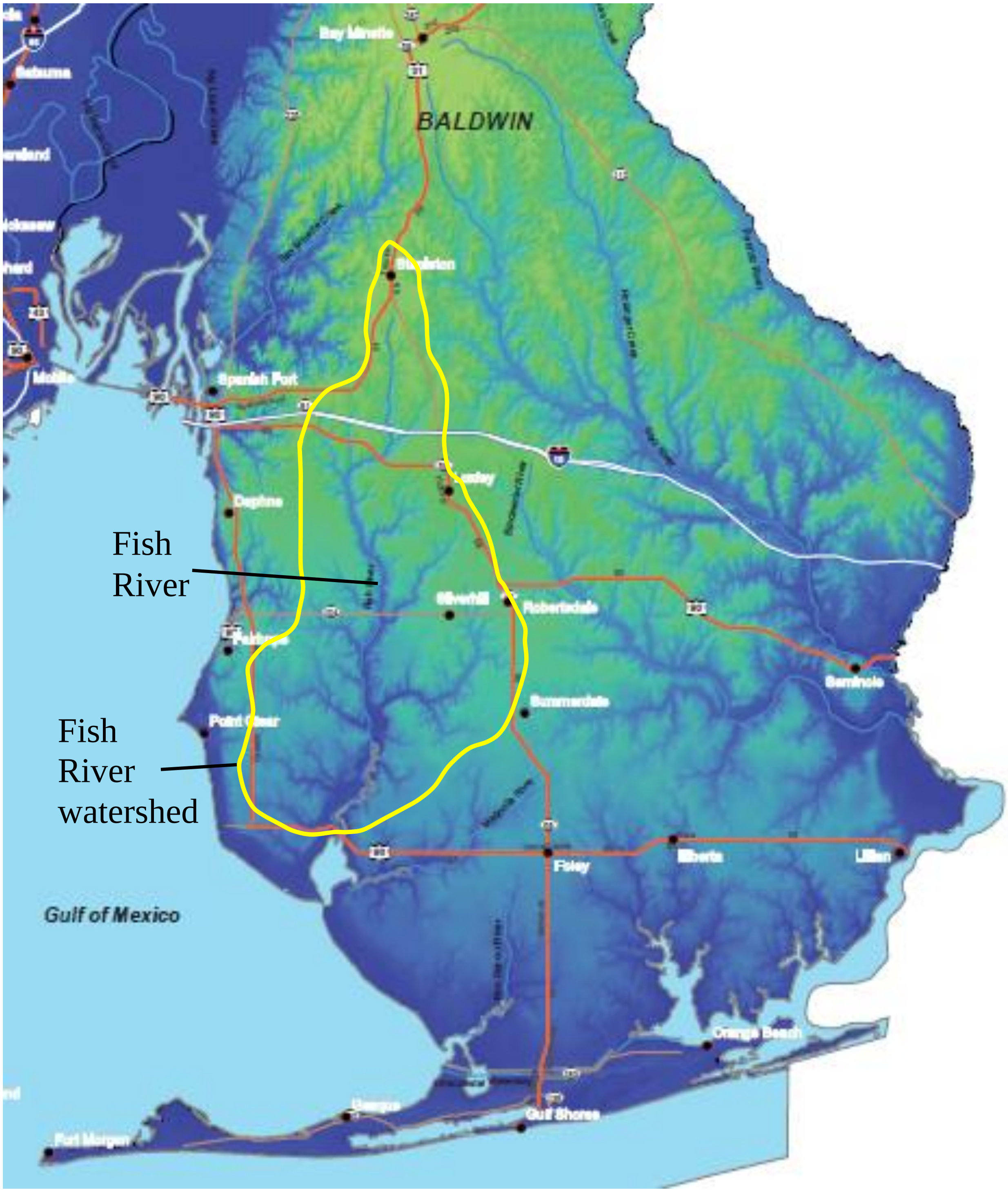


Figure 1.—The Fish River watershed in Baldwin County.

part of the watershed includes 77,440 acres (121 mi^2). The project area includes Fish River headwaters monitoring sites on 12 tributaries and five main stem sites (fig. 2). Fish River headwaters are in the Stapleton community, about six miles north of I-10. Fish

River flows southwestward from its headwaters about 23 miles to its discharge point into Weeks Bay in southwestern Baldwin County (fig. 2. Elevations in the project area vary from about 215 feet above mean sea level (ft MSL) at the headwaters to sea level at the mouth.

PROJECT MONITORING STRATEGY AND SITE CHARACTERISTICS

The strategy employed for the Fish River project was to select monitoring sites on the main stem and as many tributaries as possible, based on accessibility and reach length. Each stream reach was monitored over a wide range of measured discharge from base flow to high flow. Water samples were collected for measurement of specific conductance, pH, temperature, turbidity, salinity (where applicable), and dissolved oxygen. Laboratory analyses was performed for total suspended solids, nitrate, and total phosphorus. Bed sediment transport rates were measured and daily and annual loads were estimated for suspended and bed sediment, nitrate, and phosphorus.

Site FR1 is on the main stem of Fish River at I-10, about 6 miles downstream from the headwaters (latitude (lat) 30.65289, longitude (long) -87.79173). The watershed upstream from site FR1 covers 2,176 acres (2.1 mi^2) (USGS, 2016) (fig. 2).

Site FR2 is on Threemile Creek at I-10 (lat 30.65154, long -87.78061). The watershed upstream from site FR2 covers 2,176 acres (3.4 mi^2) (USGS, 2016) (fig. 2).

Site FR3 is on Bay Branch at US Highway 90 (lat 30.65158, long -87.78086). The watershed upstream from site FR3 covers 1,408 acres (2.2 mi^2) (USGS, 2016) (fig. 2).

Site FR4 is on Fish River at Baldwin County Road 64, (lat 30.60357, long -87.81701). The watershed upstream from site FR4 covers 19,712 acres (30.8 mi^2) (USGS, 2016) (fig. 2).

Site FR5 is on Fish River at Baldwin County Road 54, (lat 30.56729, long -87.79514). The watershed upstream from site FR4 covers 28,416 acres (44.4 mi^2) (USGS, 2016) (fig. 2).

Site FR6 is on Fish River at Alabama Highway 104, (lat 30.54556, long -87.79866). The watershed upstream from site FR4 covers 35,968 acres (56.2 mi^2) (USGS, 2016) (fig. 2).

Site FR7 is on Perone Branch at Alabama Highway 104, (lat 30.54556, long -

87.78823). The watershed upstream from site FR7 covers 5,824 acres (9.1 mi^2) (USGS, 2016) (fig. 2).

Site FR8 is on Pensacola Branch at Baldwin County Road 48, (lat 30.52364, long -87.81248). The watershed upstream from site FR8 covers 3,072 acres (4.8 mi^2) (USGS, 2016) (fig. 2).

Site FR9 is on Fish River at Baldwin County Road 48, (lat 30.54569, long -87.80917). The watershed upstream from site FR9 covers 3,072 acres (68.4 mi^2) (USGS, 2016) (fig. 2).

Site FR10 is on Polecat Creek at Baldwin County Road 55, (lat 30.49831, long -87.75089). The watershed upstream from site FR10 covers 10,176 acres (15.9 mi^2) (USGS, 2016) (fig. 2).

Site FR11 is on Polecat Creek at Baldwin County Road 9, (lat 30.49091, long -87.79677). The watershed upstream from site FR11 covers 18,496 acres (28.9 mi^2) (USGS, 2016) (fig. 2).

Site FR12 is on Cowpen Creek at Baldwin County Road 33, (lat 30.48300, long -87.81900). The watershed upstream from site FR12 covers 7,552 acres (11.8 mi^2) (USGS, 2016) (fig. 2).

Site FR13 is on Baker Branch at Baldwin County Road 55, (lat 30.47634, long -87.75081). The watershed upstream from site FR13 covers 2,624 acres (4.1 mi^2) (USGS, 2016) (fig. 2).

Site FR14 is on Fish River at Baldwin County Road 32, (lat 30.47460, long -87.80261). The watershed upstream from site FR14 covers 77,184 acres (120.6 mi^2) (USGS, 2016) (fig. 2).

Site FR15 is on Green Branch at Danne Road, (lat 30.44978, long -87.83556). The watershed upstream from site FR15 covers 2,048 acres (3.2 mi^2) (USGS, 2016) (fig. 2).

Site FR16 is on Waterhole Branch at Alabama Highway 181, (lat 30.44564, long -87.85239). The watershed upstream from site FR16 covers 3,136 acres (4.9 mi^2) (USGS, 2016) (fig. 2).

Site FR17 is on Turkey Creek at Alabama Highway 181, (lat 30.42196, long -87.84385). The watershed upstream from site FR17 covers 3,712 acres (5.8 mi^2) (USGS, 2016) (fig. 2).

Site FR18 is on Corn Branch at Baldwin County Road 64, (lat 30.61827, long -87.78522). The watershed upstream from site FR18 covers 1,600 acres (2.5 mi^2) (USGS, 2016) (fig. 2).

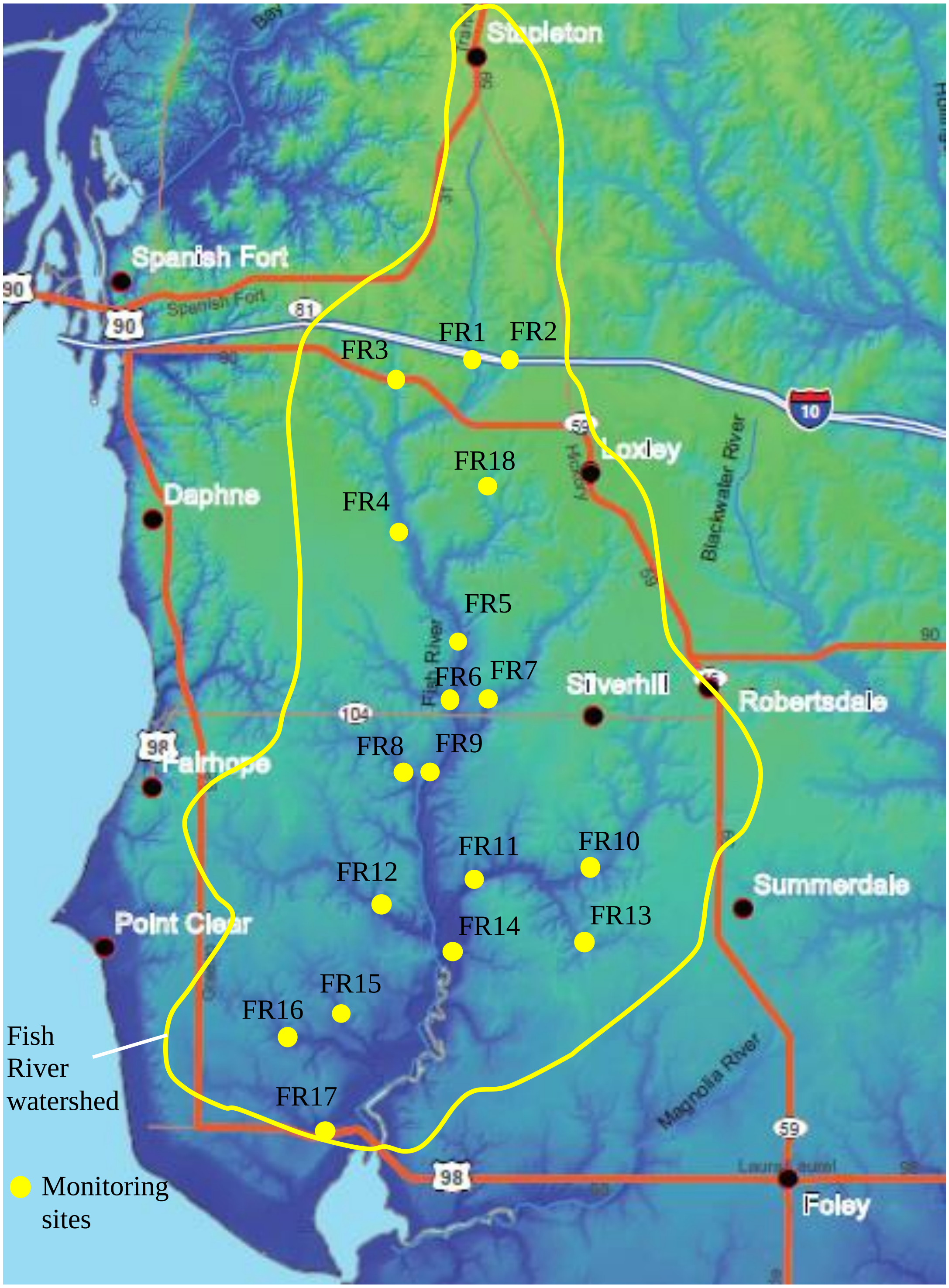


Figure 2.—Fish River watershed and monitoring sites.

LAND USE

Land use is directly correlated with water quality, hydrologic function, ecosystem health, biodiversity, and the integrity of streams and wetlands. Land-use classification for the project area was calculated from the USDA National Agricultural Statistics Service 2013 Alabama Cropland Data Layer (NASS CDL) raster dataset. The CDL is produced using satellite imagery from the Landsat 5 TM sensor, Landsat 7 ETM+ sensor, the Spanish DEIMOS-1 sensor, the British UK-DMC 2 sensor, and the Indian Remote Sensing RESOURCESAT-1 (IRS-P6) Advanced Wide Field Sensor (AWiFS) collected during recent growing seasons (USDA, 2013). Figure 3 shows land use, subdivided into 17 classified types defined as developed, forested, grassland, wetlands, barren areas, open water, and agriculture, subdivided into eight specific crops (fig. 3).

The dominant land use category in the Fish River watershed is forest, which covers about 50 percent of the watershed (fig. 3). Forest is primarily north of I-10 and in areas of lower elevation along stream channels south of I-10. Wetlands are also prominent in stream valleys and cover about 5 percent of the Fish River watershed. Wetlands are important because they provide water quality improvement and management services such as: flood abatement, storm water management, water purification, shoreline stabilization, groundwater recharge, and streamflow maintenance. Agriculture is the second largest land use and dominates headwaters and areas of higher elevation, covering about 30 percent of the watershed. Crops consist of peanuts, soybeans, corn, cotton, pecans, and pasture and hay (fig. 3). Developed land is dominated by residences and commercial development, primarily along roadways, and residential development on land previously used for agriculture. Developed land covers about 15 percent of the watershed (fig. 3). Land uses and their specific impacts are discussed in detail in the Conclusions and Sources of Water-Quality Impacts section of this report.

STREAM FLOW CONDITIONS

Stream flow characteristics are determined by a number of factors including climate, topography, hydrogeology, land use, and land cover. Numerous streams in Baldwin County exhibit flashy discharge due to relatively high topographic relief and land-use change. Stream channels in the northern part of the watershed, including the headwaters of Fish River are characterized by relatively high elevation (maximum 215 ft MSL), with topography that decreases in relief from north (upstream) to south

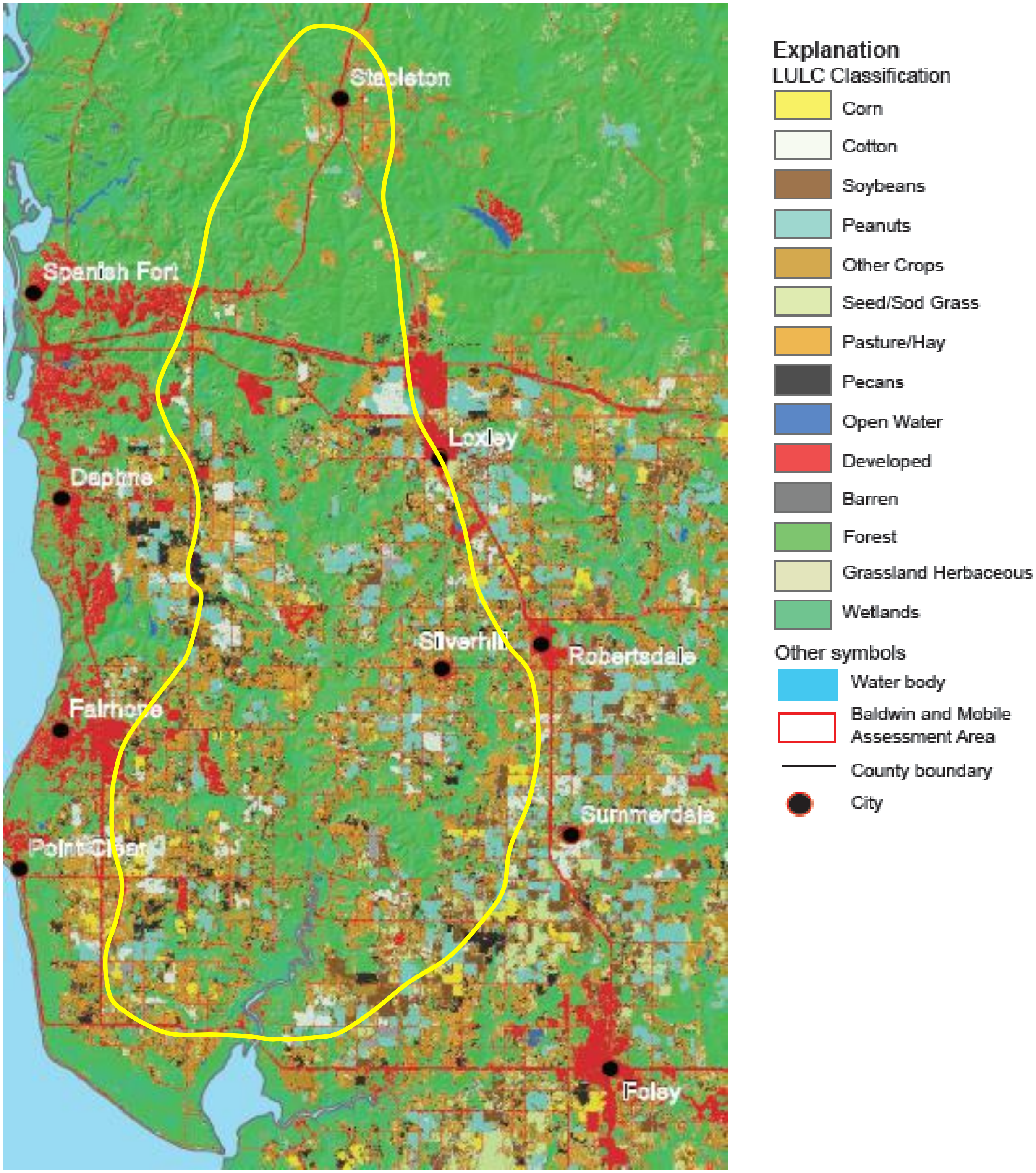


Figure 3.—Land use/land cover in southwestern Baldwin County, including the Fish River watershed.

