Water Quality Synoptic Survey Data Analysis for East Beach Water Control District

SFWMD Purchase Order Contract PO4500016453

Submitted to:

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EXECUTIVE SUMMARY

This study involves development of a framework to assist with the analysis of data associated with surface water sampling activities conducted under the South Florida Water Management District (SFWMD) monitoring project "EAA298" upstream within the East Beach Water Control District (EBWCD) canal system. The upstream monitoring is part of a joint investigation between the SFWMD and the Florida Department of Environmental Protection (FDEP) and is designed to provide data for determining the major sources of nutrient inputs to water bodies within the basin. The basin and canal network was evaluated by SFWMD staff, and 15 internal monitoring locations were identified based on contributing area, land use, and conveyance system configuration. These sites were sampled bi-weekly beginning on January 18, 2007, and ending on September 30, 2007.

The monitoring data was analyzed and several potential sources of phosphorus to the canal network were identified. As may be expected, no one source was identified as the primary nutrient source for increased phosphorus levels that were observed. During the 2007 monitoring period, conditions were fairly dry, and very little discharge from the basin was made until the months of July through September. The data collected did not indicate that urban-related infrastructure concentrated within the western portion of the basin such as wastewater collection and treatment facilities or runoff from the impervious roadway's stormwater systems had significant contribution to the high phosphorus levels detected in the basin. Relatively high phosphorus levels were observed from two areas with unique water quality and timing characteristics:

- Consistently high levels of phosphorus, specific conductivity and several other water quality parameters were found throughout the study period in the northeast portion of the basin. The surrounding areas contain historical rock-pit mining, landfill operation, agricultural activities, and nearby sugar mill operation.

- Very high phosphorus and nitrogen levels were observed in the southern portion of the basin, increasing from July through the end of the monitoring period in September. This area is dominated by agriculture with sugar cane as the primary crop.

Since the analysis within this report is based on limited upstream monitoring for only the period from January 18, 2007 through September 27, 2007, the outcome may not necessarily correlate to previous yearly basin discharges. Although the period monitored was not a typical rainfall period, the pattern for overall basin discharge concentrations appears to mimic previous years with high concentrations occurring in the months surrounding October. Recommendations are made for future study and monitoring efforts to build upon the qualified conclusions made within this document, which are based on limited data.

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INTRODUCTION AND BACKGROUND

The Everglades agricultural area (EAA), located south of Lake Okeechobee, is a natural resource unique in the United States and has been the focus of ecological concern for more than a century (Daroub et al. 2002). Recent high phosphorus levels observed in the surface water discharges from the East Beach Water Control District (EBWCD) prompted an investigation of potential sources to identify appropriate regulatory jurisdiction. This study is primarily intended to assist with the analysis of data associated with surface water sampling efforts conducted under the South Florida Water Management District (SFWMD) monitoring project "EAA298" upstream within the EBWCD canal system. The upstream monitoring is part of a joint investigation between the SFWMD and the Florida Department of Environmental Protection (FDEP) and is designed to provide data for evaluating the major sources of nutrient inputs to water bodies within the basin. The monitoring results are intended to provide information to facilitate an investigation into the contribution of major nutrient sources by the SFWMD with jurisdiction over certain permitted activities in question. The basin and canal network was evaluated by SFWMD staff, and 15 internal monitoring locations were identified based on contributing area, land use, and conveyance system configuration. These stations were sampled bi-weekly beginning on January 18, 2007, and ending on September 27, 2007. The water quality data collected at these 15 monitoring stations were used to investigate several potential sources of phosphorus to the canal network.

PROJECT STUDY AREA: EAST BEACH WATER CONTROL DISTRICT

The project study area is located entirely within Palm Beach County (Figure 1). The particular geographic region of interest, referred to as the EBWCD, is also within the

8-digit United States Geological Survey Hydrologic Unit Code (USGS HUC) number 03090202.

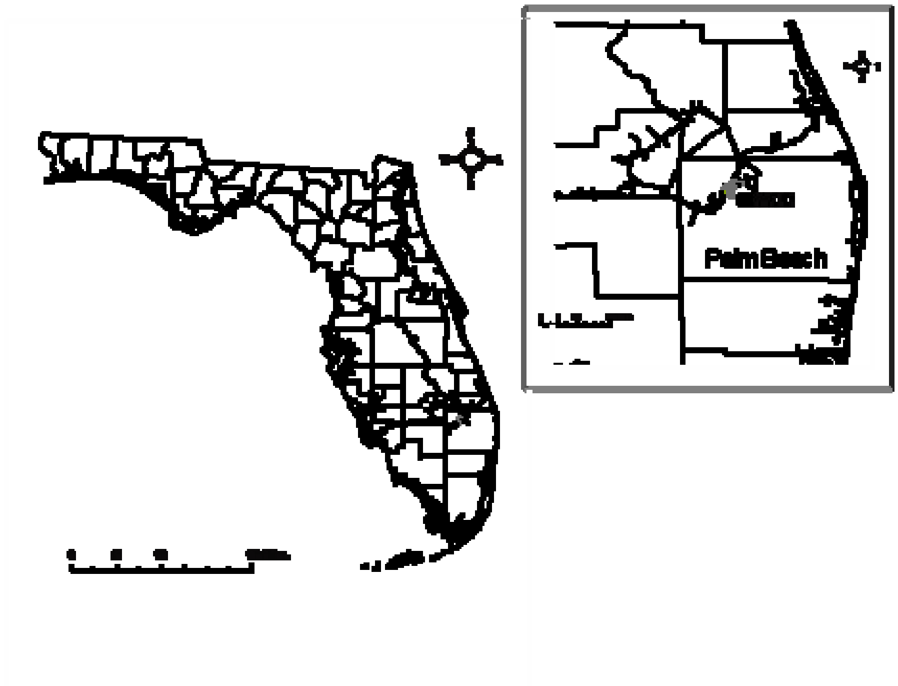

Figure 1 East Beach Water Control District project study area

PHYSIOGRAPHY

A topographical representation of the EBWCD area is provided as Figure 2. This map was generated using a USGS (United States Geological Survey) DEM (Digital Elevation Model) with a cell resolution of 10 meters x 10 meters. The DEM depicted in Figure 2 has a horizontal datum based on NAD83 and vertical datum based on NAVD88. Regarding the topography, low lying areas in the upper north east side and the lower south west side of the study area can be observed.

