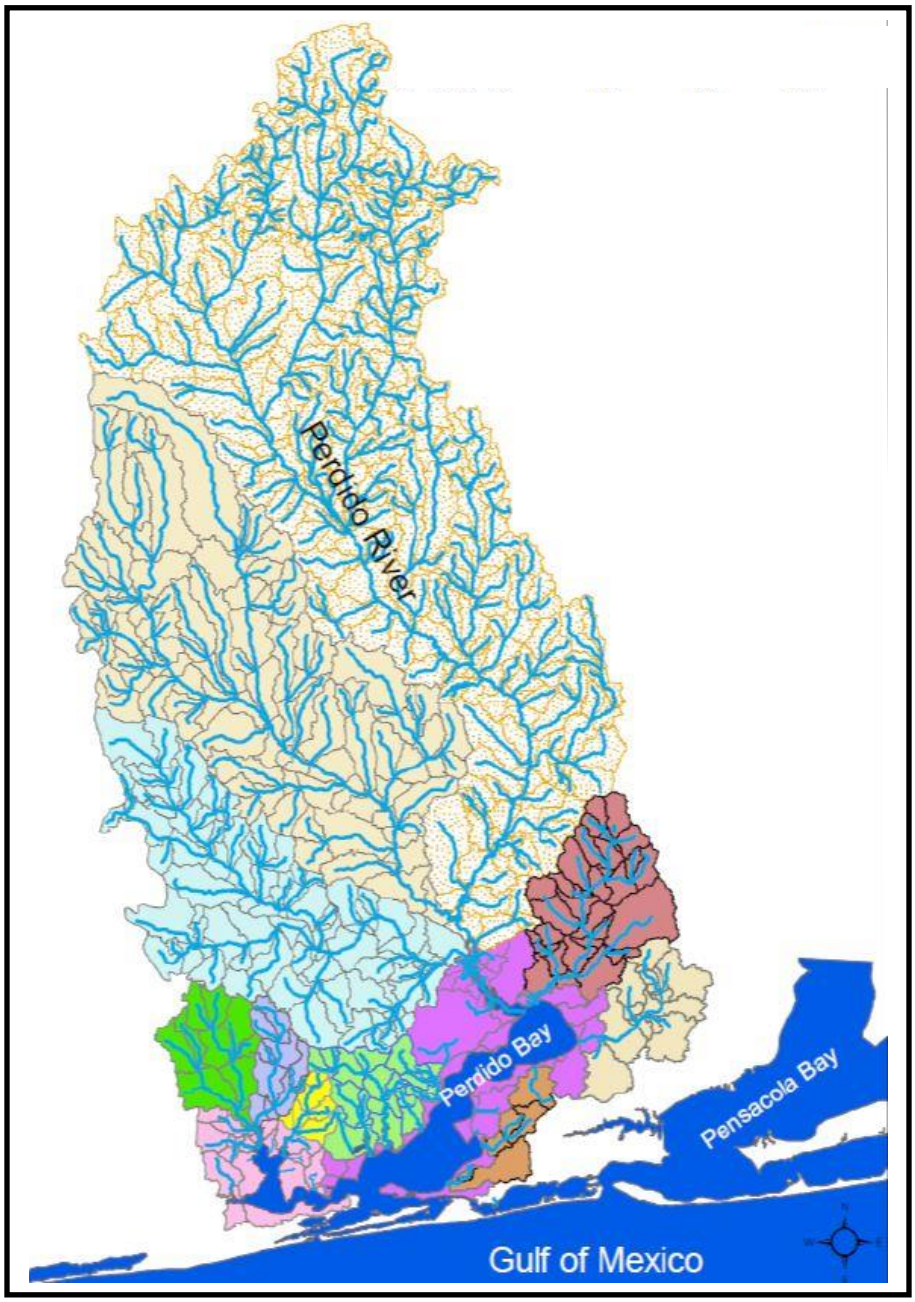
PRE-RESTORATION ANALYSIS OF DISCHARGE, SEDIMENT TRANSPORT RATES, WATER QUALITY, AND LAND-USE IMPACTS IN WATERSHEDS ALONG PERDIDO BAY, BALDWIN COUNTY, ALABAMA



Mobile Bay National Estuary Program

BARRY A. VITTOR AND ASSOCIATES

PRE-RESTORATION ANALYSIS OF DISCHARGE, SEDIMENT TRANSPORT RATES, WATER QUALITY, AND LAND-USE IMPACTS IN WATERSHEDS ALONG PERDIDO BAY, BALDWIN COUNTY, ALABAMA

By

Marlon R. Cook,
Barry A. Vittor and Associates, Inc.

Funding for this project was provided by the
Mobile Bay National Estuary Program

December, 2023

TABLE OF CONTENTS

ILLUSTRATIONS

TABLES

INTRODUCTION

The Perdido River and Perdido Bay form the Alabama-Florida border, separating Baldwin County, Alabama and Escambia County, Florida. Alabama and northwest Florida coastal counties are experiencing rapid economic and population growth. However, with rapid growth comes quality of life issues, including traffic, increasing water demand, loss of natural landscapes, and watershed degradation. When activities related to population and economic growth combine 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 in Alabama coastal watersheds have shown dramatic increases in nutrient rich runoff, sediment transport, and loss of biological habitat in streams downstream from areas affected by rapid runoff and erosion. These deleterious impacts originate from land uses dominated by impervious surfaces, deforestation, and transition of land uses from vegetated and agriculture to commercial and residential. Other areas are relatively unimpacted by land-use change and are characterized by natural landscapes dominated by forests and wetlands. The Perdido Bay watershed is an area with beautiful natural coastal landscapes and areas of rapidly expanding residential and commercial development. 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 nutrient loads and sediment transport rates for tributaries to Perdido Bay, including the Perdido River and nine tributaries in Baldwin County, Alabama (fig. 1). These data are used to quantify water quality impacts and to support development of a watershed management plan, designed to preserve, protect, and restore watersheds along the western shore of Perdido Bay.

ACKNOWLEDGMENTS

Ms. Roberta Swann, Director, and Mr. Jason Kudulis, Restoration Program Lead, and Mr. Christian Miller, Public Sector Program Lead, Mobile Bay National Estuary Program, provided administrative and coordination assistance for the project.

