Annual Report on
Water Quality Status and Trends
in the Peace and Myakka River Basins

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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
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Cities of Sanibel, Cape Coral, Fort Myers, Punta Gorda, North Port, Venice and Fort Myers Beach
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Executive Summary

Background

During the 1980's and 1990's a number of federal, state and regional resource management initiatives — including the U.S. EPA National Estuary Program (NEP), the Florida Surface Water Improvement and Management (SWIM) Program, and the Southwest Florida Water Management District Comprehensive Watershed Management (CWM) Program — designated the Charlotte Harbor watershed as a priority management area. Protection of water quality is a fundamental goal of these watershed management efforts. Meeting this goal will require adequate levels of information on water quality conditions and trends at a watershed-wide geographic scale.

In 1996 a watershed assessment project funded by the Charlotte Harbor SWIM program raised questions regarding the adequacy of the currently-available water quality data to support watershed management decisions, and recommended that more frequent (e.g., biweekly or monthly) water quality monitoring be initiated at selected stream gaging stations in the Peace and Myakka River basins (Squires et al. 1996). That recommendation, and other concerns regarding the sufficiency of available information to characterize water quality conditions and pollutant loadings in the Charlotte Harbor watershed, motivated the Charlotte Harbor National Estuary Program (CHNEP) and a number of its partner organizations to carry out the water quality monitoring and assessment project reported here.

Using funds provided by the 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), the Florida Department of Environmental Protection (FDEP), and the City of Punta Gorda, the cooperating organizations carried out a monthly water quality monitoring program at 10 stations in the Peace River basin from October 1997 through September 1998, at 10 stations in the Peace River basin and 5 stations in the Myakka River basin from October 1998 through September 1999, and at 11 stations in the Peace River basin and 5 stations in the Myakka River basin from October 1999 through September 2000. This report provides a summary of water quality conditions and estimated pollutant loads occurring during those periods. As background information, the report also includes an overview of long-term water quality and streamflow trends occurring at selected locations in the Peace and Myakka River basins between 1970 and 1998.

Sampling Methods

Hydrographic parameters (specific conductance, salinity, pH, temperature, and dissolved oxygen) were measured at each monitoring station using Hydrolab™ or YSI™ multi-probe datasondes. Water samples were collected at mid-depth at each station and transported on ice to the analytical laboratory. Laboratory analytes included total organic carbon (TOC), nitrate+nitrite nitrogen (NO_{2+3} –N), ammonium nitrogen (NH_4 -N), total Kjeldahl nitrogen (TKN), dissolved ortho-phosphate (PO_4), total phosphorus (TP), chlorophyll *a*, color, total suspended solids (TSS), turbidity, and water column transparency (Secchi disk depth). All sampling activities were performed by SWFWMD staff, and all sample collection, preservation, transport, and chain of custody procedures were carried out in accordance with an EPA-approved quality assurance plan.

Ambient Water Quality

A water quality index (WQI) developed for Florida streams by FDEP was used to characterize existing water quality conditions at the stations monitored during the 1997-2000 study period. The WQI was developed by Hand et al. (1994, 1996), based on sampling data collected in 1987 from 2,000 stream reaches throughout the state. Those data were used to determine percentile distributions for several groups of water quality indicators (e.g., nutrients, water clarity, dissolved oxygen and oxygen-demanding substances) on a statewide basis (Hand et al. 1994, 1996). The calculation of WQI values is 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 (Hand et al. 1994, 1996).

For this study, average WQI values were calculated using five parameters (turbidity, total suspended solids, total organic carbon, nitrate+nitrite nitrogen, and total nitrogen) to characterize water quality conditions observed during the 1997-2000 monitoring period (Table ES-1). The Saddle Creek at Structure P-11 station, which is located immediately downstream from Lake Hancock in the upper Peace River basin, exhibited the poorest water quality among the sites sampled, falling in the 75th to 95th percentiles of Florida streams for most parameters. Overall, six sites (all located in the Peace River basin) produced WQI values >60, indicative of “poor” water quality conditions. Four sites (Horse Creek near Myakka Head, Shell Creek near Punta Gorda, Myakka River at Myakka City, and Myakka River near Sarasota) exhibited average WQI values that would be characterized as “good” (average WQI < 45) based on the FDEP classification system. The remaining sites were characterized as “fair” based on the WQI.

Specific conductance values greater than 1,275 umhos/cm, the Florida criterion for Class I and Class III surface waters, were observed at four stations (Joshua Creek at Nocatee, Shell Creek near Punta Gorda, Big Slough near Myakka City, and Big Slough near North Port) during the study period.

Stream Discharge and Pollutant Loads

The monitoring sites used in this project were co-located with U.S. Geological Survey (USGS) long-term stream gaging stations. At each site the USGS collects continuous records of stream stage (elevation of the water surface), makes periodic measurements of stream discharge (flow volume per unit time) throughout a range of stages, and computes an estimate of daily mean stream discharge based on the continuous stage records and the measured stage-discharge relationship. The long-term gaging stations are operated and maintained by the USGS as part of that agency’s national surface water monitoring network.

For each site, daily mean discharge estimates were obtained from the USGS for the 1998 and 1999 "water years." (By convention, the USGS defines a "water year" as the 12-month period extending from October 1 through September 30. Each water year is numbered based on the calendar year in which it ends. Thus, the year ending September 30, 1999, is called the "1999 water year.") Records for the 2000 water year had not yet been published by the USGS at the time this report was prepared.

Above-average rainfall associated with the 1997-1998 El Niño event produced increased stormwater runoff and elevated stream discharge during the 1998 water year. At the Peace River-Arcadia gaging site, for example, annual average discharge during that year was more than two times higher than the site's long-term (1932-1998) average. Rainfall and runoff returned to more typical levels during the 1999 water year, and annual average discharge at most monitoring sites were near or below their long-term means.

We calculated annual mass loads of selected water quality constituents (nitrogen forms, phosphorus forms, and TSS) for the 1998 and 1999 water years, using the flow data provided by the USGS and water quality data from the monthly monitoring program. Monthly loads for each constituent were calculated by summing estimated daily values, which were obtained by multiplying monthly average constituent concentration (milligrams per liter) and daily average stream discharge (liters per day). Annual loads were estimated by summing the monthly values. These estimated annual loads are summarized in Table ES-2. (Gaps in the available discharge data prevented calculation of loading estimates for USGS gage 02299455, located on Big Slough Canal north of the City of North Port.)

We also calculated unit area loads or "yields" of pollutants (expressed in units of kg/ha/yr) for each gaging station whose surface drainage area has been estimated by the USGS. These sub-basin yields are shown in Table ES-3. Yield information is helpful to watershed managers because it can be used as a screening tool to identify sub-basins that may be contributing disproportionate loadings of particular pollutants. In the current data set, for example, the "Saddle Creek at Structure P-11" sub-basin appears to be discharging disproportionate loads of TSS and TN (Table ES-3), presumably reflecting the severely impaired water quality of Lake Hancock, which is located immediately upstream from the station.

Table ES-1. Florida stream water quality index (WQI) values, based on October 1997 - September 2000 monitoring data.

STATION	Turbidity	TSS	TOC	TN	NO_{2+3}	TP	Avg WQI (w/out TP)	Water Quality Characterization
Peace Creek Canal near Wahneta	54.4	51.4	71.7	76.1	77.6	78.9	66.2	"poor"
Saddle Creek at Structure P-11	>95	>95	75.3	>95	16.4	76.1	76.8	"poor"
Peace River at Bartow	67.2	80.9	69.0	80.4	73.1	91.4	74.1	"poor"
Peace River at Ft. Meade	54.5	63.6	53.3	70.7	82.1	90.4	64.8	"poor"
Peace River at Zolfo Springs	45.0	52.4	52.8	71.4	90.9	93.6	62.5	"poor"
Peace River at Arcadia	48.1	47.9	56.1	65.7	87.2	90.0	61.0	"poor"
Joshua Creek at Nocatee	18.3	27.1	55.4	82.6	>95	61.8	55.2	"fair"
Charlie Creek near Gardner	19.6	23.3	72.1	60.4	77.0	83.0	50.5	"fair"
Horse Creek near Myakka Head	18.5	34.0	65.3	46.3	55.2	80.2	43.8	"good"
Horse Creek near Arcadia	17.4	24.6	61.6	58.5	83.2	80.5	49.1	"fair"
Shell Creek near Punta Gorda	14.7	14.5	62.2	50.2	43.6	57.1	37.1	"good"
Myakka River at Myakka City	12.1	16.2	66.0	41.8	36.6	73.0	34.5	"good"
Myakka River near Sarasota	16.0	23.2	71.2	56.4	15.3	77.0	36.4	"good"
Deer Prairie Slough near North Port	54.6	53.9	72.9	71.9	17.5	80.2	54.2	"fair"
Big Slough Canal near Myakka City	57.4	60.8	68.0	75.9	72.7	76.8	67.0	"poor"
Big Slough Canal near North Port	42.6	37.7	65.1	55.3	45.9	73.4	49.3	"fair"

Table ES-2. Estimated annual loads (metric tons/year) of selected water quality constituents during water year 1998 (WY98) and water year 1999 (WY99).

	TN		Inorganic N		TP		PO_4-P		TSS	
Station	WY98	WY99	WY98	WY99	WY98	WY99	WY98	WY99	WY98	WY99
Peace Creek Canal near Wahneta	278	--	38	10	37	12	24	10	585	146
Saddle Creek at Structure P-11	771	--	4	1	115	10	24	3	12,111	1,965
Peace River at Bartow	781	--	86	18	214	70	132	49	8,309	2,645
Peace River at Ft`. Meade	963	--	179	28	540	112	384	86	6,454	1,234
Peace River at Zolfo Springs	1,811	--	559	136	1,038	311	850	260	9,167	1,848
Peace River at Arcadia	2,997	899	1,056	295	1,577	551	1,167	484	12,158	4,021
Joshua Creek at Nocatee	--	--	--	121	--	20	--	16	--	285
Charlie Creek nr Gardner	1,057	286	281	42	331	111	270	94	3,277	969
Horse Creek nr Myakka Head	78	--	7	1	23	7	21	6	258	44
Horse Creek nr Arcadia	555	--	145	41	197	62	167	54	3,518	102
Shell Creek nr Punta Gorda	624	471	83	56	68	75	48	57	1,293	727
Myakka River at Myakka City	--	--	--	16	--	51	--	48	--	52
Myakka River nr Sarasota	--	284	--	11	--	113	--	97	--	255
Deer Prairie Slough nr North Port	--	--	--	1	--	2	--	2	--	78
Big Slough Canal nr Myakka City	--	--	--	10	--	10	--	8	--	140

Table ES-3. Estimated annual yields (kg/ha/yr) of selected water quality constituents from gaged sub-basins during water year 1998 (WY98) and water year 1999 (WY99).