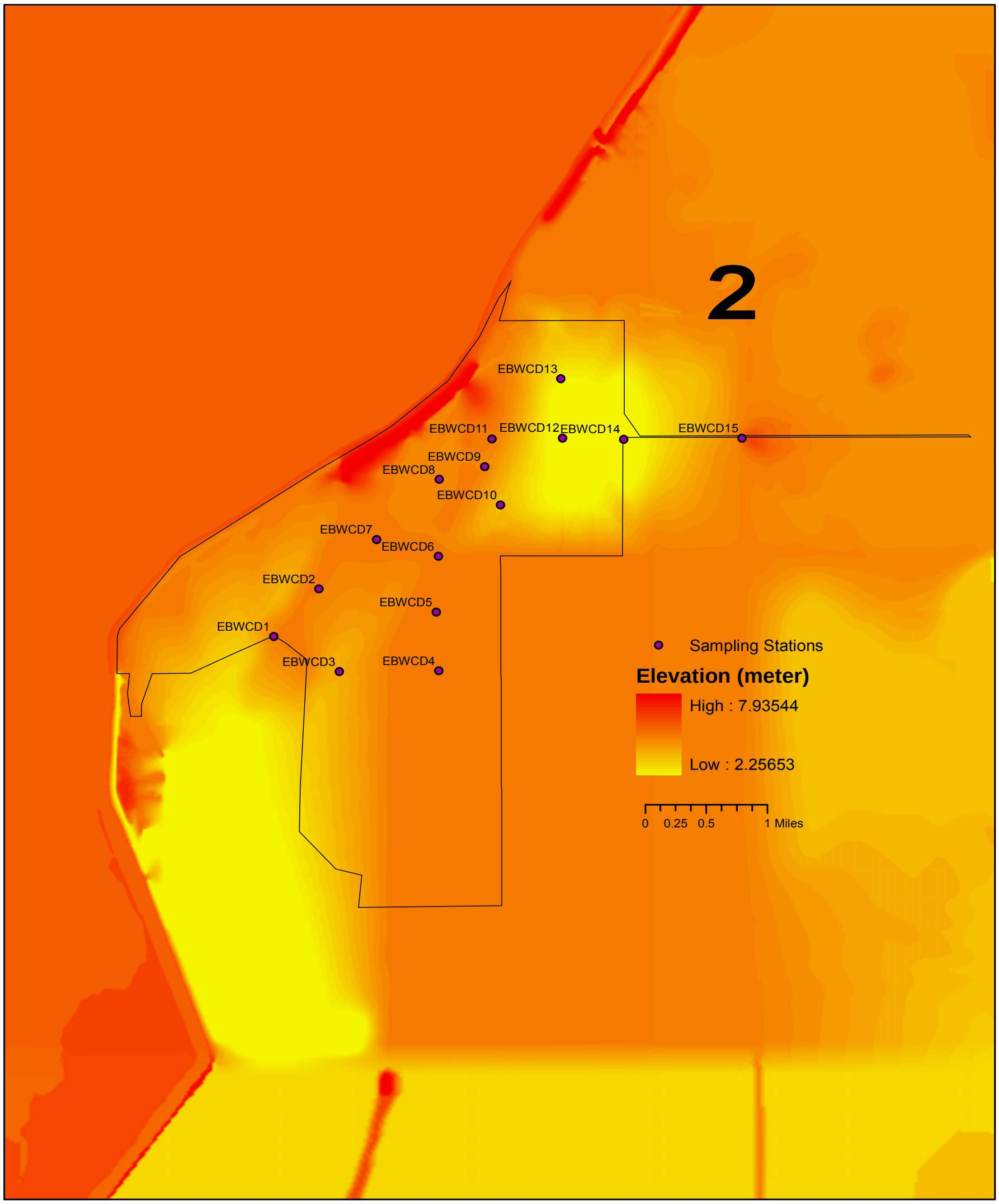

Figure 2 Topography of the EBWCD as depicted by a digital elevation model (DEM)

HYDROLOGY

The project study area is located within the EBWCD limits and includes the discharge channel to the West Palm Beach Canal (Figure 3). The Backbone Canal runs in a general west to east direction from the C-10 culvert (on the Herbert Hoover Dike) to the EBPS3 pump station. The EAA is located south of Lake Okeechobee and contains soils that are predominately Histosols underlain by marl and limestone (Daroub et al. 2002). Following the construction of the Herbert Hoover Dike, the study area's flows were divided with the majority of basin draining west to Lake Okeechobee through culvert C-10. Only the northeastern-most two sections of land drain east to the West Palm Beach Canal. A diversion project was initiated to protect the water quality of the lake by allowing the majority of the basin to discharge east to the West Palm Beach Canal and downstream stormwater treatment areas (STAs). The current land use distribution of the EBWCD and the surrounding areas is shown in Figure 3. It is apparent from the land use descriptions that the land use is varied but a majority of the EBWCD and surrounding areas are dominated by land use primarily meant for sugar cane production.

