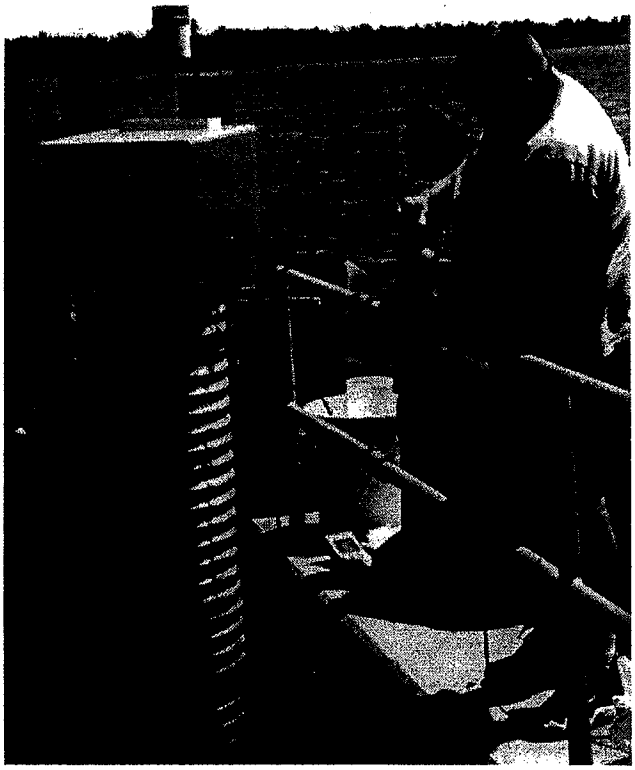
Technical Report No. 99-01

Peace River Water Quality Monitoring Project

Summary Report



1998 Water Year

(October 1997 to September 1998)

- ***Peace River & Watershed***
- ***Myakka River & Watershed***
- ***Coastal Venice/Lemon Bay/Gasparilla Sound/Cape Haze***
- ***Charlotte Harbor Proper***
- ***Pine Island Sound/Matlacha Pass***
- ***Estero Bay & Watershed***
- ***Tidal Caloosahatchee River & Watershed***

March 1999

The Charlotte Harbor National Estuary Program is a partnership of citizens, elected officials, resource managers and commercial and recreational resource users working to improve the water quality and ecological integrity of the greater Charlotte Harbor watershed. A cooperative decision-making process is used within the program to address diverse resource management concerns in the 4,400 square mile study area. Many of these partners also financially support the Program, which, in turn, affords the Program opportunities to fund projects such as this. The entities that have financially supported the program include the following:

U.S. Environmental Protection Agency
Southwest Florida Water Management District
South Florida Water Management District
Florida Department of Environmental Protection
Florida Coastal Zone Management Program
Peace River/Manasota Regional Water Supply Authority
Polk, Sarasota, Manatee, Lee, Charlotte, DeSoto and Hardee Counties
Cities of Sanibel, Cape Coral, Fort Myers, Punta Gorda, North Port, Venice and Fort Myers Beach
and the Southwest Florida Regional Planning Council.

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Background

Using funds provided by the Charlotte Harbor National Estuary Program (CHNEP) and the Peace River/Manasota Regional Water Supply Authority (PR/MRWSA), and in-kind services provided by the Southwest Florida Water Management District (SWFWMD) and the Florida Department of Environmental Protection (FDEP), monthly water quality monitoring was conducted at 10 long-term stream gaging stations in the Peace River watershed during 1997 and 1998. This report provides a summary of water quality conditions and estimated pollutant loadings occurring during the 1998 water year (October 1, 1997 through September 30, 1998).

The U.S. Geological Survey (USGS) maintains the stream gaging stations used as monitoring sites in this study, recording and disseminating stage and discharge data as part of that agency's national surface water monitoring network. Due to resource limitations, however, water quality data have been collected relatively infrequently (e.g., 0-6 samples per year) at most Peace River stations in recent years. The need for more frequent water quality monitoring, to support more confident characterizations of water quality conditions and pollutant loadings in the Peace River system, motivated the participants to undertake the project reported here.

Sampling Methods

Monthly water quality monitoring was performed by SWFWMD staff. Hydrographic parameters (specific conductance, salinity, pH, temperature, and DO) were measured in the field using a calibrated Hydrolab™ datasonde. Water samples were collected at mid-depth at each gaging station and transported on ice to the analytical laboratory. Laboratory analytes included total organic carbon (TOC), dissolved nitrate+nitrite nitrogen, dissolved ammonia nitrogen, total ammonia+organic nitrogen (TKN), dissolved ortho-phosphate (PO_4), total phosphorus (TP), chlorophyll *a*, color (PCU), total suspended solids (TSS), turbidity (NTU), and water column transparency (Secchi disk depth). All sampling, sample preservation and transport, and chain of custody procedures were performed in accordance with EPA, FDEP, and SWFWMD quality assurance requirements.

Water Quality

A water quality index (WQI) developed for Florida streams by FDEP was used to characterize water quality conditions at the 10 gaging stations. The WQI was developed by Hand et al. (1994, 1996), based on sampling data collected in 1987 from 2,000 stream reaches. Those data were used to determine percentile distributions for several groups of water quality indicators (e.g., nutrients, water clarity, DO and oxygen-demanding substances) on a statewide basis (Hand et al. 1994, 1996). WQI scores are

calculated based on these percentile distributions: for example, a station exhibiting an average annual TN concentration of 1.2 mg N/l (the median value observed in the 1987 data set) would receive an index score of 50 for that indicator. Scores are averaged across indicator categories to obtain an average WQI value per site. FDEP guidelines suggest that average index values of 0-44 indicate "good," 45-60 indicate "fair," and >60 indicate "poor" water quality conditions in Florida streams.

WQI values were calculated using four parameters (turbidity, TSS, TOC, and TN) to characterize water quality conditions at the 10 Peace River gaging stations during the 1997-1998 monitoring period (Table ES-1). Based on these data, the Saddle Creek at Structure P-11 gaging station, which is located immediately downstream from Lake Hancock, exhibited the poorest water quality, falling in the 60th to 90th percentiles of Florida streams for the indicators assessed. Four of the 10 stations produced WQI values >60, indicative of "poor" water quality conditions. Only two sites (Horse Creek near Myakka Head and Shell Creek near Punta Gorda) exhibited average WQI values which would be characterized as "good" (average WQI < 45) based on the FDEP classification system. Because they are based on a single year of monitoring, these results should be viewed as a relatively short-term "snapshot" of water quality conditions in the Peace River drainage basin. In general, however, they appear consistent with previous water quality information collected from the basin (e.g., Fraser 1991, Hand et al. 1994).

Discharge and loadings

Daily mean discharge data for the 10 monitoring stations were provided by the USGS for the 1998 water year. (These values have not yet been published by the USGS, and must therefore be treated as provisional estimates that are potentially subject to revision.) Above-average rainfall during the study period, primarily associated with the 1997-1998 El Niño event, produced elevated stream discharge throughout the Peace River watershed. At six USGS gaging stations located on major tributaries and the river's main stem, for example, annual mean discharges measured over the course of the 1998 water year were two to four times higher than the stations' long-term average values.

