Nonpoint Source Model Development and Basin Management Strategies for Lemon Bay

Final Report

Prepared for:

SOUTHWEST FLORIDA WATER MANAGEMENT DISTRICT

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SECTION 1

INTRODUCTION

1.1 Description of the Lemon Bay System

Lemon Bay is a 31 km^2 estuarine system located on the West Coast of Florida between Sarasota Bay and Charlotte Harbor. An overview of the Lemon Bay system and contributing watershed areas is given in Figure 1-1. Lemon Bay and its contributing watershed are within the jurisdiction of the Charlotte Harbor National Estuary Program (NEP) and the Southwest Florida Water Management District (SWFWMD) Charlotte Harbor SWIM Plan.

Lemon Bay is relatively narrow, especially in the far northern and southern reaches, and has an average depth of approximately 2 m. Lemon Bay begins adjacent to South Venice and continues south to Gasparillo Sound. County Road 776, which extends from Englewood to Englewood Beach, is one of two causeways across the Bay. The causeway is located at approximately the north-south midpoint in the Bay. The Manasota Bridge, which connects Manasota to Manasota Beach, is located on the northern end of the Bay. Lemon Bay has two connections to the Gulf of Mexico, Stump Pass and Gasparillo Pass. Stump Pass is located south of the Englewood Beach causeway, and Gasparillo Pass is located at the far southern end of the Bay in Placido Harbor.

Of primary concern in Lemon Bay is the apparent loss of seagrass coverage over the past decade (Tomasko, et al., 2001). The loss of seagrass coverage is associated with an increase in phytoplankton populations and a decrease in light penetration. The loss of seagrass coverage accelerates water quality degradation and typically results in a loss of fisheries habitat. It is generally accepted that the loss in seagrass coverage is related to an increase in nitrogen loads to Lemon Bay (Tomasko, et al., 2001).

The Lemon Bay Watershed encompasses an area of approximately 161 km^2, including areas within Sarasota County and Charlotte County. The watershed is experiencing rapid population growth which is expected to continue well into the future. It is expected that population growth will

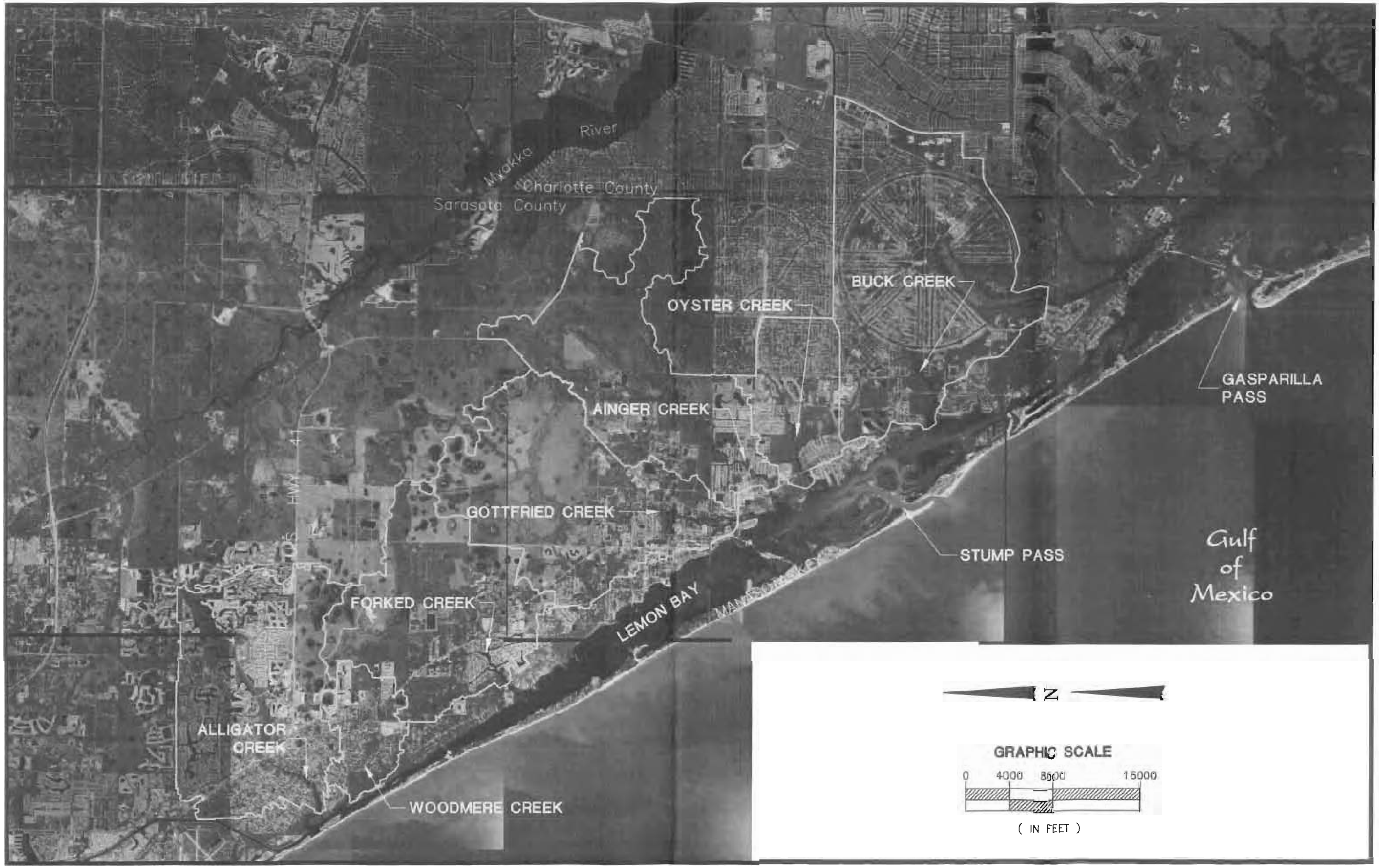


Figure 1-1. Overview of Lemon Bay System and Contributing Watershed Areas.

significantly increase nonpoint source pollutant loads into Lemon Bay, further degrading water quality and decreasing seagrass coverages. Lemon Bay is believed to be nitrogen-limited and, therefore, nitrogen loads from anthropogenic sources are of primary concern.

Six major tributaries discharge to Lemon Bay. From north to south, these include Alligator Creek, Forked Creek, Gottfried Creek, Rock Creek, Oyster Creek, and Buck Creek. In addition to these six primary tributaries, there are a large number of small sub-basins which discharge through small pipes or ditches directly to the Bay or discharge to the Bay by overland flow. In 1995, land uses within the watershed included 41% residential, 32% forested/uplands, and 14% wetlands (Tomasko, et al., 2001). Most of the development in the watershed over the next 10-20 years is expected to be residential. A significant portion of the development within the watershed occurred prior to the implementation of stormwater regulations in 1980 and, therefore, has no stormwater treatment.

1.2 Previous Loading Studies

Due to the apparent loss of seagrass and concerns over water quality, the SWFWMD and Florida Department of Environmental Protection (FDEP) cooperated in a preliminary evaluation of nitrogen loads to Lemon Bay and examination of the relationship between nitrogen loads, water quality, and seagrass depth distribution. Nitrogen loads were estimated for an existing condition (1995), and a future condition (2010). Components of the nitrogen load included nonpoint sources (stormwater runoff), baseflow (uncontaminated groundwater), direct rainfall to Lemon Bay, and septic tank systems. Nitrogen loads from stormwater runoff were calculated using estimated runoff coefficients ("C" values) for various land uses and literature values for event mean nitrogen concentrations. Land use was based on SWFWMD's Geographical Information System (GIS) database.

Baseflow (groundwater flow) was calculated using an empirical formula and an estimated transmissivity of the surficial aquifer, hydraulic gradient of the watershed, and length of flow zone. Nitrogen loads associated with direct rainfall were calculated by multiplying historic rainfall depths times literature values for rainfall nitrogen concentration. Nitrogen loads from septic tank systems were estimated based on the number of systems, assumed flow per system, estimated nitrogen concentration of septic tank effluent, and an estimated attenuation prior to reaching surface waters. The nitrogen loads were estimated, based on available literature information, for the existing condition (1995) and a future condition in the year 2010. The future condition land use information was obtained from the Charlotte Harbor NEP. No field measurements were performed to verify the accuracy of the developed pollutant loads.

1.3 Work Efforts Performed by ERD

On December 6, 2001, Environmental Research & Design, Inc. (ERD) entered into an agreement with SWFWMD to refine existing nitrogen loading assumptions for watershed areas discharging to Lemon Bay and to develop basin-specific models for six primary watershed areas. A field monitoring program was conducted by ERD from March-November 2002 to document the quantity and quality of inputs to Lemon Bay from six major tributaries, including Buck Creek, Oyster Creek, Ainger Creek, Gottfried Creek, Forked Creek, and Alligator Creek. Estimates of mass loadings from each primary tributary to Lemon Bay were generated for both wet and dry season conditions.

A stormwater monitoring program was conducted by ERD from November 2002-February 2003 to document the characteristics of stormwater runoff from residential, commercial, and natural areas in the Lemon Bay watershed. This information is used to develop a basin loading model for Lemon Bay which predicts inputs of nitrogen, phosphorus, TSS, and BOD from each of the six primary tributaries to Lemon Bay. This model was calibrated using the field monitoring efforts performed from March-November 2002. The model is used to estimate loadings to Lemon Bay under future development conditions.

This report has been divided into five separate sections for presentation of the work efforts performed by ERD. Section 1 provides a general description of the Lemon Bay area and summarizes the overall work efforts performed by ERD. The result of the tributary monitoring efforts, including estimation of tributary loadings, is provided in Section 2. The characteristics of stormwater runoff and stormwater management systems within the Lemon Bay watershed are discussed in Section 3. Section 4 provides a discussion of the characteristics of the Lemon Bay watershed under current and future conditions. Section 5 contains a discussion of the nutrient loading model developed by ERD, and provides estimates of nutrient inputs to Lemon Bay under current, future, and undeveloped conditions. An evaluation of potential alternatives for improvement of water quality is included in Section 6. Overall conclusions from the study and recommendations for improvement of water quality in Lemon Bay are given in Section 7. Various appendices are also attached, containing information from field monitoring and computer modeling efforts conducted by ERD.

SECTION 2

EVALUATION OF TRIBUTARY LOADINGS

Field evaluations were performed by ERD from March-November 2002 to provide information on the quantity and quality of significant tributary inflows to Lemon Bay, including (from north to south) Alligator Creek, Forked Creek, Gottfried Creek, Ainger Creek, Oyster Creek, and Buck Creek. Estimates of tributary inflow were collected on a continuous basis using dedicated underwater flow meters installed in each tributary. Collection of water samples for laboratory analyses was conducted on approximately a monthly basis. The results of field studies and associated evaluations conducted to quantify hydrologic and mass inputs to Lemon Bay are summarized in the following sections. A general overview of the surface hydrology of Lemon Bay is also provided.

2.1 Surface Hydrology

An overview of contributing watershed areas to Lemon Bay is included on Figure 1-1. Each of the seven sub-basin areas identified in Figure 1-1 discharge to Lemon Bay through a single well-defined pond, channel, or creek. Areas located between the delineated drainage basins and Lemon Bay discharge directly to Lemon Bay by either overland flow or small conveyance channels.

Initial basin delineations for areas located in Sarasota County were obtained from the Advanced ICPR Model developed by Sarasota County for Alligator Creek, Woodmere Creek, Forked Creek, Gottfried Creek, and Ainger Creek. Based upon discussions with Sarasota County personnel, a high level of confidence exists for the accuracy of the delineated areas for these sub-basins. As a result, no modifications to these basin areas were performed by ERD as part of this project.

Basin delineations for Oyster Creek and Buck Creek, located in Charlotte County, were obtained from GIS coverages provided by SWFWMD. An outline of the basin boundaries provided by SWFWMD for Oyster Creek and Buck Creek is given on Figure 2-1. After reviewing these basin boundaries, and viewing water movement within the basin areas during significant storm events, ERD proposed modifications to the basin boundaries for Oyster Creek and Buck Creek. A comparison of the original SWFWMD and modified basin boundaries for Oyster Creek and Buck Creek is given in Figure 2-1. The modified Oyster Creek boundary, indicated by the brown shaded area, was modified on both the northern and southern portions of the basin. An area on the northeast portion of the SWFWMD designation was removed since it appears that this area drains eastward toward the Myakka River Basin rather than into Oyster Creek. A second area on the southern portion of the basin was moved from the Oyster Creek basin into the Buck Creek basin based upon field observations of water movement during rain events.

Two significant modifications were also made to the original SWFWMD Buck Creek boundary. The most significant modification is the exclusion of a large area in the northeastern portion of the original SWFWMD boundary. Based upon field observations, it appears that this area discharges east and is part of the Myakka River basin. The second modification is the previously described exchange of basin area from Oyster Creek to Buck Creek.

A summary of basin areas for tributaries discharging to Lemon Bay, based upon the basin delineations outlined in Figure 1-1, is given in Table 2-1. Drainage basin sizes range from 597 ha (1475 ac) in Woodmere Creek to 3729 ha (9211 ac) in Buck Creek. Overall, the area represented by the seven primary tributaries discharging to Lemon Bay is approximately 161 km^2 (39,773 ac). Additional information on land use and hydrologic characteristics of the drainage basin areas is given in Section 4.

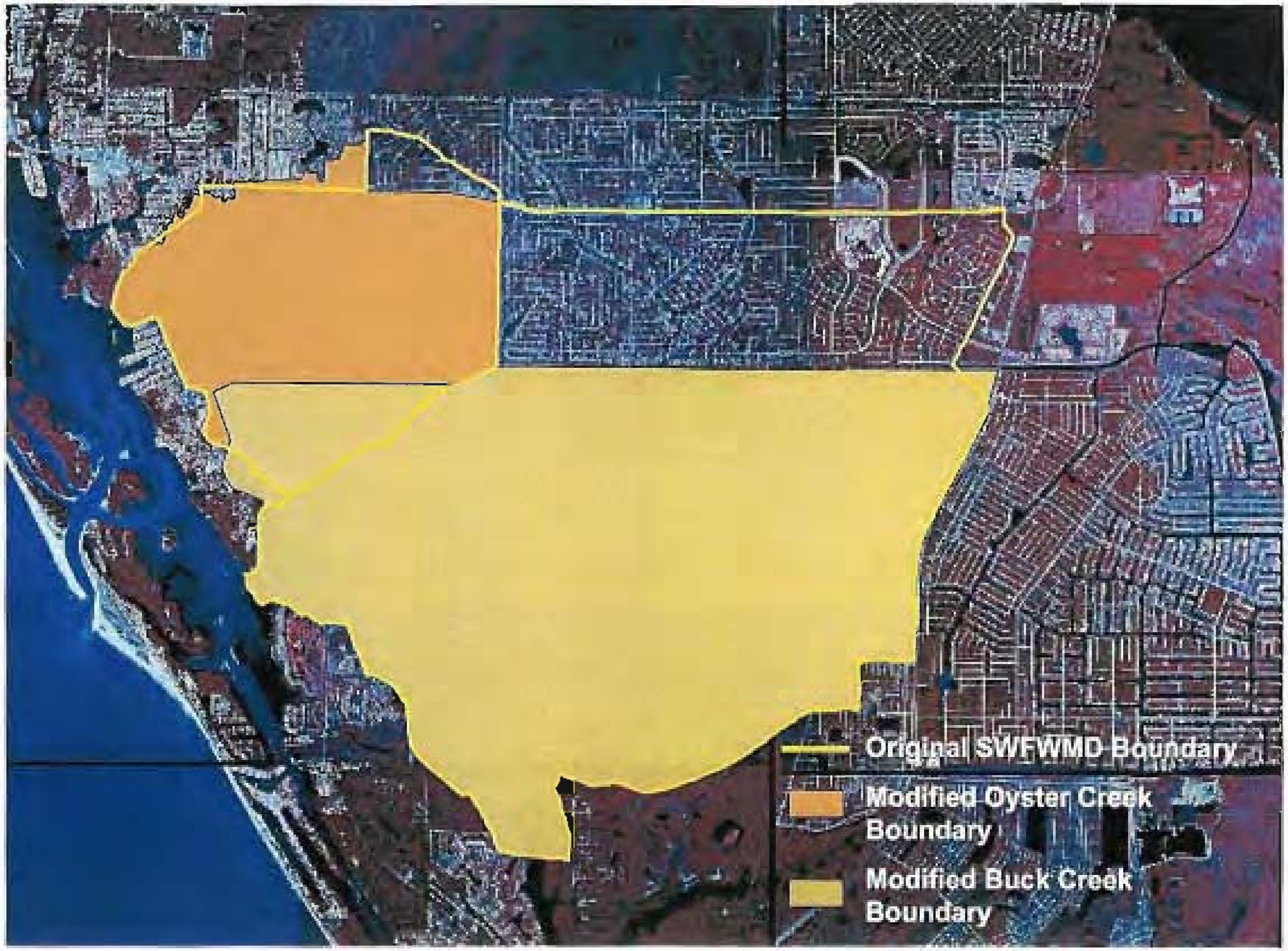


Figure 2-1. Comparison of Original SWFWMD and Modified Basin Boundaries for Oyster Creek and Buck Creek.

TABLE 2-1

BASIN AREAS FOR TRIBUTARIES DISCHARGING TO LEMON BAY

TRIBUTARY	BASIN AREA	
	ACRES (ac)	HECTARE (ha)
Alligator	6787.3	2748.1
Woodmere	1475.3	597.3
Forked	5860.0	2372.7
Gottfried	7272.4	2944.5
Ainger	6636.6	2687.1
Oyster	2530.4	1024.5
Buck	9210.9	3729.4
Totals:	**39,772.9**	**16,103.6**

2.2 Field Monitoring Efforts

2.2.1 Hydrologic Measurements

Measurements of tributary discharges to Lemon Bay were performed from March-November 2002 by ERD field personnel near the primary points of discharge for Alligator Creek, Forked Creek, Gottfried Creek, Ainger Creek, Oyster Creek, and Buck Creek. Field monitoring for the Woodmere Creek basin was not included as part of this project. Flow monitoring in the six tributaries was performed on both a continuous and instantaneous basis to assist in generating estimates of net discharge through each major tributary during the study period.

Locations for monitoring sites in Alligator Creek, Forked Creek, and Gottfried Creek are indicated on Figure 2-2. Monitoring sites in Alligator Creek and Forked Creek were selected to be near the downstream boundary of the drainage basin area for each tributary. The monitoring site for Gottfried Creek was selected at the bridge structure where SR 776 crosses Gottfried Creek.

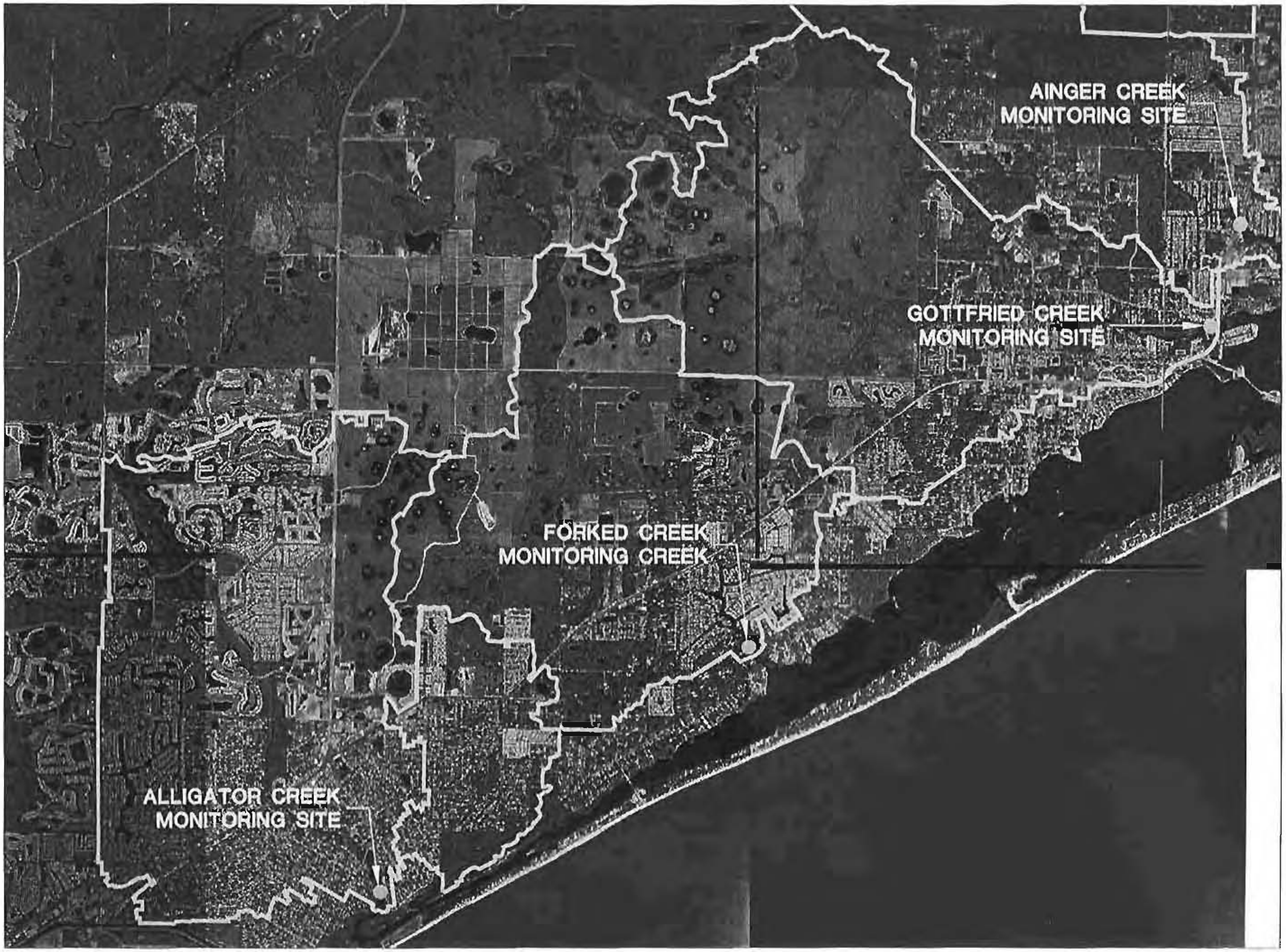


Figure 2-2. Field Monitoring Sites for Alligator, Forked and Gottfried Creeks.

Locations for field monitoring sites in Ainger Creek, Oyster Creek, and Buck Creek are indicated on Figure 2-3. Monitoring sites for these tributaries were selected at the intersection of SR 775 and each tributary.

Continuous records of net discharge through each tributary were performed using a bi-directional digital underwater flow meter, General Oceanics Model 2030R6, which was adapted with a high resolution rotor for low-speed applications. An illustration of the digital flow meter is given in Figure 2-4. The support rod for each flow meter was attached to a 3.2 cm (1.25 in) diameter PVC pipe which was firmly inserted into the channel bottom at each site. The flow meters were mounted at a depth of approximately two-thirds of the total water depth to avoid damage by boat propellers and other recreational water activities.

Each of the underwater flow meters was equipped with a counter which provided a record of the number of revolutions turned by the high resolution rotor, providing a continuous record of the net movement of water at each monitoring location. This information was coupled with the instantaneous readings and information on the channel geometry to provide estimates of the total volume of water discharging through each site during the monitoring period.

Measurements of tributary discharge rates were performed at each of the six monitoring sites to calibrate the underwater flow meters. Discharge rates were determined using the velocity/cross-sectional area method. A graduated rope was stretched across each tributary monitoring site, and field measurements of water depth and flow velocity were performed at periodic intervals across the channel. Velocity measurements were performed using a Marsh McBirney Model 201D flow meter. If the water depth of a given section was approximately 1 m or less, velocity measurements were performed at 60% of the water depth. If the water depth at a given site exceeded 1 m, velocity measurements were performed at 20% and 80% of the water depth and averaged to obtain an estimate of mean velocity in the monitored section. Discharge rates were calculated for each channel section by multiplying the mean section velocity times the cross-sectional area for the section.

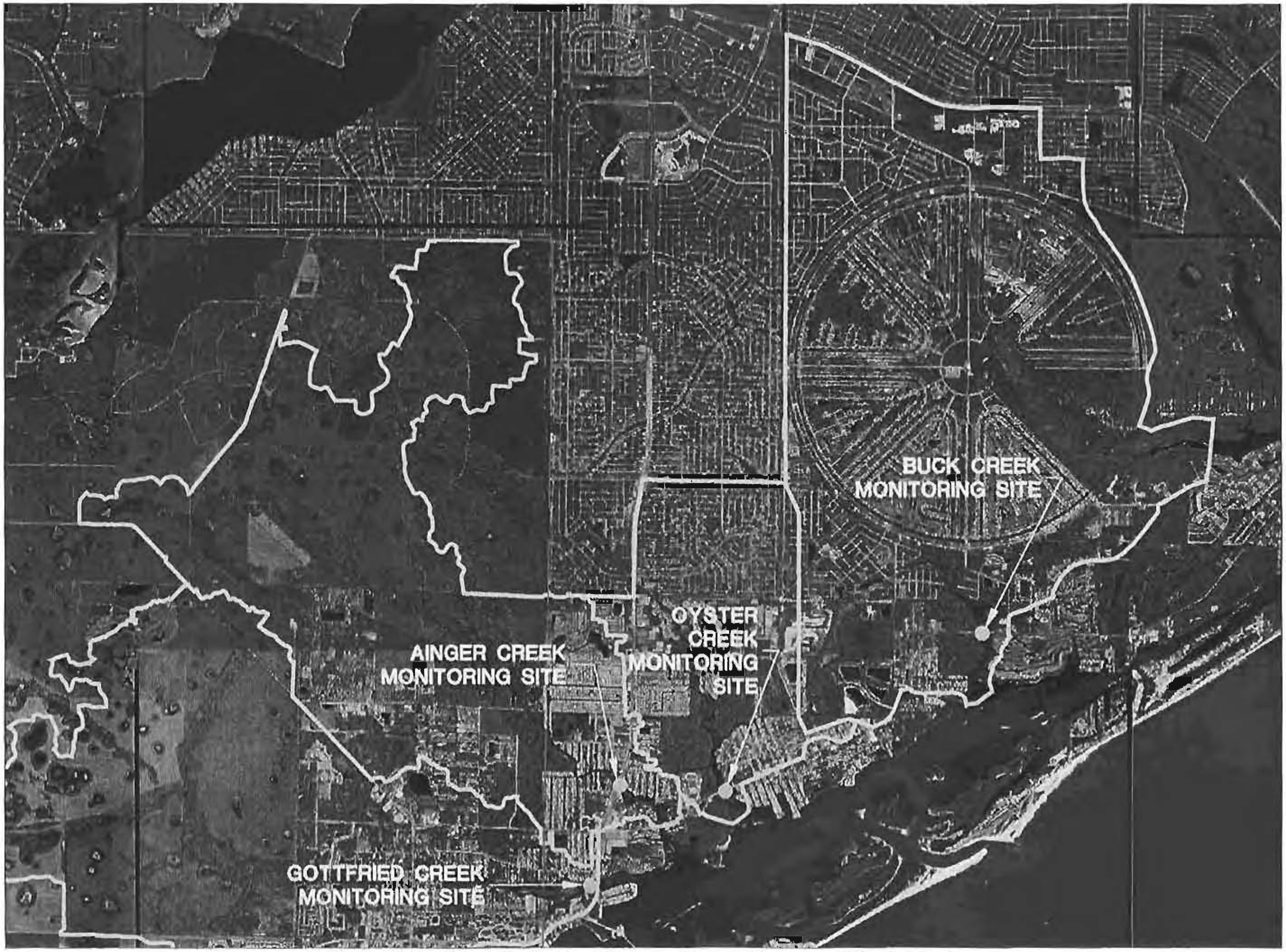


Figure 2-3. Field Monitoring Sites for Ainger, Oyster and Buck Creeks.

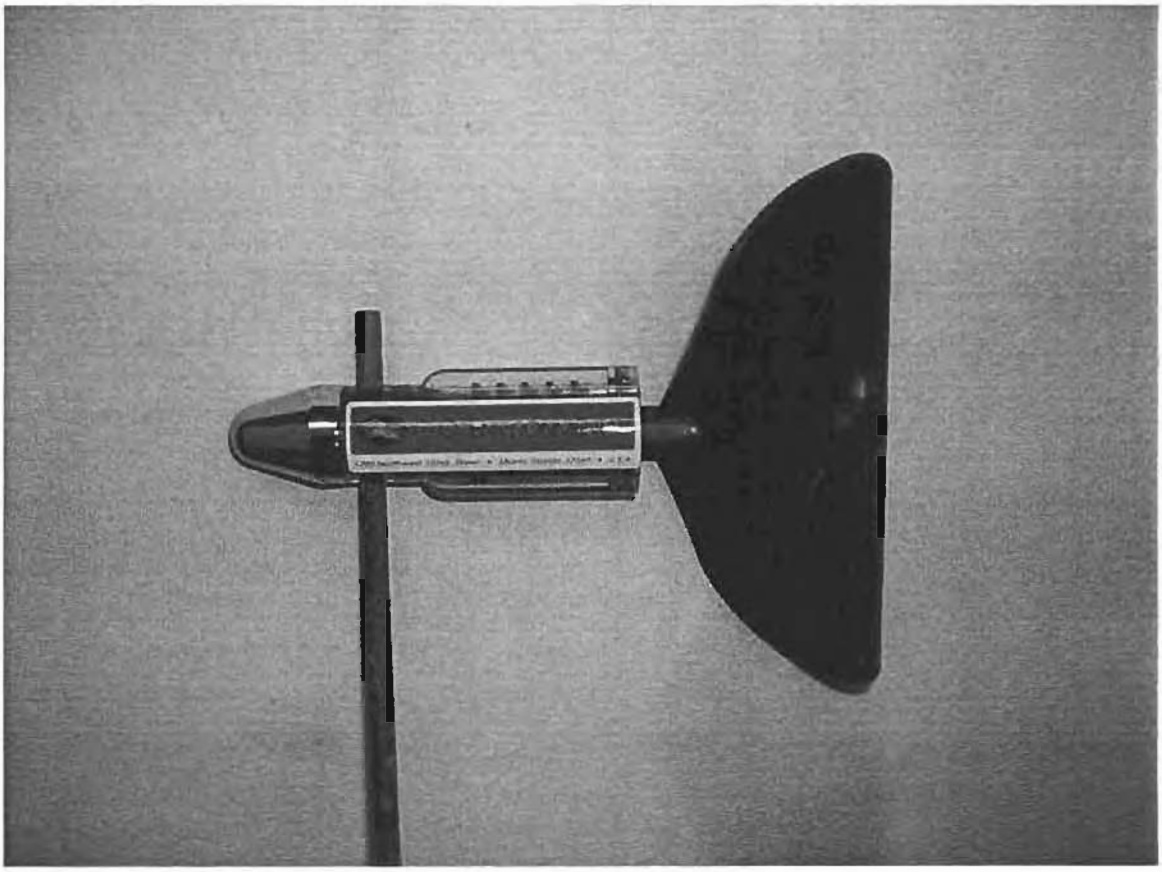


Figure 2-4. Typical Digital Flow Meter used for Tributary Inflow Measurements.

The calibration events for the underwater flow meters were performed during a period of moderate flow conditions at each site. To begin a calibration event, an initial measurement of tributary discharge would be performed using the methodology outlined previously. The time of initiation of the flow measurements was recorded, along with the counter reading on the digital underwater flow meter. After approximately 1-2 hours, an additional measurement of tributary discharge rate was performed, and the ending time and counter reading for the underwater flow meter were recorded. The calculated initial and final discharge rates over the calibration period were averaged together to obtain an estimate of the mean discharge rate during the calibration period. The total flow which discharged through the creek section was then calculated by multiplying the mean discharge rate times the time interval over which the calibration event was performed. The total flow volume (in cubic feet) is divided by the change in counter reading to obtain an estimate of the discharge volume associated with each revolution of the flow meter rotor for each channel.

The change in counter readings between two individual monitoring events is multiplied by the field-determined calibration factor to estimate the total flow discharging past the monitoring location during the two monitoring events. Since the underwater flow meters are bidirectional, the flow measurements obtained using this methodology represent the net discharge through each section between the two field events. Flow calibration data for each of the six monitored tributaries is given in Appendix A.1. Field notes for the underwater flow meters, including counter readings and general flow meter operation, is included in Appendix A.2.

Readings from the underwater mechanical flow meters were retrieved by ERD on approximately a 2-4 week interval using a diver. During each event, operation of the flow meter was observed, and any barnacles, debris, vegetation, or other matter was removed from the propeller, if necessary. In general, the propeller and counter site glass were cleaned on each visit to ensure proper operation of the device and data retrieval.

2.2.2 Water Quality Monitoring

A water quality monitoring program was conducted at each of the six tributary inflow monitoring sites identified in Figures 2-2 and 2-3 to characterize the water quality in the primary tributary inflows to Lemon Bay. A total of seven separate water quality monitoring events was conducted in Ainger Creek, Alligator Creek, Forked Creek, Gottfried Creek, and Oyster Creek, with six separate events conducted in Buck Creek. In general, surface water monitoring events were conducted on approximately a monthly basis from April-October 2002.

Tributary inflow samples were collected at mid-depth in the water column at each monitoring site. Each of the collected samples was filtered and preserved in the field as appropriate for the parameters to be analyzed, and returned on ice to the ERD laboratory for further analyses. The tributary inflow samples were analyzed for general parameters, nutrients, suspended solids, and fecal coliform bacteria. A listing of laboratory methodologies utilized to analyze the collected tributary samples is given in Table 2-2.

TABLE 2-2

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES CONDUCTED ON TRIBUTARY SAMPLES

MEASUREMENT PARAMETER	METHOD	METHOD DETECTION LIMITS (MDLs)[1]
General Parameters		
Hydrogen Ion (pH)	EPA-83[2], Sec. 150.1/Manf. Spec.[3]	NA
Specific Conductivity	EPA-83, Sec. 120.1/Manf. Spec.	0.1 µmho/cm
Salinity	SM-19, Sec. 2520 B.[4]	NA
Alkalinity	EPA-83, Sec. 310.1	0.5 mg/l
Color	EPA-83, Sec. 110.3	1 Pt-Co Unit
Turbidity	EPA-83, Sec. 180.1	0.1 NTU
T.S.S.	EPA-83, Sec. 160.2	0.7 mg/l
Biological Parameters		
Chlorophyll-a	SM-19, Sec. 10200 H.3	0.1 mg/m^3
Nutrients		
Ammonia-N (NH_3-N)	SM-19, Sec. 4500-NH_3 G.	0.01 mg/l
Nitrate + Nitrite (NO_x-N)	EPA-83, Sec. 353.3	0.01 mg/l
Organic Nitrogen	Alkaline Persulfate Digestion[5]	0.03 mg/l
Orthophosphorus	SM-19, Sec. 4500-P E.	0.001 mg/l
Total Phosphorus	Alkaline Persulfate Digestion[5]	0.001 mg/l

1. MDLs are calculated based on the EPA method of determining detection limits.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. Subject to manufacturer's specifications for test equipment used.
4. Standard Methods for the Examination of Water and Wastewater, 19th Edition, 1992.
5. FDEP-approved method.

In addition to collection of samples for laboratory analyses, vertical field profiles of temperature, pH, specific conductivity, salinity, dissolved oxygen, and turbidity were performed at each monitoring site beginning with the June 2002 monitoring event. Field measurements were performed at water depths of 0.25 m and 0.5 m, and at 0.5 m intervals to the bottom at each site.

2.3 Tributary Inflow

Measurements of net discharge at each of the six monitored tributaries were performed by ERD from March 29-November 12, 2002, covering a period of 228 days. Assuming that "wet season" conditions occur during the months of June-September, and "dry season" conditions occur from October-May, the 228-day monitoring period included 106 days of dry season conditions and 122 days of wet season conditions.

A summary of net flow measurements recorded at the six monitored tributaries from March 28-November 12, 2002 is given in Table 2-3, based upon the flow meter readings summarized in Appendix A.2. The measured tributary inflows reflect the total flow volume, in units of ac-ft, discharging through the six primary tributaries over each of the monitored time intervals, ranging from 21-48 days. A net positive discharge was recorded from the six tributaries during each monitored interval, with the exception of the initial interval from March 29-April 21, 2002. During this interval, which reflected dry season conditions, flow conditions in the six tributaries appear to be relatively stagnant, with a slight negative discharge (upstream) recorded at each site. In general, flow through each of the six tributaries appears to increase substantially during wet season conditions, with a rapid decrease in flow characteristics during dry season conditions.

TABLE 2-3

NET FLOW MEASUREMENTS AT THE SIX MONITORED TRIBUTARIES FROM MARCH 29-NOVEMBER 12, 2002

TIME INTERVAL	NO. OF DAYS	TOTAL FLOW (ac-ft)					
		OYSTER CREEK	BUCK CREEK	AINGER CREEK	GOTTFRIED CREEK	FORKED CREEK	ALLIGATOR CREEK
3/29-4/21	23	-55	-58	-38	-21	-82	-26
4/21-6/8	48	119	616	241	279	387	389
6/8-7/10	32	310	1764	517	658	725	662
7/10-7/31	21	425	1545	305	890	574	1388
7/31-9/15	46	609	2013	924	1168	604	1323
9/15-10/18	33	364	572	200	324	251	292
10/18-11/12	25	51	279	102	238	110	183
Totals:	**228**	**1823**	**6732**	**2249**	**3535**	**2569**	**4212**

A summary of recorded rainfall during 2002 at the SWFWMD rainfall station in Englewood, identified as Site 314, is given in Table 2-4. This rainfall station is located in the Gottfried Creek sub-basin. Dates included in the 228-day field monitoring program are highlighted, with dry season conditions highlighted in yellow and wet season conditions highlighted in green. Based upon the information provided in Table 2-4, a total of 5.96 inches of rainfall fell in the vicinity of the Lemon Bay Watershed during the 106-day dry season monitoring period, with 30.6 inches of rainfall during the 122-day wet season monitoring period.

A summary of mean seasonal rainfall at the Englewood station (Site 314) from 1974-2000 is given in Table 2-5. Over the 27-year period from 1974-2000, mean dry season rainfall has averaged approximately 18.76 inches/year, with 28.32 inches/year recorded during wet season conditions. Total annual rainfall over the 27-year period has averaged 47.08 inches.

As seen in Table 2-4, wet season rainfall during the field monitoring program was approximately 30.6 inches compared with a mean annual wet season rainfall of approximately 28.32 inches. Rainfall conditions during the monitoring program were approximately 8% greater than "normal" rainfall measured at the site. Rainfall during dry season conditions generated only 5.96 inches compared with a "normal" dry season rainfall of 18.76 inches. However, the monitoring program performed by ERD covered only a portion of the dry season conditions during the year 2002. Total dry season rainfall measured at the Englewood monitoring station was 21.28 inches during 2002, which is approximately 13% greater than normal.

A comparison of estimated wet season and dry season inflow to Lemon Bay during the 228-day field monitoring program, based upon the net flow measurements provided in Table 2-3, is given in Table 2-6. Recorded net inflow during the period from 3/29-5/10 and 10/1-11/12 was summed to provide an estimate of inflow during the "dry season" portion of the monitoring program. Flow measured during monitoring intervals which overlap "wet season" and "dry season" periods, such as the 4/21-6/8 and 9/15-10/18 intervals, was converted into a mean daily flow which was allocated to "wet" and "dry" season conditions based on the number of days in each season included.

TABLE 2-4

RECORDED RAINFALL DURING 2002 AT THE SWFWMD RAINFALL STATION (SITE 314) IN ENGLEWOOD, FL

DAY	MONTH											
	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0.17	0	0	0	0
2	0.68	0	0	0	0	0	0	0.62	0	0	0	0
3	0	0	0	0	0	0	0	0.05	1.1	0	0	0
4	0.04	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0.05	0.54
6	0.06	0	0	0	0	0	0.21	0	0	0	0	0.02
7	0.02	0.71	0.4	0	0	0	0.35	0	0	0	0	0
8	0	0	0	0	0	0.31	0.48	0	0	0	0	0.1
9	0	0	0	0	0	0.02	0.07	0	0	0.06	0	0.9
10	0	0.23	0	0	0	0	0	0	0.42	0	0	0.14
11	0	0	0	0	0	0.28	0	0.67	1	0	0	0
12	0.02	0	0	2.03	0.15	0.22	0.05	0	0.48	0	0.12	0.16
13	0.04	0.06	0	0	0	0.52	0.25	0	0.02	0.12	0	0.8
14	1.6	0	0	0	0	0.6	0	1.1	0.02	0.54	0	0
15	0.02	0.02	0	0	0	0.03	0	0.87	0	0.08	0	0
16	0	0	0	0.15	0	0.24	0	0.07	0.03	0	1.35	0
17	0	0	0	0.42	0	0.6	0.05	0	0	0	1.5	0
18	0	0	0	0	1.15	0.28	0.55	0.16	0	0	0	0
19	0	0	0	0	0.98	0.04	0	0	0	0	0	0
20	0.02	0	0	0	0	0.52	0	0	0	0	0	0.14
21	0	2.1	0.03	0	0	1.25	0	0.6	0	0	0.03	0
22	0	2	0	0	0	1.87	0	0.6	0	0	0	0
23	0	0.68	0	0	0	1.45	0	0.35	0.98	0	0	0
24	0	0	0	0	0	0.1	0.15	0	0	0	0	0.6
25	0	0	0	0	0	2.6	0.08	0.16	0.02	0	0	0
26	0	0	0	0	0	0.03	0	0.11	0	0	0	0
27	0	0	0	0	0.08	0.05	0	2.35	0	0	0	0
28	0	0	0	0	0	0.39	0	0.41	0	0	0	0
29	0		0	0	0	0.18	0.15	0.07	0.09	0.03	0	0
30	0		0	0	0	0.05	0	1.58	0	0	0	0
31	0		0		0		0	2.48		0		0.31
Totals	2.5	5.8	0.43	2.6	2.36	11.63	2.39	12.42	4.16	0.83	3.05	3.71

Monitoring Period Totals:										
	0	2.6	2.36	11.63	2.39	12.42	4.16	0.83	0.17	

Dry Season Total: 5.96 **Wet Season Total:** 30.6

TABLE 2-5

MEAN SEASONAL RAINFALL AT THE ENGLEWOOD STATION (SITE 314) FROM 1974-2000

PERIOD	MEAN RAINFALL (inches)
Dry Season	18.76
Wet Season	28.32
Annual	47.08

TABLE 2-6

ESTIMATES OF MEASURED AND ANNUALIZED TRIBUTARY DISCHARGES ENTERING LEMON BAY DURING 2002

1. Measured Tributary Flows

SEASON	DAYS MONITORED	OYSTER CREEK	BUCK CREEK	AINGER CREEK	GOTTFRIED CREEK	FORKED CREEK	ALLIGATOR CREEK
Dry	106	294	792	373	626	488	641
Wet	122	1529	4456	1877	2909	2081	3571
Total	**228**	**1823**	**5248**	**2249**	**3535**	**2569**	**4212**

2. Annual Tributary Flows

SEASON	RAINFALL	ESTIMATED TRIBUTARY DISCHARGE (ac-ft)					
		OYSTER CREEK	BUCK CREEK	AINGER CREEK	GOTTFRIED CREEK	FORKED CREEK	ALLIGATOR CREEK
Dry	18.82	927	2500	1177	1978	1540	2024
Wet	28.76	1437	4188	1764	2734	1956	3356
Total	**47.58**	**2364**	**6688**	**2941**	**4711**	**3496**	**5380**

Estimates of annualized tributary inflows to Lemon Bay are also provided in Table 2-6 by adjusting the measured tributary inflow volumes times the ratio of measured rainfall to normal rainfall conditions. Based upon the information provided in Table 2-4, a total of 5.96 inches of rainfall occurred in the Lemon Bay Watershed during dry season monitoring performed by ERD. However, the normal rainfall occurring in the Lemon Bay Watershed during dry season conditions is approximately 18.76 inches, as indicated in Table 2-5. Therefore, the measured tributary inflows at each of the six monitoring sites were multiplied by the ratio of 18.76/5.96 to adjust the dry season conditions for normal rainfall conditions. Similarly, the measured wet season tributary inflows were adjusted by the ratio of 28.32 inches of rainfall which normally occurs under wet season conditions to the 30.6 inches of rainfall measured during the wet season monitoring program. This resulted in a slight reduction in estimated annual flows during wet season conditions compared with the measured tributary inflow values. This methodology appears appropriate since discharges through the primary tributaries are regulated primarily by rain events and the resulting groundwater drawdown during inter-event dry periods.