	TN		Inorganic N		TP		PO_4-P		TSS	
Station	WY98	WY99	WY98	WY99	WY98	WY99	WY98	WY99	WY98	WY99
Peace Creek Canal nr Wahneta	6.6	--	0.9	0.2	0.9	0.3	0.6	0.2	14	3
Saddle Creek at Structure P-11	22.1	--	0.1	0.03	3.3	0.3	0.7	0.1	346	56
Peace River at Bartow	7.7	--	0.8	0.2	2.1	0.7	1.3	0.5	82	26
Peace River at Ft`. Meade	8.0	--	1.5	0.2	4.5	0.9	3.2	0.7	54	10
Peace River at Zolfo Springs	8.5	--	2.6	0.6	4.9	1.5	4.0	1.2	43	9
Peace River at Arcadia	8.5	2.5	3.0	0.8	4.4	1.6	3.3	1.4	34	11
Joshua Creek at Nocatee	--	--	--	3.5	--	0.6	--	0.5	--	8
Charlie Creek nr Gardner	12.4	3.3	3.3	0.5	3.9	1.3	3.2	1.1	38	11
Horse Creek nr Myakka Head	7.4	--	0.7	0.1	2.2	0.6	1.9	0.6	24	4
Horse Creek nr Arcadia	9.8	--	2.6	0.7	3.5	1.1	3.0	1.0	62	2
Shell Creek nr Punta Gorda	6.5	4.9	0.9	0.6	0.7	0.8	0.5	0.6	13	8
Myakka River at Myakka City	--	--	--	0.5	--	1.6	--	1.5	--	2
Myakka River nr Sarasota	--	4.8	--	0.2	--	1.9	--	1.6	--	4
Deer Prairie Slough nr North Port	--	--	--	--	--	--	--	--	--	--
Big Slough Canal nr Myakka City	--	--	--	1.0	--	1.1	--	0.9	--	15

In addition to the constituent loads observed at individual gaging stations in the Peace and Myakka River basins, the CHNEP and other stakeholders are also interested in quantifying the annual mass loads of nutrients and TSS that are discharged from the watershed to Charlotte Harbor. For the Peace River basin, estimates of these values can be obtained by summing the estimated loads from three gaging stations (Peace River at Arcadia, Horse Creek near Arcadia, and Shell Creek near Punta Gorda), which are located immediately upstream from the Harbor on the Peace 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 loads of each constituent that are comparable (on a per-unit-area basis) to the upstream portion, loads observed at these stations should represent (as a first approximation) about 83% of the watershed totals. Estimated annual loads calculated using these assumptions are shown in Table ES-4. (Similar estimates were not calculated for the Myakka River basin, because <50% of the surface area of that basin is currently gaged.) Previous loading estimates, prepared by Coastal Environmental, Inc., as part of an earlier SWIM-funded watershed assessment project, are also shown in Table ES-4.

Table ES-4. Estimated annual loads (metric tons/year) of selected constituents from the Peace River watershed to Charlotte Harbor.

Constituent	1985-1991 average[a]	1998 water year[b]	1999 water year[b]
TN	1,633	5,013	--
Inorganic N	--	1,540	471
TP	580	2,212	825
PO_4-P	--	1,659	714
TSS	13,061	20,366	5,821

[a] Data source = Coastal Environmental, Inc. 1995
[b] Data source = this study

Long-Term Trends in Streamflow and Water Quality

When interpreting the water quality conditions observed during the 1998-2000 water years, it is helpful to evaluate them in the context of long-term trends in water quality and stream discharge that have occurred in the Peace and Myakka River basins in recent decades.

To assist in that effort, water quality observations for water years 1970-1998 were obtained from the USGS database. These observations were examined for the presence of long-term trends in their annual minimum, annual mean, and annual maximum values using the nonparametric Mann-Kendall test (Gilbert 1987). Trend tests were not performed for water quality constituents for which the available period of record was <10 years.

We also downloaded daily and monthly stream discharge data from the USGS database for water years 1970 through 1999. We assessed potential changes in flow regime by performing trend tests on dry season ("lowest monthly mean"), wet season ("highest monthly mean"), and annual average (mean of the monthly means) discharge at each monitoring station.

Streamflow Trends

Statistically significant declining trends in dry-season discharge were observed at two gaging stations on the main stem of the Peace River (at Bartow and Zolfo Springs) during water years 1970-1999. Significant increasing trends in dry season flows occurred on three Peace River tributaries (Charlie Creek, Joshua Creek, and Horse Creek) and at the Myakka River-Sarasota gage. Increasing trends in annual mean discharge occurred at four stations (Saddle Creek at Structure P-11, Peace River-Ft. Meade, Joshua Creek-Nocatee, and Horse Creek-Myakka Head). No statistically significant trends in dry season, wet season, or annual mean discharge were observed at the Peace River-Arcadia gage over the 1970-1999 period.

Long-term trends in discharge and runoff in the Peace River watershed are a topic of considerable interest to resource managers in the west-central Florida region. Several investigators have documented long-term declines in annual mean discharge, particularly at gaging stations on the river's main stem in the northern portion of the watershed, that occurred between the 1930's and the mid-1960's (e.g., Hammett 1987, Coastal Environmental Services 1995). These declining trends appear to have been caused by a combination of natural (e.g., reduced frequency of tropical cyclones) and anthropogenic factors (e.g., increased groundwater pumpage; surface strip mining)(Hammett 1987, Coastal Environmental Services 1995). Because these declines occurred prior to 1970 (Hammett 1987), they were not detected in the analyses reported here.

Water quality trends

During the 1970-1998 period, specific conductance — a potential indicator of the magnitude of groundwater discharges to surface waters — exhibited significant increasing trends at four stations (Charlie Creek-Gardner, Joshua Creek-Nocatee, Horse Creek-Myakka Head, and Myakka River-Sarasota). Declining trends in specific conductance occurred at three stations (Saddle Creek at Structure P-11, Peace River at Bartow and Zolfo Springs), all located in the northern portion of the Peace River basin. In central Florida increasing trends in specific conductance in inland surface waters are often associated with increasing groundwater discharges, frequently due to agricultural or residential irrigation or industrial discharges. The declining specific conductance trends observed at some upper Peace River stations were presumably caused by declines in groundwater discharge, which enters the river from a variety of man-made sources and from natural springs and seeps located in the riverbed.

Concentrations of NO_{2+3} -N (nitrite plus nitrate nitrogen) increased significantly at the Horse Creek-Arcadia and Charlie Creek-Gardner gage sites during the 1970-1998 period. Significant declines in NO_{2+3} -N concentrations occurred at the Bartow, Ft. Meade, and Zolfo Springs gages on the main stem of the Peace River. Changes in NO_{2+3} –N concentrations in surface water bodies are frequently used by watershed managers as indicators of changing inorganic nitrogen loads from manmade sources.

Concentrations of ammonia nitrogen also declined significantly at several stations on the main stem of the Peace River (Bartow, Ft. Meade, Zolfo Springs and Arcadia), presumably reflecting long-term reductions in discharges of ammonia-N via domestic and industrial wastewaters in the upper Peace River basin.

Phosphorus (PO_4 and TP) concentrations declined significantly at several sites in the Peace River basin (Horse Creek-Arcadia, and Peace River at Bartow, Ft. Meade, Zolfo Springs, and Arcadia), but increased significantly at a Peace River tributary site (Charlie Creek-Gardner) and at a long-term monitoring station located on the Myakka River (Myakka River-Sarasota). The increasing trend observed at the Myakka River site, which is located between the Upper and Lower Myakka Lakes within Myakka River State Park, may be an item of interest to state and regional water resource managers because of its potential implications for future water quality conditions in the park's lakes.

1.0 INTRODUCTION

1.1 Background

During the 1980's and 1990's a number of federal, state and regional resource management initiatives — including the U.S. EPA National Estuary Program (NEP), the Florida Surface Water Improvement and Management (SWIM) Program, and the Southwest Florida Water Management District Comprehensive Watershed Management (CWM) Program — designated the Charlotte Harbor watershed as a priority management area. Protection of water quality is a fundamental goal of these watershed management efforts. Meeting this goal will require adequate levels of information on water quality conditions and trends at a watershed-wide geographic scale.

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1.2 Water Quality Management Issues

The Peace and Myakka River basins lie in a naturally fertile area that contains extensive phosphate-bearing geological deposits (the Bone Valley formation of the Hawthorn group) and experiences abundant seasonal 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 "eutrophic" (exhibit high rates of biological productivity) as a result of naturally elevated phosphate inputs (Odum 1953, Canfield and Hoyer 1988). These naturally eutrophic waterbodies have the potential to become hypereutrophic — exhibiting undesirably high levels of biological productivity — if human activities cause nutrient loads to increase to excessive levels. Several historically-eutrophic lakes located in the headwaters region of the Peace River basin (e.g., Lake Parker, Lake Hancock, Banana Lake) appear to have shifted to hypereutrophic productivity levels in recent decades as a result of additional, manmade nutrient loads.

Eutrophication is a process in which increasing nutrient loads cause changes in the water chemistry and ecological structure of surface water bodies. These changes, which are currently affecting many Florida waters, often include:

- increasing rates of biological production, 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

(Day et al. 1989). In addition to ecological and esthetic impacts, excessive nutrient loads 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 an 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 through its rulemaking process and are established for all waterbodies within a state's jurisdiction (e.g., Ch. 62-302.400, Florida Administrative Code). *Water quality criteria*, which describe the specific water quality conditions needed 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 manmade nutrient discharges, state criteria typically include provisions intended to prevent excessive loads from anthropogenic sources (e.g., stormwater runoff; wastewater discharges from municipal, industrial, and agricultural facilities). State policies and programs also support the restoration of water bodies degraded by historical anthropogenic discharges. Like many states, however, Florida has not established numerical criteria for regulating nutrient loads and eutrophication, relying instead on a narrative guideline which states 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 and Myakka River basins, where many surface water bodies receive naturally-elevated phosphorus loads as well as manmade nutrient discharges from a variety of point and nonpoint sources, regular monitoring and reporting of water quality conditions are helpful to ensure that watershed stakeholders and managers have access to the information needed to assess progress toward the achievement of these state and national water quality goals.