Estimated monthly and annual loadings of selected water quality constituents (nitrogen forms, phosphorus forms, and TSS) were calculated at each of the 10 monitoring stations for the 1998 water year. Mass loadings (in units of mass/time) were calculated as the product of stream discharge (volume/time) and constituent concentration (mass/volume). The estimated annual loadings are summarized in Table ES-2.

Table ES-1. Florida stream water quality index (WQI) values, based on September 1997 - September 1998 sampling events. FDEP guidelines suggest that average index values of 0-44 indicate "good," 45-60 indicate "fair," and >60 indicate "poor" water quality conditions.

MONITORING STATION	Turbidity	TSS	TOC	TN	Avg. WQI	WQI Water Quality Characterization
Peace Creek Canal near Wahneta	52	34	71	73	58	"fair"
Saddle Creek at Structure P-11	>95	>95	61	>95	89	"poor"
Peace River at Bartow	71	85	65	81	75	"poor"
Peace River at Ft. Meade	65	80	60	73	70	"poor"
Peace River at Zolfo Springs	55	65	55	73	62	"poor"
Peace River at Arcadia	51	55	60	74	60	"fair"
Charlie Creek near Gardner	33	24	75	69	51	"fair"
Horse Creek near Myakka Head	18	23	72	47	40	"good"
Horse Creek near Arcadia	23	35	64	58	45	"fair"
Shell Creek near Punta Gorda	19	17	58	59	38	"good"

Table ES-2. Estimated annual loading (tons/year) of selected water quality constituents (TN, DIN, TP, PO_4-P and TSS) during the 1998 water year.

MONITORING STATION	TN	DIN[1]	TP	PO_4-P	TSS
Peace Creek Canal near Wahneta	333	47	46	31	693
Saddle Creek at Structure P-11	720	4	116	24	11,052
Peace River at Bartow	761	92	229	152	6,186
Peace River at Ft. Meade	999	205	591	436	5,870
Peace River at Zolfo Springs	1,877	613	1,071	872	7,931
Peace River at Arcadia	3,350	1,232	1,743	1,208	10,849
Charlie Creek near Gardner	1,063	295	331	265	3,462
Horse Creek near Myakka Head	80	7	24	21	226
Horse Creek near Arcadia	611	183	210	173	4,692
Shell Creek near Punta Gorda	667	77	79	51	1,032

[1]DIN = dissolved inorganic nitrogen (ammonia-N and nitrate+nitrite-N)

In addition to the constituent loadings that occur at individual gaging stations within the Peace River watershed, the CHNEP and other stakeholders are also interested in quantifying the nutrient and TSS loads that are discharged from the watershed to Charlotte Harbor. Estimates of these values can be obtained by summing the loadings observed at the three gaging stations (Peace River at Arcadia, Horse Creek near Arcadia, and Shell Creek near Punta Gorda) that are located immediately upstream from the Harbor on the river and its southernmost tributaries. These three stations have a cumulative drainage area of 1,958 mi^2 (USGS 1997), representing 83% of the Peace River watershed (Hammett 1987). Assuming that the portion of the watershed lying downstream from the gages generates loadings of each constituent that are comparable (on a per-acre basis) to the upstream portion, loadings observed at these stations should represent (as a first approximation) about 83% of the watershed totals. Estimated annual loadings calculated using these assumptions are shown in Table ES-3.

Table ES-3. Estimated annual constituent loadings (tons) to Charlotte Harbor from the Peace River watershed during the 1998 water year.

CONSTITUENT	ESTIMATED ANNUAL LOAD (TONS)
TN	4,628
DIN	1,492
TP	2,032
PO_4-P	1,432
TSS	16,574

ACKNOWLEDGMENTS

Many organizations and individuals contributed to the completion of this report. Alton Cheatham (CHEC), Samuel Stone (PR/MRWSA), and David Moldal (CHNEP) provided project oversight, logistical support and technical information regarding the Peace River watershed. Yvonne Stoker (USGS) provided provisional discharge data from the USGS gaging stations for the 1998 water year. Chris Anastasiou, Fran Flores, Jason Hood, Ralph Meder, Nita Ostermann, Kelly Permenter, Jill Spencely, Chris Tomlinson, and Chris Zajac (SWFWMD) collected the water samples and *in situ* hydrographic data. SWFWMD staff also provided data entry, data management and quality assurance services. Chemical analysis were performed by laboratory staff at FDEP, SWFWMD, and the Environmental Quality Laboratory, Inc. The report was written by Gerold Morrison (FDEP) and Roberta Starks (SWFWMD).

This project was funded by the Southwest Florida Water Management District, the Florida Department of Environmental Protection, the Peace River/Manasota Regional Water Supply Authority, the Charlotte Harbor Environmental Center, Inc. and the Charlotte Harbor National Estuary Program. Copies of this report may be obtained by contacting the Charlotte Harbor National Estuary Program, 4980 Bayline Drive, 4th Floor, North Fort Myers, FL 33917-3909, or by calling (941) 995-1777.

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1.0 INTRODUCTION

1.1 Background

Using funds provided by the Charlotte Harbor National Estuary Program (CHNEP) and the Peace River/Manasota Regional Water Supply Authority (PR/MRWSA), monthly water quality monitoring was initiated at 10 long-term stream gaging stations in the Peace River watershed (Fig. 1, Table 1) in September, 1997. The project, which is intended to serve as the initial year of a long-term monitoring effort, is being carried out cooperatively by the following entities:

- the Charlotte Harbor Environmental Center, Inc. (CHEC), providing overall project coordination and public outreach;
- the Southwest Florida Water Management District (SWFWMD), performing data collection, chemical analyses and database management; and
- the Florida Department of Environmental Protection (FDEP), providing data analysis and reporting.

The U.S. Geological Survey (USGS) maintains the stream gaging stations used in this study, recording and disseminating stage and discharge data as part of that agency's national surface water monitoring network. Due to resource limitations, however, water quality data have been collected relatively infrequently (e.g., 0-6 samples per year) at most Peace River stations in recent years. A watershed assessment project carried out as part of the Charlotte Harbor Surface Water Improvement and Management (SWIM) initiative (Squires et al. 1996) focused attention on this issue and recommended that more frequent (e.g., monthly) water quality monitoring be conducted at selected gaging stations. That recommendation, and other concerns regarding the availability of information characterizing water quality conditions and pollutant loadings in the Peace River system, motivated the participants to undertake the project reported here.

The Peace River watershed is a naturally fertile area, containing extensive phosphate-bearing geological deposits (the Bone Valley formation of the Hawthorn group), abundant rainfall, and a humid subtropical climate. Phosphate is an important nutrient supporting the growth of terrestrial and aquatic organisms, and many lakes and streams that drain the Bone Valley region are highly productive ("eutrophic") as a result of naturally elevated phosphate inputs (Odum 1953, Canfield and Hoyer 1988). These naturally eutrophic waterbodies are potentially at risk of becoming hypereutrophic, and exhibiting undesirably high levels of biological productivity, if human activities cause nutrient loadings to increase to excessive levels. Several historically-eutrophic lakes located in the headwaters region of the Peace River watershed (e.g., Lake Parker, Lake Hancock, Banana Lake) appear to have shifted to hypereutrophic productivity levels in recent decades as a result of additional, anthropogenic nutrient loadings.

