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ESTERO BAY AND WATERSHED ASSESSMENT
PHASE II
PSI PROJECT NO. 552-1G002

ESTERO BAY AND WATERSHED ASSESSMENT
PHASE II

Prepared for:

SOUTH FLORIDA WATER MANAGEMENT DISTRICT
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Prepared by:

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May 16, 2007

PSI PROJECT NO. 552-1G002

psi

May 16, 2007

South Florida Water Management District
2301 McGregor Boulevard
Ft. Myers, Florida 33901

Attention: Mr. Clyde Dabbs

Re: ESTERO BAY AND WATERSHED ASSESSMENT PHASE II
PSI Project No. 552-1G002

Dear Mr. Dabbs:

Professional Service Industries, Inc. (PSI) has developed an Estero Bay and Watershed Assessment Phase II report. The report utilizes data collected from locations within the Estero Bay watershed from September 2003 to August 2006. Two copies of the report are enclosed.

If you have any questions or comments, please contact us at (813) 886-1075.

Respectfully submitted,

PROFESSIONAL SERVICE INDUSTRIES, INC.

Christopher L. Cummins
Senior Geologist/Contract Manager

Enclosures

CLC/ams

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1.0 INTRODUCTION

Professional Service Industries, Inc. (PSI) has been contracted by the South Florida Water Management District (SFWMD) to conduct a pollutant loading study for the Estero Bay and Watershed. The study consisted of monitoring selected subcatchments within the Estero Bay Watershed to measure runoff and nutrient/sediment loading. The acquired data will be utilized to evaluate runoff discharge rates and sediment/nutrient loading produced by representative land use types within the watershed. The monitoring program was conducted from September 2003 through August of 2006. PSI detailed the results of the first year of monitoring in "Estero Bay Phase II, Stormwater Monitoring Report, 2003-2004 Annual Report", dated March 22, 2005. PSI detailed the results of the second year of monitoring in "Final 2004-2005 Annual Stormwater Monitoring Report" dated November 28, 2006.

1.1 PROJECT HISTORY

The Estero Bay Watershed lies primarily within Lee County, Florida, south of the Caloosahatchee River, and includes parts of Northeastern Collier County and a small portion of southwest Hendry County. Estero Bay is vulnerable to environmental degradation due to increasing urbanization, limited flushing in the bay and limited water volume. SFWMD has undertaken an assessment of Estero Bay and the Estero Bay Watershed to evaluate the effects of development on the bay and the watershed. The assessment will be utilized to develop management strategies to protect the bay and watershed. Phase I, completed in 1999, included information regarding land use characterization as well as existing hydrology and pollutant loading information. The results of the Phase I recommended environmental monitoring to calibrate the hydrologic model of Estero Bay and the watershed.

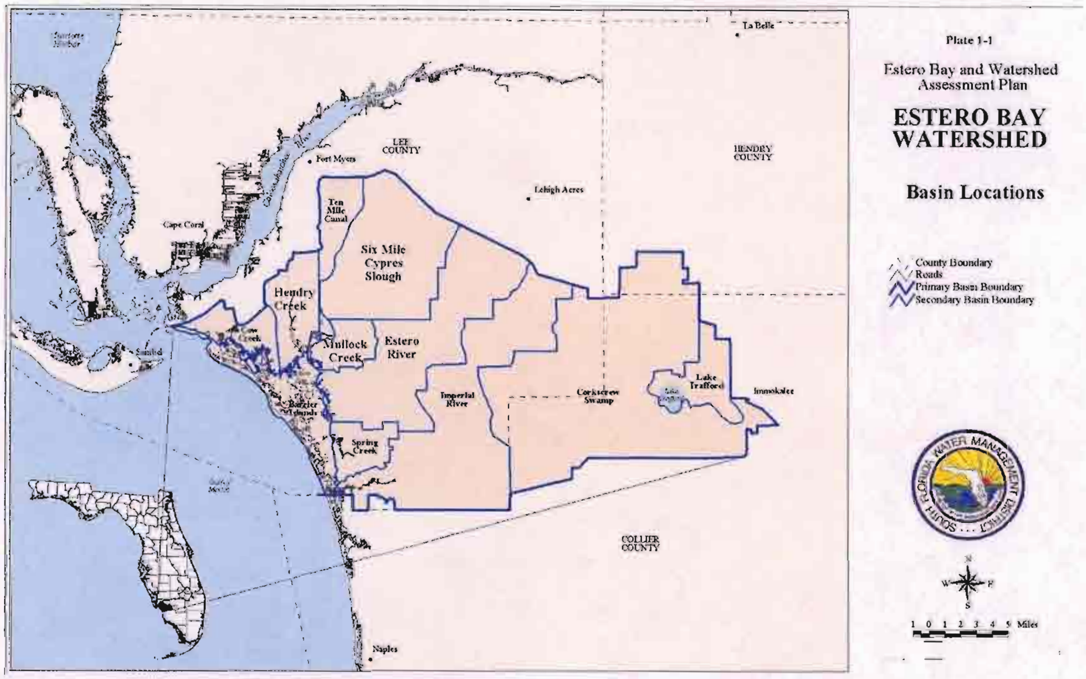
PSI, on behalf of the SFWMD, has performed the three years (September 1, 2004 through August 31, 2006) of monitoring and surface water sampling for a network of eleven surface water and weather monitoring stations constructed for the Estero Bay Phase II assessment.

1.2 WORK AUTHORIZATION

Authorization to complete the scope of work for the Estero Bay Watershed Assessment, Phase II was in the form of SFWMD Contract No. C-11180, dated March 15, 2001; SFWMD Contract No. C-11180 Amendment No. 1, dated January 10, 2002; SFWMD Contract No. C-11180 Amendment No. 2, dated April 29, 2005; SWFMD Contract No. C-1180 Amendment No. 3, dated May 16, 2005; SFWMD Purchase Order PC P602302 Dated May 18, 2006, and SFWMD Contract #C-4600000432, dated November 20, 2006, between the South Florida Water Management District and PSI.

1.3 Location

The Estero Bay Watershed lies primarily within Lee County south of the Caloosahatchee River and includes parts of Northeastern Collier County and a small portion of southwest Hendry County. (See figure below.)



2.0 METHODOLOGY

Stormwater subcatchments of selected representative land use types were instrumented to monitor surface water discharges, groundwater elevation, precipitation and evapotransportation. Discharge at various sites were sampled during stormwater events and under dry conditions for nitrate/nitrite (NOX), Total Kjeldahl Nitrogen (TKN), ammonia (NH_3-N), total phosphorus (TP), orthophosphorus (OP), total suspended solids (TSS) and copper (CU). Quality control/quality assurance (QA/QC) samples including equipment blanks, field blanks and sample duplicates were also collected. In addition, physical water quality data including temperature, pH, conductivity, dissolved oxygen and turbidity were also monitored.

The monitoring stations and the respective land use types monitored are summarized in the table below:

Stormwater/Weather Monitoring Stations Summary

Station Identification	Land Use Type
Austin Street Stormwater Monitoring Station	Residential
Brooks Tropical Stormwater Monitoring Station	Agricultural
Corkscrew Road Stormwater Monitoring Station	Roadway
Corkscrew Swamp Stormwater Monitoring Station	Wetland
Corkscrew Swamp Weather Monitoring Station	Wetland
Eastwood Gulf Course Stormwater/Weather Monitoring Station	Park
Florida Gulf Coast University (FGCU) Stormwater Monitoring Station	Industrial/Commercial
Galeana Street Stormwater Monitoring Station	Industrial/Commercial
Kiehl Canal Stormwater/Weather Monitoring Station	Mixed Use
Koreshan State Park Stormwater Monitoring Station	Wooded Upland
Mullock Creek	Residential

Specific monitoring station locations are presented on **Figure 1.**

Each monitoring station was constructed with a concrete pad, mounting pole, and security fence. A shallow one-inch diameter piezometer was installed within the concrete mounting pad for groundwater level measurement. A staff gauge was installed at each site. Dataloggers in weatherproof enclosures were attached to mounting poles. For weather stations, sensors were attached to horizontal arms and wired to the dataloggers. A pressure transducer was deployed in the piezometer for groundwater level measurement and another pressure transducer was deployed in a 3-inch diameter slotted pipe set below surface water to monitor surface water stage elevation. Information stored in the data logger was periodically downloaded to a computer and compiled in a database. Stormwater samples for laboratory analysis were collected either manually or by utilizing automated samplers. Five monitoring stations were equipped with Campbell Scientific CR510 dataloggers to monitor stage, groundwater elevation and precipitation. Three stations were equipped with CR10X dataloggers to monitor various weather parameters, which in turn were used to calculate evapotranspiration (ET) by the Penmann-Monteith Method. One monitoring station (FGCU) utilized an Isco 4250 flowmeter and a tipping bucket rain gauge to monitor stage, discharge and precipitation. The FGCU station also was equipped with a pressure transducer deployed within a shallow piezometer to monitor groundwater levels. The transducer was wired to a Campbell Scientific CR510 data logger which recorded groundwater elevation data.

A more detailed description of equipment deployed at each station is presented in the table below:

Estero Bay Phase II Monitoring Station Equipment Matrix

Equipment	Austin Street	Brooks Tropical	Corkscrew Road	Corkscrew Swamp	Corkscrew Swamp Weather	Eastwood Golf Course	FGCU	Galeana Street	Kiehl Canal	Koreshan State Park	Mullock Creek
Campbell Datalogger	X	X		X	X	X	X	X	X	X	
ISCO Flowmeter							X				
Pressure Transducer -stage	X	X		X		X		X	X	X	
Pressure Transducer - groundwater elevation	X	X		X		X	X	X	X	X	
Flume										X	
Rain Gauge	X	X	X		X	X		X	X	X	
Temperature/Relative Humidity Sensor					X	X			X		
Wind Speed/Direction Sensor					X	X			X		
Solar Radiation Sensor					X	X			X		
Staff Gauge	X	X		X		X	X	X	X		X

Notes:

Four ISCO Autosamplers equipped with 24 bottle carousels were periodically deployed for time weighted surface water sample collection.

Four Sontek Multiparameter Sondes equipped with pH, temperature, conductivity, dissolved oxygen and turbidity sensors were periodically rotated to the various monitoring stations for surface water monitoring.

2.1 DATALOGGER PROGRAMMING

Campbell Scientific dataloggers were programmed utilizing Campbell's "Shortcut for Windows" software program. Shortcut creates programs for the dataloggers and configures sensor signals (i.e. pressure transducer voltage signals or signal digital interface (SDI-12) signals for multiparameter sondes) for compatibility with the output arrays. The programs include commonly used calculations, such as the Penmann-Monteith equation and supports user entered equations.

The dataloggers were programmed to produce output reports every twenty minutes. Pressure transducer readings for stage and groundwater elevation were recorded in units of feet of water and were taken at ten second intervals. The 10 second scans were then averaged over a twenty minute time period for an output report. For weather stations, temperature, relative humidity, wind speed, wind direction and solar radiation were also scanned every ten seconds and averaged for each twenty minute output report. Maximum and minimum wind speed for each twenty minute interval is recorded as a sample for the output reports.

Tipping bucket rain gauges tip every 0.01 inches of rain, breaking an electrical circuit which was then counted as a pulse by the datalogger. Total rain was recorded every twenty minute interval as a pulse count by the datalogger and converted to inches for the output report.

Potential evapotranspiration was calculated internally by the datalogger utilizing the Penmann-Monteith equation. The Penmann-Monteith equation is expressed as follows:

$$ET_o = \frac{\Delta(R_n - G)}{\lambda(\Delta + \gamma^*)} + \frac{\gamma^* M_w (e_a - e_d)}{R\Theta r_v (\Delta + \gamma^*)}$$

ET_o	Potential evaporation (kg m^{-2} s^{-1} or mm s^{-1})
R_n	Net radiation (kW m^{-2})
G	Soil heat flux density (kW m^{-2})
M_w	Molecular mass of water (0.018 Kg mol^{-1})
R	Gas constant (8.31 X 10^{-3} kJ mol^{-1} K^{-1})
Θ	Kelvin temperature (293 K)
e_a-e_d	Vapor pressure deficit of the air (kPa)
λ	Latent heat of vaporization of water (2450 kJ kg^{-1})
r_v	Canopy plus boundary layer resistance for vapor (s m^{-1})
Δ	Slope of the saturation vapor pressure function (Pa °C^{-1})
γ^*	Apparent psychrometer constant (Pa °C^{-1})

A number of conversions and assumptions are made by Campbell Scientific in the Penmann-Monteith algorithm programmed by the Campbell "Shortcut for Windows" software program. For a detailed discussion of the computations made in order to modify the equation for the weather perimeters monitored by the Campbell Scientific weather station package, the reader is referred to "On-line Estimation of Grass Reference Evapotranspiration with the Campbell Scientific Automated Weather Station, Application Note 4-D."

Potential evaporation is defined as the amount of water that would be removed from the land surface by evaporation and transpiration if sufficient water is available in the soil to meet demand (Freeze and Cherry, 1979). For the locations monitored within the Estero Bay watershed, groundwater is close to land surface; therefore, it is assumed that actual evapotranspiration is close to potential evapotranspiration.

The Isco 4250 Flowmeter deployed at FGCU consisted of a datalogger and an area velocity sensor. The flowmeter measured stage, channel velocity, discharge and precipitation (with a tipping bucket rain gauge). Data was output every 15 minutes and printed on a paper strip recorder. Daily reports totaling all parameters for a 24 hour period were also printed to the strip recorder.

2.2 DATABASE DEVELOPMENT

A database has been developed in Microsoft Excel for each site utilizing site visit data, datalogger output reports, and laboratory analytical reports. Water budget data has been developed by totaling the output reports for precipitation, evapotranspiration, baseflow and surface runoff flow. Graphs illustrating the water budget parameters as well as additional parameters such as stage and groundwater elevation have also been developed from the database (see Appendix A). The database has also been utilized to develop graphical depictions of stage/discharge calibration curves, stage/discharge relationship and precipitation/discharge relationship. Discharge and precipitation data from the database were used to calculate event mean concentration (EMC) values for the analytes tested in collected surface water samples.

Data recorded on the Campbell Scientific dataloggers was downloaded to a laptop computer equipped with Campbell Loggernet software. The data was then imported into Microsoft Excel as a comma delimited file (.csv) and converted to a worksheet format (.xls) which allowed a great deal of flexibility in terms of graphing and the performance of calculations.

Stage readings were utilized as a variable for stage/discharge rating equations, flume equations and weir equations. The equations for discharge (Q) are present in each cell of the database column labeled "Q (cfs)." Each cell represents a twenty minute time interval. Flow, defined as volume in cubic feet (cf) was calculated in each cell of the column labeled $Flow_{tot.}$(cf) and was calculated by multiplying Q by 1200 (60 seconds/minute x 20 minutes/time interval). Each cell within the $Flow_{tot.}$ (cf) column was then totaled to obtain quarterly and yearly flow values for the site.

Surface runoff flow was also calculated within the database by calculating the percentage of the cross-sectional area of flow of a given channel or culvert that is surface runoff. This was accomplished by assuming the groundwater elevation measured in the piezometer equals baseflow elevation. If stage was higher than the baseflow elevation, surface runoff was present. The generalized calculation for the portion of flow that consists of surface runoff is expressed as follows:

$$Flow_{sr}\text{ (cf)} = Flow_{tot.}\text{ (cf)} * ((\text{stage(ft)} - \text{groundwater elevation (ft))/stage(ft))}$$

Depending upon the channel bottom of culvert geometry, additional conditions may be added to the above equation in order to estimate the surface runoff component of flow. Similar to the total flow calculation, surface runoff calculated in each cell was totaled to obtain quarterly and yearly estimates of surface runoff flow.

Rain was totaled for each twenty minute time interval and, therefore, each cell in the column label labeled Rain (in.) was totaled to obtain quarterly and yearly estimates of rainfall.

For the weather stations equipped to monitor evapotranspiration (ET), ET was totaled at the end of each 24 hour time period in the column labeled DET_o (in.). The daily ET value is then copied from the DET_o (in) column into the column labeled ET total. Cells of the ET total column represent one day. By totaling the values in the ET column, quarterly and yearly estimates of total ET were obtained.

2.3 Discharge Measurement Techniques

Discharge (Q) was calculated for the various sites utilizing a variety of techniques including weir equations, flume equations, stage/discharge rating curves and estimations based upon a Sontek Flowtracker handheld Acoustic Doppler Velocimeter (ADV) measurements. The ADV was utilized to estimate discharge during each site visit conducted by PSI.

The Flowtracker used acoustic Doppler technology to measure flow in a small sampling volume located a fixed distance from the probe. Sound generated by a transmitter bounces off suspended particles in water, returns to two receivers and allows for the determination of water velocity. In accordance with United States Geologic Survey (USGS) techniques, the velocities were obtained for regular cross-sectional areas across the channel and are used by the ADV to compute discharge.

Other methods utilized to determine discharge are as follows:

A discharge (Q) formula for a free-flowing rectangular weir was utilized for the canal at the Brooks Tropical Monitoring Station for periods of high flow. The formula (Grant and Dawson, 1997) is expressed as follows:

$$Q \text{ (cfs)} = 3.33 * \text{(length of weir in feet)} * \text{(head on the weir in feet)}^{1.5}$$

cfs = cubic feet per second

A discharge formula for an extra large 60° V-trapozoidal flume was utilized to measure flow in a ditch at the Koreshan State Park. The formula (Wachter, 2001) is expressed as follows:

$$Q \text{ (cfs)} = 1.646 * \text{(head in flume (ft))}^{2.58058}$$

Stage/discharge calibration curves were relied upon for the majority of stations. Discharge was measured with the ADV during site visits while stage was simultaneously noted. After approximately six months into monitoring, enough stage/discharge data was accumulated to allow for the development of stage/discharge calibration curves.

The stage/discharge calibration curves in this report were derived by using the Microsoft Excel spreadsheet "Trendline" feature. The trendline feature creates a mathematical regression equation for stage and discharge data utilizing the least squares method. Linear, logarithmic, polynomial, power, and exponential equations can be selected. Generally, the equations describing stage/discharge calibration curves this study are those with the highest R^2 values. R^2, Pearson's Coefficient of Determination, is the relative error measurement which predicts the degree of relationship of one variable to another for mathematical regressions. R^2 values close to 0 indicate little relationship between variables while R^2 values approaching one indicates a high degree of relationship between variables. Equation values were also compared to the actual stage/discharge measurements for "goodness of fit" and discarded if there was a poor match between values.

It should be noted that calibration curves were developed with data from 2003 through 2006 for Brooks Tropical and Eastwood Golf Course. Since the velocity of water going over the weir is controlled by stage height and the cross-sectional area formed by the weir is unchanging (unlike a natural channel with a cross-sectional area that may change with time), it is reasonable to combine data from the three year monitoring period, since a larger data set will provide a more accurate stage/discharge equation.

When it was not possible to use any of the above described methods, discharge measured by the ADV was extrapolated for the time period between site visits (usually a two-week time period). Extrapolated ADV Q measurements were also utilized for a number of other stations where stage/discharge calibration curves could not be developed due to lack of correlation between stage and discharge measurements or due to stage pressure transducer malfunction.

Finally, the method used to measure discharge at the Corkscrew Road Monitoring Station consisted of taking periodic discharge measurements during storm events and correlating total flow for the storm event to the total storm event rainfall amount. The total flow of each monitored storm event was summed and divided by the total rainfall sum of each monitored storm event to obtain an average flow per inch of rain. This figure was multiplied by total annual rainfall to obtain a total amount of flow for each monitored year. Similar to Brooks Tropical and Eastwood Golf Course, flow data from the entire three year monitoring time period was utilized for the flow per inch of rainfall calculation due to the unchanging cross sectional area of the drainage culvert. It should be noted that surface water discharge only occurs at this site during storm events (i.e., there is no base flow).

Discharge measurement techniques are further discussed on a per station basis later in this report.

2.4 ELEVATION SURVEY

Relevant measurement points were surveyed for each station utilizing a survey level. Surveyed points include top of piezometer casings, weir crests, base of staff gauges, culvert inverts and the bottoms of open channels. The elevations were referenced to the lowest point of discharge measurement (i.e. channel bottoms or culvert inverts) and assigned an arbitrary elevation of 0 feet. Surveyed elevations were then utilized to develop flow equations and to relate stage and groundwater elevation. Survey points elevations were also referenced to NAVD 88 (the 1988 North American Vertical Datum) (see PSI's letter report "Survey of Stormwater Monitoring Stations to the 1988 North American Vertical Datum(NAVD 88), dated November 5, 2005).