1.3 Report Objectives and Structure

This report provides a summary of water quality status and trends at a number of USGS gaging stations located in the Peace and Myakka River basins. The report is organized as follows:

- **Sect. 2.0 Existing Water Quality Conditions** – summarizes the monthly water quality monitoring data collected at 10 gaging stations during the 1998 water year and 15 stations during the 1999 water year, and pollutant loading estimates calculated using those data.

- **Sect. 3.0 Long-term Trends in Stream Flow and Water Quality** – summarizes stream discharge and water quality trends observed at the Peace and Myakka River gaging stations over the period 1970 through 1999.

- **Sect. 4.0 References Cited**

- **Appendix: Quarterly QA reports, Water Year 2000**

2.0 Existing Water Quality Conditions

2.1 Methods

In order to characterize current water quality conditions, monthly monitoring was conducted at a number of sites in the Peace and Myakka River basins during water years 1998, 1999, and 2000. The monitoring locations used each year are listed in Table 1.

The water quality monitoring stations were co-located with long-term USGS stream gaging stations, whose locations are shown in Fig. 1. At each gaging station the USGS collects continuous records of stream stage, makes periodic measurements of stream discharge throughout a range of stages, and computes an estimate of daily mean stream discharge based on the continuous stage records and the measured stage-discharge relationship.

Co-location of water quality monitoring and stream gaging stations is important for at least three reasons (NRC 1999):

- Concentrations of many water quality constituents vary with stream stage, and adequate information on both concentration and stage is needed to allow these dynamic relationships to be documented and understood;

- Records of stream discharge (volume/time) and constituent concentrations (mass/volume) are necessary for the calculation of constituent loadings (mass/time), which are important indicators of the effectiveness of water quality management efforts;

- Watershed management efforts are more likely to succeed if managers have an adequate understanding of relationships between the quantity and quality of surface water flows within the watershed, and relationships between these variables and other ecosystem components.

Monthly water quality monitoring began in the Peace River watershed in October 1997, and in the Myakka River basin in October 1998. Water samples were collected by SWFWMD field staff over a three-day period during the first week of each month. Stations located in the northern portion of the Peace River basin were normally sampled on the initial day of field work; the remaining stations were sampled over the following two days.

Water quality parameters monitored included: specific conductance, pH, temperature, dissolved oxygen (DO), total organic carbon (TOC), nitrate+nitrite nitrogen, ammonia nitrogen, total ammonia+organic nitrogen (TKN), dissolved ortho-phosphate (PO_4), total phosphorus (TP), chlorophyll *a*, color (PCU), total suspended solids (TSS), and turbidity (NTU).

Table 1. Stations where monthly water quality monitoring was conducted, by water year.

Station name	USGS ID	WY 1998	WY 1999	WY2000
Peace Creek Canal near Wahneta	02293987	**U**	**U**	**U**
Saddle Creek at Structure P-11	02294491	**U**	**U**	**U**
Peace River at Bartow	02294650	**U**	**U**	**U**
Peace River at Ft. Meade	02294898	**U**	**U**	**U**
Peace River at Zolfo Springs	02295637	**U**	**U**	**U**
Peace River at Arcadia	02296750	**U**	**U**	**U**
Joshua Creek at Nocatee	02297100	--	**U**	**U**
Charlie Creek near Gardner	02296500	**U**	**U**	**U**
Horse Creek near Myakka Head	02297155	**U**	**U**	**U**
Horse Creek near Arcadia	02297310	**U**	**U**	**U**
Shell Creek near Punta Gorda	02298202	**U**	**U**	**U**
Myakka River at Myakka City	02298608	--	**U**	**U**
Myakka River near Sarasota	02298830	--	**U**	**U**
Deer Prairie Slough near North Port	02299120	--	**U**	**U**
Big Slough Canal near Myakka City	02299410	--	**U**	**U**
Big Slough Canal near North Port[a]	02299455	--	**U**	**U**

[a] Incomplete discharge records prevented calculation of loading estimates for this station

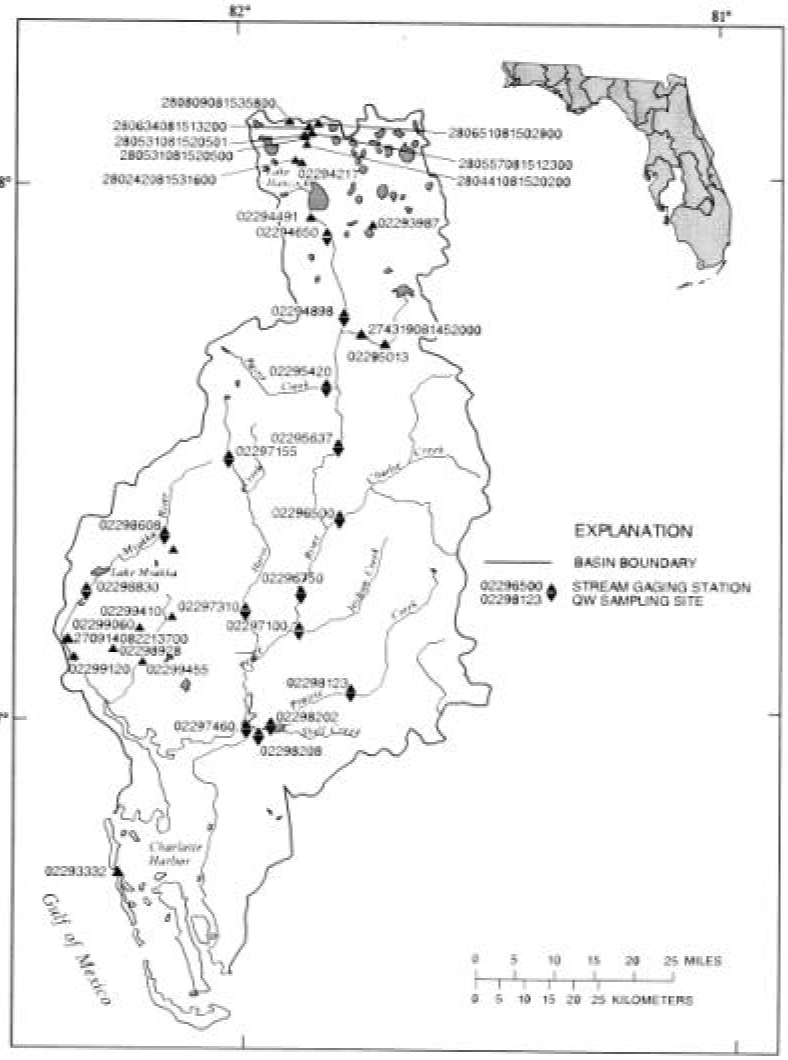

Figure 1. Locations of USGS gaging stations in Peace and Myakka River basins. (Source: USGS)

Hydrographic parameters (specific conductance, salinity, pH, temperature, and DO) were measured in the field using a multi-probe (Hydrolab ™ or YSI ™) datasonde that was calibrated at the beginning and end of each field day.

Water samples were collected at mid-depth at each gaging station and transported on ice to the analytical laboratory. Concentrations of dissolved ortho-phosphate were determined using samples that were field-filtered, immediately following collection, through 0.45 *u*m membrane filters and stored on ice until analysis. Samples used for chlorophyll analysis were filtered in the laboratory immediately following sample delivery, using Gellman A/E (1 *u*m) glass fiber filters, and the filters and attached algal cells were stored frozen prior to chlorophyll extraction. All sampling, sample preservation and transport, and chain of custody procedures were performed in accordance with an EPA-approved quality assurance plan and with existing state (FDEP) and regional (SWFWMD) quality assurance requirements. Chemical analyses were performed by three laboratories (SWFWMD, FDEP, and EQL, Inc.) during the 1997-2000 study period, using EPA-approved analytical methods.

Data quality was assessed and reported on a quarterly basis by SWFWMD staff (see Appendix). The most significant quality assurance issues noted involved exceedances of laboratory holding times (primarily affecting samples collected in December, 1997), and questions concerning the accuracy and precision of some of the nitrogen determinations reported by the analytical laboratory during 1999. Data points affected by these QA concerns have been omitted from the analyses performed for this report. The greatest impact of these omissions has been the creation of data gaps in the estimates of TN loads and yields (Tables 4 and 6) for the 1999 water year.

In addition to the CHNEP-sponsored monitoring effort, the USGS also conducts periodic water quality monitoring at the gaging stations used in this study, following methods that are summarized in annual Water Resource Data reports (e.g., USGS 1999). Where available, the USGS monitoring data have been incorporated in the analyses reported here.

2.2 Constituent concentrations and water quality index (WQI) values

Concentrations of major water quality constituents observed during the 1998-2000 water years are listed in Table 2. Relative to median values observed in Florida streams (e.g., Hand et al. 1994), many of the Peace and Myakka River stations exhibited elevated concentrations of phosphorus forms, nitrogen forms, total organic carbon, turbidity, TSS, color, and chlorophyll *a* during the October 1997-September 2000 time period (Table 2).

The State of Florida has developed a stream water quality index (WQI) — based on observed concentrations of nutrients, water clarity, DO, and oxygen demanding substances — that is helpful for summarizing water quality monitoring data (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). State 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 WQI to the 1997-1999 Peace and Myakka River sampling data is shown in Table 3. (In recognition of the naturally-elevated phosphate concentrations that can occur in these basins, TP concentrations were omitted from the average WQI values shown in Table 3.) 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 sites monitored in this project, falling in the 75th to 90th percentiles of Florida streams for most WQI parameters. Several sites — primarily located in the northern portion of the Peace River basin — exhibited WQI values >60, indicative of "poor" water quality conditions (Table 3). Four sites (Horse Creek near Myakka Head, Shell Creek near Punta Gorda, Myakka River at Myakka City, and Myakka River near Sarasota) exhibited average WQI values that would be characterized as "good" (average WQI < 45) based on the State classification system. The remaining sites exhibited "fair" conditions based on the WQI.

Specific conductance values greater than 1,275 umhos/cm, the Florida criterion for Class I and Class III surface waters, were observed at four stations (Joshua Creek at Nocatee, Shell Creek near Punta Gorda, Big Slough Canal near Myakka City, and Big Slough Canal near North Port) during the study period. The largest and most frequent of these exceedances, with values greater than 1,450 umhos/cm, occurred at the Joshua Creek-Nocatee monitoring station during the spring and summer of water years 1999 and 2000.

Table 2. Constituent concentrations (mean and range) observed in October 1997 - September 2000 sampling events. ("BDL" indicates value below detection limit of analytical method.)