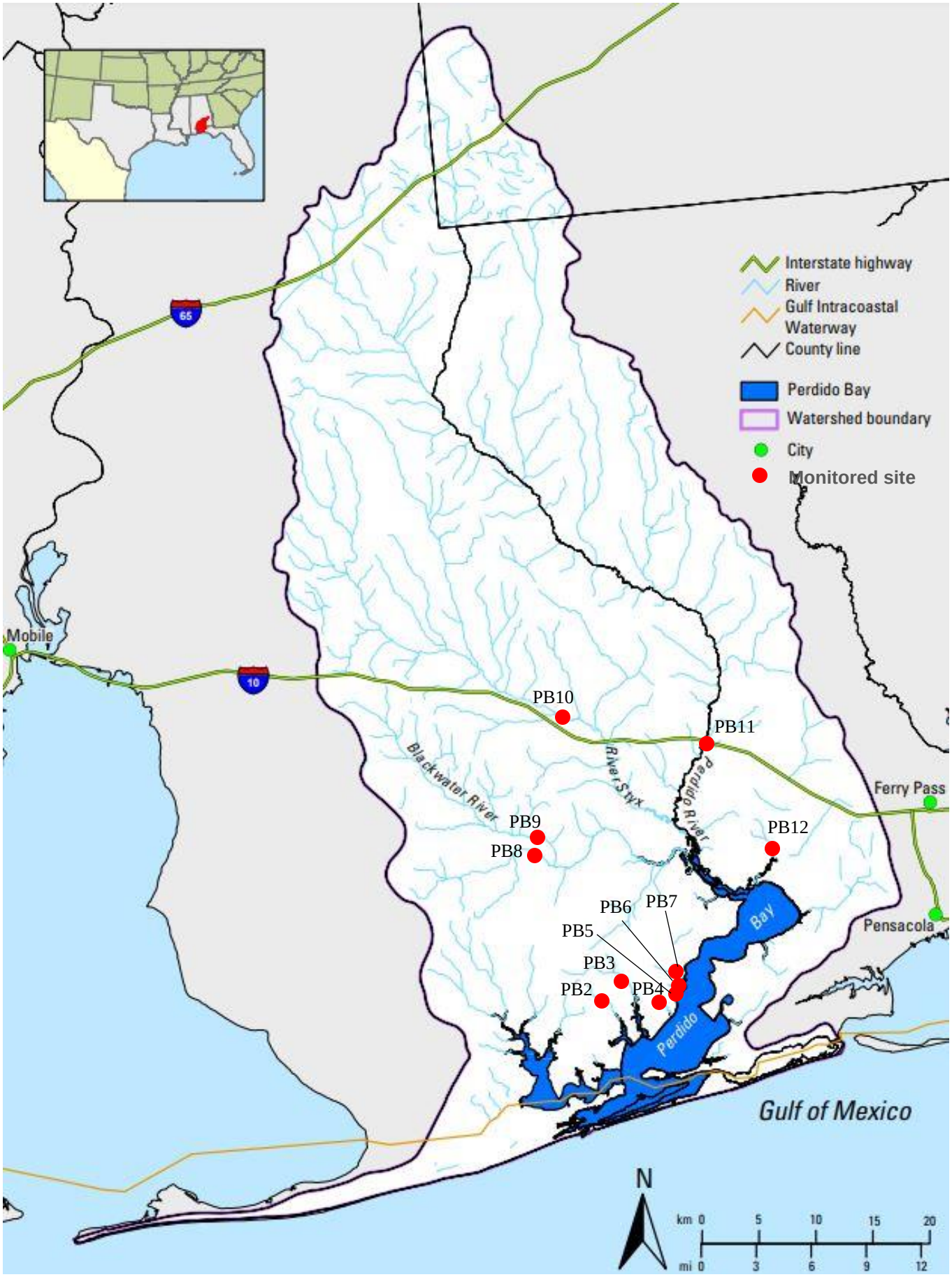


Figure 1.—Perdido Bay watershed with monitored sites (modified from Kirschenfeld and others, 2006).

PROJECT AREA

Perdido River and Bay watershed covers 1,165 square miles, with 70 percent in Alabama. Average discharge of the Perdido River is 783 cubic feet per second (cfs) or 506 million gallons per day (mgd) (Northwest Florida Water Management District, 2021) (fig. 1). Total fresh-water flow into Perdido Bay is estimated to be 1.42 billion gallons per day (USEPA, 1999). The project area has 10 monitoring sites, extending on the Alabama side from Perdido River at I-10 southward to Palmetto Creek at John Bloch Road, 6.8 miles north of the Gulf of Mexico (fig. 1). Elevations in the project area vary from sea level along the Perdido Bay shoreline to about 100 feet above mean sea level (ft MSL) at Seminole, along the Styx River in Baldwin County, Alabama.

The Alabama Department of Environmental Management (ADEM) 303(d) list of impaired waters in Alabama (ADEM, 2020) includes five streams and the upper part of Perdido Bay (north of the Lillian bridge). Streams included on the list addressed in this report are Styx River, Blackwater River, and Perdido River, which are listed for atmospheric deposition of mercury.

PROJECT MONITORING STRATEGY AND SITE CHARACTERISTICS

The strategy employed for the Perdido Bay project was to select monitoring sites on all accessible tributary streams to Perdido Bay (table 1). Each stream reach was monitored over a wide range of measured discharge from base flow to high flow, from January to July 2020, including tropical storm Cristobal in June 2020. Water samples were collected for measurement of specific conductance, pH, temperature, turbidity, and dissolved oxygen. Laboratory analyses were performed for total suspended solids, nitrate+nitrite nitrogen, and total phosphorus. Bed sediment transport rates were measured, where possible, and daily and annual loads were estimated for suspended and bed sediment.

LAND USE/LAND COVER

Land use is directly correlated with water quality, hydrologic function, ecosystem health, biodiversity, and the integrity of streams and wetlands. Land-use classifications for the project area were calculated from the Multi-Resolution Characteristics Consortium's National Land Cover Dataset 2011 land use data. This data set had a 16-

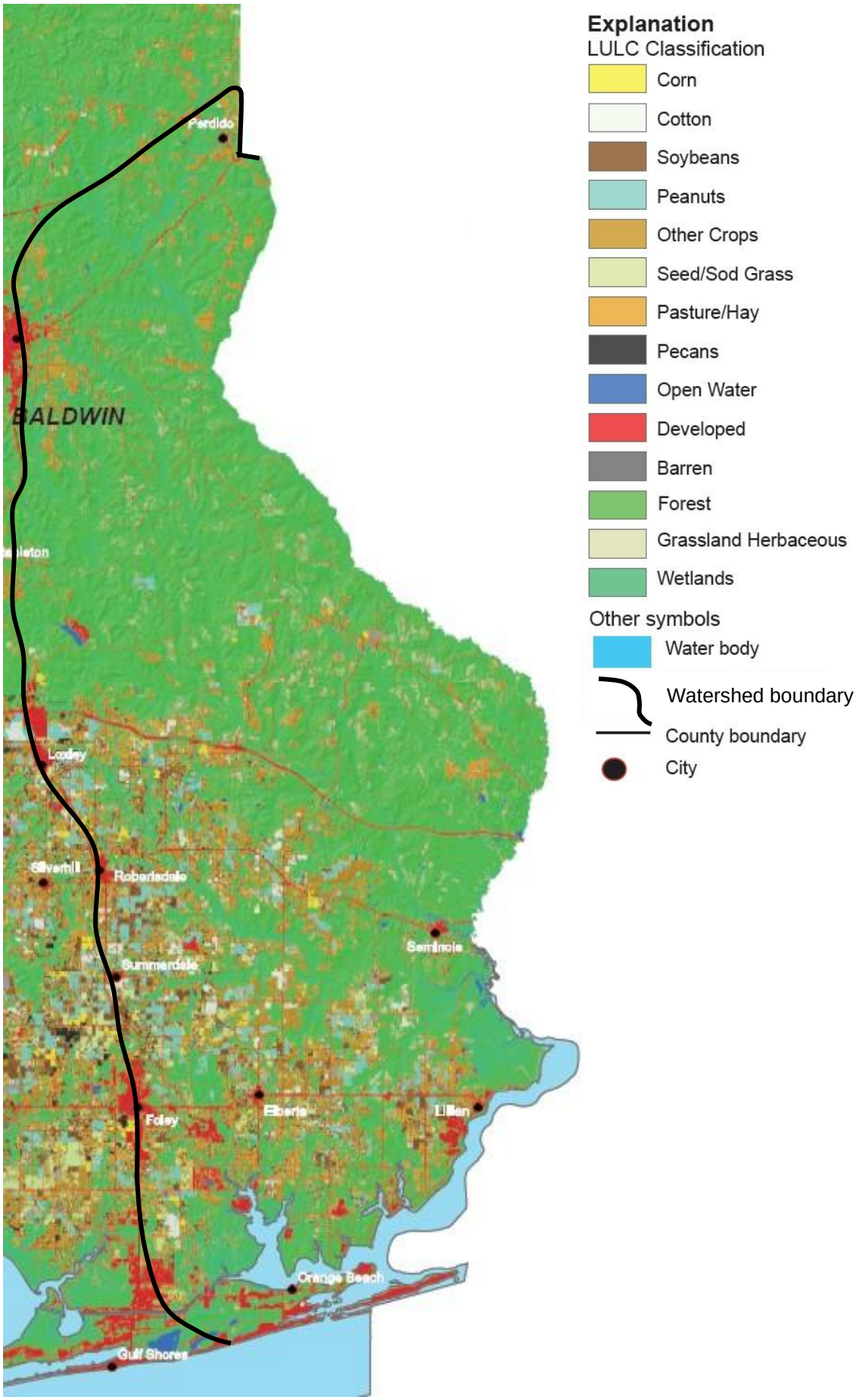


Figure 2.—Land use/land cover in the Perdido Bay watershed in Alabama.