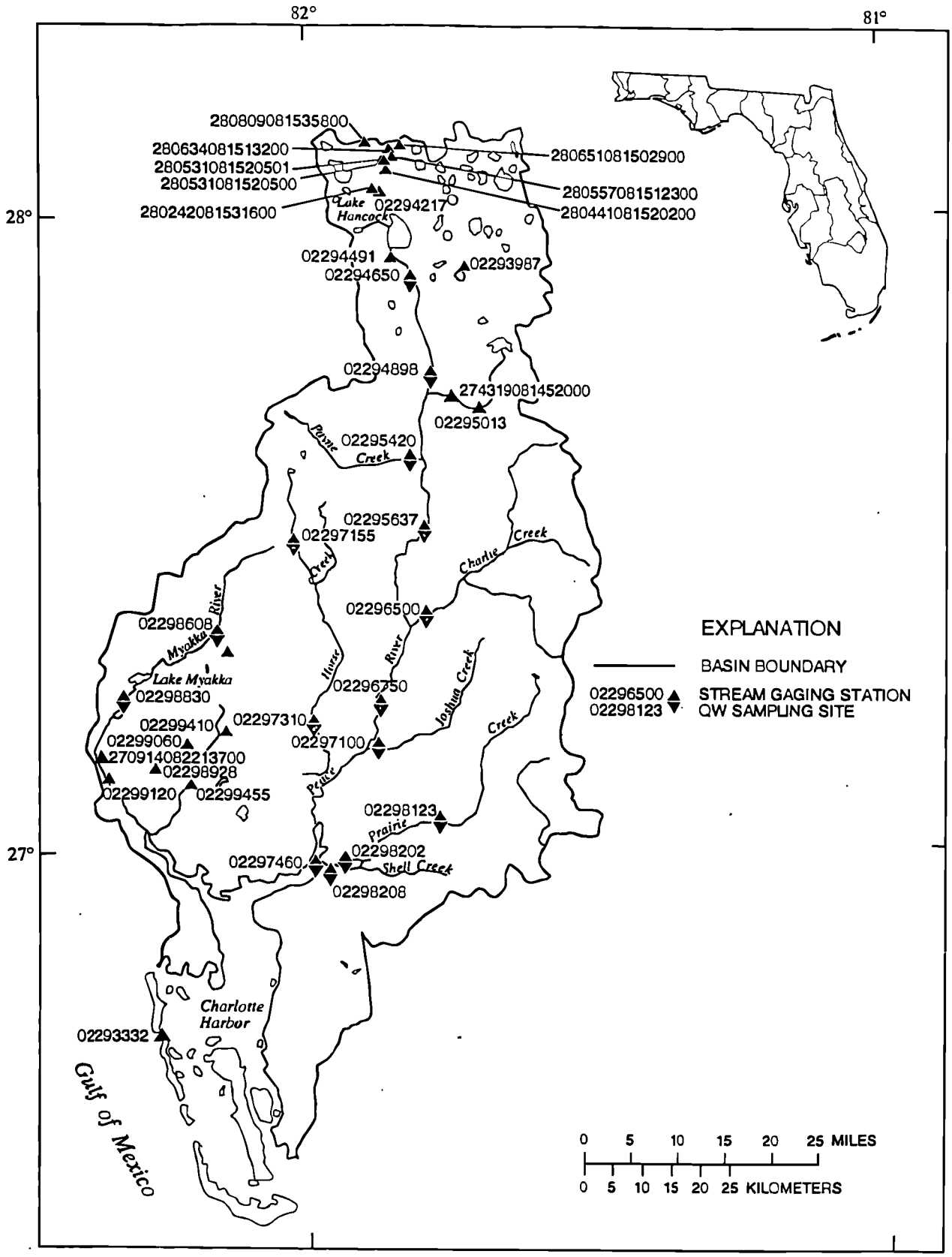

Figure 1. Locations of USGS gaging stations in the Peace River watershed (source: USGS 1997).

Table 1. USGS stream gaging stations used as monitoring locations in this study.

SITE NAME	USGS GAGE NO.	LOCATION
Peace Creek Canal near Wahneta	02293987	Peace Creek Canal at Co. Rd. 665, Polk Co., Florida
Saddle Creek at Structure P-11	02294491	Lake Hancock discharge point, Polk Co., Florida
Peace River at Bartow	02294650	Peace River at State Rd. 60, Polk Co., Florida
Peace River at Ft. Meade	02294898	Peace River at U.S. Highway 98 Polk Co., Florida
Peace River at Zolfo Springs	02295637	Peace River at U.S. Highway 17 Hardee Co., Florida
Peace River at Arcadia	02296750	Peace River at State Rd. 70 DeSoto Co., Florida
Charlie Creek near Gardner	02296500	Charlie Creek at U.S. Highway 17 Hardee Co., Florida
Horse Creek near Myakka Head	02297155	Horse Creek at State Rd. 64 Hardee Co., Florida
Horse Creek near Arcadia	02297310	Horse Creek at State Rd. 72 DeSoto Co., Florida
Shell Creek near Punta Gorda	02298202	Shell Creek, 60 ft. upstream from City of Punta Gorda dam, Charlotte Co., Florida

Eutrophication is a process in which increasing nutrient loadings cause changes in the water chemistry and ecological structure of surface water bodies. These changes, which are currently affecting many Florida waters, often include (Day et al. 1989):

- increasing rates of biological productivity, and increasing biomass of algae or rooted aquatic plants;

- increasing deposition of unutilized organic material to the sediment zone (with associated increases in sediment oxygen demand);

- reduced water clarity, due to increased algal densities and resuspension of unconsolidated bottom sediments; and

- shifts in the composition of plant and animal communities, with increasing abundance of species more highly adapted to nutrient-enriched conditions.

In addition to ecological and esthetic impacts, excessive nutrient loadings can also affect human uses of surface waters by increasing the frequency of nuisance algal blooms, causing taste and odor problems in potable water sources, and contributing to oxygen-related stress or mortality in economically important fish and shellfish species.

From a regulatory perspective the Federal Water Pollution Control Act ("Clean Water Act"), as amended, provides the underlying legal framework for water quality management throughout the United States. The Clean Water Act requires that the chemical, physical and biological integrity of the Nation's waters be maintained at levels that provide "fishable and swimmable" conditions for all citizens. Regulations developed by the U.S. EPA and other agencies to implement the Act have therefore focused on maintaining water quality at levels necessary to support viable populations of fish and wildlife and protect human health.