A graphical comparison of estimated seasonal flows into Lemon Bay from the six primary tributaries is given in Figure 2-5. Each of the six tributaries appears to contribute less inflow during dry season conditions, although dry season conditions are assumed to occur for 243 days compared with only 122 days for wet season conditions, at each site. However, differences in discharge volumes during wet and dry season conditions appear to be relatively minimal for several of the tributaries, including Oyster Creek, Ainger Creek, and Forked Creek. Larger differences between wet and dry season conditions appear to exist for Buck Creek, Gottfried Creek, and Alligator Creek.

The sum of the wet season and dry season estimates reflect the estimated total annual inflow through each of the six tributaries. The largest annual inputs into Lemon Bay occur through Buck Creek which contributes approximately 6688 ac-ft of water each year. Alligator Creek, the second largest contributor of water volume to Lemon Bay, contributes approximately 5380 ac-ft per year. Gottfried Creek contributes approximately 4711 ac-ft per year. Combined together, Buck Creek, Gottfried Creek, and Alligator Creek contribute approximately 68% of the annual hydrologic inputs to Lemon Bay from the six evaluated tributaries. The lowest contributing tributary to Lemon Bay appears to be Oyster Creek which has an estimated input of 2364 ac-ft per year.

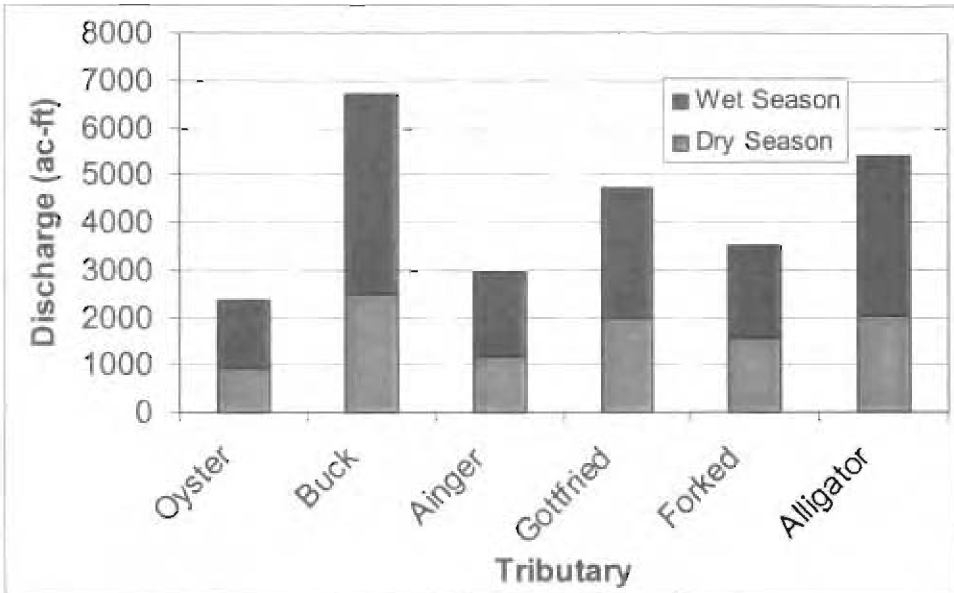


Figure 2-5. Comparison of Estimated Seasonal Flows into Lemon Bay.

2.4 Water Quality Characteristics of Tributary Inflows

A field water quality monitoring program was conducted in the six primary tributaries discharging to Lemon Bay from April-October 2002. Water quality samples were collected from each of the tributaries on approximately a monthly basis to document both seasonal and long-term characteristics of discharges from the tributaries to Lemon Bay. The water quality monitoring program involved both field measurements and laboratory analyses of collected samples. A discussion of the results of the collected field measurements, laboratory analyses of tributary samples, and a comparison of characteristics between the six tributary inflow sites is given in the following sections.

2.4.1 Field Measurements

With the exception of the initial monitoring event during April 2002, field measurements of pH, temperature, salinity, and dissolved oxygen were performed at each tributary inflow site during each of the monthly monitoring events. Vertical profiles for the measured parameters were collected at a water depth of 0.25 m and 0.5 m, with additional measurements performed at 0.5 m intervals to the bottom at each site. A complete listing of field measurements conducted during this project is given in Appendix B.1.

2.4.1.1 Buck Creek

A compilation of vertical depth profiles collected in Buck Creek from June-October 2002 is given in Figure 2-6. Water depths at the Buck Creek monitoring site range from approximately 0.9-1.3 m during the monitoring program. In general, temperature profiles appear to be relatively uniform during each of the monitoring events. No significant evidence of thermal stratification is apparent during any monitoring event at the Buck Creek site. Measured temperatures at this site range from approximately 29-34.5 °C.

Measured pH values at the Buck Creek monitoring site also appear to be relatively uniform throughout the water column on each of the monitoring dates. In general, pH differences between top and bottom measurements appear to be less than 0.1 unit on most days. Measured pH values range from approximately 7.6 during wet season conditions to 8.3 during borderline wet/dry conditions.

Measured salinity at the Buck Creek site was found to be highly variable, with salinity measurements ranging from approximately 7-32 ppt between the monitoring events. Three of the salinity monitoring events at Buck Creek reflect relatively isograde conditions for salinity, with virtually no difference between top and bottom measurements. However, measurements performed during July and August, reflecting wet season conditions, show increases in salinity in lower portions of the water column.

Similar to the trends observed for salinity, measurements of dissolved oxygen also appear to be highly variable in discharges from Buck Creek. Measured dissolved oxygen concentrations

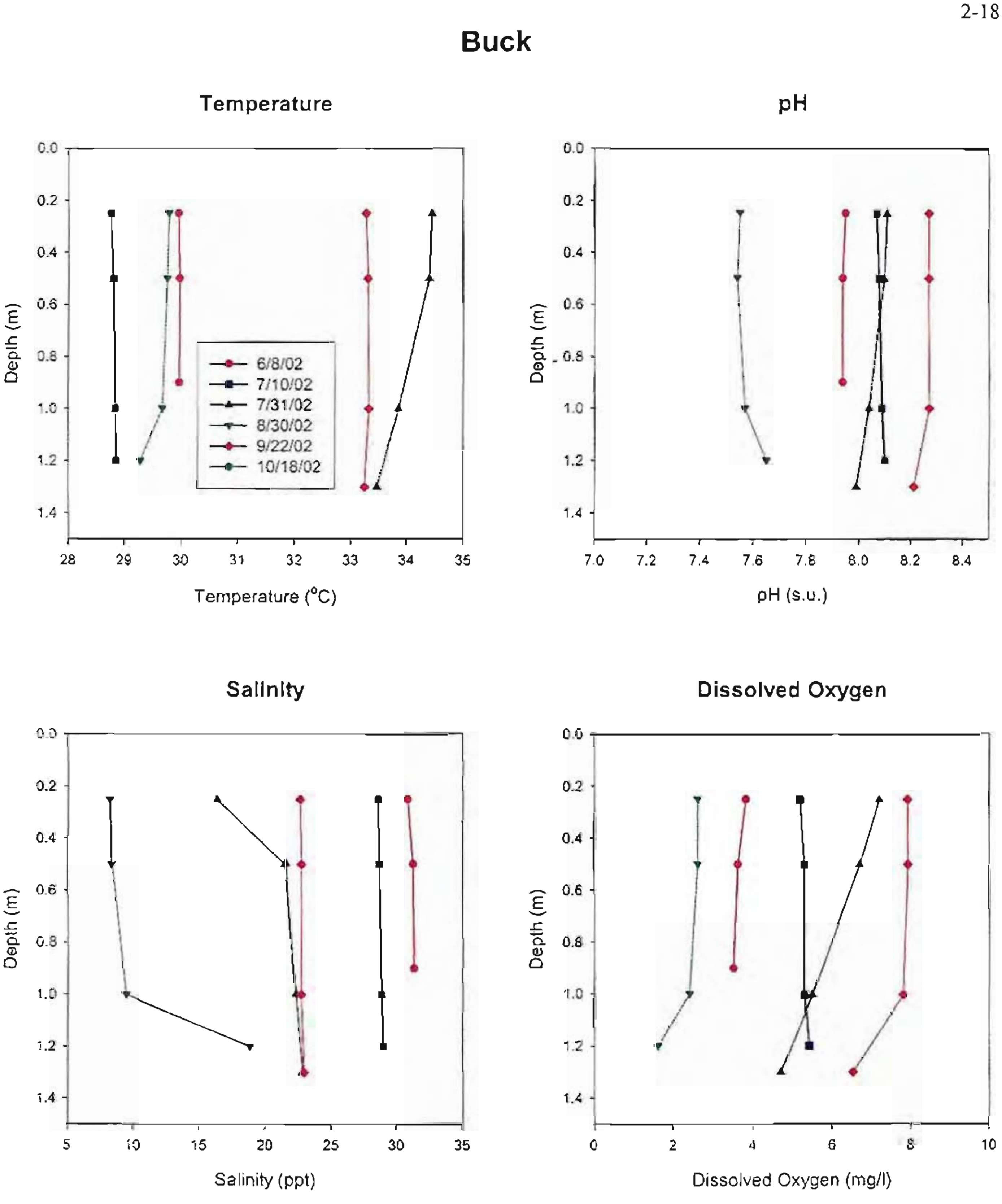


Figure 2-6. Compilation of Vertical Depth Profiles Collected in Buck Creek from June - October 2002.

at this site range from approximately 2-8 mg/l. A general trend of decreasing dissolved oxygen with increasing water depth is apparent during most events. Monitoring events performed during July and September are characterized by dissolved oxygen concentrations in excess of 4 mg/l which is the minimum dissolved oxygen criterion for discharges to marine systems, as outlined in Chapter 62-302 of the Florida Administrative Code (FAC). Dissolved oxygen measurements performed during August and June indicate concentrations less than 4 mg/l, reflecting values lower than the water quality criterion for this parameter.

2.4.1.2 Oyster Creek

A compilation of vertical depth profiles collected in Oyster Creek from June-October 2002 is given in Figure 2-7. Water depth at the Oyster Creek monitoring site was somewhat variable, ranging from approximately 0.6-1.2 m.

In general, temperature measurements performed in Oyster Creek indicate relatively uniform temperature profiles throughout the water column on each of the six monitored dates. Temperature measurements in Oyster Creek ranged from 26-34 °C during the monitoring program. Differences in temperature between top and bottom samples are typically less than 0.2 °C.

Relatively isograde conditions were also observed for pH measurements performed in Oyster Creek. No significant increase or decrease in pH value was observed on any of the monitoring dates. Measurements of pH at this site ranged from approximately 7.5-8.2 during the monitoring program.

Measured salinity concentrations in Oyster Creek were found to be highly variable, ranging from approximately 15-34 ppt. No significant change in salinity is apparent with increasing water depth during five of the six monitoring events. However, a significant increase in salinity was observed with increasing water depth during the monitoring event performed in August, where salinity measurements increase from approximately 15 ppt near the surface to approximately 20 ppt near the bottom.

Oyster

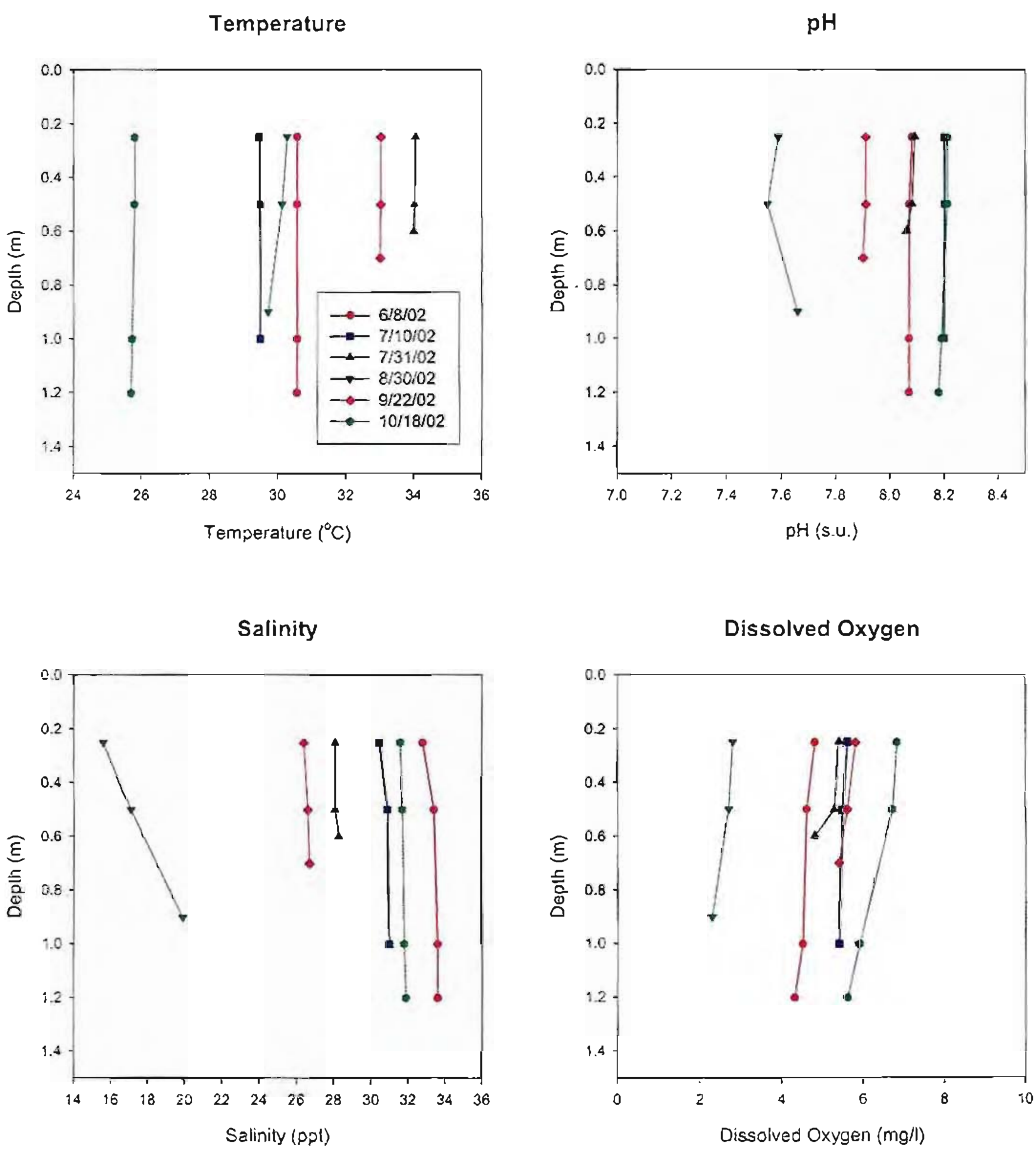


Figure 2-7. Compilation of Vertical Depth Profiles Collected in Oyster Creek from June - October 2002.

In general, a slight decrease in dissolved oxygen was observed with increasing water depth during each monitoring event. Five of the six monitoring events indicated dissolved oxygen concentrations in excess of the minimum criterion of 4 mg/l, with the August monitoring event indicating dissolved oxygen concentrations less than 4 mg/l. Dissolved oxygen concentrations measured in Oyster Creek ranged from approximately 2-7 mg/l.

2.4.1.3 Ainger Creek

A compilation of vertical depth profiles collected in Ainger Creek from June-October 2002 is given in Figure 2-8. Water depths at the Ainger Creek monitoring site ranged from approximately 0.8-1.4 m during the monitoring program.

In general, temperature profiles in Ainger Creek reflect relatively uniform values on each of the six monitoring dates, with measured temperature values ranging from approximately 26-34 ^{o}C. No significant evidence of thermal stratification was observed during any event.

Measured pH profiles in Ainger Creek also appear to be relatively uniform during each monitoring event. Overall pH measurements range from approximately 7.4-8.3, with the majority of events exhibiting pH values ranging from 7.9-8.3.

Similar to the trends observed at previous monitoring sites, salinity measurements in Ainger Creek were found to be highly variable, ranging from approximately 10-34 ppt throughout the monitoring program. In general, a slight increase in salinity is apparent with increasing depth during many of the monitoring events. The lowest salinity measurements were observed during August, reflecting wet season conditions. This date also corresponds to the lowest values for pH and dissolved oxygen measured at this site.

Measurements of dissolved oxygen were found to be highly variable at the Ainger Creek monitoring site, with values ranging from approximately 2-8 mg/l. Monitoring events performed during July, September, and October exhibit dissolved oxygen concentrations in excess of 4 mg/l, while events performed during June and August exhibit dissolved oxygen concentrations less than 4 mg/l. In general, a slight trend of decreasing dissolved oxygen is apparent with increasing water depth.

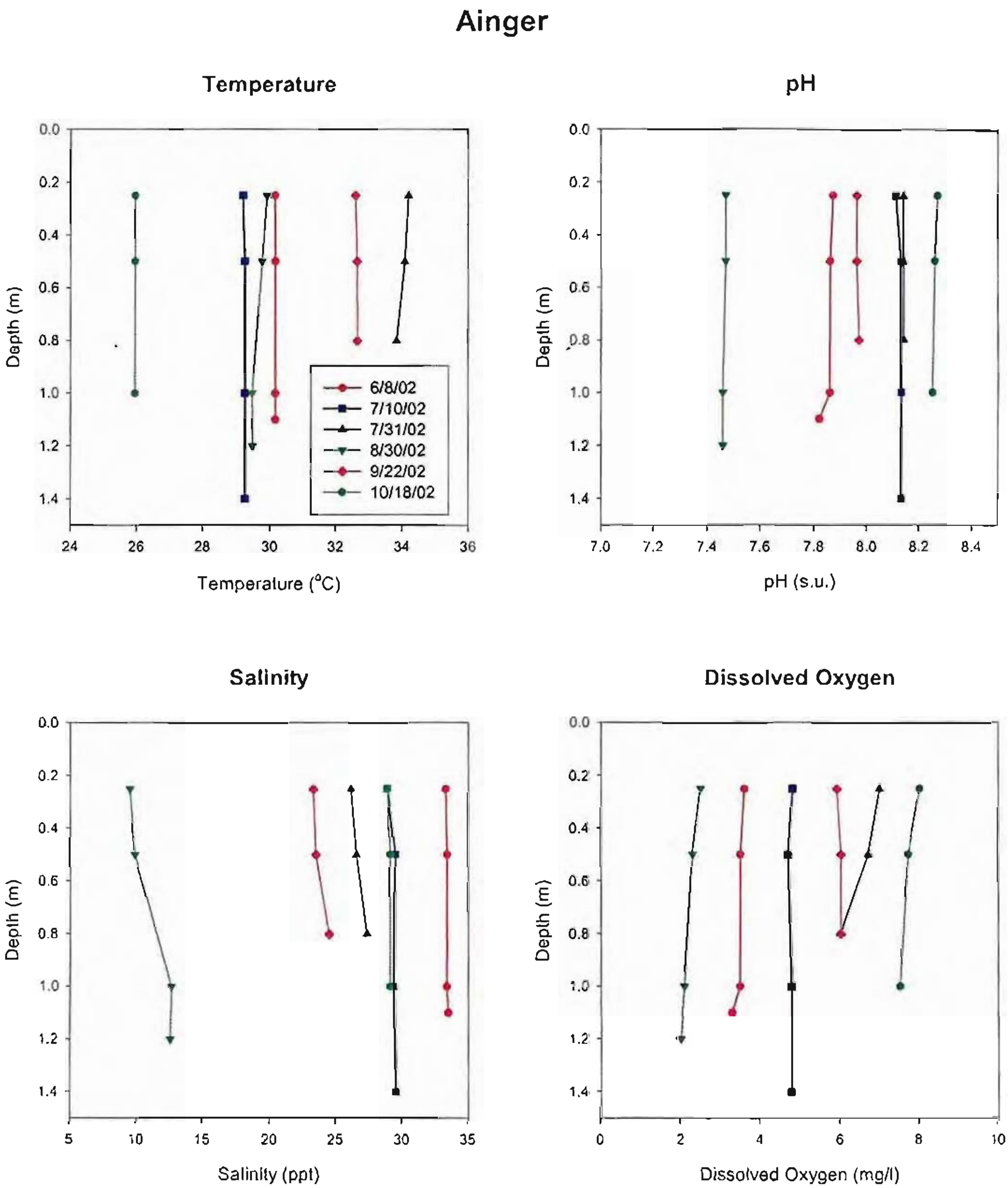


Figure 2-8. Compilation of Vertical Depth Profiles Collected in Ainger Creek from June - October 2002.

2.4.1.4 Gottfried Creek

A compilation of vertical depth profiles collected in Gottfried Creek from June-October 2002 is given in Figure 2-9. Water depths at the monitoring site range from approximately 1.4-1.9 m. The monitoring location had to be relocated to a more shallow location during the July 31st monitoring event due to heavy boat traffic.

In general, temperature profiles collected in Gottfried Creek reflect relatively uniform conditions throughout the water column on a majority of the monitoring dates. A slight decrease in temperature with increasing water depth is apparent during three of the six monitoring depths. Overall, water temperatures ranged from approximately 28.5-34 °C at this site.

Relatively uniform pH measurements were observed at the Gottfried Creek monitoring site during a majority of the monitoring events. Measured pH values at the site range from approximately 7.5-8.4. A general trend of decreasing pH with increasing water depth is apparent for the July and August monitoring events.

A relatively high degree of variability is apparent in salinity measurements performed in Gottfried Creek, with measurements ranging from approximately 14-34 ppt. The majority of the monitored events exhibit salinity values ranging from 25-34 ppt, while substantially lower salinity was observed during the August monitoring event. A slight trend of increasing salinity with increasing water depth is apparent during most of the events collected at this site. Similar to the trends observed at the previous monitoring sites, the low salinity event observed during August also corresponds to the lowest measurements of pH and dissolved oxygen at this site.

In general, dissolved oxygen concentrations measured in Gottfried Creek were found to be highly variable between the six monitoring events. Five of the monitoring events appear to exhibit dissolved oxygen concentrations in excess of 4 mg/l, while the August monitoring event is characterized by dissolved oxygen concentrations ranging from 2-3 mg/l. A slight trend of decreasing dissolved oxygen with increasing water depth is apparent during a majority of the monitored events.

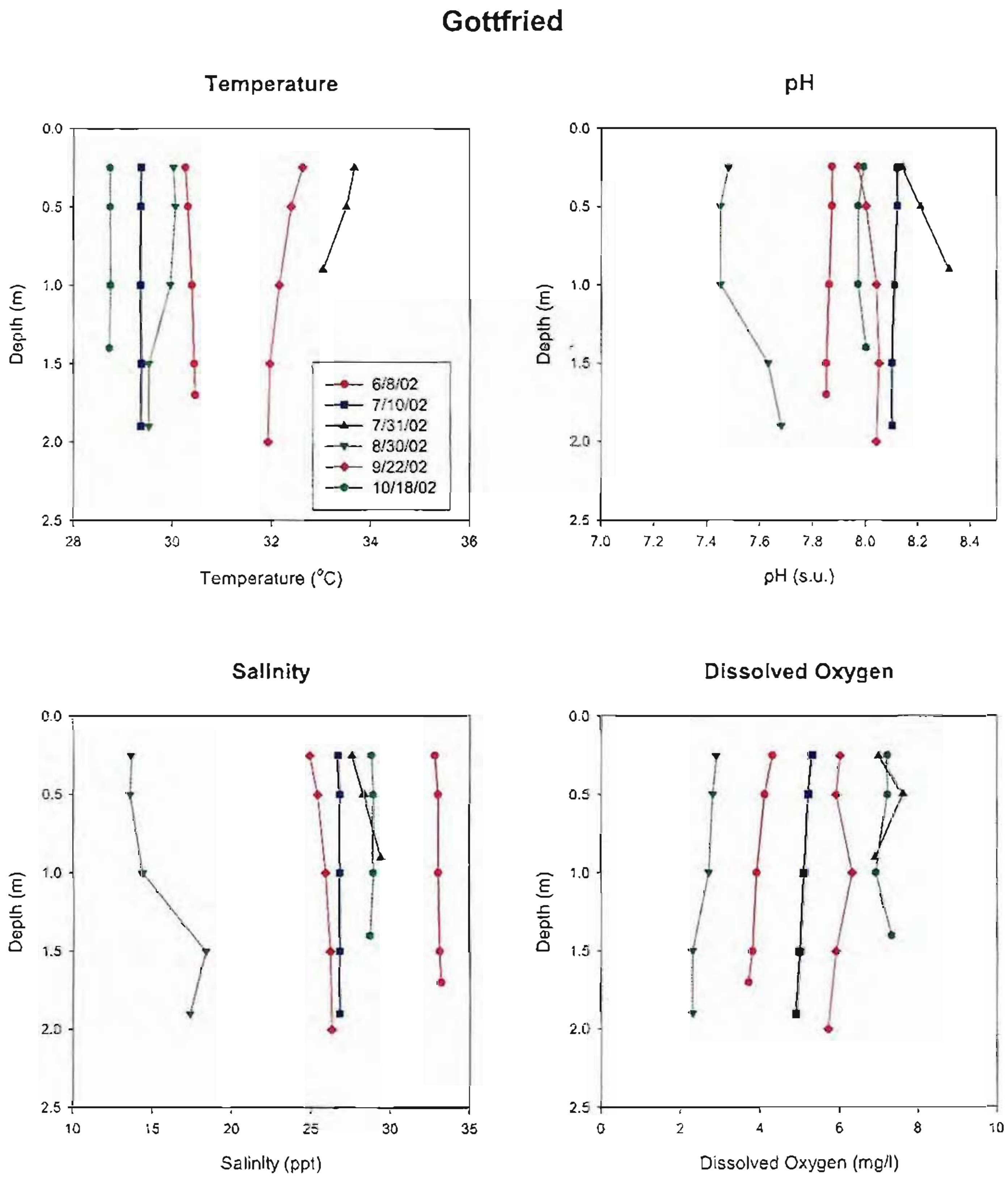


Figure 2-9. Compilation of Vertical Depth Profiles Collected in Gottfried Creek from June - October 2002.

2.4.1.5 Forked Creek

A compilation of vertical depth profiles collected in Forked Creek from June-October 2002 is given in Figure 2-10. Water depths at the Forked Creek monitoring site ranged from approximately 1-1.4 m during the monitoring program.

In contrast to the trends observed at the previous monitoring sites, water column temperature measurements in Forked Creek appear to be more variable than observed at other sites. Overall, temperature measurements at this site range from approximately 25-34 °C. A slight trend of decreasing temperature with increasing water depth is apparent for events conducted during July, August, September, and October, while temperature appears to increase with increasing water depth during June and early July.

Measured pH profiles at the Forked Creek site also appear to be highly variable compared with pH profiles observed at previous sites. Measured pH values at this site range from approximately 8-8.5, with a general trend of decreasing pH with increasing water depth during most events. A substantial decrease in pH with increasing water depth is apparent during the August monitoring event.

Similar to trends observed at previous sites, salinity regimes in Forked Creek were found to be highly variable during the monitoring program, with measured values ranging from approximately 16-31 ppt. Five of the six monitoring events exhibit salinity values ranging from 24-31 ppt, with substantially lower salinity values measured during the August monitoring event. A general trend of increasing salinity with increasing water depth is apparent at this site.

Dissolved oxygen concentrations in Forked Creek were also found to be highly variable, although most of the measurements performed at this site exhibit values in excess of 4 mg/l. A general trend of decreasing dissolved oxygen with increasing water depth is apparent during each monitored event. Surface dissolved oxygen concentrations measured during the August monitoring event exceeded 20 mg/l, reflecting supersaturated oxygen conditions. The elevated concentrations of dissolved oxygen and pH levels observed during this event suggest that a significant algal bloom was occurring in Forked Creek at the time of the August monitoring event.

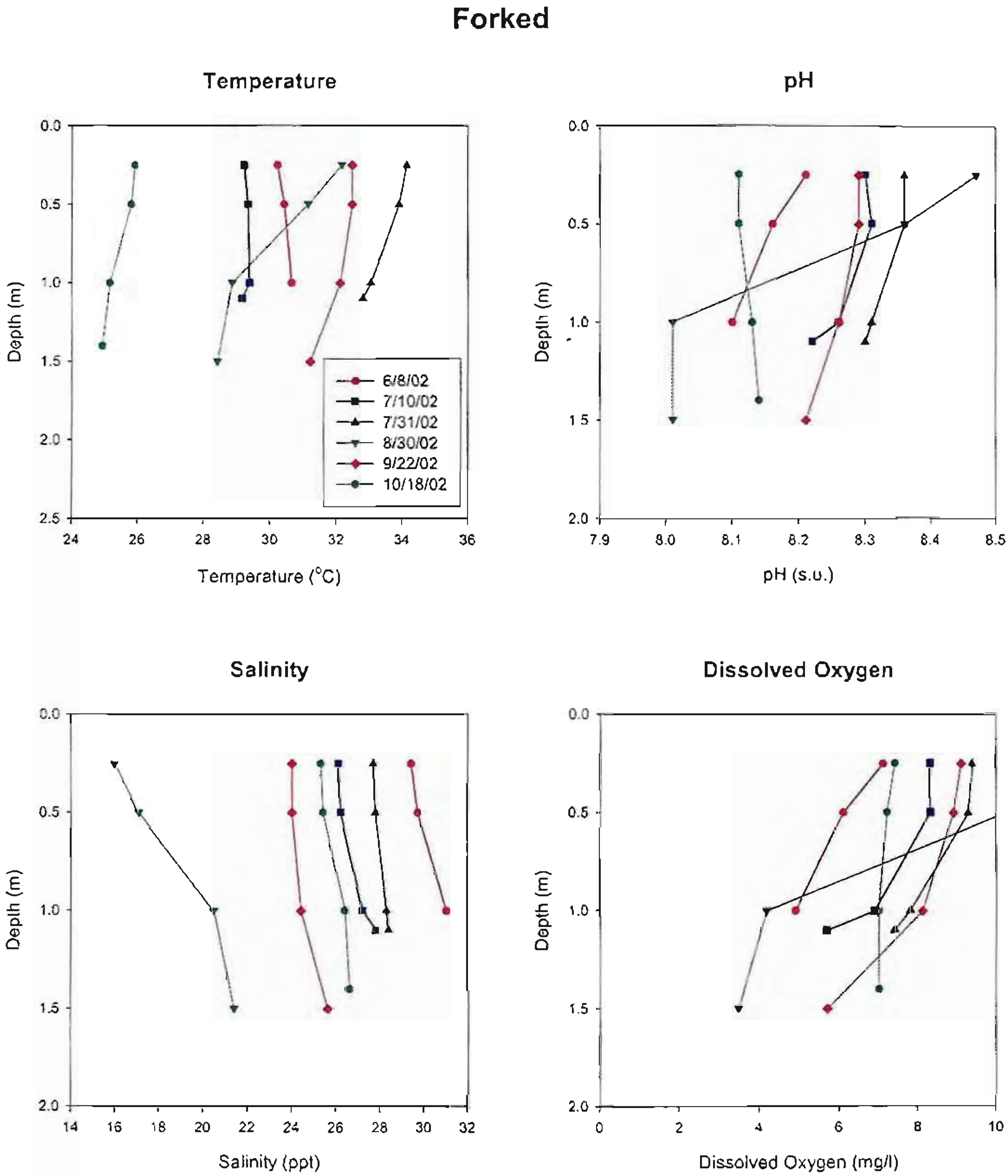


Figure 2-10. Compilation of Vertical Depth Profiles Collected in Forked Creek from June - October 2002.

2.4.1.6 Alligator Creek

A compilation of vertical depth profiles collected in Alligator Creek from June-October 2002 is given in Figure 2-11. Water depths at the Alligator Creek monitoring site ranged from approximately 0.4-0.5 m.

In general, relatively uniform temperature measurements were observed in the shallow water column at the Alligator Creek monitoring site. Temperature measurements at this site range from approximately 26.5-35.5 °C.

Measured pH values in Alligator Creek range from 7.6-8.1 during the monitoring program. A general trend of slightly decreasing pH with increasing water depth is apparent during each of the monitoring events.

Salinity measurements performed in Alligator Creek were found to be highly variable, ranging from approximately 2-27 ppt. Similar to the trends observed at the previous sites, minimum salinity measurements occurred during the August monitoring event, with the remainder of the monitoring events exhibiting salinity values ranging from approximately 15-27 ppt.

Dissolved oxygen measurements in Alligator Creek also appear to be highly variable, ranging from approximately 3-9 mg/l. Five of the six monitoring events were found to exhibit dissolved oxygen concentrations in excess of 4 mg/l, with only the June monitoring event exhibiting concentrations less than 4 mg/l.

2.4.2 Laboratory Measurements

A complete listing of laboratory measurements performed on Lemon Bay tributary samples is given in Appendix B.2. A total of seven separate tributary samples were collected in Ainger Creek, Alligator Creek, Forked Creek, Gottfried Creek, and Oyster Creek, with six samples collected in Buck Creek. A discussion of the general characteristics of water quality samples collected at each of the tributary inflow monitoring sites is given in the following sections.

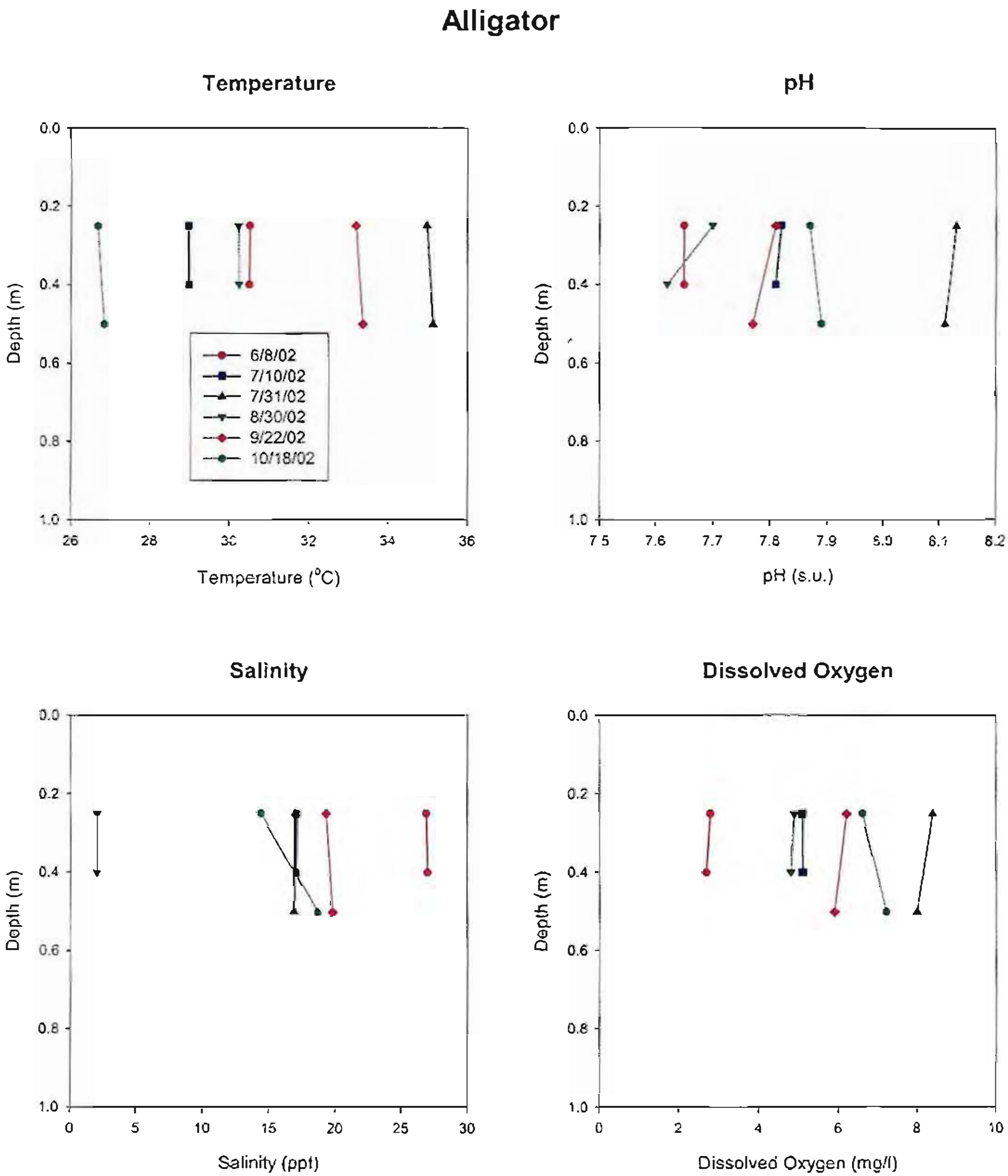


Figure 2-11. Compilation of Vertical Depth Profiles Collected in Alligator Creek from June - October 2002.

For purposes of the analyses provided in the following sections, dry season conditions are assumed to exist during monitoring events performed on 4/21/02, 6/8/02, and 10/18/02. Although June is normally considered to be part of the wet season, dry season conditions were still prevalent at the time of the 6/8/02 monitoring event, with less than 0.1 inch of rainfall during the 19-day period preceding the event. Wet season conditions are assumed to have existed during monitoring events performed on 7/10/02, 7/31/02, 8/30/02, and 9/22/02.

2.4.2.1 Buck Creek

A statistical summary of water quality monitoring performed in Buck Creek from April-October 2002 is given in Table 2-7. Mean values are provided for both wet and dry seasons conditions, along with the minimum measured value, maximum measured value, and the calculated coefficient of variation (CV). The coefficient of variation is defined as the standard deviation expressed as a percentage of the mean and can be used to compare the degree of variability between two separate data sets.

In general, many of the measured parameters in Buck Creek exhibited both higher mean values as well as a higher degree of variability during wet season conditions than during dry season conditions. Mean values for alkalinity, ammonia, organic nitrogen, total nitrogen, orthophosphorus, color, TSS, and BOD all appear to be greater during wet season conditions than during dry season conditions at this site. These higher values measured during wet season conditions suggest impacts from stormwater runoff on these parameters. In addition, the variability in measured parameters, as indicated by the calculated CV values, also appears to be greater during wet season conditions for salinity, alkalinity, ammonia, organic nitrogen, total nitrogen, orthophosphorus, color, TSS, and BOD. In contrast, mean salinity values, as well as pH values, appear to be lower during wet season conditions than during dry season conditions.

Discharges from Buck Creek are characterized by moderate levels of color, with a mean of 40 Pt-Co units during wet season conditions and 33 Pt-Co units during dry season conditions. Measured TSS concentrations appear to be somewhat elevated during wet season conditions, with a mean of 10.1 mg/l compared with a mean of 6.4 mg/l during dry season conditions.

However, fecal coliform concentrations in Buck Creek appear to be relatively low in value, with no exceedances of the Class III criterion of 200 organisms/100 ml, outlined in Chapter 62-302 FAC, during any of the monitoring events. Measured BOD concentrations appear to be moderately elevated during wet season conditions, with a mean of 3.1 mg/l compared with a mean of 1.0 mg/l during dry season conditions.

TABLE 2-7

STATISTICAL SUMMARY OF WATER QUALITY MONITORING PERFORMED IN BUCK CREEK FROM APRIL-OCTOBER 2002

PARAMETER	UNITS	WET SEASON (n = 4 samples)				DRY SEASON (n = 2 samples)			
		MEAN	MIN.	MAX.	C.V.	MEAN	MIN.	MAX	C.V.
pH	s.u.	8.00	7.58	8.26	4	8.04	7.94	8.13	2
Salinity	ppt	20.9	11.3	28.8	35	31.8	31.1	32.4	3
Alkalinity	mg/l	152	132	159	9	146	141	151	5
Ammonia	µg/l	122	20	337	120	79	47	111	57
NO_x	µg/l	10	6	14	34	24	7	40	99
Organic N	µg/l	764	398	959	35	626	514	738	25
Total N	µg/l	896	744	1067	17	729	665	792	12
Ortho-P	µg/l	14	1	30	111	6	3	8	64
Total P	µg/l	55	31	69	31	58	37	78	50
Color	Pt-Co	40	14	55	48	33	24	42	39
TSS	mg/l	10.1	4.3	18.0	63	6.4	6.2	6.5	3
Fecal	#/100 ml	36	1	65	75	62	12	111	114
BOD	mg/l	3.1	1.0	5.7	65	1.0	1.0	1.0	0

A comparison of nitrogen species measured in Buck Creek from April-October 2002 is given in Figure 2-12. In general, nitrogen concentrations appear to increase during wet season conditions compared to dry season conditions. Organic nitrogen is clearly the dominant nitrogen source in discharges from Buck Creek, contributing approximately 80-90% of the total nitrogen measured during most monitoring events. Ammonia appears to be the second most dominant nitrogen species, comprising approximately 10-15% of the total nitrogen measured during most events. Measured concentrations of NO_x appear to be low in value during virtually all events. The only exception to this generality appears to be the somewhat elevated ammonia concentrations measured in discharges from Buck Creek during the September 22nd monitoring event. Measured total nitrogen concentrations at the Buck Creek monitoring site range from 665-1067 µg/l.

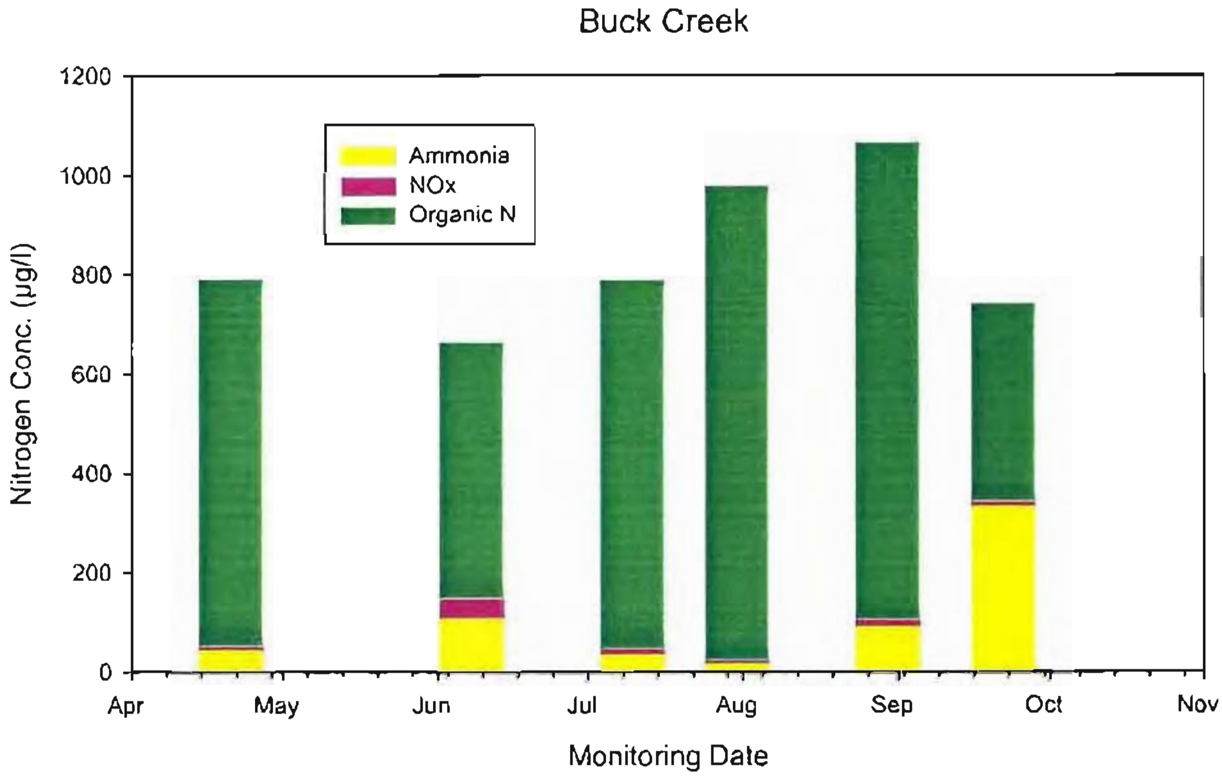


Figure 2-12. Comparison of Nitrogen Species Measured in Buck Creek from April-October 2002.

A comparison of phosphorus species measured in Buck Creek from April-October 2002 is given in Figure 2-13. There appears to be no pattern of increasing or decreasing phosphorus concentrations between wet and dry conditions. Measured total phosphorus concentrations range from 31-78 µg/l, with orthophosphorus representing a relatively small proportion of the total phosphorus measured on most monitoring dates. The dominant phosphorus fraction appears to be dissolved and particulate forms.