(downstream) towards Weeks Bay. The Fish River floodplain is dominated by forest and wetlands and the stream gradient is 10 ft per mile (ft/mi) (fig. 3). Monitored tributary floodplains are also dominated by forest and wetlands, channels that are in part, anastomosing, with stream gradients that vary from 9 to 38 ft/mi (table 1).

A wide range of discharge events are required to adequately evaluate hydrologic conditions and water quality in the Fish River watershed. Table 1 shows that sampling occurred in the Fish River watershed during discharge conditions from base flow to flood. For example, minimum discharge measured for Fish River at Baldwin County Road 48 (site FR9) was 102 cfs (January 6, 2016) and the maximum was 2,399 cfs, on April 1, 2016. Average daily discharge for each monitored stream is also required to adequately estimate constituent loading. Discharge data collected at the USGS stream gaging site 02378500, Fish River near Silver Hill, Alabama was used as a basis for average daily discharge calculation for each monitored stream.

Table 1.—Stream-flow characteristics for monitored sites in the Fish River watershed.

Monitored site	Average measured discharge (cfs)	Maximum measured discharge (cfs)	Minimum measured discharge (cfs)	Average discharge per unit area (cfs/mi)	Stream gradient (ft/mi)
FR1	83	205	19.0	24.0	17
FR2	70	120	8.0	21.0	20
FR3	54	115	4.2	25.0	26
FR4	267	736	40.0	8.7	13
FR5	421	1,936	60.0	9.5	7
FR7	150	1,085	17.0	17.0	15
FR8	136	668	4.1	28.0	23
FR9	723	2,399	102.0	11.0	11
FR10	293	740	22.0	18.0	9
FR11	298	1,595	41.0	10.0	19
FR12	168	630	7.1	14.0	18
FR13	105	430	7.5	26.0	20
FR14	764	1,600	200.0	6.3	11
FR15	86	300	1.8	27.0	28
FR16	152	540	0.3	31.0	17
FR17	174	638	0.4	30.0	21
FR18	118	504	10.0	47.0	38

SPECIFIC CONDUCTANCE

Surface water in each project watershed is characterized by a unique specific conductance (SC) (microseimens/centimeter (µS/cm)) profile based on physical and chemical properties. The variability of SC is influenced by differences in stream temperature, discharge, total dissolved solids, local geology, soil conditions, and ionic influxes from nonpoint sources of pollution or from seawater in reaches of streams with tidal influence. Streams without significant contaminant sources exhibit increased SC values with decreasing discharge due to increasing volumes of relatively high SC groundwater inflow and decreased SC with increasing discharge due to increasing volumes of relatively low SC runoff. The opposite SC character is exhibited for streams with significant contaminant sources where relatively high conductance runoff causes increasing SC with increasing discharge. Fluctuations of SC in streams with tidal influence correspond to tidal cycles with relatively high SC (salt water) at high tide and relatively low SC (fresh water) at low tide. Table 2 shows SC in monitored streams in the Fish River watershed. Sites FR11 (Polecat Creek) and FR14 (most downstream Fish River site) are the only monitoring sites at sea level that may be influenced by tidal influx. Only one monitoring event detected tidal influence at site FR14, where SC was 6,890 micro siemens/centimeter (μS/cm) on January 6, 2016, which was measured during base flow conditions. Generally, SC was relatively low due to no significant contaminant sources in the watershed and most SC measurements were made immediately after precipitation events (table 2). However, after evaluating a number of constituents and land use, site FR18 (Corn Branch at Baldwin County Road 64) has relatively high SC, which is most likely due to urban runoff on the west side of the town of Loxley (table 2). ADEM established reference sites on streams throughout Alabama to determine reference water-quality standards for selected level IV ecoregions. The ADEM reference concentration for SC for ecoregion 65f, which includes the Fish River watershed is 20.4 μS/cm. Average SC for all sites exceeded the ADEM standard (table 2).

TURBIDITY

Turbidity in water is caused by suspended and colloidal matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microscopic organisms (Eaton, 1995). Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted with no change in direction or flux level through the stream (Eaton, 1995). Turbidity values measured in nephlametric turbidity units (NTU) from water samples may be utilized to formulate a rough estimate of long-term trends of total suspended solids (TSS) and therefore may be used to observe trends in suspended sediment transport in streams.

Table 2.—Measured specific conductance values for Fish River watershed monitoring sites.

Monitored site	Average SC (µS/cm)	Maximum SC (µS/cm)	Minimum SC (µS/cm)
FR1	25	31	17
FR2	48	161	22
FR3	26	33	17
FR4	43	62	32
FR5	47	63	36
FR7	46	57	31
FR8	45	59	26
FR9	48	71	30
FR10	51	69	33
FR11	50	58	34
FR12	47	57	30
FR13	67	174	35
FR14	737	6,890	33
FR15	64	79	34
FR16	64	92	38
FR17	57	67	41
FR18	75	102	47

Analyses of turbidity and stream discharge provide insights into hydrologic, land-use, and general water-quality characteristics of a watershed. Average measured turbidity shown in figure 4, illustrates that sites FR8 (Pensacola Branch), FR18 (Corn Branch), and FR12 (Cowpen Creek) have the highest turbidity (145, 126, and 94 NTUs, respectively). Commonly, excessive turbidity is closely tied to land uses that cause land disturbances that lead to erosion or to land uses that cause excessive runoff. Evaluation of land-use data indicates that watersheds with dominant urban development and/or agriculture are more likely to have streams with significant turbidity concentrations. Although there are a number of areas in the Fish River watershed that are undergoing conversion from agriculture to commercial and residential development, the majority of human activity in the watershed continues to be agricultural. Cowpen Creek and Corn Branch have the highest percentages of residential and commercial development (31.9 and 29.8%, respectively). However, Pensacola Branch has neither a large percentage of developed or agricultural land use. Therefore, relatively recent land-use change, substantial land disturbance, or stream bed or bank erosion may be responsible for the elevated turbidity in

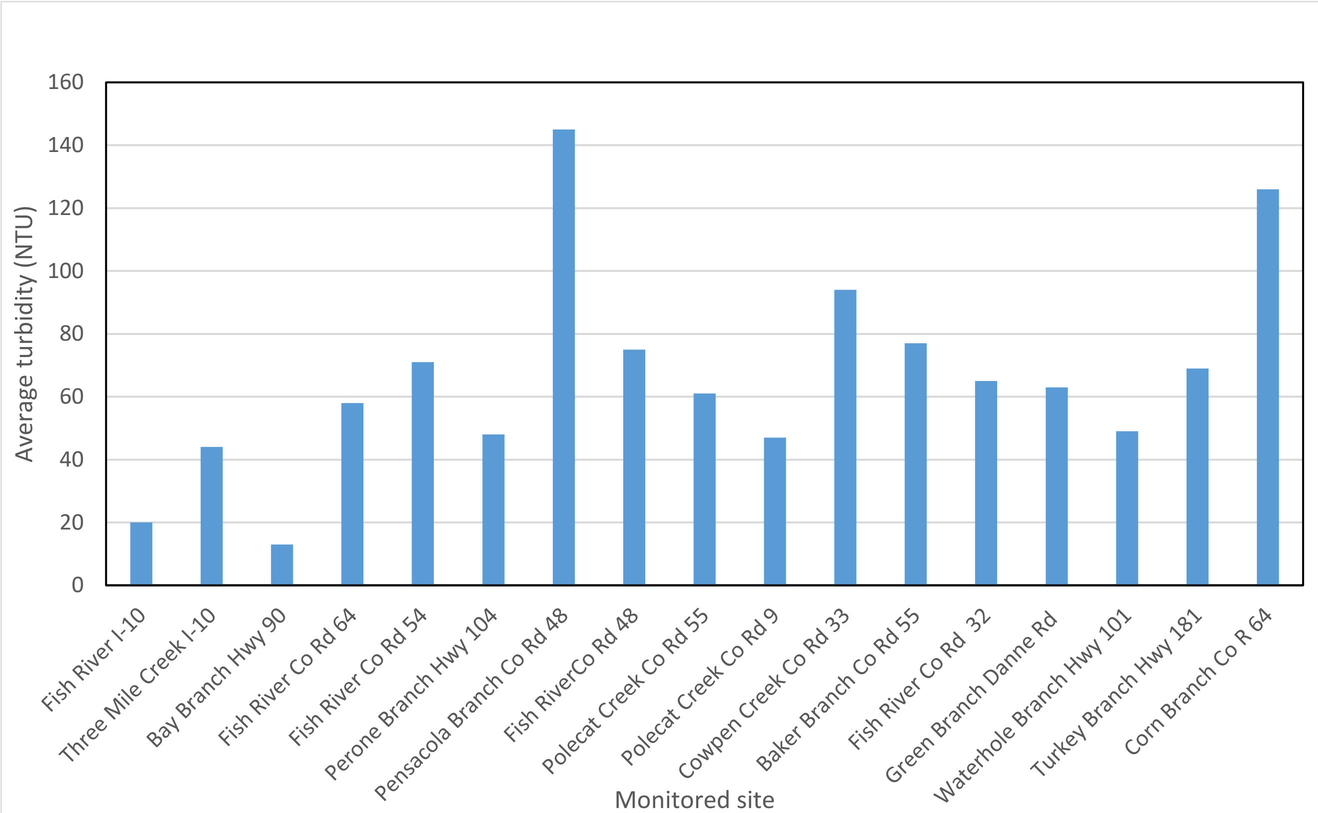


Figure 4.—Average turbidity for Fish River watershed monitoring sites.

Pensacola Branch. The ADEM reference concentration for turbidity is 9.7 NTU for ecoregion 65f. Average turbidity for all Fish River watershed sites exceeded the ADEM standard by 1.3 to 15 times.

SEDIMENTATION

Sedimentation is a process by which eroded particles of rock are transported primarily by moving water from areas of relatively high elevation to areas of relatively low elevation, where the particles are deposited. Upland sediment transport is primarily accomplished by overland flow and rill and gully development. Lowland or flood plain transport occurs in streams of varying order, where upland sediment joins sediment eroded from flood plains, stream banks, and stream beds. Erosion rates are accelerated by human activity related to agriculture, construction, timber harvesting, unimproved roadways, or any activity where soils or geologic units are exposed or disturbed. Excessive sedimentation is detrimental to water quality, destroys biological habitat, reduces storage volume of water impoundments, impedes the usability of aquatic recreational areas, and causes damage to structures.

Precipitation, stream gradient, geology, soils, and land use are all important factors that influence sediment transport characteristics of streams. Sediment transport conditions in the Fish River watershed were evaluated and quantified by tributary, in order to evaluate factors impacting erosion and sediment transport at a localized scale. In addition to commonly observed factors above, wetlands, vegetation, and tidal effects in the downstream part of the watershed also play prominent roles in sediment transport and overall water quality in the Fish River watershed. Estimates of sediment loads for this assessment are based on measured sediment and stream discharge. Therefore, a stream flow dataset composed of values ranging from base flow to flood is desirable. Observed stream flow conditions are shown in table 1.

Sediment loads in streams are composed of relatively small particles suspended in the water column (suspended solids) and larger particles that move on or periodically near the streambed (bed load). Six Fish River watershed monitoring sites had measurable suspended and bed sediment loads. Only suspended sediment could be measured at the other 12 sites due to flow and channel conditions.

SEDIMENT LOADS TRANSPORTED BY PROJECT STREAMS

The rate of sediment transport is a complex process controlled by a number of factors primarily related to land use, precipitation runoff, erosion, stream discharge and flow velocity, stream base level, and physical properties of the transported sediment. Deterrents to excessive erosion and sediment transport include wetlands, forests, vegetative cover and field buffers for croplands, limitations on impervious surfaces, and a number of constructed features to promote infiltration of precipitation and to store and slow runoff. Currently, the Fish River watershed is characterized by a relatively rural setting, extensive row crop agriculture, floodplains dominated by abundant wetlands, anastomosing stream channels, and forest. Anthropogenic impacts to stream flow, sediment transport, and water quality include erosion from agricultural fields, increased runoff and land disturbance related to residential development and commercial areas of Loxley and Fairhope.

SUSPENDED SEDIMENT

The basic concept of constituent loads in a river or stream is simple. However, the mathematics of determining a constituent load may be quite complex. The constituent load is the mass or weight of a constituent that passes a cross-section of a stream in a specific amount of time. Loads are expressed in mass units (tons or kilograms) and are measured for time intervals that are relative to the type of pollutant and the watershed area for which the loads are calculated. Loads are calculated from concentrations of constituents obtained from analyses of water samples and stream discharge, which is the volume of water that passes a cross-section of the river in a specific amount of time.

Suspended sediment is defined as that portion of a water sample that is separated from the water by filtering. This solid material may be composed of organic and inorganic particles that include algae, industrial and municipal wastes, urban and agricultural runoff, and eroded material from geologic formations. These materials are transported to stream channels by overland flow related to storm-water runoff and cause varying degrees of turbidity. Figure 5 is an x-y plot of average turbidity and average total suspended solids (TSS) for each monitored Fish River watershed site. It shows an excellent correlation between turbidity and TSS, with the exception of site FR18 (Corn Branch), which shows a higher turbidity to TSS ratio (fig. 5). This may indicate finer-grained suspended sediment that has less measured mass for similar turbidity.

Annual suspended sediment loads were estimated for Fish River monitored streams using the computer regression model Regr_Cntr.xls (*Regression with Centering*) (Richards, 1999). The program is an Excel adaptation of the U.S. Geological Survey (USGS) seven-parameter regression model for load estimation in perennial streams (Cohn and others, 1992). The regression with centering program requires total suspended solids (TSS) concentrations and average daily stream discharge to estimate annual loads. Although average daily discharge for project streams was not available from direct measurement for the monitored sites, it was calculated by establishing a ratio between periodic measured discharge in project streams and discharge values for the same times obtained from USGS stream gaging site (02378500, Fish River near Silver Hill, Alabama).