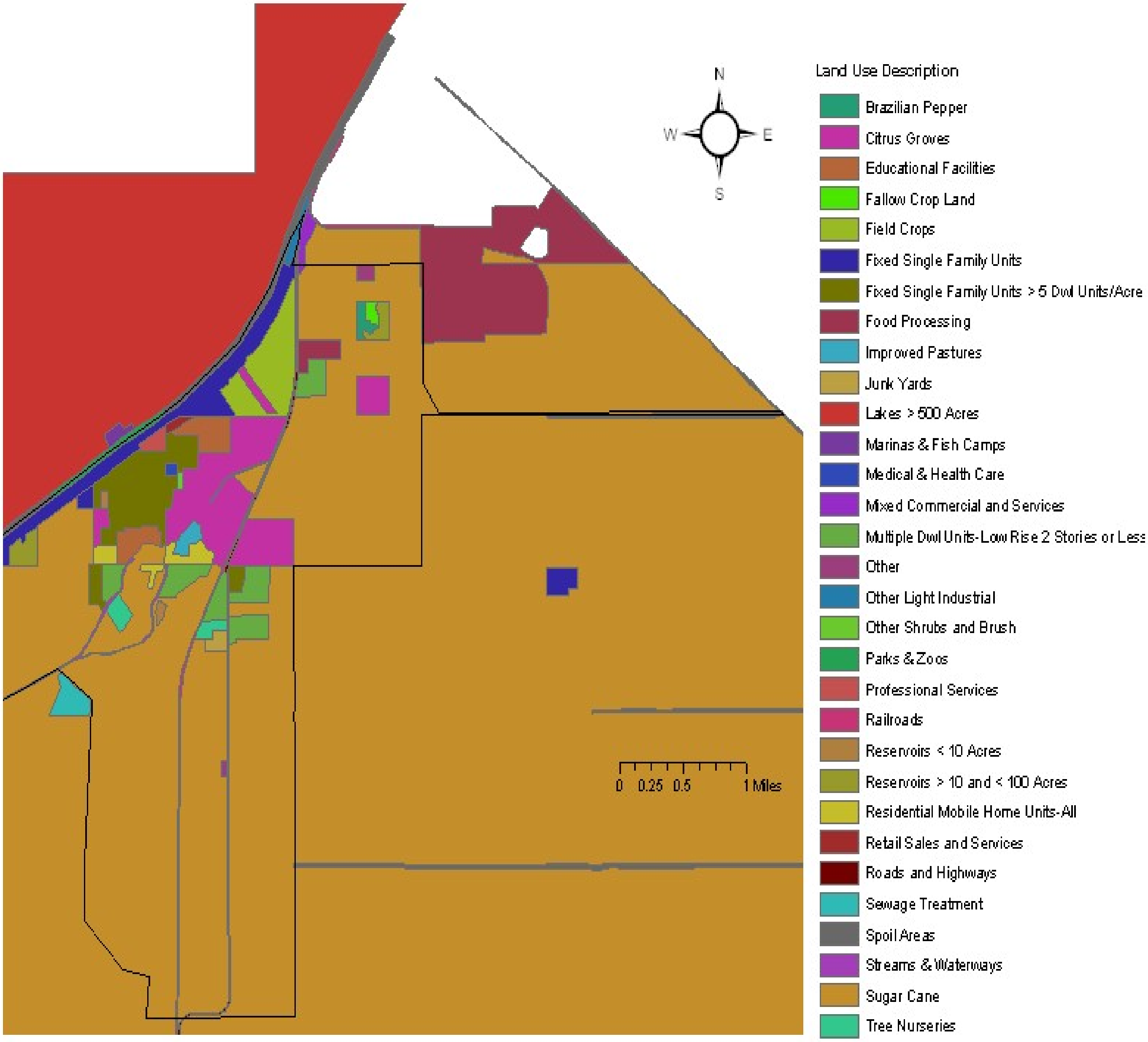

Figure 3 Land use pattern in the East Beach Water Control District

PHOSPHORUS ENRICHMENT

The EAA, located south of Lake Okeechobee, has been a focal point for many studies attempting to address high nutrient levels. More recent investigations (Daroub et al. 2002) have focused on field data collection and assessment of agricultural practices and fertilizer use for sugarcane production. The focus of these studies has been on phosphorus, especially the identification of possible sources of particulate phosphorus.

Phosphorus levels observed from the EAA S5A sub-basin have prompted further investigation of upstream sources contributing to overall nutrient loading. The EBWCD is one contributor to the S5A basin and, through data collected at its pump station EBPS (a.k.a. WPB16.8TS/EBPS3) to the West Palm Beach Canal, has been identified as a significant contributor of phosphorus loading. Appendix A summarizes EBWCD discharges from the "Updated Flow and Phosphorus Data Sets for ECP Basins" (Goforth, October 2007). As stated earlier, the land use mix within the EBWCD is varied, and several potential nutrient contributors other than agriculture have been identified. This analysis was performed in order to characterize upstream water quality and identify potential sources so that the appropriate regulatory jurisdiction could be determined for future action by the SFWMD and/or FDEP.

POTENTIAL SOURCES OF PHOSPHORUS

The SFWMD has identified several potential sources of phosphorus enrichment in the study area. These sources may include landfills, treated wastewater disposal, sewer and septic systems, agricultural activities, rock pit mines, and other industrial sources. Details of these sources are discussed later in this section. However, extensive monitoring is required to confirm that these potential sources have resulted in phosphorus enrichment of surface waters in the EBWCD. To initiate this task, a site visit was conducted by SFWMD to select water quality monitoring locations that were accessible and could represent various contributing areas and land use activities in the affected areas.

Additional data that can be used for assessing potential sources may be obtained from EBWCD Everglades Works of the District BMP permits, MS4 permits, NPDES permits, verification visit reports, and permittee-provided data. Information regarding sewer and septic system leaks and land application of sludge could also be collected and potentially correlated to sampling results.

The contributing internal sources to the elevated total phosphorus levels in the EBWCD basin are unknown, but may include: landfills, rock pit mines, agricultural activities, the Pahokee WWTP (all NPDES permits), and other industrial sources (ex. Bryant Sugar Mill). These sources have high relevance to the study as it relates to phosphorus enrichment in the EBWCD study area. Based on spatial data available from www.fgdl.org, two NPDES facilities and four solid waste facilities (three inactive and one non-monitoring site) and several documented septic systems were identified within the EBWCD study area. Details of the four solid waste facilities are provided in Table 12 in Appendix C.