Table 1—Monitoring sites in the Perdido Bay watershed.

Site	Site description
PB2	Palmetto Creek at John Bloch Road, 3.3 mi upstream from Perdido Bay Lat 30.37876°N Long -087.53063°W
PB3	Soldier Creek at Baldwin Co Road 97, 4.0 mi upstream from Perdido Bay Lat 30.39511°N Long -087.51026°W
PB4	Manuel Bayou at Baldwin Co Road 91, 1.9 mi upstream from Perdido Bay Lat 30.37724°N Long -087.48062°W
PB5	Unnamed tributary to Perdido Bay at Baldwin Co Road 99, 0.5 mi upstream from Perdido Bay Lat 30.38176°N Long -087.45915°W
PB6	Unnamed tributary to Perdido Bay at Baldwin Co Road 99, 0.4 mi upstream from Perdido Bay Lat 30.38939°N Long -087.45712°W
PB7	Peterson Branch at Baldwin Co Road 99, 0.6 mi upstream from Perdido Bay Lat 30.39319°N Long -087.45598°W
PB8	Negro Creek (Blackwater River tributary) at Cowpen Creek Road, 15.5 mi upstream from Perdido Bay Lat 30.50078°N Long -087.58158°W
PB9	Blackwater River at Cowpen Creek Road, 16.5 mi upstream from Perdido Bay Lat 30.51126°N Long -087.58165°W
PB10	Styx River at US Highway 90, 8.3 mi upstream from Perdido Bay Lat 30.51861°N Long -087.46290°W
PB11	Perdido River at Interstate 10, 14.0 mi upstream from Perdido Bay Lat 30.57297°N Long -087.41106°W

class land cover classification scheme at 30-meter resolution.

Land use/land cover in the upper part of the Perdido Bay watershed is dominated by forested lowlands, wetlands, and upland forests and agriculture. The lower part of the watershed is dominated by row crop agriculture, pasture, low intensity residential with minimal urban development, and forested wetlands. Most streams in the watershed flow through forested floodplains with substantial wetlands or urban areas with small areas of impervious surface. 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. This is particularly important as forested and agricultural land is

being converted to residential or commercial development. Developed land is dominated by residences and commercial development, primarily along roadways, and residential development on land previously forested or used for agriculture.

STREAM FLOW CONDITIONS

Stream flow characteristics are determined by factors including climate, topography, hydrogeology, land use, and land cover. Streams in the Perdido Bay watershed exhibit flashy discharge due to land-use change with increasing impervious surfaces related to residential development on the southwestern Alabama side of the bay. Northwestern and northern sides of the bay are dominated by wetlands and tidal marsh related to the Perdido, Styx, and Blackwater Rivers floodplains. Wetlands along the margin of the bay are most likely caused by sediment deposition in a rising sea level environment over the past 20,000 years (Donoghue, 2011).

Elevations of headwaters of the monitored watersheds range from 50 to 300 ft relative to mean sea level (MSL). Stream gradients upstream from monitoring sites vary from 113 ft/mi for the unnamed tributary upstream from Baldwin County Road 99 (PB6) to 2.5 ft/mi for Blackwater River upstream from Cowpen Creek Road (PB9) (table 2).

A wide range of discharge events are required to adequately evaluate hydrologic conditions and water quality in the Perdido Bay watershed. Table 2 shows that sampling occurred during discharge conditions from base flow to flood, with the largest discharges occurring during Tropical Storm Cristobal on June 8, 2020, where discharge was bank full or out of banks estimated in Blackwater River and Negro Creek at Cowpen Creek Road (45,713 and 3,150 cfs). Average daily discharge for each monitored stream is required to adequately estimate constituent loading. Discharge data collected at the USGS stream gaging site 023777750, Styx River at Seminole, Alabama, Alabama was used as a basis for average daily discharge calculation for each monitored stream.

Table 2.—Stream-flow characteristics for monitored sites in the Perdido Bay watershed.

Monitored site	Average measured and estimated discharge (cfs)	Maximum measured or estimated discharge (cfs)	Minimum measured or estimated discharge (cfs)	Average measured and estimated discharge per unit area (cfs/mi^2)	Stream gradient (ft/mi)
PB2 (Palmetto Creek @ (John Bloch Road)	1.3	63	0.3	1.4	25
PB3 (Soldier Creek@ Baldwin Co Road 97)	10	504	2.7	2.0	13
PB4 (Manuel Bayou @ Baldwin Co Road 91)	0.9	42	0.2	1.6	36
PB5 (unnamed tributary @ Baldwin Co Road 99)	1.2	59	0.3	1.6	40
PB6 (unnamed tributary @ Baldwin Co Road 99)	0.3	15	0.08	2.1	113
PB7 (Peterson Branch @ Baldwin Co Road 99)	4.7	231	1.2	1.3	26
PB8 (Negro Creek @ Cowpen Creek Road)	65	3,150	17	2.2	2.6
PB9 (Blackwater River @ Cowpen Creek Road)	125	45,713	33	2.2	2.5
PB10 (Styx River @ Baldwin Co Rd 87)	431	21,000	112	2.3	9.0
PB11 (Perdido River @ Interstate Highway 10)	1,034	50,400	269	2.2	5.8

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 Perdido Bay watershed), which is 6.94 mg/L (ADEM, 2020).

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 3 where observed DO is compared to the 100 percent dissolved oxygen saturation for the observed average stream temperature for each monitoring site.

Dissolved oxygen was measured at Perdido Bay watershed monitoring sites from January 2020 through June 2020. Stream water temperatures during the monitoring period varied from 12.5 to 26.3°C. Site PB2 (Palmetto Creek at John Bloch Road) had the lowest average DO (4.0 mg/L) and site PB 11 (Perdido River at I-10) had the highest average DO (8.3 mg/L) (table 3). Values lower than the ADEM Fish and Wildlife standard (5.0 mg/L) were measured at sites PB2, PB5, and PB 6 (table 3). All sites but PB8 (Negro Creek at Cowpen Creek Road) had measured DO values less than the ADEM reference standard (6.94 mg/L) (table 3). Average DO and water temperature values were compared with atmospheric DO saturation. Sites PB5 and PB6 (unnamed tributaries at Co Rd 99) had the lowest percentage of atmospheric saturation (56%) and sites PB10 (Styx River at Co Rd 87) and PB11 (Perdido River at I-10) had the highest percentage (88%) (table 3).

Table 3.—Dissolved oxygen measured in monitored streams in the Perdido Bay watershed.

Site	Dissolved oxygen (mg/L)			Average DO saturation (% atmospheric saturation)
	Maximum	Minimum	Average	
PB2	7.8	4.0	5.8	58
PB3	8.6	6.2	6.9	75
PB4	7.2	5.9	6.5	67
PB5	5.9	4.8	5.3	56
PB6	6.6	3.8	4.9	56
PB7	7.7	5.7	6.7	73
PB8	9.8	6.9	7.9	85
PB9	8.2	5.6	6.9	75
PB10-	8.4	5.8	7.9	88
PB11	10.6	5.9	8.3	88

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 or at times of large rainfall runoff volumes. Table 2 shows SC in monitored streams in the Perdido Bay watershed.

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 4). The Alabama Department of Environmental Management (ADEM) established reference sites on streams throughout Alabama to determine reference water-quality standards for selected level IV ecoregions. The ADEM reference median concentration for SC for ecoregion 65f, which includes the Perdido Bay watershed is 20.4 µS/cm (ADEM, 2020). Median measured SC for all Perdido Bay watershed sites exceeded the ADEM standard (table 4).

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 4.—Measured specific conductance values for Perdido Bay watershed monitoring sites.