Concentrations of TSS in mg/L were determined by laboratory analysis of periodic water grab samples. These results were used to estimate the mass of suspended

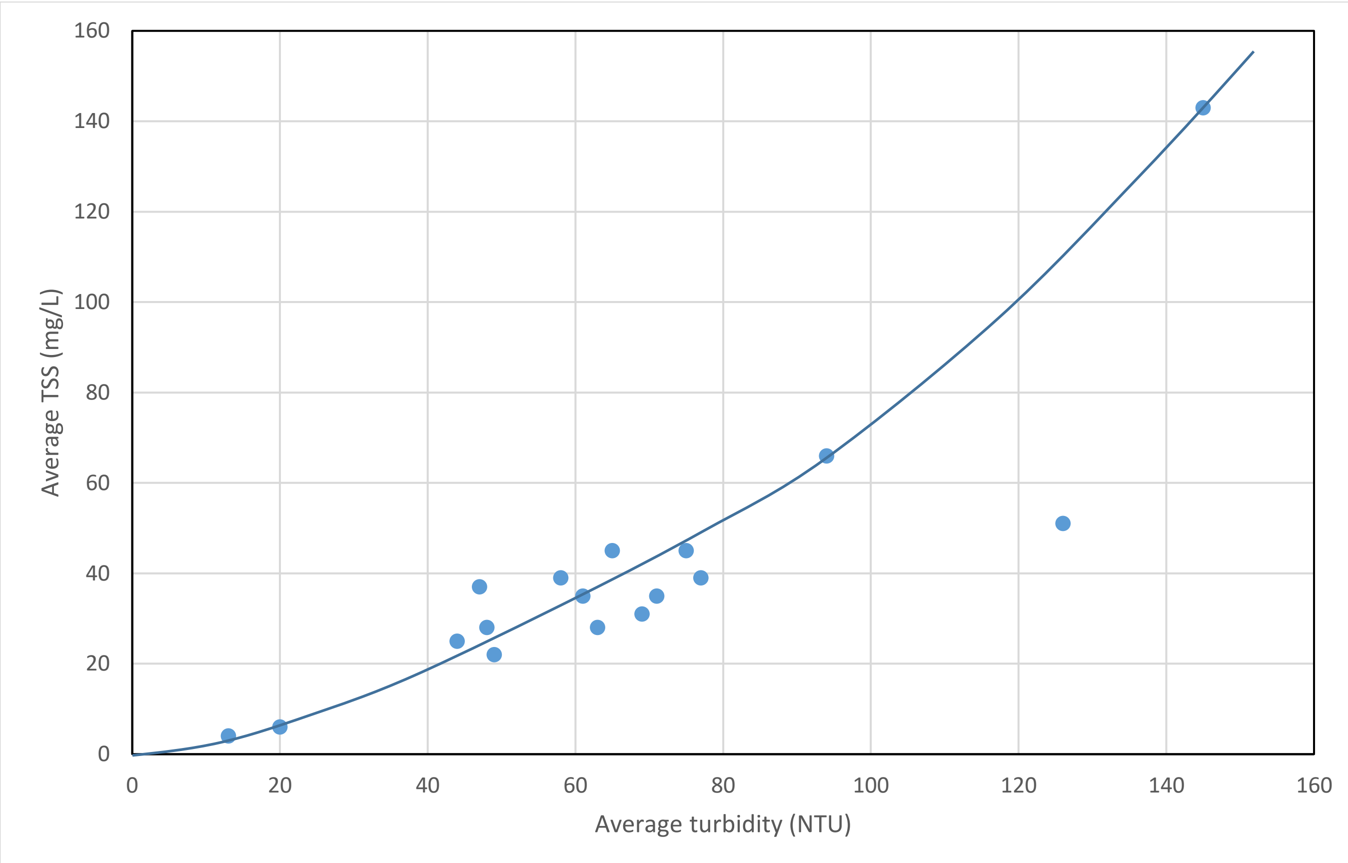


Figure 5.—Average turbidity and average TSS for Fish River watershed monitoring sites.

sediment for the period of stream flow (June 1, 2015 to May 30, 2016). Pensacola Branch (FR8), Polecat Creek (FR11), and Cowpen Creek (FR12) had the largest suspended sediment loads for tributary streams (3,732, 3,090, and 2,355 tons per year (t/yr), respectively (fig. 6, table 3). Fish River sites (FR1, FR4, FR5, FR9, FR14) show increasing suspended sediment loads from upstream to downstream, as expected, (fig. 6, table 3). Figure 7 shows estimated average annual daily discharge and annual suspended sediment loads, illustrating that generally, increased discharge results in increased suspended sediment loads. Exceptions to this trend occur at Pensacola Branch (FR8), Cowpen Creek (FR12), and Corn Branch (FR18), where relatively large suspended sediment loads correspond to relatively small average discharge, indicating excessive erosion in those watersheds.

Normalizing suspended loads to unit watershed area permits comparison of monitored watersheds and negates the influence of drainage area size and discharge on sediment loads. Normalized loads for monitored sites in the Fish River watershed are portrayed on figure 8, which shows that the largest normalized suspended sediment loads at tributary sites are FR8 (Pensacola Branch, 778 t/mi^2/yr), FR18 (Corn Branch, 689 t/mi^2/yr), and FR12 (Cowpen Creek, 200 t/mi^2/yr). The largest normalized load for Fish River sites was the downstream most site 14 (201 t/mi^2/yr) (table 3).

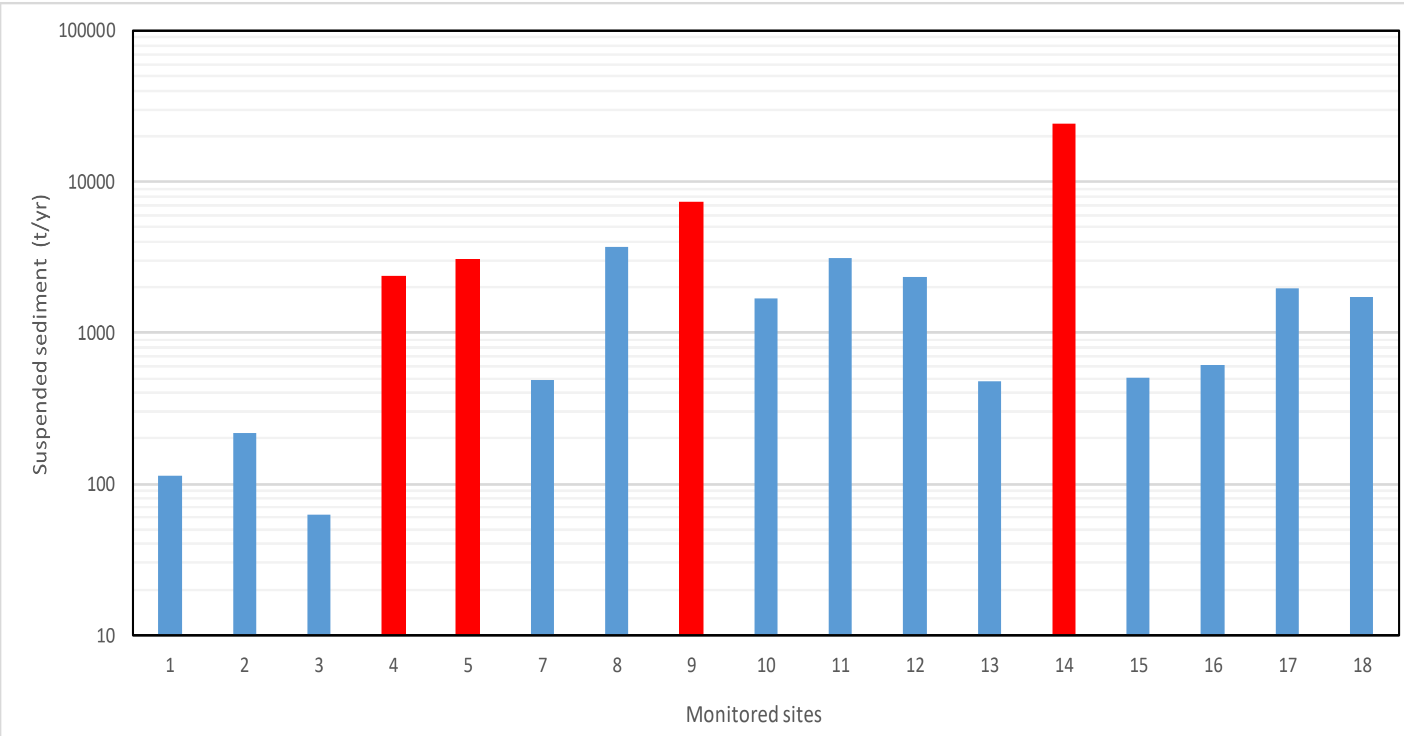


Figure 6.—Estimated suspended sediment loads for Fish River watershed monitoring sites (red bars are main stem Fish River sites).

The ADEM reference concentration for TSS for ecoregion 65f, which includes the Fish River watershed is 13.2 mg/L. Comparisons of average TSS concentrations for Fish River monitor sites with the ADEM reference standard is shown on table 3.

Land use is a major factor in the magnitude of erosion and stream sediment loading. Figure 9 shows suspended sediment loads and urban development as a percentage of total monitored watershed area. Three major urban development/suspended sediment load relationships are identified on the graph. First are watersheds with relatively large urban development and corresponding, relatively large suspended sediment loads, which includes Cowpen Creek (FR12) and Corn Branch (FR18) (fig. 9). The second are watersheds with relatively large urban development and relatively small suspended sediment loads, which includes Bay Branch (FR3) (fig. 9).

Table 3.—Measured discharge, turbidity, TSS, and estimated suspended sediment loads in monitored streams in the Fish River watershed.

Monitored site	Average daily discharge (cfs)	Average turbidity (NTU)	Maximum turbidity (NTU)	Average TSS (mg/L)	ADEM[1] Level IV Ecoregion 65f reference standard for TSS (mg/L)	Maximum TSS (mg/L)	Estimated suspended sediment load (t/yr)	Estimated normalized suspended sediment load (t/mi^2/yr)
FR1	19	20	32	6	13.2	56	113	33.2
FR2	14	44	83	25	13.2	229	216	63.5
FR3	17	13	25	4	13.2	6	62	28.1
FR4	79	58	136	39	13.2	136	2,380	77.3
FR5	109	71	275	35	13.2	275	3,076	69.3
FR7	23	48	198	28	13.2	104	486	53.4
FR8	35	145	504	143	13.2	464	3,732	778
FR9	199	75	260	45	13.2	108	7,430	109
FR10	88	61	126	35	13.2	74	1,701	107
FR11	72	47	125	37	13.2	71	3,090	107
FR12	41	94	181	66	13.2	113	2,355	200
FR13	24	77	222	39	13.2	153	477	116
FR14	189	65	294	45	13.2	295	24,295	201
FR15	20	63	140	28	13.2	90	504	158
FR16	32	49	98	22	13.2	37	606	124
FR17	49	69	164	31	13.2	96	691	119
FR18	37	126	273	51	13.2	110	1,723	689

[1] Alabama Department of Environmental Management

The third is watersheds with relatively small urban development and relatively large suspended sediment loads, which includes Pensacola Branch (FR8), Polecat Creek at Co. Road 9 (FR11), Baker Branch (13), and Turkey Branch (FR17) (fig. 9). These watersheds are dominated by agricultural land use with 32, 57, 66, and 71 percent of total watershed area upstream from the monitoring site. Main stem Fish River sites FR1, FR4, FR5, FR9, and FR14 are depicted on figure 6 in red and show increasing, cumulative suspended sediment loads from upstream to downstream.

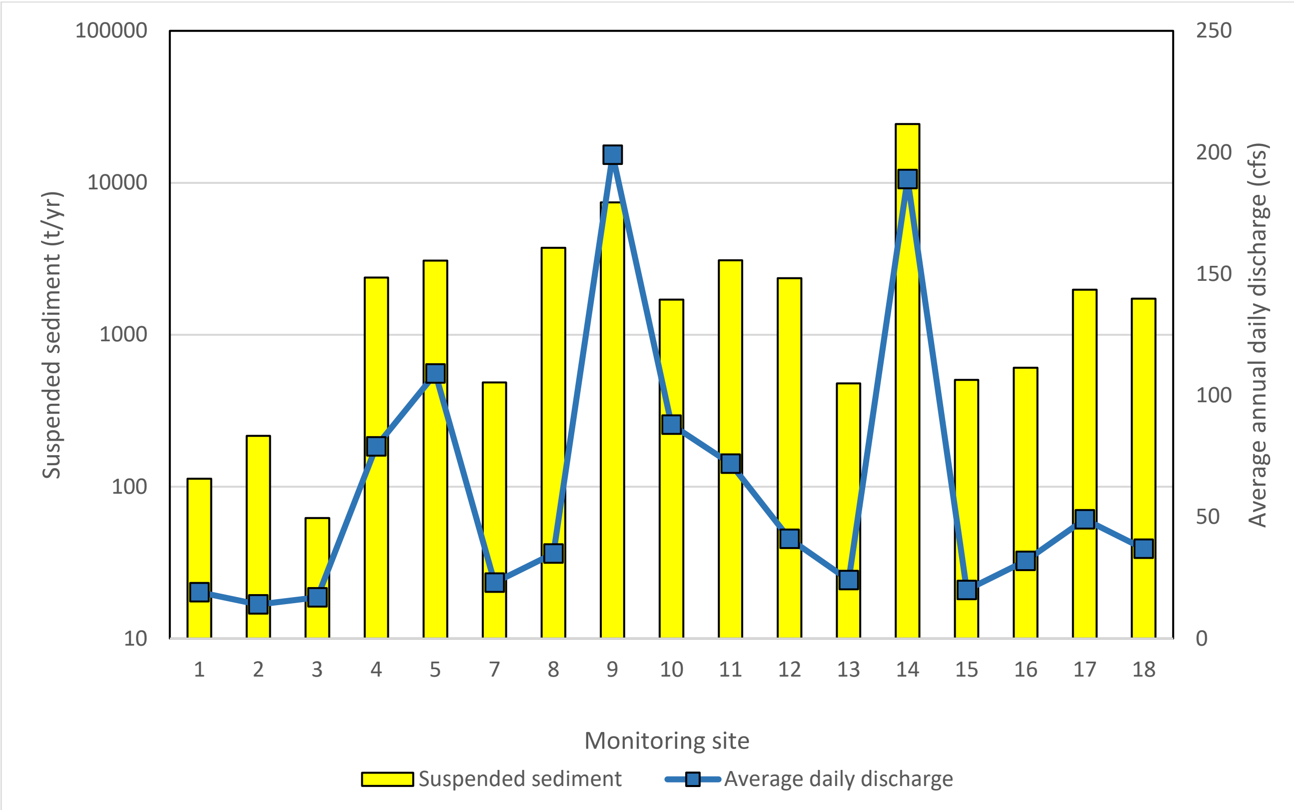


Figure 7.—Estimated suspended sediment loads and average annual daily discharge for Fish River watershed monitoring sites.

BED SEDIMENT

Transport of streambed material is controlled by a number of factors including stream discharge and flow velocity, erosion and sediment supply, stream base level, and physical properties of the streambed material. Most streambeds are in a state of constant flux in order to maintain a stable base level elevation. The energy of flowing water in a stream is constantly changing to supply the required power for erosion or deposition of bed load to maintain equilibrium with the local water table and regional or global sea level. Stream base level may be affected by regional or global events including fluctuations of sea level or tectonic movement. Local factors affecting base level include fluctuations in the water table elevation, changes in the supply of sediment to the stream caused by changing precipitation rates, and/or land use practices that promote excessive erosion in the floodplain or upland areas of the watershed.

Bed sediment loads are composed of particles that are too large or too dense to be carried in suspension by stream flow. These particles roll, tumble, or are periodically suspended as they move downstream. Traditionally, bed load sediment has been difficult

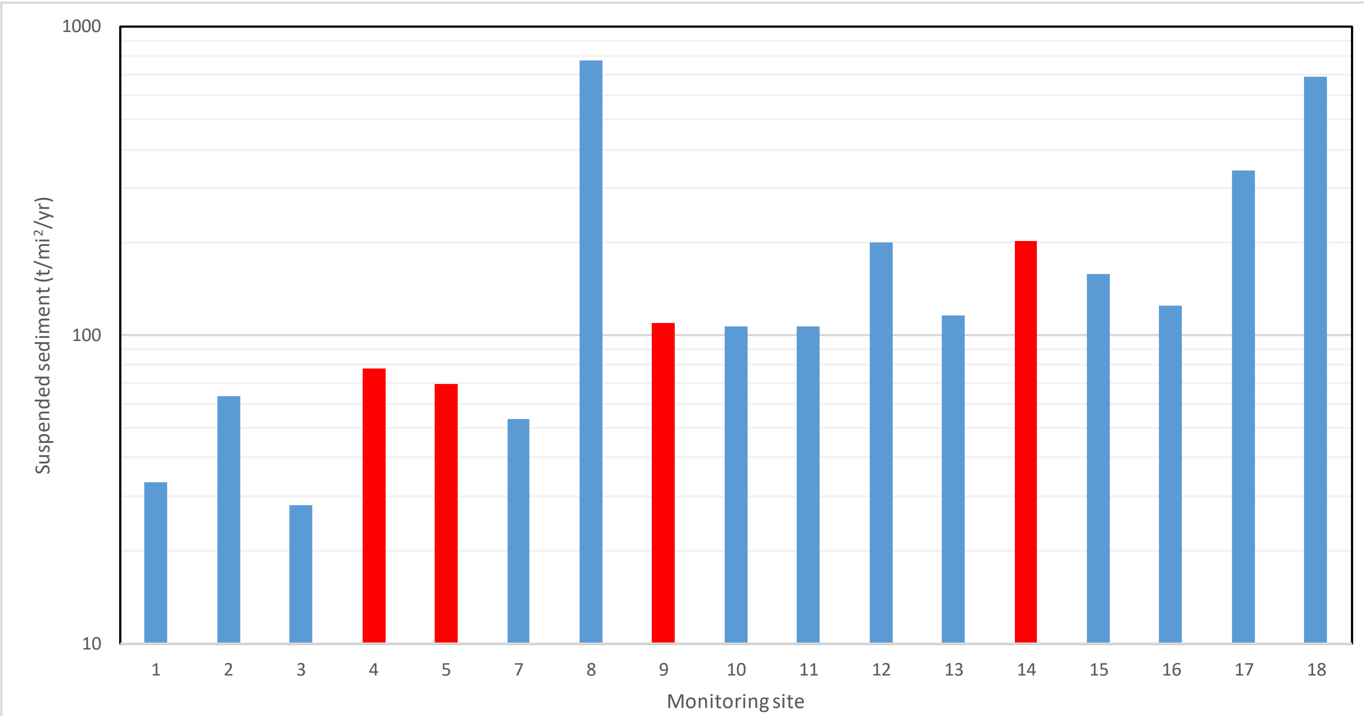


Figure 8.—Normalized suspended sediment loads for the Fish River watershed monitoring sites (red bars are main stem Fish River sites).

to quantify due to deficiencies in monitoring methodology or inaccuracies of estimating volumes of sediment being transported along the streambed. This is particularly true in streams that flow at high velocity or in streams with excessive sediment loads.