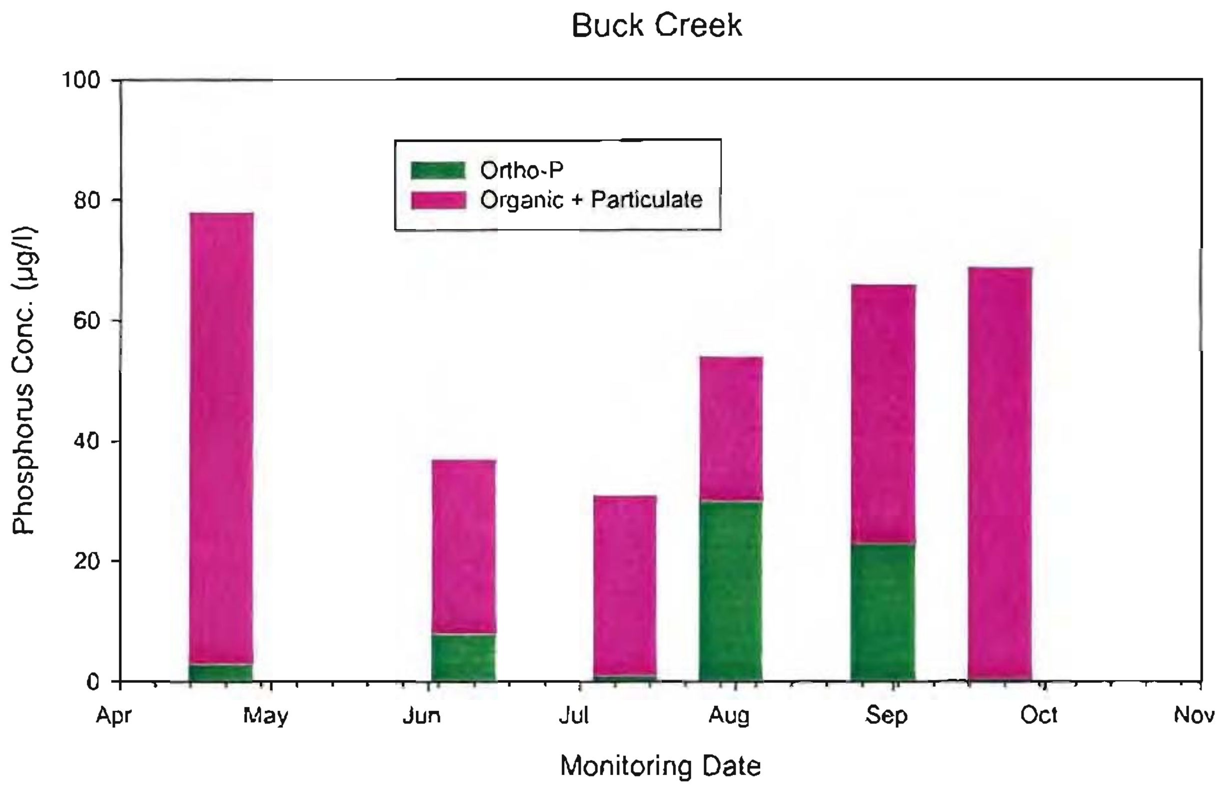


Figure 2-13. Comparison of Phosphorus Species Measured in Buck Creek from April-October 2002.

2.4.2.2 Oyster Creek

A statistical summary of water quality monitoring performed in Oyster Creek from April-October 2002 is given in Table 2-8. Wet season statistics are based upon four sampling events, while dry season statistics are based upon three sampling events.

Similar to the trends observed in Buck Creek, measured concentrations of many parameters appear to be greater during wet season conditions than during dry season conditions. This trend is particularly apparent for ammonia, organic nitrogen, total nitrogen, orthophosphorus, total phosphorus, color, and BOD. Tributary discharges from Oyster Creek are slightly to moderately colored, with moderate levels of TSS. Fecal coliform bacteria counts in Oyster Creek inflow are low in value, with no exceedances of the Class III criterion of 200 organisms/100 ml. Measured BOD concentrations are low in value and appear to pose no significant threat to overall dissolved oxygen levels within Lemon Bay.

TABLE 2-8

STATISTICAL SUMMARY OF WATER QUALITY MONITORING PERFORMED IN OYSTER CREEK FROM APRIL-OCTOBER 2002

PARAMETER	UNITS	WET SEASON (n = 4 samples)				DRY SEASON (n = 3 samples)			
		MEAN	MIN.	MAX.	C.V.	MEAN	MIN.	MAX	C.V.
pH	s.u.	7.95	7.60	8.20	3	8.14	8.07	8.20	1
Salinity	ppt	25.8	17.5	30.8	22	32.7	31.8	33.4	3
Alkalinity	mg/l	124	119	129	3	133	128	137	3
Ammonia	µg/l	128	28	258	83	116	<5	287	130
NO_x	µg/l	19	13	30	41	19	<5	44	121
Organic N	µg/l	757	526	1371	54	495	338	601	28
Total N	µg/l	903	569	1568	51	629	606	669	6
Ortho-P	µg/l	31	7	73	99	9	7	10	18
Total P	µg/l	61	40	108	53	55	26	76	47
Color	Pt-Co	30	6	69	93	26	15	34	38
TSS	mg/l	6.4	4.3	9.5	34	6.6	4.4	9.0	35
Fecal	#/100 ml	23	1	40	78	38	4	81	103
BOD	mg/l	1.7	<2	2.5	47	<2	<2	<2	0

A comparison of nitrogen species measured in Oyster Creek from April-October 2002 is given in Figure 2-14. With the exception of the September monitoring event, total nitrogen concentrations in Oyster Creek were found to be relatively stable, with typical values ranging from 600-800 µg/l. A maximum concentration of 1568 µg/l was measured for total nitrogen during September. The dominant nitrogen species in Oyster Creek is organic nitrogen which comprises 50-90% of the total nitrogen inputs for the monitored event. Ammonia is the second most dominant nitrogen species, although measured concentrations are substantially lower than those for organic nitrogen. NO_x comprises a relatively insignificant portion of the nitrogen species.

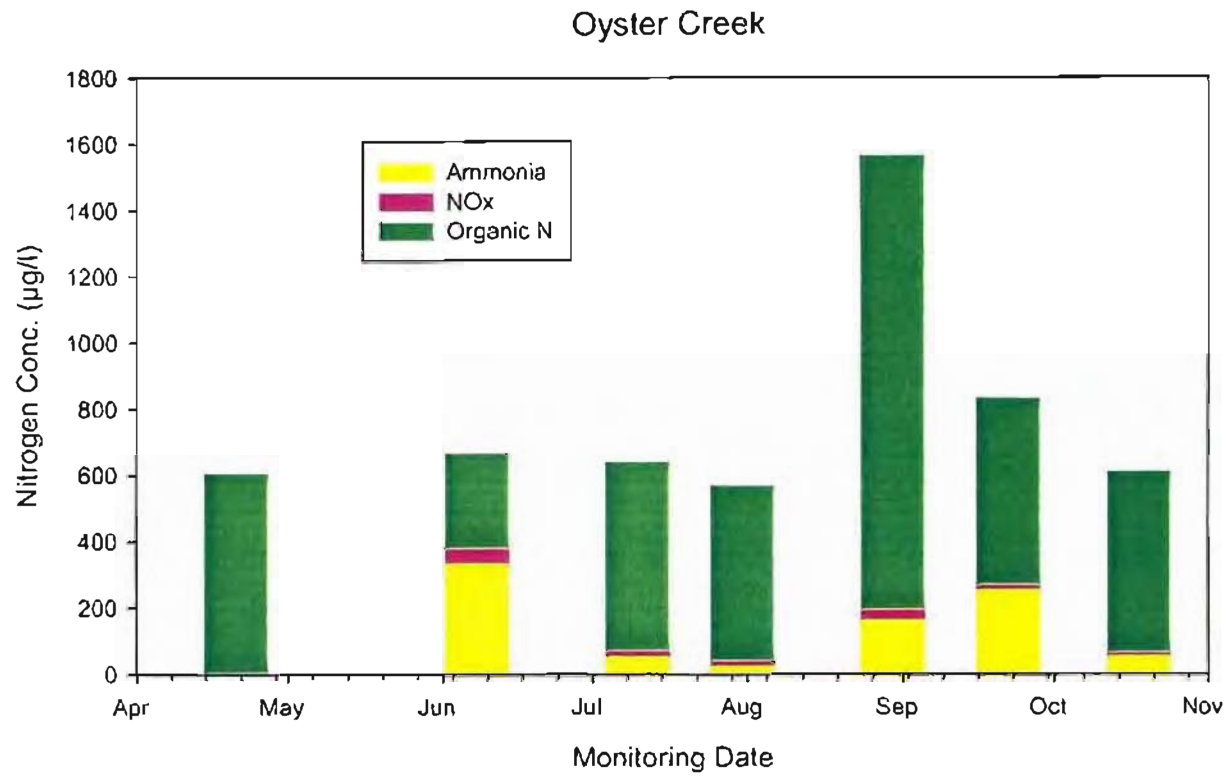


Figure 2-14. Comparison of Nitrogen Species Measured in Oyster Creek from April-October 2002.

A comparison of phosphorus species measured in Oyster Creek from April-October 2002 is given in Figure 2-15. Phosphorus concentrations in Oyster Creek were found to be highly variable, ranging from 26-108 µg/l. No distinct pattern in phosphorus concentrations is apparent between wet and dry season conditions. The speciation of total phosphorus also appears to be highly variable between the seven monitoring dates. Dissolved orthophosphorus was found to be the dominant phosphorus species during two of the seven events, with dissolved and particulate phosphorus representing the dominant species during the remaining events.

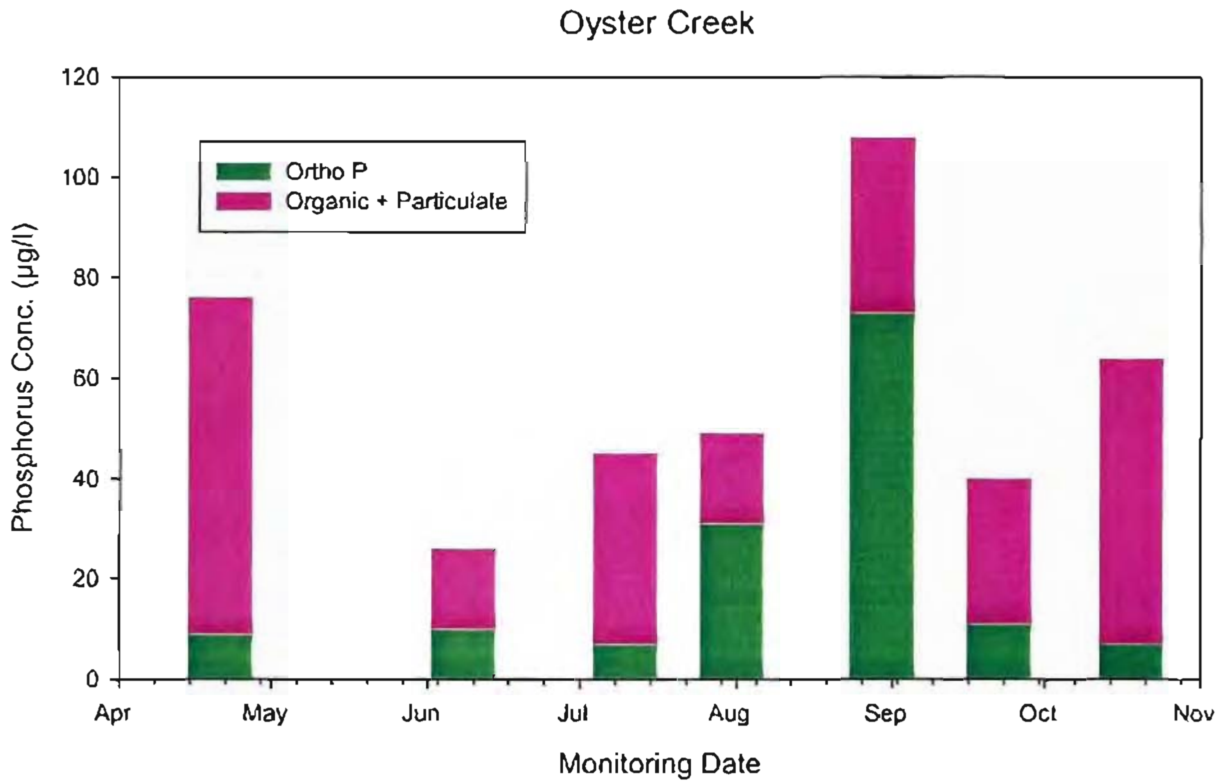


Figure 2-15. Comparison of Phosphorus Species Measured in Oyster Creek from April-October2002.

2.4.2.3 Ainger Creek

A statistical summary of water quality monitoring performed in Ainger Creek from April-October 2002 is given in Table 2-9. Similar to the trends observed in Buck Creek and Oyster Creek, measured concentrations of ammonia, orthophosphorus, total phosphorus, color, TSS, fecal coliform, and BOD appear to be greater in Ainger Creek during wet season conditions than during dry season conditions. These differences reflect the impacts of direct stormwater runoff entering Ainger Creek during wet season rain events. In general, discharges from Ainger Creek were found to be moderately colored, with slightly elevated concentrations of TSS and BOD under wet season conditions.

A comparison of nitrogen species measured in Ainger Creek from April-October 2002 is given in Figure 2-16. No significant pattern for nitrogen concentrations is apparent between wet and dry season conditions. Organic nitrogen is clearly the dominant nitrogen species in discharges from Ainger Creek, representing more than 60% of the total nitrogen measured during each of the monitoring dates. Ammonia appears to be the second most dominant nitrogen species, although concentrations are substantially lower than those observed for organic nitrogen. NO_x represents a relatively small proportion of the total nitrogen inputs.

TABLE 2-9

STATISTICAL SUMMARY OF WATER QUALITY MONITORING PERFORMED IN AINGER CREEK FROM APRIL-OCTOBER 2002

PARAMETER	UNITS	WET SEASON (n = 4 samples)				DRY SEASON (n = 3 samples)			
		MEAN	MIN.	MAX.	C.V.	MEAN	MIN.	MAX	C.V.
pH	s.u.	7.93	7.47	8.14	4	8.07	7.86	8.26	2
Salinity	ppt	22.8	11.2	29.4	35	31.7	29.0	33.4	8
Alkalinity	mg/l	124	97	136	14	139	133	143	4
Ammonia	µg/l	70	<5	219	145	35	18	63	70
NO_x	µg/l	18	6	42	90	29	6	69	122
Organic N	µg/l	596	408	714	24	725	298	1037	53
Total N	µg/l	683	423	814	26	788	430	1061	41
Ortho-P	µg/l	27	9	64	95	10	7	12	28
Total P	µg/l	65	44	109	46	59	32	73	39
Color	Pt-Co	51	8	151	133	26	18	32	28
TSS	mg/l	7.1	<0.7	14.8	86	6.7	5.0	9.4	35
Fecal	#/100 ml	68	1	168	113	28	4	69	130
BOD	mg/l	2.3	<2	3.4	45	<2	<2	<2	0

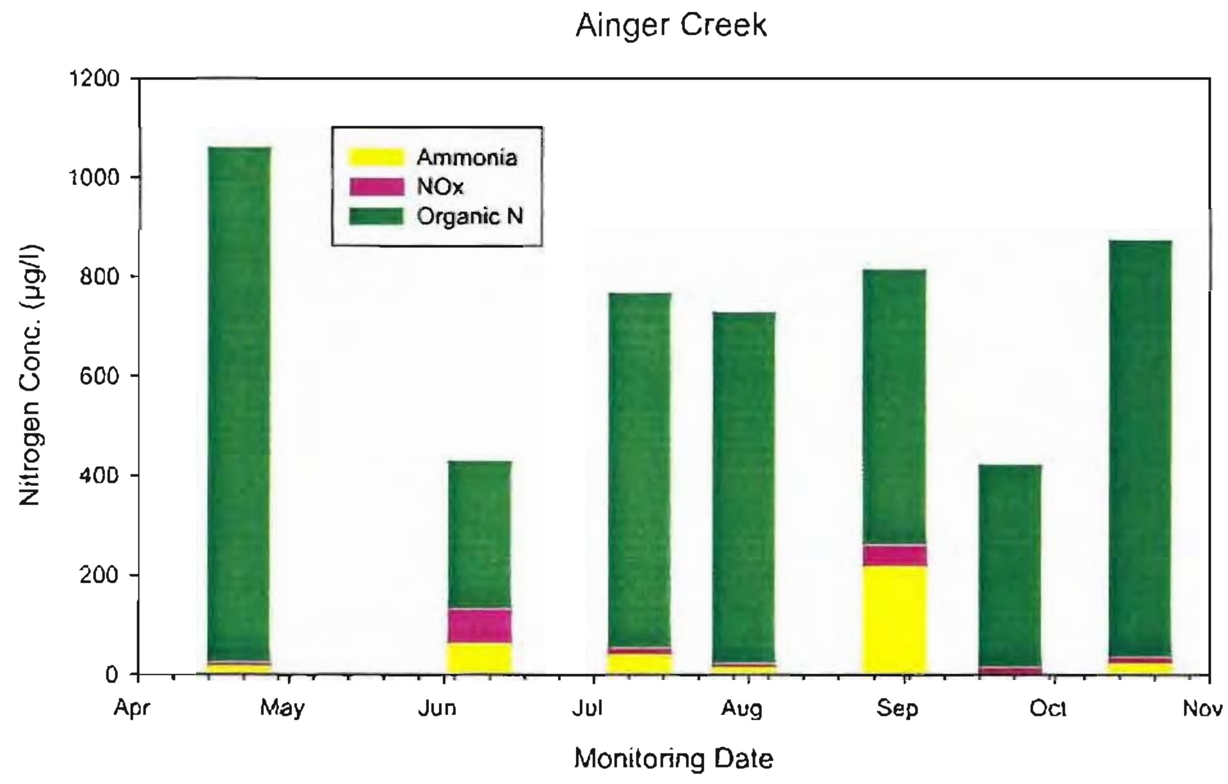


Figure 2-16. Comparison of Nitrogen Species Measured in Ainger Creek from April-October 2002.

A comparison of phosphorus species measured in Ainger Creek from April-October 2002 is given in Figure 2-17. Measured total phosphorus concentrations at this site range from 32-109 µg/l, with no distinct pattern of increasing or decreasing concentrations during wet and dry season conditions. The dominant phosphorus species at this site appears to be organic plus particulate phosphorus which comprise approximately 75% of the measured phosphorus during most monitoring events. Measured orthophosphorus concentrations appear to be relatively low in value, ranging from 9-66 µg/l.

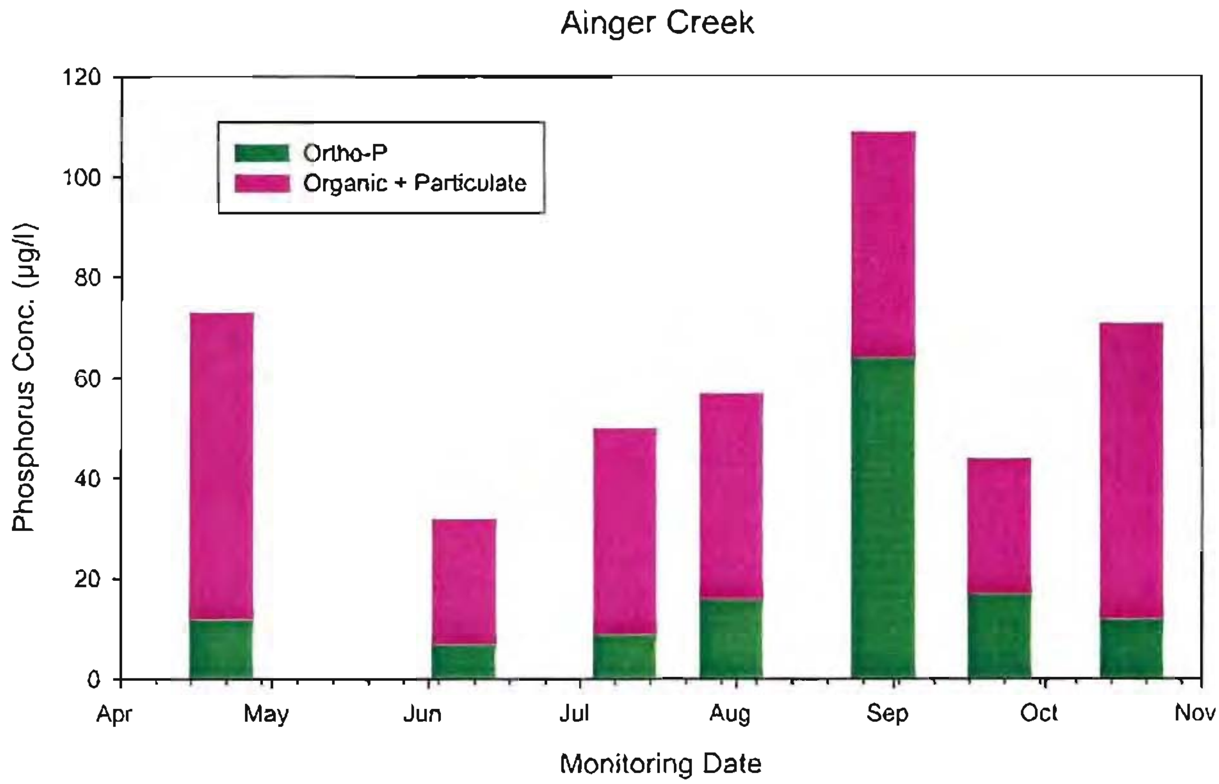


Figure 2-17. Comparison of Phosphorus Species Measured in Ainger Creek from April-October 2002.

2.4.2.4 <u>Gottfried Creek</u>

A statistical summary of water quality monitoring performed in Gottfried Creek from April-October 2002 is given in Table 2-10. Wet season statistics represent four separate samples, while dry season statistics represent three separate samples. Similar to the trends observed at previous tributary sites, measured concentrations for many parameters appear to be somewhat greater during wet season conditions than during dry season conditions. This trend is apparent for ammonia, organic nitrogen, total nitrogen, orthophosphorus, total phosphorus, TSS, and BOD. In general, discharges from Gottfried Creek appear to be moderately colored, with moderate levels of suspended solids and fecal coliform bacteria. None of the measured fecal coliform counts at this site exceeded the Class III criterion of 200 organisms/100 ml during any monitoring event.

TABLE 2-10

STATISTICAL SUMMARY OF WATER QUALITY MONITORING PERFORMED IN GOTTFRIED CREEK FROM APRIL-OCTOBER 2002

PARAMETER	UNITS	WET SEASON (n = 4 samples)				DRY SEASON (n = 3 samples)			
		MEAN	MIN.	MAX.	C.V.	MEAN	MIN.	MAX	C.V.
pH	s.u.	7.98	7.59	8.19	3	7.94	7.86	7.98	1
Salinity	ppt	24.1	15.5	28.4	24	31.2	28.8	33.0	7
Alkalinity	mg/l	138	132	145	4	136	133	140	3
Ammonia	µg/l	105	<5	224	98	93	21	222	121
NO_x	µg/l	12	5	26	79	31	10	48	62
Organic N	µg/l	748	516	1056	31	417	359	532	24
Total N	µg/l	865	565	1306	39	541	417	629	20
Ortho-P	µg/l	105	33	214	74	44	34	61	34
Total P	µg/l	131	82	221	49	83	58	114	34
Color	Pt-Co	35	7	95	118	46	16	88	82
TSS	mg/l	6.2	3.0	10.3	51	4.4	3.2	5.7	29
Fecal	#/100 ml	40	6	80	96	50	4	132	141
BOD	mg/l	2.5	<2	3.7	45	1.6	<2	2.8	65

A comparison of nitrogen species measured in Gottfried Creek from April-October 2002 is given in Figure 2-18. Measured total nitrogen concentrations in Gottfried Creek range from 417-1306 µg/l. Measured concentrations of total nitrogen during the wet season appear to be somewhat greater than concentrations observed during dry season conditions. The dominant nitrogen species appears to be organic nitrogen which comprises the vast majority of nitrogen measured on each monitoring date. Measured ammonia concentrations in Gottfried Creek range from <5-224 µg/l, with an overall mean of approximately 100 µg/l. NO_x concentrations at the site appear to be relatively low in value, ranging from 5-48 µg/l.

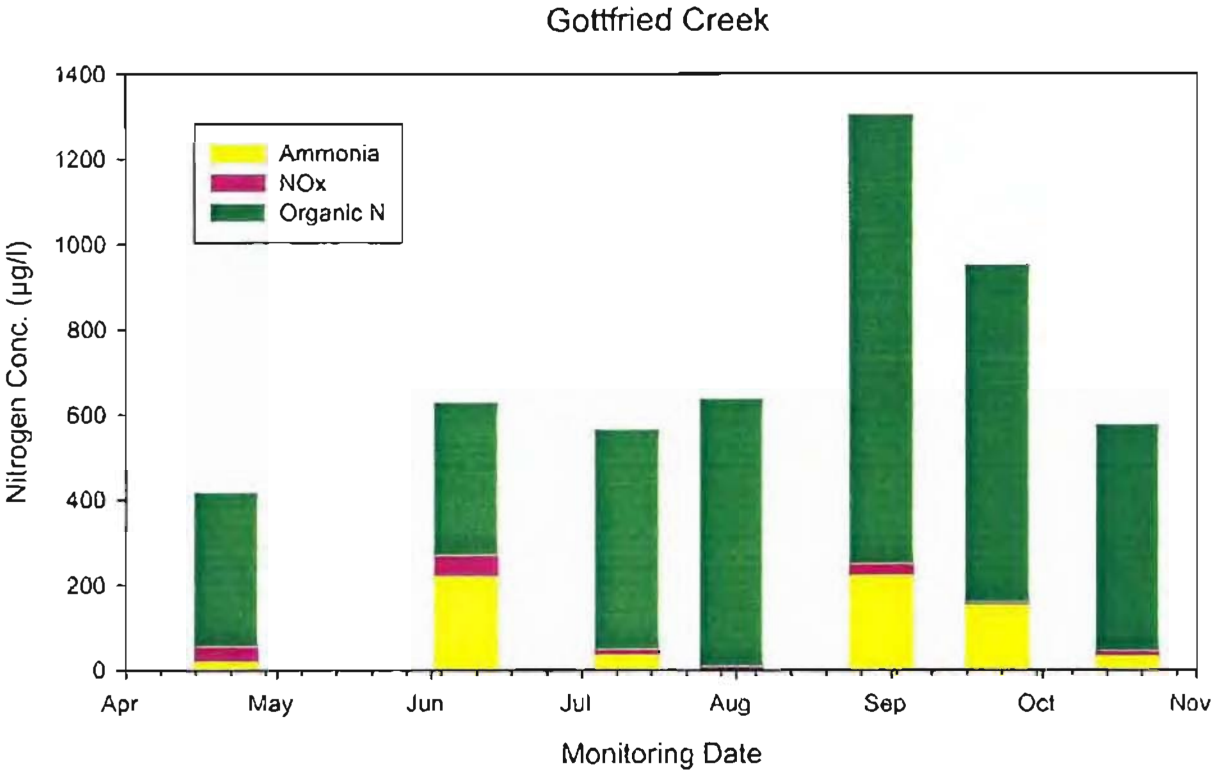


Figure 2-18. Comparison of Nitrogen Species Measured in Gottfried Creek from April-October 2002.

A comparison of phosphorus species measured in Gottfried Creek from April-October 2002 is given in Figure 2-19. Measured total phosphorus concentrations in discharges from Gottfried Creek were found to be highly variable, ranging from 58-221 µg/l. A trend of increasing phosphorus concentrations is apparent during wet season conditions. In contrast to the trends observed at the previous monitoring sites, the dominant phosphorus species in discharges from Gottfried Creek appears to be orthophosphorus which comprises approximately 50% or more of the total phosphorus measured during each monitoring event. Contributions from organic and particulate phosphorus appear to be relatively minimal in Gottfried Creek.

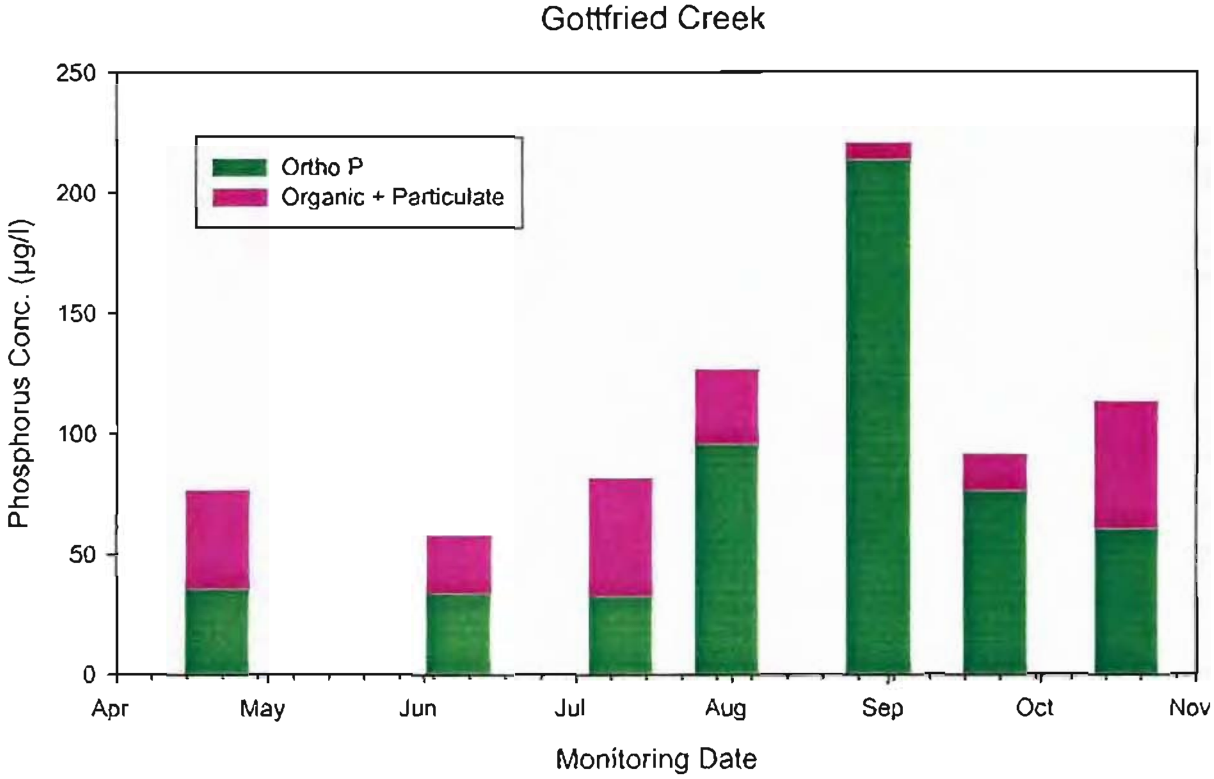


Figure 2-19. Comparison of Phosphorus Species Measured in Gottfried Creek from April-October 2002.

2.4.2.5 Forked Creek

A statistical summary of water quality monitoring performed in Forked Creek from April-October 2002 is given in Table 2-11. Wet season statistics reflect a total of four samples, while dry season statistics reflect a total of three separate samples. Slight increases in concentrations were observed during wet season conditions for organic nitrogen, total nitrogen, orthophosphorus, total phosphorus, TSS, and BOD, although the percentage increases in these parameters during wet season conditions appear to be relatively small. In general, water discharging from Forked Creek was found to be slightly colored, with elevated levels of suspended solids. The wet season BOD concentration of 3.8 mg/l appears to be elevated to the point where impacts to dissolved oxygen resources would be possible as a result from discharges from this tributary. Measured fecal coliform counts at this site range from 4-480 organisms/100 ml, with exceedances of the Class III criterion observed during one of the seven monitoring events.

TABLE 2-11

STATISTICAL SUMMARY OF WATER QUALITY MONITORING PERFORMED IN FORKED CREEK FROM APRIL-OCTOBER 2002

PARAMETER	UNITS	WET SEASON (n = 4 samples)				DRY SEASON (n = 3 samples)			
		MEAN	MIN.	MAX.	C.V.	MEAN	MIN.	MAX	C.V.
pH	s.u.	8.27	8.21	8.33	1	8.08	7.97	8.16	1
Salinity	ppt	22.6	18.8	26.8	17	28.9	25.9	30.8	9
Alkalinity	mg/l	140	125	154	9	140	125	151	10
NO_x	µg/l	29	<5	54	73	131	46	261	88
Nitrate	µg/l	6	<5	12	74	10	<5	20	97
Organic N	µg/l	697	431	953	32	566	518	633	11
Total N	µg/l	733	465	1019	32	706	599	799	14
Ortho-P	µg/l	135	88	212	43	115	87	147	26
Total P	µg/l	236	136	363	42	200	187	206	5
Color	Pt-Co	22	4	43	74	22	14	33	45
TSS	mg/l	11.0	5.7	19.7	56	7.0	5.2	9.6	33
Fecal	#/100 ml	29	4	61	82	164	4	480	167
BOD	mg/l	3.8	3.2	4.0	10	<2	<2	<2	0

A comparison of nitrogen species measured in Forked Creek from April-October 2002 is given in Figure 2-20. Measured total nitrogen concentrations at this site range from 465-1019 µg/l, with slightly higher concentrations apparent during wet season conditions. Organic nitrogen appears to be the dominant nitrogen species measured in Forked Creek, representing the majority of nitrogen measured on each monitoring date. Measured concentrations of ammonia appear to be highly variable, ranging from <5-261 µg/l. NO_x concentrations comprise a relatively insignificant portion of the total nitrogen discharged from Forked Creek.

A comparison of phosphorus species measured in Forked Creek from April-October 2002 is given in Figure 2-21. Measured total phosphorus concentrations range from 136-363 µg/l, with slightly higher concentrations observed during wet season conditions. The dominant phosphorus species in Forked Creek appears to be orthophosphorus, with concentrations ranging from 87-221 µg/l.

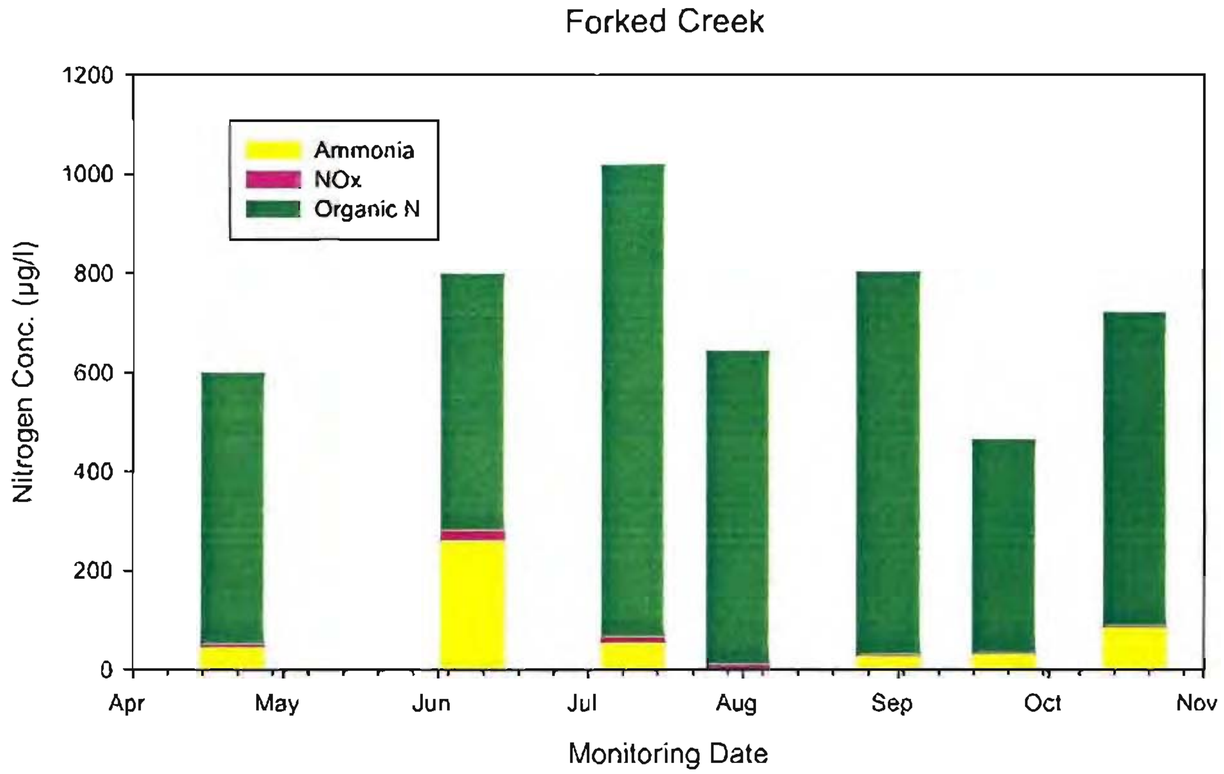


Figure 2-20. Comparison of Nitrogen Species Measured in Forked Creek from April-October 2002.

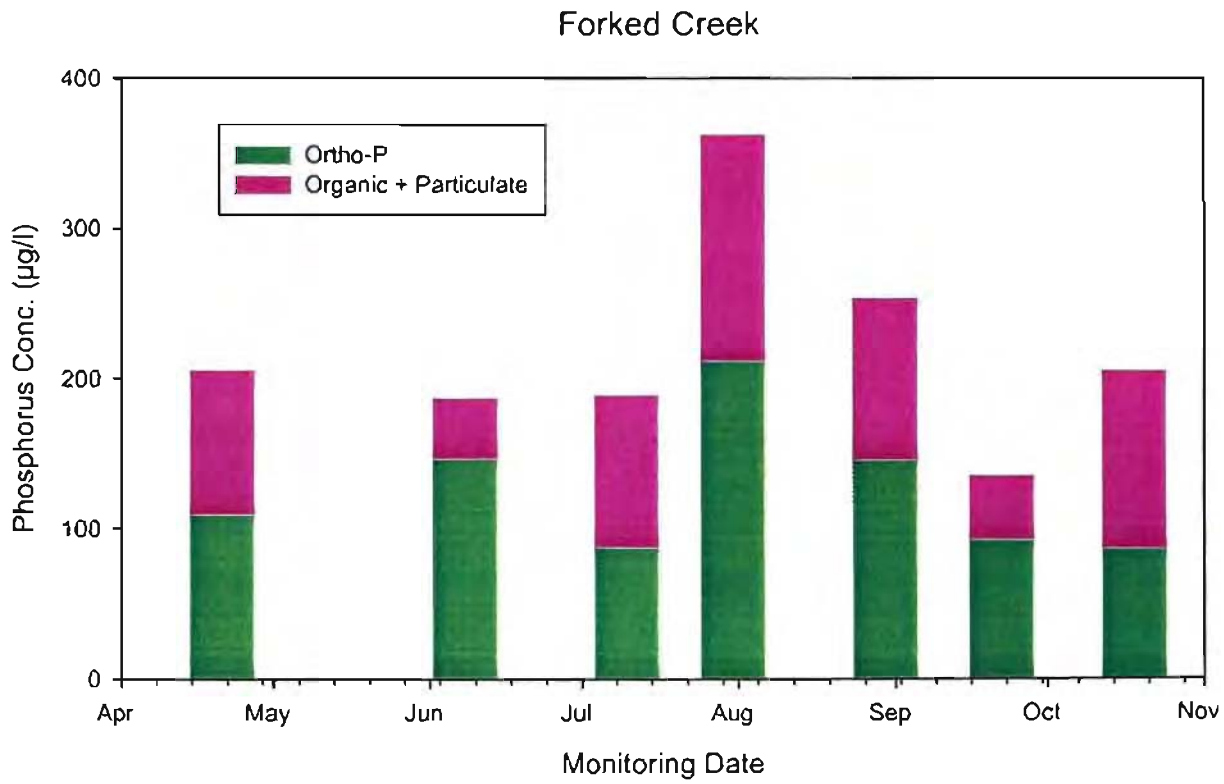


Figure 2-21. Comparison of Phosphorus Species Measured in Forked Creek from April-October 2002.

2.4.2.6 Alligator Creek

A statistical summary of water quality monitoring performed in Alligator Creek from April-October 2002 is given in Table 2-12. Wet season statistics reflect a total of four separate monitoring events, with three monitoring events reflected under dry season statistics. In general, measured concentrations for many parameters appear to be greater during wet season conditions, including NO_x, organic nitrogen, total nitrogen, orthophosphorus, total phosphorus, color, TSS, fecal coliform, and BOD. In general, discharges from Alligator Creek appear to exhibit moderate color, with elevated levels of TSS and BOD. Measured fecal coliform counts range from 1-450 organisms/100 ml, with exceedances of the Class III criterion of 200 organisms/100 ml observed on one of the seven monitoring dates.

TABLE 2-12

STATISTICAL SUMMARY OF WATER QUALITY MONITORING PERFORMED IN ALLIGATOR CREEK FROM APRIL-OCTOBER 2002

PARAMETER	UNITS	WET SEASON (n = 4 samples)				DRY SEASON (n = 3 samples)			
		MEAN	MIN.	MAX.	C.V.	MEAN	MIN.	MAX	C.V.
pH	s.u.	7.85	7.66	8.12	2	7.89	7.65	8.15	3
Salinity	ppt	14.0	2.1	19.6	57	25.0	16.6	31.4	30
Alkalinity	mg/l	151	136	165	9	144	133	157	9
Ammonia	µg/l	62	30	133	78	84	<5	159	94
NO_x	µg/l	44	9	139	144	25	8	38	62
Organic N	µg/l	667	544	737	13	570	365	972	61
Total N	µg/l	773	587	1009	23	679	385	1169	63
Ortho-P	µg/l	138	112	180	23	118	84	168	37
Total P	µg/l	212	134	296	32	170	135	201	20
Color	Pt-Co	39	5	73	73	25	10	34	53
TSS	mg/l	8.2	5.1	11.8	36	4.1	1.9	6.6	58
Fecal	#/100 ml	121	1	450	181	49	4	84	84
BOD	mg/l	2.7	<2	4.3	50	<2	<2	<2	0

A comparison of nitrogen species measured in Alligator Creek from April-October 2002 is given in Figure 2-22. Measured total nitrogen concentrations range from 385-1169 µg/l, with a general trend of increasing concentrations during wet season conditions. The dominant nitrogen species is clearly organic nitrogen which comprises approximately 80% or more of the nitrogen measured during each monitoring event. Measured concentrations of ammonia range from <5-159 µg/l and represent approximately 20% or less of the total nitrogen measured. Contributions from NO_x appear to be relatively minimal.

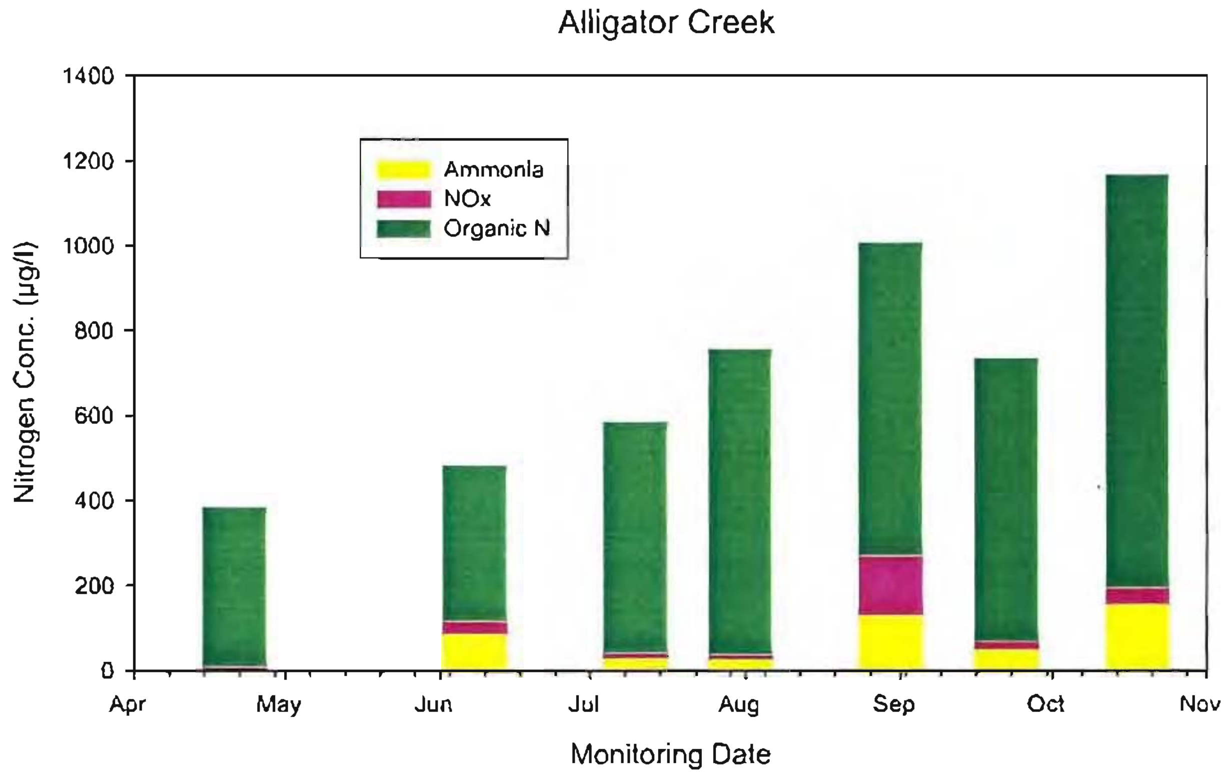


Figure 2-22. Comparison of Nitrogen Species Measured in Alligator Creek from April-October 2002.