Monitored site	Average SC (µS/cm)	Maximum SC (µS/cm)	Minimum SC (µS/cm)	ADEM median reference (µS/cm)	Median SC (µS/cm)
PB2	146	390	50	20.4	71
PB3	62	74	50	20.4	61
PB4	N/A	N/A	N/A	20.4	N/A
PB5	75	86	65	20.4	75
PB6	209	261	128	20.4	223
PB7	99	134	51	20.4	101
PB8	79	101	46	20.4	90
PB9	91	118	70	20.4	85
PB10	33	40	27	20.4	32
PB11	33	53	23	20.4	29

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 2, illustrates that sites PB6 (unnamed tributary at Co Rd 99), PB7 (Peterson Branch at Co Rd 99), and PB10 (Styx River at Co Rd 87) have the highest average turbidity (73, 62, and 47 NTUs, respectively).

Commonly, excessive turbidity results from land uses that cause land disturbances, leading to erosion or to land uses that cause excessive runoff. Evaluation of land-use data indicates that watersheds with dominant urban development and/or row crop agriculture are more likely to have streams with significant turbidity concentrations. Streams with the highest turbidity in the Perdido Bay watershed receive runoff from major commercial and residential development in Daphne and Fairhope. Figure 3 relates average turbidity with percentage of urban development in each monitored watershed. It shows that sites PB6 (unnamed tributary at Co Rd 99), and PB7 (Peterson Branch at Co Rd 99) have the highest average turbidity and the highest percentage of urban development. Exceptions are Site PB5 (unnamed tributary at Co Rd 99) has the most urban development but is not among the highest turbidities and Site PB 10 (Styx River at Co Rd 87) which is among the highest turbidities but has among the least urban development. The ADEM reference

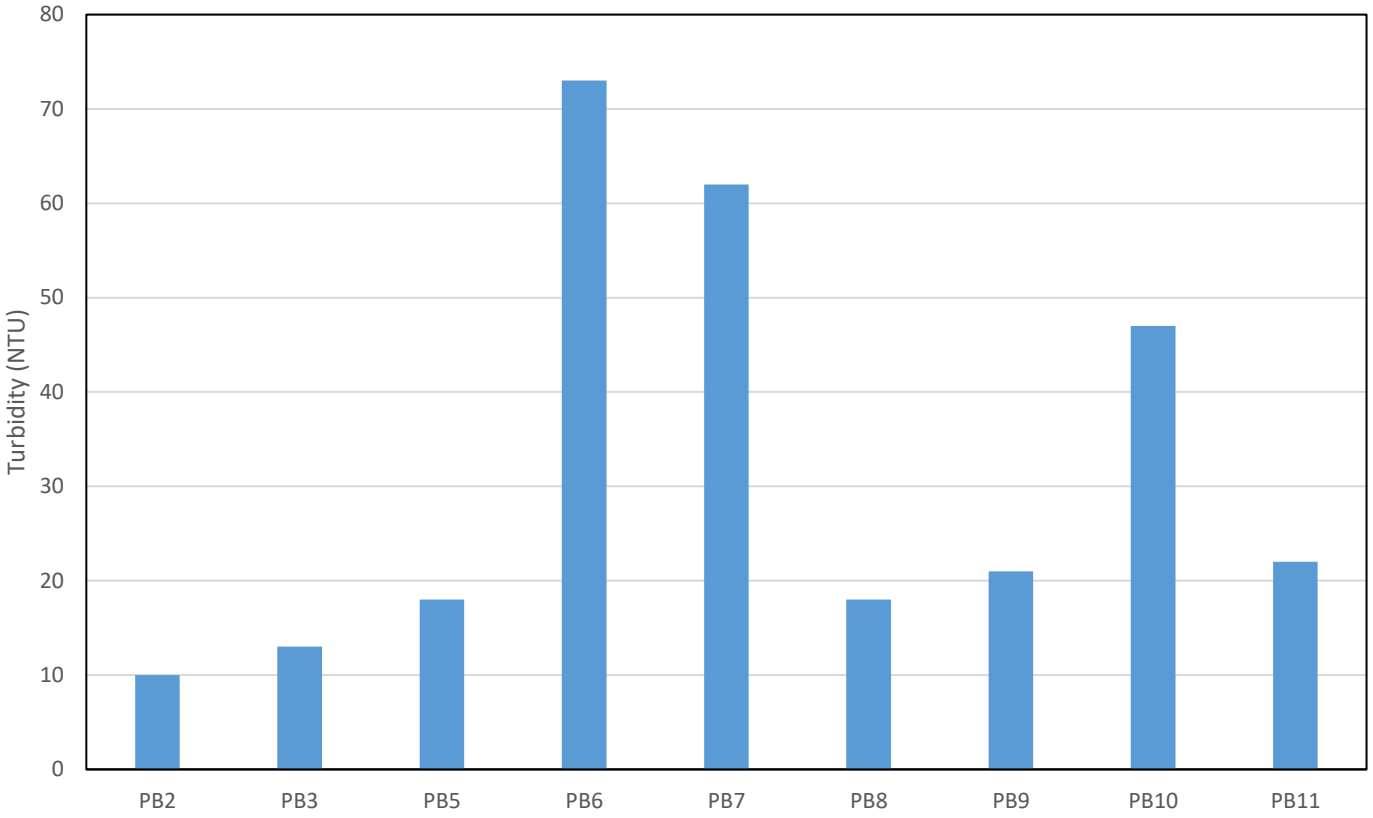


Figure 3.—Graph showing average turbidity for Alabama Perdido Bay monitoring sites.