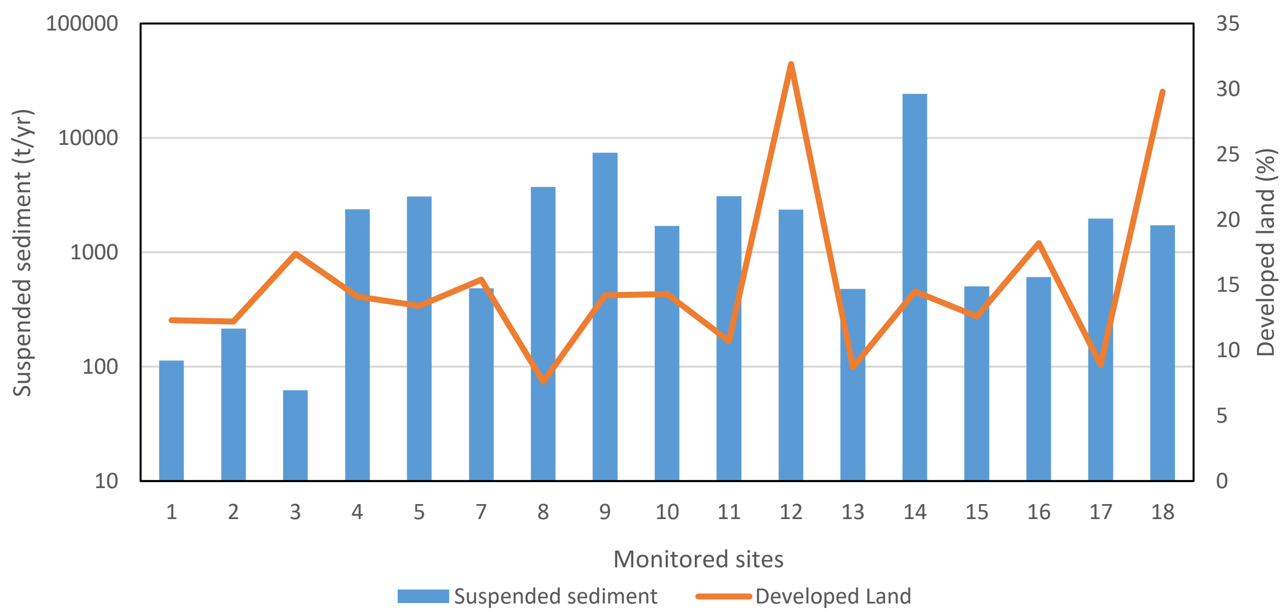


Figure 9.—Comparison of estimated suspended sediment loads and developed land as a percentage of the monitored watershed.

In 1998, Marlon Cook developed a portable bed load sedimentation rate-monitoring device in response to the need for accurate bed sediment transport rates in shallow streams with sand or gravel beds (Cook and Puckett, 1998). The device was utilized to measure bed sediment transport rates periodically over a range of discharge events at six Fish River sites (FR4, FR5, FR7, FR8, FR9, and FR12). All other sites had deep channels with slow moving water, anastomosing reaches with no sand bed, or hard surface beds where all sediment was assumed to be suspended.

As with suspended sediment, it is possible to use discharge/sediment relationships to develop regression models to determine mean daily bed load volumes and annual bed sediment loads. Figure 10 shows average measured stream discharge and bed sediment for sites with measurable bed sediment. Note the excellent correlation between measured discharge and corresponding bed sediment transport rates. Figure 11 shows estimated

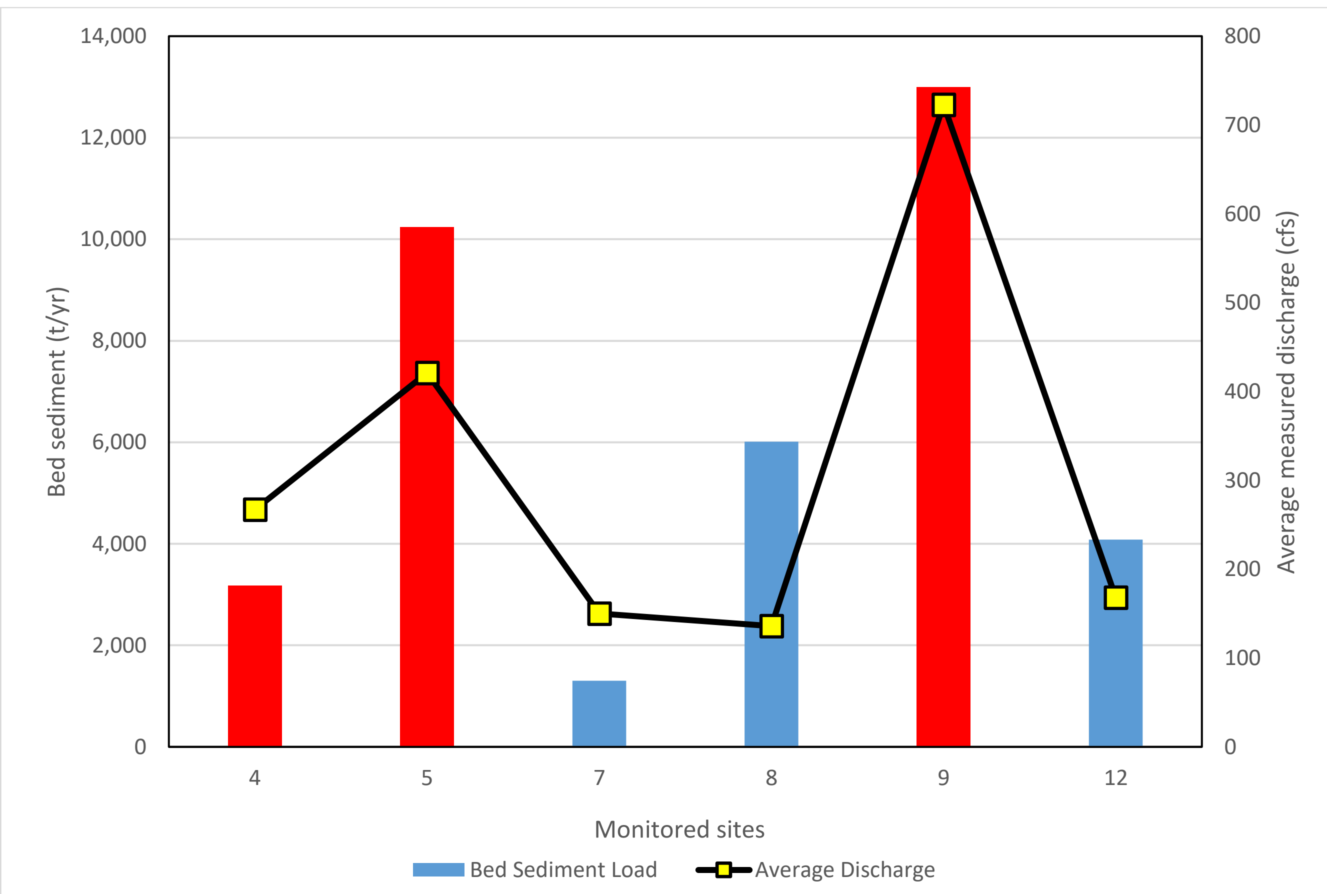


Figure 10.—Estimated bed sediment loads and average measured discharge for Fish River monitored site with measurable bed sediment (red bars are main stem Fish River sites).

annual bed sediment loads normalized with respect to watershed drainage area. Table 4 gives average measured stream discharge, annual bed sediment loads, and normalized annual bed sediment loads for monitoring sites in streams with measurable bed sediment in the project area. Sites FR9 (Fish River at Baldwin Co Road 32 crossing) and FR5 (Fish River at Baldwin Co Road 54 crossing) had the largest bed sediment loads with 13,000 and 10,241 tons per year, respectively. This is expected, since these are main stem sites, with relatively large drainage areas and discharge, are representative of cumulative sediment loads from the Fish river channel, floodplain, and tributaries upstream from the sites (fig. 2). After normalization of bed sediment loads relative to drainage area, sites FR8 (Pensacola Branch) and FR12 (Cowpen Creek) had the largest loads with 1,253 and 346 tons/mi^2/yr, respectively.

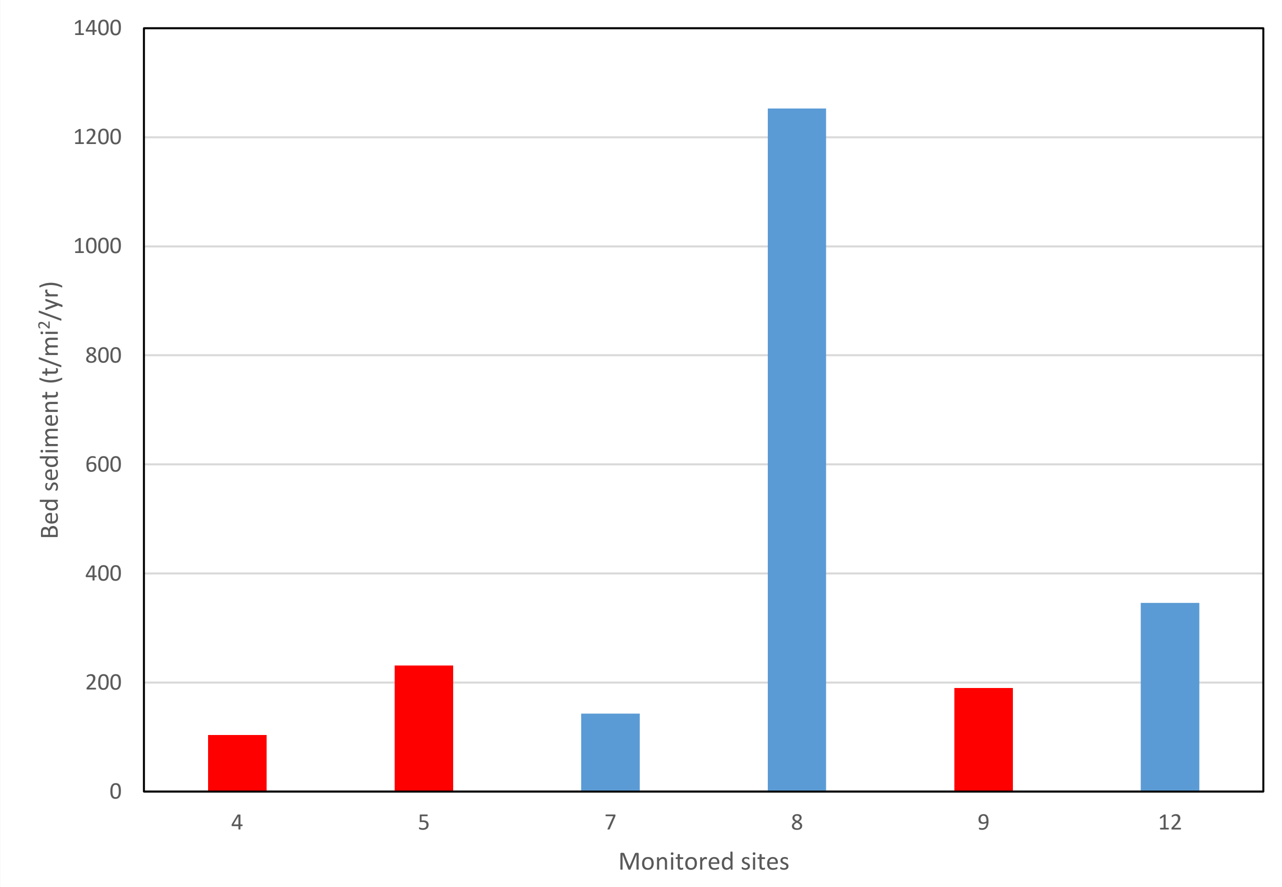


Figure 11.—Normalized estimated bed sediment loads for Fish River sites with measurable bed sediment (red bars are main stem Fish River sites).

Table 4—Average measured discharge and estimated bed sediment loads for monitoring sites on streams with measurable bed sediment in the project area.

Monitored site	Average discharge (cfs)	Estimated annual bed sediment loads (tons/yr)	Estimated Normalized annual bed sediment loads (tons/mi ^{2}/yr)
FR4	267	3,180	103
FR5	421	10,241	231
FR7	150	1,300	143
FR8	136	6,012	1,253
FR9	723	13,000	190
FR12	168	4,085	346

BED SEDIMENT GRAIN SIZE ANALYSES

Sedimentation processes, including erosion, transport, deposition, and consolidation and sorting, are critical considerations in evaluating stream stability and developing restoration designs. The form of a channel is a consequence of the magnitude, timing, and frequency of both runoff and sediment yield from the watershed. The composition of streambed and banks is an important facet of stream character, which influences channel form and hydraulics, erosion rates, sediment supply, and other parameters. Sediment characteristics that may be important in executing stream restoration projects include the sediment size, shape, specific weight, fall velocity, and parent geology (Fischenich and Little, 2007).

The composition of streambed and banks is an important facet of stream character, which influences channel form and hydraulics, erosion rates, sediment supply, and other parameters. Particle-size data are usually reported in terms of di, where i represents some percentile of the distribution, and di for a particle grain size, usually expressed in millimeters, where i percent of the total sample by weight is finer. For example, 84 percent of the total sample would be finer than the d84 particle size (Fischenich and Little, 2007).

Bed sediment samples were collected at each Fish River watershed monitoring site with measurable bed sediment. One cubic ft of wet sediment was weighed on site and a representative subsample was placed in a one gallon plastic bag for transport. Samples were sieved and data were analyzed according to procedures developed by the North

Carolina Stream Restoration Institute at North Carolina State University (Doll and others, 2003). Samples were-sieved, using a sieve set that retains material with the following sizes in millimeters: >4, 2-4, 2-0.5, 0.5-0.25, 0.25-.11, a bottom pan for silt and clay. Retained material on each sieve was weighed and the weights (less tare weight) were recorded by size class. The percentage of each size class relative to the total weight was determined. The percentage of finer material to each class was also determined. The percentages are represented for sites FR4, FR7, and FR8 on graphs in figure 12.

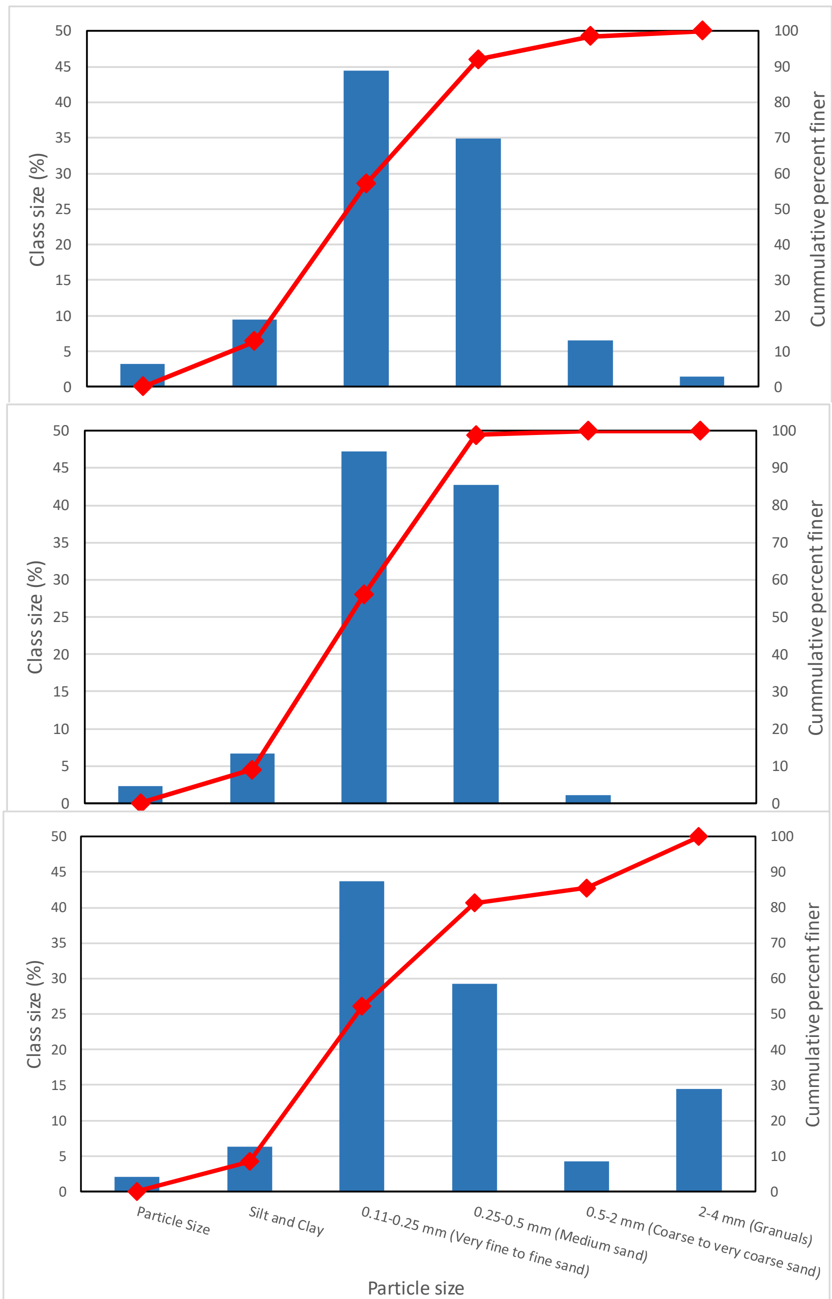


Figure 12.—Results of sieve analysis for Fish River watershed sites FR4 (top), FR7 (center), and FR8 (bottom).