Water quality standards — which include designated uses, numeric and narrative water quality criteria and anti-degradation policy — have been the primary tools used in the national management effort. *Designated uses*, such as potable water supply, shellfish harvesting, wildlife propagation and recreational contact, are identified by each state (e.g., Ch. 62-302.400, Florida Administrative Code) through its rulemaking process and are established for all waterbodies within a state's jurisdiction. *Water quality criteria*, which describe the specific water quality conditions necessary to achieve designated uses, are also established by rulemaking at the state level (e.g., Ch. 62-302.530, F.A.C.). *Anti-degradation policy*, which is implemented through the permitting process, holds that all existing uses of a waterbody (including those that may exceed the designated uses) should also be maintained. If existing water quality is higher than is strictly necessary to support designated uses, for example, regulatory agencies will seek to maintain that quality unless important economic and social goals require otherwise.

In order to prevent or correct water quality degradation caused by anthropogenic nutrient loadings, state criteria typically include provisions intended to discourage excessive loadings from manmade sources (e.g., urban or agricultural stormwater runoff , or municipal or industrial wastewater discharges). State policies and criteria also support the restoration of water bodies degraded by historical anthropogenic discharges. Like many states, however, Florida has not yet chosen to adopt numerical criteria related to nutrient loadings and eutrophication, relying instead on a narrative standard which requires that "in no case shall nutrient concentrations of a body of water be altered so as to cause an imbalance in natural populations of aquatic flora or fauna" (Chap. 62-302.530, F.A.C.).

In areas such as the Peace River watershed, where naturally-elevated phosphorus concentrations are augmented by anthropogenic nutrient loadings from a variety of point and nonpoint sources, periodic monitoring and reporting of water quality conditions are helpful in providing the information needed to assess compliance with these state and national water quality goals.

1.2 Report Objectives and Structure

This report provides a summary of water quality conditions and estimated constituent loadings occurring during the 1998 water year (October 1, 1997 through September 30, 1998) at the 10 gaging stations listed in Table 1. Water quality data collected during the project's initial (September 1997) sampling event are also reported here, but are not used in calculating estimated constituent loadings for the 1998 water year.

The report is organized as follows:

Sect. 2.0	Methods - briefly summarizes the sample collection and analysis methods used in the project. (A more comprehensive discussion of sampling and analytical methods, and associated quality control issues, is provided in a separate Quality Assurance Project Plan [QAPP] that is available from the CHEC on request.)
Sect. 3.0	Results and Discussion - summarizes the data collected during the initial 13 months of sampling.
Sect. 4.0	References Cited
Appendices	Quarterly Quality Assurance Reports - summarize the steps taken to ensure that the precision, accuracy, and completeness of project data are known, documented, and within acceptable limits as defined in the QAPP.

2.0 METHODS

Monthly monitoring was initiated in September 1997 and is currently projected to continue through September 1999. Sampling is performed by SWFWMD field staff over a two-day period during the first week of each month. Stations located in the northern portion of the watershed are normally sampled on the initial day of field work; the remaining stations are sampled the following day.

Water quality parameters monitored include: specific conductance, pH, temperature, dissolved oxygen (DO), total organic carbon (TOC), dissolved nitrate+nitrite nitrogen, dissolved ammonia nitrogen, total ammonia+organic nitrogen (TKN), dissolved ortho-phosphate (PO_4), total phosphorus (TP), chlorophyll *a*, color (PCU), total suspended solids (TSS), turbidity (NTU), and water column transparency (Secchi disk depth). Biochemical oxygen demand (BOD) was monitored at three stations (Peace River at Arcadia, Horse Creek near Arcadia, and Shell Creek near Punta Gorda) during the initial months of the project. Following this initial period, however, BOD was deleted from the parameter list due to logistics, cost and data-quality concerns.

Hydrographic parameters (specific conductance, salinity, pH, temperature, and DO) are measured in the field using a Hydrolab™ datasonde that is pre-calibrated and post-calibrated on the day of sampling. Water samples are collected at mid-depth at each gaging station and transported on ice to the analytical laboratory. All sampling, sample preservation and transport, and chain of custody procedures are performed in accordance with federal (US EPA), state (FDEP), and regional (SWFWMD) quality assurance requirements.

Concentrations of dissolved nitrogen and phosphorus forms are measured using samples which are field-filtered, immediately following collection, through MFS 0.45 *um* cellulose acetate membrane filters and stored on ice until analysis. Samples used for chlorophyll analysis are filtered in the laboratory, immediately following sample delivery, using glass fiber filters (Gellman A/E, 1 *um*). The filters and attached algal cells are stored frozen prior to chlorophyll extraction.

Laboratory analyses are performed using standard, EPA-approved methods (summarized in Table 2). Analyses of the September - November, 1997 samples were performed by FDEP environmental laboratories located in Tallahassee (chemical parameters) and Tampa (biological parameters). Analyses of the December 1997-September 1998 samples were carried out by the Environmental Quality Laboratory, Inc., (EQL) located in Port Charlotte. Nutrient forms in several samples collected during December 1997 were not analyzed within EPA-approved holding times. As a result, all data from the December 1997 sampling event have been omitted from this report.

Table 2. Laboratory analytical methods.

ANALYTE	METHOD NUMBER
Chlorophyll *a*	Standard Methods (18th ed.), 10200 H.2
$NO_2 + NO_3$ (dissolved)	EPA 353.2
$NH_3 + NH_4$ (dissolved)	EPA 350.1
Total Kjeldahl Nitrogen	EPA 351.2
PO_4 (dissolved)	EPA 365.2
Total Phosphorus	EPA 365.4
Total Organic Carbon	EPA 415.1
Turbidity	EPA 180.1
Total Suspended Solids	EPA 160.2
BOD_5	EPA 405.1
Color	EPA 110.2

3.0 RESULTS AND DISCUSSION

3.1 Constituent concentrations and water quality index (WQI) values

Given the relatively brief period this project has been underway, and the unusually high levels of rainfall and stormwater runoff that occurred throughout the study area during the El Niño-influenced winter of 1997-1998, an overly-detailed analysis of these water quality data would be premature. For comparative purposes, however, summary statistics (means, minima, maxima) for several major water quality constituents are listed in Table 3. Relative to median values observed in Florida streams (Hand et al. 1994), most of the Peace River stations exhibited elevated concentrations of total phosphorus, total nitrogen, total organic carbon, turbidity, TSS, color, and chlorophyll *a* during the September 1997-September 1998 time period (Table 3).

The FDEP has developed a Florida stream water quality index (WQI) based on several groups of indicators (e.g., nutrients, water clarity, DO, oxygen demanding substances) (Hand et al. 1994, 1996). Sampling data collected in 1987 from 2,000 Florida stream reaches were used to determine percentile distributions for each indicator on a statewide basis (Hand et al. 1994, 1996). Index scores are calculated based on these percentile distributions: for example, a site exhibiting an average TN concentration of 1.2 mg N/l (the median value observed in the 1987 data set) would receive an index score of 50 for that indicator. Scores are averaged across indicator categories to obtain an average WQI value per site (Hand et al. 1994, 1996). FDEP guidelines suggest that average index values of 0-44 indicate "good," 45-60 indicate "fair," and >60 indicate "poor" water quality conditions in Florida streams.