STATION	Turbidity (NTU)	TSS (mg/L)	Color	pH	Spec. Cond. (umhos)	DO (mg/L)	Chl *a* (ug/L)
Peace Creek Canal near Wahneta	6.8 (1.8 – 25.0)	6.9 (BDL – 34.1)	206 (5 – 350)	6.8 (5.9 – 7.5)	288 (125 – 646)	4.1 (0.2 – 8.3)	2.8 (BDL – 20.4)
Saddle Creek at Structure P-11	27.9 (8.6 – 61.0)	57.1 (7.2 – 211.0)	68 (35 – 156)	8.3 (6.5 – 9.6)	202 (147 – 324)	6.1 (1.7 – 11.6)	138.4 (13.4 – 512.0)
Peace River at Bartow	11.2 (1.3 – 55.0)	18.8 (BDL – 151.2)	173 (35 – 320)	6.7 (5.4 – 7.6)	277 (129 – 683)	3.9 (0.1 – 8.5)	23.2 (BDL – 155)
Peace River at Ft. Meade	6.8 (0.8 – 29.0)	10.6 (BDL – 54.0)	100 (20 – 225)	7.3 (6.0 – 8.5)	368 (172 – 685)	6.4 (4.1 – 12.2)	12.6 (BDL – 64.2)
Peace River at Zolfo Springs	4.8 (0.7 – 15.3)	7.2 (BDL – 30.0)	99 (15 – 200)	7.5 (6.3 – 9.0)	396 (194 – 733)	7.4 (4.2 – 11.6)	7.3 (BDL – 79.8)
Peace River at Arcadia	4.5 (0.5 – 15.8)	6.3 (BDL – 26.0)	143 (40 – 300)	7.4 (5.7 – 8.3)	368 (81 – 650)	7.2 (4.1 – 12.4)	2.7 (BDL – 26.7)
Joshua Creek at Nocatee	2.7 (0.6 – 7.5)	3.7 (BDL – 12.0)	106 (25 – 300)	7.2 (5.9 – 8.1)	949 (293 – 1989)	7.7 (5.4 – 20.2)	1.4 (0.5 – 8.5)
Charlie Creek near Gardner	3.0 (0.4 – 14.1)	3.3 (BDL – 10.0)	221 (50 – 500)	6.7 (5.1 – 7.7)	260 (BDL – 630)	6.5 (3.9 – 10.8)	0.7 (BDL – 2.6)
Horse Creek near Myakka Head	2.8 (0.8 – 18.6)	4.6 (BDL – 51.0)	218 (30 – 640)	6.8 (5.4 – 8.3)	159 (66 – 372)	7.3 (4.4 – 10.7)	4.6 (BDL – 129.0)
Horse Creek near Arcadia	2.6 (0.4 – 8.6)	3.5 (BDL – 32.0)	172 (25 – 500)	6.7 (4.4 – 7.8)	397 (72 – 907)	7.0 (3.9 – 11.2)	2.1 (BDL – 31.5)
Shell Creek near Punta Gorda	2.2 (1.0 – 4.7)	2.4 (BDL – 11.0	121 (46 – 220)	7.5 (6.8 – 8.5)	716 (113 – 1300)	5.1 (1.4 – 8.9)	6.9 (BDL – 24.2)
Myakka River at Myakka City	1.8 (0.2 – 7.6)	2.6 (BDL – 10.0)	132 (40 – 300)	7.0 (6.3 – 7.9)	401 (119 – 859)	6.1 (3.3 – 10.1)	1.4 (BDL – 3.8)
Myakka River near Sarasota	2.4 (0.8 – 8.0)	3.3 (BDL – 24.0)	148 (40 – 300)	6.8 (4.6 – 8.5)	355 (101 – 809)	4.1 (BDL – 11.3)	5.8 (BDL – 23.3)
Deer Prairie Slough near North Port	6.9 (1.4 – 24.0)	7.7 (BDL – 53.0)	190 (20 – 350)	6.9 (6.0 – 8.0)	254 (58 – 533)	5.9 (1.1 – 11.6)	2.8 (BDL – 16.0)
Big Slough Canal near Myakka City	57.9 (1.1 – 28.0)	9.7 (BDL – 47.0)	165 (30 – 500)	7.1 (6.5 – 7.8)	617 (298 – 1419)	6.0 (2.3 – 9.6)	4.0 (BDL – 19.2)
Big Slough Canal near North Port	4.7 (1.1 – 14.7)	5.2 (BDL – 17.7)	146 (30 – 350)	7.3 (6.7 – 7.9)	684 (203 – 1276)	6.7 (1.8 – 16.8	2.6 (BDL – 16.0)
Florida median[a]	5.2	6.5	70	7.2	366	5.8	12

[a] median lake value for chl-a; median stream value for all other constituents

Table 2 (cont.)

STATION	NH4 (mg N/L)	NO2+3 (mg N/L)	TKN (mg N/L)	TN (mg N/L)	PO4 (mg P/L)	TP (mg P/L)	TOC (mg C/L)
Peace Creek Canal nr Wahneta	0.092 (BDL – 0.23)	0.291 (BDL – 0.79)	1.59 (0.73 – 3.32)	1.84 (1.19 – 3.39)	0.35 (0.06 – 1.23)	0.43 (0.11 – 1.45)	22.1 (11.5 – 37.6)
Saddle Creek at Structure P-11	0.068 (BDL – 1.26)	0.023 (BDL – 0.41)	4.29 (1.22 – 12.1)	4.37 (1.23 – 12.1)	0.05 (BDL – 0.24)	0.37 (0.05 – 0.96)	24.5 (11.8 – 46.8)
Peace River at Bartow	0.088 (BDL – 0.32)	0.238 (BDL – 0.90)	1.81 (0.10 – 5.10)	2.03 (0.11 – 5.11)	0.75 (BDL – 3.44)	0.95 (BDL – 3.53)	20.7 (11.7 – 39.4)
Peace River at Ft. Meade	0.043 (BDL – 0.10)	0.386 (BDL – 1.17)	1.27 (0.55 – 3.10)	1.63 (0.67 – 3.16)	0.68 (0.22 – 1.02)	0.91 (0.55 – 1.42)	15.2 (3.2 – 44.0)
Peace River at Zolfo Springs	0.036 (BDL – 0.12)	0.670 (BDL – 1.43)	1.01 (0.55 – 1.72)	1.66 (1.17 – 2.24)	0.88 (0.32 – 1.23)	1.05 (0.70 – 1.78)	15.0 (8.7 – 30.6)
Peace River at Arcadia	0.042 (BDL – 0.12)	0.551 (BDL – 1.35)	0.95 (0.54 – 1.57)	1.51 (0.81 – 2.33)	0.71 (BDL – 1.20)	0.89 (0.52 – 1.30)	16.1 (8.1 – 31.0)
Joshua Creek at Nocatee	.036 (BDL – 0.13)	1.12 (0.02 – 2.93)	0.99 (0.48 – 1.66)	2.18 (0.82 – 4.59)	0.14 (0.05 – 0.25)	0.17 (0.08 – 0.34)	15.9 (9.65 – 27.3)
Charlie Creek nr Gardner	0.050 (BDL – 0.16)	0.284 (BDL – 0.91)	1.12 (0.56 – 2.00)	1.41 (0.58 – 2.42)	0.50 (0.02 – 1.10)	0.59 (0.23 – 1.20)	22.4 (5.0 – 50.0)
Horse Creek nr Myakka Head	0.043 (BDL – 0.85)	0.121 (BDL – 1.95)	0.98 (0.41 – 3.08)	1.13 (0.48 – 5.03)	0.41 (0.18 – 0.98)	0.47 (0.23 – 1.23)	19.4 (7.5 – 35.0)
Horse Creek nr Arcadia	0.039 (BDL – 0.09)	0.424 (BDL – 1.06)	0.94 (0.37 – 1.60)	1.37 (0.43 – 2.34)	0.42 (0.23 – 1.57)	0.48 (0.25 – 1.57)	18.1 (7.5 – 37.6)
Shell Creek nr Punta Gorda	0.036 (BDL – 0.11)	0.081 (BDL – 0.25)	1.11 (BDL – 1.78)	1.20 (0.07 – 1.91)	0.09 (BDL – 0.36)	0.14 (BDL – 0.36)	18.3 (11.6 – 30.8)
Myakka River at Myakka City	0.074 (BDL – 0.30)	0.063 (BDL – 0.17)	0.95 (0.67 – 1.21)	1.04 (0.68 – 1.38)	0.27 (0.10 – 0.46)	0.30 (0.13 – 0.53)	19.6 (12.7 – 28.5)
Myakka River nr Sarasota	0.071 (BDL – 0.57)	0.021 (BDL – 0.07)	1.31 (0.62 – 2.60)	1.33 (0.68 – 2.61)	0.34 (0.08 – 0.63)	0.39 (0.18 – 0.69)	21.8 (14.9 – 32.0)
Deer Prairie Slough nr North Port	0.063 (BDL – 0.28)	0.025 (BDL – 0.11)	1.64 (0.55 – 3.73)	1.68 (0.55 – 3.78)	0.26 (0.01 – 1.40)	0.47 (0.04 – 1.88)	22.9 (10.6 – 49.1)
Big Slough Canal nr Myakka City	0.156 (BDL – 0.95)	0.232 (BDL – 1.84)	1.46 (0.59 – 2.35)	1.83 (0.66 – 4.19)	0.29 (0.09 – 0.52)	0.39 (0.13 – 0.75)	20.3 (7.8 – 38.2)
Big Slough Canal nr North Port	0.06 (BDL – 0.20)	0.088 (BDL – 0.76)	1.17 (0.61 – 2.04)	1.31 (0.76 – 2.80)	0.24 (0.10 – 0.54)	0.31 (0.12 – 0.61)	19.3 (9.3 – 35.9)
Florida median:	N/A	0.10	N/A	1.2	N/A	0.09	14

Table 3 Florida Stream Water Quality Index values (Hand et al. 1994, 1996), based on October 1997 - September 2000 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.