TOTAL SEDIMENT LOADS

The total sediment loads in a stream is composed of suspended and bed sediment. Six monitored sites had both suspended and bed sediment loads. On average, bed sediment makes up 64% of the total sediment loads for streams with measurable suspended and bed sediment. Table 5 and figures 13 and 14 show total sediment loads for monitored reaches in the Fish River watershed. As expected, due to relatively large drainage area, discharge, and cumulative sediment, main stem Fish River sites FR5 (Fish River at Baldwin Co Road 54), FR9 (Fish River at Baldwin County Road 48), and FR14 (Fish River at Baldwin Co Road 32) have the largest sediment loads (table 5, fig. 13). However, when total sediment loads are normalized relative to drainage area, sites FR8 (Pensacola Branch), FR18 (Corn Branch), and FR12 (Cowpen Creek) have the largest loads (table 5, fig. 14).

Without human impact, watershed erosion rates, called the geologic erosion rate, would be 64 t/mi^2/yr (Maidment, 1993). Normalized sediment loads show that 13 of 17 monitored watersheds were from 1.7 to 31.7 times greater than the geologic erosion rate (fig. 14). Only headwaters sites FR1 (Fish River at I-10), FR2 (Three-Mile Creek), and FR3 (Bay Branch) were at or below the geologic erosion rate (fig. 14).

Comparisons of sediment loads from other watersheds are helpful in determining the severity of erosion problems in a watershed of interest. Figure 15 shows comparisons of estimates of normalized total sediment loads from Fish River watershed sites FR8 (Pensacola Branch), FR18 (Corn Branch), and FR12 (Cowpen Creek) with sites in seven previously monitored watersheds in Mobile and Baldwin Counties, including Fowl River site FR2 (at Half-Mile Road), Dog River tributary, Spencer Branch (at Cottage Hill Road in the city of Mobile) (Cook, 2012), D'Olive Creek site FR3 (at U.S. Highway 90 in Daphne) (Cook, 2008), Tiawasee Creek site FR7 (upstream from Lake Forest) (Cook, 2008), D'Olive Creek tributary Joes Branch site FR10 (at North Main Street in Daphne) (Cook, 2008), Magnolia River site FR4 (at U.S. Highway 98) (Cook, 2009), and Bon Secour River site FR3 (County Road 12 in Foley) (Cook, 2013) (fig. 14).

Table 5—Watershed area, average measured discharge, and estimated total sediment loads for monitoring sites in the project area.

Monitored site	Monitored watershed area (mi^2)	Average discharge (cfs)	Estimated annual total sediment loads (tons/yr)	Estimated normalized annual total sediment loads ($tons/mi^2/yr$)
FR1	3.4	83	113	33
FR2	3.4	70	216	64
FR3	2.2	54	62	28
FR4	30.8	267	5,560	180
FR5	44.4	421	13,317	300
FR7	9.1	150	1,786	196
FR8	4.8	136	9,744	2,031
FR9	68.4	723	20,430	299
FR10	15.9	293	1,701	107
FR11	28.9	298	3,090	107
FR12	11.8	168	6,440	546
FR13	4.1	105	477	116
FR14	121	764	24,295	201
FR15	3.2	86	504	158
FR16	4.9	152	606	124
FR17	5.8	174	691	119
FR18	2.5	118	1,723	689

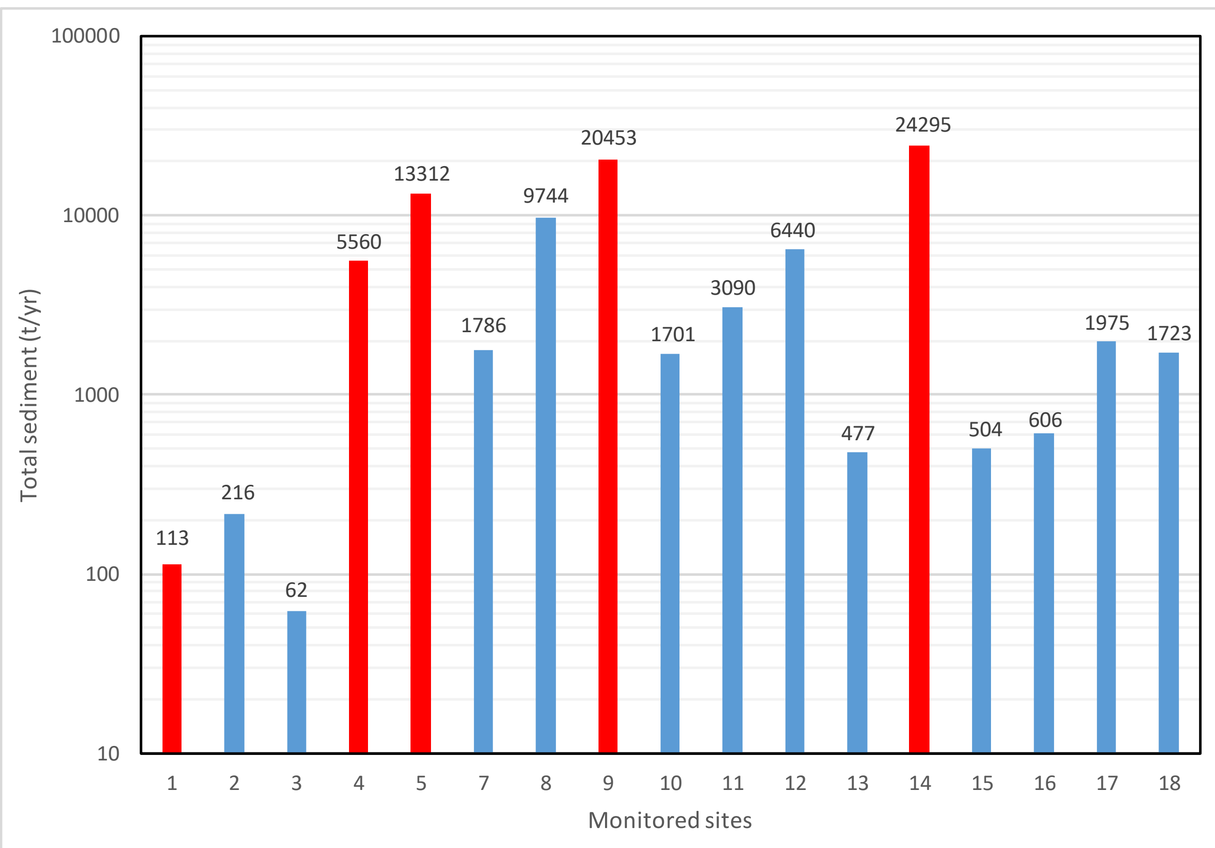


Figure 13.—Estimated total sediment loads for Fish River monitored sites (red bars are main stem Fish River sites).

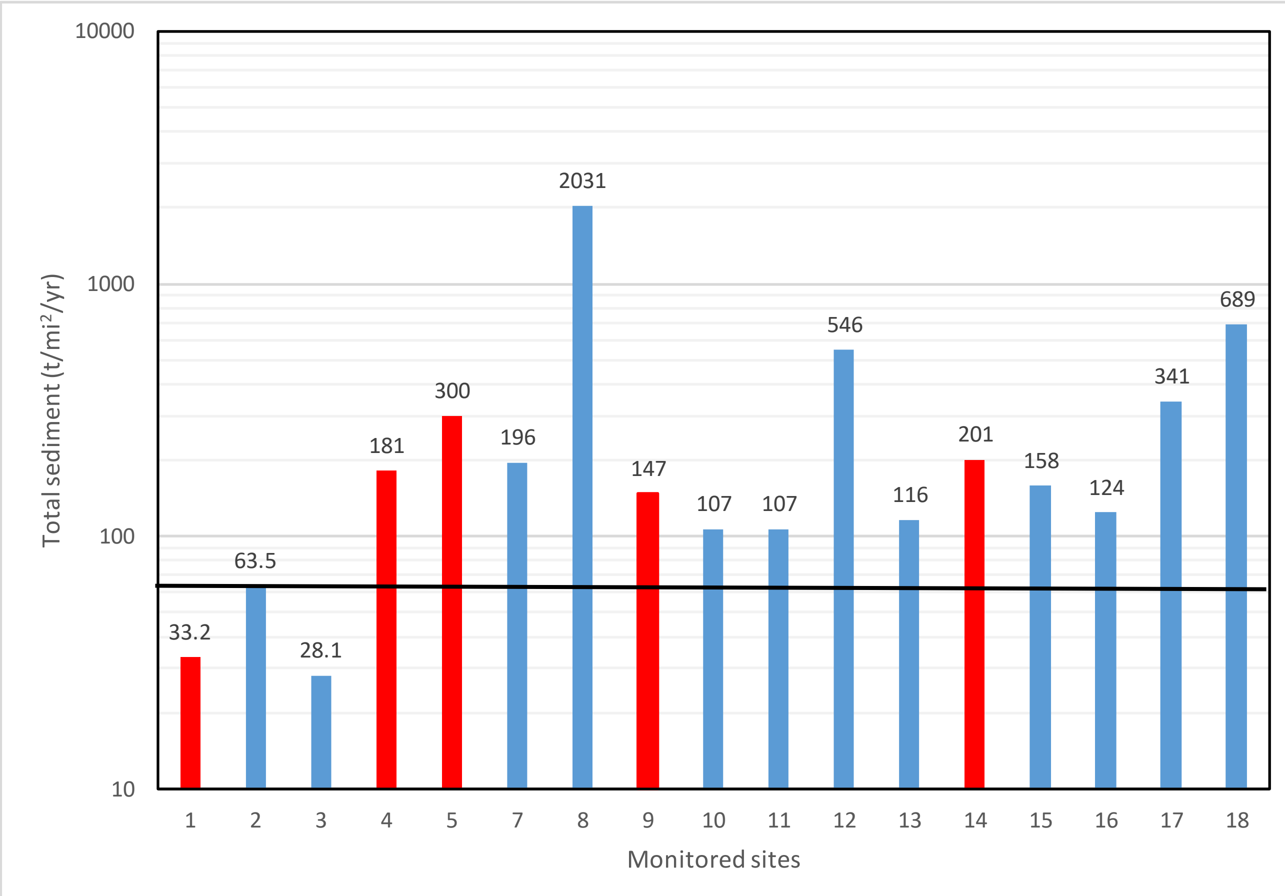


Figure 14.—Estimated normalized total sediment loads for Fish River sites (red bars are main stem Fish River sites).

Fowl River at Half Mile Road (site 2), is an excellent sediment reference site for streams in southern Mobile and Baldwin Counties, with geology, topography, soils, and wetlands similar to most streams in the region (fig. 15).

Fish River at I-10 (site FR1) and tributaries, Three Mile Creek at I-10 (site FR2) and Bay Branch at US Highway 90 (site FR3), are excellent sediment reference sites for streams in central Baldwin County, including the eastern shore, and northern Mobile and Baldwin Counties. The estimated total sediment loads at sites FR1, FR2, and FR3 are 33, 64, and 28 t/mi^2/yr, respectively (table 5, fig. 13). These loads are 49, 0, and 56 percent lower than the geologic erosion rate (fig.13).

NUTRIENTS

Excessive nutrient enrichment is a major cause of water-quality impairment. Excessive concentrations of nutrients, primarily nitrogen and phosphorus, in the aquatic environment can lead to increased biological activity, increased algal growth, decreased

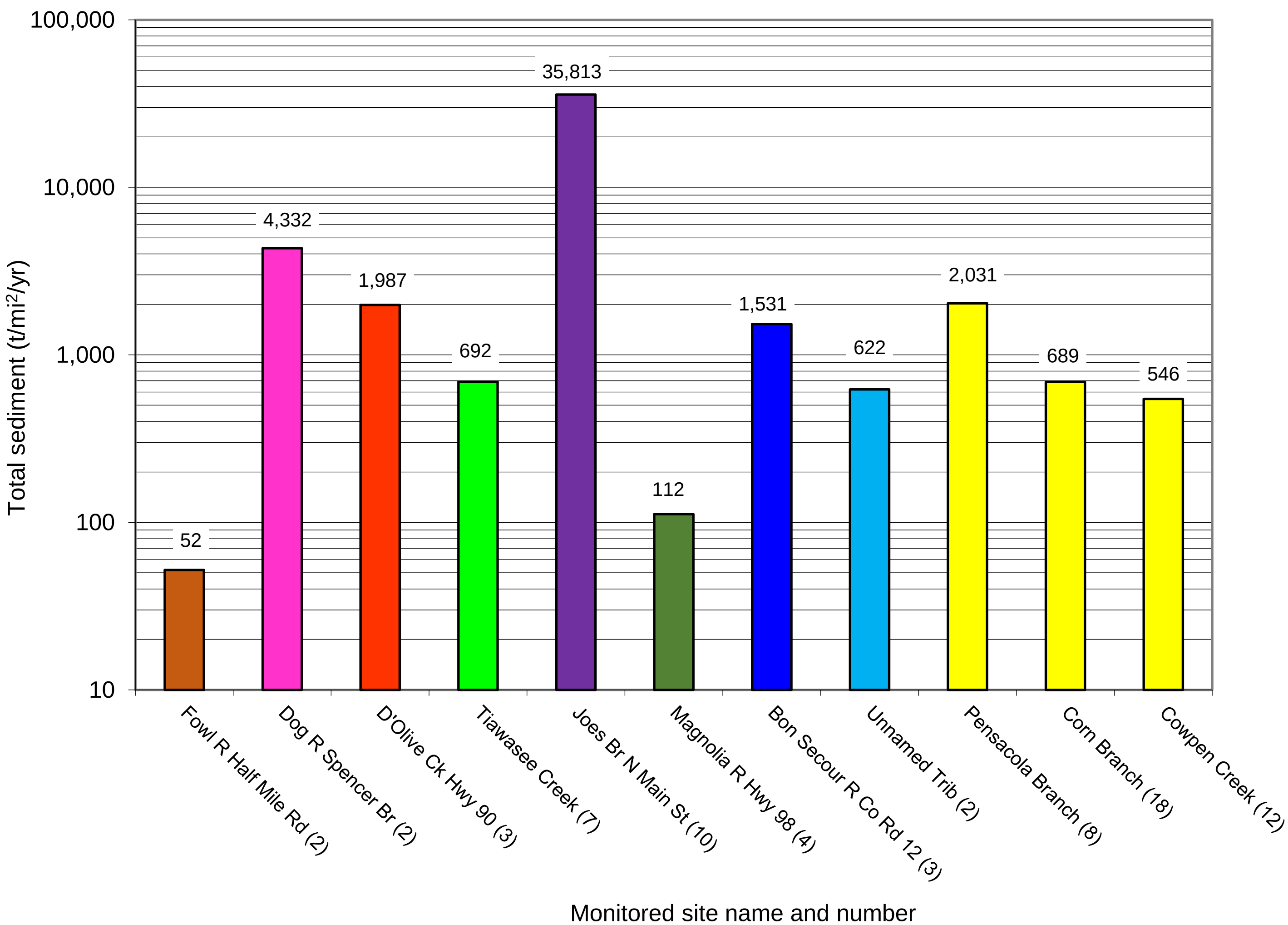


Figure 15.—Comparisons of estimated normalized total sediment loads for selected streams in Mobile and Baldwin Counties.

dissolved oxygen concentrations at times, and decreased numbers of species (Mays, 1996). Nutrient-impaired waters are characterized by numerous problems related to growth of algae, other aquatic vegetation, and associated bacterial strains. Blooms of algae and associated bacteria can cause taste and odor problems in drinking water and decrease oxygen concentrations to eutrophic levels. Toxins also can be produced during blooms of particular algal species. Nutrient-impaired water can dramatically increase treatment costs required to meet drinking water standards. Nutrients discussed in this report are nitrate (NO_3-N) and phosphorus (P-total).

NITRATE

The U.S. Environmental Protection Agency (USEPA) Maximum Contaminant Level (MCL) for nitrate in drinking water is 10 mg/L. Typical nitrate (NO_3 as N) concentrations in streams vary from 0.5 to 3.0 mg/L. Concentrations of nitrate in streams without significant nonpoint sources of pollution vary from 0.1 to 0.5 mg/L. Streams fed by shallow groundwater draining agricultural areas may approach 10 mg/L (Maidment, 1993). Nitrate concentrations in streams without significant nonpoint sources of pollution generally do not exceed 0.5 mg/L (Maidment, 1993).

Water samples were collected from January through May 2016 at Fish River watershed monitoring sites for discharge events from base flow to bank full. Samples were analyzed for nitrate as N. The critical nitrate concentration in surface water for excessive algae growth is 0.5 mg/L (Maidment, 1993). Nitrate analytical results for all sites are shown in table 6.