Elevation Survey data is presented on Table 1.

2.5 SITE MONITORING/SURFACE WATER SAMPLING AND ANALYSIS

The procedure for each site visit was to record a staff gauge reading and measure the depth to groundwater in the piezometer. Site visits were scheduled at two week intervals. Pressure transducers measuring surface water and groundwater elevations and weather sensors were checked for proper operation. The pressure transducers measuring surface water and groundwater elevations were then calibrated to the staff gauge and the groundwater elevation measured in the piezometer. Once field measurements were obtained, data was downloaded from the data logger onto a laptop computer utilizing Campbell Scientific Loggernet software. The data was later transferred from the laptop computer to a database at PSI's base of operation.

Dry weather surface water sampling was conducted during dry conditions or just prior to rain events at selected sites. Surface water samples were collected manually using a decontaminated Teflon dipper or with an Isco 3700 autosampler equipped with a carousel of 24 Teflon one liter bottles. During sampling events, surface water samples were collected as a single grab sample or on a time-weighted basis. A first flush sample was collected within the first 30 minutes of the rain event. Subsequent samples are collected at 30 minute intervals until the rain has ceased. Typically, a rise in surface water level of approximately ½ inch in conjunction with the initiation of rainfall was used as the criteria for the initiation of stormwater sampling.

Once collected, samples were placed immediately into an iced cooler and transported under proper chain of custody to Millennium Laboratories in Tampa, Florida.

The samples were then analyzed by EPA Method 350.1 for ammonia nitrogen, EPA Method 6010 for copper, EPA Method 353.3 for nitrate/nitrite, EPA Method 365.3 for orthophosphorus, EPA Method 6010/200.7 for total phosphorus, EPA Method 160.2 for total suspended solids and EPA Method 351.2 for Total Kjeldahl Nitrogen.

Field measurements for surface water include pH, temperature, specific conductivity, dissolved oxygen and turbidity. The parameters were measured either with handheld meters or with a YSI 6820 multiparameter sonde programmed to communicate with the Campbell dataloggers using SDI-12 protocol. Field measurements were collected at the time surface water samples were collected for laboratory analysis and for periods of time up to several weeks with the sonde. The sondes were routinely rotated between sites. Normally, a sonde was deployed in conjunction with the Isco auto sampler immediately prior to stormwater sampling.

2.6 Event Mean Concentration (EMC) Calculations

Event mean concentrations for the study were composited by reviewing flow data and mathematically flow proportioning the time weighted parameter results to obtain EMCs values. In cases where an analyte was not detected, the method detection level (MDL) was halved in order to provide an estimated concentration for EMC and loading calculations.

2.7 Pollutant Loading Calculations

Loading estimates for the land use types monitored were calculated by first averaging analyte concentrations obtained from sampling events conducted under storm conditions and then multiplying flow evaluated to be representative of storm conditions. Storm condition flow was evaluated by comparing rainfall and stage to increased flow in the database. The following rule was adopted in determining whether storm condition was applicable for loading calculations:

> Initiation of storm condition:
> ½ inch of rainfall within a two-hour time period, followed by an increase of
> ½ inch of stage within a 24-hour time period.

Cessation of storm flow condition:

a. A return of stage to its initial pre-rainfall level or;
b. No rainfall within a two-day time period exceeding an intensity of ½ inch within two hours.

The average of annual storm condition analytical results were multiplied by total annual flow under storm conditions. The result of multiplying analyte concentration by flow for the corresponding time period is an analyte (or pollutant) weight in micrograms. Micrograms/year is then converted to pounds/year and divided by the number of acres drained by the channel to obtain loading values in pounds(lbs)/acre-year. Loading calculations have been performed for three annual time periods: September 2003 through August 2004, September 2004 through August 2005 and September 2005 through August 2006. An example calculation is as follows:

Pollutant Loading (lbs/acre-year) = (analyte concentration (micrograms per liter)* total flow (cubic ft)* 28.32 L/ft^3*(2.2*10^{-9} lbs/micrograms))/drainage area (acres)/year

The average of annual dry flow condition analytical results were multiplied by annual flow under non-storm conditions. Pollutant loading under dry conditions was then calculated by the same formula as that is for the storm flow condition. The dry condition loading and the storm condition loading are then added together to obtain total pollutant loading for a given time period.

It should be noted that the drainage area for each sub-basin is subject to a high degree of uncertainty. PSI attempted to obtain drainage area estimates from a number of sources, but was not able to obtain this information other than rough estimates. Drainage area estimates for the Austin Street, Galeana Street, and Mullock Creek stations were provided by Lee County Natural Resources. The drainage area for Eastwood Golf Course was provided by the City of Fort Myers. The drainage areas for Brooks Tropical, Corkscrew Swamp, Kiehl Canal, and Koreshan State Park were estimated from aerial photograph review. The drainage area for the Corkscrew Road station was mapped during a rain event by physically observing surface water flow direction.

2.8 HYDROLOGIC BUDGET CALCULATIONS

Measurement of precipitation, evapotranspiration and flow allow for the development of a hydrologic (water) budget which in turn provides a crude approximation of the hydrologic system (Freeze and Cherry). If it is assumed that for the sub-basins monitored, surface water and groundwater divides coincide, a steady state hydrologic budget equation is expressed as follows:

$\Delta V = P\text{-}ET\text{-}Flow_{sr}/\text{Drainage Area}$

Where ΔV= annual change in groundwater/surface water storage per unit area in inches.

P = annual precipitation in inches
ET = annual evapotranspiration in inches
$Flow_{sr}$ = annual surface runoff flow in cubic inches.
Drainage Area = Drainage Area (square inches).

ΔV is calculated as the difference in groundwater elevation on September 1 and the following August 31 for each of the three annual monitoring periods. Utilization of Groundwater elevations were utilized in the calculation (as opposed to surface water elevation) due to the relatively small aerial extent of surface water bodies present within the various subbasins.

At Corkscrew Road, surface water running directly off of pavement during storm events is monitored. Therefore, there is no water storage. The hydrologic budget for the Corkscrew Road station is a simplified equation expressed as:

$$P = Flow_{tot} / \text{Drainage Area} + ET$$

Where P = annual precipitation in inches
ET = annual evapotranspiration in inches
$Flow_{tot}$ = annual total flow in cubic ft.

Given that the basin boundaries are uncontrolled and there are numerous uncertainties in the budget calculation (i.e. roughly defined drainage boundaries, unaccounted for storage conditions due to groundwater pumping, irrigation, inflow from springs and other possible unknown groundwater and surface water inflows and outflows) the above listed hydrologic budget variables are presented as general information with the expectation that budgets will only roughly balance.

3.0 SITE MONITORING/SURFACE WATER SAMPLING AND ANALYSIS

3.1 AUSTIN STREET MONITORING STATION (FT. MYERS)

Land Use Type: Residential

GPS Coordinates: Latitude 26° 33' 39.40980" N
Longitude 81° 52' 14.38036" W

Site Location: On Austin Street, approximately 800 feet south of Crystal Drive and 300 feet east of US 41.

Drainage Area: 315 acres

Surface water is conveyed at the Austin Street Monitoring Station by a ditch that runs east to west, draining a residential neighborhood. The ditch runs under US 41 and terminates into a lake on the west side of US 41. The drainage area and monitoring station location is presented on Figure 2.

Discharge at the site is measured periodically with an ADV. A pressure transducer was deployed in the ditch to continuously monitor stage. A pressure transducer deployed in a shallow piezometer was utilized to continuously monitor groundwater elevation. The site was also equipped with a rain gauge.

Seasonal stage/discharge calibration curves have been developed for Austin Street Monitoring Station (see Graphs 1.1A through 1.4A (2003-2004),1.1B through 1.4B (2004-2005) and 1.1C through 1.3C (2005-2006). The graphs are presented in Appendix A.

Fall 2003 Discharge vs. Stage Calibration Curve:

$$Q\ (cfs) = 3.1392 * (stage\ (ft.)) - 0.3674$$
$$R^2 = 0.8176$$

Fall 2005 Discharge vs. Stage Calibration Curve:

Stage between 1.00 ft. and 1.70 ft.:

$$Q\ (cfs) = 8.1482\ (stage\ (ft.))^2 - 7.8592\ (stage\ (ft.)) + 0.5893$$
$$R^2 = 0.9446$$

Discharge was estimated at 0.1 cfs for stage less than 1.00 feet and 10 cfs for stage greater than 1.70 ft.

Winter 2003-2004 Discharge vs. Stage Calibration Curve:

Q (cfs) = 2.9673 (stage (ft.))^2 – 1.8768 (stage (ft.)) +0.6225
$R^2 = 0.9285$

Winter 2005-2006 Discharge vs. Stage Calibration Curve:

Stage between 0.5 ft. and 0.96 ft.:

Q (cfs) = -0.9658(stage (ft.))^2 + 2.081 (stage (ft.)) –0.6913
$R^2 = 0.8314$

ADV discharge measurements were extrapolated between site visits when stage was not between 0.5 and 0.96 ft.

Spring 2004 Discharge vs. Stage Calibration Curve:

Q (cfs) = 1.8344 (stage (ft.))$^{2.0986}$
$R^2 = 0.9495$

Summer 2004 Discharge vs. Stage Calibration Curve:

Q (cfs) = 1.3413 (stage (ft.))$^{2.0986}$ + 3.2943 (stage(ft.))
$R^2 = 0.9331$

Spring / Summer 2005 Discharge vs. Stage Calibration Curve:

Stage less than 0.67 ft.:
Q (cfs) = 8.343 * (stage (ft.))^4.1177
$R^2 = 0.914$

Stage greater than 1.03 ft..:
Q (cfs) = -4.8478 * (stage (ft.))^2-33.502*(stage (ft.))-27.754
$R^2 = 0.9906$

Discharge was estimated at 1.5 cfs for stage between 0.67 ft. and 1.03 ft..

Spring / Summer 2006 Discharge vs. Stage Calibration Curve:

Stage between 1.02 ft. and 1.28 ft.:

Q (cfs) = 62.983(stage (ft.))^2 – 1.28.14 (stage (ft.)) +66.399
$R^2 = 0.9551$

ADV discharge measurements were extrapolated between site visits when stage was not between 1.02 and 1.28 ft.

The ADV measurements alone are utilized to measure discharge at Austin Street for the Fall and Winter of 2004-2005 because of a lack of correlation between stage and discharge at the site. This was due to the dry Fall and Winter which resulted in low discharge values, which in turn made correlation between stage and discharge difficult. However, extrapolating ADV measurements for the time period between site visits should be relatively accurate since, with little or no rainfall, discharge probably did not vary significantly between site visits.

It should be noted that the seasonal calibration curves were developed with relatively few data points. Total annual flow was calculated by summing total flow for each respective year.

Relationships between stage and discharge, rainfall and discharge, and stage and groundwater elevation are presented on Graphs 1.5A through 1.7A (2003-2004), 1.5B through 1.7B (2004-2005), and 1.4C through 1.8C (2005-2006). The graphs are presented in Appendix A.

During most of the year, discharge at the site was typically less than 1 cfs. During rain events, however, discharge can spike rapidly to over 10 cfs. During a storm event on June 8, 2004, stage was observed to rise rapidly to the top of the culverts running underneath Austin Street, resulting in discharges up to 28 cfs. The highest discharge appears to have occurred in the Fall of 2006 during Hurricane Wilma. Discharge was as high as 34 cfs. Discharge rapidly decreases at the station with the onset of drier Winter conditions. In Spring, discharge at the site is almost nonexistent, although the Spring of 2005 appears to have been wetter than the Springs of 2004 and 2006.

Graphs 1.8A through 1.11A depict relationships between surface water pH, temperature, conductivity, and turbidity, and time for a rain event that occurred on the evening of December 16, 2003. Changes in the field parameters corresponded with the peak flow of the rain event between the hours of 2100 and 2200. Turbidity and pH spiked slightly upwards, while temperature and conductivity spiked downwards. Dissolved oxygen was not measured for the storm event due to a probe malfunction. A handheld D.O. meter reading indicated 3.3 mg/L of dissolved oxygen at 1800, a time interval near the beginning of the rain event but prior to peak flow.

Graphs 1.8B through 1.12B, (see Appendix A), depict relationships between surface water pH, temperature, conductivity, dissolved oxygen and turbidity, and time from the afternoon of August 26, 2005 to the morning of August 27, 2005. pH values are stable at around 7.0. Temperature is 27.3° C in the midafternoon and dips to a low point of 25.3° C at 6:30 am the following morning. The temperature begins climbing again thereafter in response to increasing radiant energy from sunlight. Specific conductivity remained stable throughout the measurement period at a 0.6 millisiemans, a value considered normal for freshwater. Dissolved oxygen levels ranged from approximately 7.0 milligrams per liter (mg/L) at the time of deployment to 0.84 mg/L in the early morning. The fluctuations in dissolved oxygen values likely correspond to aquatic plant photosynthesis with early afternoon marking the highpoint in levels of photosynthesis and the early morning marking a low point. As indicated by the graph, once sunlight begins to reach the vegetation, photosynthesis increases along with the dissolved oxygen levels, since oxygen is a photosynthesis waste product. Turbidity ranged from 1 to 6 nephlometric turbidity units (ntus) for the measurement period. A spike of 6 ntus occurred at 9:20 pm in response to increased discharge resulting from some light precipitation (see Graph 1.13, Appendix A).

Surface water samples were collected on December 16, 2003, April 28, 2004, June 8, 2004, February 3, 2005, August 26, 2005, October 27, 2005, February 27, 2006 , June 12, 2006 and June 13, 2006. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C. Field parameter measurements for each sampling event are summarized on Table 3.

Field work sheets for the site visits performed for the Austin Street Monitoring Station are presented in Appendix B.1.

Evapotranspiration for the site has been estimated by averaging the ET values obtained from the weather stations located at Corkscrew Swamp, Eastwood Golf Course and the Kiehl Canal.

The following estimates for parameters measured at the Austin Street Monitoring Station are presented below:

2003-2004 Monitoring Period:

P = 54.0 inches
ET = 42.3 inches
$Flow_{tot}$ = 7.54 x 10^7 $ft.^3$
$Flow_{sr}$ = 1.06 x 10^6 $ft.^3$
$Flow_{storm}$ = 2.10 x 10^7 $ft.^3$

2004-2005 Monitoring Period:

P = 54.6 inches
ET = 40.1 inches
$Flow_{tot}$ = 6.69 x 10^7 $ft.^3$
$Flow_{sr}$ = 5.62 x 10^6 $ft.^3$
$Flow_{storm}$ = 1.84 x 10^7 $ft.^3$

2005-2006 Monitoring Period:

psi

$P = 64.6$ inches
$ET = 40.7$ inches
$Flow_{tot} = 4.50 \times 10^7$ ft.^{3}
$Flow_{sr} = 6.52 \times 10^6$ ft.^{3}
$Flow_{storm} = 1.42 \times 10^7$ ft.^{3}

Where P = precipitation in inches
ET = evapotranspiration in inches
$Flow_{tot}$ = total flow in cubic ft.
$Flow_{sr}$ = total flow minus baseflow in cubic ft.
$Flow_{storm}$ = flow under storm water conditions

The 2003-2004 annual hydrologic budget for the Austin Street Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr}$ / Drainage Area

Where P = 54.0 inches
ET = 42.3 inches
$Flow_{sr}$ / Drainage Area = 0.9 inches
ΔV = 13.3 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(1.06*10^6 \text{ ft}^3 * 1728 \text{ inches/ft}^3)/ (315 \text{ acres} * 43,560 \text{ ft}^2\text{/acres}*144 \text{ inches}^2$

ΔV is calculated as follows:

ΔV = (2.04 ft. – 0.93 ft.) * 12 inches/ft.
2.04 ft. = groundwater elevation on 8/31/04.
0.93 ft. = groundwater elevation on 9/1/03.

The 2004-2005 annual hydrologic budget for the Austin Street Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr}$ / Drainage Area

Where P = 54.6 inches
ET = 40.1 inches
$Flow_{sr}$ / Drainage Area = 4.9 inches
ΔV = -13.0 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
($5.62*10^6$ ft^3 * 1728 inches/ft^3)/ (315 acres * 43,560 ft^2/acres*144 inches^2)

ΔV is calculated as follows:

ΔV = (1.15 ft. – 2.23 ft.) * 12 inches/ft.
1.15 ft. = groundwater elevation on 8/31/05.
2.23 ft. = groundwater elevation on 9/1/04.

The 2005-2006 annual hydrologic budget for the Austin Street Monitoring Station is as follows:

ΔV = P - ET - $Flow_{sr}$ / Drainage Area

Where P = 64.6 inches
ET = 40.7 inches
$Flow_{sr}$ / Drainage Area = 5.7 inches
ΔV = -3.60 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
($6.52*10^6$ ft^3 * 1728 inches/ft^3)/ (315 acres * 43,560 ft^2/acres*144 inches^2)

ΔV is calculated as follows:

ΔV = (0.85 ft. – 1.15 ft.) * 12 inches/ft.
0.85 ft. = groundwater elevation on 8/31/06.
1.15 ft. = groundwater elevation on 9/1/05.

The computations for the event mean concentrations and loading calculations are presented on Tables 4A, 4B and 4C.

The databases for Austin Street are provided on the compact disc included with this report and are labeled “Austin Street 2003-2004”, “Austin Street 2004-2005” and “Austin Street 2005-2006”.

Site Photographs 1 & 2 - Austin Street Monitoring Station

3.2 BROOKS TROPICAL MONITORING STATION (LEE COUNTY)

Land Use Type: Agricultural

GPS Coordinates: Latitude 26° 26' 10.71682" N
Longitude 81° 34' 43.80216" W

Site Location: Approximately 1 mile south of Corkscrew Road and 15 miles east of I-75.

Drainage Area: 620 acres

Surface water is conveyed at the Brooks Tropical Monitoring Station by a canal that drains a large citrus grove located to the north. The grove extends from the weir location to the south side of Corkscrew Road.

The monitoring station is located one mile south of Corkscrew Road at a weir constructed to regulate flow downstream where the canal parallels the Corkscrew Swamp. The weir is located at the southeast corner of the Brooks Tropical orange grove. The drainage area and monitoring station locations are presented on Figure 3.

It should be noted that a ditch that feeds into the orange grove canal and originates from the north of Corkscrew Road. Two 6 by 8 ft. box culverts provide conveyance for the ditch water beneath Corkscrew Road . The ditch is approximately 6 to 8 feet wide and 4 feet deep. According to South Florida Water Management District personnel, large orange groves (approximately 2,500 acres) with large reservoirs are present within the drainage area along with a mine, wetlands and a residential community near State Road 82. However, the ditch does not flow very much for a significant part of the year, and is designed to accept flow from the mine and orange grove only during high water situations (i.e. when reservoirs and bermed areas exceed their holding capacity). The monitored orange grove canal south of Corkscrew Road is 32 feet across and typically filled with 5 to 6 feet of water. The canal is much larger than the ditch, and therefore would appear to primarily contain discharge from the orange grove south of Corkscrew Road.

Discharge at the site is measured periodically with an ADV. A pressure transducer is deployed in the canal to continuously monitor stage. A pressure transducer deployed in a shallow piezometer is utilized to continuously monitor groundwater elevation. The site is also equipped with a rain gauge.

A stage/discharge calibration curve has been developed for the Brooks Tropical Monitoring Station based on data collected for the 2003-2006 study period (see Graphs 2.1A, 2.1B and 2.1C, Appendix A) and is applicable when stage is less than 5.35 ft.

The equation is as follows:

$$Q\ (cfs) = 81.054\ (stage\ (ft.))^2 - 647.4\ (stage\ (ft.)) + 1270.5$$
$$R^2 = 0.9703$$

For stage 5.35 ft. and above, an open end rectangular weir equation (Grant and Dawson, 1997) is utilized to estimate discharge:

$$Discharge\ (cfs) = 3.33 * 30\ (ft.) * (stage(ft))^{1.5}$$

The weir equation was used to estimate flow above 5.35 foot of stage because it produces what appears to be a more realistic estimate of flow when compared with the stage/discharge equation which computes very high levels of flow when outside the calibration range. Additionally, it should be noted that for short periods of time, high stage may have resulted in submerged weir conditions. However these time periods were brief and should not have resulted in significant inaccuracy in measuring flow.