STATION	Turbidity	TSS	TOC	TN	NO_{2+3}	TP	Avg WQI (w/out TP)	Water Quality Characterization
Peace Creek Canal near Wahneta	54.4	51.4	71.7	76.1	77.6	78.9	66.2	"poor"
Saddle Creek at Structure P-11	>95	>95	75.3	>95	16.4	76.1	76.8	"poor"
Peace River at Bartow	67.2	80.9	69.0	80.4	73.1	91.4	74.1	"poor"
Peace River at Ft. Meade	54.5	63.6	53.3	70.7	82.1	90.4	64.8	"poor"
Peace River at Zolfo Springs	45.0	52.4	52.8	71.4	90.9	93.6	62.5	"poor"
Peace River at Arcadia	48.1	47.9	56.1	65.7	87.2	90.0	61.0	"poor"
Joshua Creek at Nocatee	18.3	27.1	55.4	82.6	>95	61.8	55.2	"fair"
Charlie Creek near Gardner	19.6	23.3	72.1	60.4	77.0	83.0	50.5	"fair"
Horse Creek near Myakka Head	18.5	34.0	65.3	46.3	55.2	80.2	43.8	"good"
Horse Creek near Arcadia	17.4	24.6	61.6	58.5	83.2	80.5	49.1	"fair"
Shell Creek near Punta Gorda	14.7	14.5	62.2	50.2	43.6	57.1	37.1	"good"
Myakka River at Myakka City	12.1	16.2	66.0	41.8	36.6	73.0	34.5	"good"
Myakka River near Sarasota	16.0	23.2	71.2	56.4	15.3	77.0	36.4	"good"
Deer Prairie Slough near North Port	54.6	53.9	72.9	71.9	17.5	80.2	54.2	"fair"
Big Slough Canal near Myakka City	57.4	60.8	68.0	75.9	72.7	76.8	67.0	"poor"
Big Slough Canal near North Port	42.6	37.7	65.1	55.3	45.9	73.4	49.3	"fair"

2.3 Stream Discharge and Estimated Constituent Loads

Daily mean discharge records for the Peace and Myakka River gaging stations were obtained from the USGS for water years 1998 and 1999. (Values from the 2000 water year had not yet been published by the USGS at the time this report was prepared.)

Above-average rainfall, primarily associated with the 1997-1998 El Niño event, produced elevated stream discharge in both basins during the 1998 water year. At the Peace River-Arcadia gage, for example, annual average discharge during the 1998 water year was more than two times higher than the station's long term (1932-1998) annual mean. Rainfall and runoff returned to more typical levels during the 1999 water year, and annual average discharge at most monitoring sites were near or below their long-term means in that year.

Estimated loads of selected water quality constituents (nitrogen forms, phosphorus forms, and TSS) were calculated at each monitoring station for each month of the 1998 and 1999 water years, using the following equation:

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

where:

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

C_{jk} = measured concentration of constituent *i* during month *j* at station *k* (inunits of mg/L)

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

f_1, f_2 = conversions factors (used to convert mg to metric 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 (water year) loads were estimated by summing the estimated monthly loads for the period October 1997 - September 1999. The annual loading estimates are summarized in Table 4.

2.4 Loadings to Charlotte Harbor

In addition to the estimated constituent loads passing individual gaging stations each year, the CHNEP and other stakeholders are also interested in quantifying the nutrient and TSS loads that are discharged from the river basins to Charlotte Harbor. For the Peace River basin, estimates of these values can be obtained by summing the loads from 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

Table 4. Estimated constituent loads (metric tons/yr) at monitored stations during the 1998 and 1999 water years.

	TN		Inorganic N		TP		PO_4-P		TSS	
Station	WY 98	WY 99 [a]	WY 98	WY 99	WY 98	WY 99	WY 98	WY 99	WY 98	WY 99
Peace Creek Canal near Wahneta	278	--	38	10	37	12	24	10	585	146
Saddle Creek at Structure P-11	771	--	4	1	115	10	24	3	12,111	1,965
Peace River at Bartow	781	--	86	18	214	70	132	49	8,309	2,645
Peace River at Ft`. Meade	963	--	179	28	540	112	384	86	6,454	1,234
Peace River at Zolfo Springs	1,811	--	559	136	1,038	311	850	260	9,167	1,848
Peace River at Arcadia	2,997	899	1,056	295	1,577	551	1,167	484	12,158	4,021
Joshua Creek at Nocatee	--	--	--	121	--	20	--	16	--	285
Charlie Creek nr Gardner	1,057	286	281	42	331	111	270	94	3,277	969
Horse Creek nr Myakka Head	78	--	7	1	23	7	21	6	258	44
Horse Creek nr Arcadia	555	--	145	41	197	62	167	54	3,518	102
Shell Creek nr Punta Gorda	624	471	83	56	68	75	48	57	1,293	727
Myakka River at Myakka City	--	--	--	16	--	51	--	48	--	52
Myakka River nr Sarasota	--	284	--	11	--	113	--	97	--	255
Deer Prairie Slough nr North Port	--	--	--	1	--	2	--	2	--	78
Big Slough Canal nr Myakka City	--	--	--	10	--	10	--	8	--	140

on the river and its southernmost tributaries. These three stations have a cumulative drainage area of 1,958 mi^2 (USGS 1997), representing about 83% of the Peace River watershed (Hammett 1987). Assuming that the portion of the watershed lying downstream from the gages generates loads of each constituent that are comparable (on a per-acre basis) to the upstream portion, loads observed at these stations should represent (as a first approximation) about 83% of the watershed totals. Estimated annual loads calculated using these assumptions are shown in Table 5.

In an earlier study, annual average loads of TN, TP, and TSS from the Peace River watershed to Charlotte Harbor for 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 loads calculated by Coastal Environmental, Inc. for the 1985-1991 period are substantially lower than the values we calculated for the 1998 water year (Table 5). These differences are presumably due, at least in part, to the different amounts of rainfall and stormwater runoff that occurred in the watershed during the two periods. Over the years 1985-1991, for example, mean discharge at the Peace River-Arcadia gage was <60% of the site's long-term annual average. As noted previously, annual average discharge during the 1998 water year was more than two times higher than the long-term mean.

During the 1999 water year, annual average discharge in the lower Peace River basin fell once again to levels below the long-term mean. At the Peace River-Arcadia gage, annual average discharge during the 1999 water year was about 70% lower than in 1998. Estimated annual loads also declined, with the size of the reduction ranging from roughly 60% (TP and PO_4-P) to 70% (inorganic N and TSS) between the two years.

Table 5. Estimated constituent loads (metric tons/year) from the Peace River watershed to Charlotte Harbor.

Constituent	1985-1991[a]	1998 water year[b]	1999 water year[b]
TN	1,633	5,013	--
Inorganic N	--	1,540	471
TP	580	2,212	825
PO_4-P	--	1,659	714
TSS	13,061	20,366	5,821

[a] Data source = Coastal Environmental, Inc. 1995
[b] Data source = this study

2.5 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 as mass per unit area per unit time) observed in different portions of a river basin. Estimated yields (in kilograms per hectare per year) for the gaged sub-basins included in this project during the 1998 and 1999 water years are summarized in Table 6.

In general, higher per-hectare yields of nutrients and TSS occurred in both river basins during the 1998 water year, presumably due to the elevated rainfall and runoff that occurred in that year. Seven gaging stations (Saddle Creek at Structure P-11, Charlie Creek near Gardner, Joshua Creek at Nocatee, and the Peace River gages at Bartow, Ft. Meade , Zolfo Springs, and Arcadia), all located in the Peace River watershed, exhibited per-hectare nitrogen or phosphorus yields that appear elevated relative to the other sub-basins monitored in this project.

The highest estimated yields of TN (22 kg/ha/yr) occurred at the Saddle Creek gaging station during the 1998 water year, presumably reflecting the impact of discharges from Lake Hancock, a hypereutrophic waterbody that is located immediately upstream from the station. Interestingly, estimated yields of “inorganic” (nitrate, nitrite, and ammonium) nitrogen at the Saddle Creek gage were low relative to other sites in the Peace River basin. Concentrations of inorganic N were frequently below detection limits at the Saddle Creek gage, suggesting that the abundant phytoplankton populations in Lake Hancock had effectively stripped much of the inorganic N from the water column and converted it to organic forms. (Nitrogen fixation by cyanobacteria in Lake Hancock may also provide a significant proportion of the organic N measured at the Saddle Creek gage.)

The Saddle Creek station also exhibited the highest yields of TSS (346 kg/ha/yr and 56 kg/ha/yr, respectively) during the 1998 and 1999 water years, perhaps due to episodic discharges of phytoplankton cells and unconsolidated sediments resuspended from the bottom of Lake Hancock during storm events. Much lower TSS yields were calculated for the Peace River-Bartow gaging station, which is located less than 5 miles downstream from the Saddle Creek station, in both years.

Elevated TP yields were observed at the gages located on the main stem of the Peace River (at Ft. Meade, Zolfo Springs and Arcadia) and on the main stem of the Myakka River (at Myakka City and Sarasota) presumably reflecting the abundance of phosphate-bearing geological deposits and the active mining and processing of phosphate products that occur in both basins.

Substantial increases in the estimated yields of inorganic N, TP, and PO_4-P occurred between the upstream and downstream stations located on Horse Creek, suggesting the potential presence of anthropogenic sources of those constituents at one or more locations between the two stations.

Table 6. Estimated sub-basin yields (kilograms/hectare/year) for stations monitored during the 1998 and 1999 water years.

	TN		Inorganic N		TP		PO_4-P		TSS	
Station	WY98	WY99 [a]	WY98	WY99	WY98	WY99	WY98	WY99	WY98	WY99
Peace Creek Canal nr Wahneta	6.6	--	0.9	0.2	0.9	0.3	0.6	0.2	14	3
Saddle Creek at Structure P-11	22.1	--	0.1	0.03	3.3	0.3	0.7	0.1	346	56
Peace River at Bartow	7.7	--	0.8	0.2	2.1	0.7	1.3	0.5	82	26
Peace River at Ft`. Meade	8.0	--	1.5	0.2	4.5	0.9	3.2	0.7	54	10
Peace River at Zolfo Springs	8.5	--	2.6	0.6	4.9	1.5	4.0	1.2	43	9
Peace River at Arcadia	8.5	2.5	3.0	0.8	4.4	1.6	3.3	1.4	34	11
Joshua Creek at Nocatee	--	--	--	3.5	--	0.6	--	0.5	--	8
Charlie Creek nr Gardner	12.4	3.3	3.3	0.5	3.9	1.3	3.2	1.1	38	11
Horse Creek nr Myakka Head	7.4	--	0.7	0.1	2.2	0.6	1.9	0.6	24	4
Horse Creek nr Arcadia	9.8	--	2.6	0.7	3.5	1.1	3.0	1.0	62	2
Shell Creek nr Punta Gorda	6.5	4.9	0.9	0.6	0.7	0.8	0.5	0.6	13	8
Myakka River at Myakka City	--	--	--	0.5	--	1.6	--	1.5	--	2
Myakka River nr Sarasota	--	4.8	--	0.2	--	1.9	--	1.6	--	4
Deer Prairie Slough nr North Port	--	--	--	--	--	--	--	--	--	--
Big Slough Canal nr Myakka City	--	--	--	1.0	--	1.1	--	0.9	--	15

3.0 Long-term Trends in Water Quality and Stream Flow

In addition to the monthly water quality monitoring data collected by the project participants from September 1997 through October 2000, water quality records for water years 1970-1998 were also obtained, in digital form from a USGS database, for a number of long-term gaging stations located in the Peace and Myakka River basins. These stations are listed in Table 7. Summaries of the methods used to collect, analyze and disseminate these records are provided in Water Resources Data Reports (e.g., USGS 1999), which are published annually by the agency.