Nitrate concentrations are highly variable for each monitoring site, due to temporal variations in the sources of nitrate and highly variable stream discharge. Nitrate and discharge form negative regressions, indicating that increased discharge results in decreased concentrations of nitrate. Nitrate loads were estimated using regressions generated from measured nitrate concentrations and discharge. The largest normalized annual nitrate loads were estimated at sites FR8 (Pensacola Branch), 0.46 tons/mi^2/yr and FR10 (Polecat Creek at Baldwin County road 55), 0.36 tons/mi^2/yr (table 6, fig. 16).

PHOSPHORUS

Phosphorus in streams originates from the mineralization of phosphates from soil and rocks or runoff and effluent containing fertilizer or other industrial products. The principal components of the phosphorus cycle involve organic phosphorus and inorganic phosphorus in the form of orthophosphate (PO_4) (Maidment, 1993). Orthophosphate is

Table 6.—Measured nitrate as N concentrations and estimated loads in monitored streams in the Fish River watershed.

Monitored site	Average nitrate as N (mg/L)	Maximum nitrate as N (mg/L)	Minimum nitrate as N (mg/L) (% samples BDL[1])	Samples above 0.5 mg/L criterion (%)	Estimated nitrate as N load (t/yr)	Estimated normalized nitrate as N load (t/mi^2/yr)
FR1	BDL	BDL	BDL (100)	0	N/A[2]	N/A
FR2	0.7	1.6	BDL (38)	50	N/A	N/A
FR3	BDL	BDL	BDL (100)	0	N/A	N/A
FR4	0.6	1.5	BDL (25)	38	5.6	0.18
FR5	1.0	2.0	BDL (13)	50	10.2	0.23
FR7	0.9	1.6	BDL (13)	75	1.8	0.20
FR8	0.6	1.2	BDL (38)	50	2.2	0.46
FR9	0.9	1.7	BDL (13)	63	17.2	0.25
FR10	0.7	1.5	BDL (25)	50	5.7	0.36
FR11	0.8	1.4	BDL (13)	63	5.3	0.18
FR12	0.4	1.4	BDL (33)	33	0.16	0.01
FR13	0.5	1.5	BDL (57)	43	N/A	N/A
FR14	0.8	1.6	BDL (22)	67	18.2	0.15
FR15	0.1	0.4	BDL (75)	0	N/A	N/A
FR16	0.1	0.4	BDL (88)	0	N/A	N/A
FR17	0.4	0.4	BDL (63)	0	N/A	N/A
FR18	0.3	1.0	BDL (67)	33	N/A	N/A

[1] Below detection limit
[2] Insufficient data for load estimation

soluble and is the only biologically available form of phosphorus. Since phosphorus strongly associates with solid particles and is a significant part of organic material, sediments influence water column concentrations and are an important component of the phosphorus cycle in streams.

The natural background concentration of total dissolved phosphorus is approximately 0.025 mg/L. Phosphorus concentrations as low as 0.005 to 0.01 mg/L may cause algae growth, but the critical level of phosphorus necessary for excessive algae is around 0.05 mg/L (Maidment, 1993). Although no official water-quality criterion for phosphorus has been established in the United States, total phosphorus should not exceed 0.05 mg/L in any stream or 0.025 mg/L within a lake or reservoir in order to prevent the development of biological nuisances (Maidment, 1993). ADEM established a reference standard for total phosphorus for level IV ecoregion 65f (including the Fish River watershed) of 0.04 mg/L. In many streams phosphorus is the primary nutrient that influences excessive biological activity. These streams are termed “phosphorus limited.”

Thirteen of 17 Fish River watershed monitoring sites had average phosphorus concentrations above the 0.05 mg/L standard (table 7). Sites FR18 (Corn Branch) and FR13 (Baker Branch) have the largest average phosphorus concentrations, 0.77 and 0.72 mg/L, respectively. Nine of 17 sites had sufficient phosphorus data to estimate annual loads. Although sites FR18 and FR13 have average concentrations more than two times higher than all other sites, individual concentrations, when plotted with discharge, did not form a discernable regression so that no annual phosphorus loads could be estimated. The largest phosphorus loads for tributaries were at sites FR17 (Turkey Branch), FR8 (Pensacola Branch), and FR10 (Polecat Creek at Baldwin Co. Road 55).

Table 7.—Measured total phosphorus concentrations and estimated loads in monitored streams in the Fish River watershed.

Monitored site	Average total phosphorus (mg/L)	Maximum total phosphorus (mg/L)	Minimum total phosphorus (mg/L) (% samples BDL)	Samples above 0.04 mg/L ADEM criterion (%)	Estimated total phosphorus load (t/yr)	Estimated normalized total phosphorus load ($t/mi^2/yr$)
FR1	0.20	0.70	BDL (83)	17	N/A	N/A
FR2	0.01	0.06	BDL (38)	50	N/A	N/A
FR3	BDL	BDL	BDL (100)	0	N/A	N/A
FR4	0.13	0.23	0.05 (0)	100	9.9	0.32
FR5	0.14	0.31	0.07 (0)	100	9.1	0.21
FR7	0.02	0.11	BDL (75)	25	1.5	0.16
FR8	0.10	0.20	BDL (25)	75	4.0	0.83
FR9	0.09	0.18	BDL (13)	100	15.1	0.22
FR10	0.12	0.46	BDL (25)	75	3.3	0.21
FR11	0.05	0.13	BDL (50)	50	N/A	N/A
FR12	0.08	0.31	BDL (33)	33	1.6	0.13
FR13	0.72	2.00	BDL (14)	14	N/A	N/A
FR14	0.19	1.48	BDL (56)	44	N/A	N/A
FR15	0.12	0.25	BDL (22)	78	N/A	N/A
FR16	0.32	1.68	0.05 (0)	100	3.1	0.63
FR17	0.20	0.42	0.08 (0)	100	10.4	1.8
FR18	0.77	1.57	0.31 (0)	100	N/A	N/A

DISSOLVED OXYGEN

Dissolved oxygen (DO) concentration is an essential constituent that affects the biological health and the chemical composition of surface waters. Biological processes, oxidation, and sediment loads all contribute to depletion of DO in surface water. The ADEM standard for DO in surface water classified as Fish and Wildlife is 5.0 mg/L except under extreme conditions when it may be as low as 4.0 mg/L. ADEM established a reference standard for dissolved oxygen for level IV ecoregion 65f (including the Fish River watershed), which is 6.94 mg/L.

The equilibrium concentration of DO in water that is in contact with air is primarily related to water temperature and barometric pressure and secondarily related to concentrations of other solutes (Hem, 1985). Equilibrium DO in water at 10° C and 25° C is 11.27 mg/L and 8.24 mg/L, respectively. DO concentrations in the project watersheds are significantly affected by water temperature, stream discharge, concentrations of organic material in the water, and oxygen-consuming pollutants. These factors are represented in table 8 where observed DO is compared to the 100 percent dissolved oxygen saturation for the observed stream temperature for each of the monitoring periods.

Dissolved oxygen was measured at Fish River watershed monitoring sites from February through May 2016. Stream water temperatures during the monitoring period varied from 17.3 to 23.2°C. Sites FR13 (Baker Branch) and FR16 (Waterhole Branch) had the lowest average DO (6.7 mg/L) and site FR2 (Threemile Creek) had the highest average DO (8.3 mg/L). Values lower than the ADEM Fish and Wildlife standard (5.0 mg/L) were measured at sites FR13 and FR16 (fig. 16). Fifteen of 17 sites had measured DO values less than the ADEM reference standard (6.94 mg/L) (table 8). Average DO and water temperature values were compared with atmospheric DO saturation (table 8). Sites FR13 (Baker Branch) and FR17 (Turkey Branch) had the lowest percentage of atmospheric saturation and site FR2 (Three Mile Creek) had the highest percentage (table 8). Currently, Baker Branch is on the 2016 ADEM 303-D list of impaired waters and is listed for organic enrichment (ADEM, 2016).

Table 8.—Dissolved oxygen measured in monitored streams in the Fish River watershed.

Site	Dissolved oxygen (mg/L)			Average DO saturation (% atmospheric saturation)
	Maximum	Minimum	Average	
FR1	10.8	6.5	7.8	84
FR2	9.2	7.7	8.3	91
FR3	9.1	6.7	7.8	85
FR4	8.5	7.0	7.9	87
FR5	9.0	6.8	7.7	84
FR7	9.1	6.9	7.7	85
FR8	10.5	6.7	8.0	87
FR9	9.6	6.0	8.0	88
FR10	8.5	6.6	7.6	82
FR11	9.2	5.7	7.7	85
FR12	9.9	6.8	8.0	88
FR13	8.7	4.5	6.7	74
FR14	8.6	6.3	7.4	80
FR15	9.1	6.7	7.9	87
FR16	9.3	4.1	6.7	74
FR17	9.0	5.2	7.0	77
FR18	10.0	5.9	8.0	87

PATHOGENS

In 1986 the US Environmental Protection Agency (EPA) recommended Escherichia coli (E. coli) as the bacterial indicator to assess concentrations of bacteria in fresh water. On December 11, 2009, ADEM adopted the E. coli criteria as the bacterial indicator for Alabama freshwater bodies. Criterion for acceptable bacteria levels for the Fish &Wildlife use classification (fresh water) is described in ADEM Admin. Code R. 335-6-10-.09(5)(e)7(i) and (ii) as follows:

7. Bacteria:

(i) In non-coastal waters, bacteria of the E. coli group shall not exceed a geometric mean of 548 colonies/100 ml; nor exceed a maximum of 2,507 colonies/100 ml in any sample.

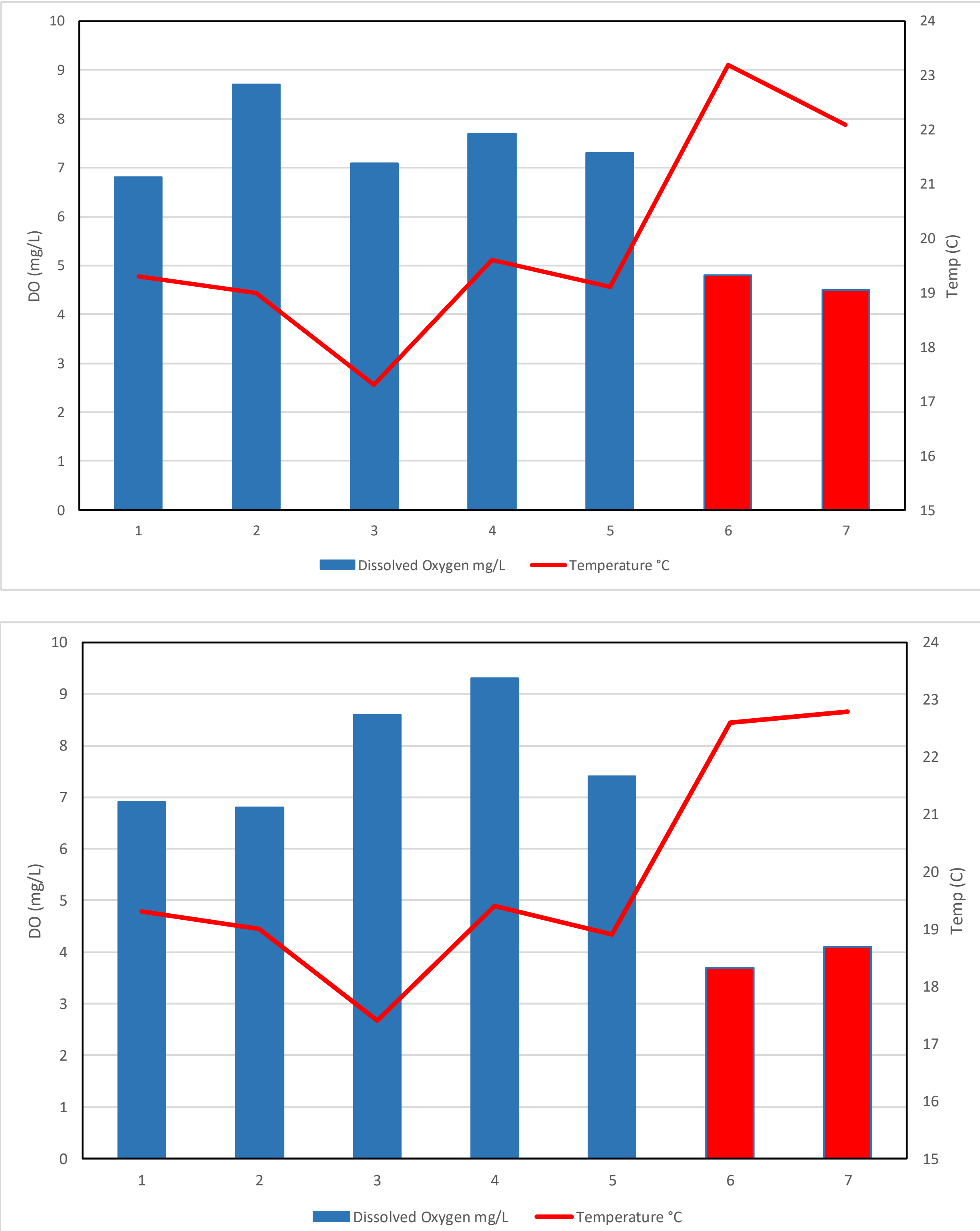


Figure 16.—Measured DO and water temperature at sites FR13 (Baker Branch) (upper graph) and FR16 (Waterhole Branch) (lower graph) (red bars below ADEM DO criterion).

Prior to the adoption of the E. coli criteria, fecal coliform was used as the bacterial indicator for freshwater. In 1996, the Geological Survey of Alabama (GSA) performed a water quality assessment for Fish River, including an evaluation of fecal coliform concentrations (ADEM, 2013). As a result, Fish River was placed on the 303(d) list for pathogens from Weeks Bay to its source north of I-10. A TMDL for E. coli was developed by ADEM in 2013 from data collected at station FI-1 (Fish River at Alabama Highway 104), which was sampled in 2010, 2011, and 2012 (ADEM, 2013). Subsequently, the Fish River listing for pathogens was removed from the 2014 303(d) list.

During this assessment samples were collected during a low discharge event on May 10, 2016 and a high discharge event on May 20, 2016. Samples were analyzed for E. coli by personnel from the Riviera Utilities Wolf Creek wastewater treatment plant, using the IDEXX Quanti Tray 2000 method. Experience shows that bacteria concentrations in streams at low flow are more likely to represent point sources, including municipal and industrial waste-water discharge and sewer line leaks, where impacts of runoff are minimized, whereas bacteria during high flow events are more representative of nonpoint sources maximized by overland runoff.

The IDEXX Quanti Tray 2000 method results in a most probable number (mpn) of E. coli colonies in a 100-ml sample. The maximum mpn is 2,419. Since the maximum mpn is only 3.5% lower than the ADEM single sample criterion maximum mpn of 2,507, for the purposes of this assessment, a value of >2,419 was considered to exceed the criterion. Sites FR1 and FR14 were not sampled during the low discharge event. Sites FR3 (Bay Branch) and FR18 (Corn Branch) had the highest mpn for the low discharge event with 344 and 272, respectively (fig. 17). Neither site has treated wastewater effluent upstream, but both sites have significant upstream urban and residential development in Spanish Fort and Loxley. Eight of 17 sites had mpn >2,419 during the high discharge event. Five other sites had mpn >1,000. The lowest mpn were from sites FR13 (Baker Branch) and FR14 (Fish River at Baldwin Co. Road 32), with 317 and 157 mpn, respectively (fig. 17).

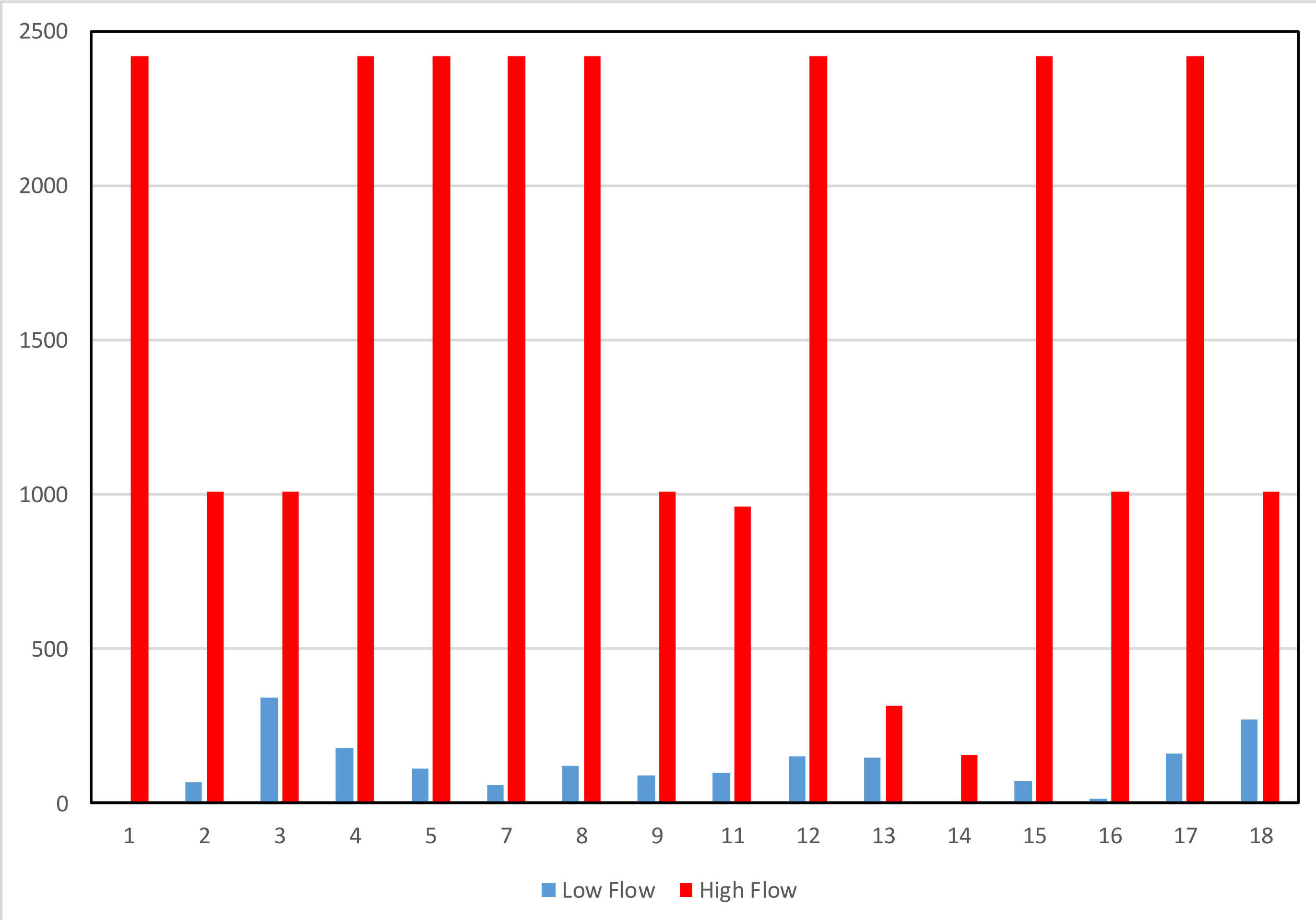


Figure 17.—E. coli mpn for low and high discharge events at Fish River watershed monitoring sites.