A comparison of phosphorus species measured in Alligator Creek from April-October 2002 is given in Figure 2-23. Measured total phosphorus concentrations at this site range from 134-296 µg/l, with a general trend of increasing concentrations during wet season conditions. Dissolved orthophosphorus concentrations at this site range from 84-180 µg/l and appear to be the dominant phosphorus species at this site. The orthophosphorus concentrations measured in Alligator Creek are greater than those measured in any of the other tributaries.

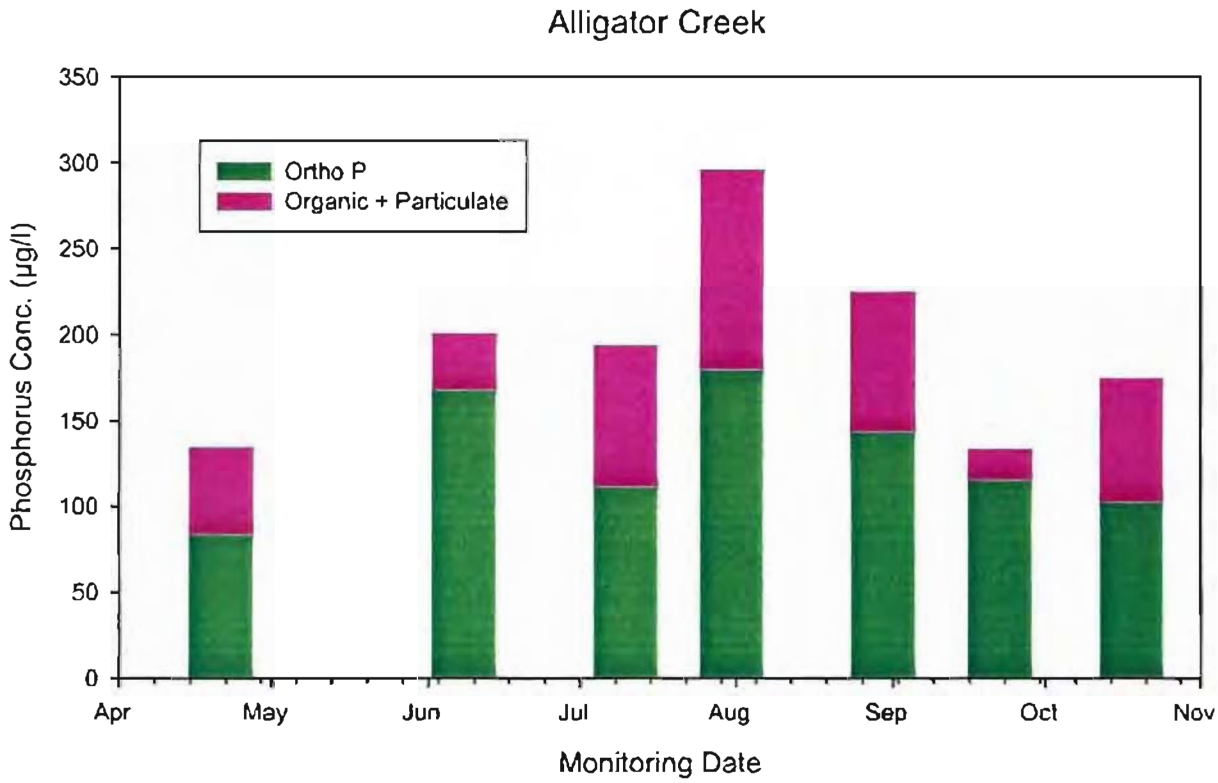


Figure 2-23. Comparison of Phosphorus Species Measured in Alligator Creek from April-October 2002.

2.4.3 Comparison of Water Quality Characteristics Between the Monitoring Tributaries

A statistical comparison of tributary inflow characteristics for ammonia, NO_x, total nitrogen, and salinity at the six monitoring locations is given in Figure 2-24. A graphical summary of data at each site is presented in the form of box plots. The bottom line of the box portion of each plot represents the lower quartile, with 25% of the data points lying below this line. The upper line of the box represents the 75% upper quartile, with 25% of the data lying above this value. The blue horizontal line in each box represents the median value, with 50% of the data lying above and below this value. The horizontal red line within each box represents the mean value.

As seen in Figure 2-24, both mean and median concentrations for ammonia appear to be relatively similar between the six monitored tributaries. However, ammonia concentrations in Ainger Creek and Forked Creek appear to exhibit a relatively low degree of variability, with a substantially higher degree of variability observed in Gottfried Creek and Oyster Creek. Mean concentrations of total nitrogen appear to be virtually identical in Ainger Creek, Alligator Creek, Forked Creek, and Gottfried Creek, with somewhat higher values observed in Buck Creek and Oyster Creek. Total nitrogen concentrations in Buck Creek, Forked Creek, and Oyster Creek appear to exhibit a relatively low degree of variability, with a higher degree of variability present in Ainger Creek, Alligator Creek, and Gottfried Creek. Measured NO_x concentrations appear to be highly variable between the six monitoring sites, with variable and elevated values of NO_x observed in Ainger, Alligator, and Gottfried Creeks, with lower concentrations and a lower degree of variability observed in Buck and Forked Creek.

Field salinity measurements range from approximately 25-28 ppt at each of the monitoring sites with the exception of Alligator Creek. Salinity measurements in Alligator Creek suggest a lower salinity regime in this tributary, with an overall mean of approximately 18 ppt.

Box plots of orthophosphorus, total phosphorus, color, and TSS measurements at the tributary inflow sites from April-October 2002 are given in Figure 2-25. A high degree of

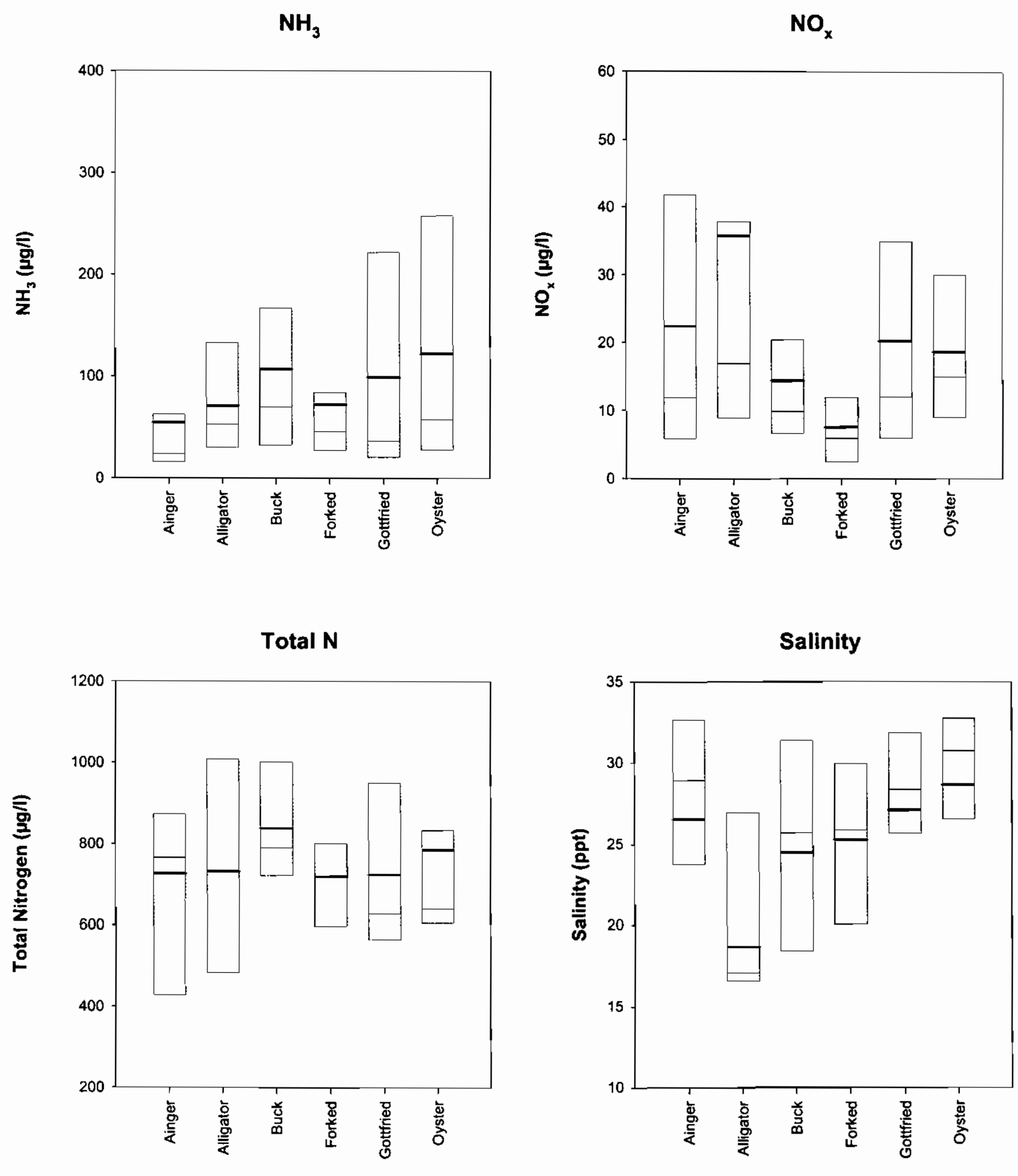


Figure 2-24. Box Plots of NH_3, NO_x, Total N and Salinity Measurements at the Tributary Inflow Sites from April - October 2002.

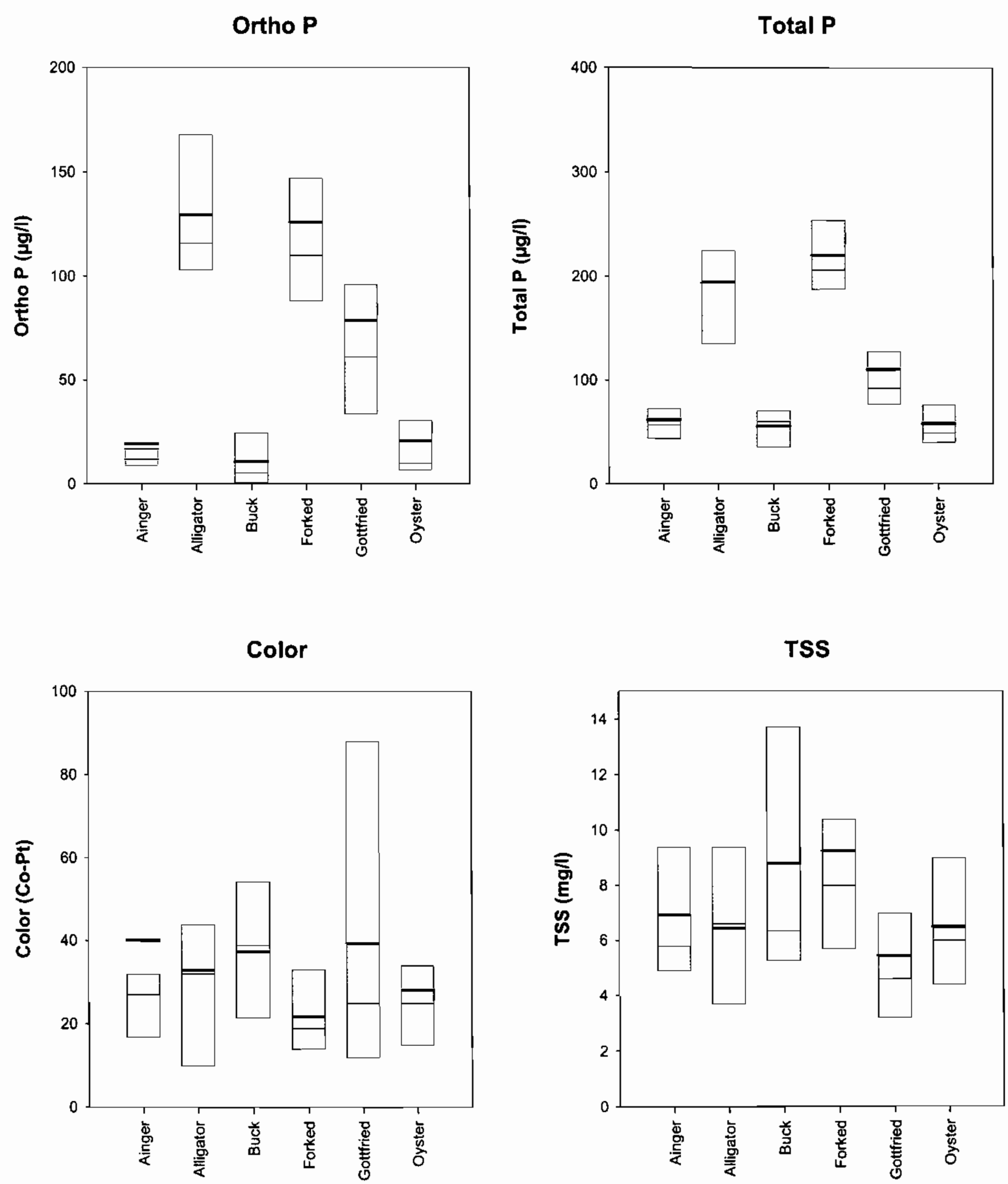


Figure 2-25. Box Plots of Ortho-P, Total P, Color and TSS Measurements at the Tributary Inflow Sites from April - October 2002.

variability is apparent in measured orthophosphorus concentrations, with relatively low values measured in Ainger, Buck, and Oyster Creeks, and elevated concentrations and high variability apparent in Alligator, Forked, and Gottfried Creeks. A similar pattern is apparent in measured concentrations of total phosphorus, with substantially lower values present in Ainger, Buck, and Oyster Creeks, and somewhat elevated levels present in Alligator and Forked Creek.

Mean measured color concentrations range from approximately from 20-40 Pt-Co units at the six monitoring sites. A relatively low degree of variability in color measurements is apparent in Ainger, Forked, and Oyster Creeks, with a substantially higher degree of variability apparent in Alligator, Buck, and Gottfried Creeks.

Differences also appear to exist in measured TSS concentrations between the six tributaries. Measured TSS concentrations in Ainger, Alligator, Gottfried, and Oyster Creeks exhibit mean concentrations ranging from 6-7 mg/l. However, measured TSS concentrations in Buck and Forked Creeks exhibit a mean concentration of approximately 9-10 mg/l.

Box plots of fecal coliform bacteria and BOD concentrations at the tributary inflow sites from April-October 2002 are illustrated on Figure 2-26. Fecal coliform concentrations appear to be somewhat variable at the six monitoring sites, although the vast majority of concentrations were found to be less than the applicable Class III criterion for Lemon Bay. Exceedances of the 200 organisms/100 ml standard were observed on one occasion each in Alligator and Forked Creeks.

In general, BOD values appear to be relatively similar between the six inflow tributaries, with slightly higher concentrations along with a higher degree of variability apparent in Buck and Forked Creeks.

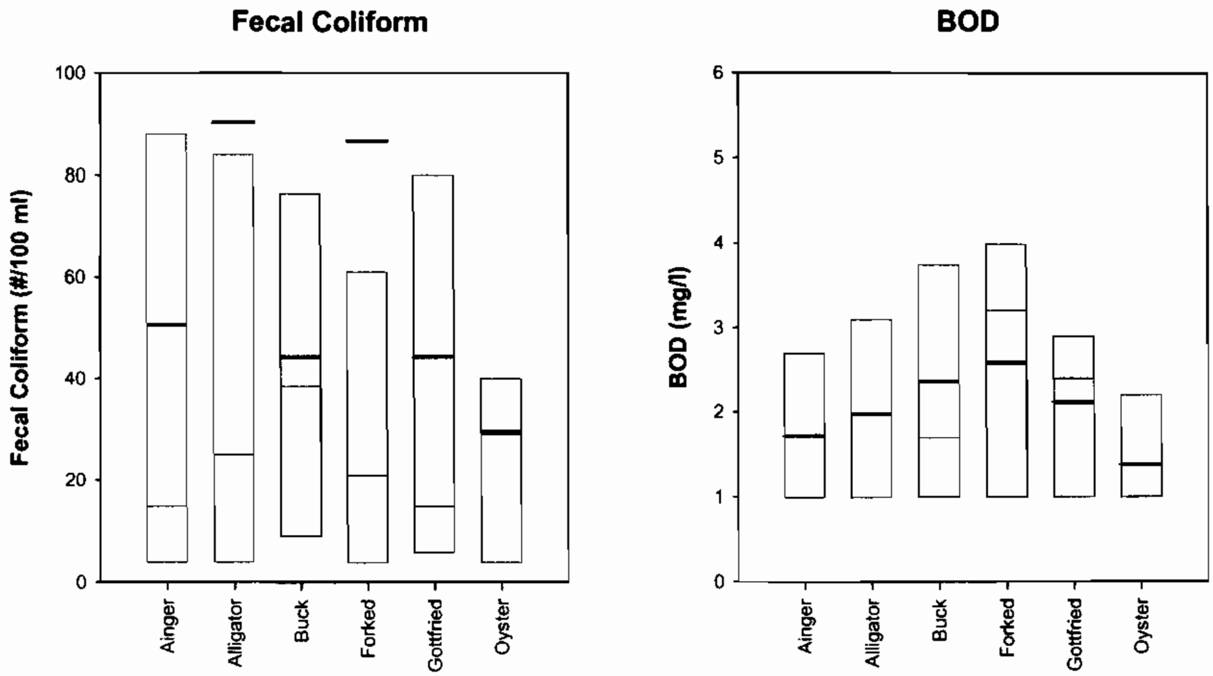


Figure 2-26. Box Plots of Fecal Coliform and BOD Measurements at the Tributary Inflow Sites from April-October 2002.

2.5 Estimated Mass Loadings from Tributaries to Lemon Bay

Estimates of mass loadings of nitrogen species, phosphorus species, TSS, and BOD were calculated on a seasonal and annual basis for each of the six tributary inflow sites. Mass loading estimates were calculated by multiplying the estimated seasonal tributary inflows, summarized in Table 2-6 (2), times the mean seasonal concentrations for the evaluated constituents summarized in Tables 2-7 through 2-12.

A summary of seasonal and annual mass loadings from tributary inflows to Lemon Bay is given in Table 2-13 for ammonia, NO_x, organic nitrogen, total nitrogen, orthophosphorus, total phosphorus, TSS, and BOD. Listed values reflect estimated inputs in terms of kg of each constituent per season or year.

TABLE 2-13

ESTIMATED SEASONAL AND ANNUAL MASS LOADINGS FROM TRIBUTARY INFLOWS TO LEMON BAY

SITE	SEASON	PARAMETER (kg)							
		AMMONIA	NO_x	ORG. N	TOTAL N	ORTHO-P	TOTAL P	TSS	BOD
Oyster Creek	Wet	226	33	1,340	1,599	54	107	11,374	2,965
	Dry	132	21	565	718	10	63	7,497	1,142
	Total:	358	54	1,905	2,317	64	170	18,871	4,107
Buck Creek	Wet	631	52	3,938	4,620	70	284	51,839	15,732
	Dry	243	72	1,928	2,243	17	177	19,552	3,079
	Total:	874	124	5,866	6,863	87	461	71,391	18,811
Ainger Creek	Wet	151	39	1,294	1,484	58	141	15,451	4,942
	Dry	51	42	1,051	1,143	15	85	9,762	1,450
	Total:	202	81	2,344	2,627	73	226	25,213	6,392
Gottfried Creek	Wet	352	41	2,519	2,913	354	439	20,960	8,418
	Dry	226	76	1,016	1,318	106	202	10,717	3,897
	Total:	578	117	3,535	4,230	460	642	31,677	12,315
Forked Creek	Wet	70	15	1,679	1,765	325	567	26,382	9,095
	Dry	248	18	1,073	1,339	217	379	13,273	1,896
	Total:	317	33	2,753	3,104	542	946	39,656	10,991
Alligator Creek	Wet	256	182	2,757	3,195	570	877	33,998	11,264
	Dry	208	62	1,422	1,693	295	425	10,138	2,493
	Total:	464	244	4,179	4,888	865	1,302	44,136	13,757

A comparison of estimated seasonal and annual loadings of total nitrogen, total phosphorus, TSS, and BOD from tributaries to Lemon Bay is given in Figure 2-27. The most significant inputs of total nitrogen in Lemon Bay appear to originate in Buck Creek which exhibits nitrogen loadings approximately 50% greater than any other single tributary source, with an estimated annual loading of approximately 6863 kg/yr. Nitrogen inputs from Gottfried Creek and Alligator Creek appear to be relatively similar, ranging from 4230-4888 kg/yr. Similar nitrogen loadings also appear to originate from Oyster Creek, Ainger Creek, and Forked Creek,

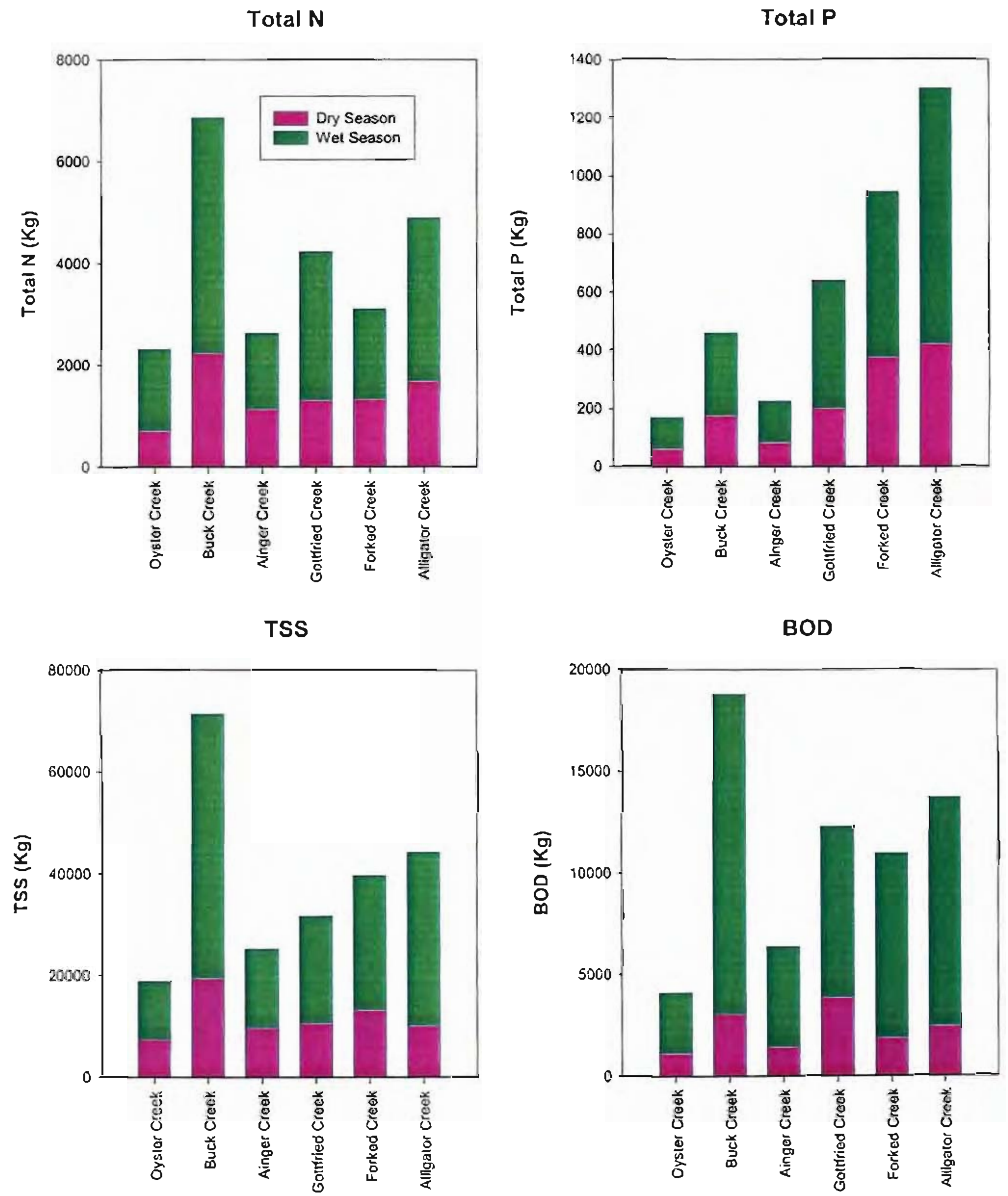


Figure 2-27. Comparison of Estimated Seasonal and Annual Loadings of Total N, Total P, TSS and BOD from Tributaries to Lemon Bay.

ranging from 2317-3104 kg/yr. The largest contributions of nitrogen species appear to occur during wet season conditions, although dry season loadings reflect approximately 25% or more of nitrogen inputs from each tributary.

Total phosphorus loadings from the tributaries to Lemon Bay appear to be highly variable, with the highest loadings originating in Forked and Alligator Creeks. Phosphorus loadings from these sources range from approximately 946-1302 kg/yr, Phosphorus inputs from Buck and Gottfried Creeks appear to be relatively similar, ranging from 461-642 kg/yr. The lowest phosphorus loadings appear to originate in Oyster and Ainger Creeks, with estimated loadings ranging from 170-226 kg/yr.

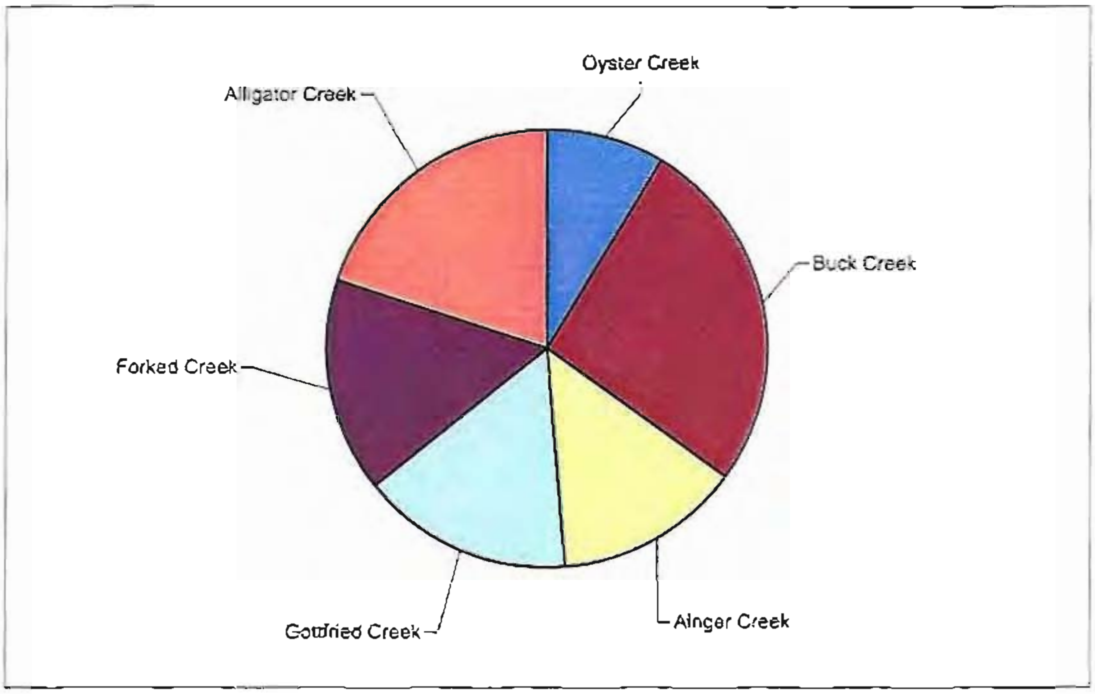
As seen in Figure 2-27, Buck Creek appears to be the single largest contributor of TSS to Lemon Bay, contributing 71,391 kg/yr. Inputs from Buck Creek are approximately 60% greater than the inputs from the second largest source. Inputs of TSS from Oyster, Ainger, Gottfried, Forked, and Alligator Creeks range from approximately 18,871-44,136 kg/yr.

Similar to the trend observed for TSS, Buck Creek appears to be the single largest contributor of BOD loadings to Lemon Bay, with an annual estimated input of 18,811 kg/yr. This value is approximately 25-40% greater than the estimated inputs from Gottfried, Forked, and Alligator Creeks, and approximately 3-4 times greater than inputs originating from Oyster and Ainger Creeks.

A comparison of dry season and wet season inputs of total nitrogen from the six tributaries to Lemon Bay is given in Figure 2-28. Buck Creek is clearly the largest contributor of total nitrogen loadings to Lemon Bay under both dry season and wet season conditions. The second most significant input of nitrogen appears to be Alligator Creek, followed by Gottfried Creek, Forked Creek, Ainger Creek, and Oyster Creek.

A comparison of dry season and wet season inputs of total phosphorus to the six primary tributaries to Lemon Bay is given in Figure 2-29. The largest phosphorus loadings to Lemon Bay appear to originate in Alligator Creek under both wet season and dry season conditions. Forked Creek appears to be the second largest contributor of phosphorus loadings to Lemon Bay, followed by Gottfried, Buck, Ainger, and Oyster Creeks.

Dry Season Total N



Wet Season Total N

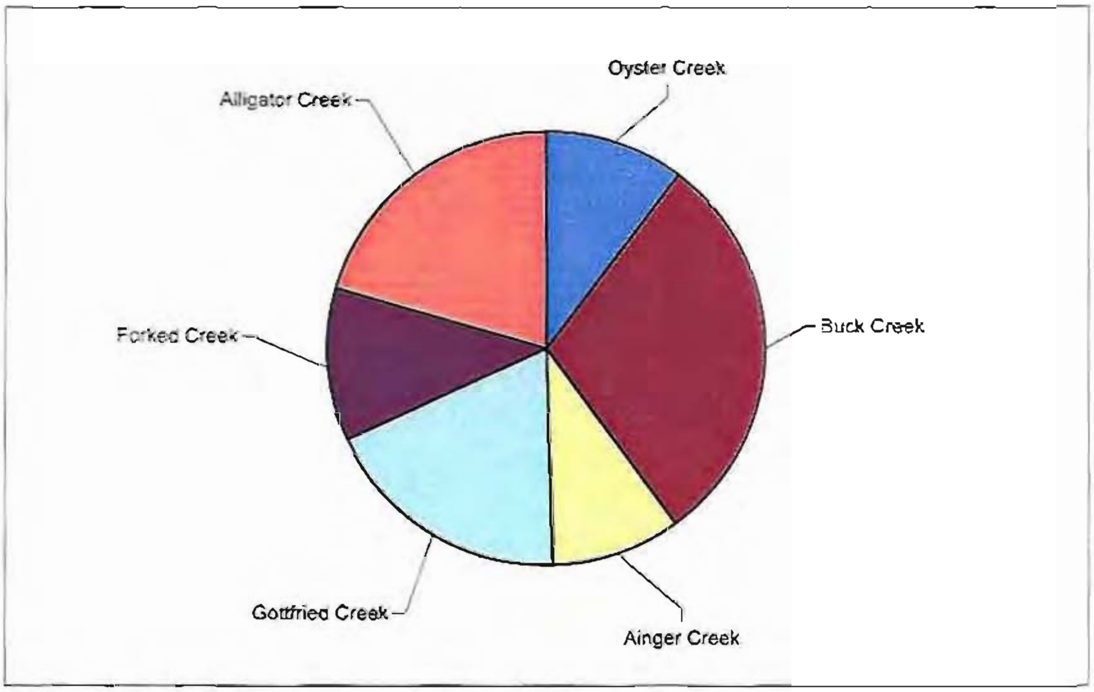
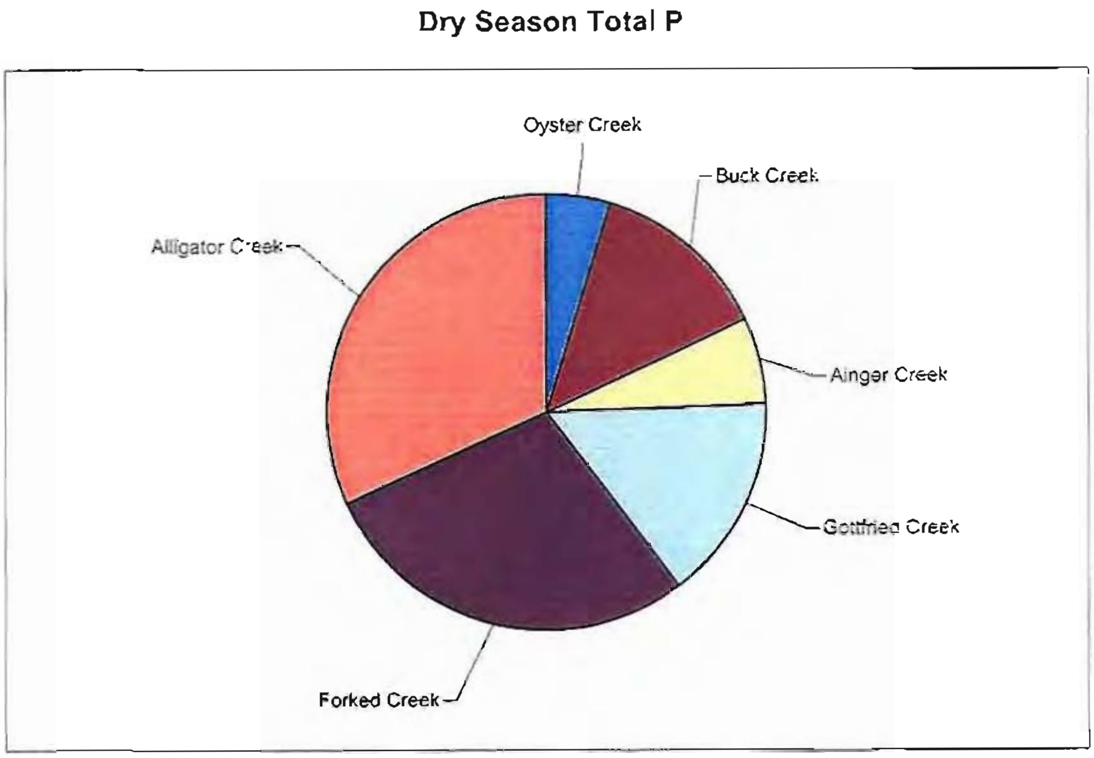


Figure 2-28. Comparison of Seasonal Inputs of Total N to Lemon Bay.



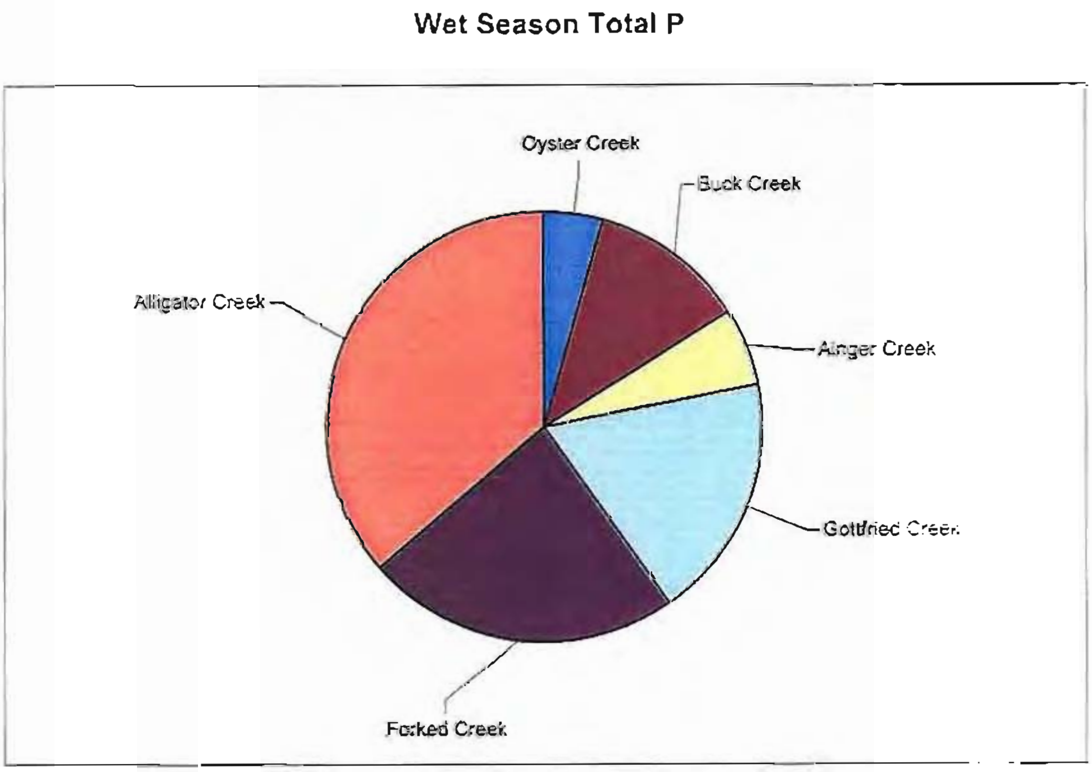


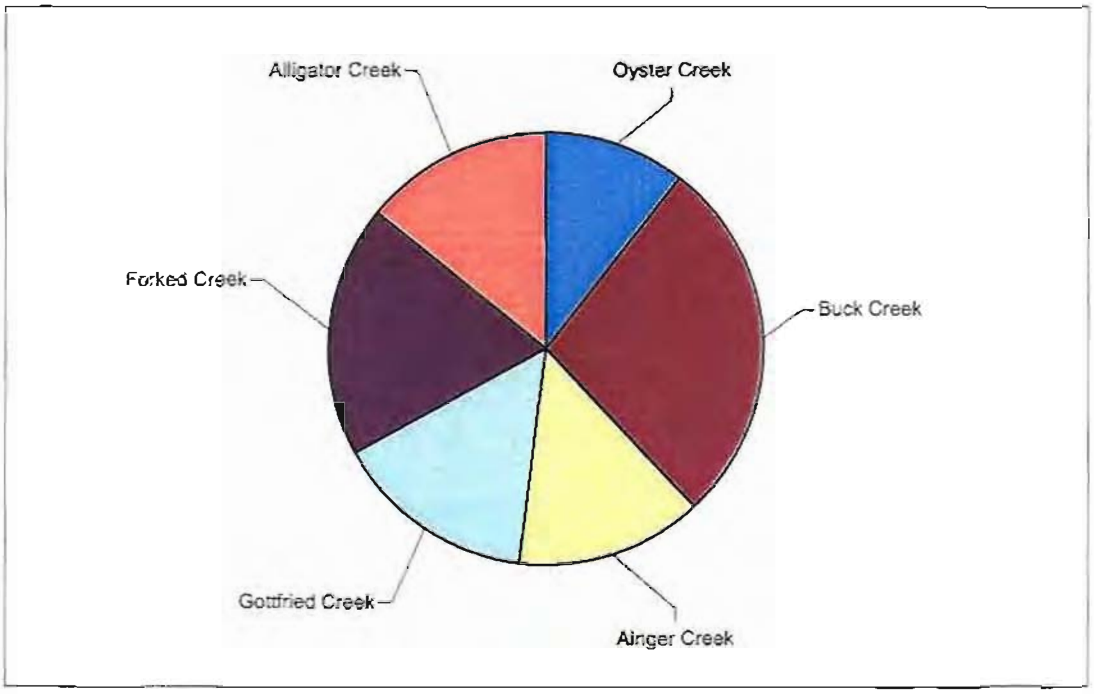
Figure 2-29. Comparison of Seasonal Inputs of Total P to Lemon Bay.

A comparison of wet season and dry season inputs of TSS from the six tributaries to Lemon Bay is given in Figure 2-30. Similar to the trends observed for total nitrogen, Buck Creek appears to be the largest single contributor of TSS to Lemon Bay under both wet season and dry season conditions. The second largest contributor of TSS to Lemon Bay appears to be Alligator Creek, followed by Forked, Gottfried, Ainger, and Oyster Creeks.

A comparison of wet season and dry season inputs of BOD from the six tributaries to Lemon Bay is given in Figure 2-31. Buck Creek also appears to be the largest single source of BOD, contributing more than 18,811 kg of BOD per year to Lemon Bay. The second largest contributor appears to be Alligator Creek, followed by Gottfried, Forked, Ainger, and Oyster Creeks.

In general, Buck Creek appears to be the single largest source of inputs of nitrogen, TSS, and BOD to Lemon Bay. The second largest contributor for these parameters appears to be Alligator Creek which is also the largest single contributor of total phosphorus inputs. Relatively large contributions of total nitrogen, TSS, and BOD are also contributed by Gottfried and Forked Creeks. Inputs of evaluated parameters from Oyster and Ainger Creeks appear to be relatively minimal in comparison to inputs from the other tributary sources.

Dry Season TSS



Wet Season TSS

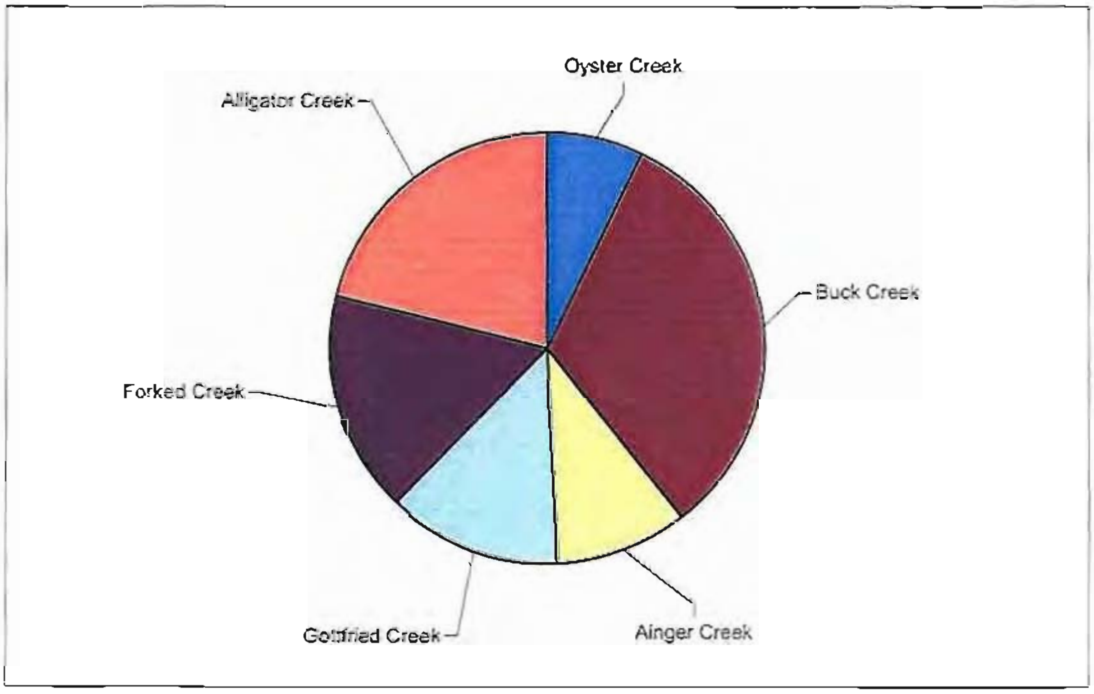
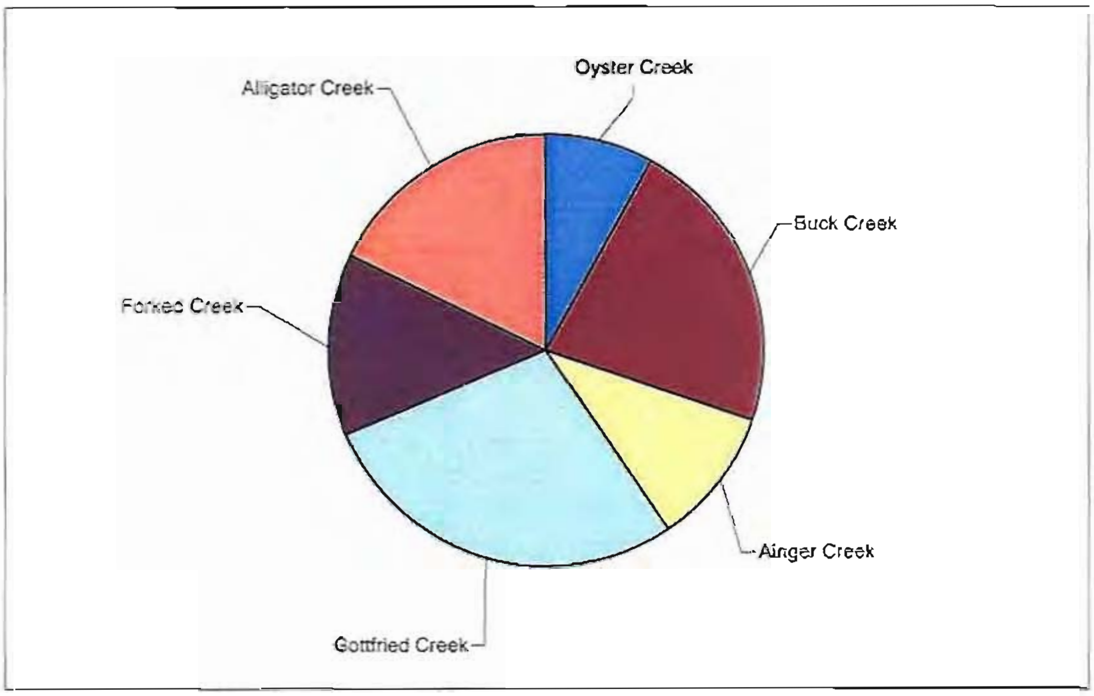


Figure 2-30. Comparison of Seasonal Inputs of TSS to Lemon Bay.