Long-term daily mean discharge records were also obtained for these stations from the USGS, focusing on the period from 1970 to the present. Within this period, the years for which discharge records were available varied between stations (summarized in Tables 7 and 8). Eight stations in the Peace River basin and 1 station in the Myakka River basin had complete daily records covering the entire period (Tables 7, 8). Monitoring at two additional stations (Peace River at Fort Meade and Horse Creek near Myakka Head) began in the mid-to-late 1970's and extended through the 1999 water year.

The number of water quality records present in the USGS data set also varied between stations, years, and water quality constituents. For a given constituent and station, all years in which <4 records were available were omitted from the analyses reported here, due to a concern that relatively infrequent (e.g., less than quarterly) sampling might produce data that are not representative of the full range of water quality conditions occurring in those years.

For cases meeting these minimum data requirements, summary statistics (e.g., minimum, mean and maximum values) were calculated for stream discharge and constituent concentrations, on monthly and annual time steps. Concentration data flagged as "<" by the USGS — indicating that the actual value was known to be less than the reported value — were reduced to 0.5x the reported values prior to analysis.

The statistical significance of multi-year trends was assessed using the nonparametric Mann-Kendall test (Gilbert 1987). Tests for trend were performed on annual minimum, annual mean, and annual maximum values of each water quality indicator. Trend tests were also performed on annual minimum ("lowest monthly mean") and annual maximum ("highest monthly mean") monthly discharge, and on annual runoff (serving as a proxy for annual mean discharge). Trend tests were not performed for water quality constituents for which the available period of record was <10 years.

Table 7. USGS gaging stations used in the analysis of long-term streamflow and water quality trends.

Station Name	USGS ID	Period of Record available for flow trend analysis (since 1970)
Saddle Creek at Structure P-11	02294491	1970 – 1999
Peace River at Bartow	02294650	1970 – 1999
Peace River at Ft. Meade	02294898	1975 – 1999
Peace River at Zolfo Springs	02295637	1970 – 1999
Charlie Creek near Gardner	02296500	1970 – 1999
Peace River at Arcadia	02296750	1970 – 1999
Joshua Creek at Nocatee	02297100	1970 – 1999
Horse Creek near Myakka Head	02297155	1978 – 1999
Horse Creek near Arcadia	02297310	1970 – 1999
Shell Creek near Punta Gorda	02298608	1970 – 1999
Myakka River near Sarasota	02298830	1970 – 1999

3.1 Long-term Trends at Peace River Stations

3.1.1 Stream Discharge

Levels and trends in minimum, mean, and maximum monthly discharge at the Peace River gaging stations are summarized in Table 8. Monthly mean discharge was extremely variable, ranging from zero in headwater areas and tributary streams following periods of low rainfall to >6,000 cubic feet per second (cfs) on the river's main stem during periods of high flow.

Trend analyses indicate that streamflow regimes underwent changes at several stations between water years 1970 and 1998. The magnitude or duration of low-flow periods apparently intensified at the Bartow and Zolfo Springs stations, as evidenced by significant ($p<0.05$) downward trends in "lowest monthly mean" discharges over the period. In contrast, low-flow episodes apparently became less pronounced at three tributary sites (Charlie Creek-Gardner, Joshua Creek-Nocatee, and Horse Creek-Myakk Head). At these stations, lowest monthly mean discharges increased significantly (Table 8). Marginally significant increasing trends in dry-season flows also occurred at the Saddle Creek-P11 and Peace River-Ft. Meade stations during the period (Table 8).

Wet-season flows — as measured by the "highest monthly mean" discharges recorded each year — exhibited significant increasing trends at several stations (Saddle Creek-P11, Peace River-Bartow, Peace River-Ft. Meade, and Horse Creek-Myakka Head) during the period.

Annual mean discharge exhibited significant increasing trends at one station on the river's main stem (Peace River-Ft. Meade), and at three tributary stations (Saddle Creek-P11, Joshua Creek-Nocatee, and Horse Creek-Myakka Head). Marginally significant ($0.05 < p < 0.10$) increasing trends in annual mean discharge occurred at two other sites (Peace River-Bartow and Horse Creek-Arcadia).

Long-term trends in discharge and runoff in the Peace River watershed are a topic of considerable interest to resource managers in the west-central Florida region. Several investigators have documented long-term declines in annual mean discharge, particularly at gaging stations on the river's main stem in the northern portion of the watershed, that occurred between the 1930's and mid-1960's (e.g., Hammett 1987, Coastal Environmental Services 1995). These declining trends appear to have been caused by a combination of natural (e.g., reduced frequency of tropical cyclones) and anthropogenic factors (e.g., increased groundwater pumpage; surface strip mining)(Hammett 1987, Coastal Environmental Services 1995). Because the declines occurred prior to 1970 (Hammett 1987), they were not detected in the analyses shown in Table 8.

Human activities can also produce increasing trends in dry-season stream discharge, through the pumpage and subsequent release of groundwater at the land surface, and in wet-season discharge by increasing the amount of impervious material (e..g., paved roadways) present on the land surface.

The variety of discharge and runoff trends observed at different gaging stations over the 1970-1998 period appear to reflect the full range of these natural and manmade effects.

3.1.2 Specific Conductance

Specific conductance records provided by the USGS for water years 1970 through 1998 are summarized in Table 9. Statistically significant ($p<0.05$) trends in annual mean specific conductance occurred at three tributary stations (Charlie Creek-Gardner, Joshua Creek-Nocatee, and Horse Creek-Myakka Head), and a marginally significant ($p<0.10$) increasing trends occurred at one station (Shell Creek-Punta Gorda). Significant downward trends in annual mean specific conductance occurred at three stations (Saddle Creek-P11, Peace River-Bartow, and Peace River-Zolfo Springs), all located in the northern half of the watershed. A marginally significant downard trend in annual mean values occurred at the Peace River-Ft. Meade station, which is also located in the northern half of the watershed.

The upward trends in specific conductance most likely reflect increased discharges of groundwater (e.g., via spring discharges or return flows from industrial or agricultural facilities) into surface waters in the sub-basins in which the trends were observed. The downward trends presumably reflect declining inputs of groundwater to surface waters in the areas where those trends occurred, perhaps in response to regional declines in the potentiometric surface of the Upper Floridan aquifer in the northern portion of the Peace River basin (e.g., Hammett 1987).

3.1.3 pH

Higher-than-normal pH levels (>10 standard units) were observed at the Saddle Creek-P11 and Peace River-Bartow gaging stations, presumably in response to discharges from Lake Hancock and other hypereutrophic lakes and impoundments located upstream from these stations (Table 10). The high rates of algal photosynthesis occurring in hypereutrophic lakes tend to reduce CO_2 concentrations in the water column, affecting the equilibrium point of the CO_2-H_2CO_3 buffering system and increasing ambient pH values.

More acidic pH values (e.g., <6.0 standard units) were also recorded occasionally at all stations during the 1970-1998 period (Table 10), perhaps reflecting episodic inputs of low-pH water from natural (e.g., cypress swamps or the surficial aquifer) or manmade sources (e.g., mine discharges).

A significant downward trend in annual mean pH occurred at the Charlie Creek-Gardner site, and a marginally significant downward trend occurred at the Horse Creek-Arcadia site over the period 1970 - 1998. No stations exhibited significant increasing trends in annual mean pH during the period.

3.1.4 Dissolved oxygen

Substantially elevated (>10 mg/L) and depressed (<3 mg/L) DO concentrations were recorded at most stations during the 1970-1998 period (Table 11). A significant upward trend in annual mean DO occurred at the Peace River-Ft. Meade station, and a marginally significant increase was observed at the Peace River-Zolfo Springs stations. Significant downward trends occurred at the Charlie Creek-Gardner and Peace River-Arcadia stations.

3.1.5 Nitrogen forms

3.1.5.1 Nitrite+Nitrate N

Average concentrations of NO_{2+3} –N during 1970-1998 ranged from <0.05 mg N/L at the Saddle Creek-P11 station to >0.5 mg N/L at several stations in other portions of the watershed (Table 12). Significant upward trends in annual mean NO_{2+3}-N concentration occurred at the Horse Creek-Arcadia and Charlie Creek-Gardner stations, both located on tributary streams in the southern half of the watershed. Significant downward trends in annual mean NO_{2+3}-N concentration occurred at the Peace River-Bartow, Peace River-Ft. Meade, and Peace River-Zolfo Springs stations, all located on the river's main stem in the northern portion of the watershed.

Substantial changes in concentrations of NO_{2+3} –N in surface water bodies are frequently caused by land use changes and other anthropogenic activities occurring within their watersheds. Such activities could be examined as potential causes underlying the trends in NO_{2+3} –N concentrations observed at gaging stations in the Peace River basin during the 1970-1998 period.

3.1.5.2 NH_4-N

Average NH_4-N concentrations ranged from below detection limit (observed periodically at most stations) to >10 mg N/L (the maximum value recorded at the Saddle Creek-P11 station, located immediately downstream from Lake Hancock)(Table 13). No significant upward trends in annual mean ammonium concentrations were observed at any station. Significant downward trends in annual mean concentrations occurred at the four stations located on the river's main stem (Peace River-Bartow, Ft. Meade, Zolfo Springs, and Arcadia), presumably reflecting reductions in NH_4 loads from one or more manmade sources discharging in the northern portion of the watershed.