Relationships between stage and discharge, rainfall and discharge, and stage and groundwater elevation are presented on Graphs 2.2A through 2.4A (2003-2004), 2.2B and 2.3B (2004-2005), and 2.2C through 2.4C (2005-2006). The graphs are presented in Appendix A.

As indicated by the graphs, discharge is relatively low during late fall, winter and spring. The highest flows are during late summer and early fall. With the beginning of the summer rains, discharge increased to between 10 to 50 cfs. Towards the end of Summer, discharge is 50 to over 100 cfs. The high discharges continue until late September and then decrease with the beginning of the Winter dry season. As indicated by Graphs 2.3A and 2.2B rapid swings of stage occurred in August and early September of 2004. The cause of the swings is unknown. A datalogger or pressure transducer malfunction is possible, however, the groundwater transducer also mirrored the swings in stage making a pressure transducer malfunction unlikely. Another possibility is discharges of surface water from the citrus grove. Since equipment malfunction cannot be ruled out, some overestimation of flow may have occurred for the August-early September 2004 time period.

The most intense period of precipitation is late summer, with discharge becoming very responsive to rain events in late summer and early fall (Graphs 2.3A, 2.2B and 2.4C).

Graphs 2.12A through 2.16A (2003-2004), 2.4B through 2.9B (2004-2005) and 2.5C through 2.10C (2005-2006), depict relationships between surface water pH, temperature, conductivity, dissolved oxygen and turbidity. The graphed field parameters were measured with the YSI sonde and with handheld field meters. pH values range from 7.0 to 8.0 during each monitored time period and did not reveal any trends in relation to discharge. pH spiked upward in conjunction with rain on September 2, 2005 (see Graph 2.6C). Temperature graphs 2.5B and 2.7C show a cyclical pattern, as would be expected, with low points in the early morning and the highest temperatures present in the late afternoon. Specific conductivity remained stable throughout each measurement period with measurements between 0.350 to 0.400 millisiemans in August and September of 2005 (Graphs 2.7B and 2.8C) and approximately 0.500 millisiemans in February of 2004 (Graph 2.14A). Similar to temperature, dissolved oxygen levels also varied in 24 hour cycles. The fluctuations in dissolved oxygen values likely correspond to rates aquatic plant photosynthesis. Dissolved oxygen levels ranged from approximately 7.5 milligrams per liter (mg/L) in late afternoon to 2.50 mg/L in the early morning (Graphs 2.8B and 2.9C). Turbidity ranged from 40 to 80 ntus on February 25, 2004 and was much lower when measured in August and September of 2005 (0.5 to 7.0 ntus).

Surface water samples were collected on February 25, 2004, June 7, 2004, February 2, 2005, August 26, 2005, September 20, 2005, October 26, 2005, February 27, 2006, May 25, 2006 and June 12, 2006. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C. Field parameter measurements for each sampling event are summarized on Table 3.

Analytical results from the February 25, 2004 stormwater sampling event were compared to corresponding discharge and presented on Graphs 2.5A through 2.11A. The graphs reveal some trends for the measured analytes in relation to stormwater discharge. It should be noted that samples were not collected towards the end of the stormwater event, therefore the observed trends are applicable only for the beginning of increased discharge resulting from the storm. Nitrate/nitrite and total phosphorus concentrations appeared to increase along with an increase in stormwater discharge. Orthophosphorus concentration appeared to slightly increase along with stormwater discharge. Total suspended solids spiked at the onset of increased stormwater flow and decreased shortly thereafter. Total Keldahl Nitrogen concentration appeared to decrease with an increase in stormwater discharge. Ammonia was not present at detectable levels, therefore there was no discernable ammonia trend. There was no discernable trend for copper due to the low measured concentrations, which were only several micrograms per liter above the laboratory method detection limit.

Field work sheets for the site visits performed for the Brooks Tropical Monitoring Station are presented in Appendix B.2.

Evapotranspiration for the site has been estimated by utilizing the value obtained from the nearest weather station installed for the project, located in the Corkscrew Swamp approximately one-half mile to the south.

The following estimates for parameters measured at the Brooks Tropical Monitoring Station are presented below:

2003-2004 Monitoring Period:

P = 65.0 inches
ET = 41.3 inches

$Flow_{tot}$ = 1.08 x 10^9 ft.^{3}
$Flow_{sr}$ = 5.25 x 10^7 ft.^{3}
$Flow_{storm}$ = 2.21 x 10^8 ft.^{3}

2004-2005 Monitoring Period:

P = 61.3 inches
ET = 40.1 inches
$Flow_{tot}$ = 8.97 x 10^8 ft.^{3}
$Flow_{sr}$ = 4.84 x 10^7 ft.^{3}
$Flow_{storm}$ = 3.18 x 10^8 ft.^{3}

2005-2006 Monitoring Period:

P = 63.9 inches
ET = 44.0. inches
$Flow_{tot}$ = 8.18 x 10^8 ft.^{3}
$Flow_{sr}$ = 9.27 x 10^7 ft.^{3}
$Flow_{storm}$ = 2.88 x 10^7 ft.^{3}

Where P = precipitation in inches
ET = evapotranspiration in inches
$Flow_{tot}$ = total flow in cubic ft.
$Flow_{sr}$ = total flow minus baseflow in cubic ft.
$Flow_{storm}$ = flow under storm water conditions

The 2003-2004 annual hydrologic budget for the Brooks Tropical Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where P = 65.0 inches
ET = 41.3 inches
$Flow_{sr}$ / Drainage Area = 23.3 inches
ΔV = 10.1 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(5.25 \times 10^7 \text{ ft.}^3) * 1728 \text{ inches/ft}^3 / (620 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2$

ΔV is calculated as follows:

ΔV = (5.61 ft. – 4.77 ft.) * 12 inches/ft.
5.61 ft. = groundwater elevation on 8/31/04.

4.77 ft. = groundwater elevation on 9/1/03.

The 2004-2005 annual hydrologic budget for the Brooks Tropical Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where $P = 61.3$ inches
$ET = 40.1$ inches
$Flow_{sr}$ / Drainage Area = 21.5 inches
$\Delta V = -11.5$ inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(4.84 \times 10^7 \text{ ft.}^3) * 1728 \text{ inches/ft}^3 / (620 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2$

ΔV is calculated as follows:

$\Delta V = (4.70 \text{ ft.} - 5.66 \text{ ft.}) * 12$ inches/ft.
4.70 ft. = groundwater elevation on 8/31/05.
5.66 ft. = groundwater elevation on 9/1/04.

The 2005-2006 annual hydrologic budget for the Brooks Tropical Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where $P = 63.9$ inches
$ET = 44.0$ inches
$Flow_{sr}$ / Drainage Area = 41.2 inches
$\Delta V = -1.0$ inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(9.27 \times 10^7 \text{ ft.}^3) * 1728 \text{ inches/ft}^3 / (620 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2$

ΔV is calculated as follows:

$\Delta V = (4.62 \text{ ft.} - 4.70 \text{ ft.}) * 12$ inches/ft.
4.62 ft. = groundwater elevation on 8/31/05.
4.70 ft. = groundwater elevation on 9/1/04.

The computations for the event mean concentrations and loading calculations are presented on Tables 5A, 5B and 5C.
The databases for Brooks Tropical are provided on the compact disc included with this report and are labeled "Brooks Tropical 2003-2004", "Brooks Tropical 2004-2005" and "Brooks Tropical 2005-2006".

Site Photographs 3 & 4 – Brooks Tropical Monitoring Station

3.3 CORKSCREW ROAD (LEE COUNTY)

Land Use Type: Roadway

GPS Coordinates: Latitude 26° 25' 53.41792" N
Longitude 81° 47 '33.83568" W

Site Location: North side of Corkscrew Road, approximately 1 mile west of I-75 and 0.5 miles east of .US 41.

Estimated Drainage Area: 0.91 acres.

Surface water is conveyed at the Corkscrew Road Monitoring Station by a small culvert draining the northern portion of the roadway. Water from the culvert is conveyed to a ditch that runs east to west. That ditch in turn discharges water into a large ditch that runs north to south and is 250 feet to the west of the monitoring station. Surface water discharge is monitored at the point where the culvert discharges to the ditch. Discharge at the Corkscrew Road Monitoring Station is measured at the site with the ADV. No discharge occurs unless a rain event is occurring. Based upon a correlation between rainfall and discharge, an approximation of discharge can be made based upon rainfall records at the site. Since the culvert exists in the road foundation and is elevated above the surrounding ground surface, baseflow is not considered to be a factor in calculating the volume of storm water runoff. Equipment used at the Corkscrew Road Station consists of a bucket rain gauge checked at the site visits (every two weeks). The rain data was also compared to bucket gauge rain data collected at Koreshan State Park by park personnel, located one-half mile to the west. Due to loss of rain data at the Corkscrew Road site, the Koreshan State Park bucket rain gauge data was utilized to estimate precipitation at the Corkscrew Road station. In 2005, PSI retrofitted its monitoring station at Koreshan State Park with a tipping bucket rain gauge and a groundwater pressure transducer. This data, in addition to the park ranger data was also utilized for precipitation measurements for the 2005-2006 monitoring period. The drainage area and monitoring station location are presented on Figure 4. A detail of the Corkscrew Road drainage flow is presented as Figure 5.

Surface water samples, field parameters, and discharge measurements were obtained on February 25, 2004, July 19, 2004, April 7, 2005, May 25, 2006 and June 13, 2006.

An estimate of flow as a function of rainfall for 2003-2006 is estimated as follows:

Date/Time	Flow (cf)	Rain (inches)	Flow (cf)/rain (inches)
9/25/03 25 minute time period	299	0.25	1196
2/25/04 120 minute time period	1481	1.5	987
7/19/04 60 minute time period	1263	2.0	632
5/25/06 120 minute time period	85	0.4	215
6/13/06 20 minute time period	134	0.15	893
Average amount of flow per inch of rain			759

2003-2004 Monitoring Period:
72 inches (annual rainfall) x 759 (cf)/inch ≈ 54,600 cf/year

2004-2005 Monitoring Period:
76.5 inches (annual rainfall) x 759 (cf)/inch ≈ 58,000 cf/year

2005-2006 Monitoring Period:
52 inches (annual rainfall) x 759 (cf)/inch ≈ 39,500 cf/year

Graphs 3.1A, 3.1B and 3.2C, Appendix A compares rainfall records at Koreshan State Park and the Corkscrew Road Station for the 2003-2004, 2004-2005 and 2005-2006 monitoring periods. Overall rainfall levels at Koreshan State Park are higher. This is due to both evaporation and instances when the bucket gauge at Corkscrew Road was tipped over. Rain data is missing from Koreshan Park for the 2003-2004 monitoring period which, since discharge is directly correlated to rainfall as a measurement technique for this station, would result in pollutant loading values skewed slightly low. More specifically, in 2003-2004, rainfall data is missing for eighteen days in February 2004, eleven days in July 2004 and eleven days in August 2004. The July data appears to have been a time period of heavy precipitation. Two inches are roughly estimated to have been lost in July. Rainfall data missing for the 2004-2005 monitoring period includes nineteen days in December 2004, eleven days in January 2005, all of February 2005, 24 days in April 2005, ten days in June 2005, 15 days in July 2005, and 12 days in August 2005. Typically, the summer months have the highest precipitation; therefore, the largest amount of lost data would have been then. Three to four inches of rain are estimated to have been unmeasured for the 2004-2005 monitoring period. The missing estimated rainfall amounts were not added into the annual totals for the flow calculations. Rainfall for the 2005-2006 monitoring period is significantly less than the previous monitoring periods. However the 2005-2006 rainfall data set is the most accurate- essentially no data was lost. This was due to PSI installing a tipping bucket rain gauge at the Koreshan State Park monitoring station in May 2005. Some tipping bucket rain gauge data was lost in April 2006, however since park personnel recorded their data at the ranger station bucket gauge, this data was substituted for PSI's missing data.

Graphs 3.2A and 3.3A, Appendix A compare rainfall versus discharge and rainfall versus stage for a rain event that occurred on July 19, 2004. Discharge reaches a maximum within the first 20 minutes of the rain event and then decreases due to the receiving ditch filling with runoff.

Graphs 3.3C through 3.7C depict pH, temperature, conductivity, dissolved oxygen and turbidity in relation to discharge at a May 25, 2006 storm event.

Surface water samples were collected on February 25, 2004, July 19, 2004, April 7, 2005, May 25, 2006 and June 13, 2006. The highest concentrations of copper detected for the study were measured in the first flush sample collected at the Corkscrew Road Station on February 25, 2004. The measured concentration was 38.1 µg/L. Relative to other land use types, first flush is more immediate and would have a tendency to contain street dust with an elevated concentration of copper. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C.

Graphs 3.8C through 3.14C compare analytical results to discharge for the May 25, 2006 storm event. Nitrate/nitrite show a slight decreasing trend as discharge increases. Total Keldahl nitrogen, ammonia, total suspended solids, copper and total phosphorus concentrations appear to mirror discharge trends. There is no strong trend revealed with orthophosphorus, perhaps a muted concentration trend that mirrors discharge. Field parameter measurements for each sampling event are summarized on Table 3.

Field work sheets for the site visits are presented in Appendix B.3.

An average evapotranspiration value, derived from the three Estero Bay weather stations, was utilized for the Corkscrew Road Monitoring Station. The following estimates for parameters measured at the Corkscrew Road Monitoring Station are presented below:

2003-2004 Monitoring Period:

$P = Flow_{tot}/\text{Drainage Area} + ET$

Where P = 72.0 inches
ET = 42.3 inches
$Flow_{tot}$ / Drainage Area = 16.5 inches

$Flow_{tot}$ / Drainage Area is calculated as follows:

$Flow_{tot}$ / Drainage Area =
$(5.46*10^4 ft^3) * 1728 inches/ft^3 / (0.91 acres * (43{,}560 (ft^2/acres)*144 inches^2/ft^2)$

2004-2005 Monitoring Period:

P = $Flow_{tot}$ /Drainage Area + ET

Where P = 76.5 inches
ET = 40.1 inches
$Flow_{tot}$ / Drainage Area = 17.6 inches

$Flow_{tot}$ / Drainage Area is calculated as follows:

$Flow_{tot}$ / Drainage Area =
$(5.80*10^4 ft^3) * 1728 inches/ft^3 / (0.91 acres * (43{,}560 (ft^2/acres)*144 inches^2/ft^2)$

2005-2006 Monitoring Period:

P = $Flow_{tot}$ /Drainage Area + ET

Where P = 52.0 inches
ET = 40.7 inches
$Flow_{tot}$ / Drainage Area = 12.0 inches

$Flow_{tot}$ / Drainage Area is calculated as follows:

$Flow_{tot}$ / Drainage Area =
$(3.95*10^4 ft^3) * 1728 inches/ft^3 / (0.91 acres * (43{,}560 (ft^2/acres)*144 inches^2/ft^2)$

The computations for the event mean concentrations and loading calculations are presented on Tables 6A, 6B and 6C.

The databases for Corkscrew Road are provided on the compact disc included with this report and are labeled “Corkscrew Road 2003-2004”, “Corkscrew Road 2004-2005” and “Corkscrew Road 2005-2006”.

Site Photographs 5 & 6 – Corkscrew Road Monitoring Station

3.4 CORKSCREW SWAMP (CORKSCREW SWAMP SANCTUARY, LEE COUNTY)

Land Use Type: Wetlands

GPS Coordinates: Latitude 26° 25' 04.29252" N
Longitude 81° 34' 42.36837" W

Approximate Site Location: Dirt road south off Corkscrew Road, approximately 15 miles east of I-75. Continue past Brooks Tropical monitoring station, into Corkscrew Swamp Sanctuary. Approximately ½ mile south of observation platform.

Drainage Area: 862 acres.

Surface water is conveyed at the Corkscrew Swamp Monitoring Station by two four-foot diameter corrugated steel culverts that underlay a dirt road traversing a causeway through the Corkscrew Swamp wetlands. The culverts drain wetlands to the east and convey surface water into a canal that parallels the road on the west side. The canal on the west side is the same as that which drains the citrus grove located to the north at Brooks Tropical. According to Audubon Society personnel at the Corkscrew Swamp Sanctuary, discharge from citrus groves to the north contributed flow to the Corkscrew Swamp in the area of the monitoring station, particularly in times of low stage. A review drainage basins with topographic maps indicates that when stage is less than 17.5 feet the North American Vertical Datum 1988 (NAVD 88), flow is entirely from the citrus groves located to the north. When stage is above 17.5 feet NAVD 88, wetland flow from the east blocks flow from the north. Laboratory analytical and flow data has therefore not been utilized for evaluating wetland pollutant loading for times when stage is below 17.5 feet. This leaves a limited amount of laboratory data (two sampling events August 26, 2005 and October 26, 2005) for wetland pollutant loading calculations.

Discharge at the Corkscrew Swamp Monitoring Station was measured with the ADV. Pressure transducers are used to continuously monitor stage and groundwater elevation. Rainfall and Evapotranspiration was obtained from the Corkscrew Weather Monitoring Station, located 0.5 miles to the north. The drainage area for stage above 17.5 feet and monitoring station location are presented on Figure 6.

Stage/discharge calibration curves have been developed for each of the drainage culverts at the Corkscrew Swamp Monitoring Station based on data collected to date (see Graphs 4.1A through 4.4A (2003-2004), 4.1B through 4.6B (2004-2005) and 4.1C through 4.6 (2005-2006). The graphs are presented in Appendix A.

Fall 2003 Discharge vs. Stage Calibration Curve for the South Culvert:

Q (cfs) = 12.799 * (stage (ft.)) –23.316
R^2 = 0.9747

Summer 2004 Discharge vs. Stage Calibration for the South Culvert when stage is greater than 1.62 ft*:

Q (cfs) = 16.556 * (stage (ft.)) - 26.682 (stage(ft.))
$R^2 = 0.9853$

Summer 2004 Discharge vs. Stage Calibration Curve for the North Culvert when stage is greater than 1.65 ft*:

Q (cfs) = 32.935*Ln (stage (ft.)) – 16.648
$R^2 = 0.9502$

Fall 2004 Discharge vs. Stage Calibration Curve for the South Culvert:

Q (cfs) = 12.02 * $(\text{stage (ft.)})^2$ –37.228(stage (ft.))+25.342
$R^2 = 0.9909$

Fall 2004 Discharge vs. Stage Calibration Curve for the North Culvert:

Q (cfs) = 0.0156* $(\text{stage (ft.)})^{6.1024}$
$R^2 = 0.9946$

Summer 2005 Discharge vs. Stage Calibration Curve for the South Culvert when stage is less than 2.96 ft.*:

Q (cfs) = 6.2651 (stage (ft.)) – 9.7446
$R^2 = 1$

Summer 2005 Discharge vs. Stage Calibration Curve for the South Culvert when stage is greater than 2.96 ft.*:

Q (cfs) = -16.161$(\text{stage (ft.)})^2$ +122.3(stage (ft.))– 210.34
$R^2 = 0.765$

Summer 2005 Discharge vs. Stage Calibration Curve for the North Culvert when stage is less than or equal to 2.96 ft.*:

Q (cfs) = 6.988 (stage (ft.)) – 12.984
$R^2 = 1$

Summer 2005 Discharge vs. Stage Calibration Curve for the North Culvert when stage is greater than 2.96 ft.*:

Q (cfs) = -11.599$(\text{stage (ft.)})^2$ +90.687(stage (ft.))– 158.7

$R^2 = 0.8286$

Fall 2005 Discharge vs. Stage Calibration Curve for the South Culvert:

$$Q \text{ (cfs)} = -4.698 * (\text{stage (ft.)})^2 + 37.778(\text{stage (ft.)}) - 54.949$$
$$R^2 = 0.8104$$

Fall 2005 Discharge vs. Stage Calibration Curve for the North Culvert:

$$Q \text{ (cfs)} = 0.4748 * (\text{stage (ft.)})^2 + 8.1405(\text{stage (ft.)}) - 17.186$$
$$R^2 = 0.8891$$

Winter 2005-2006 Discharge vs. Stage Calibration Curve for the South Culvert:

$$Q \text{ (cfs)} = 4.4437 * (\text{stage (ft.)})^2 - 12.695(\text{stage (ft.)}) + 10.687$$
$$R^2 = 0.8506$$

Summer 2006 Discharge vs. Stage Calibration Curve for the South Culvert:.:

$$Q \text{ (cfs)} = 0.2006(\text{stage (ft.)})^{4.2424}$$
$$R^2 = 0.9973$$

Fall 2005 Discharge vs. Stage Calibration Curve for the North Culvert:

$$Q \text{ (cfs)} = 0.4748 * (\text{stage (ft.)})^2 + 8.1405(\text{stage (ft.)}) - 17.186$$
$$R^2 = 0.8891$$

Winter 2005-2006 Discharge vs. Stage Calibration Curve for the North Culvert:

$$Q \text{ (cfs)} = 3.5814 * (\text{stage (ft.)})^2 - 9.6162(\text{stage (ft.)}) + 6.6217$$
$$R^2 = 0.89994$$

Summer 2006 Discharge vs. Stage Calibration Curve for the North Culvert when stage is greater than 2.06 ft.*:

$$Q \text{ (cfs)} = 6.3964(\text{stage (ft.)})^2 - 16.861(\text{stage (ft.)}) + 7.6288$$
$$R^2 = 0.9983$$

* Elevations referenced to the bottom of the south culvert.