Landfills

Research conducted by Meeroff et al. (2008) reveals that landfill leachate in Florida is a highly concentrated waste stream, enriched in chemical oxygen demand (COD), total dissolved solids (TDS), ammonia, and certain trace metals (see Table 13 in Appendix E).

If leachate is entering into the subsurface, then total dissolved solids, conductivity, and ammonia would be expected to be present in extremely elevated concentrations compared to background levels. If the landfill is Class III, it will contain construction and demolition (C&D) waste, with treated wood making up a large percentage of the C&D waste stream. These treated wood materials contain copper, chromium, and arsenic (CCA) to counteract the natural rotting process. Landfills that operated prior to 1984 may not have been constructed with a liner. As a result, leachate generated in the landfill likely contains mobilized trace metals, particularly arsenic present as the soluble oxyanions of arsenate and arsenite. Since the landfill did not have a liner, movement of the leachate into the surrounding ground water would be facilitated. Thus, monitoring for copper, chromium, and arsenic could be used as potential conservative tracers to indicate if surrounding landfills are also contributing to the high nutrient content. Another waste material routinely found in C&D landfills is gypsum board (dry wall). This material contains high amounts of sulfates (present as calcium sulfate) that could also be used as a tracer. It is important to note that sulfate is not unique to landfills and is naturally found in surface and ground water as well as in rain water.

Rock Pit Mining Activities

Rock pit ponds contain high concentrations of phosphorus (1700 – 12,000 mg/L as P), sulfate (4000 – 10,000 mg/L), fluoride (200 – 15,000 mg/L), and ammonia (40-1500 mg/L as N) (Miller and Sutcliffe 1982). Any of these tracers could be used to track potential sources of pollutants entering the canal. Phosphogypsum stacks may also contain radioactive isotopes that can be used as tracers as well. One specific area previously mined was found to later be filled with waste material, as documented in the United States District Court Judgment in Case Number 01-8100-CR-RYSKAMP, United States of America v. EMI-SAR Trucking & Equipment, Inc. The site of this violation is in close proximity to other rock pit mining sites as well as the municipal landfill and Bryant Mill, near this project's water quality station number 13. Information provided by FDEP regarding this case is included as Appendix D.

Agricultural activities

Agricultural activity in the EBWCD could possibly be one of the major sources resulting in high levels of phosphorus. Directly measuring nutrient concentrations in surface water may not be sufficient to properly identify these sources. Several methods can be used to distinguish agricultural sources from other potential sources: 1) nitrogen isotopic ratios to signal an influence from fertilizer usage; 2) specific broad spectrum persistent pesticides, such as arsenic and halogentated organo-pesticides; 3) elevated levels of nitrates vs. ammonia; and 4) elevated levels of particulate phosphorus vs. dissolved phosphorus to signal recent agricultural runoff. The agricultural activity depending on the timing of harvesting/replanting activities vs. the growing season may introduce seasonal variations in the fertilizer usage.

Wastewater Disposal

Several facilities operate within the EBWCD that hold industrial wastewater permits and could potentially contribute to phosphorus loading to the canal system. The Pahokee Wastewater Treatment plant serves the western portion of the basin and is considered a potential source of phosphorus to the canals. In addition, the sewer network, by way of sewer overflows or collection system leaks, may also be an important contributor, along with septic tanks and other on-site treatment and disposal systems (OSTDS). A variety of techniques can be employed for source tracking of wastewater disposal, including microbiological indicators, molecular techniques, and seasonal variations in nutrient concentrations.

Industrial Sources

One of the suspected industrial sources is the Bryant Sugar Mill, which is located just outside the limits of the EBWCD. However, effluent ponds are in close proximity to the discharge canal leading to the pump station, and ground water transport of nutrients may be considered as a possible input.

TASKS AND OBJECTIVES

The main objective of this study is to conduct water quality data analysis with the goal of characterizing water quality to identify potential major sources of phosphorus within the basin, by location and originating activity.

The main tasks of the study are listed below.

1. Obtain water quality analysis results from the upstream grab sampling project EAA298 as well as the data collected at the outflow pump station WPB16.8TS/EBPS3.
2. Obtain the water quality monitoring plan including monitoring station location map in electronic format to support spatial data analysis and reporting.
3. Review the water quality data provided and determine applicable data analysis techniques to substantiate identification of likely phosphorus sources.
4. Coordinate with SFWMD staff to correlate the likely sources to regional land use potentially contributing to the EBWCD surface water system and potentially to elevated nutrient levels.
5. Prepare draft and final reports presenting the findings.

The main objectives of the study were as follows:

1. Identify, select, and assemble available monitoring and project water quality data sets.
2. Conduct a comprehensive analysis of the data to draw conclusions about nutrient concentrations in space and time.
3. Within the context of the information available, assess and identify the possible sources responsible for high nutrient concentrations and provide recommendations.

WATER QUALITY MONITORING

The next few sections discuss the surface water quality monitoring efforts in the EBWCD for the synoptic survey conducted between January 2007 and September 2007. Information presented in these sections include: sampling locations, parameter lists, and sampling frequencies as well as documentation of the project scope and ongoing historical perspectives.

ACTIVE MANDATES AND PERMITS

The monitoring activities under this project were initiated in response to long term total phosphorus flow weighted mean concentrations in excess of 350 ppb observed at the EBWCD Pump Station #3 (EBPS3, a.k.a. WP16.8TS), which is currently the primary discharge for the EBWCD. The pump station's discharge to the West Palm Beach Canal is monitored under EAA BMP Works of the District permit No. 50-00033-E, as mandated by the EFA 373.4592, F.S. and subsequent Implementing Rule Ch 40E-63, F.A.C. The BMP permit monitoring fulfills the EFA mandate [section 373.4592(4)(f)(1)] to evaluate the effectiveness of BMP implementation in improving and maintaining beneficial uses of the EPA. STA-1W, located downstream of the project area, could potentially be affected by elevated phosphorus levels discharged from the EBWCD. Achievement of STA-1W discharge water quality goals depends on a combination of STA operational plans and an effective upstream source control BMP program. STA-1W operates under EFA permit No. 503074709 and NPDES permit No. FL0177962-001.