3.1.5.3 TKN

Average concentrations of total Kjeldahl (combined organic + ammonia) nitrogen at the Saddle Creek-P11 and Peace River-Bartow stations exceeded 2 mg N/L over the 1970-1998 period. Average concentrations in other portions of the watershed ranged between 0.7 and 1.7 mg/L (Table 14). Significant downward trends in annual mean concentrations occurred at the Peace River-Bartow and Charlie Creek-Gardner stations, and a marginally significant downward trend occurred at the Peace River-Arcadia station. A marginally significant upward trend occurred at the Peace River-Zolfo Springs station (Table 14).

3.1.5.4 Total Nitrogen

Average TN concentrations ranged from ca. 1 mg/L at the two Horse Creek stations to >5 mg/L at the Saddle Creek station located immediately downstream from Lake Hancock (Table 15). Average concentrations at or above the FDEP "screening level" (Hand et al. 1988) of 2.0 mg/L occurred at the Saddle Creek, Peace River-Bartow, Peace River-Ft. Meade, and Peace River-Zolfo Springs stations. (The FDEP screening level is intended to serve as an indicator of potential water quality impacts.)

Significant declining trends in annual mean TN concentrations were recorded at the Peace River-Bartow and Peace River-Ft. Meade gaging stations (Table 15), presumably reflecting the significant downward trends in concentrations of NO_{2+3} and other nitrogen forms also observed at those stations.

3.1.5.5 Phosphorus Forms (PO_4 and TP)

Average TP concentrations ranged from <0.2 mg P/L (at the Shell Creek-Punta Gorda station) to >1 mg P/L (at the Arcadia, Zolfo Springs, Ft. Meade, and Bartow stations on the river's main stem)(Table 17). PO_4 concentrations were of similar magnitude and showed similar spatial patterns (Table 16). The FDEP "screening level" for TP in streams is 0.46 mg P/L (Hand et al. 1988).

Long-term declining trends in phosphorus concentrations in surface waters within the Peace River basin, apparently associated with the activity levels and production processes used by the phosphate mining and fertilizer processing industries, have been noted by several investigators (e.g., Fraser 1986, Hammett 1987). Those trends are also evident in the 1970-1998 USGS data (Tables 14-15). Highly significant downward trends in PO_4 and TP concentrations occurred at the Peace River-Bartow, Peace River-Ft. Meade, Peace River-Zolfo Springs, Peace River-Arcadia, and Horse Creek-Arcadia gaging stations. Only the Charlie Creek-Gardner station exhibited significant upward trends, suggesting that an increase in anthropogenic phosphorus discharges may have occurred in the Charlie Creek sub-basin during the years 1970-1988.

Table 8. Streamflow levels and trends, water years1970-1999. (ρ or ο indicate highly significant [p<0.05] trend; ω or ξ indicate marginally significant [0.10>p>0.05] trend; n.t. indicates non-significant [p>0.10] trend. In trend columns, values in parentheses indicate significance levels of Mann-Kendall test. (Data source: USGS)

		Discharge (cfs)			Trends in Discharge (Mann-Kendall significance level)		
Station	Period (water years)	Lowest Monthly Mean	Overall Mean	Highest Monthly Mean	Lowest Monthly Mean Discharge	Annual Mean Discharge	Highest Monthly Mean Discharge
Saddle Creek Structure P-11	1970 – 1999	0.00	60.89	693.39	ω (0.08)	ρ (0.04)	ρ (0.03)
Peace River Bartow	1970 – 1999	4.06	161.95	1536.13	ο (0.004)	ω (0.10)	ρ (0.04)
Peace River Ft. Meade	1975 – 1999	2.15	198.31	1849.68	ω (0.09)	ρ (0.001)	ρ (0.001)
Peace River Zolfo Springs	1970 – 1999	35.70	498.20	3860.00	ο (0.02)	n.t. (>0.10)	n.t. (>0.10)
Charlie Creek Gardner	1970 – 1999	0.28	225.73	2274.94	ρ (0.01)	n.t. (>0.10)	n.t. (>0.10)
Peace River Arcadia	1970 – 1999	51.61	866.42	6410.10	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Joshua Creek Nocatee	1970 – 1999	1.22	100.41	1133.17	ρ (0.001)	ρ (0.03)	n.t. (>0.10)
Horse Creek Myakka Head	1978 – 1999	0.02	30.80	297.03	ρ (0.001)	ρ (0.001)	ρ (0.001)
Horse Creek Arcadia	1970 – 1999	0.30	169.80	1854.00	n.t. (>0.10)	ω (0.08)	n.t. (>0.10)
Shell Creek Punta Gorda	1970 – 1999	0.00	326.68	2485.16	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Myakka River Sarasota	1970 – 1999	0.00	245.91	1853.63	ρ (0.04)	ω (0.06)	n.t. (>0.10)

Table 9. Specific conductance levels and trends, 1970-1998. (Data source: USGS)

				Specific Conductance (uS/cm)			Specific ConductanceTrends (Mann-Kendall significance level)		
Station	Period (water years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1973 – 1994	17	100	198	317	595	n.t. (>0.10)	ο (0.05)	ο (0.01)
Peace River Bartow	1971 – 1998	28	195	125	323	790	ξ (0.07)	ο (0.001)	ο (0.001)
Peace River Ft. Meade	1973 – 1998	26	180	175	405	715	n.t. (>0.10)	ξ (0.09)	ξ (0.07)
Peace River Zolfo Springs	1970 – 1998	28	201	130	395	742	n.t. (>0.10)	ο (0.04)	ο (0.02)
Charlie Creek Gardner	1970 – 1998	20	127	70	207	410	ρ (0.03)	ρ (0.002)	ρ (0.004)
Peace River Arcadia	1970 – 1998	28	266	81	342	635	n.t. (>0.10)	n.t. (>0.10)	ο (0.05)
Joshua Creek Nocatee	1973 – 1998	21	132	125	533	1040	ρ (0.001)	ρ (0.002)	ω (0.098)
Horse Creek Myakka Head	1979 – 1998	11	67	46	132	340	ρ (0.03)	ρ (0.01)	ρ (0.03)
Horse Creek Arcadia	1971 – 1998	28	187	64	297	945	ω (0.07)	n.t. (>0.10)	n.t. (>0.10)
Shell Creek Punta Gorda	1972 – 1998	23	146	130	640	1200	ρ (0.009)	ω (0.08)	n.t. (>0.10)
Myakka River Sarasota	1971 – 1998	28	134	70	217	678	ρ (0.001)	ρ (0.001)	ρ (0.004)

Table 10. pH levels and trends, 1970-1998. (Data source: USGS)

				pH			pH Trends (Mann-Kendall significance level)		
Station	Period (water years)	n (years)	N (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1978 – 1994	17	102	5.8	8.4	10.4	n.t. (>0.10)	n.t. (>0.10)	ο (0.02)
Peace River Bartow	1971 – 1998	25	168	5.3	6.9	10.1	n.t. (>0.10)	n.t. (>0.10)	ξ (0.065)
Peace River Ft. Meade	1978 – 1998	21	144	5.7	7.1	9.1	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Zolfo Springs	1970 – 1998	26	168	4.2	7.2	9.2	n.t. (>0.10)	n.t. (>0.10)	ρ (0.05)
Charlie Creek Gardner	1978 – 1998	14	90	5.1	6.8	9.3	ο (0.01)	ο (0.045)	n.t. (>0.10)
Peace River Arcadia	1970 – 1998	27	239	4.5	7.2	9.1	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Joshua Creek Nocatee	1978 – 1998	16	96	4.7	7.0	8.8	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Horse Creek Myakka Head	1979 – 1998	11	68	4.7	6.4	7.9	n.t. (>0.10)	n.t. (>0.10)	ξ (0.07)
Horse Creek Arcadia	1978 – 1998	21	142	4.4	6.7	9.0	ξ (0.08)	ξ (0.06)	ο (0.003)
Shell Creek Punta Gorda	1978 – 1998	17	103	5.9	7.2	9.0	ω (0.08)	n.t. (>0.10)	n.t. (>0.10)
Myakka River Sarasota	1978 – 1998	14	116	4.6	6.6	8.4	ξ (0.08)	ο (0.02)	ο (0.02)

Table 11. DO levels and trends, 1970-1998. (Data source: USGS)

				Dissolved Oxygen (mg/L)			D.O.Trends (Mann-Kendall significance level)		
Station	Period (water years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1973 – 1993	16	92	0.1	7.5	16.7	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Bartow	1971 – 1998	27	193	1.1	5.0	11.1	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Ft. Meade	1973 – 1998	25	168	1.0	6.1	11.2	ρ (<0.001)	ρ (0.02)	n.t. (>0.10)
Peace River Zolfo Springs	1971 – 1998	25	190	3.8	7.3	12.9	n.t. (>0.10)	ω (0.09)	n.t. (>0.10)
Charlie Creek Gardner	1970 – 1998	20	128	3.5	6.8	16.8	n.t. (>0.10)	ο (0.01)	n.t. (>0.10)
Peace River Arcadia	1971 – 1998	28	235	3.5	7.2	12.4	n.t. (>0.10)	ο (0.03)	ο (0.04)
Joshua Creek Nocatee	1972 – 1998	21	124	3.2	6.9	11.6	ω (0.08)	n.t. (>0.10)	n.t. (>0.10)
Horse Creek Myakka Head	1979 – 1998	11	67	1.0	7.2	11.0	n.t. (>0.10)	ξ (0.06)	n.t. (>0.10)
Horse Creek Arcadia	1971 – 1998	27	173	1.9	7.1	11.7	ρ (0.02)	n.t. (>0.10)	n.t. (>0.10)
Shell Creek Punta Gorda	1972 – 1998	23	144	0.2	4.6	9.6	ρ (0.001)	n.t. (>0.10)	n.t. (>0.10)
Myakka River Sarasota	1978 - 1998	14	106	0.1	4.4	9.0	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)

Table 12. Nitrate + nitrite nitrogen concentrations and trends, 1970-1998. (Data source: USGS)

				NO_{2+3} – N (mg/L)			NO_{2+3} Trend (Mann-Kendall significance level)		
Station	Period (water years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 – 1994	9	44	<0.01	0.023	0.3			
Peace River Bartow	1975 – 1998	24	147	0.01	0.29	2.6	n.t. (>0.10)	o (0.001)	o (0.001)
Peace River Ft. Meade	1982 – 1998	17	101	<0.001	0.59	4.0	n.t. (>0.10)	o (0.004)	o (0.003)
Peace River Zolfo Springs	1975 – 1998	23	139	0.09	0.93	2.7	o (0.02)	o (0.001)	o (0.001)
Charlie Creek Gardner	1980 – 1998	12	67	<0.001	0.28	1.7	n.t. (>0.10)	ρ (0.004)	ρ (0.009)
Peace River Arcadia	1974 – 1998	13	96	0.01	0.74	2.6	n.t. (>0.10)	ρ (0.05)	ρ (0.02)
Joshua Creek Nocatee	1984 – 1998	9	51	0.01	0.88	2.1			
Horse Creek Myakka Head	1992 – 1998	6	35	0.01	0.10	0.4			
Horse Creek Arcadia	1980 – 1998	19	108	<0.001	0.48	4.0	n.t. (>0.10)	ρ (0.01)	ρ (0.001)
Shell Creek Punta Gorda	1984 – 1998	7	44	<0.01	0.08	0.2			
Myakka River Sarasota	1978 - 1998	8	86	<0.001	0.01	0.04			