A stage/discharge calibration curve could not be developed for the following time periods due to lack of correlation between stage and the ADV discharge measurements:

North culvert Fall 2003
South culvert Summer 2004 when stage is less than or equal to 1.62 ft.
North culvert Summer 2004 when stage is less than or equal to 1.65 ft.
North culvert Summer 2006 when stage is less than 2.06 ft.

Discharge measured with the ADV during site visits was extrapolated to estimate discharge between site visits for conditions where calibration curves could not be developed. Separate calculations for the two culverts were necessary for two reasons: a stage/discharge relationship for total discharge (i.e. the individual culvert discharges added together) could not be developed and the two culverts had different invert elevations). It should be noted that the calibration curves were developed with relatively few data points.

Relationships between stage and discharge, rainfall and discharge, stage and groundwater elevation are presented on Graphs 4.5A through 4.8A (2003-2004), 4.7B through 4.10B (2004-2005), and 4.7C through 4.10C (2005-2006). The graphs are presented in Appendix A.

As indicated by the graphs, discharge ranges between 11 and 65 cfs during periods of wetland flow. Wetland flow occurs in late summer and early fall when stage levels are at a peak as a result of the summer rainy season.

A YSI 6820 multi-parameter sonde was deployed at the site from May 13 to June 9, 2004 to record surface water pH, temperature, specific conductivity, dissolved oxygen and turbidity. Graphs 4.9A through 4.13A, Appendix A, depict relationships between surface water pH temperature, conductivity, and turbidity for mid May through mid June. A spike in pH and turbidity corresponds to the initiation of the summer rains in early June. Conductivity dropped from around 0.425 mS to 0.350 mS at the initiation of the summer rainy season. Turbidity spikes as high as 140 ntus corresponding to rain events are depicted on Graph 4.13A. Dissolved oxygen levels (monitored from May 13 to May 16 2004) fluctuate from 4.5 mg/L to 0.25 mg/L diurnally, most likely due to decreased plant respiration in the evening.

The sonde was also deployed at the site from February 3 to February 17, 2005 to record surface water pH, temperature, specific conductivity, dissolved oxygen and turbidity during dry conditions. Graphs 4.11B through 4.15B, Appendix A, depict relationships between surface water pH temperature, conductivity, and turbidity. pH appears to be typical of a surface water body ranging from 6.9 to 7.2. Temperature fluctuated diurnally and ranged from 13.4° C and 21.7° C. Conductivity ranged from 0.460 to 0.506 mS. Dissolved oxygen levels fluctuated from 1.5 mg/L to 7.0 mg/L diurnally. Turbidity was between 3.1 and 8.6 NTUs. It should be noted that the field parameter measurements with the were obtained during times when stage was below

17.50 ft. NAVD 88 and were measurements of agricultural discharge. Field parameters with hand held meters were obtained on two occasions when wetland discharge was occurring- October 29, 2005 and October 26, 2005 (see Table 3). There do not appear to be any striking differences in field parameters with the wetland flow measurements as opposed to the agricultural discharge measurements.

Surface water samples were collected on February 25, 2003, April 27, 2004, June 7, 2004, January 6, 2005, August 26, 2005 (an orthophosphate sample was collected on August 29, 2005), September 21, 2005, October 26, 2005, February 27, 2006, May 25, 2006 and June 12, 2006. The analytical results are summarized on Table 2. As previously indicated, the analytical results of only two of the sampling results were utilized for pollutant loading calculations - the results August 26, 2005 and October 26, 2005. Analyte concentrations from these two sampling events were lower than results from sampling events conducted when stage was low and discharge was from the citrus grove. An exception was results from February of 2004 and 2006 when samples were collected under low stage conditions (agricultural discharge). The February sample results were only slightly higher than the sample results collected during wetland flow conditions. This may because February is the month just prior to the time when citrus groves typically apply fertilizers and fungicides before the trees bloom in Spring. The complete laboratory results are presented in Appendix C.

Field work sheets for the site visits are presented in Appendix B.4.

The following estimates for parameters measured at the Corkscrew Swamp Monitoring Station during periods of wetland flow are presented below:

2003-2004 Monitoring Period:

$Flow_{tot} = 8.13 \times 10^7$ ft.^{3}
$Flow_{sr} = 3.24 \times 10^6$ ft.^{3}
$Flow_{storm} = 1.07 \times 10^6$ ft.^{3}

2004-2005 Monitoring Period:

$Flow_{tot} = 4.85 \times 10^8$ ft.^{3}
$Flow_{sr} = 3.05 \times 10^7$ ft.^{3}
$Flow_{storm} = 8.74 \times 10^7$ ft.^{3}

2005-2006 Monitoring Period:

$Flow_{tot} = 2.03 \times 10^8$ ft.^{3}
$Flow_{sr} = 4.76 \times 10^6$ ft.^{3}
$Flow_{storm} = 4.42 \times 10^7$ ft.^{3}

Where $Flow_{tot}$ = total wetland flow in cubic ft.

$Flow_{sr}$ = total wetland flow minus baseflow in cubic ft.
$Flow_{storm}$ = wetland flow under storm water conditions

Due to the shift in the location of the drainage sub-basins between periods of high and low flow and the difficulties in determining the correct rainfall and evapotranspiration values for each sub-basin, annual hydrologic budgets for the Corkscrew Swamp Monitoring Station are not presented.

The computations for the event mean concentrations and loading calculations are presented on Tables 7A and 7B.

The databases for Corkscrew Swamp are provided on the compact disc included with this report and are labeled "Corkscrew Swamp 2003-2004", "Corkscrew Swamp 2004-2005" and "Corkscrew Swamp 2005-2006".

Site Photograph 7 - Corkscrew Swamp Monitoring Station

3.5 CORKSCREW SWAMP WEATHER STATION (CORKSCREW SWAMP SANCTUARY, LEE COUNTY)

Land Use Type: Wetlands

GPS Coordinates: Latitude 26° 25' 24.32784" N
Longitude 81° 34' 42.81310" W

Site Location: Dirt road south off Corkscrew Road, approximately 15 miles east of I-75. Continue past Brooks Tropical monitoring station, into Corkscrew Swamp Sanctuary. The station is located at the observation platform that straddles the access road.

The various monitored weather parameters (temperature, relative humidity, precipitation, wind speed, solar radiation, and evapotranspiration) are presented on Graphs 5.1A through 5.6A (2003-2004), 5.1B through 5.6B (2004-2005) an 5.1C through 5.6C (2005-2006), Appendix A. The monitored parameters are used to derive an evapotranspiration value utilizing the Penmann-Monteith equation. The weather monitoring station location is presented on Figure 6.

Rainfall and evapotranspiration values for the Corkscrew Swamp Weather Monitoring Station are presented below:

2003-2004 Monitoring Period:

P = 44.3 inches
ET = 41.3 inches

2004-2005 Monitoring Period:

P = 58.9 inches
ET = 40.1 inches

2005-2006 Monitoring Period:

P = 60.7 inches
ET = 43.9 inches

Where P = precipitation in inches
ET = evapotranspiration in inches

It should be noted that the relative humidity gauge became unstable in April of 2005, however, the relative humidity gauge malfunction does not appear to have significantly effected the evapotranspiration calculation.

Field work sheets for the site visits are presented in Appendix B.5.

The databases for Corkscrew Weather Station are provided on the compact disc included with this report and are labeled "Corkscrew Weather Station 2003-2004", "Corkscrew Weather Station 2004-2005" and "Corkscrew Weather Station 2005-2006".

Site Photograph 8 - Corkscrew Swamp Weather Station

3.6 EASTWOOD GOLF COURSE (FT. MYERS)

Land Use Type: Park (Golf Course)

GPS Coordinates: Latitude 26° 36' 45.3" N
Longitude 81° 49' 24.5" W

Site Location: Approximately 500 ft north of Winkler Avenue. ½ mile west of Ortiz Avenue. The monitoring station is located at the southwest corner of the Eastwood Golf Course.

Drainage Area: 207 acres

Surface water is conveyed from the Eastwood Golf Course by a canal that runs off site towards the west. The monitoring station was located at a weir where the canal leaves the golf course. The site was equipped with a weather station which monitors weather parameters including temperature, relative humidity, solar radiation, wind speed, wind direction, and evapotranspiration. Stage was continuously monitored at the Eastwood Golf Course Monitoring Station with a pressure transducer monitoring deployed in the canal. stage. A pressure transducer was also utilized to continuously monitor groundwater elevation. The drainage area and monitoring station are presented on Figure 7.

A stage/discharge calibration curve has been developed for the Brooks Tropical Monitoring Station based on data collected to date (see Graphs 2.1A, 2.1B and 2.1C, Appendix A) and is applicable when stage is less than 5.35 ft.

A stage/discharge calibration curve has been developed for the Eastwood Golf Course Monitoring Station based on data collected for the 2003-2006 study period (see Graphs 6.1A, 6.1B and 6.1C, Appendix A) and is applicable when stage is less than or equal to 4.42 ft.

The equation is as follows:

$$Q\ (\text{cfs}) = 66.808(\text{stage (ft.)})^2 - 505.49\ (\text{stage (ft.)}) + 956.21$$
$$R^2 = 0.8718$$

Relationships between stage and discharge, rainfall and discharge, and stage and groundwater elevation are presented on Graphs 6.2A through 6.5A (2003-2004), 6.2B through 6.4B (2004-2005), and 6.2C through 6.4C (2005-2006). The graphs are presented in Appendix A.

Discharge at the Eastwood Golf Course occurs sporadically and is dependent upon stage being above the weir crest. Average discharge at the site is from 5 to 10 cfs.

Similar to other monitored locations within the Estero Bay watershed, discharge did not occur in the spring due to dry conditions. As indicated by the graphs, the highest discharge was a brief spike up to 74 cfs and was associated with precipitation occurring on September 28, 2003.

The various monitored weather parameters (temperature, relative humidity, precipitation, wind speed, solar radiation, and evapotranspiration) are presented on Graphs 6.6A through 6.11A (2003-2004), 6.6B through 6.11B (2004-2005) an 6.6C through 6.11C (2005-2006), Appendix A. The monitored parameters are used to derive an evapotranspiration value utilizing the Penmann-Monteith equation.

A YSI 6820 multi-parameter sonde was deployed at the site on two occasions during the 2003-2004 monitoring period to record surface water pH, temperature, specific conductivity, dissolved oxygen and turbidity. Graphs 6.12A through 6.21A, Appendix A, show surface water pH temperature, conductivity, dissolved oxygen and turbidity for slightly over one month in the spring and for an eight day period in mid-July. pH was between 7.6 and 8.5 in the spring during a time when no discharge was occurring. pH was lower (7.4-7.8) in mid-July when the site had surface water discharge. Water temperature gradually increased in the spring and again in mid July in response to increased atmospheric temperature. Specific conductivity was stable in the spring under no flow conditions (690-760 microsiemans (µS)). Specific conductivity was higher (900 µS) in mid July under flow conditions. A pronounced dip in conductivity corresponding to a rain event on July 11, 2004 is apparent on Graph 6.17A. Dissolved oxygen ranged from less than 1 mg/L to 10 mg/L to for the spring deployment. Lower values were measured for the mid-July deployment with dissolved oxygen measured between 0.03 to 2 mg/L (Graphs 6.18A and 6.19A). Graphs 6.20A and 6.21compare turbidity measurements with rainfall for both the spring and mid-July sonde deployments. The rain events do not appear to have affected turbidity for either measurement period. The sonde was also deployed in August of 2006, but with the exception of the temperature sensor, malfunctioned. Graph 6.12C depicts water temperature vs. discharge for the time period of August 21, 2006 to August 29,2006.

Surface water samples were collected on August 28, 2003, February 25, 2004, July 19, 2004, March 15, 2005, August 26, 2005, October 27, 2005, February 27, 2006, and August 30, 2006. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C. Field parameter measurements for each sampling event are summarized on Table 3.

Field work sheets for the site visits are presented in Appendix B.6.

The following estimates for parameters measured at the Eastwood Golf Course for the are presented below:

2003-2004 Monitoring Period:

P = 71.1 inches
ET = 35.7 inches
$Flow_{tot}$ = 2.02 x 10^8 ft.^{3}
$Flow_{sr}$ = 2.00 x 10^7 ft.^{3}
$Flow_{storm}$ = 7.88 x 10^7 ft.^{3}

2004-2005 Monitoring Period:

P = 70.7 inches
ET = 34.2 inches
$Flow_{tot}$ = 1.36 x 10^8 ft.^{3}
$Flow_{sr}$ = 6.94 x 10^6 ft.^{3}
$Flow_{storm}$ = 2.09 x 10^7 ft.^{3}

2005-2006 Monitoring Period:

P = 81.9 inches
ET = 36.7. inches
$Flow_{tot}$ = 1.02 x 10^8 ft.^{3}
$Flow_{sr}$ = 4.88 x 10^6 ft.^{3}
$Flow_{storm}$ = 3.00 x 10^7 ft.^{3}

Where P = precipitation in inches
ET = evapotranspiration in inches
$Flow_{tot}$ = total flow in cubic ft.
$Flow_{sr}$ = total flow minus baseflow in cubic ft.
$Flow_{storm}$ = flow under storm water conditions

The 2003-2004 annual hydrologic budget for the Eastwood Golf Course Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr}$ / Drainage Area

Where P = 71.1 inches
ET = 35.7 inches
$Flow_{sr}$ / Drainage Area = 26.6 inches
ΔV = 2.8 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(2.00 \times 10^7 \text{ ft}^3 \times 1728 \text{ inches/ft}^3)/(207 \text{ acres} \times 43{,}560 \text{ ft}^2\text{/acres} \times 144 \text{ inches}^2\text{/ ft}^2)$

ΔV is calculated as follows:

ΔV = (4.28 ft. – 4.05 ft.) * 12 inches/ft.)
4.28 ft. = groundwater elevation on 8/31/04.
4.05 ft. = groundwater elevation on 9/1/03.

The 2004-2005 annual hydrologic budget for the Eastwood Golf Course Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr}$ / Drainage Area

Where P = 70.7 inches
ET = 34.2 inches
$Flow_{sr}$ / Drainage Area = 9.2 inches
ΔV = -2.2 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
($6.94*10^6$ ft ^{3}* 1728 inches/ft ^{3})/(207 acres * 43,560 ft^2/acres*144 inches^2/ ft^2)

ΔV is calculated as follows:

ΔV = (3.87 ft. – 4.05 ft.) * 12 inches/ft.)
3.87 ft. = groundwater elevation on 8/31/05.
4.05 ft. = groundwater elevation on 9/1/04.

The 2005-2006 annual hydrologic budget for the Eastwood Golf Course Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr}$ / Drainage Area

Where P = 81.9 inches
ET = 36.7 inches
$Flow_{sr}$ / Drainage Area = 6.5 inches
ΔV = -0.6 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
($4.88*10^6$ ft ^{3}* 1728 inches/ft ^{3})/(207 acres * 43,560 ft^2/acres*144 inches^2/ ft^2)

ΔV is calculated as follows:

ΔV = (3.87 ft. – 4.43 ft.) * 12 inches/ft.)
4.43 ft. = groundwater elevation on 8/31/06.
3.87 ft. = groundwater elevation on 9/1/05.

The computations for the event mean concentrations and loading calculations are presented on Tables 8A, 8B and 8C.

The databases for Eastwood Golf Course are provided on the compact disc included with this report and are labeled "Eastwood Golf Course 2003-2004", "Eastwood Golf Course 2004-2005" and "Eastwood Golf Course 2005-2006".

Site Photograph 9 – Eastwood Golf Course Monitoring Station

3.7 FLORIDA GULF COAST UNIVERSITY (FGCU) (FT. MYERS)

Land Use Type: Commercial/Industrial

GPS Coordinates: Latitude 26° 27' 38.49124" N
Longitude 81° 46' 33.06282" W

Site Location: East of I-75 on Alico Road. Turn south on Ben Hill Griffin Parkway. Turn into FGCU and take the first right. The station is approximately 500 feet down on the right.

Drainage Area: 68 acres

Surface water is managed at FGCU by a series of detention ponds which, when overflowing, discharge into a ditch that conveys runoff into a wetland located immediately west of the campus. The monitoring station is located at the point where runoff discharges from a culvert underneath the road bordering the west side of the campus. The culvert is a continuation of the main drainage ditch. The drainage area and monitoring station location is presented on Figure 8.

Discharge at the FGCU Monitoring Station was measured with an ISCO 4250 Flowmeter equipped with an area velocity sensor. The area velocity sensor was deployed in the culvert. The flowmeter was periodically calibrated utilizing stage and ADV measurements. Surface water elevation and rainfall were also measured and recorded on an ISCO data logger. The data logger information was then output onto a strip chart. Groundwater elevation was measured with a water level indicator measuring the depth to water in a shallow groundwater piezometer.

The monitoring station was retrofitted with a CR510X datalogger and groundwater pressure transducer in late May 2005. The pressure transducer was installed in the groundwater piezometer and wired to the new datalogger to continuously record groundwater levels, allowing for a more accurate estimation of groundwater elevation.

Relationships between stage and discharge, rainfall and discharge, and stage and groundwater elevation are presented on Graphs 7.1A an 7.2B (2003-2004), 7.1B through 7.3B (2004-2005), and 7.1C through 7.3C (2005-2006). The graphs are presented in Appendix A.

The area flowmeter did not operate for a significant period of time during the 2003-2004 monitoring period primarily due to power failure. Discharge for the site, therefore, was estimated by utilizing ADV measurements for times when the flowmeter did not operate.

As indicated by Graph 7.1A, discharge at the site is low very to nonexistent for much of the winter and spring. By late July, discharge was as high as 2 cfs in response to summer rain events.

Graphs 7.1B and 7.2B depict discharge at the site during the 2004-2005 monitoring period. Discharge was at 1 cfs or less from September 1 through November 9 2004 (discharge as high as 1.22 cfs was measured for a short period on September 9, 2004). After November 9, 2005, there was no discharge at FGCU until March 17, 2006. In mid-March surface water discharge occurred in response to rainy weather. Discharge occurred on a continuous basis in summer. The ISCO 4250 Flowmeter was removed from the site for repair in early July and was not placed back until after August 31, 2005. Discharge for mid to late summer was estimated by using ADV readings obtained at the site visits. It should be noted that due to the flowmeter inoperation during the summer, flow rates may be skewed low for late summer of 2005.

Graphs 7.1C and 7.2C depict discharge at the site during the 2005-2006 monitoring period. While most of the year was fairly dry, heavy rains during the summer produced some heavy flows for short periods. The flowmeter data also indicates that occasional backflow occurs from the wetland into which the FGCU surface water drains to and is the reason for the negative flow spikes depicted on graph 7.2C.

Data for pH, temperature, conductivity, dissolved oxygen and turbidity measurements logged by the sonde for November 13, 2003 through November 26, 2003 are presented on Graphs 7.3A through 7.7A. Data for mid-November is missing due to a failure in power supply. The sonde data reveals field parameter data similar to patterns seen at the other stations. Temperature and dissolved oxygen cycled diurnally. Turbidity spikes in late November may be due to either storm events or other disturbances.