Hand et al. (1996) provides the following summary of the WQI: "The Florida Water Quality Index has several advantages over previous measures. First, since it is based on the percentile distribution of Florida stream data, it is tailored to Florida. Second, the index uses the most important measures of water quality in Florida: clarity, dissolved oxygen, oxygen-demanding substances, nutrients, bacteria, and biological diversity. Third, it is simple to understand and calculate and does not require a mainframe computer or any complex data transformations or averaging schemes. Finally, the index nicely identifies areas of good, fair, and poor water quality that correspond to professional and public opinion."

An application of the FDEP water quality index to the 1997-1998 Peace River sampling data is summarized in Table 4. (Due to the presence of naturally phosphorus-rich geological deposits in the watershed, total phosphorus concentrations were not included when calculating the average WQI values shown in Table 4.)
Based on these data, the Saddle Creek at Structure P-11 gaging station, which is located immediately downstream from Lake Hancock, appears to have the poorest water quality of the 10 sites sampled, falling in the 60th to 90th percentiles of Florida

Table 3. Constituent concentrations (average and range) observed in September 1997 - September 1998 sampling events. ("BDL" indicates value below method detection limit.)

SAMPLING STATION	Turbidity (NTU)	TSS (mg/l)	Color	pH	Conduct. (umhos)	DO (mg/l)	Chl *a* (ug/l)
Peace Creek Canal Near Wahneta	6.0 (3.8 - 14.9)	4.9 (BDL - 15.0)	243 (140 - 350)	6.6 (5.9 - 7.5)	207 (127 - 405)	4.4 (2.0 - 7.5)	1.0 (BDL - 8.5)
Saddle Creek at Structure P-11	30.2 (13.0 - 50.0)	60.5 (14.0 - 100.0)	97 (55 - 156)	8.4 (6.9 - 9.2)	182 (148 - 203)	5.8 (1.7 - 8.9)	117.4 (43.0-267.0)
Peace River at Bartow	12.5 (7.3 - 30.0)	22.0 (7.0 - 67.1)	196 (140 - 320)	6.8 (6.2 - 7.3)	207 (129 - 350)	4.0 (1.8 - 6.7)	21.2 (BDL - 69.4)
Peace River at Ft. Meade	10.5 (3.2 - 29.0)	18.2 (2.0 - 54.0)	130 (50 - 187)	7.2 (6.7 - 7.5)	302 (182 - 550)	5.6 (4.1 - 7.4)	15.4 (BDL - 64.1)
Peace River at Zolfo Springs	6.8 (2.0 - 15.3)	11.0 (BDL - 30.0)	126 (60 - 197)	7.4 (7.0 - 8.0)	316 (194 - 450)	7.1 (6.1 - 8.7)	10.7 (BDL - 79.8)
Peace River at Arcadia	5.7 (2.6 - 15.8)	7.9 (BDL - 26.0)	169 (60 - 275)	7.2 (6.7 - 8.0)	299 (194 - 436)	6.8 (6.0 - 8.2)	3.4 (BDL - 26.7)
Charlie Creek Near Gardner	4.2 (1.0 - 14.1)	3.5 (BDL - 10.0)	273 (70 - 377)	6.7 (6.1 - 7.1)	196 (122 - 333)	6.3 (4.5 - 8.1)	BDL
Horse Creek Near Myakka Head	2.7 (1.0 - 5.3)	3.3 (BDL - 10.0)	272 (80 - 520)	6.8 (6.0 - 7.5)	140 (73 - 248)	7.4 (4.8 - 9.1)	BDL
Horse Creek Near Arcadia	3.3 (1.2 - 8.6)	4.8 (BDL - 32.0)	204 (66 - 337)	6.8 (6.1 - 7.3)	302 (131 - 739)	6.7 (4.9 - 8.2)	2.5 (BDL - 31.5)
Shell Creek Near Punta Gorda	2.8 (1.7 - 4.7)	2.7 (BDL - 11.0)	131 (55 - 210)	7.2 (6.8 - 7.6)	647 (394 - 993)	4.7 (2.0 - 8.5)	6.8 (BDL - 24.2)
Median Fla. Stream	5.2	6.5	70	7.2	366	5.8	12 [1]

[1] Median Florida lake concentration (Chl *a*)

Table 3 (cont.)

SAMPLING STATION	diss. NH3 (mg N/l)	diss. NO_{2+3} (mg N/l)	TKN (mg N/l)	TN (mg N/l)	PO_4 (mg P/l)	TP (mg P/l)	TOC (mg C/l)
Peace Creek Canal near Wahneta	0.094 (BDL - 0.22)	0.295 (0.03 - 0.72)	1.4 (1.2 - 2.1)	1.7 (1.2 - 2.1)	0.22 (0.07 - 0.63)	0.31 (0.11 - 0.77)	30.0 (13.0 - 31.0)
Saddle Creek at Structure P-11	0.016 (BDL - 0.04)	0.011 (BDL -0.06)	4.3 (2.1 - 6.5)	4.3 (2.1 - 4.1)	0.09 (BDL - 0.24)	0.51 (0.15 - 0.71)	17.9 (11.8 - 26.0)
Peace River at Bartow	0.076 (BDL - 0.24)	0.175 (0.06 - 0.46)	1.9 (0.5 - 3.6)	2.1 (0.6 - 2.3)	0.47 (0.01 - 1.30)	0.72 (0.25 - 1.66)	19.2 (12.6 - 30.0)
Peace River at Ft. Meade	0.043 (BDL - 0.07)	0.328 (0.12 - 0.89)	1.4 (0.8 - 2.4)	1.7 (1.1 - 2.0)	0.61 (0.22 - 0.94)	0.92 (0.55 - 1.27)	17.6 (8.3 - 44.0)
Peace River at Zolfo Springs	0.031 (BDL - 0.09)	0.601 (0.25 - 1.14)	1.1 (0.7 - 1.5)	1.7 (1.4 - 2.0)	0.73 (0.32 - 1.12)	0.97 (0.70 - 1.78)	15.8 (9.1 - 30.6)
Peace River at Arcadia	0.044 (BDL - 0.10)	0.622 (0.29 - 1.35)	1.1 (0.6 - 1.6)	1.7 (0.9 - 2.0)	0.64 (0.06 - 0.96)	0.86 (0.67 - 1.07)	17.3 (8.5 - 26.0)
Charlie Creek near Gardner	0.045 (BDL - 0.07)	0.341 (0.08 - 0.88)	1.2 (0.7 - 1.8)	1.6 (1.2 - 2.2)	0.48 (0.02 - 0.91)	0.63 (0.43 - 1.00)	24.2 (9.0 - 40.0)
Horse Creek near Myakka Head	0.022 (BDL - 0.04)	0.098 (0.03 - 0.18)	1.0 (0.6 - 1.6)	1.1 (0.8 - 1.5)	0.35 (0.18 - 0.58)	0.41 (0.23 - 0.64)	22.3 (9.5 - 35.0)
Horse Creek near Arcadia	0.039 (BDL - 0.07)	0.457 (0.09 - 1.06)	0.9 (0.4 - 1.4)	1.4 (0.5 - 1.6)	0.40 (0.29 - 0.52)	0.49 (0.35 - 0.58)	19.0 (8.1 - 36.0)
Shell Creek near Punta Gorda	0.031 (BDL - 0.09)	0.091 (BDL - 0.21)	1.3 (0.9 - 1.6)	1.4 (1.2 - 1.7)	0.10 (0.03 - 0.20)	0.17 (0.11 - 0.27)	17.0 (11.6 - 24.0)
Median Florida Stream	N/A	N/A	N/A	1.2	N/A	0.09	14

Table 4. Florida Stream Water Quality Index values (Hand et al. 1994, 1996), based on September 1997 - September 1998 sampling events. FDEP guidelines suggest that average index values of 0-44 indicate "good," 45-60 indicate "fair," and >60 indicate "poor" water quality conditions.