Dry Season BOD



Wet Season BOD

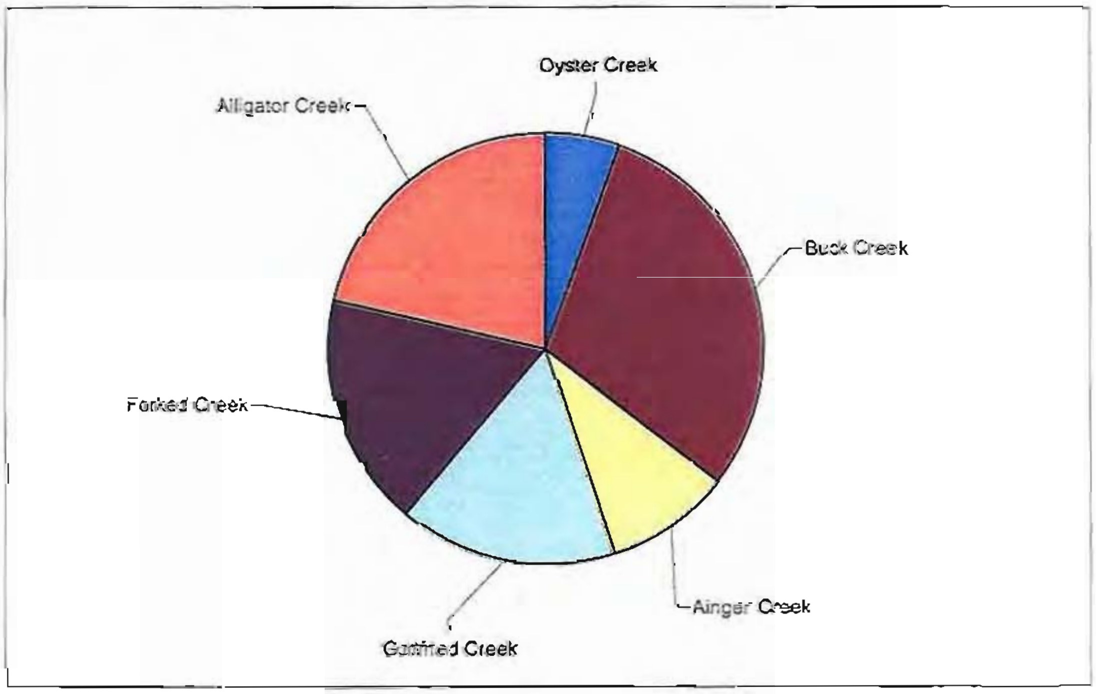


Figure 2-31. Comparison of Seasonal Inputs of BOD to Lemon Bay.

SECTION 3

STORMWATER CHARACTERISTICS IN THE LEMON BAY WATERSHED

3.1 Characterization of Runoff Quality

A field monitoring program was conducted by ERD from November 2002-March 2003 to characterize stormwater runoff generated from selected land use categories in the Lemon Bay Watershed. Since the dominant land use categories within the basin consist of natural areas, residential communities, and commercial developments, these land use categories were included during the field monitoring program. The results of the field monitoring program are used to develop recommended stormwater characterization data for land uses within the Lemon Bay basin. This information is used to develop a loading model for Lemon Bay to predict loadings under current and future conditions and to evaluate water quality impacts from evaluated treatment options. Details of the stormwater monitoring program and recommended stormwater characteristics for the Lemon Bay Watershed are presented in the following sections.

3.1.1 Field Monitoring Program

3.1.1.1 Description of Study Sites

Stormwater characterization sites were selected jointly by SFWMD and ERD personnel. Each of the characterization sites was selected based upon several criteria, including general similarity to other areas of similar land use within the Lemon Bay Watershed, absence of extraneous impacts from unwanted pollutant sources, and suitability for instrumentation and field monitoring. A general description of the selected monitoring sites is given in Table 3-1 and in the following sections. Locations of the evaluated land use characterization sites are indicated on Figures 3-1 and 3-2.

Figure 3-1. Locations of the Rotunda and Equestrian Club Natural Sites Used for Stormwater Characteristic Studies.

Figure 3-2. Locations of Residential, Commercial and Natural Sites Used for Stormwater Characteristic Studies.

TABLE 3-1

SUMMARY OF STORMWATER CHARACTERIZATION MONITORING SITES

LAND USE	SITE DESCRIPTION	PERVIOUS LAND COVER
Natural Areas	1. Rotunda-natural area in undeveloped portion of Rotunda west of SR 771 near intersection of Brig Circle W. and Yardarm Drive	Pine Flatwood/ Palmetto
	2. Equestrian Club - natural area in undeveloped portion of Equestrian Club east of SR 771 near the intersection of Lark Drive and Oak Court	Pine Flatwood/ Scrub
	3. River Road - Low-lying natural area north of intersection of River Road and Winchester Blvd.	Scrub/Wetland Species
Residential	1. French Avenue - Single-family residential area with roadside swale drainage near the intersection of French Avenue and E. Langsner Street	Lawns in fair/ good condition
	2. McCall Road - Single-family residential area with roadside swale drainage	Lawns in fair/ good condition
Commercial	1. SR 776 - Commercial area adjacent to SR 776 with stormsewer drainage	Landscaping/ gravel parking areas

3.1.1.1.1 Natural/Undeveloped Areas

Natural and undeveloped areas occupy a large portion of the land within the Lemon Bay Watershed under current conditions. Predominant land use in the natural and undeveloped areas appears to be pine flatwoods, with an understory of palmetto and shrub. Other natural areas, particularly those in low-lying areas, consist of shrubs and tall grasses. As a result, each of these primary land use types was evaluated for stormwater characteristics.

The first selected natural area is a pine flatwood/palmetto community which is located in an undeveloped area within the Rotunda Subdivision near the eastern edge of the Buck Creek basin. This site is located west of SR 771 on the western edge of the Rotunda area (Figure 3-1) near the intersection of Brig Circle W. and Yardarm Drive. An overview of the Rotunda natural/undeveloped site is given in Figure 3-3. This site was selected because the drainage from the natural/undeveloped areas is collected in a shallow swale adjacent to the undeveloped site.

The natural areas constitute virtually all of the runoff inputs into the swale system, providing a well defined channel for collection of runoff inflow.

The second natural/undeveloped area utilized for stormwater characterization monitoring is located east of SR 771 in an undeveloped portion of the Equestrian Club Development (Figure 3-1) on the eastern edge of the Buck Creek basin near the intersection of Lark Drive and Oak Street. The dominant vegetation in the natural area consists of long leaf pine and smaller scrub species. An overview of the Equestrian Club natural/undeveloped site is given in Figure 3-4. Runoff from the undeveloped areas drains by overland flow into a shallow grassed swale which was constructed as part of the future drainage system for the Equestrian Club project. This shallow swale provided a confined channel for collection of runoff inputs.

The final natural areas selected for monitoring is a low-lying natural area north of the intersection of River Road and Winchester Blvd. east of the City of Englewood. This monitoring site is located in the Gottfried Creek sub-basin (Figure 3-2). Vegetation at the site consists primarily of scrub and tall grasses. Runoff from the natural area is directed through a small channel into the roadside conveyance system which runs parallel to River Road. Sample collection at this site was performed in the natural channel immediately upstream of the point of discharge into the River Road drainage system. An overview of this area is given in Figure 3-5.

3.1.1.1.2 <u>Residential</u>

Two separate residential areas were evaluated for purposes of characterizing runoff quality from residential areas. The first site is located in a single-family residential area in the Gottfried Creek sub-basin, south of River Road, near the intersection of French Avenue and E. Langsner Street (Figure 3-2). The residential community is a typical single-family development with vegetated roadside swales used for collection and conveyance of stormwater runoff. The drainage system consists entirely of grassed swales with the exception of RCP culverts under individual driveways. An overview of the residential subdivision area is given in Figure 3-6.

Figure 3-3. Overview of the Rotunda Natural /Undeveloped Site.

Figure 3-4. Overview of the Equestrian Club Natural/Undeveloped Site.

Figure 3-5. Overview of the River Road Natural/Undeveloped Site.

Figure 3-6. Overview of the French Avenue Residential Subdivision.

An overview of the French Avenue monitoring site is given in Figure 3-7. Stormwater samples were collected in a concrete-lined swale, immediately upstream of the point of discharge into Gottfried Creek. The majority of runoff samples from residential areas was collected from the French Avenue monitoring site.

A second single-family area, identified as the McCall Road site, was also utilized during one of the monitoring events (Figure 3-2). This area is a residential community, similar to the area indicated on Figure 3-6, with vegetated roadside swales used for collection and conveyance of runoff. Pervious land cover within this basin consists of lawns in fair/good condition.

3.1.1.1.3 Commercial

The commercial stormwater monitoring site is located on SR 776 approximately one-half mile south of the intersection of SR 776 and SR 771 (River Road). Land use in this area consists primarily of commercial activities located immediately adjacent to the four-lane highway. An overview of the SR 776 commercial site is given in Figure 3-8. Pervious areas in the basin consist primarily of landscaping, with a few gravel parking areas. Runoff generated within this basin is directed into the FDOT stormsewer system which runs adjacent to SR 776, ultimately discharging directly into Lemon Bay.

3.1.1.2 Monitoring Details

3.1.1.2.1 Natural/Undeveloped Sites

A summary of stormwater monitoring details for the characterization sites is given in Table 3-2. Stormwater monitoring in the natural/undeveloped areas was performed in shallow grassed swales which receive runoff inputs from adjacent natural/undeveloped areas. Due to the difficulties in instrumentation at these sites, stormwater monitoring was performed using a manual collection technique conducted during runoff events. When significant rainfall appeared likely in the Lemon Bay watershed, ERD field personnel would mobilize to each of the natural/undeveloped monitoring sites. Collection of stormwater samples was initiated as soon as

Figure 3-7. Overview of the French Avenue Monitoring Site.

Figure 3-8. Overview of the SR 776 Commercial Site.

measurable runoff was present within the shallow grassed swale. Additional samples were collected at 15-minute intervals until runoff inputs into the grassed swale areas were no longer observed. A volume of one liter was collected for each sample event. Simultaneous measurements of depth of flow within the grassed swale were also performed at the time of collection for each sample.

TABLE 3-2

STORMWATER MONITORING DETAILS FOR THE CHARACTERIZATION SITES

SITE	CHANNEL TYPE	EQUIPMENT/ SAMPLING METHOD	NO. OF SAMPLES COLLECTED
Natural/ Undeveloped Areas			
1. Rotunda	Shallow grassed swale	Manual grab samples collected on a flow-weighted basis during runoff events	2
2. Equestrian Club	Shallow grassed swale	Manual grab samples collected on a flow-weighted basis during runoff events	2
3. River Road	Shallow grassed swale	Manual grab samples collected on a flow-weighted basis during runoff events	2
Residential			
A. French Avenue	Concrete-lined swale discharging to Gottfried Creek	Sigma autosampler paced on a flow-weighted basis using sharp-crested weir	6
B. McCall Road	Deep roadside swale	Manual grab samples collected on a flow-weighted basis during runoff events	1
Commercial			
1. SR 776	Underground 48-inch RCP stormsewer (FDOT)	Sigma autosampler paced on a flow-weighted basis using area/velocity method	5

Upon return to the ERD laboratory, estimates of discharge rates through the swale section were calculated based upon the cross-sectional geometry and slope of the channel. The estimated flows at the time of each sample collection were used in flow-weighting the collected sub-samples for each event. The following equation was used for determining the volume to be taken from each discrete sample to form the composite sample for each event:

$$A_i = \frac{(F_i)(V_c)}{F_t}$$

where:

A_i	=	volume to be used from the i^{th} discrete sample
i	=	an index indicating the order in which the n discrete samples are taken, $1 \leq i \leq n$
F_i	=	the interval volume between the i^{th} and i^{th}-1 samples
V_c	=	the total composite sample volume desired
F_t	=	total event volume

3.1.1.2.2 Residential Site

Stormwater monitoring in the residential neighborhoods were conducted using two separate methodologies. Monitoring at the French Avenue site was performed using a permanently installed Sigma autosampler which was programmed to collect samples on a flow-weighted sample. The point of sample collection was a concrete-lined swale which discharged directly to Gottfried Creek, representing the primary point of outfall for the residential community. A small sharp crested weir was constructed across the concrete-lined channel to provide a control section for flow measurements. ERD field personnel would visit the monitoring site prior to a significant anticipated rain event and fill the center of the autosampler compartment with ice to cool the samples during the collection process. The samples were then removed from the autosampler at the completion of the runoff event. A total of six flow composite stormwater samples was collected at this site using this methodology.

Stormwater monitoring at the McCall Road residential site was conducted on only one occasion. Stormwater samples were collected using the manual methodology outlined for the natural/undeveloped areas, with samples collected from a deep roadside swale adjacent to the residential area. In general, the roadside swales had vegetated side slopes with a non-vegetated earthen bottom.

3.1.1.2.3 Commercial Site

Stormwater monitoring at the commercial site was performed using a Sigma autosampler paced on a flow-weighted basis. The conveyance system which was monitored at this site consists of an underground 48-inch RCP FDOT stormsewer. An area velocity probe was inserted onto the bottom of the stormsewer which provided simultaneous measurements of water depth and velocity. These measurements were then converted into a flow rate based upon the geometry of the pipe. ERD field personnel visited the autosampler immediately prior to anticipated significant rain events and placed ice in the center compartment to cool the samples during the collection process. Samples were removed immediately following the end of the runoff event at this site. A total of five separate flow composite samples of commercial runoff was collected at this site during the monitoring program.

3.1.2 Characteristics of Monitored Runoff Samples

Each of the collected composite stormwater samples was analyzed for pH, conductivity, alkalinity, nitrogen species, phosphorus species, TSS, and BOD. Analytical methods and detection limits for laboratory analyses conducted on stormwater samples are identical to the methods and detection limits outlined in Table 2-2 for analysis of tributary samples. A discussion of the chemical characteristics of the collected samples, along with a comparison with runoff characteristics monitored during other studies, is given in the following sections.

3.1.2.1 Chemical Characteristics of Monitored Runoff Samples

3.1.2.1.1 Natural/Undeveloped Site

Characteristics of stormwater runoff monitored at the natural/undeveloped land use site are summarized in Table 3-3. A total of six separate flow composite runoff samples was collected from the natural/undeveloped sites, with two collected at the Rotunda site, two at the Equestrian Club site, and two at the River Road site. Rainfall amounts for the collected events at the natural/undeveloped sites range from 0.31-1.35 inches, based upon rainfall measured at the Englewood rainfall station (Site 134) for the stormwater characterization dates.

TABLE 3-3

CHARACTERISTICS OF STORMWATER RUNOFF MONITORED AT THE NATURAL/UNDEVELOPED LAND USE SITES

PARAMETER	UNITS	SITE / DATE / RAINFALL DATA						MEAN
		EQUESTRIAN CLUB		RIVER ROAD		ROTUNDA		
		11/16/02 (1.35 in)	12/13/02 (0.80 in)	12/13/02 (0.80 in)	12/31/02 (0.31 in)	11/16/02 (1.35 in)	12/13/02 (0.80 in)	
pH	s.u.	7.29	7.10	7.42	7.44	7.06	6.64	7.16
Conductivity	µmho/cm	151	325	202	346	53	33	185
Alkalinity	mg/l	61.6	52.1	101	115	25.7	172	87.9
Ammonia	µg/l	< 5	32	29	16	33	94	35
NO_x	µg/l	< 5	20	39	175	< 5	17	43
Organic N	µg/l	457	830	943	1047	214	263	626
Total N	µg/l	462	882	1011	1238	250	374	703
Ortho-P	µg/l	11	5	9	17	12	6	10
Total P	µg/l	19	31	27	62	18	29	31
TSS	mg/l	< 0.7	1.0	1.7	5.4	< 0.7	2.6	1.9
BOD	mg/l	< 2	< 2	< 2	< 2	< 2	< 2	< 2

In general, runoff collected from the natural/undeveloped land use site was found to be approximately neutral in pH, with a mean pH of 7.16. Specific conductivity at these sites was found to be somewhat variable, ranging from 33-346 μmho/cm, with an overall mean of 185 μmho/cm. Runoff collected from the natural/undeveloped sites was found to be moderately to well buffered, with a mean alkalinity of 87.9 mg/l.

Stormwater runoff collected from the natural/undeveloped sites was found to have relatively low concentrations of ammonia, with measured concentrations ranging from <5-94 μg/l, and an overall mean of 35 μg/l. Measured concentrations of NO_x also appear to be low in value, ranging from <5-175 μg/l, with an overall mean of 43 μg/l. The dominant nitrogen species measured in runoff at this site is organic nitrogen, which comprises approximately 89% of the total nitrogen present on an average basis. Combined together, ammonia and NO_x contribute approximately 11% of the total nitrogen at these sites. Measured total nitrogen concentrations range from 250-1238 μg/l, with an overall mean of 703 μg/l.

In general, measured concentrations of phosphorus species at the natural/undeveloped sites were found to be low in value. Measured orthophosphorus concentrations range from 5-17 μg/l, with an overall mean of 10 μg/l. Measured total phosphorus concentrations range from 18-62 μg/l, with an overall mean of 31 μg/l. On an average basis, orthophosphorus comprises approximately 33% of the total phosphorus species measured at the natural/undeveloped sites, with the remaining total phosphorus comprised of particulate and dissolved organic species.

In general, measured TSS concentrations at the natural/undeveloped site were found to be low in value, with event mean concentrations ranging from <0.7-5.4 mg/l, with an overall mean of only 1.9 mg/l. Measured BOD concentrations in the collected samples were all less than the BOD detection limit of 2 mg/l.

3.1.2.1.2 <u>Residential Land Use Sites</u>

A summary of the characteristics of stormwater runoff collected at the residential land use sites is given in Table 3-4. A total of seven separate flow composite runoff samples was collected from the residential monitoring sites, with six samples collected from the French

Avenue site and one sample collected from the McCall Road site. Rainfall amounts for the collected events at the residential land use sites range from 0.31-1.35 inches, based upon rainfall measured at the Englewood rainfall station (Site 134) for the stormwater characterization dates.

TABLE 3-4

CHARACTERISTICS OF STORMWATER RUNOFF MONITORED AT THE RESIDENTIAL LAND USE SITES

PARAMETER	UNITS	SITE / DATE / RAINFALL DATA							MEAN
		FRENCH STREET						McCALL ROAD	
		11/16/02 (1.35 in)	12/5/02 (0.54 in)	12/24/02 (0.60 in)	12/31/02 (0.31 in)	2/16/03 (0.48 in)	3/16/03 (0.83 in)	11/16/02 (1.35 in)	
pH	s.u.	7.26	7.58	7.82	7.69	7.61	8.08	7.32	7.62
Conductivity	μmho/cm	247	260	282	175	183	381	307	262
Alkalinity	mg/l	82.2	87.3	108	139	91.1	146	83.4	106
Ammonia	μg/l	63	80	137	114	< 5	183	83	95
NO_x	μg/l	253	74	192	59	283	78	219	165
Organic N	μg/l	945	968	861	669	645	996	1282	909
Total N	μg/l	1261	1122	1190	842	931	1257	1584	1170
Ortho-P	μg/l	394	36	387	261	39	412	581	301
Total P	μg/l	464	876	528	350	172	480	671	506
TSS	mg/l	< 0.7	7.6	10.2	3.4	45.4	3.7	< 0.7	10.1
BOD	mg/l	< 2	< 2	< 2	< 2	2.1	2.5	< 2	1.4

In general, runoff collected from the residential land use sites was found to be slightly alkaline in pH, with measured values ranging from approximately 7.25-8.1. Specific conductivity at the residential sites was found to be relatively consistent between the monitored events, with event mean concentrations ranging from 175-381 μmho/cm. Runoff collected from the residential sites was found to be moderately to well buffered, with a mean alkalinity of 106 mg/l.

Stormwater runoff collected from the residential land use sites was found to have moderate levels of ammonia, with measured concentrations ranging from <5-183 μg/l, and an overall mean of 95 μg/l. Measured concentrations of NO_x also appear to be moderate in value, ranging from 74-253 μg/l, with an overall mean of 165 μg/l. The dominant nitrogen species measured in runoff from the residential areas is organic nitrogen which comprises approximately 78% of the total nitrogen present on an average basis. Combined together, ammonia and NO_x contribute approximately 22% of the total nitrogen measured at these sites. Measured total nitrogen concentrations range from 842-1584 μg/l, with an overall mean of 1170 μg/l.

In general, measured concentrations of phosphorus species at the residential land use sites were found to be somewhat elevated in value. Measured orthophosphorus concentrations were highly variable, ranging from 36-581 μg/l, with an overall mean of 301 μg/l. These values appear to be somewhat elevated compared to orthophosphorus concentrations typically observed in residential runoff. Measured total phosphorus concentrations also appear to be highly variable, as well as elevated in value, with measured concentrations ranging from 172-876 μg/l, with an overall mean of 506 μg/l. On an average basis, orthophosphorus contributes approximately 59% of the total phosphorus measured at the residential sites.

In general, measured TSS concentrations at the residential site were found to be relatively low in value, with event mean concentrations ranging from <0.7-45.4 mg/l, and an overall mean of 10.1 mg/l. Measured BOD concentrations in the collected samples were approximately 2 mg/l or less.

3.1.2.1.3 <u>Commercial Land Use Site</u>

Characteristics of stormwater runoff collected at the commercial land use site are summarized in Table 3-5. A total of five separate flow composite runoff samples was collected from the commercial monitoring site located on SR 776. Rainfall amounts for the collected events at the commercial monitoring site range from 0.31-0.83 inches, based upon rainfall measured at the Englewood rainfall station (Site 134) on the stormwater characterization dates.

TABLE 3-5

CHARACTERISTICS OF STORMWATER RUNOFF MONITORED AT THE COMMERCIAL LAND USE SITE

PARAMETER	UNITS	SITE / DATE / RAINFALL DATA					MEAN
		SR 776					
		12/5/02 (0.54 in)	12/24/02 (0.60 in)	12/31/02 (0.31 in)	2/16/03 (0.48 in)	3/16/03 (0.83 in)	
pH	s.u.	7.29	7.57	7.45	7.92	7.91	7.63
Conductivity	µmho/cm	91	122	151	325	193	176
Alkalinity	mg/l	37.8	53.1	50.9	130	85.3	71.4
Ammonia	µg/l	< 5	22	58	< 5	40	25
NO_x	µg/l	167	140	230	274	357	234
Organic N	µg/l	396	559	483	1116	573	625
Total N	µg/l	566	721	771	1393	970	884
Ortho-P	µg/l	66	55	34	557	37	150
Total P	µg/l	166	333	176	653	207	307
TSS	mg/l	13.7	113	21.3	4.4	47.0	39.9
BOD	mg/l	2.2	< 2	4.3	< 2	3.2	2.3

In general, runoff collected from the commercial land use site was found to be approximately neutral to in pH, with a mean pH of 7.63. Specific conductivity at this site was found to be somewhat variable, ranging from 91-325 µmho/cm, with an overall mean of 176 µmho/cm. Runoff collected from the commercial site was found to be poorly to moderately buffered, with a mean alkalinity of 71.4 mg/l.

Stormwater runoff collected from the commercial land use site was found to have relatively low concentrations of ammonia, with measured values ranging from <5-58 µg/l and an overall mean of 25 µg/l. However, measured concentrations of NO_x appear to be more elevated, with values ranging from 140-357 µg/l and an overall mean of 234 µg/l. The dominant nitrogen species measured in runoff collected at the commercial land use site is organic nitrogen which comprises approximately 71% of the total nitrogen present on an average basis. Combined together, ammonia and NO_x comprise approximately 29% of the total nitrogen measured at this site. Measured total nitrogen concentrations were relatively low in value, ranging from 566-1393 μg/l, with an overall mean of 804 μg/l.

In general, measured concentrations of phosphorus species were found to be moderate in concentration at the commercial land use site. Measured orthophosphorus concentrations range from 34-557 μg/l, with an overall mean of 150 μg/l. Measured total phosphorus concentrations range from 166-653 μg/l, with an overall mean of 207 μg/l. On an average basis, dissolved orthophosphorus comprises approximately 49% of the total phosphorus species measured at the commercial site, with the remaining total phosphorus comprised of particulate and dissolved organic species.

In general, measured TSS concentrations at the commercial site were highly variable, with event mean concentrations ranging from 4.4-113 mg/l, and an overall mean of 39.9 mg/l. Measured BOD concentrations in the commercial runoff were typically low in value, with an overall mean of 2.3 mg/l.

3.1.2.1.4 Comparison of Stormwater Characteristics Between the Monitored Sites

A statistical comparison of nitrogen species measured at the natural, residential, and commercial sites is given in Figure 3-9. A graphical summary of data for each general land use category is presented in the form of box plots. The box plots include all monitoring data collected from multiple sites for each individual land use category. As discussed in Section 2.4.3, the bottom line of the box portion of each plot represents the lower quartile, with 25% of the data points lying below this line. The upper line of the box represents the 75% upper quartile, with 25% of the data lying above this line. The blue horizontal line in each box represents the median value, with 50% of the data points lying above and below this value. The horizontal red line within each both represents the arithmetic mean value. A comparison of mean characteristics of stormwater runoff monitored at the natural, residential, and commercial land use sites is also given in Table 3-6.

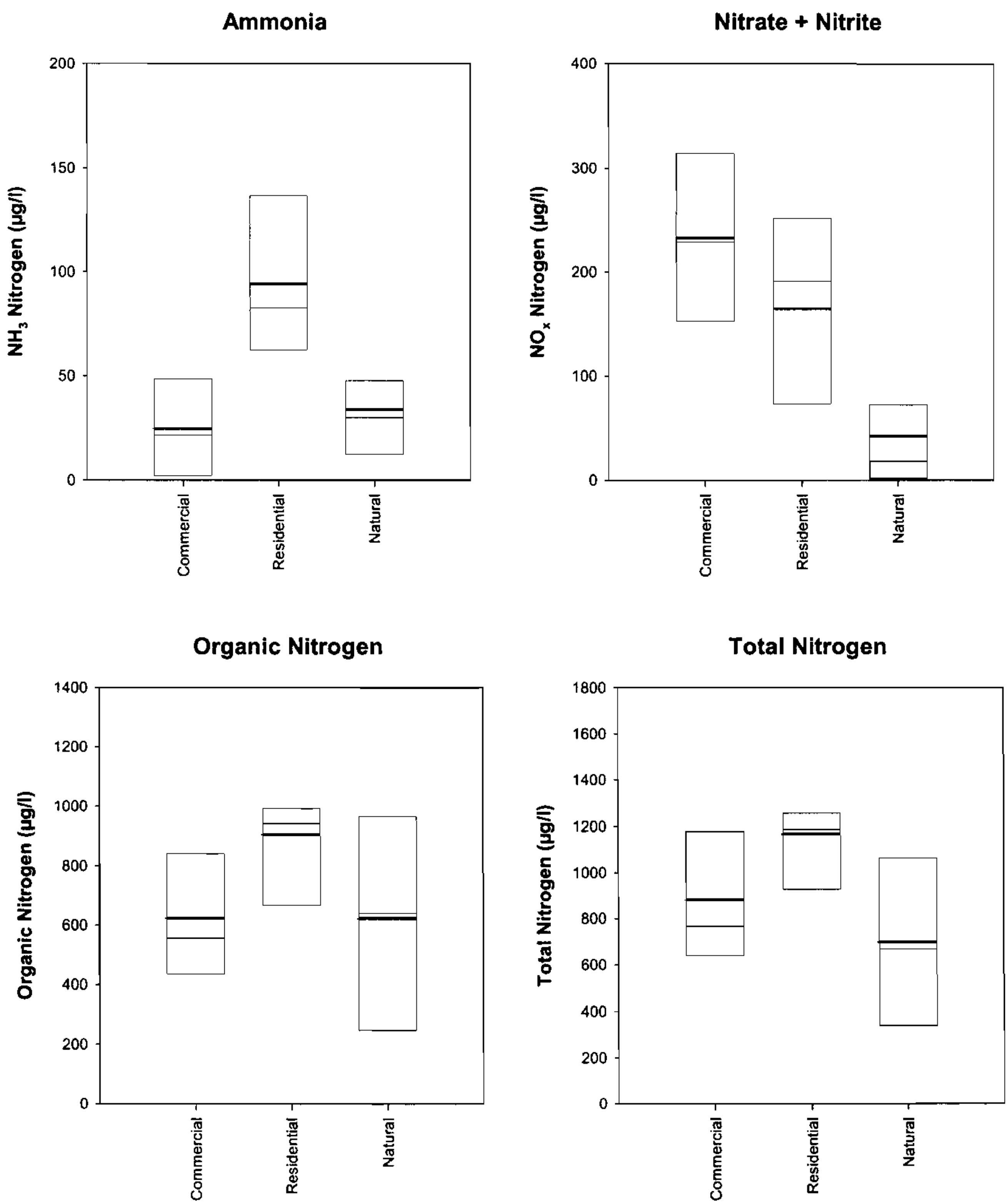


Figure 3-9. Statistical Comparison of Nitrogen Species Measured at the Natural, Residential and Commercial Sites.

TABLE 3-6

COMPARISON OF MEAN STORMWATER CHARACTERISTICS MONITORED AT THE NATURAL/UNDEVELOPED, RESIDENTIAL, AND COMMERCIAL LAND USE SITES

PARAMETER	UNITS	MEAN VALUE BY LAND USE		
		NATURAL AREA	RESIDENTIAL AREA	COMMERCIAL AREA
pH	s.u.	7.16	7.62	7.63
Conductivity	μmho/cm	185	262	176
Alkalinity	mg/l	87.9	106	71.4
Ammonia	μg/l	35	95	25
NO_x	μg/l	43	165	234
Organic N	μg/l	626	909	625
Total N	μg/l	703	1170	884
Ortho-P	μg/l	10	301	150
Total P	μg/l	31	506	307
TSS	mg/l	1.9	10.1	39.9
BOD	mg/l	< 2	< 2	2.3

As seen in Figure 3-9, measured concentrations of ammonia in residential runoff appear to be higher in value and substantially more variable than observed at either the commercial or natural sites. The highest concentrations of NO_x were observed at the commercial site, followed by residential and natural sites. Organic nitrogen concentrations appear to be similar between the natural and commercial areas, with more elevated values present in the residential areas. Overall, residential areas appear to have the highest total nitrogen concentrations, with a mean of 1170 μg/l. Commercial areas are characterized by a total nitrogen concentration of 884 μg/l, compared with 703 μg/l in the natural area.

A statistical comparison of phosphorus species measured in the three land use types is given in Figure 3-10. A substantial degree of variability is present in measured orthophosphorus concentrations between the three land use types. Low concentrations of orthophosphorus were observed at the natural site, with a mean of 10 μg/l. Orthophosphorus concentrations measured at the commercial and residential areas were found to be highly variable and substantially elevated compared with the natural area sites. Mean orthophosphorus in the commercial areas is approximately 150 μg/l, with a mean of 301 μg/l in residential areas.

A similar pattern is apparent for measured concentrations of total phosphorus. Total phosphorus concentrations in natural areas appear to be low in value, with a mean of only 31 μg/l. Substantially elevated concentrations of total phosphorus are present in the commercial and residential areas, with a mean of 307 μg/l in the commercial area and 506 μg/l in the residential area. Overall, the residential area appears to be the largest contributor for loadings of both nitrogen and phosphorus.

A statistical comparison of suspended solids concentrations measured at the three land use sites is also given in Figure 3-10. Suspended solids concentrations at the commercial site appear to be highly variable, with a mean concentration of approximately 39.9 mg/l. Substantially less variability is apparent at the residential and natural sites, with a mean of 10.1 mg/l at the residential and 1.9 mg/l at the natural site.

A statistical comparison of BOD concentrations at the three land use sites is also given in Figure 3-10. In general, mean concentrations of BOD appear to be relatively similar between the three monitoring sites, with slightly higher concentrations and higher variability observed at the commercial site.

3.1.2.2 Comparison of Runoff Characteristics with Other Studies

During 1990, ERD performed an extensive literature search and analysis of runoff characteristics for selected parameters and land use types within Central and South Florida as part of the Tampa Bay SWIM Project. This analysis was summarized in a document titled "Stormwater Loading Rate Parameters for Central and South Florida" which was originally

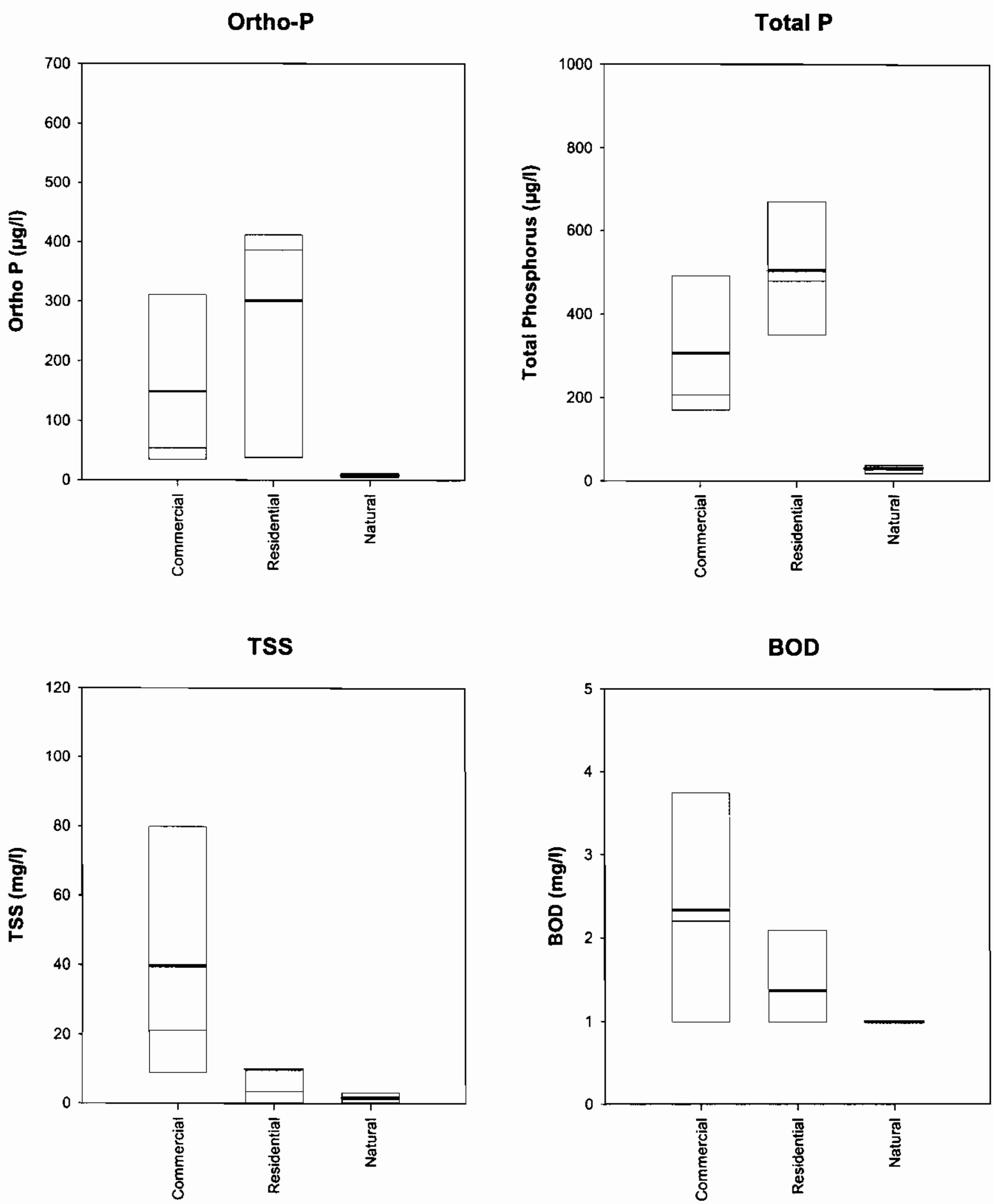


Figure 3-10. Statistical Comparison of Phosphorus Species, TSS and BOD Measured at the Natural, Residential and Commercial Sites.

published in 1990 and later updated by Harper in 1994. Runoff characteristics provided in this document include publications and studies conducted specifically within Central and South Florida by a variety of state, federal, and local governments, along with private consultants. Each study was reviewed for adequacy of the database, with special attention to factors such as length of study, number of runoff events monitored, monitoring methodology, as well as completeness and accuracy of the work. This publication is widely used throughout the State of Florida for land use characterization data and loading rate studies.

A comparison of the chemical characteristics of stormwater runoff measured in Lemon Bay with "typical" runoff characteristics summarized by Harper (1994) is given in Figure 3-11. Each of the general land use categories evaluated in Lemon Bay appears to have nitrogen concentrations which are substantially lower than typical values measured throughout the State of Florida. Nitrogen concentrations measured in Lemon Bay at the commercial and residential land use sites appear to be approximately 50% of the values reported by Harper (1994), while nitrogen concentrations at the natural land use site appear to be approximately 60% of the state-wide mean values.

Phosphorus concentrations measured in the Lemon Bay watershed in commercial and natural land use areas appear to be similar to values measured in other parts of the State. However, phosphorus concentrations measured at the residential site appears to be substantially greater than values measured in other parts of the State of Florida.

Similar to the trends observed for total nitrogen, suspended solids concentrations in the Lemon Bay watershed appear to be substantially lower than observed in other parts of Florida. Suspended solids concentrations measured in commercial and residential areas are less than half of the values measured in other areas of Florida. Suspended solids observed at the natural sites appear to be less than 20% of the values measured in other areas of the State.

Substantially lower concentrations of BOD were also observed in the Lemon Bay watershed compared with values measured in other portions of the State. Measured BOD concentrations in commercial, residential, and natural areas in the Lemon Bay watershed represent only a small fraction of the BOD concentrations observed in other portions of the State.

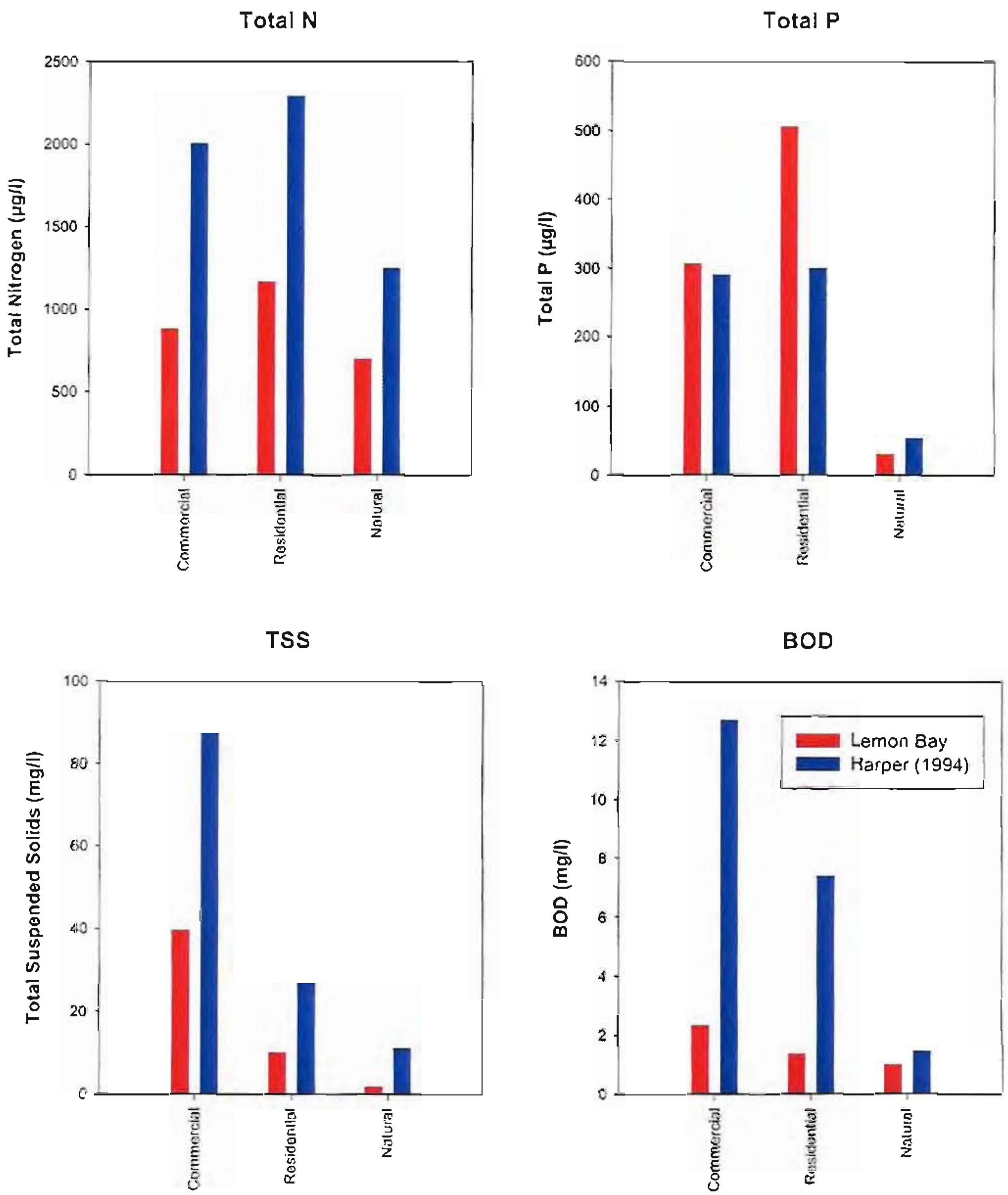


Figure 3-11. Comparison of Lemon Bay and "Typical" Runoff Characteristics.

3.1.3 Recommended Stormwater Characteristics for the Lemon Bay Watershed

The primary objective of the stormwater characterization study summarized in the previous sections is to develop estimates of stormwater characteristics for use in developing a loading rate model for the Lemon Bay watershed. Since land use in the Lemon Bay watershed is dominated primarily by natural, residential, and commercial areas, these three land use types were included in the characterization studies performed by ERD. For purposes of the loading evaluations summarized in subsequent sections of this report, the mean characteristics measured during this project are assumed to be representative of stormwater characteristics generated in commercial, residential, and natural areas.

Although commercial, residential, and natural areas represent the dominant land use categories in the Lemon Bay watershed, other land use categories are also present. These additional land use categories include agriculture, extractive, industrial, low-density residential, high-density residential, transportation, and wetlands. Since these land uses were not specifically evaluated as part of the field monitoring conducted for this project, estimates of the general runoff characteristics for these land use types were obtained from two separate sources. Runoff characteristics for total phosphorus, BOD, and TSS in land use types which were not directly evaluated are assumed to be similar to the state-wide runoff concentrations contained in the Harper (1994) report. Estimates of event mean concentrations of total nitrogen in industrial, extractive, agricultural, and wetlands were obtained from Tomasko, et al. (2001) which provides an assessment of present and future nitrogen loads to Lemon Bay based upon loading models and field monitoring performed in the Charlotte Harbor and Sarasota Bay Estuaries. Since this modeling was performed in watersheds which are close to the Lemon Bay watershed, the nitrogen concentrations developed in this assessment are assumed to be representative of nitrogen concentrations in the Lemon Bay watershed.

Areas identified as agricultural land use in the Lemon Bay watershed appear to exhibit relatively low-intensity agricultural activities, based upon field observations and review of aerial photography within the basin. As a result, estimated runoff characteristics for total phosphorus, BOD, and TSS in the Lemon Bay watershed are probably somewhat lower than the state-wide averages summarized in the Harper (1994) report. Therefore, for purposes of this evaluation, runoff concentrations for total phosphorus, BOD, and TSS in agricultural areas are assumed to be the average of the state-wide agricultural concentrations for these parameters, and runoff characteristics measured in open/undeveloped areas. The arithmetic average of these two land uses is assumed to be reflective of runoff characteristics for total phosphorus, BOD, and TSS in agricultural areas in the Lemon Bay watershed.