OBJECTIVES

The objective of the water quality monitoring program described herein is to identify potential sources of nutrients to the surface water upstream of the EBWCD Pump

Station #3 (EBPS3, a.k.a. WP16.8TS), which is the primary discharge for EBWCD to the West Palm Beach Canal. The results of the monitoring program will be analyzed with the goal of distinguishing land use and individual areas with significant nutrient discharges to the surface water system.

DURATION

Surface water quality samples and in situ measurements were collected for the period from January 2007 through September 2007. Extension of the monitoring program beyond the September 2007 end date would only be considered if adverse weather or other conditions impacted data collection during the initial nine (9) month monitoring period.

LOCATION OF MONITORING SITES

Locations of the 15 monitoring sites selected for this synoptic survey are shown in the Figure 4.

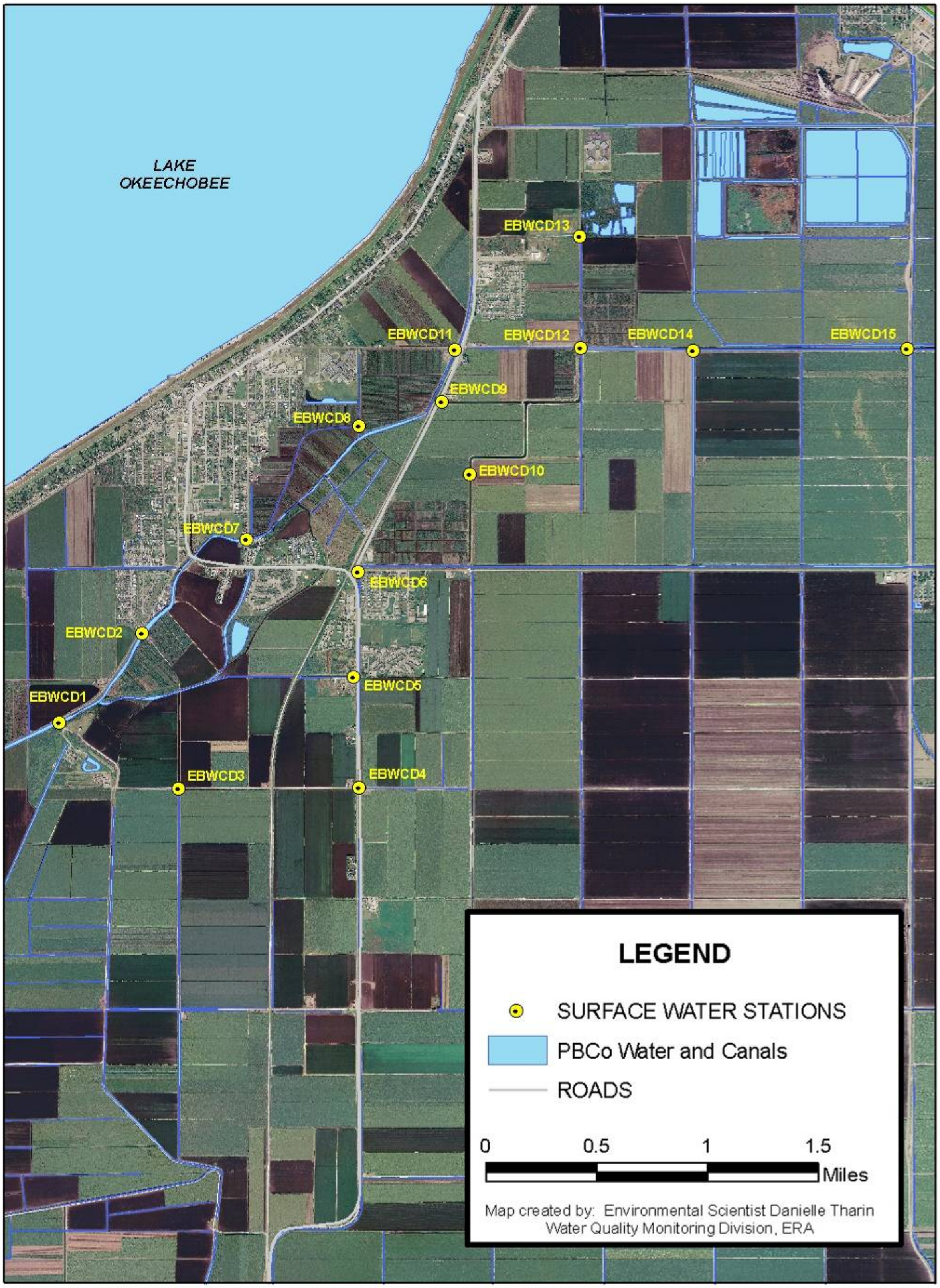

Figure 4 Monitoring Sites in the EBWCD Synoptic Survey

SAMPLING LOCATIONS

The fifteen surface water quality stations monitored for this synoptic survey were registered in the District's Laboratory Information Management System (LIMS). Table 1 provides the Global Positions System (GPS) coordinates and location description for each monitoring station.