CONCLUSIONS AND SOURCES OF WATER-QUALITY IMPACTS

Evaluations of sediment loads, water-quality analyses, land-use data, and aerial imagery led to conclusions of probable sources of water quality and habitat impairments in the Fish River watershed. Stream flow conditions are important factors that influence erosion, sediment transport, and attenuation of nutrients and other contaminants that impact water quality in a watershed. Topographically, the Fish River watershed can be divided into two regions; north of US Highway 90, characterized by higher gradients, and significantly greater forest coverage; and south of US Highway 90, characterized by lower gradients, anastomosing channels, forested flood plains, extensive row crop agriculture in upland headwaters areas, extensive wetlands, and tidal impacts in the downstream part of the watershed. The watershed is primarily rural but impacted by land-use conversion from agriculture to commercial and residential. Urban impacts to tributaries come from the towns of Loxley, Robertsdale, Silver Hill, and Fairhope.

Four streams in the Fish River watershed are currently on the ADEM 303-D list of impaired waters. Baker Branch is listed for organic enrichment related to cattle grazing and Fish River, Polecat Creek, and Cowpen Creek are listed for metals (mercury) caused by atmospheric deposition (ADEM, 2016). DO and phosphorus concentrations measured during the project period confirm the Baker Branch listing. However, water samples collected during the project period were not analyzed for metals. No streams in the watershed are listed for pathogens or sedimentation.

Suspended sediment loads in Fish River increased from upstream to downstream from 113 t/yr (33.2 t/mi^2/yr) in headwaters site FR1 (Fish River at I-10) to 24,295 t/yr (201 t/mi^2/yr) at site FR14, just upstream from Weeks Bay. Sites FR8 (Pensacola Branch), FR11 (Polecat Creek at Baldwin Co. Road 9), and FR12 (Cowpen Creek) had the largest suspended sediment loads for tributary watersheds, 3,732, 3,090, and 2,355 t/yr, respectively. When loads are normalized relative to drainage area, sites FR8, FR18 (Corn Branch), and FR 12 have the largest suspended sediment loads; 778, 689, and 201 t/mi^2/yr, respectively.

Six sites had measurable bed sediment. Fish River sites FR4, FR5, and FR9 had bed sediment loads of 3,180, 10,231, and 13,000 t/yr, respectively. Normalized loads are 103, 231, and 190 t/mi^2/yr, respectively. Loads for tributary sites FR7 (Perone Branch), FR8, and FR12 are 1,300, 6,012, and 4,085 t/yr. Normalized loads are 143, 1,253, and 346 t/mi^2/yr, respectively.

Due to relatively large drainage area, discharge, and cumulative sediment, main stem Fish River sites FR5, FR9, and FR14 have the largest total sediment loads. However, when total sediment loads are normalized relative to drainage area, tributary sites FR8 (Pensacola Branch), FR18 (Corn Branch), and FR12 (Cowpen Creek) have the largest loads. On average, bed sediment makes up 64% of total sediment loads for streams with measurable bed sediment.

Without human impact, watershed erosion rates, called the geologic erosion rate, would be 64 t/mi^2/yr (Maidment, 1993). Normalized sediment loads show that 13 of 17 monitored watersheds were from 1.7 to 31.7 times greater than the geologic erosion rate.

Only headwaters sites FR1 (Fish River at I-10), FR2 (Three-Mile Creek), and FR3 (Bay Branch) were at or below the geologic erosion rate.

Site FR8 (Pensacola Branch) had the largest normalized estimated sediment loads in the Fish River watershed. An evaluation of aerial imagery (Google Earth, 2016) indicates that the northern part of the east trending headwaters of Pensacola Branch is dominated by row crop agriculture (fig. 18). The upland row crop fields are drained by a series of ditches that form the headwaters of the stream and are incised, in part, and have highly eroded stream banks that obviously contribute excessive amounts of sediment during large rain events. The southern part of the headwaters is dominated by several residential developments that provide a high volume of runoff to the stream (fig. 18).

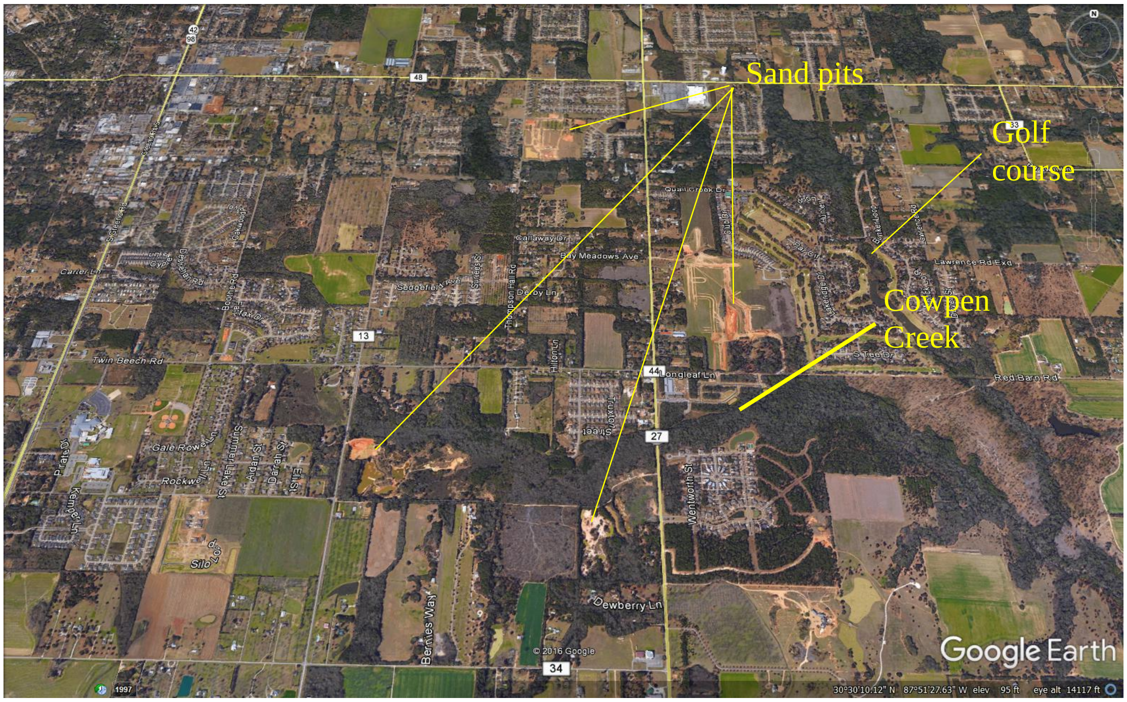
Figure 18.—Aerial imagery of the headwaters of Pensacola Branch.

Sediment loads at site FR18 (Corn Branch) were only exceeded by those at site FR8. Aerial imagery reconnaissance revealed that Corn Branch drains upland row crop agricultural fields at its headwaters between I-10 and US Highway 90. Further downstream, south of Baldwin County Road 66, the stream drains row crop fields and a large predominantly barren area with some recently clear cut forest. The stream channel, downstream from Road 66 becomes incised with highly eroded stream banks and several highly eroded stream crossings. This appears to be the obvious source for most of the excessive sediment measured further downstream at site FR18. There are also several sand pits on the east side of the stream downstream from the monitoring site that probably contribute additional sediment.

Figure 19.—Aerial imagery of the Corn Branch headwaters.

The third largest sediment loads were estimated at site FR12 (Cowpen Creek). An evaluation of aerial imagery indicates that the headwaters are dominated by large residential developments, at least four sand mining areas, and a golf course (fig. 20 upper). Further downstream, immediately upstream from the monitoring site, the watershed is dominated by row crop agriculture and a large area that appears to have been recently clear cut (fig. 20 upper).

Comparisons of sediment transport rates and water-quality data in watersheds in Baldwin and Mobile Counties indicate that streams in the Fish River watershed have moderate-sized sediment loads and generally good water quality. This is attributed to the relatively rural setting, extensive wetlands and forests, and use of winter cover crops on agricultural fields. However, the largest total sediment loads in Fish River watershed monitoring sites (Pensacola Branch, Corn Branch, and Cowpen Creek) are comparable to loads in D'Olive and Tiawasee Creeks.



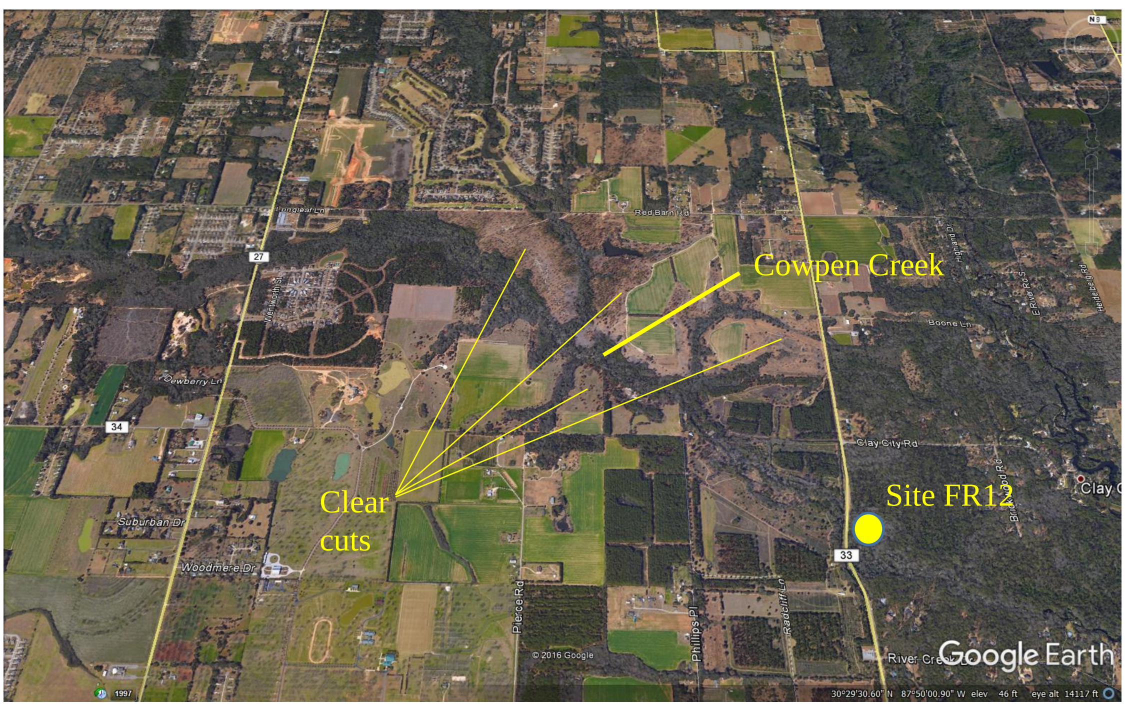


Figure 20.—Aerial imagery of the Cowpen Creek headwaters (upper) and downstream reach (lower).

Bed sediment samples were collected at sites FR4 (Fish River at Baldwin County Road 64), FR7 (Perone Branch), and FR8 (Pensacola Branch). Wet samples were weighed to determine the mass in pounds per cubic ft (lbs/ft^3), which was 142, 148, and 154 lbs/ft^3, respectively. Samples were sieved to determine sediment grain sizes. Grain size classes were dominated by medium- and coarse-grained sands, which are sourced from erosion of undifferentiated Miocene and the Citronelle Formations.

Water samples were collected from January through May 2016 at Fish River watershed monitoring sites for discharge events from base flow to bank full. Samples were analyzed for nitrate as N and total phosphorus. The critical nitrate concentration in surface water for excessive algae growth is 0.5 mg/L. The largest loads were at main stem Fish River sites FR4, FR5, FR9, and FR14, with 5.6, 10.2, 17.2, and 18.2 t/yr, which shows the accumulation of nitrogen from upstream to downstream. However, the largest normalized annual nitrate loads were estimated at tributary sites FR8 (Pensacola Branch), 0.46 tons/mi^2/yr and FR10 (Polecat Creek at Baldwin County road 55), 0.36 tons/mi^2/yr.

Thirteen of 17 Fish River watershed monitoring sites had average phosphorus concentrations above the 0.05 mg/L standard. Sites FR18 (Corn Branch) and FR13 (Baker Branch) have the largest average phosphorus concentrations, 0.77 and 0.72 mg/L, respectively. Nine of 17 sites had sufficient phosphorus data to estimate annual loads. Although sites FR18 and FR13 have average concentrations more than two times higher than all other sites, individual concentrations, when plotted with discharge, did not form a regression that could be used to estimate annual phosphorus loads, although it can be reasonably assumed that these sites would have the largest phosphorus loads. Of the nine sites with estimated phosphorus loads, the largest were at sites FR17 (Turkey Branch), FR8 (Pensacola Branch), and FR10 (Polecat Creek at Baldwin Co. Road 55), with 10.4, 4.0, and 3.3 t/yr, respectively. When loads are normalized relative to drainage area, sites FR17, FR16 (Waterhole Branch), and FR8 have the largest loads, with 1.8, 0.83, and 0.63 tons/mi^2/yr. As with nitrogen, the major source of phosphorus is most likely from agriculture and urban development at higher elevations along drainage divides in headwaters of Fish River tributaries.

Dissolved oxygen was measured at Fish River watershed monitoring sites from February through May 2016. As stream water temperatures during the monitoring period increased from winter to spring and varied from 17.3 to 23.2°C, DO concentrations decreased. Sites FR13 (Baker Branch) and FR16 (Waterhole Branch) had the lowest average DO (6.7 mg/L) and site FR2 (Threemile Creek) had the highest average DO (8.3 mg/L). Values lower than the ADEM Fish and Wildlife standard (5.0 mg/L) were measured at sites FR13 and FR16. Fifteen of 17 sites had measured DO values less than the ADEM reference standard (6.94 mg/L).

No apparent correlation between nitrate and DO was observed. However, a good correlation was observed between DO and phosphorus, where the lowest DO concentrations corresponded with some of the highest phosphorus concentrations at sites FR13 and FR16.

Samples were collected at Fish River watershed monitoring sites and analyzed for E. coli during a low discharge event on May 10, 2016 and a high discharge event on May 20, 2016. Sites FR3 (Bay Branch) and FR18 (Corn Branch) had the highest mpn for the low discharge event with 344 and 272, respectively. Eight of 17 sites had mpn >2,419 during the high discharge event.

When all assessed constituents are considered with respect to water quality and potential remediation and restoration, sites FR8 (Pensacola Branch), FR12 (Cowpen Creek), FR18 (Corn Branch), FR13 (Baker Branch), FR17 (Waterhole Branch), and FR16 (Turkey Branch) have the highest degree of impairment and should be considered primary targets for various types of remediation and restoration.