Surface water samples were collected on November 19, 2003, February 25, 2004, March 17, 2005, April 8, 2005, August 26, 2005, October 26, 2005 and February 27, 2006. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C. Field parameter measurements for each sampling event is summarized on Table 3.

The 2003-2004 annual rainfall total for FGCU is low due to the significant amount of time during which the flowmeter datalogger was inoperable. For 2003-2004, precipitation is estimated as the average of precipitation measured at the other monitoring stations equipped with rain gauges. Rain data from the next nearest monitoring station, Koreshan State Park, was utilized for the FGCU data base during times when the datalogger as not operating during the 2004-2005 and 2005-2006 monitoring periods. It should be noted that the 32.2 inches annual rainfall for 2005-2006 appears to be low, however nearby stations also recorded low levels of rain for the monitoring period.

Field work sheets for the site visits are presented in Appendix B.7.

Evapotranspiration is estimated as the average of evapotransporation calculated at the Eastwood Golf Course, Corkscrew Swamp and Kiehl Canal Monitoring Stations.

The following estimates for parameters measured at FGCU are presented below:

2003-2004 Monitoring Period:

P = 72.1 inches
ET = 42.3 inches
$Flow_{tot} = 1.47 \times 10^7 ft.^3$
$Flow_{sr} = 1.01 \times 10^6 ft.^3$
$Flow_{storm} = 1.14 \times 10^7 ft.^3$

2004-2005 Monitoring Period:

P = 70.0 inches
ET = 40.1 inches
$Flow_{tot} = 5.96 \times 10^6 ft.^3$
$Flow_{sr} = 4.00 \times 10^5 ft.^3$
$Flow_{storm} = 3.58 \times 10^6 ft.^3$

2005-2006 Monitoring Period:

P = 32.2 inches
ET = 40.7 inches
$Flow_{tot} = 1.12 \times 10^7 ft.^3$
$Flow_{sr} = 6.76 \times 10^6 ft.^3$
$Flow_{storm} = 8.86 \times 10^6 ft.^3$

The 2003-2004 annual hydrologic budget for the FGCU Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where P = 72.1 inches
ET = 42.3 inches
$Flow_{sr}$ / Drainage Area = 4.1 inches
ΔV = 7.4 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(1.01 \times 10^6 \text{ ft}^3) * 1728 \text{ inches/ft}^3 / (68 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2)$

ΔV is calculated as follows:

ΔV = (2.02 ft. – 1.40 ft.) * 12 inches/ft.
2.02 ft. = groundwater elevation on 8/31/04.
1.40 ft. = groundwater elevation on 9/1/03.

The 2004-2005 annual hydrologic budget for the FGCU Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where P = 70.0 inches
ET = 40.1 inches
$Flow_{sr}$ / Drainage Area = 16.2 inches
ΔV = -6.7 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(4.00 \times 10^5 \text{ ft}^3) * 1728 \text{ inches/ft}^3 / (68 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2)$

ΔV is calculated as follows:

ΔV = (1.46 ft. – 2.02 ft.) * 12 inches/ft.
1.46 ft. = groundwater elevation on 8/31/05.
2.02 ft. = groundwater elevation on 9/1/04.

The 2005-2006 annual hydrologic budget for the FGCU Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where P = 32.21 inches
ET = 40.7 inches
$Flow_{sr}$ / Drainage Area = 27.4 inches
ΔV = -2.2 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(6.76 \times 10^6 \text{ ft}^3) * 1728 \text{ inches/ft}^3 / (68 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2)$

ΔV is calculated as follows:

ΔV = (1.52 ft. – 1.70 ft.) * 12 inches/ft.

1.70 ft. = groundwater elevation on 8/31/06.
1.52 ft. = groundwater elevation on 9/1/05.

The computations for the event mean concentrations and loading calculations are presented on Tables 9A, 9B and 9C.

The databases for FGCU are provided on the compact disc included with this report and are labeled "FGCU 2003-2004", "FGCU 2004-2005" and "FGCU 2005-2006."

3.8 GALEANA STREET (FT. MYERS)

Land Use Type: Commercial/Industrial

GPS Coordinates: Latitude 26° 31' 54.5" N
Longitude 81° 52' 4.4" W

Site Location: East on Galeana Street off of US 41. Located approximately one-half mile east of US 41.

Drainage Area: 46 acres

Surface water is conveyed at the Galeana Street Monitoring Station by a ditch that runs east to west, draining a commercial/industrial area. The drainage area and monitoring station location is presented on Figure 9.

Discharge at the site is periodically measured with an ADV. A pressure transducer was utilized to continuously monitor groundwater elevation during the 2003-2004 monitoring period. The groundwater transducer was inoperable for the 2004-2005 and 2005-2006 monitoring periods so instead, site visit groundwater transducer measurements were extrapolated for time periods between the site visits. The site was also equipped with a tipping bucket rain gauge.

Graphs 8.1A and 8.2A, Appendix A are graphs of stage/ADV discharge measurements for the 2003-2004 monitoring period. The ADV measurements alone are utilized to measure discharge at Galeana Street due to the lack of correlation between stage and discharge. Discharge at Galeana Street was typically around 1 cfs with typical discharge slightly less than 0.05 cfs for the spring of 2004.

Development of calibration curves were accomplished for the 2004-2005 and 2005-2006 monitoring periods. Graphs 8.1B and 8.2B depict stage/ADV discharge measurements for the 2004-2005 monitoring period. The 2004-2005 stage/discharge calibration curve developed for the Galeana Street Monitoring Station is as follows:

$$Q\ (cfs) = 0.9228 * (stage\ (ft.))^2 - 1.5353(stage\ (ft.)) + 0.5887$$
$$R^2 = 0.7474$$

This equation was applied when stage was greater than 1.06 ft. Discharge was estimated at 0.01 cfs when stage was less than 1.06 ft.

A 2005-2006 fall/winter stage/discharge calibration curve (Graph 8.1C) is expressed as follows:

$$Q \text{ (cfs)} = 3.0119 * (\text{stage (ft.)})^2 - 5.7553(\text{stage (ft.)}) + 2.3874$$
$$R^2 = 0.9987$$

This equation was applied when stage was greater than 1.31 ft. Discharge was estimated at 0.00 cfs when stage was less than 1.31 ft.

The 2005-2006 summer stage/discharge calibration curve (Graph 8.2C) is expressed as follows:

$$Q \text{ (cfs)} = 2.9317 * (\text{stage (ft.)})^2 - 5.0836(\text{stage (ft.)}) + 1.9795$$
$$R^2 = 0.9524$$

This equation was applied when stage was greater than 1.27 ft. Discharge was estimated at 0.00 cfs when stage was less than 1.27 ft.

No discharge occurred in the spring of 2006.

Relationships between stage and discharge, rainfall and discharge, and stage and groundwater elevation are presented on Graphs 8.3A and 8.4A (2003-2004), 8.3B through 8.6B (2004-2005), and 8.3C through 8.6C (2005-2006). The graphs are presented in Appendix A.

Graphs 8.5A through 8.9A, depict field parameter data logged by the sonde from mid May to early June. Similar to the field data collected at the other stations, pH spikes upward and conductivity spikes downward at the beginning of the summer rainy season. A spike in turbidity up to 90 NTU coincides with a June 4, 2004 rain event. Temperature and dissolved oxygen exhibit diurnal fluctuations. Dissolve oxygen levels range from close to 0 mg/L to 5 mg/L.

Graphs 8.7B through 8.9B depict field parameter data logged by the sonde from February 3, 2005 through February 5, 2005.

Graphs 8.10B through 8.12B depict field parameter data logged by the sonde from March 3, 2005 through March 6, 2005.

Graphs 8.13B through 8.16B depict field parameter data logged by the sonde from April 7, 2005 through April 8, 2005.

Graphs 8.23B and 8.24B depict pH and dissolved oxygen data logged by the sonde from August 25, 2005 through August 26, 2005.

Graphs 8.7C, 8.8C and 8.9C depict pH, temperature and conductivity data for September 20, 200 through September 22, 2005.

The 2005 February, March, and August sonde deployments were during dry conditions. The parameters measured were within typical ranges. At each of the deployments, diurnal variations of dissolved oxygen are apparent. This is probably a result of plant photosynthesis which occurs most intensely during midday and ceases during night. The monitored ditch at Galeana Street is usually vegetated.

Of interest is the April 2005 deployment which was during a rain event. pH decreased at the beginning of the rain event, similar to temperature. This may be a result of decreased levels of dissolved calcium carbonate in surface water as temperature decreases. Specific conductivity was highest just in front of peak flow (see Graph 8.15A) perhaps indicating the time at which total suspended solids (TSS) was at its highest concentration. The diurnal pattern for dissolved oxygen noted for the measurements obtained by the sonde during dry conditions appears not to have occurred for the storm event, with instead, dissolved oxygen levels gradually decreasing as a function of time. The September 2005 sonde deployment also was during several brief rain events and shows the same type of pattern with the relationship between pH and temperature.

Surface water samples were collected on December 17, 2003, April 28, 2004, June 9, 2004, February 3, 2005, April 7 & 8, 2005, August 26, 2005, February 27, 2006 and June 13, 2006. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C.

Graphs 8.17B through 8.22B, Appendix A, depict analyte concentrations graphed in relation to discharge produced from stormwater on April 7, 2005 through April 8, 2005. Four sample sets were collected at 3 hour intervals, with the first set collected during peak flow which occurred approximately two hours after the initiation of the rain event. As indicated by Graph 8.17B, nitrate/nitrite (NOX) concentrations appeared to mimic discharge. The highest nitrate/nitrite concentration (120 µg/L) was measured during peak discharge with concentrations decreasing along with flow rate thereafter. Total Keldahl Nitrogen (TKN) has a relatively high concentration during peak flow, decreases rapidly as flow decreases and then rebounds to concentrations close to the first sample concentration later on in the storm event (Graph 8.18B). Ammonia (NH3-N) is depicted on Graph 8.19B. Concentrations of ammonia increased as a function of time, with lower concentrations measured early on during the rain event and then increasing towards the end of the rain event. Similar to NOX, total phosphorus also mimicked flow, with the highest concentrations measured at the beginning of the rain event during high flow (Graph 8.19B). Total suspended solids measurements revealed no discernable trend for this sampling event (Graph 8.21B). Copper concentrations appear to peak just after peak discharge and then taper off as discharge decreases (Graph 8.22). It should be noted that orthophosphorus was not present in measurable concentrations during this sampling event.

The following estimates for parameters measured at the Galeana Street Monitoring Station are presented below:

2003-2004 Monitoring Period:
P = 61.4 inches
ET = 42.3 inches
$Flow_{tot}$ = 1.98 x 10^7 $ft.^3$
$Flow_{sr}$ = 2.44 x 10^6 $ft.^3$
$Flow_{storm}$ = 4.28 x 10^6 $ft.^3$

2004-2005 Monitoring Period:
P = 69.2 inches
ET = 40.1 inches
$Flow_{tot}$ = 9.17 x 10^6 $ft.^3$
$Flow_{sr}$ = 2.41 x 10^6 $ft.^3$
$Flow_{storm}$ = 2.62 x 10^6 $ft.^3$

2005-2006 Monitoring Period:
P = 65.3 inches
ET = 40.7 inches
$Flow_{tot}$ = 1.70 x 10^7 $ft.^3$
$Flow_{sr}$ = 5.49 x 10^6 $ft.^3$
$Flow_{storm}$ = 9.34 x 10^6 $ft.^3$

Where P = precipitation in inches
ET = evapotranspiration in inches
$Flow_{tot}$ = total flow in cubic ft.
$Flow_{sr}$ = total flow minus baseflow in cubic ft.
$Flow_{storm}$ = flow under storm water conditions

The 2003-2004 annual hydrologic budget for the Galeana Street Monitoring Station is as follows:

ΔV = P - ET - $Flow_{sr}$ / Drainage Area

Where P = 61.4 inches
ET = 42.3 inches
$Flow_{sr}$ / Drainage Area = 1.5 inches
ΔV = 1.9 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
(2.44 x 10^6 $ft.^3$) * 1728 inches/ft^3/ (46 acres * (43,560 (ft^2/acres)*144 $inches^2$/ ft^2

ΔV is calculated as follows:

ΔV = (2.37 ft. – 2.21 ft.) * 12 inches/ft.
2.21 ft. = groundwater elevation on 8/31/04.
2.37 ft. = groundwater elevation on 9/1/03.

The 2004-2005 annual hydrologic budget for the Galeana Street Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where P = 69.2 inches
ET = 40.1 inches
$Flow_{sr}$ / Drainage Area = 14.4 inches
ΔV = -12.0 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(2.41 \times 10^6 \text{ ft.}^3)$ * 1728 inches/ft ^{3}/ (46 acres * (43,560 (ft^2/acres)*144 inches^2/ ft^2

ΔV is calculated as follows:

ΔV = (1.19 ft. – 2.19 ft.) * 12 inches/ft.
1.19 ft. = groundwater elevation on 8/31/05.
2.19 ft. = groundwater elevation on 9/1/04.

The 2005-2006 annual hydrologic budget for the Galeana Street Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where P = 65.3 inches
ET = 40.7 inches
$Flow_{sr}$ / Drainage Area = 32.9 inches
ΔV = -8.6 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(5.49 \times 10^6 \text{ ft.}^3)$ * 1728 inches/ft ^{3}/ (46 acres * (43,560 (ft^2/acres)*144 inches^2/ ft^2

ΔV is calculated as follows:

$\Delta V = (1.19 \text{ ft.} - 1.91 \text{ ft.}) * 12 \text{ inches/ft.}$
1.91 ft. = groundwater elevation on 8/31/06.
1.19 ft. = groundwater elevation on 9/1/05.

The computations for the event mean concentrations and loading calculations are presented on Tables 10A, 10B and 10C.

The databases for Galeana Street are provided on the compact disc included with this report and are labeled "Galeana Street 2003-2004", "Galeana Street 2004-2005" and "Galeana Street 2005-2006".

Site Photograph 10 - Galeana Street Monitoring Station

Site Photograph 11 – Galeana Street Monitoring Station

3.9 KIEHL CANAL (BONITA SPRINGS)

Land Use Type: Mixed Use

GPS Coordinates: Latitude 26° 20' 20.78614' N
Longitude 81° 44' 15.78141' W

Site Location: East on Bonita Beach Road off I-75. Turn north on Bonita Grande Drive. The station is approximately ½ mile to the north on the right hand side.

Drainage Area: 7471 acres

Surface water is conveyed at the Kiehl Canal Monitoring Station by a canal that runs east to west. The site has a flood control structure consisting of a weir and floodgates. The weir frequently becomes submerged. Additionally, the water is too deep to measure discharge with an ADV. The drainage area and monitoring station location are presented on Figure 10.

Due to the submerged weir condition and the floodgates being opened periodically, discharge cannot currently be measured at this site with the available equipment.

Pressure transducers are utilized to continuously monitor surface water and groundwater elevations. Graphs 9.1A, 9.1B and 9.1C, Appendix A, depict the relationship between stage and groundwater for the 2003-2004, 2004-2005, and 2005-2006 monitoring periods, respectively.

The site is also equipped with a weather station which monitors temperature, relative humidity, rain, wind direction, wind speed, solar radiation, and evapotranspiration. The monitored parameters are used to derive an evapotranspiration value utilizing the Penmann-Monteith equation. The various monitored weather parameters (temperature, relative humidity, precipitation, wind speed, solar radiation, and evapotranspiration) are presented on Graphs 9.2A through 9.7A (2003-2004), 9.2B through 9.7B (2004-2005) and 9.2C through 9.7C (2005-2006), Appendix A. The monitored parameters are used to derive an evapotranspiration value utilizing the Penmann-Monteith equation.

Rainfall and evapotranspiration values for the Corkscrew Swamp Weather Monitoring Station are presented below:

2003-2004 Monitoring Period:

P = 53.5 inches
ET = 49.3 inches

2004-2005 Monitoring Period:

P = 55.8 inches
ET = 45.9 inches

2005-2006 Monitoring Period:

P = 80.2 inches
ET = 41.58 inches

Where P = precipitation in inches
ET = evapotranspiration in inches

Surface water samples were collected on February 25, 2004, January 6, 2005, August 26, 2005, September 21, 2005 and February 27, 2006. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C.

Field work sheets for the site visits are presented in Appendix B.9.

The databases for the Kiehl Canal Monitoring Station are provided on the compact disc included with this report and are labeled "Kiehl Canal 2003-2004", "Kiehl Canal Monitoring Station 2004-2005" and "Kiehl Canal 2005-2006".

Site Photograph 12 – Kiehl Canal Monitoring Station

Site Photograph 13 – Kiehl Canal Monitoring Station

3.10 KORESHAN STATE PARK (ESTERO)

Land Use Type: Wooded Upland

GPS Coordinates: Latitude 26° 26' 08.28134" N
Longitude 81° 49' 11.17700' W

Site Location: Koreshan State Park, ¼ mile west of US 41 on Corkscrew Road. Turn into park entrance and go to boat launch area. The station is several hundred feet west of the parking area on the nature trail.

Drainage Area: 17 acres

The drainage area and monitoring station location are presented on Figures 11 and 12.

Surface water is conveyed at the Koreshan State Park Monitoring Station by a ditch that runs south to north and discharges into the Estero River. Discharge at the Koreshan State Park Monitoring Station was measured with pressure transducers continuously measuring surface water elevation at front port (located in front of the weir contraction) and rear port (located within the contraction) of an extra large 60° trapezoidal flume. The pressure transducer data was continuously recorded to a data logger. Groundwater elevation was measured with a water level indicator measuring the depth to water in a shallow groundwater piezometer. The following formula was used to calculate discharge under critical flow conditions utilizing the flume as a primary measurement device:

$$Q(\text{cfs}) = 1.646 \times (\text{height of water at front port})^{2.58058}$$

Critical flow is defined by the flume manufacturer, Tracom, Inc., as stage at the rear port being less than 80% of stage at the front part. If rear port stage is more than 80% of stage at the front port, flow conditions are considered to be submerged and the equation for discharge becomes inaccurate. The rear pressure transducer was inoperable for a significant portion of the 2004-2005 monitoring period. Stage, rain and discharge as measured with the ADV was reviewed and valuated to estimate when the discharge equation was applicable. The monitored ditch usually dried quickly between rain events, therefore this estimation procedure should be relatively accurate. PSI replaced the malfunctioning rear pressure transducer in the fall of 2005.

The cross sectional area of flow utilized to determine the proportion of base flow to total flow is expressed as follows:

Cross-sectional area (ft.^{2}) =
0.5775 (stage (ft))^2 + 0.375 (stage (ft.))

The monitoring station was retrofitted with a pressure transducer to monitor groundwater elevation and a tipping bucket rain gauge to monitor rainfall. The retrofit work was performed the weeks of May 21, 2005 and May 28 2005. Rainfall data is also collected by Koreshan State Park employees from a rain bucket and recorded on a daily basis.

As indicated by the Graphs 10.1A through 10.3A (2003-2004), 10.1B through 10.3B (2004-2005) and 10.1C through 10.3C (2005-2006), the monitored ditch is dry much of the time and discharges water in response to rain events. Discharge correlates closely to rainfall. Usually discharge is around 0.5 cfs, but has been measured as high as 2.75 cfs in response to storm events.

Graphs 10.4A through 10.6A show in detail changes in pH, temperature and conductivity in conjunction with a July 19, 2004 rain event. pH readings ranged from 7.4 to 8.2 for July 19, 2004, with the pH at 7.4 for most of the time during which discharge consisted of stormwater flow. Temperature ranged between 25.7° C to 31° C, rapidly decreasing at the start of the rain event and then gradually increasing thereafter. Specific conductivity ranged between 0.345 mS to 0.684 mS. Conductivity dropped to 0.345 mS at the start pf the rain event and gradually increased thereafter. Dissolved oxygen was measured 7.3 mg/L at the beginning of the rain event with a handheld dissolved oxygen meter, while the sonde DO sensor indicated 4.5 mg/L at the beginning of the rain event. Sonde DO readings subsequently dropped to 3.0 mg/L. Since there was not good agreement between the sonde and the handheld D.O. meter, the sonde D.O. measurements have not been presented graphically. Turbidity with a handheld meter was measured at 4.01 NTUs. The sonde turbidity meter malfunctioned during the rain event; therefore, no data was recorded.