A summary of estimated runoff concentrations for selected land use categories in the Lemon Bay watershed is given in Table 3-7. Runoff characteristics for medium-density residential, commercial, and undeveloped areas are based upon the field monitoring performed in the Lemon Bay basin. Estimated runoff characteristics for low-density residential areas are assumed to be the average of medium-density residential and undeveloped areas, since low-density residential land use exhibits characteristics of each of these general land use types. Nutrient concentrations in medium-density and high-density residential areas are assumed to be similar, while runoff characteristics for BOD and TSS in high-density residential land use are scaled up from the medium-density residential characteristics measured in the Lemon Bay watershed based upon the state-wide ratio of high-density to medium-density residential runoff characteristics, as presented by Harper (1994).

Runoff characteristics in recreational areas, consisting primarily of golf courses, are assumed to be similar to medium-density residential land use. Runoff loadings for open water are assumed to be similar to rainfall characteristics. Stormwater characterization data for transportation land uses are based upon state-wide averages presented by Harper (1994). Runoff characteristics for total phosphorus, BOD, and TSS in wetlands are based upon long-term monitoring data for these land use types collected in Lee and Collier Counties. Estimates of the total nitrogen concentration for rainfall in the Lemon Bay watershed are obtained from Tomasko, et al. (2001), with concentrations of total phosphorus, BOD, and TSS based on previous monitoring performed by ERD in Central Florida.

TABLE 3-7

SUMMARY OF ESTIMATED RUNOFF CONCENTRATIONS FOR SELECTED LAND USE CATEGORIES IN THE LEMON BAY WATERSHED

LAND USE CATEGORY	TYPICAL RUNOFF CONCENTRATION (mg/l)			
	TOTAL N	TOTAL P	BOD	TSS
Low-Density Residential[1]	0.94	0.269	1.5	6.0
Medium-Density Residential[2]	1.17	0.506	2.0	10.1
High-Density Residential	1.17[3]	0.506[3]	3.1[4]	28.1[4]
Commercial[2]	0.88	0.307	2.3	39.9
Industrial	1.64[5]	0.310[7]	9.6[7]	93.9[7]
Transportation[7]	2.23	0.270	6.7	49.1
Agriculture	1.24[5]	0.188[6]	2.4[6]	28.6[6]
Undeveloped / Rangeland / Forest[2]	0.703	0.031	1.0	1.9
Extractive	1.18[5]	0.150[7]	9.6[7]	93.9[7]
Wetland	1.44[5]	0.090[8]	2.6[8]	11.2[8]
Open Water/Lake	0.309[5]	0.045[9]	2.0[9]	6.2[9]
Recreational[3]	1.17	0.506	2.0	10.1

1. Average of medium-density residential and undeveloped/open space concentrations
2. Based on monitoring period in the Lemon Bay basin
3. Concentrations assumed to be similar to medium-density residential
4. Concentrations scaled up from single-family based on state-wide HD/MD ratio
5. From Tomasko, et al. (2001)
6. Average of state-wide agricultural values and undeveloped values
7. Runoff concentrations reflect state-wide averages for these categories
8. Site-specific data collected in Lee/Collier Counties
9. Values reflect estimated rainfall characteristics

The estimated runoff characteristics presented in Table 3-7 are assumed to be representative of general chemical characteristics of stormwater runoff generated in the Lemon Bay watershed. This information is used in subsequent sections for development of a stormwater loading rate model for the Lemon Bay watershed.

3.2 Stormwater Treatment in the Lemon Bay Watershed

Since approximately 1980, stormwater management for new development within the Lemon Bay watershed has been regulated by SWFWMD. Design criteria for stormwater management systems permitted in the SWFWMD district are outlined in the SWFWMD Environmental Resource Permitting Manual. However, a significant portion of the development within the Lemon Bay watershed occurred prior to implementation of stormwater regulations in 1980 and, therefore, has no stormwater treatment at this time.

The three most common types of stormwater management systems used within the SWFWMD district today include wet detention, dry retention, and dry detention with filtration. Current SWFWMD design criteria for each of these basic system types is provided in Table 3-8, based upon information contained in the SWFWMD Environmental Resource Permitting Manual. Each of these treatment systems requires that a treatment volume be retained or detained within the system for a specified period of time, generally approximately 36-72 hours. Other design criteria, such as littoral zone, side slopes, width, depth, and filter media requirements, are specific to each of the individual system types. Due to generally high water table conditions within the Lemon Bay watershed, the majority of stormwater treatment systems constructed within the basin have consisted of either wet detention or dry detention with filtration systems.

TABLE 3-8

CURRENT SWFWMD STORMWATER SYSTEM DESIGN CRITERIA

SYSTEM TYPE	PARAMETER	DESIGN CRITERIA
Wet Detention	Treatment Volume	1-inch of runoff from contributing area
	Littoral Zone	Minimum 35% of pond surface
	Recovery Time	Bleed down 50% of treatment volume in 60 hours; 100% in 120 hours
	Width	100 ft minimum
	Depth	No specific value; shall not breach an aquitard
	Side Slopes	4:1 or less
Dry Retention (On-Line/ Off-Line)	Treatment Volume	1 inch of rainfall or 1/2 inch of runoff (if drainage area < 100 ac)
	Recovery Time	72 hours or less
	Water Velocities	Shall not cause flushing of pollutants up to 25-year/24-hour storm
Detention with Filtration	Treatment Volume	1 inch of rainfall or 1/2 inch of runoff (if drainage area < 100 ac)
	Filter Media	Specific requirements for size, flow capacity, and composition
	Recovery Time	Total treatment volume available in 36 hours
	Water Velocities	Shall not cause flushing of pollutants up to 25-year/24-hour storm

SOURCE: SWFWMD Environmental Resource Permitting Information Manual

3.2.1 Estimated Removal Efficiencies for Typical Stormwater Treatment Systems

A literature review was conducted of previous research performed in the State of Florida which quantifies pollutant removal efficiencies associated with various stormwater management systems used throughout the State. Each study which was obtained was evaluated for adequacy of the database, with special attention to factors such as length of study, number of runoff events monitored, monitoring methodology, as well as completeness and accuracy of the work. It was preferred that selected studies contain at least a 3-month period of data collection, representing a wide range of rainfall and antecedent dry period conditions.

Unfortunately, for a number of studies, the only available database for a particular stormwater management facility represented a relatively small and limited data collection process. These studies were carefully examined on a case-by-case basis and a decision was made on whether or not to include the data in the removal efficiency estimates. In general, studies with less than four monitored storm events were not included. Only stormwater management facilities constructed within the State of Florida were included in this evaluation. Pollutant removal efficiencies were obtained and summarized for the following types of stormwater management facilities:

1. Dry retention
2. Wet detention
3. Dry detention with filtration

Removal efficiencies for dry retention, wet detention, and dry detention with filtration are provided in the following sections.

3.2.1.1 Dry Retention Systems

Dry retention systems consist primarily of infiltration basins which are used to retain stormwater runoff on-site, thus reducing discharge to downstream waterbodies. Disposal of stormwater runoff occurs by infiltration into the groundwater and, to a lesser degree, evaporation from the water surface during periods of standing water. Because these systems rely primarily on infiltration of stormwater into the ground for disposal to regain the available pond storage, construction of these systems is limited to areas with low groundwater tables and relatively high permeability soils. The soil and water table conditions must be such that the system can provide for a new volume of storage through percolation or evaporation within a maximum of 72 hours following the stormwater event.

A schematic diagram of a typical dry retention system is given in Figure 3-12. Retention ponds are constructed as a dry basin with the pond bottom constructed a minimum of 3 ft above the seasonal high groundwater table elevation. The pond is typically designed to hold a volume of stormwater, called the "treatment volume", which is equivalent to a certain depth of runoff over the contributing watershed area. Dry retention ponds may be constructed as either on-line or off-line systems. Off-line systems typically provide storage for the treatment volume only. For on-line systems, an additional volume may be provided above the treatment volume for peak attenuation of on-site discharges during major (10-year, 25-year, or 100-year) storm events. The bottom of the pond is designed to be dry within 72 hours of the design storm event.

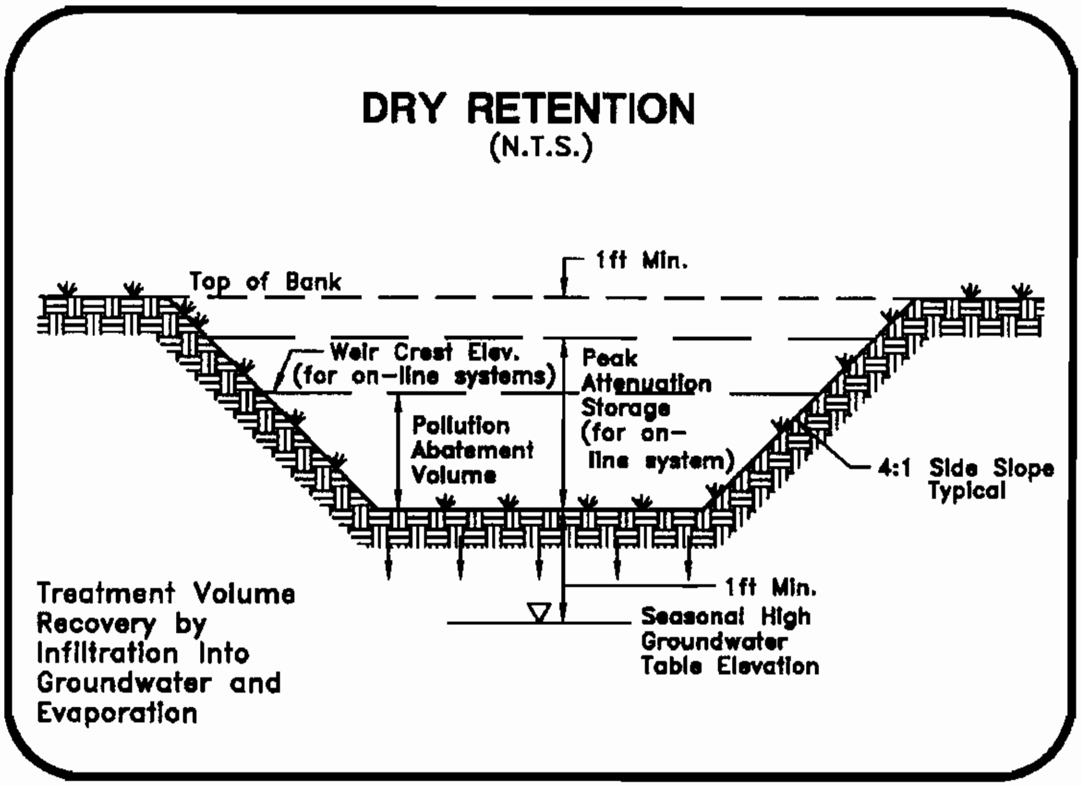


Figure 3-12. Schematic of a Dry Retention Facility.

Although retention ponds are most commonly constructed as basins similar to Figure 3-12, retention ponds may also be constructed which combine uses in addition to stormwater control. Retention ponds can be constructed as depressional areas along road right-of-way, within recreational sites such as playgrounds or athletic fields, within natural depressional areas, in open land or as part of the landscaping for a commercial site, or as a shallow swale. Dual use of facilities provides a method for conserving valuable land resources while incorporating stormwater management systems into the on-site landscaping.

As the stormwater runoff percolates through the soil, migrating toward the underlying groundwater, a variety of physical, chemical, and biological processes occur which retain a majority of the stormwater pollutants in the upper layers of the soil within the retention basin (Harper, 1985; Harper, 1988). Previous research conducted by Harper (1985, 1988) has indicated that stormwater pollutants are trapped in relatively stable associations in the upper 4 inches of soil within retention basins. Concentrations of nutrients and heavy metals in groundwater beneath dry retention basins are typically lower in value than measured in stormwater runoff entering the retention system.

Even though dry retention systems prevent direct discharge of stormwater runoff to receiving waterbodies, care must be taken in the design of retention facilities to ensure that significant underground migration of pollutants does not occur to adjacent surface waters. A substantial quantity of pollutant loadings may still reach adjacent receiving waters when retention systems are constructed adjacent to the shoreline. Lateral distances between retention ponds and surface water should be maintained as large as possible, at least 100 ft or more, depending on the site conditions (FDEP, 1988).

The side slopes and bottoms of dry retention basins should be fully vegetated with sod cover. Vegetation plays a crucial role in the removal of contaminants from stormwater and in stabilization of the soil. Bahia grass is typically used for sod cover since it is drought resistant and can withstand periods of inundation.

In spite of the fact that on-line dry retention systems are used extensively throughout the State of Florida, relatively little research has been conducted to evaluate the pollutant removal effectiveness of these systems. Only two references were identified during the literature search on dry retention systems, both of which were conducted as part of the Orlando Areawide 208 Assessment during the late 1970s. A summary of the treatment efficiencies for dry retention systems, based on selected research studies in Florida, is given in Table 3-9. The first study, published in 1978 by the East Central Florida Regional Planning Council (ECFRPC) was conducted on a commercial watershed in Orlando. Removal efficiencies for the dry retention system reported in this study ranged from approximately 61% for total phosphorus to more than 90% for species of nitrogen. Information on the amount of retention storage available within this system was not presented as part of this study.

TABLE 3-9

TREATMENT EFFICIENCIES FOR DRY RETENTION SYSTEMS BASED ON SELECTED RESEARCH STUDIES IN FLORIDA

REFERENCE	STUDY SITE/ LAND USE	TYPE OF EFFICIENCIES REPORTED	MEAN REMOVAL EFFICIENCIES (%)							
			Total N	Ortho-P	Total P	TSS	BOD	Total Cu	Total Pb	Total Zn
ECFRPC (1978)	Orlando/ Commercial	Surface Water	91	–	61	85	92	--	--	–
Wanielista (1978)	Orlando/ Urban	Calculated								
		a. 0.25" ret.	80	80	80	80	80	80	80	80
		b. 0.50" ret.	90	90	90	90	90	90	90	90
		c. 0.75" ret.	95	95	95	95	95	95	95	95
		d. 1.00" ret.	99	99	99	99	99	99	99	99
		e. 1.25" ret.	99.9	99.9	99.9	99.9	99.9	99.9	99.9	99.9

The second study, conducted by Wanielista (1978), was also part of the Orlando Areawide 208 Assessment. This study presented estimated removal efficiencies for dry retention systems based upon simulations of yearly rainfall/runoff events. Removal efficiencies are presented as a function of retention volume, with increasing removal efficiencies associated with increasing runoff volumes retained. This simulation assumes that the watershed exhibits a significant first-flush effect, and that the retention pond drains completely between rain events so that the design retention volume is available for the next storm event. Removal efficiencies of approximately 80% are associated with retention of 0.25 inches of runoff, 90% for 0.5 inches of runoff, and 95% for a retention volume of 0.75 inches of runoff. Even though these removal estimates were only calculated and are not based upon actual field measurements, these values are used extensively throughout the State of Florida.

It is obvious that removal efficiencies achieved in retention systems are regulated primarily by the amount of runoff volume retained. In general, the annual pollutant removal effectiveness of a retention system should increase as the retention volume increases. Since dry retention systems do not always recover the entire pollution abatement volume before the next storm event, the actual observed pollutant removal efficiencies for dry retention systems are less than the values presented by Wanielista. In addition, these values represent a first-flush effect which concentrates much of the pollutants in the initial portion of the runoff volume. In many cases, first-flush effects do not occur and, therefore, removal efficiencies will not be lower than reported by Wanielista.

As development intensity increases, so does the volume of runoff from a given storm event. For example, a 1-inch storm event on a rural residential development may produce 0.2 inches of runoff while the same storm event at a commercial site may produce 0.6 inches of runoff. To achieve similar pollutant removal efficiencies, a larger retention treatment volume would be required for the commercial site than the rural residential site. Therefore, the treatment volume alone cannot be directly correlated to the pollutant removal efficiency. Instead, the required treatment volume and achievable pollutant removal efficiencies will be directly related to the development intensity and the specific treatment volume. With dry retention treatment systems, the mass pollutant removal efficiencies are directly related to the volume of runoff retained as a percent of the total runoff volume produced.

3.2.1.2 Wet Detention Systems

Wet detention systems are currently a very popular stormwater management technique throughout the State of Florida, particularly in areas with high groundwater tables. A wet detention pond is simply a modified detention facility which is designed to include a permanent pool of water with a depth of approximately 6-12 ft. These permanently wet ponds are designed to slowly release collected runoff through an outlet structure. A schematic diagram of a wet detention system is given in Figure 3-13.

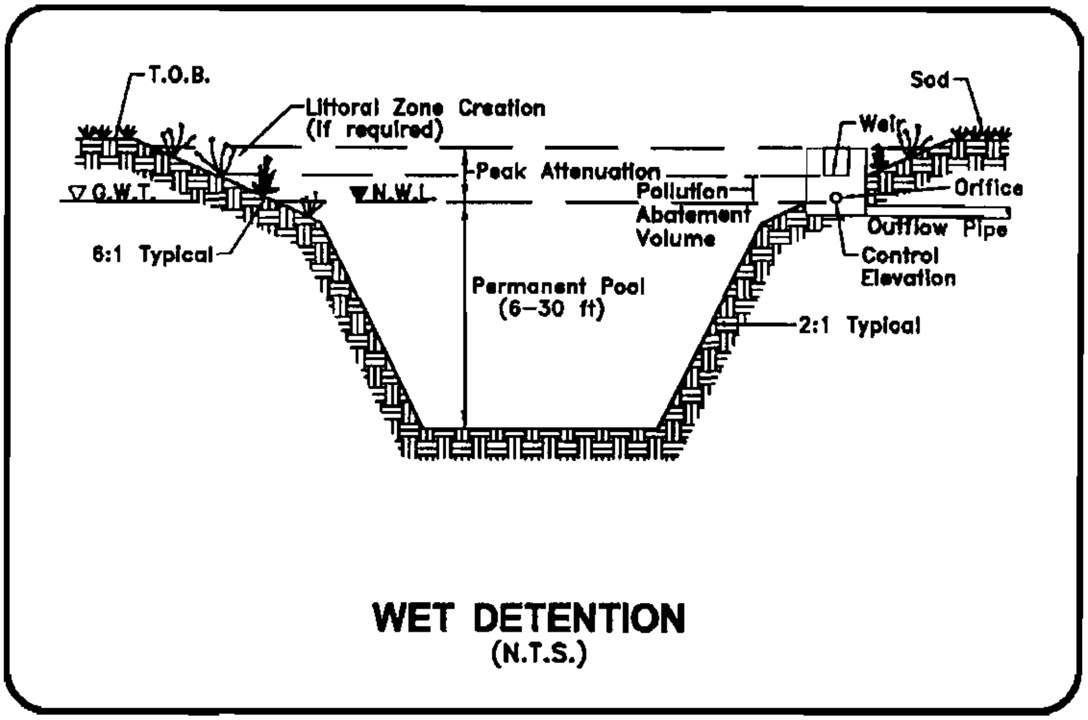


Figure 3-13. Schematic of a Wet Detention System.

Pollutant removal processes in wet detention systems occur through a variety of mechanisms, including physical processes such as sedimentation, chemical processes such as precipitation and adsorption, and biological uptake from algae, bacteria and rooted vegetation. In essence, these systems operate similar to a natural lake system.

The water level in a wet detention system is controlled by an orifice located in the outfall structure from the pond. A treatment volume is calculated for each facility based upon a specified depth of runoff over the contributing drainage basin area. Inputs of stormwater runoff equal to or less than the treatment volume exit the facility through an orifice in the outfall structure. Stormwater inputs into the facility in excess of the treatment volume can exit from the facility directly over a weir in the pond outfall structure. The weir is designed to provide attenuation for peak storm events so that the post-development rate of discharge from the facility does not exceed the pre-development rate of discharge for specified design storm events. A littoral zone may be planted around the perimeter of a wet detention facility to provide additional biological uptake and enhance biological communities. Current SWFWMD regulations require construction of littoral zones on 35% of the surface area of wet ponds.

Upon entering a wet detention facility, stormwater inputs mix rapidly with existing water contained in the permanent pool. Physical, chemical, and biological processes begin to rapidly remove pollutant inputs from the water column. Water which leaves through the orifice in the outfall structure is a combination of the mixture of partially treated stormwater and the water contained within the permanent pool. In general, the concentration of constituents in the permanent pool are typically much less than input concentrations in stormwater runoff, resulting in discharges from the facility which are substantially lower in concentration than found in raw stormwater. As a result, good removal efficiencies are achieved within a wet detention facility for most stormwater constituents. Although the littoral zone provides a small amount of enhanced biological uptake, previous research has indicated that a vast majority of removal processes occurring in wet detention facilities occur within the permanent pool volume rather than in the littoral zone vegetation for the treatment volume (Harper, 1985; Harper 1988; Harper and Herr, 1993).

Wet detention systems offer several advantages over some other stormwater management systems. First, wet detention systems provide relatively good removal of stormwater constituents since physical, chemical, and biological mechanisms are all available for pollutant attenuation. Other stormwater management facilities provide only one or two of these basic removal methods for stormwater. A second advantage of wet detention systems is that the systems are not complex and can be relatively easily maintained. Wet detention systems do not have underdrain systems which can become clogged and need periodic maintenance. Wet detention systems can also be used as amenities in development projects and as lakefront property if properly designed and constructed.

Of the stormwater facilities investigated during this evaluation, probably the most amount of research within the State of Florida has been conducted on wet detention systems. Unfortunately, much of the existing research was conducted on wet detention systems which were not constructed to current design standards regarding mean detention time and pond configuration and depth. The majority of the available studies did not present information regarding the treatment volume or residence time within the system.

A summary of treatment efficiencies for wet detention systems based on selected research studies in Florida is given in Table 3-10. Measured removal efficiencies for orthophosphorus, total phosphorus, TSS, and heavy metals are relatively consistent between the studies presented in the table. In contrast, a high degree of variability in measured removal efficiencies is present for total nitrogen. Removal efficiencies for total nitrogen range from 12-44% for the studies presented in Table 3-10. Wet detention systems provide mean removal efficiencies of approximately 60-65% for total phosphorus, BOD, and copper. Removal efficiencies for orthophosphorus, TSS, lead, and zinc approach or exceed 75%.

TABLE 3-10

TREATMENT EFFICIENCIES FOR WET DETENTION SYSTEMS BASED ON SELECTED RESEARCH STUDIES IN FLORIDA

REFERENCE	STUDY SITE/ LANDUSE	TYPE OF EFFICIENCY REPORTED	[illegible] OVAL EFFICIENCIES (%)							
			[illegible]	[illegible]	[illegible]	TSS	BOD	Total Cu	Total Pb	Total Zn
PBS&J (1982)	Brevard County/ Commercial	Surface Water	--	--	69	94	--	--	96	--
Cullum (1984)	Boca Raton/ Residential	Surface Water Overall	12 15	93 82	55 60	68 64	-- --	-- --	-- --	-- --
Yousef, et al. (1986)	Maitland/ Highway	Surface Water	35	94	81	--	--	56	88	92
Yousef, et al. (1986)	EPCOT/ Highway	Surface Water	44	92	62	--	--	0	0	88
Martin & Miller (1987)	Orlando/ Urban	Surface Water	--	57	38	66	--	--	40	--
Harper (1988)	Orlando/ Residential	Surface Water	--	--	91	82	90	90	90	96
Harper & Herr (1993)	DeBary/ Commercial & Residential	Overall a. t_d=7 days b. t_d=14 days	 20 30	 40 60	 60 70	 85 85	 50 60	 40 50	 60 85	 85 95
Ruston & Dye (1993)	Tampa/Light Commercial	Surface Water	--	67	65	55	--	--	--	51
MEAN VALUES			**26**	**73**	**65**	**75**	**67**	**59**	**77**	**85**

In many of the studies, the ability of the system to remove total nitrogen was heavily dependent upon the proportion of total nitrogen present as organic nitrogen. Organic nitrogen is not readily biologically or chemically available, and there are relatively few mechanisms for removal of this species in a wet detention system. In contrast, both NO_x and NH_3 are readily taken up in biological processes which accounts for the relatively good removal efficiencies achieved for these species in wet detention ponds. In systems where organic nitrogen represents the dominant portion of the total nitrogen in the incoming stormwater flow, removal of total nitrogen can be expected to be relatively poor. If inorganic species of NO_x and NH_3 represent the dominant nitrogen species found, then removal efficiencies for total nitrogen can be expected to increase. On an average basis, wet detention systems can be expected to provide a net removal of approximately 20-30% for total nitrogen; 60-70% for total phosphorus and copper; and 75% or more for TSS, total lead and total zinc.

The report by Harper and Herr (1993) presents separate removal efficiencies for pond residence times of approximately 7 days, along with detention times of 14 days or more. With the exception of TSS, increasing the pond detention time results in a slight improvement in removal efficiencies for the listed parameters. At a detention time of 7 days, removal of total nitrogen, total phosphorus and TSS is estimated to be approximately 20%, 50%, and 85%, respectively. At a detention time of 14 days, removal of total nitrogen, total phosphorus and TSS increase slightly to approximately 30%, 70%, and 85%, respectively. Little additional improvement in removal efficiencies has been observed for most parameters at detention times substantially in excess of 14 days.

Current research on wet detention systems clearly indicates that the performance efficiency for this type of stormwater management technique is primarily a function of residence time within the system. Residence time within the system is determined by the relationship between the permanent pool volume and the annual runoff inputs, as follows:

$$Detention\ \ Time,\ t_d\ (days)\ =\ \frac{PPV}{RO}\ x\ \frac{365\ days}{year}$$

where:

PPV	=	permanent pool volume (ac-aft)
RO	=	annual runoff inputs (ac-ft/yr)

For purposes of this calculation, the permanent pool volume is considered to include the total volume of water within the pond below the control elevation. The permanent pool volume is unrelated to the concept of treatment volume which is a common wet detention design criterion used to regulate drawdown of the runoff inputs.

Information regarding percent removal and residence time was extracted from each available study included in the literature review. Plots of removal efficiency as a function of residence time were then prepared for total nitrogen, total phosphorus, and TSS. A summary of these plots is given in Figures 3-14 through 3-16. For each of the evaluated constituents, best-fit equations are also provided for calculation of removal efficiency as a function of residence time within a given pond system. If the desired percent removal for a given constituent is known, the required residence time can be calculated using the best-fit equations provided on the respective figures. The removal efficiencies summarized in Figures 3-14 through 3-16 represent a combination of wet detention ponds both with and without vegetated littoral zones.

During the literature search, it became apparent that insufficient data is available to evaluate removal of BOD for wet detention systems based upon previous research. As a result, removal efficiencies for BOD were estimated based upon the theoretical degradation relationship for BOD as a function of time, according to the following equation:

$$BOD_t = BOD_o \quad x \quad \exp(-K \; x \; t)$$

where:

BOD_t	=	BOD at time, t (mg/l)
BOD_o	=	initial BOD (mg/l)
t	=	time (days)
K	=	decomposition constant

BOD decomposition rates range from a low of 0.1/day for surface waters to a high of 0.4/day for strong municipal wastewater. For purposes of this evaluation, a BOD decomposition constant of 0.1/day is assumed, which may impart a slight conservative bias to the evaluation.

A graphical representation of the removal of BOD as a function of time is given in Figure 3-17. This relationship can be used to estimate the time required to achieve a certain BOD removal efficiency within a wet detention pond. The analysis assumes that the pond is well mixed and maintains a minimum dissolved oxygen level of 2 mg/l throughout the water column at all times.

Although the theoretical relationship expressed in Figure 3-17 documents BOD removal efficiencies approaching 100%, the practical concentration limit for BOD within a wet detention pond is approximately 1-2 mg/l which reflects background conditions. Wet detention ponds are subjected to BOD loadings from algal respiration, waterfowl, and other sources, independent of runoff loadings, which create a continuous oxygen demand of approximately 1-2 mg/l at all times. Therefore, it is generally not possible to achieve BOD concentrations in a wet detention pond less than approximately 1-2 mg/l.

3.2.1.3 Dry Detention with Filtration Systems

Historically, dry detention with filtration facilities have been one of the most common stormwater management techniques used in Southwest Florida. These systems are commonly used in high groundwater table areas where the normal groundwater level would not allow the use of a retention type facility. Dry detention systems are normally dry stormwater basins which are designed to hold a specific quantity of stormwater runoff (treatment volume). Recovery of the design treatment volume occurs as a result of infiltration of the stormwater runoff through the pond bottom, with collection in an underdrain system constructed around the perimeter or bottom of the pond. A schematic diagram of a dry detention with filtration system is provided in Figure 3-18. The underdrain system is often used to control the existing groundwater table elevation in the vicinity of the pond and to improve the percolation rate of the on-site soils.

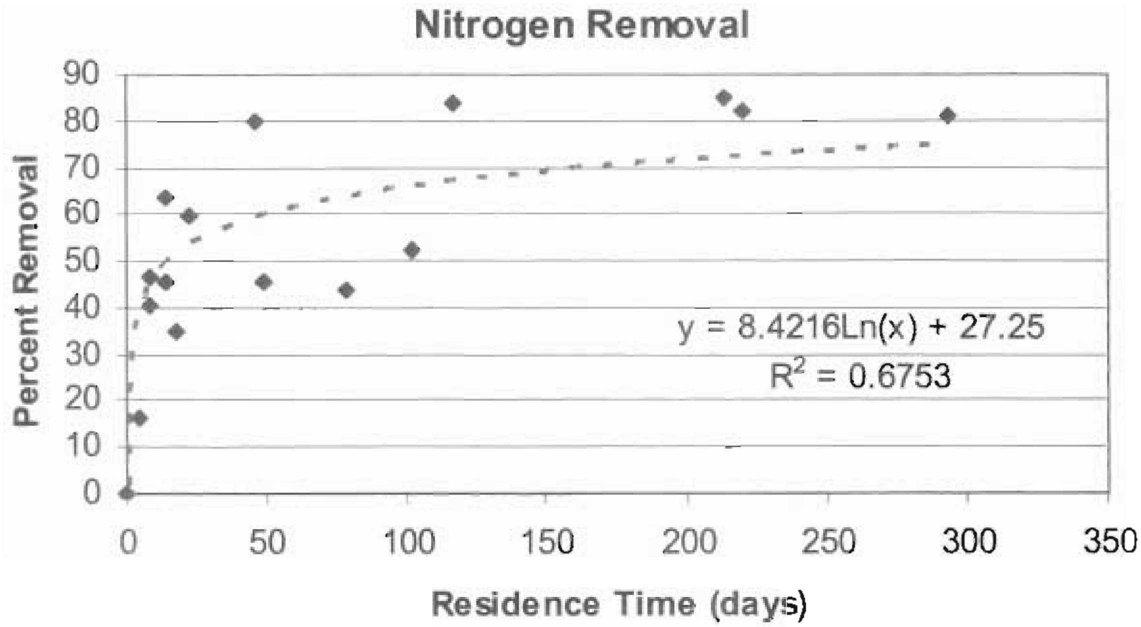


Figure 3-14. Removal of Total Nitrogen as a Function of Residence Time in a Wet Detention Pond.

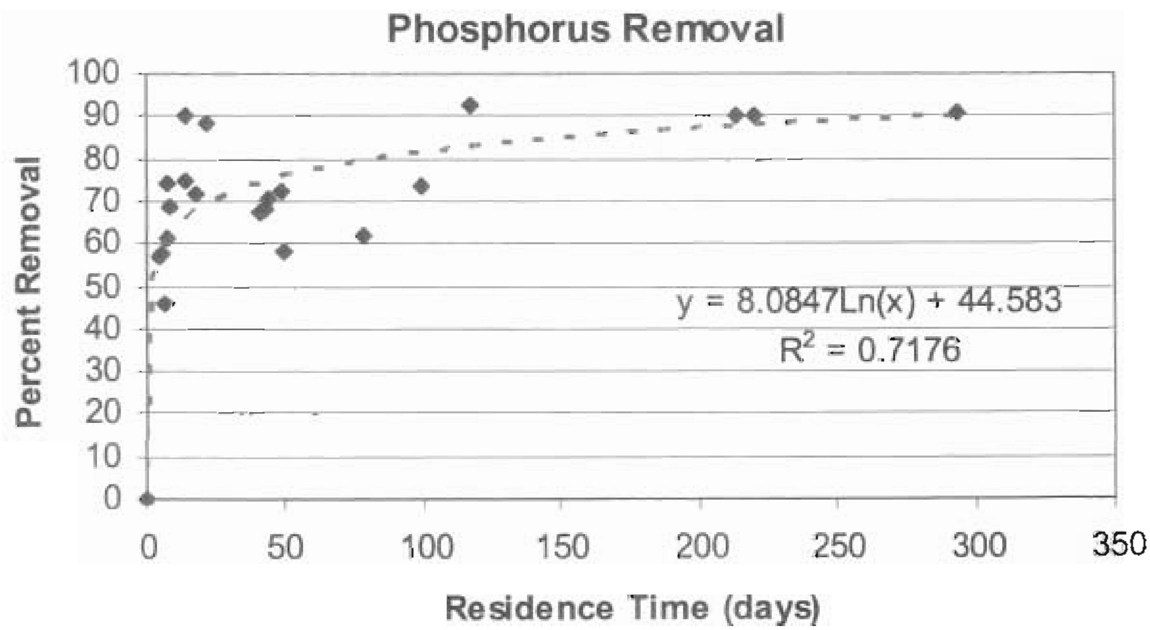


Figure 3-15. Removal of Total Phosphorus as a Function of Residence Time in a Wet Detention Pond.

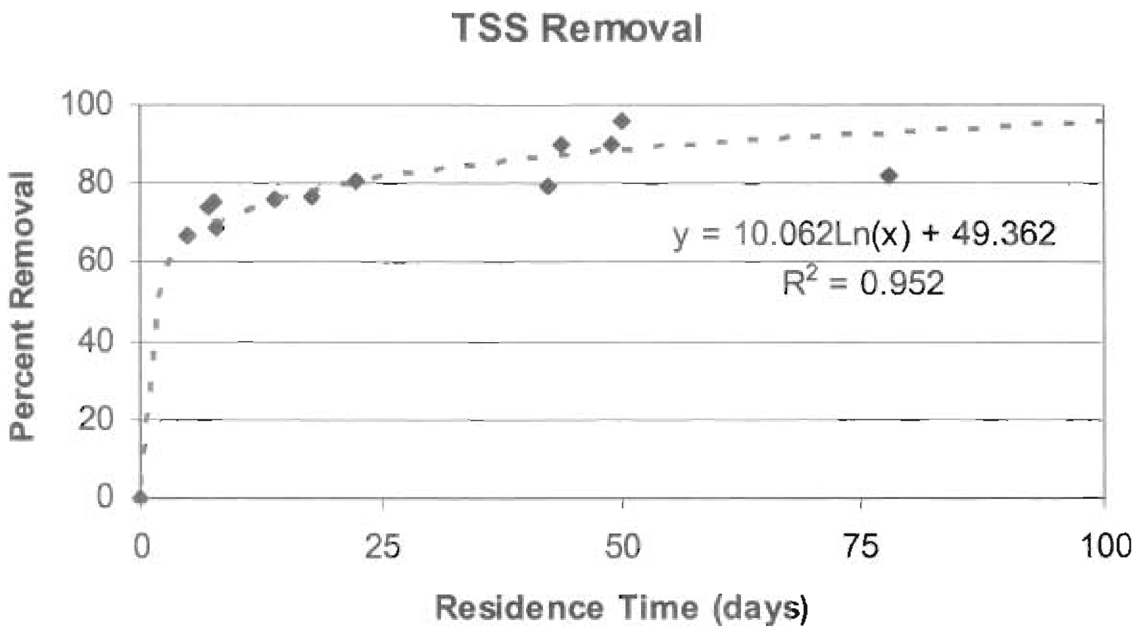


Figure 3-16. Removal of TSS as a Function of Residence Time in a Wet Detention Pond.

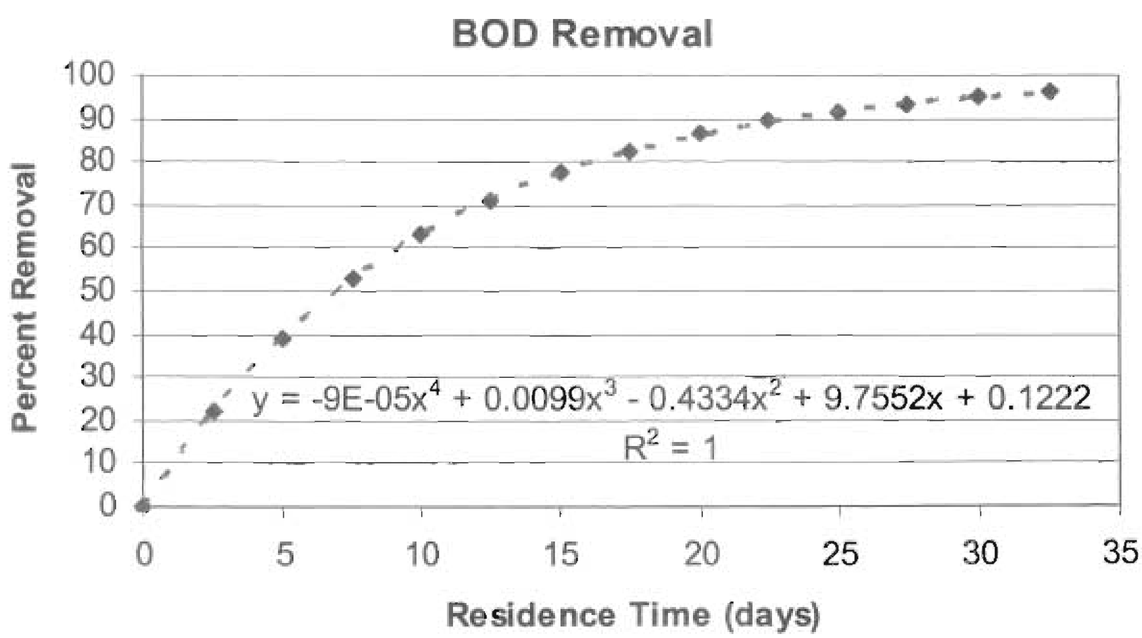


Figure 3-17. Removal of BOD as a Function of Residence Time in a Wet Detention Pond.

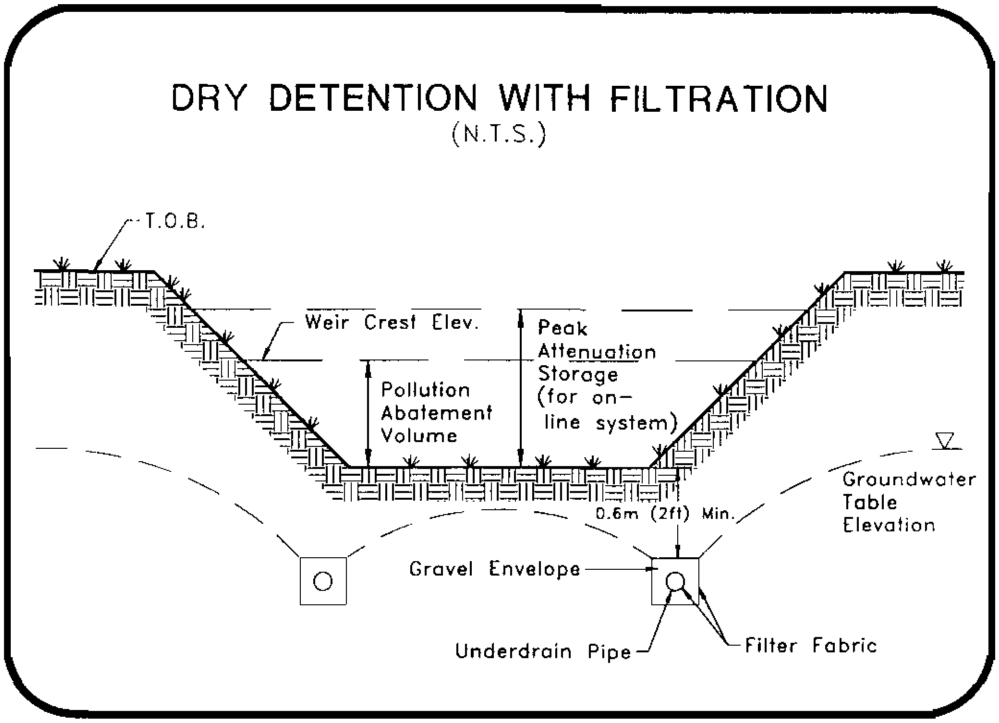


Figure 3-18. Schematic of a Dry Detention with Filtration System.

Physical processes such as sedimentation, and chemical processes such as precipitation and adsorption, are the primary mechanisms responsible for pollutant removal in dry detention with filtration systems. Stormwater inputs into these systems are typically evacuated within 24-72 hours, and as a result, biological processes such as uptake of nutrients or other ions by plant surfaces and roots, are severely limited and do not play a significant role in the removal of stormwater pollutants. Removal of particulate pollutants by sedimentation within the pond, as well as entrapment of particles within the soils during migration toward the underdrain system, are the primary physical removal processes in dry detention with filtration systems. These systems have an extremely limited ability to remove dissolved constituents which are best removed through biological processes.

Many dry detention with filtration systems are constructed in a manner which requires the stormwater to migrate through on-site soil prior to entering the underdrain system. This design technique probably enhances the removal efficiencies achieved by these systems due to the natural adsorption capacity of soils. However, the ability of filter systems to remove dissolved constituents is severely limited (Harper and Herr, 1993).

As seen in Figure 3-18, dry detention with filtration facilities are sometimes constructed to intercept and control the existing groundwater elevations in the vicinity of the basin. This results in a continuous influx of on-site groundwater into the underdrain system, resulting in a continuous flow from the system which is unrelated to rain events. This continuous flow of groundwater may actually create a situation where more mass leaves the stormwater facility on an annual basis than enters the system through stormwater runoff.

It is possible for dry detention with filtration systems to provide good removal efficiencies for total nitrogen, total phosphorus, TSS, and BOD. This can be accomplished by ensuring that the seasonal high groundwater table is one or more feet below the proposed pond bottom and underdrain elevation. The separation between pond bottom and seasonal high groundwater table elevation allows the pond to function as a dry retention pond system for some rain events. One-hundred percent removal is achieved for all runoff infiltrated through the pond bottom. Pollutant removal efficiencies for dry detention systems can also be improved by removing the underdrain filter system, and replacing the filter system with a drawdown V-notch or orifice similar to a wet detention system.

As previously discussed, the pollutant removal effectiveness of dry detention with filtration systems are largely affected by the elevation of the underdrain system and pond bottom in relation to the seasonal high groundwater table. This is evident by the treatment efficiencies for the dry detention with filtration systems based on selected research studies performed in Florida provided in Table 3-11. The first entry in Table 3-11 provides information on research conducted by ERD at the Publix shopping center dry detention with filtration pond in Bradfordville, FL. Overall mass removal efficiencies greater than 80% were achieved for total nitrogen, total phosphorus, TSS, and

BOD. These high mass removal efficiencies were a result of 66% of the runoff inputs infiltrating through the pond bottom. Only 34% of the runoff which entered the pond discharged through the underdrain system or the overflow structure. This pond functioned much differently than typical dry detention with filtration systems during the evaluation period.

TABLE 3-11

TREATMENT EFFICIENCIES FOR DRY DETENTION WITH FILTRATION SYSTEMS BASED ON SELECTED RESEARCH STUDIES IN FLORIDA

REFERENCE	STUDY SITE/ LAND USE	TYPE OF EFFICIENCIES REPORTED	MEAN REMOVAL EFFICIENCIES (%)							
			Total N	Ortho-P	Total P	TSS	BOD	Total Cu	Total Pb	Total Zn
Bradfordville Study[1]	Leon County/ Commercial	Overall	80	--	92	98	93	--	--	--
Harper & Herr[2] (1995)	Orange County/ Commercial & Residential	Overall	-136	-229	-86	77	-49	68	93	25
MEAN VALUES			-28	--	3	88	22	--	--	--

1. 66% of runoff infiltrated through pond bottom
2. Underdrain installed below surface groundwater elevation

Conversely, the second entry in Table 3-11 is for a study conducted on a dry detention with filtration pond in Orange County, FL. The underdrain for this pond was constructed several feet below the seasonal high groundwater table elevation surrounding the pond. For this reason, groundwater continually flowed from the surrounding area into the underdrain system and directly into the adjacent receiving waterbody. The excess groundwater discharge resulted in a net export of total nitrogen, orthophosphorus, total phosphorus, and BOD for this treatment facility.

Maximum removal efficiencies for this type of system could be achieved using a design which incorporates infiltration through the pond bottom and forces the remaining inputs into the underdrain system to pass through the filter media, while maintaining an underdrain elevation at least 1 ft above the seasonal high groundwater table. This system would utilize infiltration and filtration as the primary removal mechanisms.