Table 1 Surface Water Quality Monitoring Sites and GPS Coordinates

Site Name	Location	Latitude	Longitude
EBWCD1	East Beach Canal #1 at bridge near entrance to Pahokee WWTP	26 48' 10.052"	80 40' 30.141"
EBWCD2	Canal at wooden bridge on SE side of McClure Road	26 48' 31.189"	80 40' 08.427"
EBWCD3	Culvert 0.8 miles west of US441 on Section 20 Road	26 47' 54.316"	80 39' 58.977"
EBWCD4	Culvert 1 mile south of State Market Road on US441	26 47' 54.584"	80 39' 11.382"
EBWCD5	Culvert 0.5 miles south of State Market Road on US441	26 48' 20.782"	80 39' 12.598"
EBWCD6	Culvert at intersection of Muck City Road and State Market Road	26 48' 45.653"	80 39' 11.487"
EBWCD7	Culvert on S Barfield Hwy 700' north of E 7th Street	26 48' 53.263"	80 39' 40.860"
EBWCD8	Culvert with riser boards on Lime Avenue, 0.35 miles south of Larrimore Road, on Oasis Tree Farm	26 49' 20.055"	80 39' 11.044"
EBWCD9	Screw gate culvert on east side of N State Market Road, 0.25 miles south of Larrimore Road	26 49' 25.710"	80 38' 49.310"
EBWCD10	Double screw gate culvert 0.5 miles north of Muck City Road, on Oasis Tree Farm	26 49' 08.512"	80 38' 41.787"
EBWCD11	Canal 200' WSW of intersection of N State Market Road and Larrimore Road	26 49' 38.100"	80 38' 45.800"
EBWCD12	Culvert 0.5 miles east of intersection of N State Market Road and Larrimore Road	26 49' 38.353"	80 38' 12.058"
EBWCD13	Canal 0.5 north of EBWCD12	26 50' 04.789"	80 38' 12.758"
EBWCD14	Canal 1 mile east of intersection of N State Market Road and Larrimore Road	26 49' 37.758"	80 37' 42.919"
EBWCD15	Culvert 2 miles east of intersection of N State Market Road and Larrimore Road	26 49' 37.981"	80 36' 46.567"

** The standard positional goal for site coordinates is ±1 meter. This standard can be obtained with a professional grade DGPS system. The coordinates are relative to NAD83 HARN horizontal datum.

ACCESS AND AUTHORITY

There were no access issues for any of the sampling locations. The EBWCD was notified and all of their canal right-of-way levee roads accessible during this monitoring project. One of the stations requires access through the Oasis Tree Farm property and the manager was notified in advance of any sample collection efforts.

MONITORING FREQUENCIES BY SITE AND PARAMETER

A list of parameters and sampling frequencies for this project is provided in Table 2. Sample collection and field measurements were performed biweekly. No auto-samplers were used to collected water quality samples for this project.

Table 2 Monitoring Frequencies by Site and Parameters

Station	Frequency	Grab Parameters	In-Situ (Field) Parameter
Stations EBWCD1 through EBWCD15	Biweekly and Event	total phosphorus, soluble reactive phosphorus, total dissolved phosphorus, ammonia, nitrate+nitrite, sulfate, turbidity	pH, conductivity, temperature, dissolved oxygen

Details of the laboratory and field analytical methods, data and records management and data quality objectives are discussed in EBWCD (2007), monitoring plan document.

WATER QUALITY DATA ASSESSMENT FRAMEWORK

A data assessment framework was developed in the initial stages of the project. A schematic of the framework is shown in Figure 5. The assessment framework defines the analysis based on two characteristics: spatial and temporal variability. A description of these analyses along with the results from the data analysis is provided in the next sections.

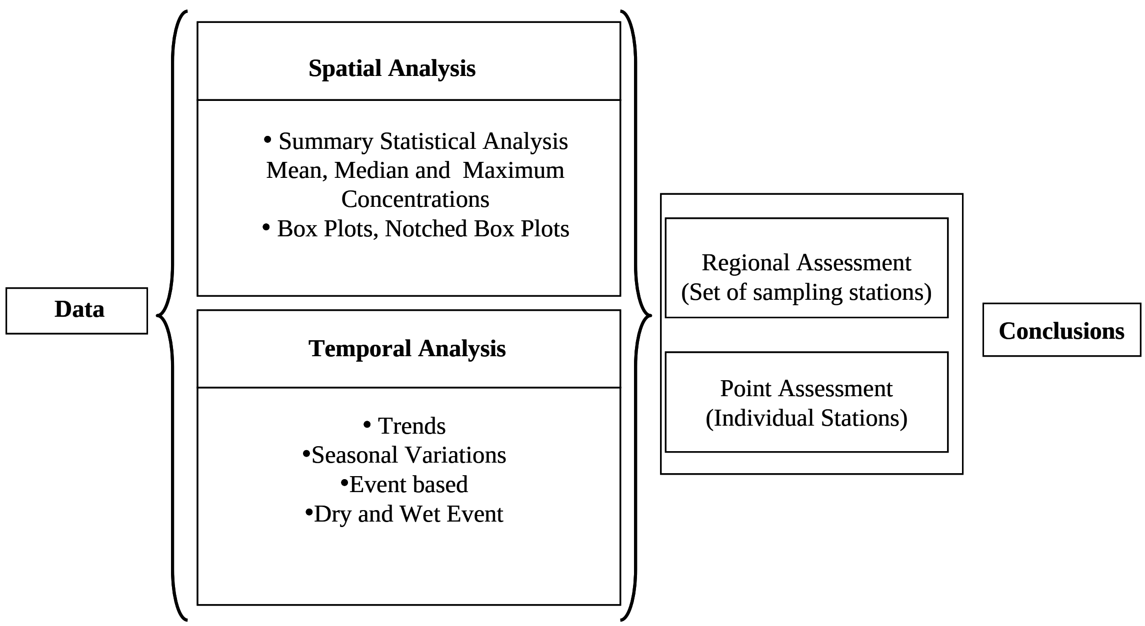

Figure 5 Data analysis framework for EBWCD monitoring effort

SPATIAL ANALYSIS

The spatial analysis conducted for this study primarily deals with summary statistics for point observation data in terms of mean and median values of the water quality parameters measured. Summary statistics include an assessment of mean, median, and maximum observed concentrations at different sampling stations or at a regional level.