As depicted on Graphs 10.3A, 10.3B, and 10.3C, groundwater elevations fall to as much as 4.00 feet below land surface during dry conditions in winter and spring but rapidly rise to close to land surface after rainy periods.

Graphs 10.4B through 10.8B show in detail changes in pH, temperature and conductivity dissolved oxygen and turbidity in conjunction with a storm event that occurred the evening of April 7, 2005 and April 8, 2005. pH readings are between 7.26 and 7.81 and appear to mimic temperature; Temperature ranged from 21.75° to 29.2° C and increased steadily towards the end of the rain event when radiant energy increased through late morning. Specific conductivity ranged between 408 μS to 694 μS with values correlating to discharge. Dissolved oxygen remained relatively stable throughout the rain event, with measured values slightly less than 5.0 mg/L. Turbidity spiked to 14.8 ntus just before peak discharge and then rapidly declined along with flow.

Graphs 10.4C through 10.6C depict pH, temperature and dissolved oxygen for the time period between August 21, 2006 and August 29, 2006. The graphs show field parameter patterns similar to the other presented graphs. pH cycles with temperature. Both parameters have an inverse relationship with discharge. Presumably water temperature increases as discharge (and stage) decreases. It should be noted that water temperature had very high peak values, as high as 38°C (100°C). No post calibration check was performed on the sonde so this data is qualified accordingly. It should be noted that late August is one of the hottest times of the year and stage in the ditch was very low (as shallow as 3 inches) at times during the measurement period.

Surface water samples were collected on November 6, 2003, July 19, 2004, March 17, 2005, April 7 and 8, 2005, August 26, 2005, October 27, 2005 and August 30, 2006. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C.

Graphs 10.9B through 10.14B, Appendix A, depict analyte concentrations graphed in relation to discharge produced from stormwater on April 7, 2005 through April 8, 2005. Four sample sets were collected at 3 hour intervals, with the first set collected during peak flow. As indicated by Graph 10.9B, NOX concentrations appeared to mimic discharge with the highest nitrate/nitrite concentration (80 µg/L) was measured during peak discharge. NOX concentrations were not detected thereafter. TKN showed a rebound effect similar to that exhibited at the Galeana Street monitoring station on April 7, 2005 (see Graph 10.10B). Ammonia is depicted on Graph 10.11B. The highest concentration of ammonia was present several hours after peak discharge and decreased thereafter. Total phosphorus was at the highest concentration during peak flow and gradually decreased for the next two sample intervals and increased towards the end of the sampling event (see Graph 10.12B). TSS concentrations were highest three hours after peak flow and gradually decreased for the remainder of the storm event (see Graph 10.13B). Copper concentrations were highest during peak discharge (5.7 µg/L) and rapidly decreased to non-detectable levels (see Graph 10.14B). It should be noted that orthophosphorus was not present in measurable concentrations during this sampling event.

Analyte concentrations of time weighted samples collected on August 30, 2006 have also been graphed along with corresponding discharge (Graphs 10.7C through 10.11C). The graphs reveal very similar to the trends depicted on the graphs presented for the April 7 and 8 2005 sampling event. An exception was total phosphorus trends, which instead of mimicing flow and decreasing in concentration after peak flow, appears to gradually increase throughout the storm event.

The following estimates for parameters measured at the Koreshan State Park Monitoring Station are presented below:

2003-2004 Monitoring Period:

P = 72.1 inches
ET = 42.3 inches
$Flow_{tot}$ = 2.76 x 10^6t. ^{3}
$Flow_{sr}$ = 1.22 x 10^6 ft.^{3}

2004-2005 Monitoring Period:

P = 76.5 inches
ET = 40.1 inches
$Flow_{tot}$ = 3.60 x 10^6 ft. ^{3}
$Flow_{sr}$ = 5.38 x 10^5ft.^{3}

2005-2006 Monitoring Period:

P = 53.9 inches
ET = 40.7 inches
$Flow_{tot}$ = 2.56 x 10^6 ft. ^{3}
$Flow_{sr}$ = 7.06 x 10^5 ft.^{3}

Where P = precipitation in inches
ET = evapotranspiration in inches
$Flow_{tot}$ = total flow in cubic ft.
$Flow_{sr}$ = total flow minus baseflow in cubic ft.

Field work sheets for the site visits are presented in Appendix B.10.

Evapotranspiration for the site has been estimated by averaging the ET values obtained from the weather stations located at Corkscrew Swamp, Eastwood Golf Course and the Kiehl Canal.

The 2003-2004 annual hydrologic budget for the Koreshan State Park Monitoring Station is as follows:

Where P = 72.1 inches
ET = 42.3 inches
$Flow_{sr}$ / Drainage Area = 19.8 inches
ΔV = 4.8 inches

ΔV is calculated as follows:

$\Delta V = (0.82 \text{ ft.} - 0.42 \text{ ft.}) * 12 \text{ inches/ft.}$
0.82 ft. = groundwater elevation on 8/31/04.
0.42 ft. = groundwater elevation on 9/1/03.

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(1.22 * 10^6 \text{ ft}^3 * 1728 \text{ inches/ft}^3) / (17 \text{ acres} * 43{,}560 \text{ ft}^2/\text{acres} * 144 \text{ inches}^2/\text{ft}^2)$

The 2004-2005 annual hydrologic budget for the Koreshan State Park Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr}$ / Drainage Area

Where P = 76.5 inches
ET = 40.1 inches
$Flow_{sr}$ / Drainage Area = 8.72 inches
ΔV = -4.2 inches

ΔV is calculated as follows:

$\Delta V = (0.13 \text{ ft.} - 0.48 \text{ ft.}) * 12 \text{ inches/ft.}$
0.48 ft. = groundwater elevation on 8/31/05.
0.13 ft. = groundwater elevation on 9/1/04.

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(5.38 * 10^5 \text{ ft}^3 * 1728 \text{ inches/ft}^3) / (17 \text{ acres} * 43{,}560 \text{ ft}^2/\text{acres} * 144 \text{ inches}^2/\text{ft}^2)$

The 2005-2006 annual hydrologic budget for the Koreshan State Park Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr}$ / Drainage Area

Where P = 53.9 inches
ET = 40.7 inches
$Flow_{sr}$ / Drainage Area = 11.4 inches
ΔV = -7.1 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(7.06*10^5 \text{ ft}^3 * 1728 \text{ inches/ft}^3) / (17 \text{ acres} * 43{,}560 \text{ ft}^2\text{/acres} * 144 \text{ inches}^2)$

ΔV is calculated as follows:

ΔV = (0.13 ft. – 0.72 ft.) * 12 inches/ft.
0.13 ft. = groundwater elevation on 8/31/06.
0.72 ft. = groundwater elevation on 9/1/05.

The computations for the event mean concentrations and loading calculations are presented on Tables 11A, 11B and 11C.

The databases for Koreshan State Park are provided on the compact disc included with this report and are labeled " Koreshan State Park 2003-2004", " Koreshan State Park 2004-2005" and " Koreshan State Park 2005-2006".

Site Photograph 14 - Koreshan State Park Monitoring Station

Site Photograph 15 – Koreshan State Park Monitoring Station

3.11 MULLOCK CREEK (SOUTH FT. MYERS)

Land Use Type: Residential

GPS Coordinates: Latitude 26° 28' 25.80834" N
Longitude 81° 49' 50.36176" W

Site Location: The Mullock Creek Station is located ½ mile east of US 41 and approximately 200 feet south of the intersection of Constitution Blvd. and Constitution Circle.

Drainage Area = 2493 acres

Mullock Creek drains a large residential neighborhood and empties into Estero Bay.

The Mullock Creek Monitoring Station is located at the bridge on Constitution Circle over Mullock Creek. Surface water passes underneath Mullock Creek through four 4-foot diameter culverts. Mullock Creek is typically 40 feet across and has a depth of approximately 1.5 feet.

A staff gauge and piezometer were deployed at the Mullock Creek Station and allow for stage and groundwater measurements during the site visits.

Discharge at Mullock Creek was measured during the site visits with the ADV. Lee County Department of Natural Resources also monitors a stage sensor deployed in the northernmost culvert of the Mullock Creek bridge. The recorded stage data has been input to a stage/discharge equation to estimate continuous discharge, thus allowing for improved estimation of annual discharge.

Discharge at Mullock Creek was measured periodically with the ADV. Discharge was then estimated between site visits by extrapolating the discharge measurements obtained at the bi-weekly site visits. Lee County Department of Natural Resources monitors a flow sensor deployed in the culvert. The sensor recorded data to a datalogger. The sensor malfunctioned during the first year of operation; however the sensor was operational during the 2004-2005 and 2005-2006 monitoring periods. With the sensor operational, it was possible to correlate total discharge for the entire creek with the stage being continuously measured in the northern culvert, thus allowing for the development of stage/discharge calibration curves.

A bucket rain gauge and an additional piezometer were installed at the Mullock Creek in late May 2005. The bucket rain gauge was destroyed by vandals and replaced a number of times until PSI decided to use rainfall data from the nearest station, Koreshan State Park (located approximately two miles away to the southwest). An additional piezometer was installed to compare groundwater levels obtained from the new piezometer with groundwater levels from the previously existing piezometer. The previously existing piezometer is located on a bridge embankment with an elevation higher than the typical elevation of the channel bank. Groundwater elevation data obtained from the old piezometer was therefore suspected of being skewed high. The new groundwater piezometer was installed on the creek bank at a location more typical of the bank elevation. Subsequent depth to water measurements in both piezometers revealed that data form the piezometer on the embankment was as sometimes much as 0.4 ft. higher than the groundwater data obtained from the new piezometer.

The 2004-2005 stage/discharge calibration curve developed for the Mullock Creek Monitoring Station (see Graph 11.1B, Appendix A) is as follows:

$$Q\ (cfs) = 45.761 * (stage\ (ft.))^2 - 129.11(stage\ (ft.)) + 102.76$$
$$R^2 = 0.9679$$

A Fall/Winter/Spring 2005-2006 stage/discharge calibration curve developed for the Mullock Creek Monitoring Station (see Graph 11.1C, Appendix A) is as follows:

$$Q\ (cfs) = 41.524 * (stage\ (ft.))^2 - 89.124(stage\ (ft.)) + 50.045$$
$$R^2 = 0.9774$$

The Summer 2006 stage/discharge calibration curve developed for the Mullock Creek Monitoring Station (see Graph 11.2C, Appendix A) is as follows:

$$Q\ (cfs) = 21.493 * (stage\ (ft.))^2 + 2.0988(stage\ (ft.)) - 36.269$$
$$R^2 = 0.9965$$

The calibration curve is applicable when stage is greater than or equal to 1.38 ft. Discharge measured with the ADV during site visits was extrapolated to estimate discharge between site visits when stage was less than 1.38 ft.

As indicated on Graphs 11.1A, 11.2B, 11.3B, 11.3C and 11.5C, discharge was typically between 10 and 20 cfs during the 2003-2006 monitoring period, but was measured as high as 256 cfs in early June 2005 after heavy rains.

A comparison of rainfall at Koreshan State Park and discharge at Molluck Creek for 2004-2005 and 2005-2006 are presented as Graphs 11.3B and 11.5C.

Groundwater elevation and stage data indicates surface water discharge is composed primarily of baseflow (see Graphs 11.2A,11.4B and 11.4C). As previously discussed, groundwater elevation data may, at times, be skewed high which in turn effects the water budget calculation (i.e. the $Flow_{sr}$ / Drainage Area variable will be skewed low).

Surface water samples were collected on December 17, 2003, April 28, 2004, July 28, 2004, March 17, 2005, August 26, 2005, October 27, 2005, February 27, 2006, May 30 2006, June 12, 2006 and June 13, 2006. The analytical results are summarized on Table 2. The complete laboratory results are presented in Appendix C.

Field work sheets for the site visits are presented in Appendix B.11.

As previously discussed, no rain gauge was present at Mullock Creek. Precipitation is estimated from Koreshan State Park rain data. Evapotranspiration for the site has been estimated by averaging the ET values obtained from the weather stations located at Corkscrew Swamp, Eastwood Golf Course and the Kiehl Canal.

The following estimates for parameters measured at the Mullock Creek Monitoring Station are presented below:

2003-2004 Monitoring Period:

P = 72.1 inches
ET = 42.3 inches
$Flow_{tot} = 9.33 \times 10^8$ ft.^{3}
$Flow_{sr} = 5.57 \times 10^6$ ft.^{3}
$Flow_{storm}$ = No Data

2004-2005 Monitoring Period:

P = 76.5 inches
ET = 40.1 inches
$Flow_{tot} = 8.43 \times 10^8$ ft.^{3}
$Flow_{sr} = 5.87 \times 10^7$ ft.^{3}
$Flow_{storm} = 5.07 \times 10^8$ ft.^{3}

2005-2006 Monitoring Period:

P = 53.9 inches
ET = 40.7 inches
$Flow_{tot} = 6.10 \times 10^8$ ft.^{3}
$Flow_{sr} = 1.06 \times 10^7$ ft.^{3}
$Flow_{storm} = 2.34 \times 10^8$ ft.^{3}

Where P = precipitation in inches
ET = evapotranspiration in inches
$Flow_{tot}$ = total flow in cubic ft.
$Flow_{sr}$ = total flow minus baseflow in cubic ft.
$Flow_{storm}$ = flow under storm water conditions

The 2003-2004 annual hydrologic budget for the Mullock Creek Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where P = 60.2 inches
ET = 72.1 inches
$Flow_{sr}$ / Drainage Area = 0.6 inches
ΔV = 6.5 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(5.57 * 10^6 \text{ ft}^3) * 1728 \text{ inches/ft}^3 / (2493 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2)$

ΔV is calculated as follows:

ΔV = (3.17 ft. – 2.63 ft.) * 12 inches/ft.
3.17 ft. = groundwater elevation on 8/31/04.
2.63 ft. = groundwater elevation on 9/1/03.

The 2004-2005 annual hydrologic budget for the Mullock Creek Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where P = 76.5 inches
ET = 40.1 inches
$Flow_{sr}$ / Drainage Area = 0.7 inches
ΔV = 11.8 inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(5.87 * 10^6 \text{ ft}^3) * 1{,}728 \text{ inches/ft}^3 / (2{,}493 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2)$

ΔV is calculated as follows:

ΔV = (2.19 ft. – 3.17 ft.) * 12 inches/ft.
2.19 ft. = groundwater elevation on 8/31/05.
3.17 ft. = groundwater elevation on 9/1/04.

The 2005-2006 annual hydrologic budget for the Mullock Creek Monitoring Station is as follows:

$\Delta V = P - ET - Flow_{sr} / \text{Drainage Area}$

Where $P = 53.9$ inches
$ET = 40.7$ inches
$Flow_{sr}$ / Drainage Area = 1.2 inches
$\Delta V = 0.6$ inches

$Flow_{sr}$ / Drainage Area is calculated as follows:

$Flow_{sr}$ / Drainage Area =
$(1.06 * 10^7 \text{ ft}^3) * 1{,}728 \text{ inches/ft}^3 / (2{,}493 \text{ acres} * (43{,}560 (\text{ft}^2/\text{acres}) * 144 \text{ inches}^2/\text{ft}^2)$

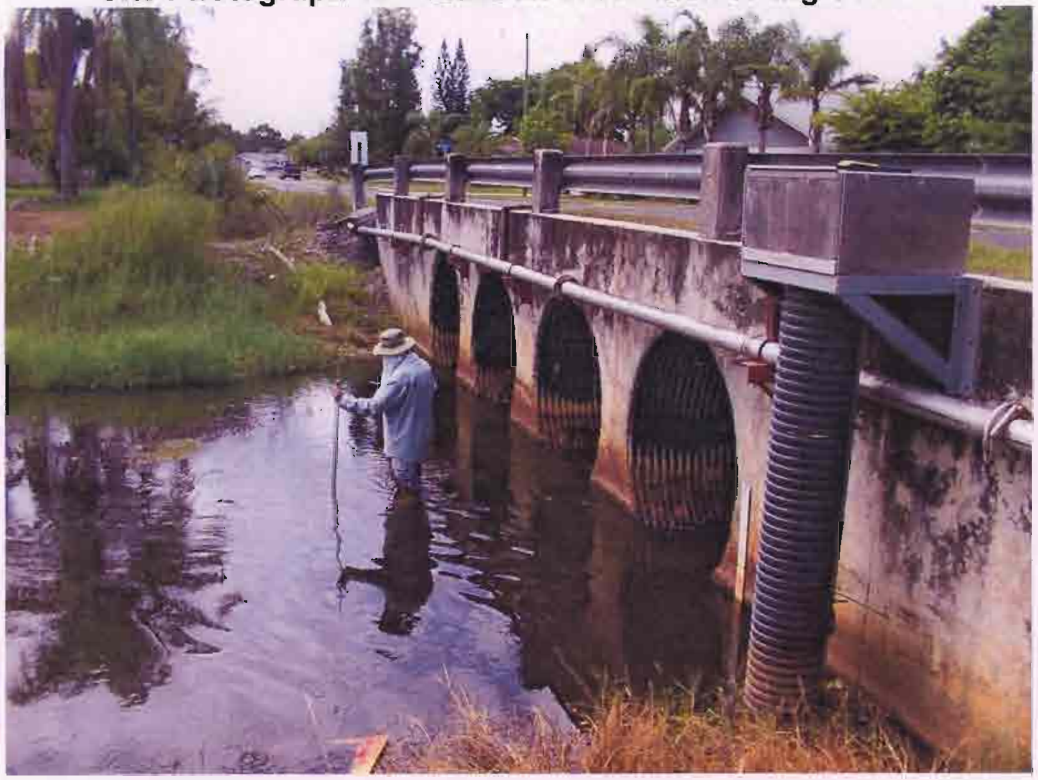
ΔV is calculated as follows:

$\Delta V = (2.13 \text{ ft.} - 2.08 \text{ ft.}) * 12 \text{ inches/ft.}$
2.08 ft. = groundwater elevation on 8/31/05.
2.13 ft. = groundwater elevation on 9/1/04.

The computations for the event mean concentrations and loading calculations are presented on Tables 11A, 11B and 11C.

The databases for Mullock Creek are provided on the compact disc included with this report and are labeled “Mullock Creek 2003-2004”, “Mullock Creek 2004-2005” and “Mullock Creek 2005-2006”.

Site Photograph 16 – Mullock Creek Monitoring Station



4.0 QUALITY ASSURANCE/QUALITY CONTROL REVIEW

A Quality Assurance/Quality Control review was conducted for the Estero Bay Watershed Monitoring Project. Anomalies noted during the course of the review are described below.

Ammonia Nitrogen analysis was initially subcontracted by PC&B Environmental Laboratories to Environmental Science. Environmental Science ran method detection level (MDL) studies in an effort to lower the method detection level for ammonia nitrogen to the level typically utilized for District groundwater modeling, but were unsuccessful. Samples collected on February 25, 2004 were therefore rerun by PPB Environmental Laboratories in Gainesville who was able to achieve the required MDL. Ammonia results for the analyses performed by PPB were occasionally significantly higher for a number of samples than the values reported by PC&B's initial subcontract laboratory, Environmental Science. This may be the result of different equipment between laboratories. PC& B's results for ammonia were utilized for the study.

Detectable levels of analytes were present in both equipment blanks collected during the 2003/2004 Winter quarter:

Equipment Blank (12/17/03	Nitrate/Nitrate Total Suspended Solids	200 µg/L 1000 µg/L
Equipment Blank (2/25/04)	Ammonia Copper Nitrate/Nitrite Orthophosphorus Total Suspended Solids	20 µg/L 2.2 µg/L 10 µg/L 2 µg/L 20,000 µg/L

Since no field blanks were collected, it is unclear whether the detections were due to unclean equipment or the presence of analytes in the water used for the blanks. As a corrective action, field blanks were collected in conjunction with the equipment blanks at future sampling events, to evaluate possible sources of contamination in equipment blanks. Additionally, the Teflon dipper used for sampling on February 25, 2004 was field cleaned. Sampling equipment was cleaned prior to field mobilization for subsequent sampling events and was used only once per event.