Table 13. NH_4-N concentrations and trends, 1970-1998. (Data source: USGS)

				NH_4 – N (mg/L)			NH_4 – N Trend (Mann-Kendall significance level)		
Station	Period (water years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 - 1994	9	44	<0.01	0.43	15			
Peace River Bartow	1971 - 1998	28	170	<0.01	0.22	2.9	n.t. (>0.10)	ο (0.045)	ξ (0.065)
Peace River Ft. Meade	1982 - 1998	17	102	<0.01	0.14	1.4	n.t. (>0.10)	ο (0.01)	ο (0.02)
Peace River Zolfo Springs	1972 - 1998	26	156	<0.01	0.08	0.88	ο (0.04)	ο (<0.001)	ο (<0.001)
Charlie Creek Gardner	1980 - 1998	12	68	<0.001	0.05	0.15	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Arcadia	1971 - 1998	22	167	<0.01	0.07	0.37	n.t. (>0.10)	ο (<0.001)	ο (<0.001)
Joshua Creek Nocatee	1984 - 1998	9	51	0.02	0.05	0.15			
Horse Creek Myakka Head	1992 – 1998	6	36	<0.01	0.03	0.07			
Horse Creek Arcadia	1980 - 1998	19	108	<0.001	0.04	0.27	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Shell Creek Punta Gorda	1984 - 1998	7	44	0.01	0.05	0.11			
Myakka River Sarasota	1970 - 1998	10	98	<0.005	0.08	0.70	ρ (0.03)	n.t. (>0.10)	n.t. (>0.10)

Table 14. Total Kjeldahl nitrogen (TKN) concentrations and trends, 1970-1998. (Data source: USGS)

				TKN (mg/L)			TKN Trend (Mann-Kendall significance level)		
Station	Period (water years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 – 1994	9	44	1.3	5.9	26			
Peace RiverBartow	1975 – 1998	24	147	0.1	2.5	11.0	ξ (0.075)	ξ (0.054)	ο (0.01)
Peace RiverFt. Meade	1982 – 1998	17	97	0.4	1.7	8.4	n.t. (>0.10)	n.t. (>0.10)	ο (0.01)
Peace RiverZolfo Springs	1975 – 1998	23	139	0.4	1.1	4.9	ρ (0.01)	ω (0.09)	n.t. (>0.10)
Charlie CreekGardner	1980 – 1998	12	67	0.1	1.2	3.1	n.t. (>0.10)	ο (0.03)	n.t. (>0.10)
Peace RiverArcadia	1974 – 1998	24	189	0.1	1.1	5.3	n.t. (>0.10)	ξ (0.095)	ο (0.04)
Joshua CreekNocatee	1984 – 1998	9	51	0.3	1.0	1.7			
Horse CreekMyakka Head	1992 – 1998	6	36	0.4	0.9	2.4			
Horse CreekArcadia	1980 – 1998	19	108	0.3	1.0	1.9	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Shell CreekPunta Gorda	1984 – 1998	7	44	0.2	1.0	1.5			
Myakka RiverSarasota	1979 – 1998	13	95	0.6	1.3	9.0	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)

Table 15. Total nitrogen concentrations and trends, 1970-1998. (Data source: USGS)

				Total Nitrogen (mg/L)			TN Trend (Mann-Kendall significance level)		
Station	Period (water years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 - 1994	9	44	1.3	5.9	26.0			
Peace River Bartow	1975 - 1998	24	147	0.1	2.8	11.0	n.t. (>0.10)	ο (0.048)	ο (0.01)
Peace RiverFt. Meade	1982 - 1998	17	101	0.7	2.3	8.4	ξ (0.10)	ο (0.02)	ο (0.04)
Peace RiverZolfo Springs	1975 - 1998	23	139	0.9	2.0	5.3	n.t. (>0.10)	ξ (0.06)	n.t. (>0.10)
Charlie Creek Gardner	1980 - 1998	12	67	0.1	1.5	3.2	n.t. (>0.10)	n.t. (>0.10)	n.t. (>0.10)
Peace River Arcadia	1974 - 1998	13	93	0.4	1.9	3.8	n.t. (>0.10)	n.t. (>0.10)	ο (0.03)
Joshua Creek Nocatee	1984 - 1998	9	51	0.4	1.9	3.4			
Horse Creek Myakka Head	1992 - 1998	6	35	0.4	1.0	2.5			
Horse Creek Arcadia	1980 - 1998	19	108	0.5	1.4	4.9	n.t. (>0.10)	ω (0.09)	ω (0.07)
Shell Creek Punta Gorda	1984 - 1998	7	44	0.2	1.1	1.7			
Myakka River Sarasota	1978 - 1998	8	73	0.7	1.5	9.1			

Table 16. Ortho-phosphorus concentrations and trends, 1970-1998. (Data source: USGS)

				PO_4 – P (mg/L)			PO_4 – P trend (Mann-Kendall significance level)		
Station	Period (water years)	n (years)	n (obs)	Minimum	Mean	Maximum	Annual Minimum	Annual Mean	Annual Maximum
Saddle Creek Structure P-11	1983 – 1994	9	44	0.02	0.20	0.90			
Peace River Bartow	1972 – 1998	27	169	<0.01	3.80	52.00	o (0.005)	o (0.001)	o (0.001)
Peace River Ft. Meade	1982 – 1998	17	103	0.40	1.20	4.90	o (0.001)	o (0.001)	o (0.001)
Peace River Zolfo Springs	1972 – 1998	26	157	0.03	2.10	21.00	o (0.001)	o (0.001)	o (0.001)
Charlie Creek Gardner	1980 – 1998	12	68	<0.01	0.50	1.00	ρ (0.10)	ρ (0.02)	n.t. (>0.10)
Peace River Arcadia	1971 – 1995	15	121	0.10	2.00	9.70	o (0.001)	o (0.001)	o (0.001)
Joshua Creek Nocatee	1984 – 1995	9	51	0.06	0.20	0.40			
Horse Creek Myakka Head	1992 – 1998	6	36	0.08	0.40	0.80			
Horse Creek Arcadia	1971 – 1998	20	113	0.05	0.40	1.00	o (0.017)	o (0.009)	o (0.032)
Shell Creek Punta Gorda	1984 – 1998	7	44	<0.01	0.12	0.66			
Myakka River Sarasota	1971 - 1998	9	89	0.02	0.32	0.77			

Table 17. Total phosphorus concentrations and trends, 1970-1998. (Data source: USGS)

Station	Period (water years)	n (years)	n (obs)	Total Phosphorus (mg/L) Minimum	Total Phosphorus (mg/L) Mean	Total Phosphorus (mg/L) Maximum	TP Trend (Mann-Kendall significance level) Annual Minimum	TP Trend Annual Mean	TP Trend Annual Maximum
Saddle Creek Structure P-11	1983 – 1994	9	44	0.2	0.7	4.4			
Peace RiverBartow	1972 – 1998	27	167	<0.01	4.1	52	ξ (0.07)	ο (0.001)	ο (0.001)
Peace RiverFt. Meade	1982 – 1998	17	103	0.4	1.4	4.9	ο (0.001)	ο (0.001)	ο (0.001)
Peace RiverZolfo Springs	1972 – 1998	26	157	0.07	2.3	21	ο (0.001)	ο (0.001)	ο (0.001)
Charlie CreekGardner	1980 – 1998	12	67	0.01	0.6	1.0	ω (0.08)	ρ (0.04)	n.t. (>0.10)
Peace RiverArcadia	1971 – 1998	28	227	0.1	1.8	10	ο (0.001)	ο (0.001)	ο (0.001)
Joshua CreekNocatee	1984 – 1998	9	50	0.7	0.2	0.5			
Horse CreekMyakka Head	1992 – 1998	6	36	0.1	0.4	0.9			
Horse CreekArcadia	1971 – 1998	20	112	0.3	0.5	1.2	ο (0.001)	ο (0.001)	ο (0.001)
Shell CreekPunta Gorda	1984 – 1998	7	44	0.04	0.16	0.9			
Myakka RiverSarasota	1971 – 1998	15	121	0.03	0.39	1.10	ρ (0.03)	ω (0.06)	n.t. (>0.10)

3.2 Long-term Trends, Myakka River Station

In contrast to the Peace River system, long-term water quality and stream discharge data were available from only one USGS monitoring station (Myakka River near Sarasota) in the Myakka River basin. Trends occurring at that station are summarized in the preceding tables.

Minimum monthly stream discharge exhibited a highly significant increasing trend, and average annual discharge showed a marginally significant increase, during water years 1970 through 1999 (Table 8). Specific conductance also showed highly significant increasing trends (Table 9). Taken together, these trends in discharge and conductance imply that surface waters at one or more locations upstream from the Myakka River-Sarasota gaging station received increasing groundwater inputs during the period.

Annual average and annual minimum total phosphorus concentrations also showed significant increasing trends over the period (Table 17), as did annual NH_4-N concentrations (Table11). Because these nutrients are important in the eutrophication process, and the increasing trends are occurring at a site that is located within the Myakka River State Park, this finding may be of interest to State and regional water quality managers.

Studies funded by the SWFWMD (e.g., Coastal Environmental/PBS&J 1998, PBS&J 1999) have explored a variety of hydrologic modifications and related habitat changes that have occurred in the upper Myakka River basin in recent decades. Increases in seasonal high water elevations, and more extended seasonal hydroperiods in wetlands, have been documented in portions of the upper basin and have been implicated in the extensive tree mortality that has occurred in the area in recent years (Coastal Environmental/ PBS&J 1998, PBS&J 1999). A combination of anthropogenic (e.g., agricultural irrigation practices) and natural factors (e.g., El Nino rain events) are thought to have contributed to the hydrologic, water quality, and ecological changes observed in the area (Coastal Environmental/PBS&J 1998, PBS&J 1999).

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