3.2.1.4 Comparison of Treatment Efficiencies for Typical Stormwater Management Systems

A comparison of treatment efficiencies for typical stormwater management systems used in Southwest Florida is given in Table 3-12 based upon information provided in the literature review. Comparative removal efficiencies are provided for dry retention, wet detention, and dry detention with filtration. For the purposes of the evaluation, retention is considered any method of infiltrating water into the ground, including ponds, stormwater reuse, source reduction, swales, or the use of exfiltration trenches.

TABLE 3-12

ESTIMATED POLLUTANT REMOVAL EFFICIENCIES FOR COMMON LEON COUNTY STORMWATER TREATMENT FACILITIES

TYPE OF SYSTEM	ESTIMATED REMOVAL EFFICIENCIES (%)			
	Total N	Total P	TSS	BOD
Retention, Reuse, Source Reduction, Swales	100% for Retained Volume			
Wet Detention a. 7-day detention time b. 14-day detention time	 20 30	 60 70	 85 85	 50 60
Dry Detention with Filtration	0-35	0-40	90	0-50

Of the three basic stormwater treatment systems, retention provides the highest level of treatment possible. All stormwater runoff retained or infiltrated into the ground has a 100% mass pollutant removal efficiency for the retained volume. This is the best possible stormwater treatment system to use in terms of pollutant removal efficiency. Mass removal efficiencies for wet detention have been divided into 7-day and 14-day detention times. Mass removal efficiencies are 20-30% for total nitrogen, 60-70% for total phosphorus, 85% for TSS, and 50-60% for BOD. Dry detention with filtration systems provide similar removal efficiencies to wet detention. Estimated mass removal efficiencies for dry detention with filtration systems are 0-35% for total nitrogen, 0-40% for total phosphorus, 90% for TSS, and 0-50% for BOD, based upon the position of the underdrain with respect to the groundwater table.

An evaluation of nonpoint source loadings from the Lemon Bay watershed to Lemon Bay is provided in Section 5. For this analysis, it is assumed that future development will be equipped with stormwater management facilities which will attenuate portions of the nonpoint source loadings prior to discharge into the primary conveyance systems. Since most of the watershed areas exhibit elevated water table conditions, wet detention ponds appear to be the most likely type of stormwater management system in future development. For purposes of this analysis, it is assumed that future development will be equipped with wet detention ponds which will provide a 7-day detention time and will achieve removal efficiencies of approximately 20% for total nitrogen, 60% for total phosphorus, 85% for TSS, and 50% for BOD.

SECTION 4

CHARACTERISTICS OF THE LEMON BAY WATERSHED

The Lemon Bay watershed encompasses an area of approximately 161 km^2 (39,773 ac), which includes areas in both Sarasota and Charlotte Counties. A total of seven significant tributaries discharge to Lemon Bay, including, from north to south, Alligator Creek, Woodmere Creek, Forked Creek, Gottfried Creek, Ainger Creek, Oyster Creek, and Buck Creek. In addition to these primary tributaries, there are a large number of sub-basins which discharge through stormsewers, ditches, or overland flow directly to Lemon Bay. Delineations of sub-basin areas discharging to Lemon Bay, utilized for purposes of this project, are given in Figure 4-1.

Information on land use in the Lemon Bay watershed was obtained from the SWFWMD Geographical Information System (GIS) database. The basin delineations indicated on Figure 4-1 were superimposed over the land use coverages so that land use characteristics could be extracted for each individual drainage basin. The land use coverages obtained from the SWFWMD GIS database reflect 1999 conditions within the watershed. For purposes of this project, the 1999 coverages are assumed to be "current" conditions within the Lemon Bay drainage basin. Although the Woodmere Creek basin was not specifically evaluated as part of this project, a general description of basin characteristics is also included for this basin.

Land use characteristics in the SWFWMD GIS database are provided in the form of Florida Land Use, Cover, and Forms Classification System (FLUCCS) code descriptions in a Level III classification system. Although valuable for planning purposes, the detail generated by a Level III classification scheme is beyond the level for which nonpoint source pollutant rate information is typically available. In general, prior research in the State of Florida has been performed on approximately 14 general land use categories, such as low-density residential, medium-density residential, high-density residential, low-intensity commercial, high-intensity

Figure 4-1. Contributing Watershed Areas to Lemon Bay.

commercial, industrial, highway/transportation, agriculture/pasture, agriculture/citrus, agriculture/row crops, general agriculture, open space/rangeland, mining/extractive, wetlands, and open water/lakes. Since the primary objective of this project is to develop estimates of nonpoint loadings to Lemon Bay, it is most useful to group the detailed land use categories together into general categories for which loading rate information is available.

Each of the Level III land use classifications provided for the Lemon Bay watershed was assigned to a general land use category based upon anticipated similarities in loading characteristics between land areas represented by the different FLUCCS codes and the general land use categories for which loading rate information is currently available. A summary of general land use categories and corresponding Level III classifications assigned to each general land use category is given in Table 4-1. The groupings summarized in Table 4-1 are used throughout the remainder of this report for evaluation of loadings from the Lemon Bay watershed under both current and future conditions.

Information on soil types within the Lemon Bay watershed was also obtained from the SWFWMD GIS database. Soil information was extracted in the form of Hydrologic Soil Groups (HSG) which groups soil types with respect to runoff producing characteristics. A summary of the characteristics of each hydrologic soil group is given in Table 4-2. The chief consideration in each of the soil group types is the inherent capacity of bare soil to permit infiltration. Soil characteristics within the Lemon Bay watershed were used in development of runoff estimates for the loading rate model.

TABLE 4-1

GENERAL LAND USE CATEGORIES AND CORRESPONDING LEVEL III CLASSIFICATIONS

LAND USE	FLUCCS CODE DESCRIPTION	FLUCCS CODE
Agriculture	Cropland and Pasture	210
Commercial	Commercial and Services Communications Utilities	140 820 830
Extractive	Extractive	160
Industrial	Industrial	150
Transportation	Transportation	810
Low-Density Residential	Residential Low-Density < 2 Dwelling Units/Acre	110
Medium-Density Residential	Residential Medium-Density 2->5 Dwelling Units/Acre	120
High-Density Residential	Residential High-Density	130
Institutional	Institutional	170
Recreational	Recreational	180
Open	Disturbed Land Hardwood Conifer Mixed Mixed Rangeland Open Land Other Open Lands (Rural) Pine Flatwoods Shrub and Brushland Upland and Coniferous Forest	740 434 330 190 260 411 320 410
Wetland	Bay Swamps Cypress Emergent Aquatic Vegetation Freshwater Marshes Mangrove Swamps Saltwater Marshes Stream and Lake Swamps (Bottomland) Wet Prairies Wetland Coniferous Forests Wetland Forested Mixed	611 621 644 641 612 642 615 643 620 630
Water	Bays and Estuaries Intermittent Ponds Lakes Reservoirs Streams and Waterways	540 653 520 530 510

TABLE 4-2

CHARACTERISTICS OF SCS HYDROLOGIC SOIL GROUP CLASSIFICATIONS

SOIL GROUP	DESCRIPTION	RUNOFF POTENTIAL	INFILTRATION RATE
A	Deep sandy soils	very low	high
B	Shallow sandy soils	low	moderate
C	Sandy soil with high clay or organic content	medium to high	low
D	Clayey soils	very high	low to none
W	Wetland or hydric soils	--	--
B / D	Shallow sandy soils	1. high in undeveloped condition 2. low in developed condition	1. low in undeveloped condition 2. moderate in developed condition

4.1 Existing Conditions

4.1.1 Alligator Creek

An overview of current land use in the Alligator Creek basin, based upon 1999 conditions, is given in Figure 4-2. The western portions of the Alligator Creek basin appear to be dominated by commercial and medium-density residential land uses. Northern and central portions of the basin appear to be dominated primarily by high-density residential and open land areas. Extreme southern portions of the Alligator Creek basin are dominated primarily by open land and water.

A tabular summary of current land use in the Alligator Creek basin is given in Table 4-3. Overall, the Alligator Creek basin occupies an area of 6787.3 acres. Approximately 26.3% of this area is covered with medium-density residential land use. High-density residential land use occupies approximately 25.9% of the basin area, with open space comprising approximately 14.6%. Each of the remaining land uses covers approximately 8% or less of the total basin area.

An overview of general hydrologic soil groups (HSG) in the Alligator Creek basin is given in Figure 4-3. The majority of the soils within the basin are classified in HSG B/D. This classification indicates drainage characteristics of "D" type soils under undeveloped conditions, with "B" type soil drainage characteristics under developed conditions. Hydrologic soil group

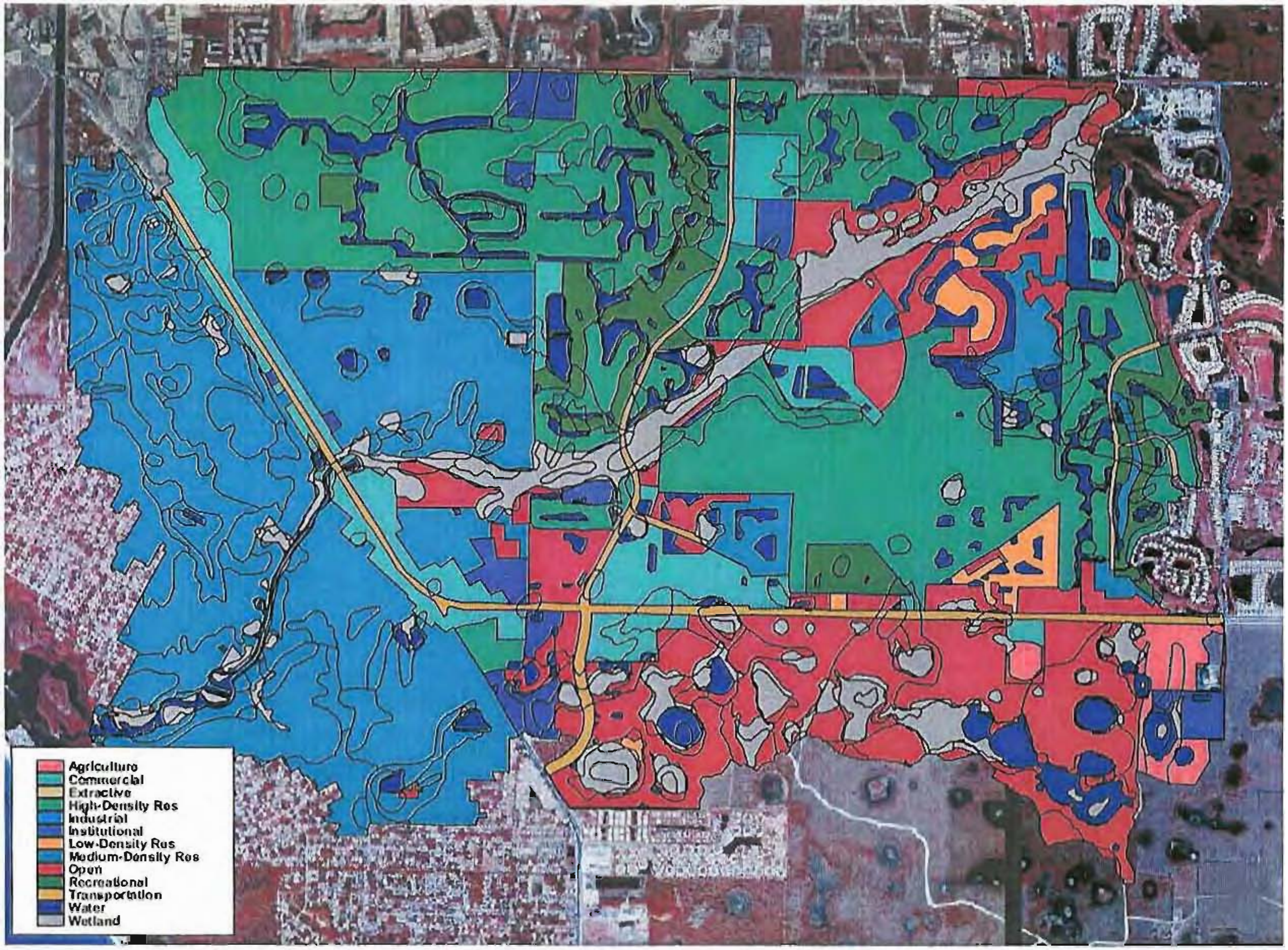


Figure 4-2. Current (1999) Land Use in the Alligator Creek Basin.

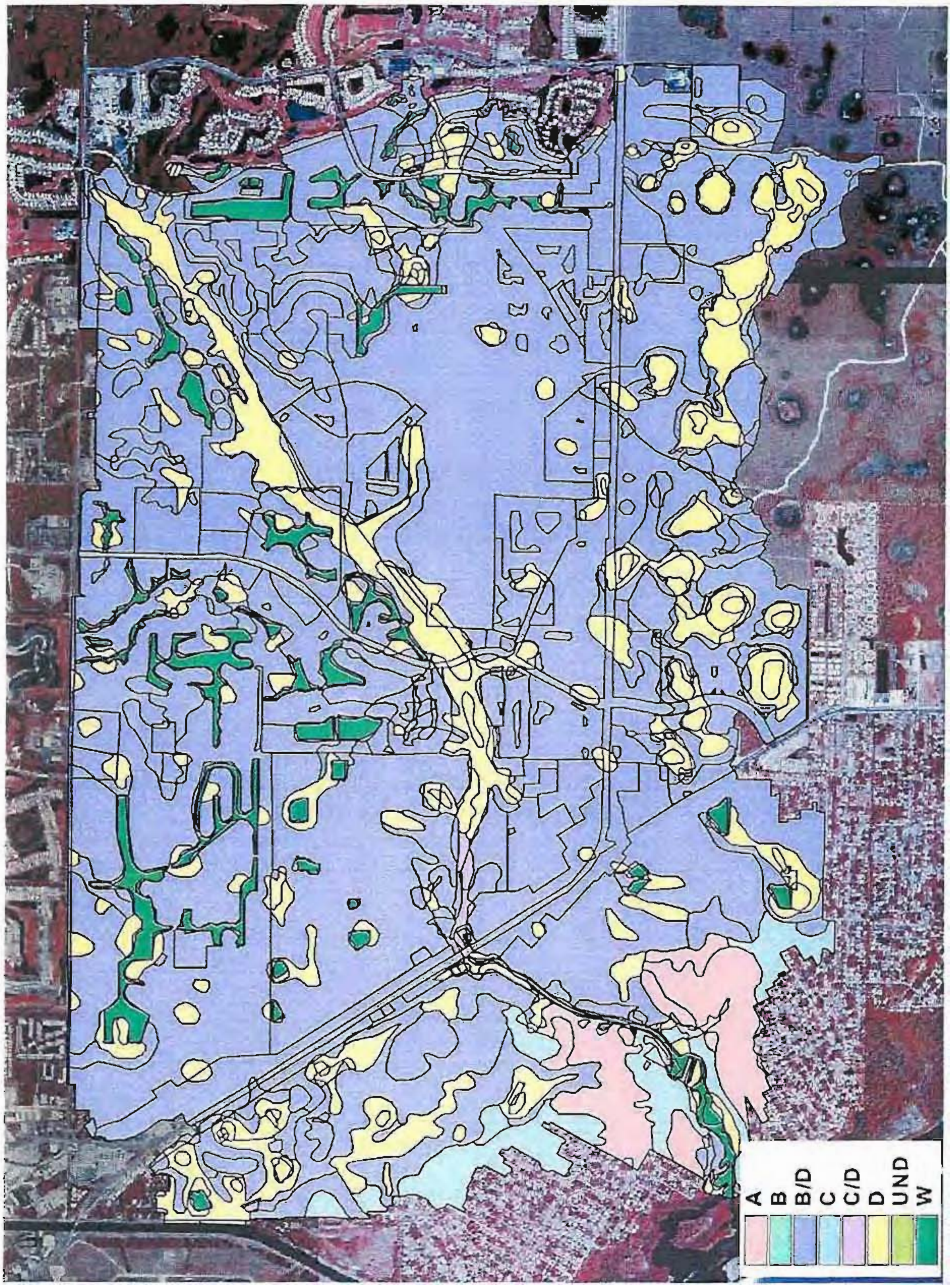


Figure 4-3. General Hydrologic Soil Groups in the Alligator Creek Basin.

"D" soils are also scattered throughout the basin area. Small areas with HSG "A" soils are also present in the southwestern portion of the basin. A tabular summary of hydrologic soil groups in the Alligator Creek basin is given in Table 4-4. Approximately 74% of the area is covered with "B/D" soils, with 15% covered by HSG "D" soils.

TABLE 4-3

SUMMARY OF LAND USE IN THE ALLIGATOR CREEK BASIN

LAND USE	TOTAL AREA (acres)	PERCENT OF TOTAL
Agriculture	70.7	1.0
Commercial	442.3	6.5
High-Density Residential	1758.7	25.9
Industrial	0.0	0.0
Institutional	147.3	2.2
Low-Density Residential	80.7	1.2
Medium-Density Residential	1787.6	26.3
Open	991.5	14.6
Recreational	256.2	3.8
Transportation	161.7	2.4
Water	576.4	8.5
Wetland	514.3	7.6
TOTAL:	**6787.3**	**100.0**

TABLE 4-4

SUMMARY OF HYDROLOGIC SOIL GROUPS IN THE ALLIGATOR CREEK BASIN

HYDROLOGIC SOIL GROUP	TOTAL AREA (acres)	PERCENT OF TOTAL
A	214.8	3.2
B/D	5021.8	74.0
C	196.8	2.9
C/D	13.0	0.2
D	1025.1	15.1
W	315.7	4.7
TOTAL:	**6787.3**	**100.0**

4.1.2 Woodmere Creek

An overview of current land use in the Woodmere Creek drainage basin, based upon 1999 conditions, is given in Figure 4-4. Extreme eastern portions of the basin appear to be covered primarily by open land and wetlands. Central portions of the basin are covered primarily with medium-density residential land use, interspersed with wetlands. Western portions of the Woodmere Creek basin appear to have a mixture of land uses which include open land, high-density residential, medium-density residential, and industrial land uses.

A tabular summary of current land use in the Woodmere Creek basin is given in Table 4-5. Medium-density residential is the largest existing land use category within the basin, occupying 51.9% of the overall basin area. The second most dominant land use is open land, covering 16.9% of the basin. High-density residential areas occupy approximately 14.1% of the basin, with 10.1% of the basin covered by wetlands. The remaining land uses occupy approximately 3% or less of the total basin area.

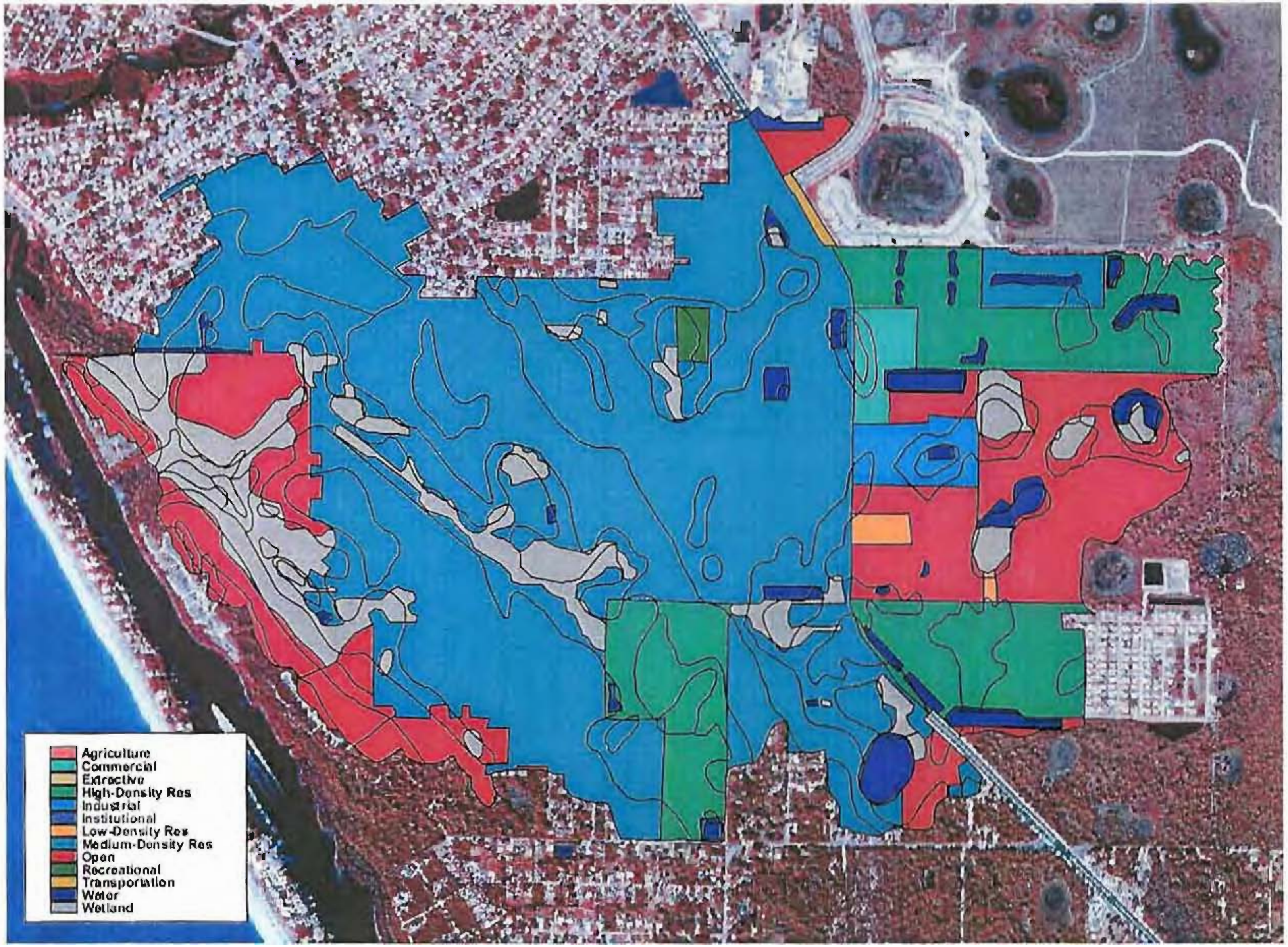


Figure 4-4. Current (1999) Land Use in the Woodmere Creek Basin.

TABLE 4-5

SUMMARY OF LAND USE IN THE WOODMERE CREEK BASIN

LAND USE	TOTAL AREA (acres)	PERCENT OF TOTAL
Commercial	16.3	1.1
High-Density Residential	208.3	14.1
Industrial	22.1	1.5
Institutional	2.2	0.1
Low-Density Residential	6.3	0.4
Medium-Density Residential	765.7	51.9
Open	248.9	16.9
Recreational	4.9	0.3
Transportation	2.3	0.2
Water	49.4	3.3
Wetland	149.0	10.1
TOTAL:	**1475.3**	**100.0**

An overview of general hydrologic soil groups in the Woodmere Creek basin is given in Figure 4-5. The majority of the basin is covered with B/D soils, intermixed with hydrologic group "C" and "D". A small pocket of HSG "A" soils is present in the northwest portion of the basin. A tabular summary of hydrologic soil groups in the Woodmere Creek basin is given in Table 4-6.

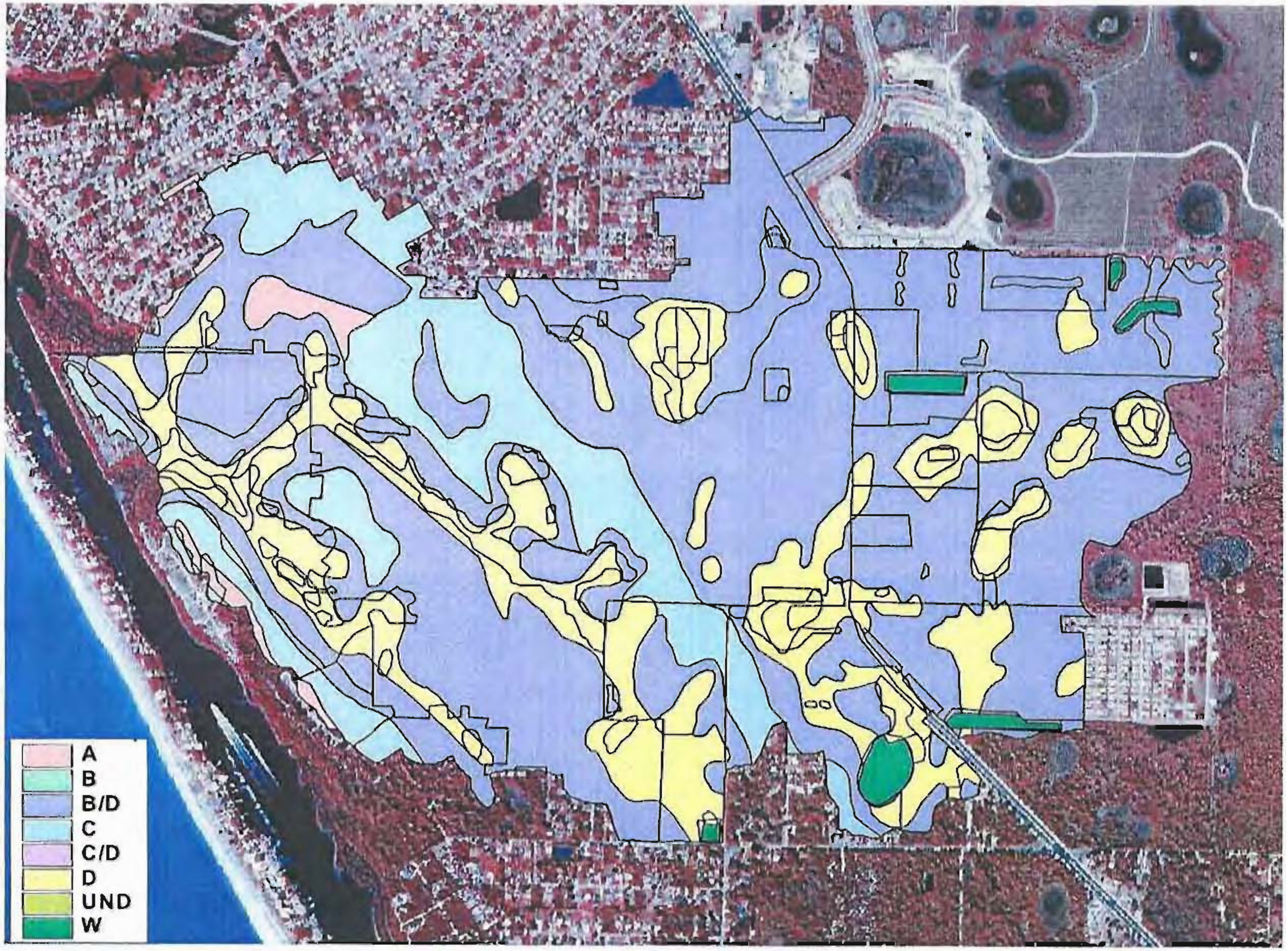


Figure 4-5. General Hydrologic Soil Groups in the Woodmere Creek Basin.

TABLE 4-6

SUMMARY OF HYDROLOGIC SOIL GROUPS IN THE WOODMERE CREEK BASIN

HYDROLOGIC SOIL GROUP	TOTAL AREA (acres)	PERCENT OF TOTAL
A	21.4	1.5
B/D	896.3	60.8
C	201.3	13.6
D	336.6	22.8
W	19.7	1.3
TOTAL:	**1475.3**	**100.0**

4.1.3 Forked Creek

An overview of current land use in the Forked Creek basin, based upon 1999 conditions, is given in Figure 4-6. The Forked Creek basin appears to contain a variety of land use types interspersed throughout the basin. Areas west of SR 776 contain numerous different land use types, including open land, medium-density residential, high-density residential, low-density residential, transportation, and open water. Similar land uses are present east of SR 776, although this area appears to be dominated primarily by agriculture and open land.

A tabular summary of current land use in the Forked Creek basin is given in Table 4-7. Open land is clearly the largest land use category in the Forked Creek basin, occupying approximately 34.8% of the total basin area. Agriculture occupies approximately 17.6% of the total basin area, with 15.3% covered by wetlands and 11.5% covered by medium-density residential. Remaining land uses within the basin occupy approximately 6% or less of the total basin area.

An overview of general hydrologic soil groups in the Forked Creek basin is given in Figure 4-7. The majority of the soils in the Forked Creek basin are in the "B/D" soil group, which is interspersed with HSG "D", "C", and a small area in HSG "A". A tabular summary of hydrologic soil groups in the Forked Creek basin is given in Table 4-8. Approximately 66.7% of the basin area is covered with HSG "B/D" soils, with 21.6% covered by HSG "D".

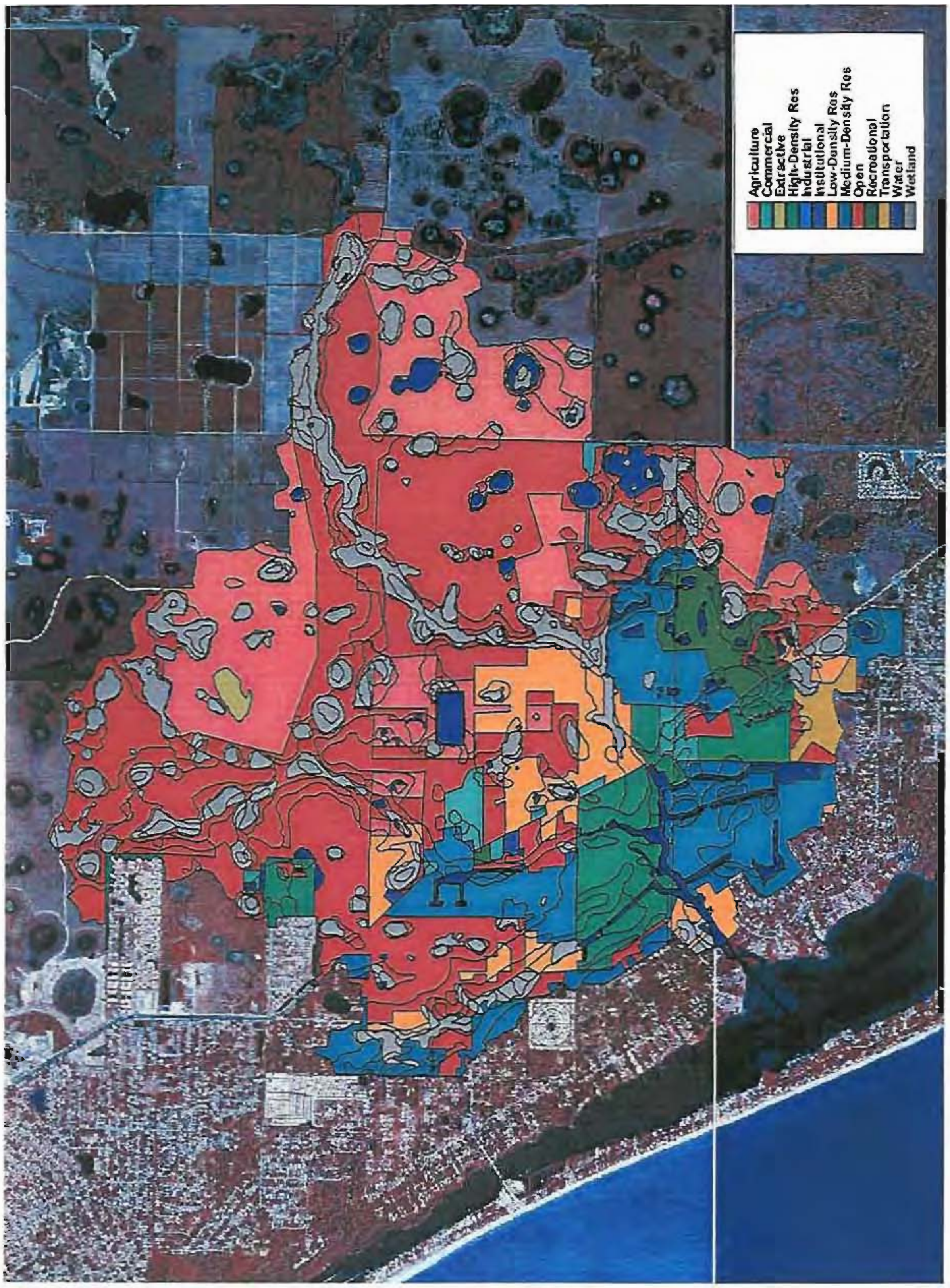


Figure 4-6. Current (1999) Land Use in the Forked Creek Basin.

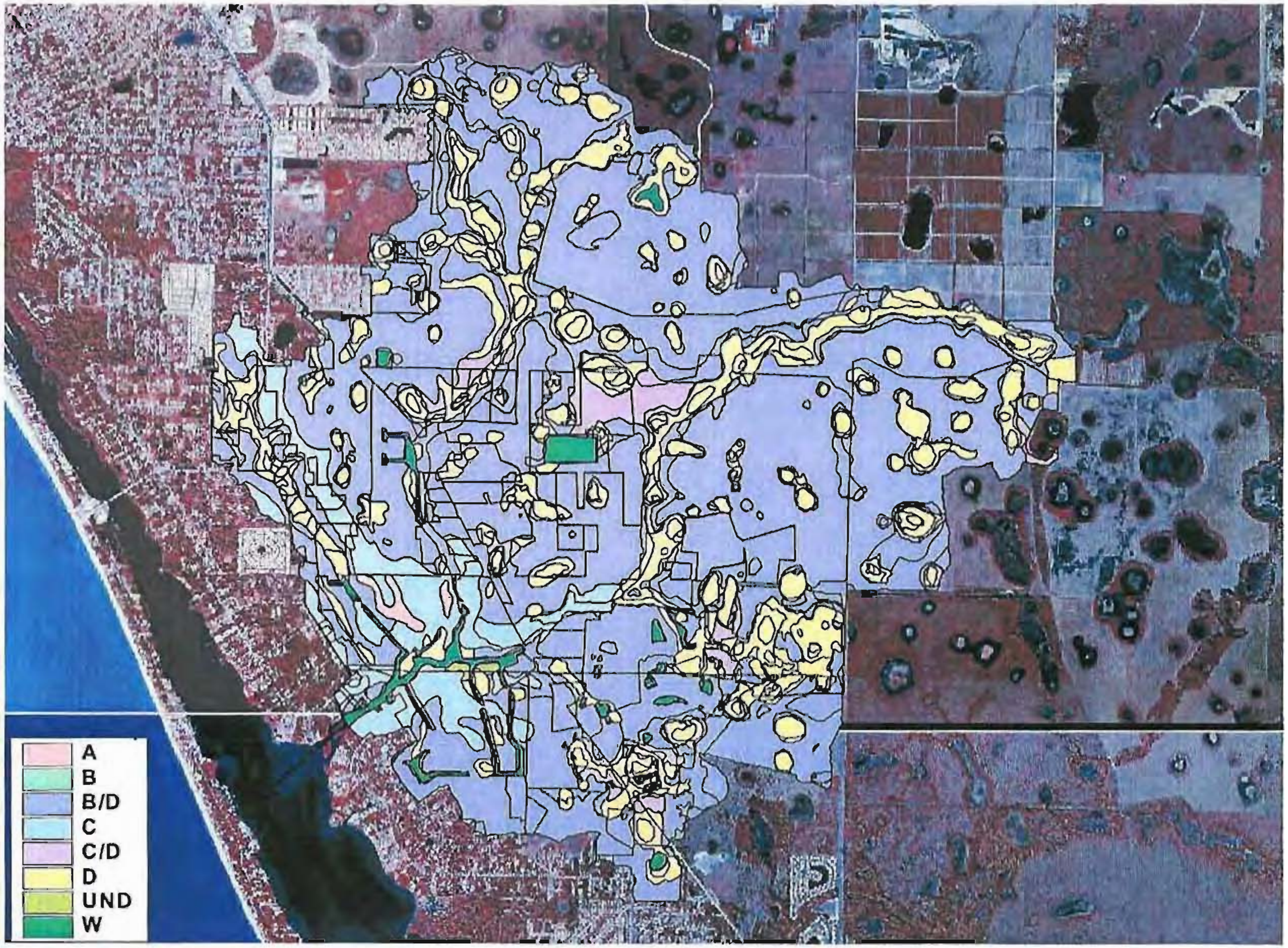


Figure 4-7. General Hydrologic Soil Groups in the Forked Creek Basin.

TABLE 4-7

SUMMARY OF LAND USE IN THE FORKED CREEK BASIN

LAND USE	TOTAL AREA (acres)	PERCENT OF TOTAL
Agriculture	1033.7	17.6
Commercial	83.7	1.4
Extractive	16.4	0.3
High-Density Residential	354.6	6.1
Institutional	7.0	0.1
Low-Density Residential	345.1	5.9
Medium-Density Residential	676.6	11.5
Open	2037.3	34.8
Recreational	113.9	1.9
Transportation	45.6	0.8
Water	250.6	4.3
Wetland	895.4	15.3
TOTAL:	**5860.0**	**100.0**

TABLE 4-8

SUMMARY OF HYDROLOGIC SOIL GROUPS IN THE FORKED CREEK BASIN

HYDROLOGIC SOIL GROUP	TOTAL AREA (acres)	PERCENT OF TOTAL
A	21.3	0.4
B/D	3907.5	66.7
C	379.0	6.5
C/D	154.3	2.6
D	1266.9	21.6
UND	6.5	0.1
W	124.5	2.1
TOTAL:	**5860.0**	**100.0**

4.1.4 Gottfried Creek

A general overview of land use in the Gottfried Creek basin, based upon 1999 conditions, is given in Figure 4-8. Areas of the Gottfried Creek basin west of SR 776 are covered primarily by medium-density residential, commercial, and open land uses. Areas west of SR 776 appear to be dominated primarily by agricultural and open land uses, interspersed with recreational areas and wetlands.

A tabular summary of current land use in the Gottfried Creek basin is given in Table 4-9. Open area appears to be the dominant land use within the basin, covering 48.9% of the total area. Wetlands cover approximately 13.1% of the Gottfried Creek basin, with medium-density residential areas occupying approximately 11.0%. Remaining land uses within the basin cover approximately 7% or less of the total basin area.

TABLE 4-9

SUMMARY OF LAND USE IN THE GOTTFRIED CREEK BASIN

LAND USE	TOTAL AREA (acres)	PERCENT OF TOTAL
Agriculture	529.8	7.3
Commercial	268.1	3.7
High-Density Residential	271.5	3.7
Institutional	54.3	0.7
Low-Density Residential	289.5	4.0
Medium-Density Residential	799.7	11.0
Open	3554.2	48.9
Recreational	184.0	2.5
Transportation	5.7	0.1
Water	365.2	5.0
Wetland	950.1	13.1
TOTAL:	**7272.4**	**100.0**

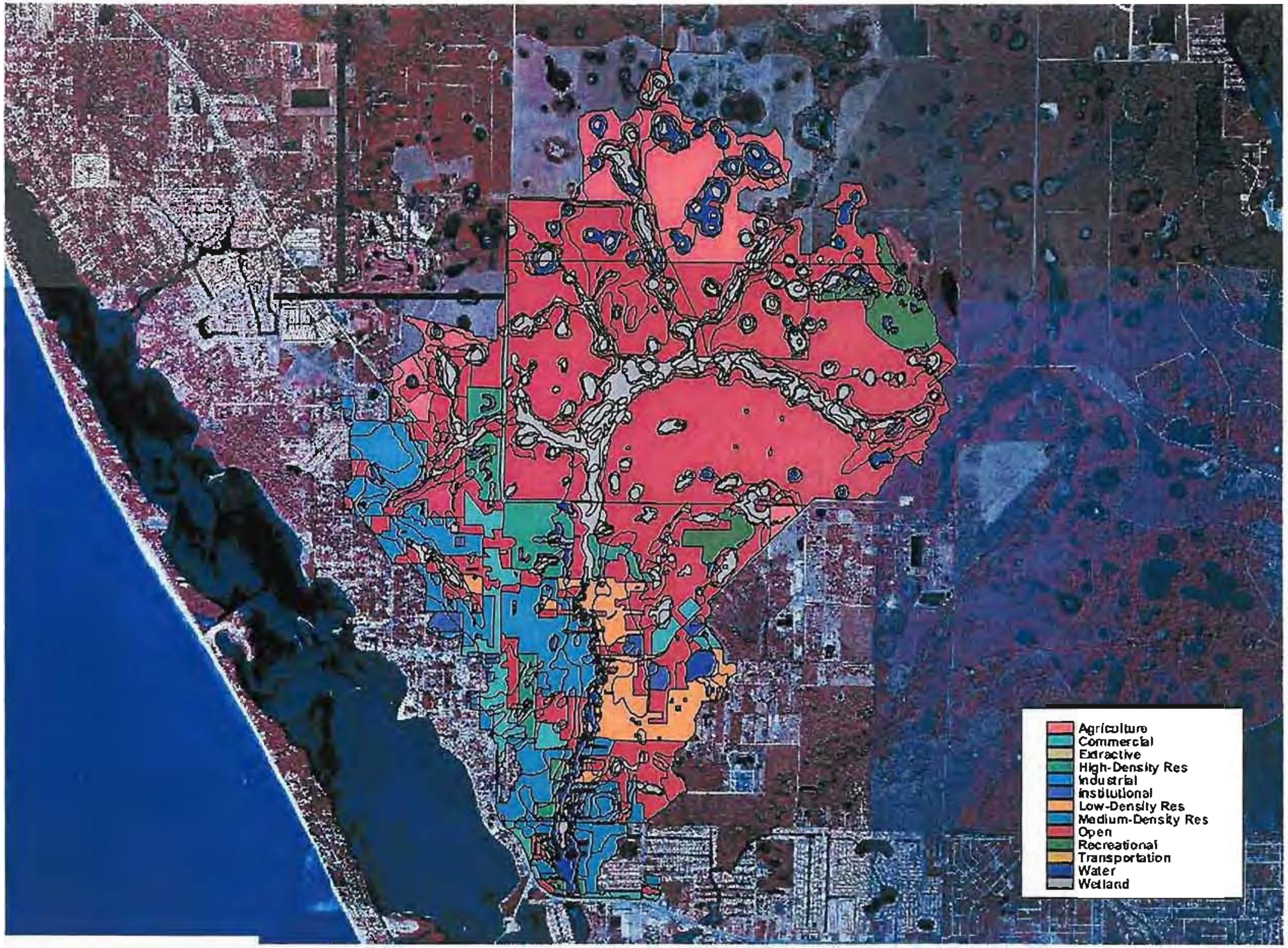


Figure 4-8. Current (1999) Land Use in the Gotfried Creek Basin.

An overview of hydrologic soil groups in the Gottfried Creek basin is given in Figure 4-9. The dominant hydrologic soil group within the basin appears to be "B/D" soils which cover the vast majority of the basin area. These soils are interspersed by HSG "D" soils, with small areas of "C/D" soils. Several isolated pockets of HSG "A" soils are present in southern portions of the basin. A tabular summary of hydrologic soil groups in the Gottfried Creek basin is given in Table 4-10.

TABLE 4-10

SUMMARY OF HYDROLOGIC SOIL GROUPS IN THE GOTTFRIED CREEK BASIN

HYDROLOGIC SOIL GROUP	TOTAL AREA (acres)	PERCENT OF TOTAL
A	188.3	2.5
B/D	4751.2	65.3
C	519.5	7.1
C/D	311.5	4.3
D	1362.6	18.7
W	144.3	2.0
TOTAL:	**7272.4**	**100.0**

4.1.5 <u>Ainger Creek</u>

An overview of current land use in the Ainger Creek basin, based upon 1999 conditions, is given in Figure 4-10. Southern portions of the basin appear to be dominated by a variety of land use types, including medium-density residential, low-density residential, high-density residential, open areas, and water. Central and northern portions of the Ainger Creek basin appear to be dominated primarily by open land, agriculture, and low-density residential, interspersed with wetlands and open water.