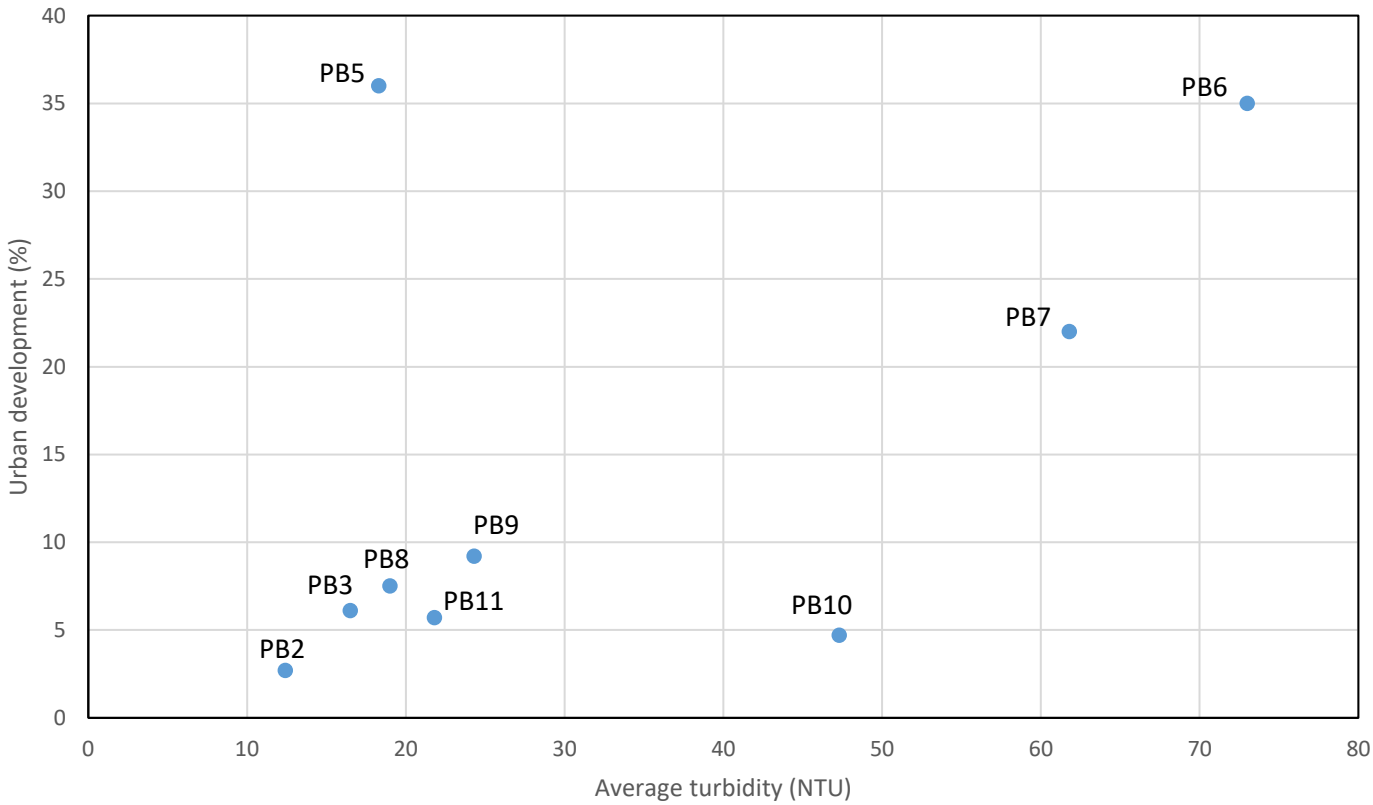


Figure 4.—Graph showing average turbidity and percentage of urban development for Alabama Perdido Bay monitoring sites.

concentration for turbidity is 9.7 NTU for ecoregion 65f (90^{th} %ile) (ADEM, 2020). Average turbidity for all Perdido Bay watershed sites exceeded the ADEM standard.

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 urbanization and impervious surfaces, agriculture, construction, timber harvesting, unimproved roadways, or any activity where soils or geologic units are exposed or disturbed. In the Perdido Bay watershed, relatively high percentages of urban development and impervious surfaces, increase runoff volumes and flow velocities, causing excessive stream bed and bank erosion. 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. All sediment transported by Perdido Bay tributary streams is deposited directly into Perdido Bay, impeding near shore navigation, decreasing water clarity, and destroying submerged vegetation and fish and shellfish habitat.

Precipitation, stream gradient, geology, soils, and land use are all important factors that influence sediment transport characteristics of streams. Sediment transport conditions in the Perdido Bay watershed were evaluated and quantified by tributary, 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 Perdido Bay 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 TRANSPORTED BY PROJECT STREAMS

The rate of sediment transport is a complex process controlled by several 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 constructed features to promote infiltration of precipitation and to store and slow runoff. Currently, the Perdido Bay watershed is characterized by an increasingly urban setting, dominated by residential development.

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). Only Sites PB3 (Soldier Creek at Co Rd 97) and PB7 (Peterson Branch at Co Rd 99) had measurable suspended and bed sediment loads. Only suspended sediment could be measured at eight sites due to flow and channel conditions.

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 4 is an x-y plot of average turbidity and average total suspended solids (TSS) for Perdido Bay Alabama tributary monitored watershed sites with adequate samples. It shows a good correlation between turbidity and TSS, except for site PB6 (unnamed tributary at Co. Rd. 99) where turbidity is relatively large compared to

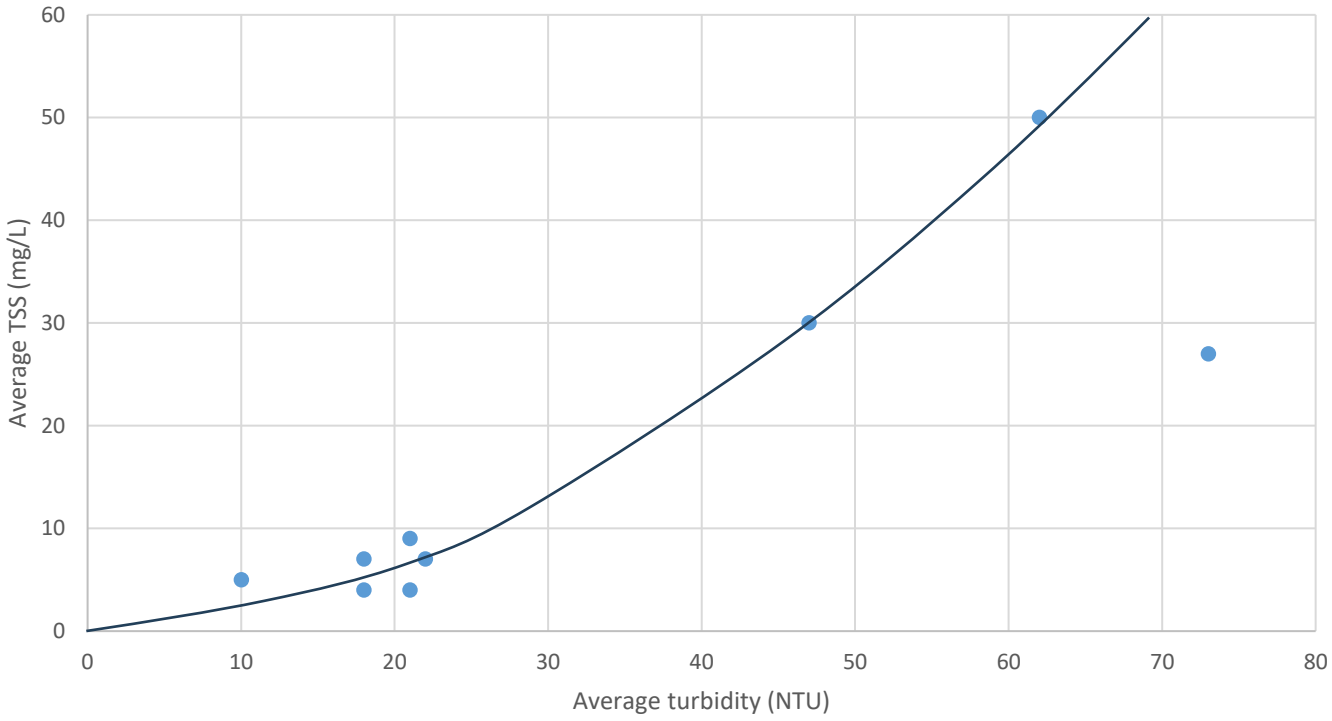


Figure 5.—Average turbidity and TSS values for monitored sites in the Perdido Bay watershed.

TSS. Also, the slope of the trend line steepens for turbidity values larger than 25 NTU, indicating that TSS is higher for comparable turbidity values. This occurs for Styx River (PB10) and Peterson Branch (PB7) (fig. 4). The largest average suspended solids concentrations were 73 mg/L at site PB7 (Peterson Branch at Buena Vista Drive), 30 mg/L at site PB10 (Styx River at Co Rd 87), and 27 mg/L at site PB6 (unnamed tributary at Co Rd 99) (table 5).

Annual suspended sediment loads were estimated for Perdido Bay watershed 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 023777750, Styx River at Seminole, Alabama (USGS, 2023).

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 sediment for the period of stream flow (January 1, 2020 to December 31, 2020). As expected, monitoring sites on streams with the largest discharge had the highest suspended sediment loads, including PB10 (Styx River at Baldwin Co Rd 87), PB11 (Perdido River at I-10, PB9 (Blackwater River at Cowpen Creek Rd), and PB8 (Negro Creek at Cowpen Creek Rd) with 28,222, 21,481, 2,295, and 854 tons per year (t/yr), respectively (table 5).

Table 5.—Measured discharge, turbidity, TSS, and estimated suspended sediment loads in monitored streams in the Perdido Bay watershed.