The mean concentration for each site as well as minimum and maximum mean site concentrations of the constituents and parameters over the entire monitoring period are listed in Table 3. The concentrations for nutrients are considered generally very high (x>0.03 mg/L as P and x> 0.07 mg/L as N) (Zhang, 2006a, 2006b). Specific stations especially, EBWCD 12, 13, 14 and 15, recorded high values for almost all the constituents. High concentrations were observed at stations EBWCD4, 5 and 6 in the month of September. The average concentrations reported in Table 3 may not reflect these observations. The high concentrations are coincident with basin discharges and therefore are significant. The temporal analysis reported later in this report may not reveal this information as the values used for that assessment are average concentration values.

Consistently high levels of phosphorus, specific conductivity and several other water quality parameters were found throughout the study period in the northeast portion of the basin. This can be concluded by evaluation of observed concentrations at sampling stations EBWCD12, 13, 14 and 15. The surrounding areas contain historical rock-pit mining, landfill operation, agriculture, and nearby sugar mill operation. The topography is also conducive to surface runoff drainage from surrounding areas due to depression evident in the northeast portion of the basin as shown in Figure 2. Very high phosphorus and nitrogen levels were observed in the southern portion of the basin increasing July through the end of the monitoring period in September. This area (i.e. area surrounding sampling stations EBWCD3, 4, 5 and 6) is dominated by agriculture with sugar cane as the primary crop.

Table 3 Mean concentrations of constituents and parameters from monitoring effort

Water Quality Constituent Concentrations and Parameter Values									
Station	**TP (mg/L)**	**TPP (mg/L)**	**TDP (mg/L)**	**SRP (mg/L)**	**NH4 (mg/L)**	**NOX (mg/L)**	**Sulfate (mg/L)**	**Turbidity (NTU)**	**Specific Conductivity (µS/cm)**
EBWCD1	0.148	0.049	0.098	0.083	0.145	0.072	45.442	14.021	610.779
EBWCD2	0.231	0.054	0.178	0.153	0.375	0.032	62.653	8.416	923.474
EBWCD3	0.266	0.063	0.202	0.181	0.285	0.064	46.716	10.126	667.663
EBWCD4	0.347	0.071	0.276	0.252	0.346	0.063	43.653	8.721	644.342
EBWCD5	0.370	0.053	0.317	**0.295**	0.425	0.143	45.126	9.158	639.500
EBWCD6	0.243	0.042	0.213	0.178	0.164	0.014	41.950	5.478	660.833
EBWCD7	0.257	0.073	0.184	0.152	0.507	0.020	79.678	8.061	1286.733
EBWCD8	0.151	0.084	0.057	0.029	0.121	0.076	72.971	16.965	1074.065
EBWCD9	0.177	0.078	0.106	0.069	0.489	0.104	166.505	7.432	2192.000
EBWCD10	0.289	0.047	0.242	0.212	0.276	0.019	53.695	4.353	733.532
EBWCD11	0.167	0.101	0.069	0.041	0.256	0.017	111.253	13.874	1567.947
EBWCD12	0.350	0.133	0.217	0.182	0.565	0.273	252.579	9.584	2742.421
EBWCD13	**0.479**	**0.147**	**0.324**	0.268	**1.209**	0.289	233.353	**18.389**	**3196.611**
EBWCD14	0.320	0.099	0.221	0.188	0.607	**0.308**	271.737	9.032	2790.842
EBWCD15	0.264	0.101	0.157	0.122	0.485	0.226	**273.278**	8.628	2733.167
Maximum	0.479	0.147	0.324	0.295	1.209	0.308	273.278	18.389	3196.611
Minimum	0.148	0.042	0.057	0.029	0.121	0.014	41.950	4.353	610.779

Table 4 Standard deviation of constituents and parameters

	Water Quality Constituent Concentrations and Parameter Values								
Station	**TP (mg/L)**	**TPP (mg/L)**	**TDP (mg/L)**	**SRP (mg/L)**	**NH4 (mg/L)**	**NOX (mg/L)**	**Sulfate (mg/L)**	**Turbidity (NTU)**	**Specific Conductivity (µS/cm)**
EBWCD1	0.090	0.019	0.076	0.068	0.325	0.068	12.319	7.553	180.951
EBWCD2	0.256	0.028	0.235	0.223	0.789	0.045	37.619	4.755	739.882
EBWCD3	0.325	0.054	0.288	0.276	0.841	0.082	18.049	6.237	284.976
EBWCD4	0.442	0.080	0.385	0.368	0.814	0.144	16.535	6.699	218.706
EBWCD5	**0.577**	0.028	**0.572**	**0.563**	1.103	0.365	15.414	6.864	259.164
EBWCD6	0.293	0.034	0.270	0.249	0.281	0.022	9.984	4.194	216.701
EBWCD7	0.296	0.065	0.249	0.231	1.041	0.048	63.148	8.414	**1209.940**
EBWCD8	0.083	0.060	0.044	0.039	0.149	0.167	40.238	**15.970**	588.879
EBWCD9	0.155	0.056	0.113	0.100	0.669	0.126	**77.966**	2.185	1132.264
EBWCD10	0.327	0.040	0.313	0.298	0.816	0.051	24.066	1.781	236.929
EBWCD11	0.122	0.096	0.055	0.049	0.593	0.023	66.931	10.774	848.054
EBWCD12	0.305	**0.179**	0.208	0.204	0.837	0.441	67.793	6.347	678.791
EBWCD13	0.274	0.089	0.277	0.269	**1.278**	**0.481**	44.300	11.921	462.534
EBWCD14	0.202	0.032	0.195	0.189	0.838	0.257	61.837	4.140	566.672
EBWCD15	0.120	0.051	0.102	0.095	0.440	0.203	51.445	2.991	460.304
Maximum	0.577	0.179	0.572	0.563	1.278	0.481	77.966	15.970	1209.940
Minimum	0.083	0.019	0.044	0.039	0.149	0.022	9.984	1.781	180.951

The median values of concentrations are provided in Table 5.