SAMPLING STATION	Turbidity	TSS	TOC	TN	TP	Avg. WQI[1]
Peace Creek Canal near Wahneta	52	34	71	73	73	58
Saddle Creek at Structure P-11	>95	>95	61	>95	81	89
Peace River at Bartow	71	85	65	81	86	75
Peace River at Ft. Meade	65	80	60	73	91	70
Peace River at Zolfo Springs	55	65	55	73	92	62
Peace River at Arcadia	52	55	60	74	89	60
Charlie Creek near Gardner	33	24	75	69	84	51
Horse Creek near Myakka Head	18	23	72	47	78	40
Horse Creek near Arcadia	23	35	64	58	81	45
Shell Creek near Punta Gorda	19	17	58	59	62	38

[1] TP values were excluded from WQI calculation

streams for all indicators assessed. Overall, 4 of the 10 sites exhibited WQI values >60, indicative of "poor" water quality conditions (Table 4). Only two sites (Horse Creek near Myakka Head and Shell Creek near Punta Gorda) exhibited average WQI values which would be characterized as "good" (average WQI < 45) based on the FDEP classification system. Because they are based on a single year of monitoring data, these results should be viewed as a relatively short-term "snapshot" of water quality conditions in the Peace River drainage basin. In general, however, they appear consistent with previous

these results should be viewed as a relatively short-term "snapshot" of water quality conditions in the Peace River drainage basin. In general, however, they appear consistent with previous water quality information collected from the basin (e.g., Fraser 1991, Hand et al. 1994).

3.2 Stream Discharge and Estimated Constituent Loadings

Daily mean discharge data for the 10 monitoring stations were provided by the USGS for the 1998 water year. (These values have not yet been published by the USGS, and must therefore be treated as provisional estimates that are potentially subject to revision.) Monthly mean discharge estimates, which were calculated using the provisional daily values, are summarized in Table 5.

Above-average rainfall during the study period, primarily associated with the 1997-1998 El Niño event, produced elevated stream discharge throughout the Peace River watershed. At the six USGS gaging stations shown in Fig. 2, for example, annual mean discharges measured over the course of the 1998 water year were two to four times higher than the stations' long-term average values.

Estimated loadings of selected water quality constituents (nitrogen forms, phosphorus forms, and TSS) were calculated at each monitoring station for each month of the 1998 water year, using the following equation:

$$L_{ijk} = C_{ijk} * Flow_{jk} * f_1 * f_2$$

where:

L_{ijk} = loading of constituent *i* during month *j* at station *k* (in units of tons/month)

C_{jk} = observed concentration of constituent *i* during month *j* at station *k* (in units of mg/l)

$Flow_{jk}$ = cumulative flow during month *j* at station *k* (in units of ft^3), and

f_1, f_2 = conversions factors (used to convert mg to tons and l to ft^3).

Missing data points were eliminated by averaging the preceding and succeeding observations (e.g., missing nutrient and TSS concentrations from the December 1997 sampling event were replaced by the averages of the November 1997 and January 1998 values.) Annual loadings for the 1998 water year were estimated by summing the estimated monthly loadings for the period October 1997 - September 1998. The estimated monthly and annual loadings are summarized in Table 5.

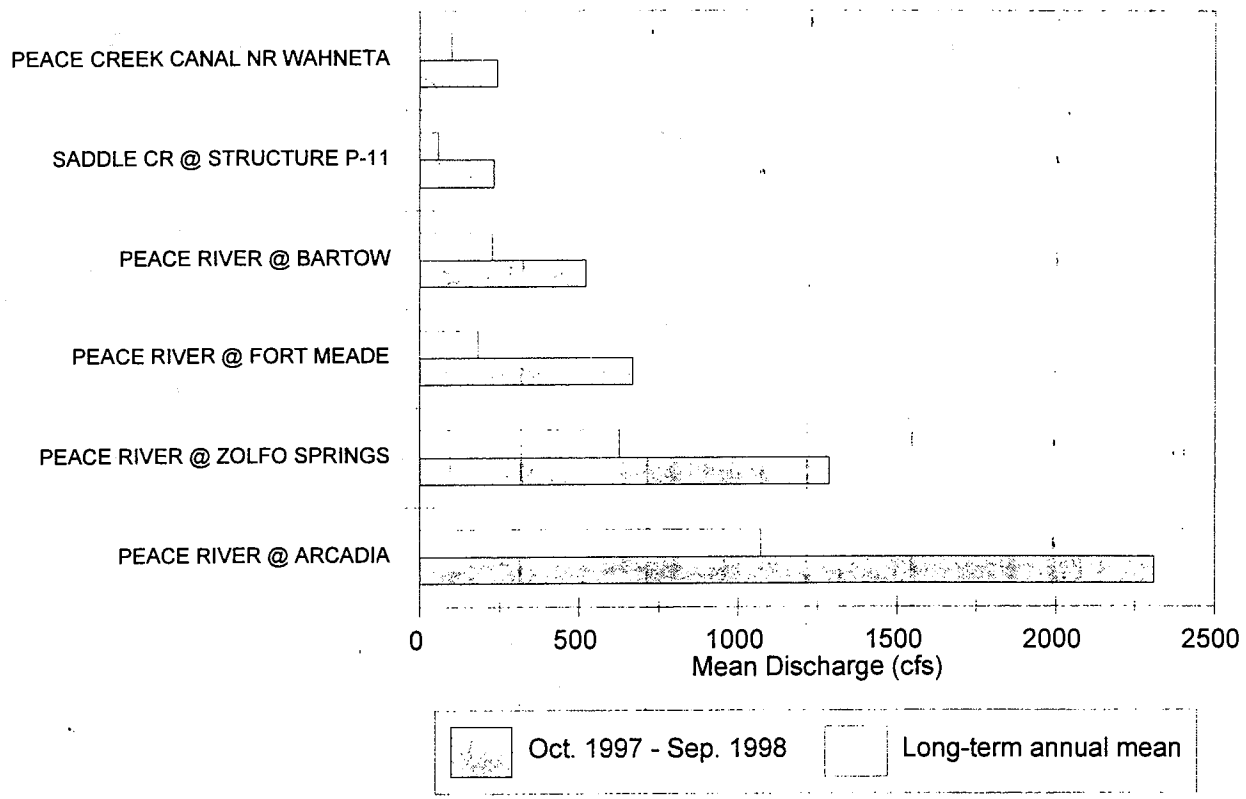

Fig. 2. Annual mean discharge at six long-term gaging stations in the Peace River watershed. (Data for the 1998 water year have not yet been published by the USGS, and are provisional.)(Source: USGS)

Table 5. Estimated monthly and annual TN loadings (tons) during the 1998 water year.