Field blanks and an equipment blanks were collected on April 27, 2004 and June 9, 2004. Laboratory supplied analyte free water was used for both the field and equipment blanks. Analytes detected in the field blanks and equipment blanks for the April 27, 2004, June 9, 2004 and July 19, 2004 sampling events are summarized below:

Equipment Blank (4/27/04)	Copper	1.8 µg/L
Field Blank (4/27/04)	Copper	2.8 µg/L
Equipment Blank (6/9/04)	Copper Nitrate/Nitrite	2.2 µg/L 50 µg/L
Field Blank (6/9/04)	Copper Nitrate/Nitrite Total Suspended Solids	2.7 µg/L 50 µg/L 3000 µg/L
Equipment Blank (7/19/04)	Nitrate/Nitrite	10 µg/L

The presence of the above listed analytes in the field blanks indicates one of the following conditions: the analytes were present in the sampling environment; sample containers were not clean; sample preservatives contained the analytes; the water used to fill the sample containers contained analytes; or the samples became contaminated with analytes during transport or storage. Samples collected at events coinciding with equipment and field blanks with detectable levels of analytes are flagged as estimates for the analytes detected.

Detectable levels of analytes were present in equipment blanks collected during the 2004-2005 monitoring period:

Equipment Blank (1/6/05)	Ammonia	18 µg/L
Equipment Blank (3/15/05)	Nitrate/Nitrite Ammonia TSS Copper	310 µg/L 17 µg/L 2,000 µg/L 2.0 µg/L
Equipment Blank (3/17/05)	Nitrate/Nitrite Ammonia TKN	15 µg/L 15 µg/L 1830 µg/L
Equipment Blank (8/26/05)	Nitrate/Nitrate Total Phosphorus TSS	7.1 µg/L 1.9 µg/L 4,500 µg/L
Equipment Blank (8/29/05)	Orthophosphorus	5.6 µg/L

Detectable levels of analytes were present in the equipment blanks and field blanks collected in the winter 2005-2006 quarter and summer 2006 quarter:

Equipment Blank (10/27/05)	Nitrate/Nitrite Ammonia TSS Copper	310 µg/L 17 µg/L 2000 µg/L 2 µg/L
Equipment Blank (2/27/06)	Nitrate/Nitrite Orthophosphorus Total Phosphorus TSS	13 µg/L 2 µg/L (est.) 1.4 µg/L (est.) 1200 µg/L (est.)
Field Blank (2/27/06)	Nitrate/Nitrite Orthophosphorus Total Phosphorus	1.4 µg/L (est.) 2 µg/L (est.) 1.5 µg/L (est.)
Field Blank (6/12/06)	Nitrate/Nitrite TKN Ammonia Orthophosphorus Copper	370 µg/L 160 µg/L (est.) 28 µg/L (est.) 3.2 µg/L (est.) 9.1 µg/L
Field Blank (6/12/06)	Nitrate/Nitrite TKN Ammonia Copper	190 µg/L 100 µg/L (est.) 110 µg/L (est.) 9.1 µg/L

Since associated field sample results were close to historical norms none of the samples results for the 2005-2006 monitoring period were discarded or modified as a result of the contaminated blanks.

Analytes have been consistently present in equipment blanks at low levels during the study. The most likely source of the equipment blank contaminants is laboratory equipment. It should be noted that the required method detection limits for the project are very low – lower than what is typically expected for the contractor laboratory to measure to. According to the laboratory, the measurement equipment is as clean as possible and would be, under typical circumstances, sufficient for the analytical results to reveal no detections for the measured nutrients in an equipment blank. Due to the very low method detection levels required for this project, detection of low levels of analytes in the QA/QC blanks appears to be unavoidable. Generally analyte levels in equipment blanks were not subtracted from respective analyte concentrations measured in field samples. An exception was the sample collected at Mullock Creek on March 17, 2005 were TKN was measured at 3150 µg/L in the field sample and 1820 µg/L in the equipment blank. In this particular case TKN, the TKN value measured in the equipment was fairly high and was therefore subtracted from the field sample TKN value (which was higher than the historical norm) for the purposes of calculating the TKN loading.

Another QA/QC issue for the project includes poor measurement precision based upon comparison of field samples and duplicates. The following field samples and associated duplicates had relative percent differences (rpds) greater than 50%:

The rpd between the field sample and field duplicate sample collected at Eastwood Golf Course on February 25, 2004 for NOX was 68% and 103% for ammonia.

The rpd between the field sample and the field duplicate sample collected at Galeana Street on June 9, 2004 was 160% for total phosphorus.

The rpd between the field sample and field duplicate sample collected at FGCU on August 26, 2005 was 83% for ammonia.

The rpd between the field sample and field duplicate sample collected at Eastwood Golf Course on October 27, 2005 was 58% for ammonia.

The rpd between the field sample and field duplicate sample collected at Eastwood Golf Course on February 27, 2006 was 112% for NOX.

The rpd between the field sample and field duplicate sample collected at Mullock Creek on May 30, 2006 was 145% for NOX.

The high rpds for those analytes appear to indicate a high degree of variability in the sampling process.

The respective copper values for the field and duplicate samples at Eastwood Golf Course were 1.1 µg/L and 5.7 µg/L, values close to the method detection level and close to typical historical values. When measuring low levels, it is reasonable to relax the 50% cutoff point for data rejection because a slight difference in values (in this case 4.6 µg/L) will lead to a large relative percent difference. For the nutrient loading calculation, 5.7 µg/L was utilized in the interest of being conservative. The higher of the concentrations for the other analytes were also utilized for the same rationale.

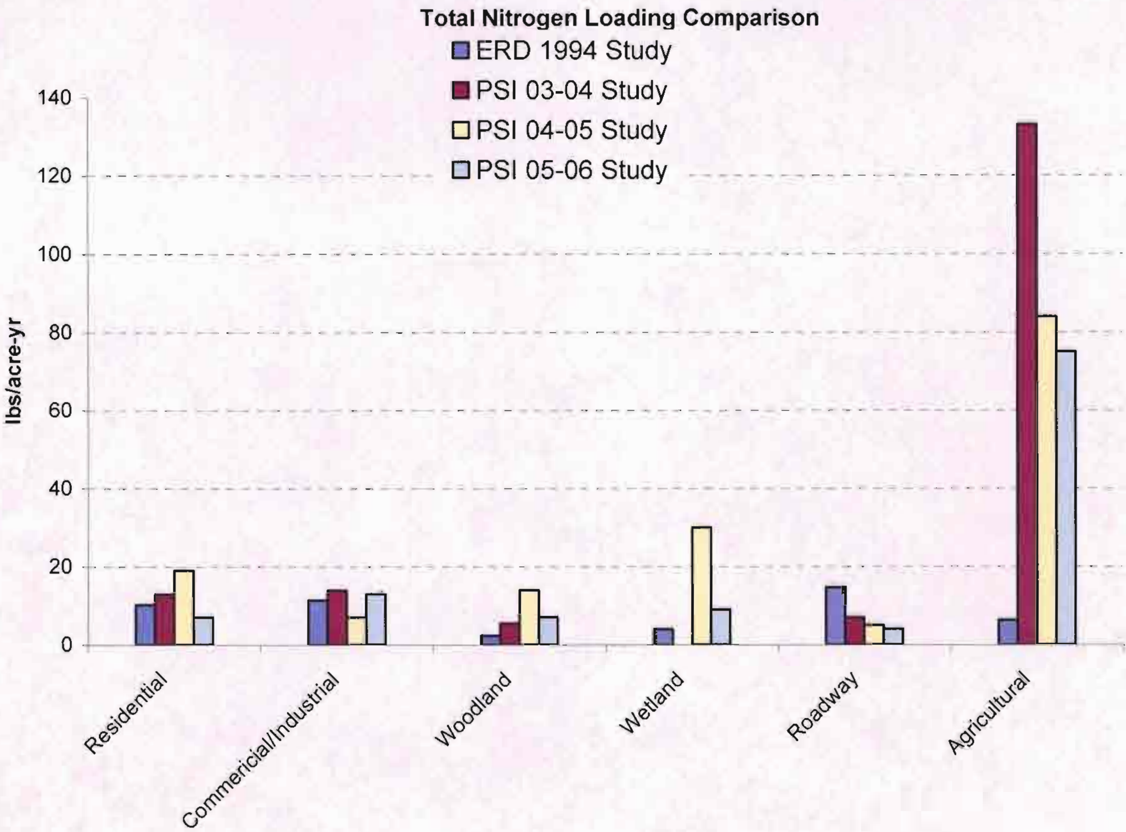
The project method detection levels were not achieved for orthophosphorus for the March 15, March 17 and April 8, 2005 sampling events at Eastwood Golf Course, FGCU and Mullock Creek. The method detection limit at these sampling events was 15 µg/L (the desired method detection level for orthophosphorus is 4 µg/L). For the purposes of loading calculations, non-detection levels are halved. In the case of the March 15, 2005 orthophosphorus values for the Eastwood Golf course, the less than 15 µg/L results were converted to 1 µg/L for the loading calculation. This was done due to the measured orthophosphorus value at the Eastwood Golf Course typically being less than 2 µg/L. For FGCU and Mullock Creek, the less than 15 µg/L value was halved to 7.5 µg/L for the loading calculation due to the typically being low levels of orthophosphorus present in the surface water at those sites. It should be noted that the method detection levels for nitrate/nitrite, TKN and ammonia were slightly higher than the required project method detection levels, however these are not considered to have significantly effected the loading calculations.

5.0 DISCUSSION

PSI has performed a three year study for the Estero Bay and Estero Bay watershed on behalf of the South Florida Water Management District. The study assessed surface water nutrient loading rates for various land use types within the Estero Bay watershed. Field work for the study was performed between September 1, 2003 and August 31, 2006. The estimated loading rates for residential, commercial/industrial, parkland, wetlands, transportation, and agricultural land use categories are presented on Tables 13A (2003-2004), 13B (2004-2005), and 13C (205-2006). The presented data provides site-specific information for land use types within the Estero Bay watershed and should be useful for Estero Bay pollutant loading model inputs. With the exception of barren land, the monitored land use types are those categorized by Post, Buckley, Schuh and Jernigan's "Estero Bay Watershed Assessment."

Pollutant loading rates presented in "Stormwater Loading Rate Parameters for Central and South Florida" by Environmental Research and Design, Inc. (ERD, 1994) are used with this report for comparison purposes. The ERD study compiled and calculated average values for a number of the same pollutants as monitored for in the Estero Bay study, including total nitrogen, total phosphorus, orthophosphorus, and total suspended solids. The data for the ERD study was gathered from a number of stormwater pollutant studies conducted in central and southern Florida in the 1980s and 1990s. ERD study broke down land use categories into subcatgories (i.e. for agriculture, citrus groves and row crop farming were subgrouped; residential was subgrouped into single and multi-residence; and commercial and industrial was subgrouped into light and heavy use. ERD data for the graphs presented below was selected from the land use subgroup that most closely matched the land use type monitored within the Estero Bay Watershed. The ERD study citrus grove agricultural land use type was compared to the Brooks Tropical agricultural land use type because Brooks Tropical is a citrus grove. Light commercial from the ERD study was matched to the Estero Bay commercial/industrial land use type because the monitored Estero Bay commercial/industrial sites are considered to be of low intensity. The single home residential land use type from the ERD study was selected for comparison with the Estero Bay residential land use type due to the Estero Bay monitored residential neighborhoods being composed primarily of single residences per lot. The woodland land use type for Estero Bay was compared with open space/ parkland land use type from the ERD study and should be considered a loose comparison. It should be noted that the ERD study did not include data on golf courses; therefore, no comparison could be made.

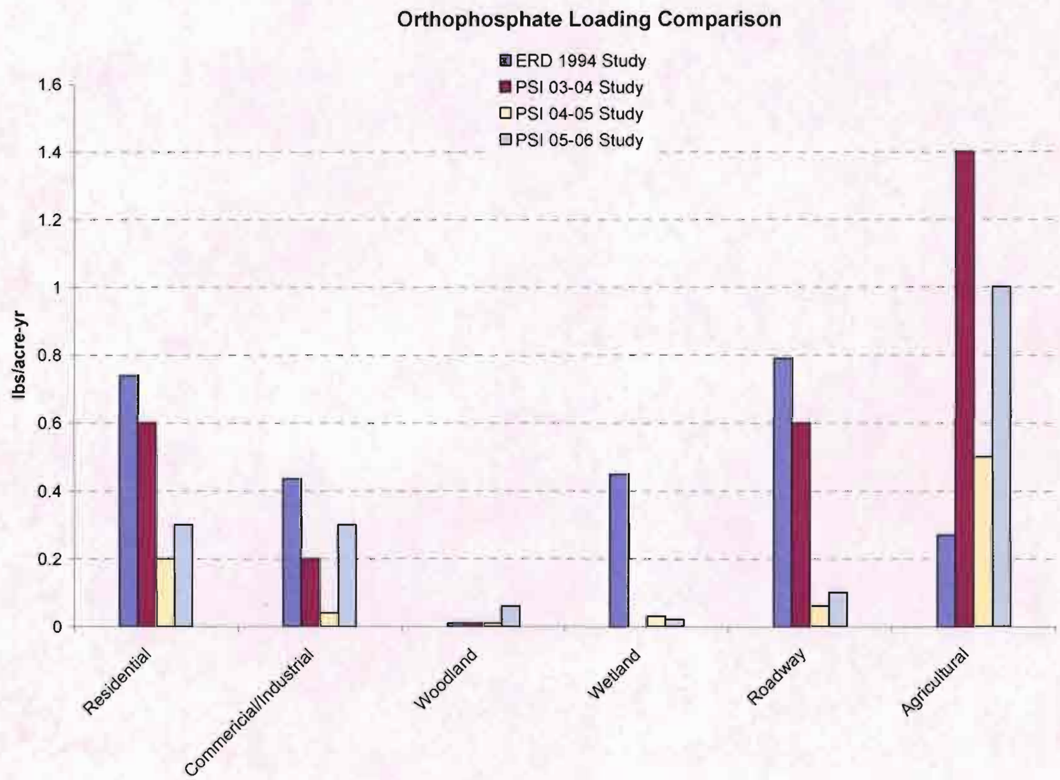
When compared with pollutant loading rates presented in "Stormwater Loading Rate Parameters for Central and South Florida" by Environmental Research and Design, Inc. (ERD), the Estero Bay data is similar for residential, commericial/industrial, woodland and wetland land use types (except for total suspended solids which was much higher for ERD commericial/industrial land use type). The PSI study indicated lower nutrient loading rates for roadways compared to the ERD study. PSI loading estimates for agricultural land use revealed higher overall levels nutrients compared to the ERD study. Pollutant loading trends are discussed in more detail below.

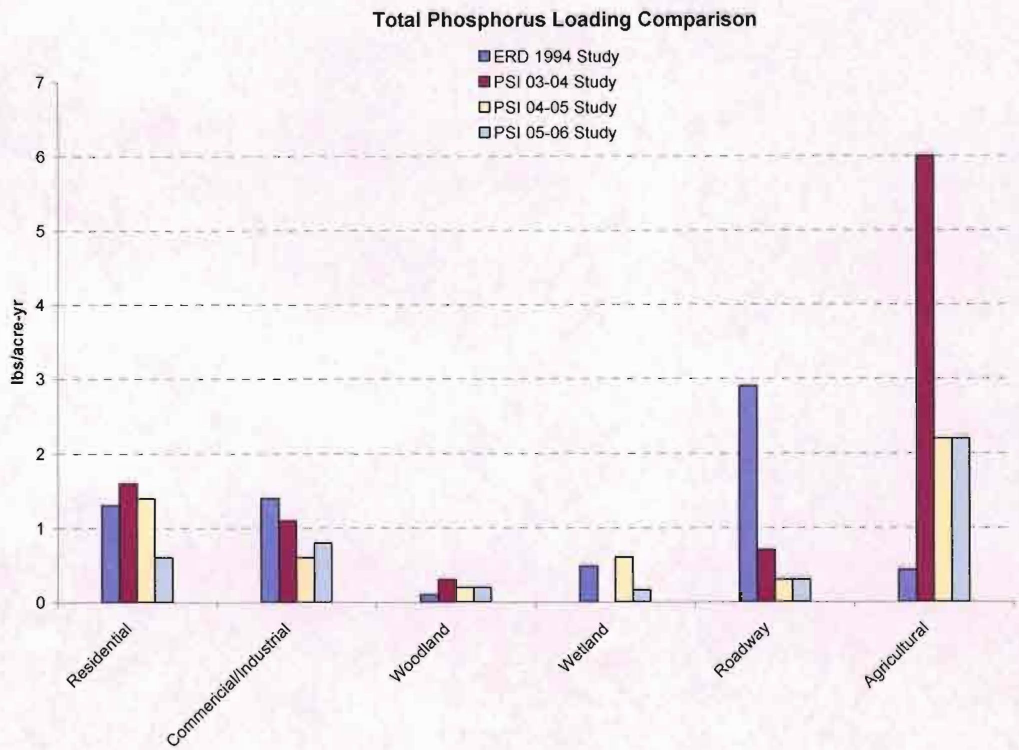


Loading estimates for agricultural land use in the Estero Bay Watershed revealed higher total nitrogen levels (nitrate/nitrite and Total Keldahl Nitrogen or TKN) when compared with the value obtained from the ERD study. Several explanations are possible. First, there are no reservoirs present at this particular orange grove, whereas many orange groves have large reservoirs that reduce storm water runoff. The relatively high levels of runoff result in high levels of nutrient loading. Another cause may be high levels of fertilizer application, although rates of application for this grove are unknown. The ERD study also indicates that their hydrologic and water quality data is from a location where discharge leaves the farm. Therefore, some pollutant attenuation occurs during travel through the surface water conveyance. At the Brooks Tropical station, the monitored discharge point abuts the citrus grove, therefore little pollution attenuation occurs before the point where water quality samples were collected.

The parkland land use type monitored was a golf course. The Eastwood Golf Course pollutant loading estimate utilized for the Estero Bay Watershed was not directly compared to pollutant loading estimates for golf courses from other studies, as none were available. It is presumed that due to fertilizing practices for golf courses, nutrient loading for a golf course would be higher than that for parkland in general.

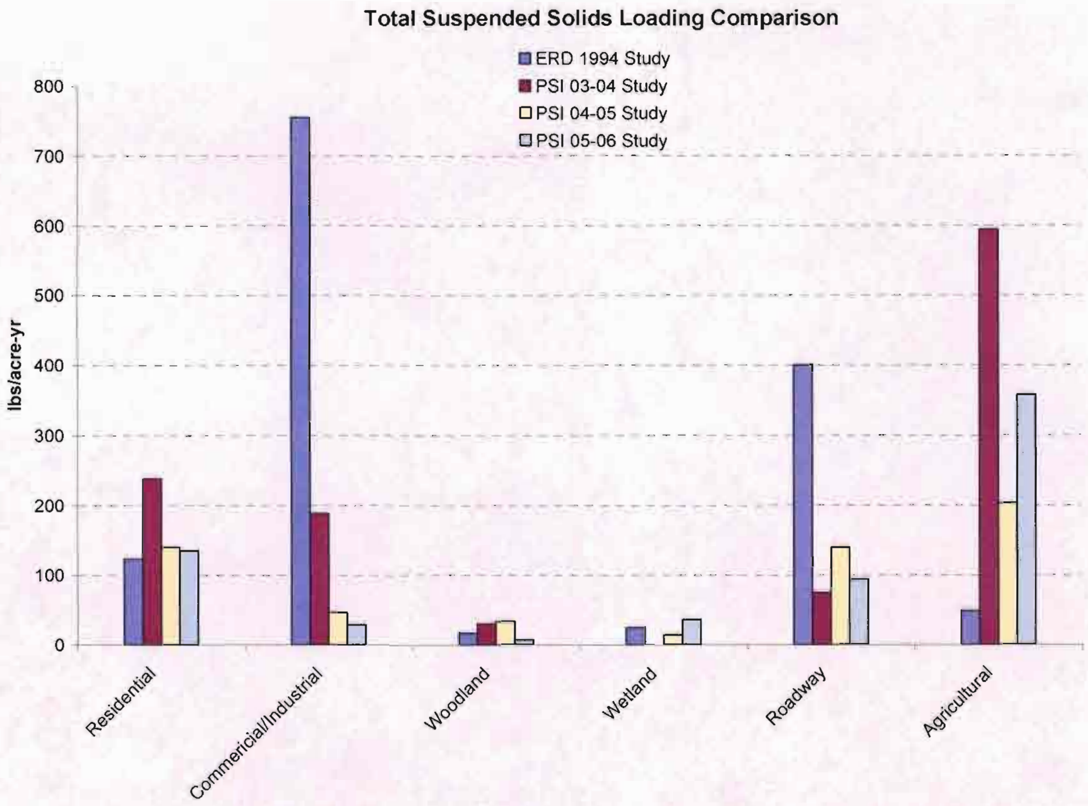
More recently citrus groves and golf courses have more sophisticated surface water management systems and would presumably have less discharge and therefore less pollutant surface water loading. The presented loading values or agriculture and golf courses likely are a "worst case scenario" in terms of pollutant loading for those respective land uses.