Monitored site	Average daily discharge (cfs)	Average turbidity (NTU)	Average TSS (mg/L)	ADEM Level IV Ecoregion 65f reference standard for TSS (mg/L)	Estimated suspended sediment load (t/yr)	Estimated normalized suspended sediment load ($t/mi^2/yr$)
PB2 (Palmetto Creek @ (John Bloch Road)	1.3	10	5	13.2	16	17
PB3 (Soldier Creek@ Baldwin Co Road 97)	10	13	4	13.2	210	40
PB4 (Manuel Bayou @ Baldwin Co Road 91)	0.9	56	45	13.2	34	62
PB5 (unnamed tributary @ Baldwin Co Road 99)	1.2	18	4	13.2	19	26
PB6 (unnamed tributary @ Baldwin Co Road 99)	0.3	73	27	13.2	20	142
PB7 (Peterson Branch @ Baldwin Co Road 99)	4.7	62	50	13.2	383	109
PB8 (Negro Creek @ Cowpen Creek Road)	65	18	7	13.2	854	30
PB9 (Blackwater River @ Cowpen Creek Road)	125	21	9	13.2	2,295	41
PB10 (Styx River @ Baldwin Co Rd 87)	431	47	30	13.2	28,222	148
PB11 (Perdido River @ Interstate Highway 10)	1,034	22	7	13.2	21,481	47
PB12 (Eleven Mile Creek @ US Highway 98)	42	68	78	13.2	1,683	59

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 Perdido Bay watershed are in table 4, which shows the largest normalized suspended sediment loads at PB10 (Styx River at Baldwin Co Rd 87), (148 t/mi^2/yr), PB6 (unnamed tributary at Co Rd 99) (142 t/mi^2/yr), and Peterson Branch at Co Rd 99 (109 t/mi^2/yr) (table 5). Eleven Mile Creek at US Highway 98 (site PB12) was also monitored to show that Florida tributaries have a significant impact on water quality in Perdido Bay. Suspended sediment loads for site PB12 were 1,683 t/yr and 59 t/mi^2/yr (table 5).

BED SEDIMENT

Transport of streambed material is controlled by several 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 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 ase 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 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.

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 two Perdido Bay watershed sites (PB3 and PB7). 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. Table 6 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. Bed sediment at site PB12 (Eleven Mile Creek at US Highway 98), on the Florida side of the bay was also measured and is included in table 6.

Table 6—Average measured discharge and estimated bed sediment loads for monitoring sites on streams with measurable bed sediment in the project area.

Monitored site	Average daily discharge (cfs)	Estimated annual bed sediment loads (tons/yr)	Estimated normalized annual bed sediment loads (tons/mi^2/yr)
PB3 (Soldier Creek@ Baldwin Co Road 97)	10	127	24.4
PB7 (Peterson Branch @ Baldwin Co Road 99)	4.7	40	11.4
PB12 (Eleven Mile Creek @ US Highway 98)	42	2,065	72

TOTAL SEDIMENT LOADS

Total sediment load in a stream is composed of suspended and bed sediment. Four monitored sites had both suspended and bed sediment loads. Table 6 shows total sediment loads for monitored reaches in the Perdido Bay watershed. PB10 (Styx River at Baldwin Co Rd 87), PB11 (Perdido River at I-10, PB9 (Blackwater River at Cowpen Creek Rd), and PB8 (Negro Creek at Cowpen Creek Rd) with 28,222, 21,481, 2,295, and 854 tons per year (t/yr), respectively (table 7).

Normalizing sediment loads to unit watershed area permits comparison of monitored watersheds and negates the influence of drainage area size and discharge on sediment loads.

Table 7—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 daily discharge (cfs)	Estimated annual total sediment loads (tons/yr)	Estimated normalized annual total sediment loads (tons/mi^2/yr)
PB2 (Palmetto Creek @ (John Bloch Road)	0.9	1.3	16	17
PB3 (Soldier Creek@ Baldwin Co Road 97)	5.2	10	337	65
PB4 (Manuel Bayou @ Baldwin Co Road 91)	0.5	0.9	34	62
PB5 (unnamed tributary @ Baldwin Co Road 99)	0.7	1.2	19	26
PB6 (unnamed tributary @ Baldwin Co Road 99)	0.14	0.3	20	142
PB7 (Peterson Branch @ Baldwin Co Road 99)	3.5	4.7	423	121
PB8 (Negro Creek @ Cowpen Creek Road)	29	65	854	30
PB9 (Blackwater River @ Cowpen Creek Road)	56	125	2,295	41
PB10 (Styx River @ Baldwin Co Rd 87)	191	431	28,222	148
PB11 (Perdido River @ Interstate Highway 10)	462	1,034	21,481	47
PB12 (Eleven Mile Creek @ US Highway 98)	29	42	3,748	129

Normalized total sediment loads for monitored sites in the Perdido Bay watershed are in table 7, which shows the largest normalized total sediment loads at sites PB10 (Styx River at Co Rd 87) (148 tons/mi^2/yr), PB6 (unnamed tributary at Co Rd 99) (142 tons/mi^2/yr), and PB7 (Peterson Branch at Co Rd 99) (121 tons/mi^2/yr). For comparison to a Florida Perdido Bay tributary, site PB12 (Eleven Mile Creek at US Highway 98 had a total sediment load of 129 tons/mi^2/yr.

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 four monitored watersheds exceeded the geologic erosion rate (table 7).

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 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+nitrite nitrogen and phosphorus (P-total).

NITROGEN

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 for selected discharge events were collected and analyzed for nitrogen. To compare Perdido Bay watershed samples to the ADEM reference concentration (0.3258 mg/L nitrate+nitrite nitrogen = 90^{th} %ile) for Ecoregion 65f, samples were analyzed for nitrate+nitrite nitrogen (ADEM, 2020). Nitrogen and discharge commonly form negative regressions, indicating that increased discharge results in decreased concentrations of nitrogen. The largest nitrate+nitrite nitrogen concentrations were in the Perdido Bay watershed at sites PB7 (Peterson Branch at Co Rd 99), PB8 (Negro Creek at Cowpen Rd), PB10 (Styx River at Co Rd 87), and PB5 (unnamed tributary at Co Rd 99) with 4.80, 1.6, 0.68, and 0.54 mg/L, respectively. Table 8 shows average nitrate concentrations for monitored Perdido Bay watershed sites.

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 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 Perdido Bay watershed) of 0.04 mg/L (90^{th} %ile) (ADEM, 2020). In many streams phosphorus is the primary nutrient that influences excessive biological activity. These streams are termed "phosphorus limited."

Most Perdido Bay tributary monitoring site water samples were below the laboratory detection limit of 0.1 mg/L. Five sites had phosphorus concentrations above the 0.1 detection limit. The largest concentrations were measured at sites PB7 (Peterson Branch at Co Rd 99) and PB8 (Negro Creek at Cowpen Rd), with 0.22 and 0.23 mg/L, respectively. Table 8 shows average total phosphorus concentrations for monitored Perdido Bay watershed sites.

SUMMARY, CONCLUSIONS, AND PROBABLE SOURCES OF WATER-QUALITY IMPACTS

Evaluations of sediment transport and water-quality analyses led to conclusions concerning which streams in the Perdido Bay watershed have impairments and should be considered for further evaluation and possible remedial actions. Evaluations of land-use data, aerial imagery, and field assessments give insight to probable sources of water-

Table 8.—Estimated daily discharge, and measured average nitrate and total Phosphorus concentrations in monitored streams in the Perdido Bay watershed.

Monitored site	Average daily discharge (cfs)	Average nitrate (mg/L)	Average total phosphorus (mg/L)
PB2 (Palmetto Creek @ (John Bloch Road)	1.3	BDL	0.04
PB3 (Soldier Creek@ Baldwin Co Road 97)	10	0.12	BDL
PB4 (Manuel Bayou @ Baldwin Co Road 91)	0.9	BDL	0.16
PB5 (unnamed tributary @ Baldwin Co Road 99)	1.2	0.40	BDL
PB6 (unnamed tributary @ Baldwin Co Road 99)	0.3	0.03	0.03
PB7 (Peterson Branch @ Baldwin Co Road 99)	4.7	2.6	0.11
PB8 (Negro Creek @ Cowpen Creek Road)	65	1.5	0.12
PB9 (Blackwater River @ Cowpen Creek Road)	125	0.4	BDL
PB10 (Styx River @ Baldwin Co Rd 87)	431	0.32	BDL
PB11 (Perdido River @ Interstate Highway 10)	1,034	0.11	BDL

quality and habitat impairments. Overall, considering physical and chemical parameters evaluated for this investigation, conditions in the Perdido Bay watershed are good, especially when compared to many other evaluated watersheds in the Mobile Bay and Alabama Gulf Coast.