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APPENDIX A

FIELD AND ANALYTICAL DATA

Fish River at I-10		30.65289									
		87.79173									
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR1	01/05/16	18.5	12.9	19	8	5.9		2		<0.3	0.729
FR1	01/22/16	19.4	13.3	17	10	5.8		3.0		<0.3	<.05
FR1	02/03/16	21.5	15.2	29	8	7.0		2		<0.3	0.306
FR1	03/11/16	110	18.7	31	32	5.5	7.5	10.0		<0.3	0.351
FR1	03/19/16	140	17.8	30	24	5.1	6.5	9.2		<0.3	<.05
FR1	03/28/16	69	17.7	25	18	5.5	10.8	2		<0.3	<.05
FR1	04/01/16	88	20.2	25	21	5.7	7.6	5.6		<0.3	<.05
FR1	04/01/16	205	18.9	24	30	5.7	7.2	16.0			
FR1	05/20/16	80	20.9	23	31	5.2	7.4	6.0	>2419.6		

Three Mile Creek		30.65154	Area									
		87.78061	3.4 mi^2									
Site	Date	Discharge	Water Level	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	ft	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR2	01/05/16	10.1	28	11.7	29	27	5.6		2		0.527	<.05
FR2	01/22/16	120	26.8	13.1	22	83	5.7		52.8		0.526	0.064
FR2	02/03/16	48.6	25.3	15.1	37	45	7.2		31.2		0.563	<.05
FR2	03/11/16	69	24.6	18.9	33	40	6.3	7.8	20.8		<.3	<.05
FR2	03/19/16	50	23.8	17.9	161	21	5.5	9.2	6		<.3	<.05
FR2	04/01/16	117	24.7	20.7	29	43	6.2	8.5	33.6		<.3	<.05
FR2	04/01/16	100	23.8	18.7	24	47	6.1	7.7	39			
FR2	05/10/16	8		21.3	45	8	5.2	8.5	3	67.6		
FR2	05/20/16	107	25.5	21.6	51	83	5.2	8.0	41	1011.2		

Bay Branch at US Hwy 90		30.65289									
		87.79173									
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR3	01/05/16	24	11.3	22	11	5.6		2		<.3	<.05
FR3	01/22/16	16	13	17	5	5.9		2.4		<.3	<.05
FR3	02/03/16	9.5	15.8	30	8	7.0		2		<.3	<.05
FR3	03/11/16	115	19.0	27	25	5.9	6.9	4.8		<.3	<.05
FR3	03/19/16	4.2	17.6	27	11	5.6	8.5	2		<.3	<.05
FR3	03/28/16	100	18.2	33	25	6.2	9.0	6.4		<.3	<.05
FR3	04/01/16	54	20.8	28	10	6.0	9.1	4		<.3	<.05
FR3	04/01/16	105	18.8	23	17	5.9	6.8	5.5			
FR3	05/10/16	28	21.0	29	6	4.9	7.5	3.0	343.6		
FR3	05/20/16	80	21.0	22	16	5.4	6.7	5.0	1011.2		

Fish River at Baldwin Co Road 64			30.60317	Area									
			87.81701	30.8 mi^2									
Site	Date	Discharge	Water Level	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Bed Sediment	Nitrate	Total Phosphorus
		cfs	ft	°C	mS/cm	NTU		mg/L	mg/L	MPN	T/d	mg/L	mg/L
FR4	01/05/16	40	17.9	12.8	57	8	5.7		1		1.5	1.460	0.098
FR4	01/22/16	275	16.3	13.5	34	66	5.8		68.0		25	0.937	0.123
FR4	02/03/16	104	17.5	15.3	50	45	6.9		26.4		13.8	1.170	0.126
FR4	02/22/16	42	17.9	18.8	62	9	6.1	7.7	4.4		2.1	0.146	0.173
FR4	03/11/16	656	14.0	19.7	36	136	6.5	7.5	84.0		45	0	0.231
FR4	03/19/16	200	14.1	17.8	34	43	5.7	8.4	19.2			0.358	0.052
FR4	03/27/16	180	14.0	19.5	38	41	6.3	8.3	27.6			0	0.070
FR4	04/01/16	300	15.0	20.6	37	76	6.3	8.1	42.0		40	0.387	0.148
FR4	04/01/16	736	13.3	19.3	32	121	6.2	7.0	85.0		50	4.458	1.021
FR4	05/10/16	50	17.7	21.0	48	12	5.3	8.5	6.0	178.5	4	0.56	0.130
FR4	05/20/16	350	16.3	21.1	43	85	5.9	7.9	60.0	>2419.6			

Fish River at Baldwin Co Road 54			30.65289	Area								
			87.79173	44.4 mi^2								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Bed Sediment	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	T/d	mg/L	mg/L
FR5	01/05/16	73.7	13.6	56	9	5.7		4.8		23.6	1.770	0.098
FR5	01/22/16	300	15.1	39	50	5.7		40.0		50	1.250	0.096
FR5	02/03/16	89.1	16.1	55	17	7.0		11.6		25	1.430	0.071
FR5	02/23/16	65	18.6	63	14	6.1	7.4	8.0		18	2.000	0.122
FR5	03/11/16	490	18.9	36	99	6.4	7.6	50.0		70	0.434	0.153
FR5	03/19/16	539	17.8	39	56	5.6	6.8	34.8		76	0.379	0.066
FR5	03/27/16	850	19.3	47	125	6.6	9.0	68.0		87	0.340	0.190
FR5	04/01/16	1,936	19.1	32	275	6.5	7.8	124.0		97	0.000	0.309
FR5	05/10/16	75	21.6	51	11	6.2	7.8	10.0	113.7	25	7.603	1.105
FR5	05/20/16	148	21.1	51	52	6.2	7.5	22.0	>2419.6	45		0.140
FR5	05/23/16	60						8.0		16		

Perone Branch at AL Hwy 104			30.54548									
			87.78785									
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Bed Sediment Load	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	T/d	mg/L	mg/L
FR7	01/06/16	17	14.3	46	5	6.4		2		1.6	1.560	0
FR7	01/22/16	45	15.2	35	52	5.8		30		13	1.150	0
FR7	02/03/16	26	17	51	16	6.6		6.8		9.2	1.280	0
FR7	02/23/16	20	19.0	57	8	6.3	7.4	2		2.0	1.590	0
FR7	03/11/16	78	19.2	43	66	6.4	7.1	47.5		17.0	0.657	0.055
FR7	03/19/16	60	18.2	50	32	6.1	6.9	14.8		15.0	0.680	0
FR7	03/27/16	100	19.5	48	67	6.5	8.3	42.8		17.7	0.472	0
FR7	04/01/16	1,085	18.8	31	198	6.4	9.1	104.0		35.0	0.000	0.114
FR7	5/10/2016	25	22.5	50	6	6.4	8.4	5.0	60.5			
FR7	5/20/2016	40	21.4	47.0	31	6.2	7.0	20.0	>2419.6			

Pensacola Branch at Baldwin Co Road 48			30.6529									
			87.7917									
Site	Date	Discharge	Temperat	Conducta	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Bed Sediment	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	T/d	mg/L	mg/L
FR8	01/06/16	4.1	13.6	46	16	6.4		5.6		4.8	1.07	0
FR8	01/22/16	64		34	139	5.7		139.0		28	1.16	0.101
FR8	02/03/16	65		49	115	6.6		113.0		29.3	1.12	0.099
FR8	02/23/16	10.4	18.3	59	99	6.1	7.0	61.6		5.7	1.08	0
FR8	03/11/16	211	18.9	39	190	6.5	7.7	142.0		100	0.338	0.182
FR8	03/19/16	205	17.7	46	185	6.1	7.3	201.0		95	0	0.121
FR8	03/27/16	35	19.4	52	142	6.7	10.5	92.4		15	0	0.090
FR8	04/01/16	668	18.9	26	504	6.4	8.2	464.0		400	0	0.197
FR8	05/10/16	40	22.3	48	15	6.4	8.8	100.0	119.8	20		
FR8	05/20/16	58	21.5	47	47	6.2	6.7	110.0	>2419.6	25		

Fish River at Baldwin Co Road 48			30.65289									
			87.79173									
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Bed Sediment	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	T/d	mg/L	mg/L
FR9	01/06/16	102	13.7	49	9	6.5		4.0		3.2	1.660	0
FR9	01/22/16	221		40	29	5.7		40.0		11	1.510	0.068
FR9	02/03/16	210		55	22	6.9		19.6		10.6	1.530	0.059
FR9	02/23/16	400	20.0	71	40	6.1	9.6	19.2		23	1.120	0.069
FR9	03/11/16	1,600	19.2	47	160	6.5	8.6	104.0		27	0.762	0.178
FR9	03/19/16	600	17.8	42	60	6.0	8.5	37.6		26	0.477	0.071
FR9	03/27/16	1,100	19.3	46	105	6.6	8.9	65.6		26	0.439	0.105
FR9	04/01/16	2,399	19.1	30	260	6.4	7.1	108.0		32.0	0.000	0.126
FR9	05/10/16	150	21.8	51	11	6.3	7.6	20.0	90.6			
FR9	05/20/16	450	21.4	50	50	6.3	6.0	35.0	1011.2			

Polecat Creek at Baldwin Co Road 55			30.65289								
			87.79173								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	Bed Sediment	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	T/d	mg/L	mg/L
FR10	01/06/16	22.1	11.7	59	6	6.5		2	0.58	1.460	0
FR10	01/22/16	500		39	86	5.8		73.6		0.978	0.126
FR10	02/03/16	110		69	36	6.5		25.1		1.050	0
FR10	02/23/16	274	19.2	57	52	6.2	7.6	40.4		0.843	0.464
FR10	03/11/16	290	19.2	47	81	6.5	8.5	31.2		0.412	0.074
FR10	03/19/16	200	17.7	49	57	6.3	6.6	31.2		0.420	0.050
FR10	03/27/16	207	19.5	54	46	6.7	8.1	18.0		0.000	0.081
FR10	04/01/16	740	19.2	33	126	6.6	7.1	56.8		0.000	0.127

Polecat Creek at Baldwin Co Road 9			30.65289								
			87.79173								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR11	01/06/16	100	12.8	52	23	6.5		2		1.430	0
FR11	01/22/16	152		43	23	5.7		34.8		1.270	0
FR11	02/03/16	119		58	22	6.9		25.4		1.110	0
FR11	02/23/16	41	20.0	55	30	6.4	8.6	14.8		1.170	0
FR11	03/11/16	350	19.3	49	95	6.4	7.2	71.2		0.448	0.082
FR11	03/19/16	275	17.9	50	54	6.3	6.8	52.4		0.570	0.056
FR11	03/27/16	175	19.3	50	65	6.6	9.2	36.2		0.378	0.091
FR11	04/01/16	1,595	19.3	34	125	6.3	8.1	90		0.000	0.127
FR11	05/10/16	40	22.2	54	8	6.4	8.1	16	98.8		
FR11	05/20/16	130	22.1	56	22	6.4	5.7	30	960.6		

Cowpen Creek at Baldwin Co 33												
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Bed Sediment Load	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	T/d	mg/L	mg/L
FR12	01/12/16	7.1		57	4	6.5		2		1.4	1.37	0
FR12	01/22/16	120		39	103	5.7		97.2		12	0.498	0
FR12	02/03/16	82		54	72	6.6		45.2		18.9	0.514	0.052
FR12	02/23/16	35	19.9	55	70	6.4	9.2	29.2		11.7	0.643	0
FR12	03/11/16	353	19.3	40	181	6.7	8.1	100		140	0.448	0.082
FR12	03/12/16	71	19.2	50	99	6.8	7.2	55		22	0.5	0.05
FR12	03/19/16	153	18.1	52	130	6.4	6.8	90.0		45	0	0.104
FR12	03/28/16	289	19.3	51	155	6.7	9.9	100		100	0	0.085
FR12	04/01/16	630	19.1	30	170	6.5	7.2	113.0		300	0	0.309
FR12	05/10/16	50	22.4	42	6	5.9	8.3	45	151.5	15		
FR12	05/20/16	52	21.7	45	39	5.8	7.2	48.0	>2419.6			

Baker Branch at Baldwin Co 55			30.47590								
			87.75077								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR13	01/06/16	7.5	11.4	174	5	6.5		2		1.450	<.05
FR13	01/22/16	37		55	73	5.6		30.0		1.090	0.112
FR13	02/23/16	35	19.3	67	47	6.2	6.8	18.8		0.955	0.461
FR13	03/11/16	155	19.0	44	140	6.6	8.7	51.6		<.03	1.850
FR13	03/19/16	150	17.3	51	119	6.5	7.1	46.4		<.03	0.254
FR13	03/27/16	70	19.6	52	61	6.8	7.7	18.4		<.03	2.000
FR13	04/01/16	430	19.1	35	222	6.6	7.3	153.0		<.03	0.355
FR13	05/10/16	30	23.2	63	6	5.9	4.8	17	148.3		
FR13	05/20/16	32	22.1	66	19	5.7	4.5	18	317.4		

Fish River at Baldwin Co Road 32			30.47413								
			87.80365								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR14	01/06/16	Tidal	13.1	6,890	19	6.1		9.2		<.3	<.05
FR14	01/22/16	200		58	1	5.7		1		1.630	<.05
FR14	02/03/16	400		68	8	6.4		2.4		1.550	<.05
FR14	02/23/16	450	19.7	63	10	6.3	8.0	2		1.530	<.05
FR14	03/11/16	1100	19.4	46	97	6.5	7.3	42.0		0.631	0.078
FR14	03/12/16	900	19.4	46	82	6.7	7.8	40.0		0.550	0.07
FR14	03/19/16	800	17.8	49	50	6.2	7.0	16.8		0.546	<.05
FR14	03/28/16	1024	19.2	49	74	6.6	8.6	31.2		0.406	0.079
FR14	04/01/16	1600	19.0	33	294	6.4	7.0	295.0		<.3	1.48
FR14	05/20/16	400	22.6	63	10	5.8	6.3	7.0	156.5		

Green Branch at Baldwin Co Danne Road			30.44985								
			87.83552								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR15	01/06/16	1.8	9.0	64	11	6.1		2		<.3	<.05
FR15	01/22/16	250		65	140	5.6		77.6		0.381	0.105
FR15	02/03/16	3.2		79	20	6.7		8.8		<.3	<.05
FR15	02/23/16	5	19.5	72	40	6.7	6.7	11.6		0.302	0.053
FR15	03/11/16	54	19.0	47	86	6.7	8.7	22.8		<.3	0.243
FR15	03/19/16	163	17.3	62	88	6.6	8.6	33.6		<.3	0.118
FR15	03/28/16	80	19.1	61	58	6.9	7.8	14.4		<.3	0.152
FR15	04/02/16	300	18.7	34	137	6.8	9.1	90.0		<.3	0.248
FR15	05/10/16	3.1	22.1	76	15	6.3	7.6	8.0	71.2		
FR15	05/20/16	3	22.0	75	39	5.9	7.0	7.8	>2419.6		

Waterhole Branch at AL Hwy 101			30.44560								
			87.85234								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR16	01/06/16	0.3	7.6	64	26	6		2		<.3	0.055
FR16	01/22/16	72		92	57	6		30.0		0.386	0.096
FR16	02/03/16	21.3		73	20	7		12.0		<.3	0.050
FR16	02/23/16	36	19.3	66	37	6	6.9	22.0		<.3	0.053
FR16	03/11/16	430	19.0	50	89	7	6.8	35.0		<.3	1.680
FR16	03/19/16	350	17.4	59	83	7	8.6	33.6		<.3	0.174
FR16	03/28/16	35	19.4	63	48	7.0	9.3	12.8		<.3	0.165
FR16	04/02/16	540	18.9	38	98	6.8	7.4	37.2		<.3	0.244
FR16	05/10/16	18	22.6	69	8	6.2	3.7	15.0	15.8		
FR16	05/20/16	21	22.8	65	22	6.0	4.1	18.0	1011.2		

Turkey Branch at AL Hwy 181			30.42169								
			87.84381								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR17	01/06/16	0.4	7.6	65	26	5.9		4.0		<.3	0.079
FR17	01/22/16	53		43	36	5.6		32.8		0.365	0.135
FR17	02/03/16	128		65	32	6.7		20.0		0.333	0.102
FR17	02/23/16	326	19.1	58	73	6.2	6.9	28.8		0.428	0.085
FR17	03/11/16	600	19.0	51	125	6.7	6.5	20.8		<.3	0.232
FR17	03/19/16	1,224	17.6	61	108	6.5	6.7	48.0		<.3	0.329
FR17	03/28/16	300	19.0	67	44	6.9	7.7	15.6		<.3	0.253
FR17	04/02/16	1,824	18.6	41	164	6.8	9.0	95.6		<.3	0.415
FR17	05/10/16	120	22.9	64	11	6.4	5.2	19.0	161.6		
FR17	05/20/16	450	22.3	59	66	6.0	6.9	22.0	>2419.6		

Corn Branch at Baldwin Co Road 64			30.65289								
			87.79173								
Site	Date	Discharge	Temperature	Conductance	Turbidity	pH	Dissolved Oxygen	TSS	E-coli	Nitrate	Total Phosphorus
		cfs	°C	mS/cm	NTU		mg/L	mg/L	MPN	mg/L	mg/L
FR18	02/03/16	70		98	120	6.9		55.0		0.892	0.580
FR18	02/24/16	100	19.4	81	136	6.7	7.2	45.2		0.951	0.409
FR18	03/11/16	80	19.3	53	111	7.1	7.7	40.0		<.3	1.570
FR18	03/19/16	80	17.3	74	132	6.7	8.6	59.6		<.3	0.495
FR18	03/27/16	50	20.3	74	84	7	9.7	28.8		<.3	0.309
FR18	04/01/16	60	20.6	69	104	6.9	10.0	50.0		<.3	1.260
FR18	04/01/16	504	18.1	47	273	6.8	8.2	110.0			4.623
FR18	05/10/16	10	20.6	75	18	5.8	5.9	12.0	272.3		
FR18	05/20/16	110	21.1	102	152	6.2	7.2	57.0	1011.2		