The comparison between the PSI study and the ERD study for total phosphorus and orthophosphate loading values reveal some differences. The agricultural land use type comparison for both. The PSI study, particularly the 2003-2004 monitoring period, reveal higher loading values for total phosphorus and orthophosphate for agricultural land. The source of phosphorus in surface water is typically fertilizer; therefore, the high loading rate for the Estero Bay agricultural land use type may indicate higher rates of fertilizer application or other factors discussed in the previous paragraph on total nitrogen loading.

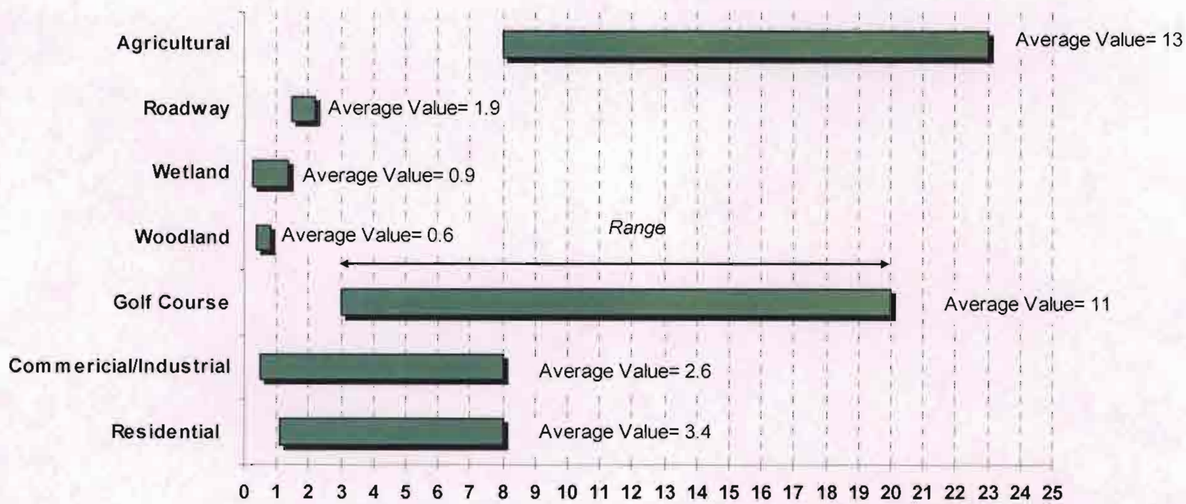
The difference in the roadway loading rates may be related to roadway use. The ERD study states that roadway data presented in their report are from heavily trafficked sites in the Orlando area. Corkscrew Road, at the monitored location, would probably be considered moderate.



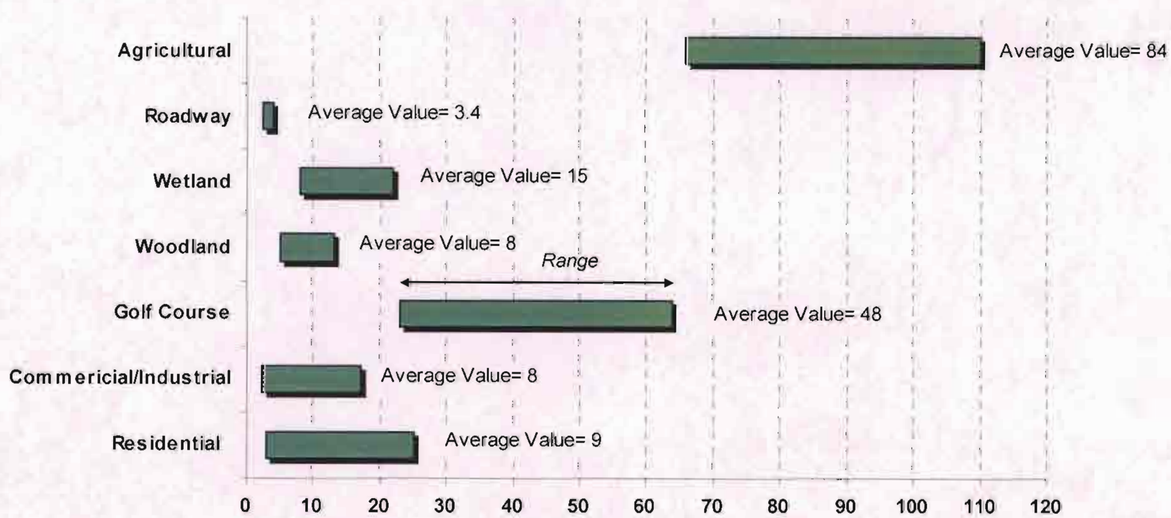
Total suspended solids (TSS) loading rates may be more of a function of surface water velocity at the monitor point than a reflection of a particular land use characteristic. The data for the ERD study may, in some instances, have been collected at locations inland with higher relief and therefore potentially steeper land surface gradients which may in turn have caused higher surface water discharge velocities. Higher surface water velocities create a higher energy environment which in turn entrains particulate matter into the water column. This would result in higher concentrations of total suspended solids. While discharge velocity data for the ERD study was not available for review, this may be a plausible explanation. Note the commericial/industrial land use type comparison; the monitored commercial/industrial land use type locations for Estero Bay have slow discharge velocities and have relatively low TSS loading. Conversely, the Estero Bay monitored agricultural and wetland land use type locations have high discharge velocities which result in high TSS loading when compared to the ERD data.

The highest nutrient loading was measured for the agricultural land use type (Brooks Tropical Monitoring Station) and parkland (golf course) land use type (Eastwood Golf Course). These two land use types also had the highest TSS and copper loading rates.

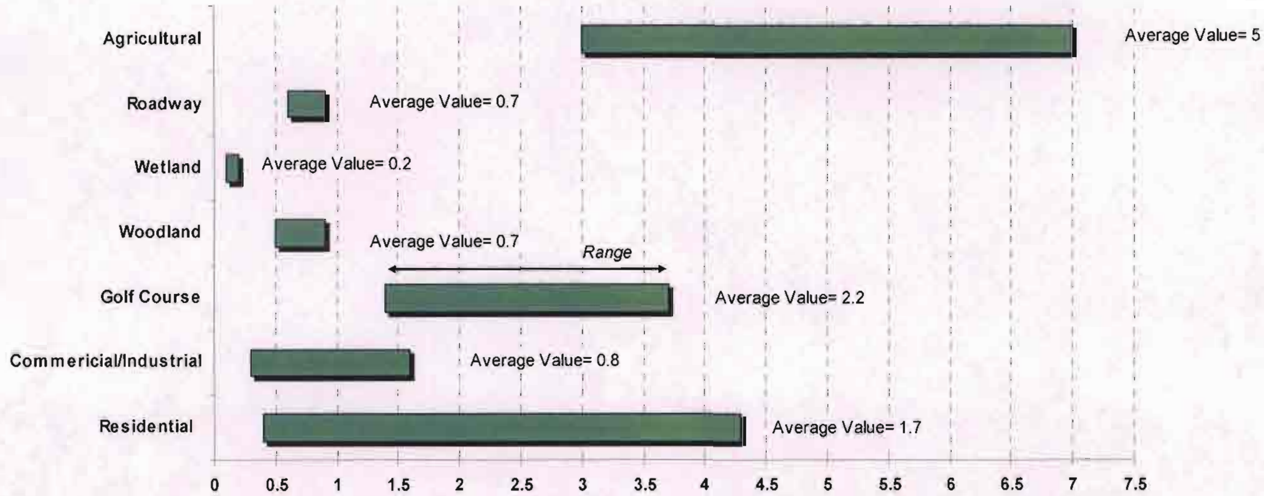
Estero Bay Watershed Nitrate/Nitrite Surfacewater Runoff Loading 2003-2006 (lb/acre-year)



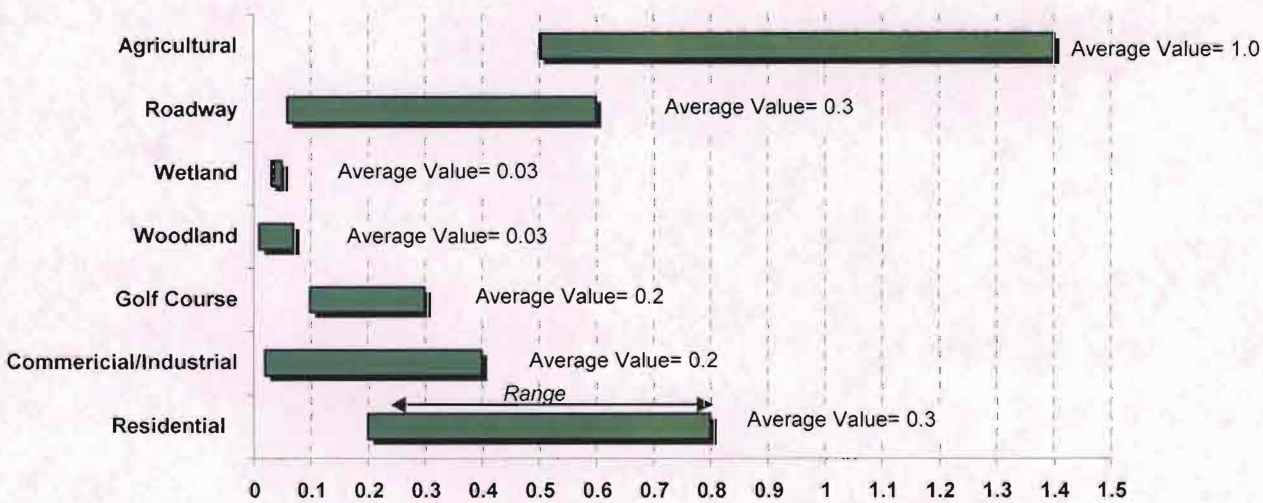
Estero Bay Watershed Total Kjeldahl Nitrogen Surfacewater Runoff Loading 2003-2006 (lb/acre-year)



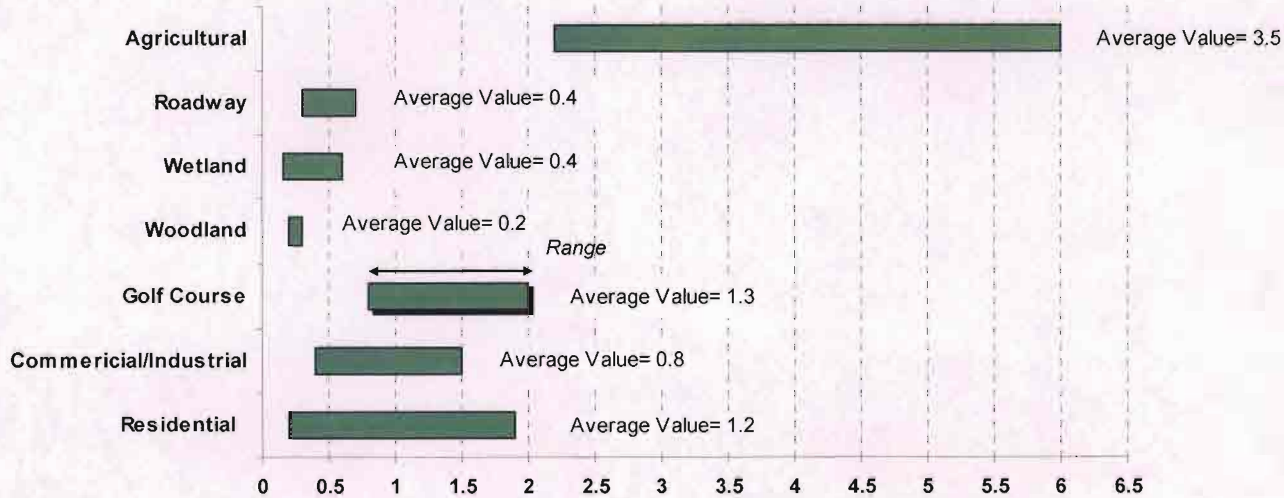
Estero Bay Watershed Ammonia Surfacewater Runoff Loading 2003-2006 (lb/acre-year)



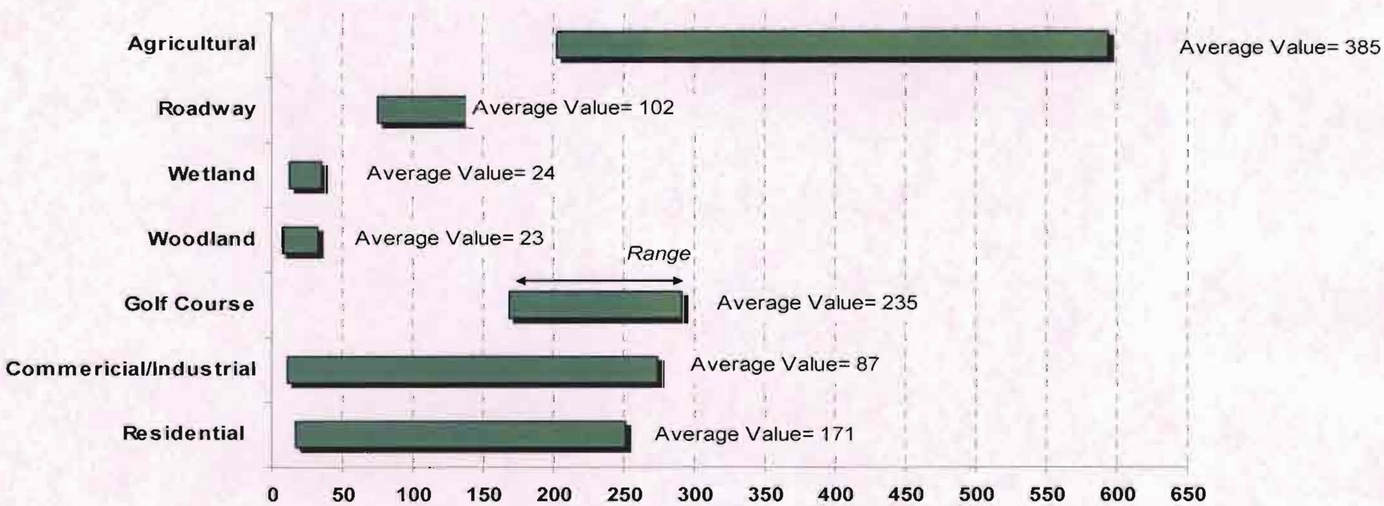
Estero Bay Watershed Orthophosphorus Surfacewater Runoff Loading 2003-2006 (lb/acre-year)

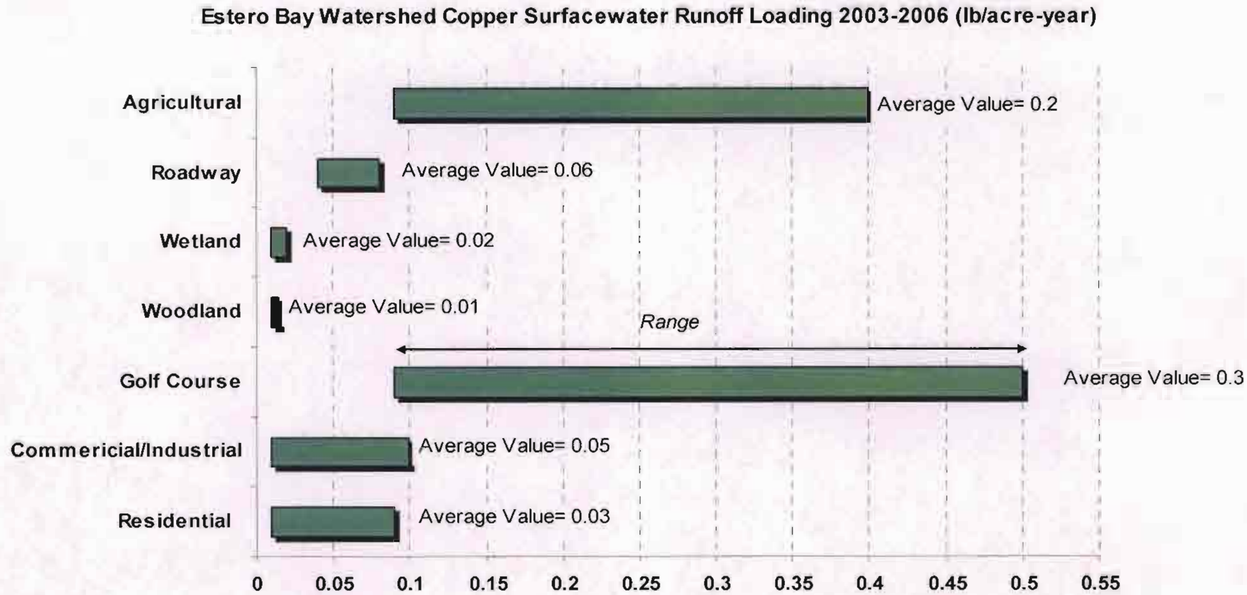


Estero Bay Watershed Total Phosphorus Surfacewater Runoff Loading 2003-2006 (lb/acre-year)



Estero Bay Watershed Total Suspended Solids Surfacewater Runoff Loading 2003-2006 (lb/acre-year)





As indicated by the above graphs, the highest pollutant loading rates were measured at the agricultural and golf course land use types. The residential and commercial/industrial land use types overall had closely matching loading rates with the exception of ammonia. The residential land use type had higher levels of ammonia possibly due to a higher density of septic tanks and/or decaying vegetation (a potential source of ammonia).

The land use types unaltered by man (wetlands and woodlands) had much lower pollutant loading rates. The woodland and wetland land use types for the PSI and ERD studies were relatively close. This study indicated lower rates of wetland orthophoshorus loading and higher rates of total nitrogen relative to the ERD study.

The roadway land use type had relatively low pollutant loading rates, however high levels of total suspended solids and copper have been measured in the first flush samples collected at the roadway monitoring station (Corkscrew Road). Copper was measured at 32.9 micrograms per liter in the first flush sample collected on April 7, 2005 and TSS was measured at 60,000 micrograms per liter(or 60 milligrams per liter).

Event concentrations were compared to the time of year fertilizers and pesticides are applied at golf courses, citrus groves and residential neighborhoods. At golf courses, fertilizers are applied in the summer, when business is slow and rain occurs frequently. Citrus groves (such as Brooks Tropical) typically apply copper compounds in March and June during citrus blooms to control fungus, lichens algae and mold. Fertilizer and pesticide application in residential neighborhoods may occur at any time of the year.

However, professional landscapers recommend applying nitrate containing fertilizers in March and April. Phosphate fertilizers are recommended for application in mid-summer.

PSI did not collect stormwater samples in early June, 2005, the first flush beginning the start of the summer rainy season, which may have captured fertilizers and herbicides applied in the spring; however, the 2004 and 2006 June first flush sampling events did not, for the most part, reveal particularly high levels of nutrients. At the residential land use type monitoring station, Austin Street, high levels of nitrate/nitrite were measured in a sample collected from a June12,2006 sampling event and as utilized in the loading calculation. At the Eastwood Golf Course, a surface water sample collected on August 29, 2006 contained 300 micrograms per liter of orthophosphorus, a value much higher than the typical historical values measured at the site.

PSI had more difficulty collecting stormwater samples for the 2004-2005 monitoring period than was the case for the 2003-2004 or 2005-2006 monitoring period, primarily due to a number of false starts that occurred with near misses for several tropical weather systems. Instead more dry screen samples were collected, the results of which were incorporated into the pollutant loading calculations. The stormwater samples tend to have higher concentrations of copper and TSS relative to dry screen samples; there does not appear to be much difference with the remaining analtyes.

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