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, 6 of 10 monitored stream reaches are characterized by high gradients that result in flashy discharge with high flow velocities. The other four (PB8, PB9, PB10, and PB11) are characterized by deep water, lower flow velocities, and tidal influence.

Land use/cover is also an important factor influencing erosion, sediment transport, and overall water quality. Generally, larger monitored watersheds, including Palmetto, Soldier, and Negro Creeks, and Blackwater, Styx, and Perdido Rivers have two primary land uses/covers. Headwaters are primarily rural with forest cover or open fields used for

pasture or row crop agriculture, and forested floodplains. Lower parts of the watersheds, near the bay are primarily forested with residential development and forested floodplains. The lower part of the Perdido River watershed is dominated by extensive, tidally influenced wetlands. Floodplains are narrow with encroaching residential development and receive significant impacts from flashy runoff from residential developments with moderate amounts of impervious surfaces. However, sediment deposition to Perdido Bay is low to moderate with no observed sediment plumes, which are common along the eastern shore of Mobile Bay.

Three monitored Perdido Bay tributaries (Styx, Blackwater, and Perdido Rivers) and Perdido Bay are currently on the ADEM 303-D list of impaired waters. All four are listed for mercury caused by atmospheric deposition (ADEM, 2022).

Dissolved oxygen was measured during each monitored event. Site PB6 (unnamed tributary at Co Rd 99) had the lowest average DO (4.9 mg/L) and site PB11 (Perdido River at I-10) 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 PB2 (Palmetto Creek and John Bloch Rd), PB5 (unnamed tributary at Co Rd 99), and PB6 (unnamed tributary at Co Rd 99). All monitored sites had measured DO values less than the ADEM reference standard (6.94 mg/L).

Sediment loads in streams are composed of suspended and bed sediment. Styx River at Co Rd 87 (PB10), Perdido River at I-10 (PB11), and Blackwater River at Cowpen Creek Rd (PB9), had the largest suspended sediment loads with 28,222, 21,481, and 2,295 t/yr, respectively. The largest normalized suspended sediment loads occurred in Styx River at Co Rd 87 (PB10) (148 t/mi^2/yr), the unnamed tributary at Co Rd 99 (PB6) (142 t/mi^2/yr), and Peterson Branch at Co Rd 99 (PB7) (109 t/mi^2/yr).

Two monitored sites had measurable bed sediment. Soldier Creek (PB3) and Peterson Branch (PB7) had bed sediment loads of 127 and 40 t/yr, respectively. Normalization of bed sediment loads relative to drainage area resulted in loads of 24.4 and 11.4 tons/mi^2/yr, respectively.

When compared to ten previously monitored sites in Mobile and Baldwin Counties, the largest normalized total sediment loads at Perdido Bay tributary sites Styx River at Co Rd 87 (PB10) (148 t/mi^2/yr), the unnamed tributary at Co Rd 99 (PB6) (142

t/mi^2/yr), and Peterson Branch at Co Rd 99 (PB7) (121 t/mi^2/yr) are minimal and are similar to loads estimated for Magnolia River and Fish River.

The critical nitrate concentration in surface water for excessive algae growth is 0.5 mg/L. The ADEM reference concentration for Ecoregion 65f is 0.3258 mg/L nitrate+nitrite nitrogen, which equals the 90th percentile). The largest nitrate+nitrite nitrogen concentrations were in the Perdido Bay watershed at sites PB7 (Peterson Branch at Co Rd 99), PB8 (Negro Creek at Cowpen Rd), PB10 (Styx River at Co Rd 87), and PB5 (unnamed tributary at Co Rd 99) with 4.80, 1.6, 0.68, and 0.54 mg/L, respectively.

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. ADEM established a reference standard of 0.04 mg/L for total phosphorus for level IV ecoregion 65f. The largest total phosphorus concentrations were measured at sites PB7 (Peterson Branch at Co Rd 99) and PB8 (Negro Creek at Cowpen Rd), with 0.22 and 0.23 mg/L, respectively.

Nutrient concentrations in monitored Perdido Bay streams are impacted by land use/cover. Generally, the monitored watersheds with limited anthropogenic impacts, dominated by forest and wetlands have no detectable nitrogen or phosphorus. Streams with the highest nutrient concentrations are dominated by headwaters agriculture.

Based on the findings of this assessment, with respect to water quality and potential remediation and restoration, Styx River, Peterson Branch, and the unnamed tributaries south of Peterson Branch have the highest degree of impairment and should be considered for various types of remediation and restoration. However, additional field assessment will be required to refine sources of impairment and specific remedial strategies.

Florida tributaries to Perdido Bay are likely to impact water quality in the bay much more than Alabama tributaries due to urbanization related to the city of Pensacola. Future cooperation between Alabama and Florida will be essential to preserve water quality and habitats in Perdido Bay.

REFERENCES CITED

ADEM, 2020, Alabama's water quality assessment and listing methodology 2010 Ecoregional Reference Guidelines, Alabama Department of Environmental Management, January 1, 2020, table 18, p. 66, http://adem.alabama.gov/programs/water/wquality/2020WAM.pdf., accessed December 5, 2020.

ADEM, 2022, Clean Water Act 303-d list for Alabama, URL http://adem.state.al.us/programs/water/wquality/2022AL303dList.pdf accessed December 10, 2023.

Cohn, T. A., Caulder D. L., Gilroy E. J., Zynjuk L. D., and Summers, R. M., 1992, The validity of a simple statistical model for estimating fluvial constituent loads: an empirical study involving nutrient loads entering Chesapeake Bay: Water Resources Research, v. 28, p. 2353-2363.

Cook, M. R., and Puckett, T. M., 1998, Section 319 national monitoring program project for Lightwood Knot Creek Watershed in southeast Alabama: A report to the Alabama Department of Environmental Management, 1997 Annual Report and Paired Watershed Calibration, Geological Survey of Alabama open file report, 140 p.

Cook, M. R., and Moss, N. E., 2008, Analysis of water quality, sediment loading, biological resources, and impacts of land-use change on the D'Olive and Tiawasee Creek watersheds, Baldwin County, Alabama, 2008: Geological Survey of Alabama Open-file Report 0811, 140 p.

Donoghue, J. F., 2011, Sea level history of the northern Gulf of Mexico coast and sea level rise scenarios for the near future, Climate Change, Volume 107, July 2011, pp. 17-33.

Eaton, A. D., Clesceri, L. S., and Greenberg, A. E., 1995, Standard methods for the examination of water and wastewater, 19th edition: Washington, D. C., American Public Health Association, p. 9-53—9-72.

Google Earth, 2020, Images of the Perdido Bay watershed, Image dates, 1985 and 11/19.

Hem, J. D., 1985, Study and interpretation of the chemical characteristics of natural waters (3rd edition): U.S. Geological Survey Water Supply Paper no. 2254, 264 p.

Kirschenfeld, T., Turpin, R. K., Handley, L. R., 2006, Perdido Bay, URL https://pubs.usgs.gov/sir/2006/5287/pdf/PerdidoBay.pdf, accessed December 15, 2023.

Maidment, D. R., ed., 1993, Handbook of hydrology: New York, Mcgraw-Hill Inc., p. 11.37-11.54.

Mays, L. W., ed., 1996, Water resources handbook: New York, McGraw-Hill, p. 8.3-8.49.

Northwest Florida Water Management District, 2021, Perdido watershed, https://nwfwater.com/Water-Resources/Regional-Wetland-Mitigation-Program/Regional-Mitigation-Plan/Watersheds/Perdido-Watershed, accessed July 30, 2021.

Richards, R. P., 1999, Estimation of pollutant loads in rivers and streams: a guidance document for NPS programs: Heidelberg College.