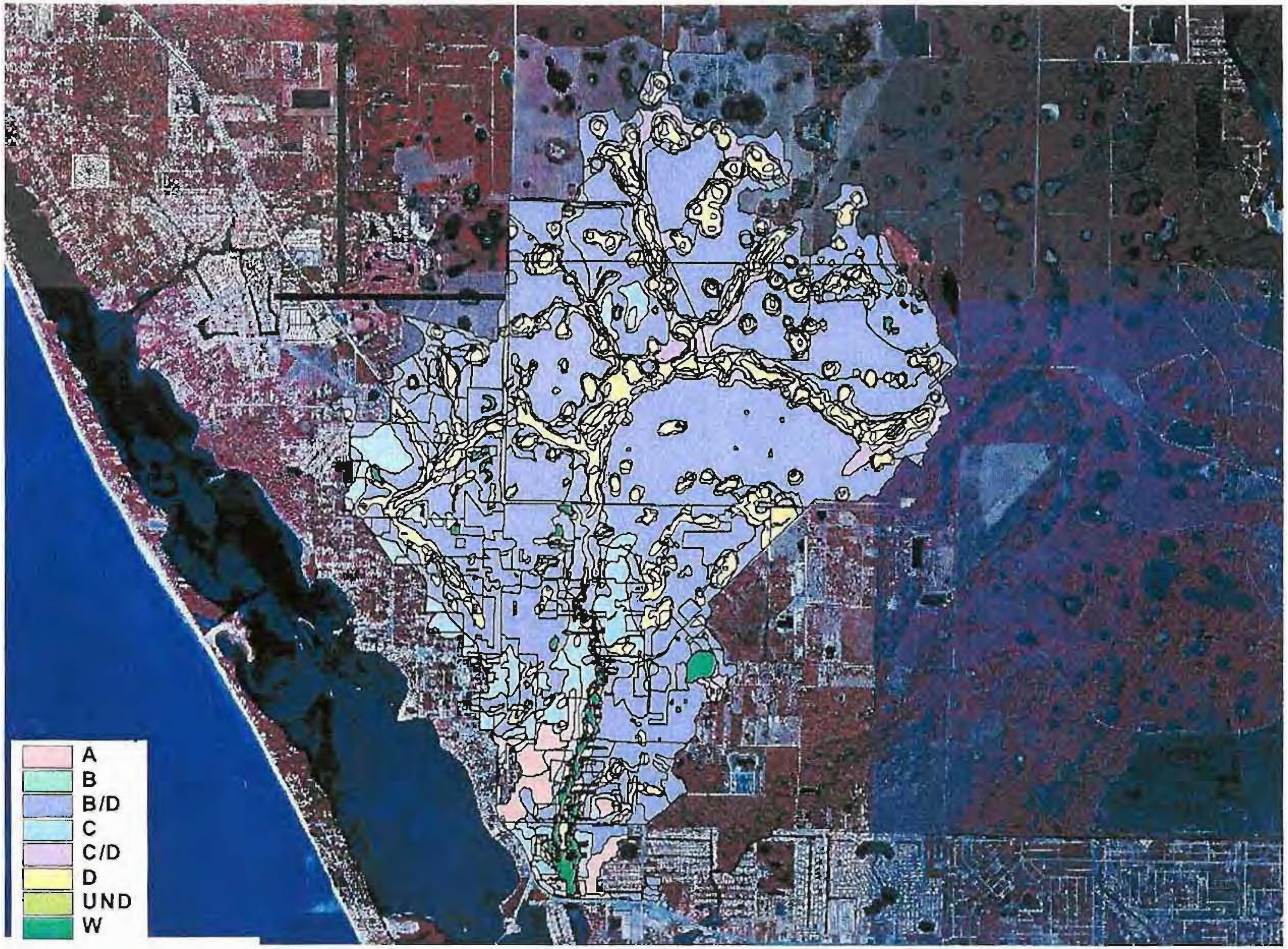


Figure 4-9. General Hydrologic Soil Groups in the Gottfried Creek Basin.

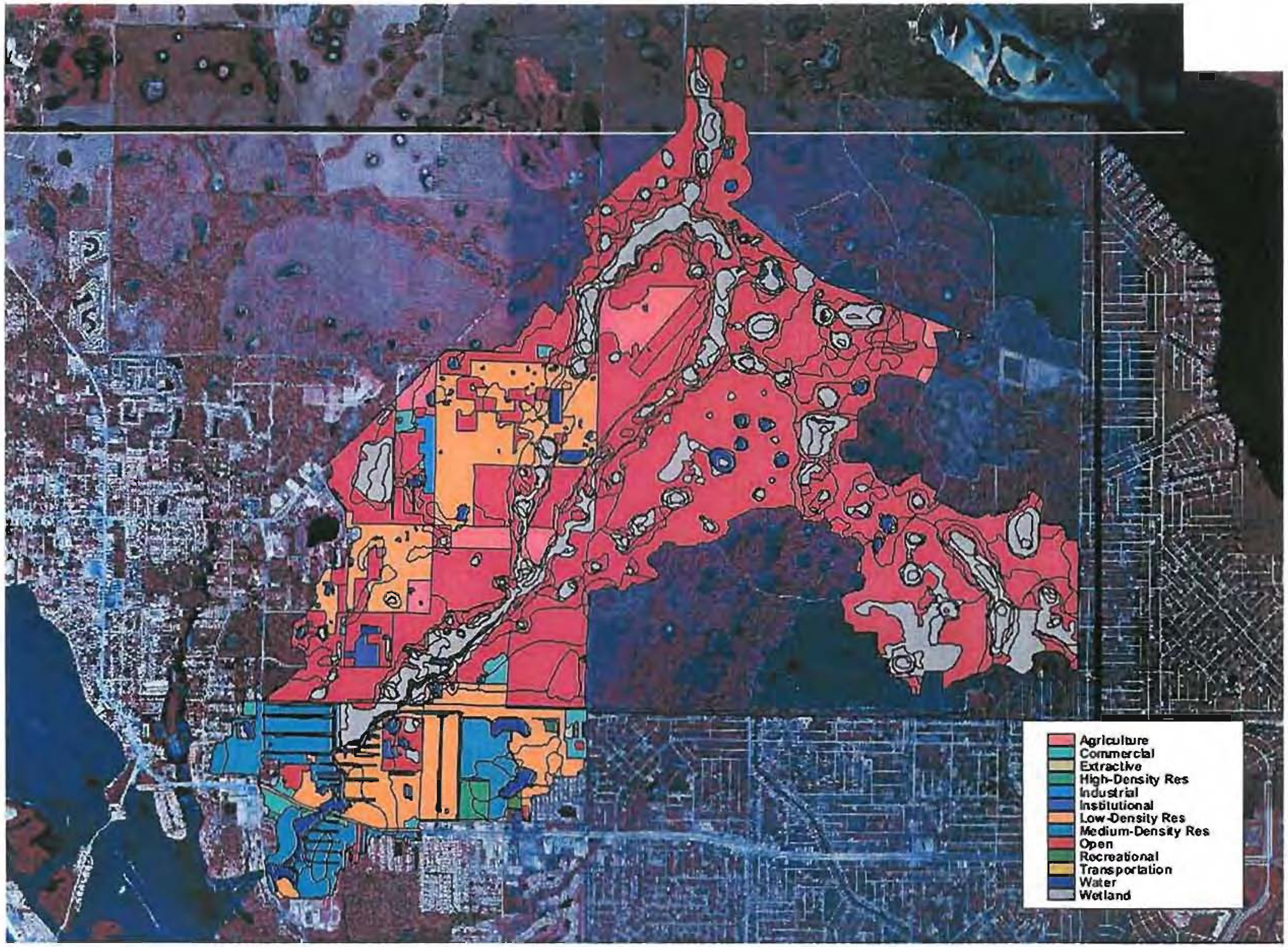


Figure 4-10. Current (1999) Land Use in the Ainger Creek Basin.

A tabular summary of current land use in the Ainger Creek basin is given in Table 4-11. Open land is clearly the dominant land use in the Ainger Creek basin, covering approximately 54.5% of the basin area. Wetlands occupy approximately 17.1% of the basin area, with 13.6% covered in low-density residential land use. The remaining land uses within the basin occupy approximately 5% or less of the total basin area.

TABLE 4-11

SUMMARY OF LAND USE IN THE AINGER CREEK BASIN

LAND USE	TOTAL AREA (acres)	PERCENT OF TOTAL
Agriculture	202.2	3.0
Commercial	84.5	1.3
High-Density Residential	29.2	0.4
Industrial	25.3	0.4
Institutional	23.0	0.3
Low-Density Residential	904.1	13.6
Medium-Density Residential	358.8	5.4
Open	3619.4	54.5
Recreational	7.4	0.1
Transportation	10.5	0.2
Water	238.9	3.6
Wetland	1133.4	17.1
TOTAL:	**6636.6**	**100.0**

An overview of general hydrologic soil groups in the Ainger Creek basin is given in Figure 4-11. The dominant hydrologic soil group within the basin appears to be "B/D" which is interspersed with areas in HSG "D" as well as HSG "C/D". A tabular summary of hydrologic soil groups in the Ainger Creek basin is given in Table 4-12.

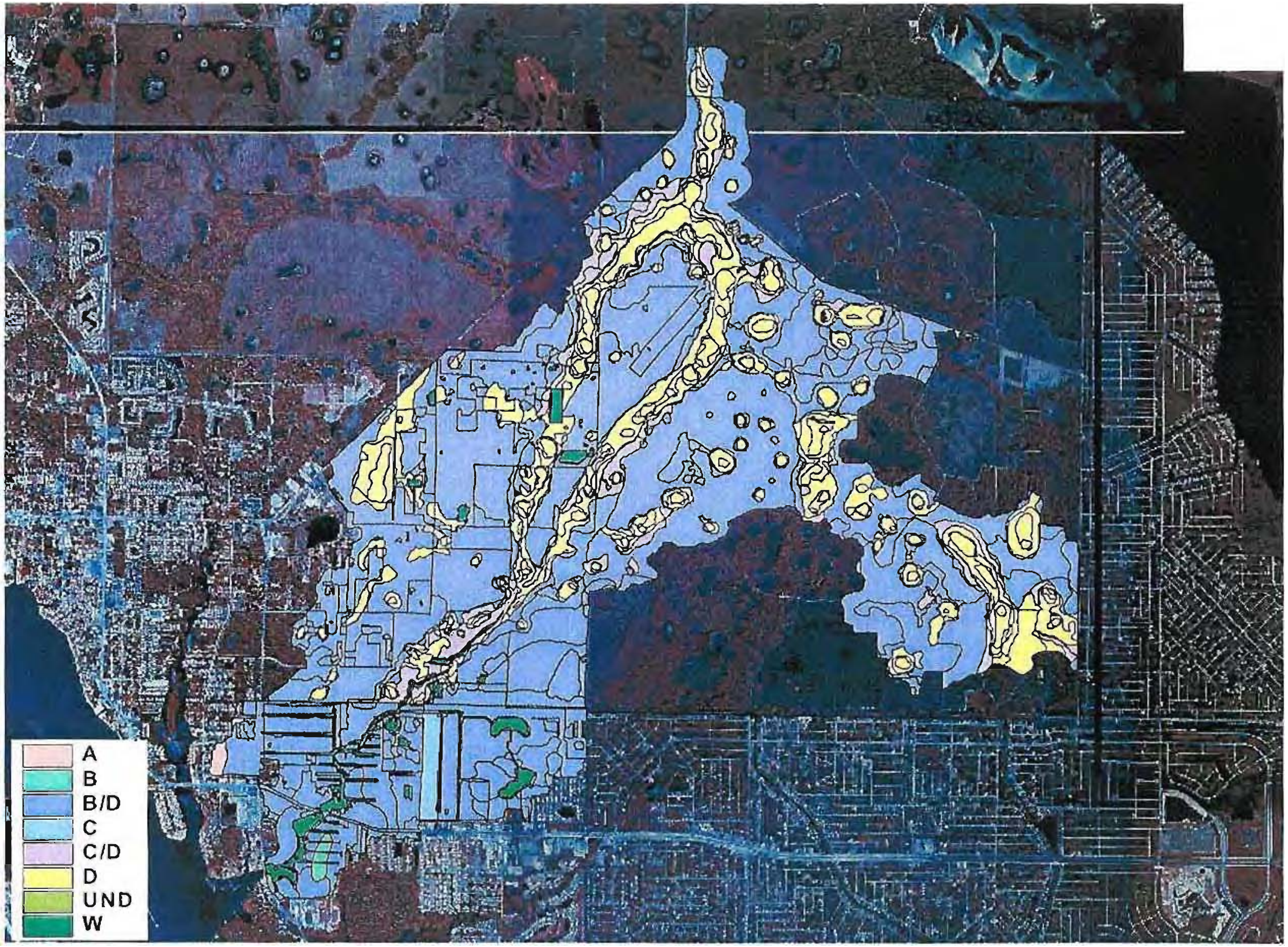


Figure 4-11. General Hydrologic Soil Groups in the Ainger Creek Basin.

TABLE 4-12

SUMMARY OF HYDROLOGIC SOIL GROUPS IN THE AINGER CREEK BASIN

HYDROLOGIC SOIL GROUP	TOTAL AREA (acres)	PERCENT OF TOTAL
A	12.1	0.2
B	16.0	0.2
B/D	4661.9	70.2
C	44.1	0.7
C/D	330.9	5.0
D	1417.7	21.4
W	153.9	2.3
TOTAL:	**6636.6**	**100.0**

4.1.6 Oyster Creek

An overview of current land use in the Oyster Creek basin, based upon 1999 conditions, is given in Figure 4-12. Areas within the basin appear to be occupied primarily by medium- and low-density residential communities interspersed with open areas and high-density residential communities. The Oyster Creek basin appears to be more heavily developed than other basins discharging to Lemon Bay, with the possible exception of the Alligator Creek basin.

A tabular summary of current land use in the Oyster Creek basin is given in Table 4-13. The dominant land use within the basin is medium-density residential which covers 45.2% of the basin area. An additional 22.9% of the basin area is covered with open land. Remaining land uses within the basin occupy approximately 5% or less of the total basin area.

An overview of general hydrologic soil groups in the Oyster Creek basin is given in Figure 4-13. Soils within the Oyster Creek basin are overwhelmingly in the "B/D" hydrologic soil group, with small pockets of soils in HSG "C" and "D". A tabular summary of hydrologic soil groups in the Oyster Creek basin is given in Table 4-14.

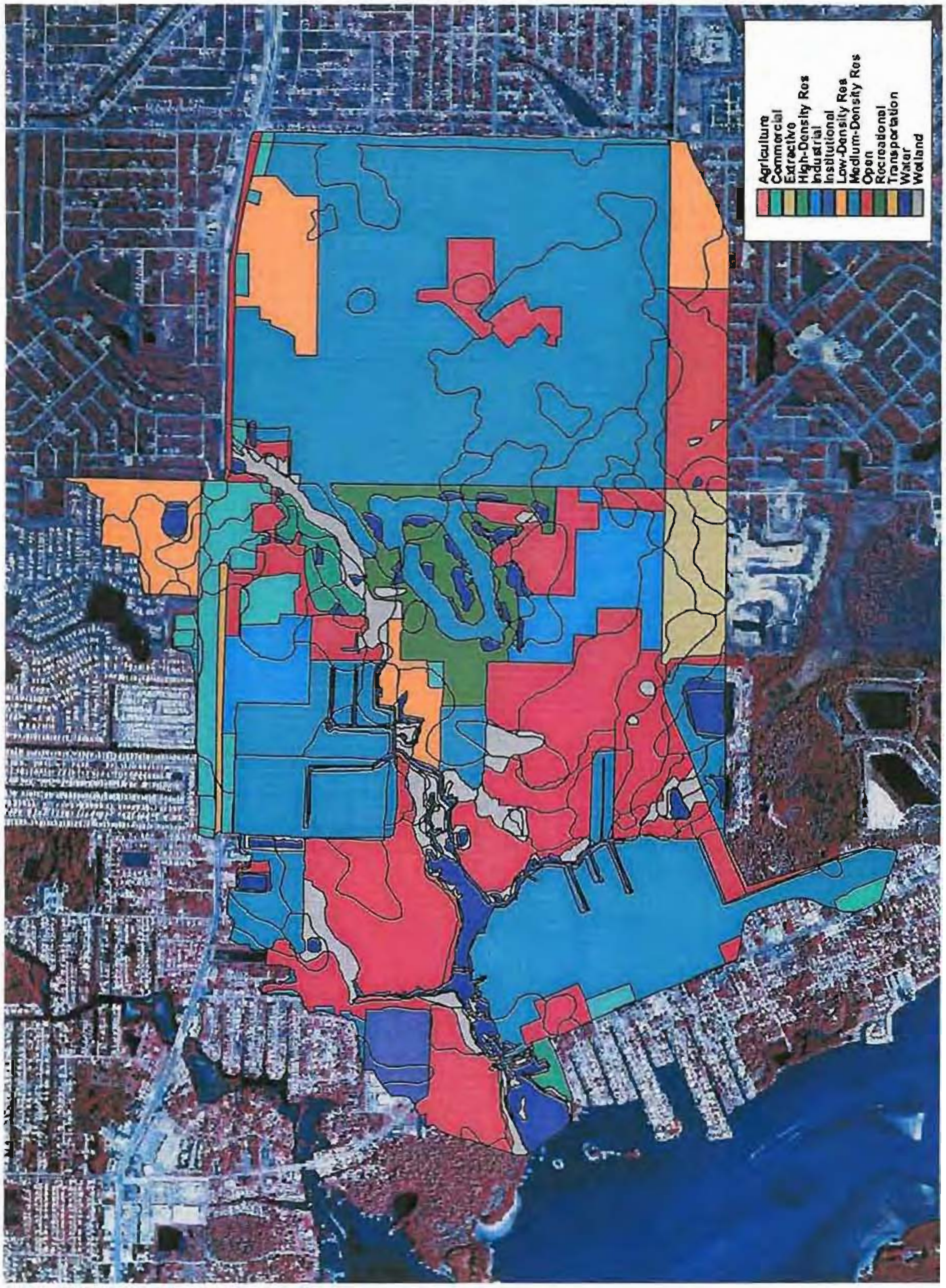


Figure 4-12. Current (1999) Land Use in the Oyster Creek Basin.

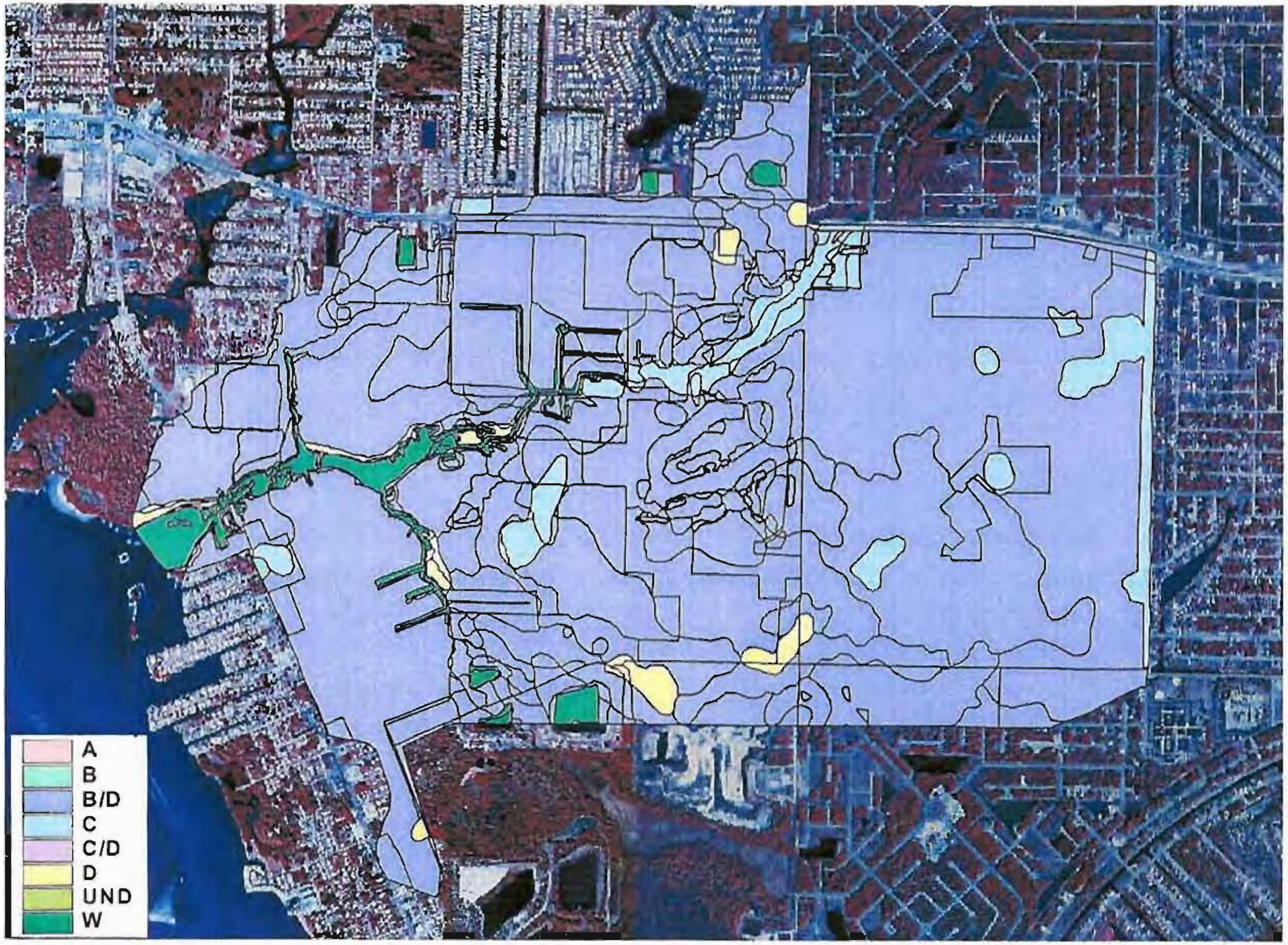


Figure 4-13. General Hydrologic Soil Groups in the Oyster Creek Basin.

TABLE 4-13

SUMMARY OF LAND USE IN THE OYSTER CREEK BASIN

LAND USE	TOTAL AREA (acres)	PERCENT OF TOTAL
Commercial	99.1	3.9
Extractive	55.2	2.2
High-Density Residential	28.4	1.1
Industrial	112.8	4.5
Institutional	28.4	1.1
Low-Density Residential	163.2	6.5
Medium-Density Residential	1145.0	45.2
Open	578.3	22.9
Recreational	81.2	3.2
Transportation	10.7	0.4
Water	115.4	4.6
Wetland	112.8	4.5
TOTAL:	**2530.4**	**100.0**

TABLE 4-14

SUMMARY OF HYDROLOGIC SOIL GROUPS IN THE OYSTER CREEK BASIN

HYDROLOGIC SOIL GROUP	TOTAL AREA (acres)	PERCENT OF TOTAL
B	1.7	0.0
B/D	2245.8	88.8
C	139.8	5.5
D	46.5	1.8
W	97.1	3.8
TOTAL:	**2530.4**	**100.0**

4.1.7 Buck Creek

An overview of current land use in the Buck Creek basin, based upon 1999 conditions, is given in Figure 4-14. The dominant land use in the Buck Creek basin appears to be open space which occupies the vast majority of the basin area. Areas of high-density residential and medium-density residential are also present, along with low-density residential, extractive, and commercial areas.

A tabular summary of current land use in the Buck Creek basin is given in Table 4-15. Open land occupies approximately 53.3% of the basin area, with medium-density residential occupying approximately 12.1%. The remaining land uses within the basin occupy approximately 8% or less of the overall basin area.

TABLE 4-15

SUMMARY OF LAND USE IN THE BUCK CREEK BASIN

LAND USE	TOTAL AREA (acres)	PERCENT OF TOTAL
Agriculture	14.6	0.2
Commercial	114.9	1.2
Extractive	216.4	2.3
High-Density Residential	321.6	3.5
Industrial	43.2	0.5
Institutional	65.7	0.7
Low-Density Residential	726.8	7.9
Medium-Density Residential	1110.7	12.1
Open	4906.7	53.3
Recreational	477.7	5.2
Water	594.4	6.5
Wetland	618.2	6.7
TOTAL:	**9210.9**	**100.0**

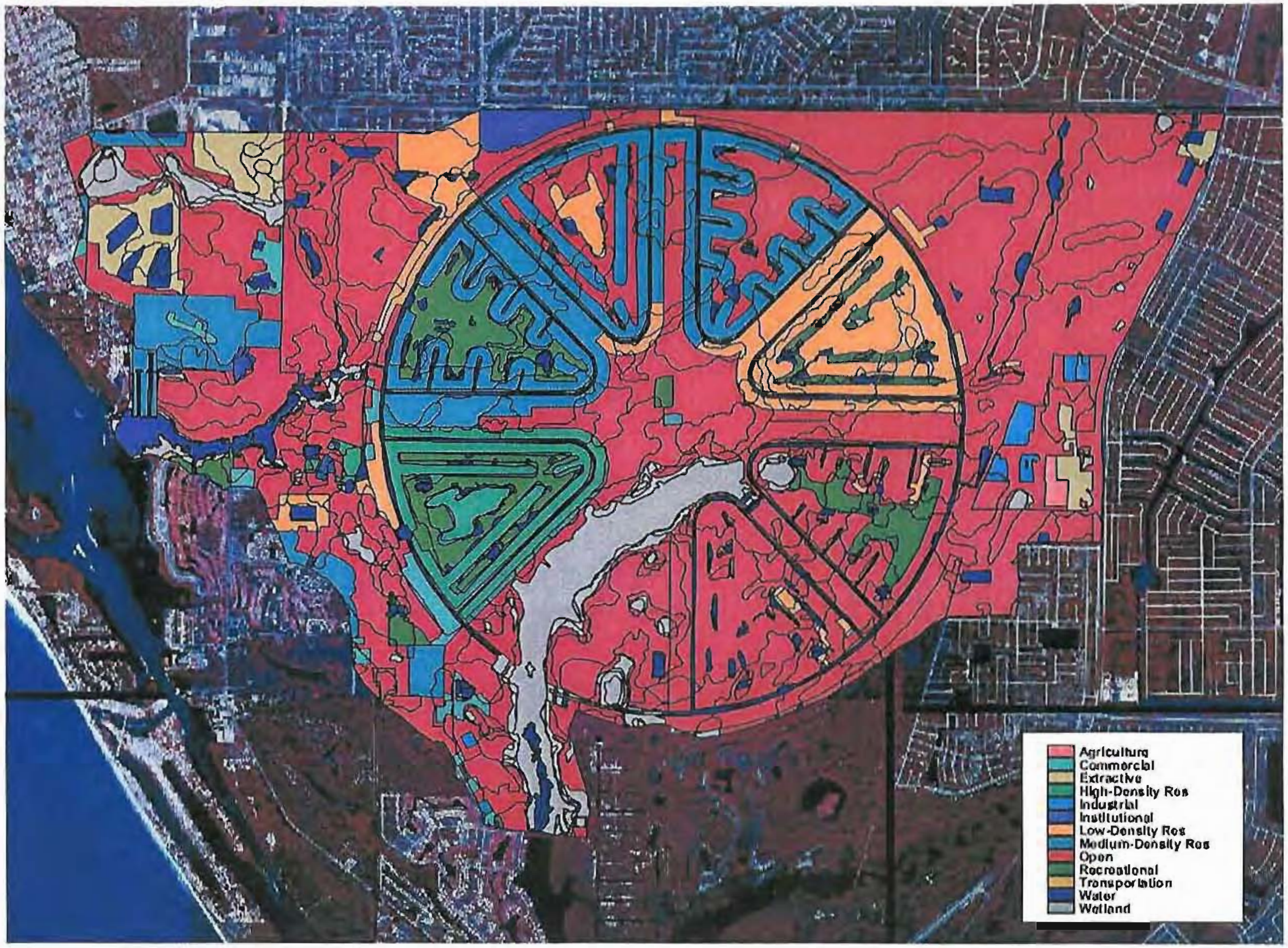


Figure 4-14. Current (1999) Land Use in the Buck Creek Basin.

An overview of general hydrologic soil groups in the Buck Creek basin is given in Figure 4-15. The dominant soil group within the basin appears to be "B/D" which is interspersed with areas of HSG "D" and "C". A tabular summary of hydrologic soil groups in the Buck Creek basin is given in Table 4-16.

TABLE 4-16

SUMMARY OF HYDROLOGIC SOIL GROUPS IN THE BUCK CREEK BASIN

HYDROLOGIC SOIL GROUP	TOTAL AREA (acres)	PERCENT OF TOTAL
A	1.9	0.0
B/D	6411.7	69.6
C	1466.2	15.9
D	823.0	8.9
W	508.0	5.5
TOTAL:	**9210.9**	**100.0**

4.2 Future Conditions

Estimates of future land use for the Lemon Bay watershed were generated by ERD for use in evaluating nonpoint source loadings under future conditions, as well as for evaluation of water quality impacts resulting from water quality improvement alternatives. Estimates of future land use conditions are not available from Sarasota County, Charlotte County, or SWFWMD for the Lemon Bay basin. Therefore, future land use conditions were estimated by ERD based upon several assumptions regarding future growth within the basin.

The future conditions assumed by ERD are based upon complete build-out of the basin area. For this scenario, it is assumed that all agricultural and open lands will be converted to developed land uses within each of the evaluated basins. Since wetland impacts are also likely as a result of development, it is assumed that approximately 20% of the wetland areas will also

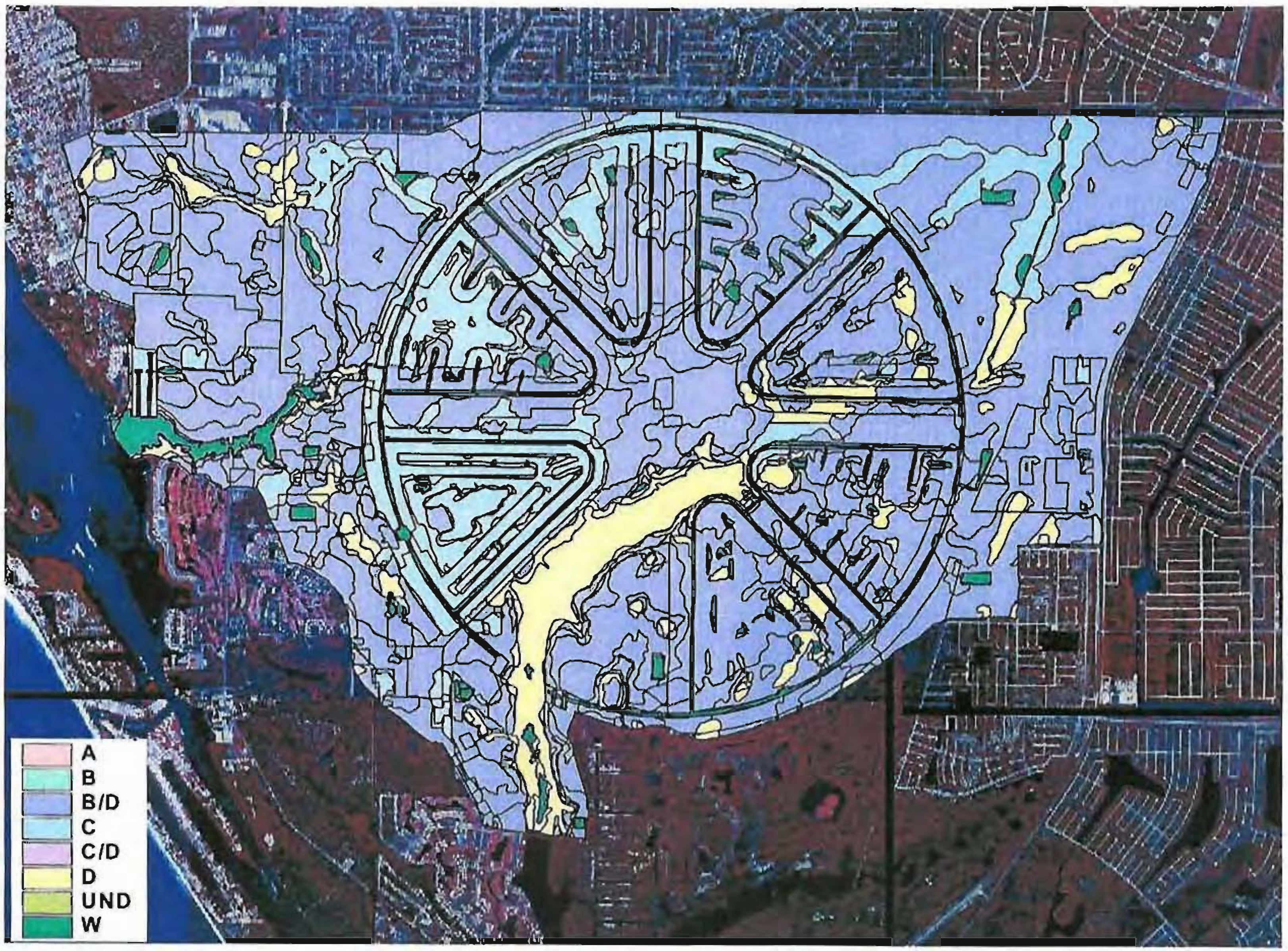


Figure 4-15. General Hydrologic Soil Groups in the Buck Creek Basin.

be converted to developed land uses. Development within the agricultural, open land, and wetland areas is assumed to occur in the same proportion as developed land uses which currently exist within the overall Lemon Bay drainage basin. For most basin areas, the newly developed areas will consist primarily of residential and commercial areas. However, transportation, recreational, and institutional areas are also allocated for the new developed areas based upon the current ratio of these land uses within the overall Lemon Bay drainage basin. A discussion of estimated future land use characteristics within each of the evaluated basins is given in the following sections.

4.2.1 Alligator Creek

Estimated land use characteristics in the Alligator Creek basin under future built-out conditions are summarized in Table 4-17. Existing land uses under current conditions are provided in the second column of Table 4-17. Changes in land use under built-out conditions are summarized in the third column. As discussed previously, these assumptions result in complete removal of agricultural and open lands, along with 20% of the wetland areas. The developable areas resulting from these losses are allocated to the remaining land use categories based upon the percentage of each category within the basin under current conditions. A summary of future land use is provided in the fourth column of Table 4-17, with the percentage of each land use under future conditions provided in the final column.

As development occurs in the Alligator Creek basin, approximately 1165 acres of agriculture, open land, and wetland will be converted to developed land uses, with the majority of these conversions becoming residential communities. Under future conditions, residential land use will be the largest single land use category in the Alligator Creek basin, comprising approximately 67.2% of the total basin area, compared with approximately 53.4% of the basin area under current conditions. Commercial areas will increase from 6.5% of the basin under current conditions to approximately 7.8% of the basin area. The remaining land uses will comprise approximately 6% or less of the basin area under built-out conditions.

TABLE 4-17

ESTIMATED LAND USE CHARACTERISTICS IN THE ALLIGATOR CREEK BASIN UNDER FUTURE BUILT-OUT CONDITIONS

LAND USE CATEGORY	1999 LAND USE (acres)	CHANGE IN LAND USE (acres)	FUTURE LAND USE (acres)	PERCENT OF TOTAL
Agriculture	70.7	-70.7	0.0	0.0
Commercial	442.3	85.4	527.7	7.8
Extractive	0.0	0.0	0.0	0.0
Industrial	0.0	15.7	15.7	0.2
Low-Density Residential	80.7	193.6	274.3	4.0
Medium-Density Residential	1787.6	511.5	2299.0	33.9
High-Density Residential	1758.7	228.8	1987.5	29.3
Transportation	161.7	18.2	179.8	2.6
Institutional	147.3	25.3	172.6	2.5
Open	991.5	-991.5	0.0	0.0
Recreational	256.2	86.7	342.9	5.1
Wetland	514.3	-102.9	411.5	6.1
Water	576.4	0.0	576.4	8.5
TOTAL:	**6787.3**	**0.0**	**6787.3**	**100.0**

4.2.2 Woodmere Creek

Estimated land use characteristics in the Woodmere Creek basin under future built-out conditions are summarized in Table 4-18. Under future conditions, approximately 278.7 acres of open land and wetlands will be converted to developed land uses. The majority of these converted areas will become residential communities of either low-density, medium-density, or high-density developments. Similar to the trends observed in Alligator Creek, residential land use will be the dominant land use in the Woodmere Creek basin under future conditions, occupying approximately 81.6% of the basin area. The remaining land uses will occupy approximately 8% or less of the basin area.

TABLE 4-18

ESTIMATED LAND USE CHARACTERISTICS IN THE WOODMERE CREEK BASIN UNDER FUTURE BUILT-OUT CONDITIONS

LAND USE CATEGORY	1999 LAND USE (acres)	CHANGE IN LAND USE (acres)	FUTURE LAND USE (acres)	PERCENT OF TOTAL
Agriculture	0.0	0.0	0.0	0.0
Commercial	16.3	20.4	36.7	2.5
Extractive	0.0	0.0	0.0	0.0
Industrial	22.1	3.7	25.9	1.8
Low-Density Residential	6.3	46.3	52.6	3.6
Medium-Density Residential	765.7	122.3	888.0	60.2
High-Density Residential	208.3	54.7	263.0	17.8
Transportation	2.3	4.3	6.7	0.5
Institutional	2.2	6.0	8.2	0.6
Open	248.9	-248.9	0.0	0.0
Recreational	4.9	20.7	25.6	1.7
Wetland	149.0	-29.8	119.2	8.1
Water	49.4	0.0	49.4	3.3
TOTAL:	**1475.3**	**0.0**	**1475.3**	**100.0**

4.2.3 Forked Creek

Estimated land use characteristics in the Forked Creek basin under future built-out conditions are summarized in Table 4-19. Under future conditions, approximately 3250 acres of agricultural, open land, and wetlands will be converted to developed land uses. The majority of these converted areas will become residential communities of either low-density, medium-density, or high-density. Under future conditions, the dominant land use within the basin will be residential which will occupy approximately 67.9% of the total basin area. Wetlands will occupy approximately 12.2% of the basin area, with the remaining land uses occupying approximately 6% or less of the total basin area.

TABLE 4-19

ESTIMATED LAND USE CHARACTERISTICS IN THE FORKED CREEK BASIN UNDER FUTURE BUILT-OUT CONDITIONS

LAND USE CATEGORY	1999 LAND USE (acres)	CHANGE IN LAND USE (acres)	FUTURE LAND USE (acres)	PERCENT OF TOTAL
Agriculture	1033.7	-1033.7	0.0	0.0
Commercial	83.7	238.2	321.9	5.5
Extractive	16.4	0.0	16.4	0.3
Industrial	0.0	43.6	43.6	0.7
Low-Density Residential	345.1	540.2	885.2	15.1
Medium-Density Residential	676.6	1426.8	2103.4	35.9
High-Density Residential	354.6	638.3	992.9	16.9
Transportation	45.6	50.7	96.3	1.6
Institutional	7.0	70.5	77.6	1.3
Open	2037.3	-2037.3	0.0	0.0
Recreational	114.0	241.8	355.8	6.1
Wetland	895.4	-179.1	716.3	12.2
Water	250.6	0.0	250.6	4.3
TOTAL:	**5860.0**	**0.0**	**5860.0**	**100.0**

4.2.4 Gottfried Creek

Estimated land use characteristics in the Gottfried Creek basin under future built-out conditions are summarized in Table 4-20. Under future built-out conditions, approximately 4274 acres of agriculture, open land, and wetlands will be converted to developed land uses in the Gottfried Creek basin. The majority of these converted areas will become residential areas of either low-density, medium-density, or high-density developments. Under future conditions, the dominant land use within the basin will be residential which will comprise approximately 65.8% of the total basin area. Wetlands will occupy approximately 10.5% of the basin area, with the remaining land uses occupying approximately 8% or less of the total basin area.

TABLE 4-20

ESTIMATED LAND USE CHARACTERISTICS
IN THE GOTTFRIED CREEK BASIN UNDER
FUTURE BUILT-OUT CONDITIONS

LAND USE CATEGORY	1999 LAND USE (acres)	CHANGE IN LAND USE (acres)	FUTURE LAND USE (acres)	PERCENT OF TOTAL
Agriculture	529.8	-529.8	0.0	0.0
Commercial	268.1	313.2	581.4	8.0
Extractive	0.0	0.0	0.0	0.0
Industrial	0.0	57.4	57.3	0.8
Low-Density Residential	289.5	710.4	999.8	13.7
Medium-Density Residential	799.7	1876.3	2676.0	36.8
High-Density Residential	271.5	839.4	1111.0	15.3
Transportation	5.7	66.7	72.4	1.0
Institutional	54.3	92.7	147.1	2.0
Open	3554.2	-3554.2	0.0	0.0
Recreational	184.0	318.0	502.0	6.9
Wetland	950.1	-190.0	760.1	10.5
Water	365.2	0.0	365.2	5.0
TOTAL:	**7272.4**	**0.0**	**7272.4**	**100.0**

4.2.5 Ainger Creek

Estimated land use characteristics in the Ainger Creek basin under future built-out conditions is summarized in Table 4-21. Under future conditions, approximately 4048 acres of agricultural, open land, and wetlands will be converted to developed land uses. The majority of this development will occur in residential communities. Under future conditions, residential areas will occupy approximately 68.4% of the basin, with 13.7% of the basin covered by wetlands. The remaining land uses within the basin will cover approximately 6% or less of the total basin area.

TABLE 4-21

ESTIMATED LAND USE CHARACTERISTICS IN THE AINGER CREEK BASIN UNDER FUTURE BUILT-OUT CONDITIONS

LAND USE CATEGORY	1999 LAND USE (acres)	CHANGE IN LAND USE (acres)	FUTURE LAND USE (acres)	PERCENT OF TOTAL
Agriculture	202.2	-202.2	0.0	0.0
Commercial	84.5	296.6	381.1	5.7
Extractive	0.0	0.0	0.0	0.0
Industrial	25.3	54.4	79.6	1.2
Low-Density Residential	904.1	672.8	1576.9	23.8
Medium-Density Residential	358.8	1777.2	2136.0	32.2
High-Density Residential	29.2	795.1	824.3	12.4
Transportation	10.5	63.2	73.7	1.1
Institutional	23.0	87.8	110.9	1.7
Open	3619.4	-3619.4	0.0	0.0
Recreational	7.4	301.2	308.6	4.7
Wetland	1133.4	-226.7	906.7	13.7
Water	238.9	0.0	238.9	3.6
TOTAL:	**6636.6**	**0.00**	**6636.6**	**100.0**

4.2.6 Oyster Creek

Estimated land use characteristics in the Oyster Creek basin under future built-out conditions are summarized in Table 4-22. Under future conditions, approximately 600.6 acres of open area and wetlands will be converted to developed land uses. The majority of this development will occur in residential communities. Under future conditions, residential communities will occupy approximately 71.9% of the basin area, with 3.6% of the basin covered by wetlands. The remaining land uses within the basin will occupy approximately 6% or less of the total basin area.

TABLE 4-22

ESTIMATED LAND USE CHARACTERISTICS
IN THE OYSTER CREEK BASIN UNDER
FUTURE BUILT-OUT CONDITIONS

LAND USE CATEGORY	1999 LAND USE (acres)	CHANGE IN LAND USE (acres)	FUTURE LAND USE (acres)	PERCENT OF TOTAL
Agriculture	0.0	0.0	0.0	0.0
Commercial	99.1	44.0	143.1	5.7
Extractive	55.2	0.0	55.2	2.2
Industrial	112.8	8.1	120.8	4.8
Low-Density Residential	163.2	99.9	263.1	10.4
Medium-Density Residential	1145.0	263.8	1408.8	55.7
High-Density Residential	28.4	118.0	146.4	5.8
Transportation	10.7	9.4	20.1	0.8
Institutional	28.4	13.0	41.4	1.6
Open	578.3	-578.3	0.0	0.0
Recreational	81.2	44.7	125.9	5.0
Wetland	112.8	-22.6	90.2	3.6
Water	115.4	0.0	115.4	4.6
TOTAL:	**2530.4**	**0.0**	**2530.4**	**100.0**

4.2.7 Buck Creek

Estimated land use characteristics in the Buck Creek basin under future built-out conditions are summarized in Table 4-23. Under full development conditions, approximately 5045 acres of agricultural land, open land, and wetlands will be converted to developed land uses. The vast majority of this development will occur in residential land uses. Under future conditions, residential areas will occupy approximately 67.3% of the basin, with 9.3% of the basin covered by recreational areas and 6.5% covered by open water. The remaining land uses will comprise approximately 5% or less of the total basin area.

TABLE 4-23

ESTIMATED LAND USE CHARACTERISTICS IN THE BUCK CREEK BASIN UNDER FUTURE BUILT-OUT CONDITIONS

LAND USE CATEGORY	1999 LAND USE (acres)	CHANGE IN LAND USE (acres)	FUTURE LAND USE (acres)	PERCENT OF TOTAL
Agriculture	14.6	-14.6	0.0	0.0
Commercial	114.9	369.7	484.6	5.3
Extractive	216.4	0.0	216.4	2.3
Industrial	43.2	67.6	110.8	1.2
Low-Density Residential	726.8	838.5	1565.3	17.0
Medium-Density Residential	1110.7	2214.7	3325.5	36.1
High-Density Residential	321.6	990.8	1312.5	14.2
Transportation	0.0	78.7	78.7	0.9
Institutional	65.7	109.5	175.1	1.9
Open	4906.7	-4906.7	0.0	0.0
Recreational	477.7	375.3	853.0	9.3
Wetland	618.2	-123.6	494.5	5.4
Water	594.4	0.0	594.4	6.5
TOTAL:	**9210.9**	**0.0**	**9210.9**	**100.0**