SAMPLING STATION	Oct. 1997	Nov. 1997	Dec. 1997	Jan. 1998	Feb. 1998	Mar. 1998	Apr. 1998	May 1998	Jun. 1998	Jul. 1998	Aug. 1998	Sep. 1998	Annual Total
Peace Creek Canal near Wahneta	4	22	29	49	61	79	30	9	4	7	7	30	333
Saddle Creek at Structure P-11	15	56	70	72	127	195	49	17	<1	11	4	104	720
Peace River at Bartow	17	57	75	138	61	224	82	26	1	11	13	56	761
Peace River at Ft. Meade	12	48	59	174	184	298	122	22	1	18	12	47	999
Peace River at Zolfo Springs	42	216	160	277	313	426	135	38	13	50	49	157	1,877
Peace River at Arcadia	105	533	308	466	556	752	189	47	25	64	75	231	3,350
Charlie Creek near Gardner	29	222	126	146	180	240	35	6	3	3	12	60	1,063
Horse Creek near Myakka Head	2	18	9	10	10	15	<1	<1	<1	<1	4	11	80
Horse Creek near Arcadia	42	128	63	79	58	128	10	1	1	7	30	63	611
Shell Creek near Punta Gorda	66	12	28	97	128	117	21	4	3	24	40	126	667

Table 5 (cont.) Estimated monthly and annual loadings (tons) of dissolved inorganic nitrogen (ammonia-N, nitrate-N, and nitrite-N) during the 1998 water year.

SAMPLING STATION	Oct. 1997	Nov. 1997	Dec. 1997	Jan. 1998	Feb. 1998	Mar. 1998	Apr. 1998	May 1998	Jun. 1998	Jul. 1998	Aug. 1998	Sep. 1998	Annual Total
Peace Creek Canal near Wahneta	1.1	5.0	6.5	5.8	3.6	10.0	1.1	2.6	1.4	1.6	2.5	6.0	47.2
Saddle Creek at Structure P-11	0.1	0.4	0.5	0.7	0.2	0.8	1.4	0.1	<0.1	<0.1	<0.1	0.1	4.2
Peace River at Bartow	0.8	11.1	14.8	7.8	8.1	25.8	7.8	1.1	0.5	2.7	0.5	11.4	92.2
Peace River at Ft. Meade	1.8	15.5	18.9	18.5	26.6	66.1	29.4	2.2	0.5	9.7	0.9	14.5	204.5
Peace River at Zolfo Springs	13.3	109.1	81.0	53.2	70.9	113.7	38.2	11.5	8.6	29.8	11.9	71.9	613.0
Peace River at Arcadia	33.4	266.3	153.9	101.6	225.8	208.6	58.1	19.1	15.7	34.1	14.5	101.1	1,232.3
Charlie Creek near Gardner	3.1	93.9	53.4	25.2	58.6	40.8	5.0	1.4	1.3	0.5	3.6	7.8	294.6
Horse Creek near Myakka Head	0.1	1.4	0.7	1.4	1.4	0.9	<0.1	<0.1	<0.1	0.1	0.2	1.2	7.3
Horse Creek near Arcadia	3.8	50.6	25.0	15.1	25.1	28.1	3.2	0.9	0.3	1.1	12.4	17.7	183.4
Shell Creek near Punta Gorda	7.7	0.3	0.6	17.3	16.3	17.4	2.1	<0.1	0.1	0.4	1.3	13.5	76.8

Table 5 (cont.) Estimated monthly and annual loadings (tons) of total phosphorus (TP) during the 1998 water year.

SAMPLING STATION	Oct. 1997	Nov. 1997	Dec. 1997	Jan. 1998	Feb. 1998	Mar. 1998	Apr. 1998	May 1998	Jun. 1998	Jul. 1998	Aug. 1998	Sep. 1998	Annual Total
Peace Creek Canal near Wahneta	0.9	2.9	3.9	5.0	5.2	10.5	3.1	1.6	0.7	3.2	1.2	8.2	46.5
Saddle Creek at Structure P-11	1.4	7.4	9.3	21.1	19.9	34.5	8.5	2.6	<0.1	1.3	0.3	10.0	116.2
Peace River at Bartow	2.1	24.2	32.2	25.9	24.8	43.8	14.5	4.4	0.8	10.9	5.9	39.7	229.2
Peace River at Ft. Meade	5.7	32.0	39.0	84.9	80.2	206.8	74.2	9.3	0.7	11.5	5.6	41.1	591.1
Peace River at Zolfo Springs	18.7	89.8	66.7	148.7	170.0	278.8	95.1	19.7	6.5	26.0	44.3	106.5	1,071.3
Peace River at Arcadia	40.8	202.1	116.8	227.2	281.0	490.1	143.8	25.8	9.2	34.5	37.5	134.1	1,742.9
Charlie Creek near Gardner	9.4	43.8	24.9	44.1	70.3	90.2	16.0	2.9	0.7	3.7	4.9	20.7	331.4
Horse Creek near Myakka Head	0.7	4.9	2.4	2.8	2.5	4.7	0.2	<0.1	<0.1	0.3	1.0	4.3	23.9
Horse Creek near Arcadia	16.5	28.3	14.0	25.4	41.1	44.8	3.6	0.4	0.4	3.4	7.8	24.2	209.9
Shell Creek near Punta Gorda	9.3	1.3	3.0	7.7	10.6	13.2	2.6	0.4	0.5	5.8	5.3	19.0	78.7

Table 5 (cont.) Estimated monthly and annual loadings (tons) of dissolved inorganic phosphorus (PO_4-P) during the 1998 water year.

SAMPLING STATION	Oct. 1997	Nov. 1997	Dec. 1997	Jan. 1998	Feb. 1998	Mar. 1998	Apr. 1998	May 1998	Jun. 1998	Jul. 1998	Aug. 1998	Sep. 1998	Annual Total
Peace Creek Canal near Wahneta	0.6	1.8	2.4	3.5	3.2	6.6	1.8	1.1	0.5	2.6	0.9	6.1	31.0
Saddle Creek at Structure P-11	0.4	0.1	0.1	3.2	5.3	9.8	4.0	1.0	<0.1	<0.1	<0.1	<0.1	24.0
Peace River at Bartow	0.1	23.9	31.8	11.2	9.4	22.1	7.3	1.5	0.8	8.5	4.0	31.1	151.8
Peace River at Ft. Meade	3.9	30.3	36.9	56.6	59.1	140.7	59.9	1.9	0.4	9.7	3.5	33.3	436.1
Peace River at Zolfo Springs	8.5	80.3	59.6	110.1	123.2	245.7	83.8	14.4	6.1	24.1	27.9	87.8	871.7
Peace River at Arcadia	32.8	16.2	9.4	176.4	221.8	420.0	129.1	21.0	8.2	31.4	34.5	106.8	1,207.5
Charlie Creek near Gardner	8.0	32.6	18.5	37.8	51.7	78.1	13.8	2.5	0.7	3.4	4.2	13.9	265.1
Horse Creek near Myakka Head	0.5	5.3	2.6	2.3	1.9	3.9	0.1	<0.1	<0.1	0.2	0.8	3.4	21.1
Horse Creek near Arcadia	14.8	23.4	11.6	21.2	33.0	38.0	3.0	0.3	0.3	2.4	6.6	18.8	173.4
Shell Creek near Punta Gorda	6.6	0.5	1.1	5.8	6.6	10.7	1.8	0.2	0.3	4.2	4.0	8.9	50.6

Table 5 (cont.) Estimated monthly and annual loadings (tons) of total suspended solids (TSS) during the 1998 water year.