USDA National Agricultural Statistics Service Cropland Data Layer, 2013, Published crop-specific data layer. http://nassgeodata.gmu.edu/CropScape/.html accessed May 20, 2013. USDA-NASS, Washington, DC.

USEPA. 1999. Ecological condition of estuaries in the Gulf of Mexico. EPA 620-R-98-004. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Gulf Ecology Division, Gulf Breeze, Florida. 80 pp.

U.S. Geological Survey, 2020, StreamStats watershed mapping and statistics, west-central Baldwin County, Alabama, URL http:// http://water.usgs.gov/osw/streamstats/ accessed November 1, 2023.

U.S. Geological Survey, 2021, Current water data for the nation, USGS stream gaging site 023777750, Styx River at Seminole, Alabama, https://waterdata.usgs.gov/nwis/uv?02378500, accessed February 1, 2023.

APPENDIX A

FIELD AND ANALYTICAL DATA

Palmetto Creek at John Bloch Road					Lat 30.378680	Area					
					Long 87.530035	0.94 mi2					
Site	Date	Time	Dis	Temp	Conductance	Turbidity	pH	DO	TSS	Nitrate	Total P
			cfs	°C	mS/cm	NTU		mg/L	mg/L	mg/L	
PB2	1/8/20	1140	0.05	13.8	71	13	6.6	5.9	4	BDL	BDL
PB2	1/24/20	1500	0.05	13.3	390	14	6.2	4	4		
PB2	2/6/20	940	1.9	13.7	62	24	6.2	6.2	8		
PB2	2/13/20	830	0.49	19	71	9	5.4	7.8	5	BDL	0.11
PB2	4/23/20	1600	0.1	21.7	50	2	6.2	5.4	<4	BDL	BDL
Soldier Creek @ Baldwin Co Rd 97					Lat 30.395062	Area					
					Long 87.510055	5.2 mi2					
PB3	1/14/20	1630	8	21.4	61	20	6.2	6.7	4	0.071	
PB3	1/24/20	1530	6.6	14.6	74	6	6.4	8.6	<4		
PB3	2/6/20	920	31.2	15.6	48	36	6.3	8.2	7		
PB3	2/13/20	900	7	20	66	7	6.1	7.3	<4	0.29	
PB3	4/23/20	1610	6.2	21.6	59	13	6.4	6.2	<4	BDL	
PB3	5/8/20	1515	2.8	26.3	50	17	5.9	5.9	<4		
Manuel Creek @ Baldwin Co Rd 91					Lat 30.377303	Area					
					Long 87.480456	0.54 mi2					
PB4	1/14/20	1400	Dry								
PB4	2/6/20	1005	0.52	19.8	46	95	6.8	6.1	21		
PB4	2/13/20	930	0.82	18.8	43	120	6.3	7.2	27	BDL	0.16
PB4	4/23/20	1630	0.32	20.2	58	73	6.7	5.9	16		
Unnamed tributary @ Baldwin Co Rd 99					Lat 30.381935	Area					
& Antietam Rd					Long 87.459274	0.73 mi2					
PB5	1/14/20	1525	0.59	21.8	67	17	6	5.3	<4	0.28	BDL
PB5	2/6/20	1030	1.3	20.2	65	38	6.1	5.2	9	0.34	BDL
PB5	2/13/20	955	0.59	20.2	82	5	5.9	5.9	<4	0.44	BDL
PB5	4/23/20	1705	0.1	21.3	86	13	6.1	4.8	<4	0.54	BDL
Unnamed tributary @					Lat 30.389331	Area					
Buena Vista Drive					Long 87.456972	0.14 mi2					
PB6	1/14/20	1515	0.1	20.9	224	12	6.5	3.8	<4	BDL	BDL
PB6	2/6/20	1050	0.58	19.3	128	156	6.7	5.2	55	BDL	BDL
PB6	2/13/20	940	0.08	18.7	261	22	6.5	4.1	13	BDL	0.11
PB6	4/23/20	1655	0.3	21.7	221	102	7.4	6.6	38	0.12	BDL

Peterson Branch @ Buena Vista Drive					Lat 30.392851	Area					
					Long 87.456014	3.5 mi2					
Site	Date	Time	Dis	Temp	Conductance	Turbidity	pH	DO	TSS	Nitrate	Total P
			cfs	°C	mS/cm	NTU		mg/L	mg/L	mg/L	mg/L
PB7	1/14/20	1500	2.1	22.1	120	18	6.2	6.4	4	3.7	0.22
PB7	2/6/20	1115	14.3	19.8	51	256	6.9	5.7	186	0.23	0.21
PB7	2/13/20	1010	1.7	20.4	134	5	6.2	7.7	<4	4.8	BDL
PB7	4/23/20	1645	1.9	21.3	101	12	6.4	6.3	8	1.8	BDL
PB7	6/8/20	1530	2.8	25.3	88	18	6.2	7.2	38		
Negro Creek @ Baldwin Co Rd 87					Lat 30.500596	Area					
					Long 87.581531	28.8 mi2					
PB8	1/8/20	1100	45	14.1	101	8	6.7	9.8	3	1.6	BDL
PB8	2/6/20	830	188	15.2	62	23	6.5	8.8	6		
PB8	4/23/20	1200	24	22.2	90	9	6.4	6.9	4	1.3	0.23
PB8	6/8/20	1455	309	25.6	46	36	5.9	7	14		
Blackwater River @ Baldwin Co Rd 87					Lat 30.511144	Area					
					Long 87.581533	56.1 mi2					
PB9	1/8/20	1050	90	13.9	118	6	6.5	5.6	<4	BDL	BDL
PB9	2/6/20	815	375	14.2	82	33	6.3	6.3	<4		
PB9	4/23/20	1150	47	21.8	85	12	5.7	8.2	5	0.7	BDL
PB9	6/8/20	1445	618	26	70	46	5.2	7	18		
Styx River @ Baldwin Co Rd 64					Lat 30.605183	Area					
					Long 87.547064	191 mi2					
PB10	2/6/20	1410	1270	17.7	27	62	5.8	5.8	41	0.086	BDL
PB10	2/13/20	1415	418	18.8	32	23	5.7	9.6	11	0.2	BDL
PB10	4/24/20	1345	170	23.4	40	16	6.4	8.4	10	0.68	BDL
PB10	6/8/20	1815	2110	24.5	31	88	5.5	7.7	58		
Perdido River @ I-10					Lat 30.572902	Area					
					Long 87.411030	462 mi2					
PB11	1/8/20	953	722	12.5	53	14	4.3	10.6	5	0.068	BDL
PB11	2/6/20	1345	3048	17.9	23	39	5.5	5.9	10	0	BDL
PB11	2/13/20	1350	994	19.5	29	12	5.8	9	3	0.13	BDL
PB11	4/23/20	1320	379	23.2	34	10	6.4	7.8	4	0.23	BDL
PB11	6/8/20	1750	5064	25.2	28	34	5.7	8	14		

Eleven Mile Creek at US Highway 98					Lat 30.498072	Area					
					Long 87.335810	27.8 mi2					
Site	Date	Time	Dis	Temp	Conductance	Turbidity	pH	DO	TSS	Nitrate	Total P
			cfs	°C	mS/cm	NTU		mg/L	mg/L	mg/L	mg/L
PB12	01/08/20	1230	29.1	16.8	75	15	5.8	8.5	4		
PB12	01/14/20	1300	121	21.8	112	69	5.3	8.2	10	0.2	BDL
PB12	01/24/20	1640	47.7	15.9	66	20	6.5	8.8	5		
PB12	02/06/20	1310	475	18.9	49	229	6.7	5.8	137	0.071	14.3
PB12	02/13/20	1315	55	20.9	112	21	6.5	8.7	5	0.4	BDL
PB12	04/24/20	1210	25.6	23.6	64	10	6.6	7.6	4	0.51	BDL
PB12	06/08/20	1715	87	25.9	75	53	6.5	7.4	9		
PB12	07/28/20	2015	250	26.1	54	125	6.5	7.2	40		