SAMPLING STATION	Oct. 1997	Nov. 1997	Dec. 1997	Jan. 1998	Feb. 1998	Mar. 1998	Apr. 1998	May 1998	Jun. 1998	Jul. 1998	Aug. 1998	Sep. 1998	Annual Total
Peace Creek Canal near Wahneta	5	84	111	62	24	26	38	9	10	6	37	282	693
Saddle Creek at Structure P-11	269	886	1,115	2,112	1,671	2,594	499	344	1	181	41	1,339	11,052
Peace River at Bartow	442	253	337	1,000	1,295	1,320	576	175	7	46	242	492	6,186
Peace River at Ft. Meade	154	71	87	1,306	648	1,384	985	442	13	54	285	441	5,870
Peace River at Zolfo Springs	267	1,162	863	1,395	442	152	616	366	9	33	747	1,880	7,931
Peace River at Arcadia	399	2,276	1,315	2,212	627	328	672	368	52	190	997	1,414	11,850
Charlie Creek near Gardner	29	916	521	108	1,232	188	12	6	1	3	3	443	3,462
Horse Creek near Myakka Head	10	60	29	4	5	10	<1	<1	<1	1	14	91	226
Horse Creek near Arcadia	57	2,587	1,277	48	178	51	4	<1	<1	38	30	421	4,691
Shell Creek near Punta Gorda	194	60	141	281	47	60	7	5.4	3.3	38	46	148	1,032

3.3 Loadings to Charlotte Harbor

In addition to the constituent loadings that occur at individual gaging stations within the Peace River watershed, the CHNEP and other stakeholders are also interested in quantifying the nutrient and TSS loads that are discharged from the watershed to Charlotte Harbor. Estimates of these values can be obtained by summing the loadings observed at the three gaging stations (Peace River at Arcadia, Horse Creek near Arcadia, and Shell Creek near Punta Gorda) that are located immediately upstream from the Harbor on the river and its southernmost tributaries. These three stations have a cumulative drainage area of 1,958 mi^2 (USGS 1997), representing 83% of the Peace River watershed (Hammett 1987). Assuming that the portion of the watershed lying downstream from the gages generates loadings of each constituent that are comparable (on a per-acre basis) to the upstream portion, loadings observed at these stations should represent (as a first approximation) about 83% of the watershed totals. Estimated annual loadings calculated using these assumptions are shown in Table 6.

In an earlier study, average annual loadings of TN, TP, and TSS from the Peace River watershed to Charlotte Harbor during the years 1985-1991 were estimated by Coastal Environmental, Inc. (1995), as part of a watershed assessment project funded by the SWFWMD Surface Water Improvement and Management (SWIM) program. For each constituent, the estimated annual loadings calculated by Coastal Environmental, Inc. for the 1985-1991 period are substantially lower than the values we have calculated for the 1998 water year (Table 6). These differences are presumably due, at least in part, to the above-average rainfall and stormwater runoff that occurred in the watershed during the 1998 water year.

Table 6. Estimated constituent loadings (tons/year) from the Peace River watershed to Charlotte Harbor.

	STUDY PERIOD AND DATA SOURCE	
CONSTITUENT	1985-1991 calendar years (Coastal Environmental, Inc. 1995)	1998 water year (this study)
TN	1,800	4,628
DIN		1,492
TP	640	2,032
PO_4-P		1,431
TSS	14,400	16,574

3.4 Unit area loads

Additional insight into water quality conditions within a watershed can often be obtained by examining the constituent "yields" or "unit area loads" (expressed in units of lbs/acre/year) observed in different portions of the basin. Estimated unit area loads for the 10 gaging stations monitored during the 1998 water year are summarized in Table 7.

The largest per-acre TN loading (17 lbs/acre/yr) were observed at the Saddle Creek gaging station, presumably reflecting the impact of discharges from Lake Hancock, a hypereutrophic waterbody that lies immediately upstream from the station. Unit area DIN loads at the Saddle Creek station were low relative to other sites in the watershed, and DIN concentrations at this station were frequently below detection limits, suggesting that algal populations in the lake were effectively removing much of the available DIN from the water column and converting it to organic forms. Nitrogen fixation by blue-green algae within Lake Hancock may also provide a significant proportion of the TN observed at the Saddle Creek station.

The Saddle Creek station also exhibited the largest unit area load of TSS (256 lbs/acre/year), perhaps due to episodic discharges of algal cells and unconsolidated sediments resuspended from the bottom of Lake Hancock during storm events. A much lower unit area load (50 lbs/acre/year) was calculated for the Bartow gaging station, which is located less than 5 miles downstream from the Saddle Creek station.

Estimated unit area TP loadings were quite elevated (ca. 4 lbs/acre/yr) at the stations located on the main stem of the Peace River at Ft. Meade, Zolfo Springs and Arcadia, reflecting the abundance of phosphate-bearing geological deposits and the active mining and processing of phosphate products that occur in this portion of the watershed.

Substantial increases in estimated unit area loads of TN, DIN, TP, PO_4-P, and TSS occurred between the upstream and downstream stations located on Horse Creek, suggesting the potential presence of significant anthropogenic sources of those constituents between the two stations.

Table 7. Estimated unit area loads, 1998 water year.

STATION	DRAINAGE AREA (mi^2)	ESTIMATED UNIT AREA LOAD (lbs/acre/year)				
		TN	DIN	TP	PO4-P	TSS
Peace Creek Canal near Wahneta	162	6	0.9	0.9	0.6	13
Saddle Creek at Structure P-11	135	17	0.1	2.7	0.6	256
Peace River at Bartow	390	6	0.7	1.8	1.2	50
Peace River at Ft. Meade	480	7	1.4	4.0	2.9	40
Peace River at Zolfo Springs	826	7	2.3	4.1	3.3	30
Peace River at Arcadia	1,367	8	2.8	4.0	2.8	25
Charlie Creek near Gardner	330	10	2.8	3.1	2.5	33
Horse Creek near Myakka Head	42	6	0.6	1.8	1.6	17
Horse Creek near Arcadia	218	9	2.6	3.0	2.5	67
Shell Creek near Punta Gorda	373	6	0.6	0.7	0.4	9

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