Table 5 Median concentrations of constituents and parameters

	Water Quality Constituent Concentrations and Parameter Values								
Station	TP (mg/L)	TPP (mg/L)	TDP (mg/L)	SRP (mg/L)	NH4 (mg/L)	NOX (mg/L)	Sulfate (mg/L)	Turbidity (NTU)	Specific Conductivity (µS/cm)
EBWCD1	0.113	0.049	0.070	0.060	0.038	0.044	42.700	12.900	554.000
EBWCD2	0.120	0.042	0.073	0.052	0.045	0.021	48.800	8.050	660.600
EBWCD3	0.116	0.047	0.073	0.059	0.037	0.016	40.100	7.200	584.000
EBWCD4	0.109	0.033	0.068	0.058	0.055	0.007	37.900	6.500	559.100
EBWCD5	0.131	0.055	0.078	0.069	0.062	0.012	38.100	6.600	563.000
EBWCD6	0.110	0.031	0.084	0.055	0.035	0.009	37.200	4.600	581.000
EBWCD7	0.114	0.050	0.055	0.041	0.054	0.012	51.600	3.900	741.000
EBWCD8	0.120	0.075	0.036	0.016	0.042	0.017	54.700	10.600	930.000
EBWCD9	0.110	0.065	0.054	0.026	0.185	0.047	151.000	6.800	1927.000
EBWCD10	0.091	0.028	0.059	0.038	0.013	0.007	39.000	4.000	592.000
EBWCD11	0.094	0.056	0.040	0.015	0.038	0.008	95.800	12.400	1357.000
EBWCD12	0.240	0.083	0.158	0.120	0.204	0.150	253.000	8.000	2724.000
EBWCD13	0.362	0.135	0.212	0.166	0.831	0.064	225.000	15.700	3117.000
EBWCD14	0.238	0.099	0.166	0.135	0.465	0.280	275.000	8.300	2743.000
EBWCD15	0.226	0.096	0.147	0.116	0.404	0.166	274.000	9.200	2678.000

Notched Box-Plots

A notched box and whisker plot provides graphical summarization of data as a function of variable. The plots provide a 5-number summary statistics (i.e. minimum, maximum range values, the upper and lower quartiles and the median) and are a quick and powerful approach of summarizing the datasets (Spear, 1952, Potter, 2006). These notched plots can also show rough statistical significance between data sets. Figures 6 through 13 provide notched box and whisker plots for constituents and parameters of interest for this study.

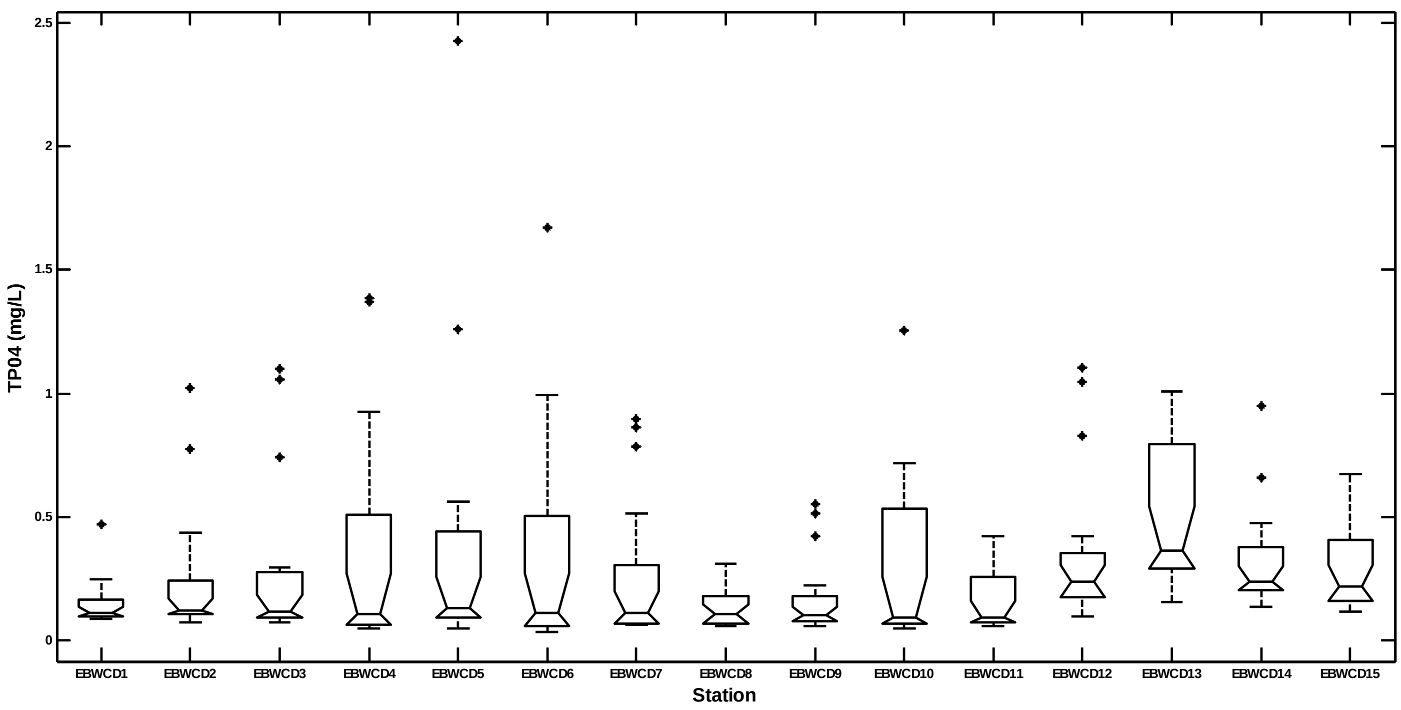

Figure 6 Notched-box plot of TP concentrations at all the stations

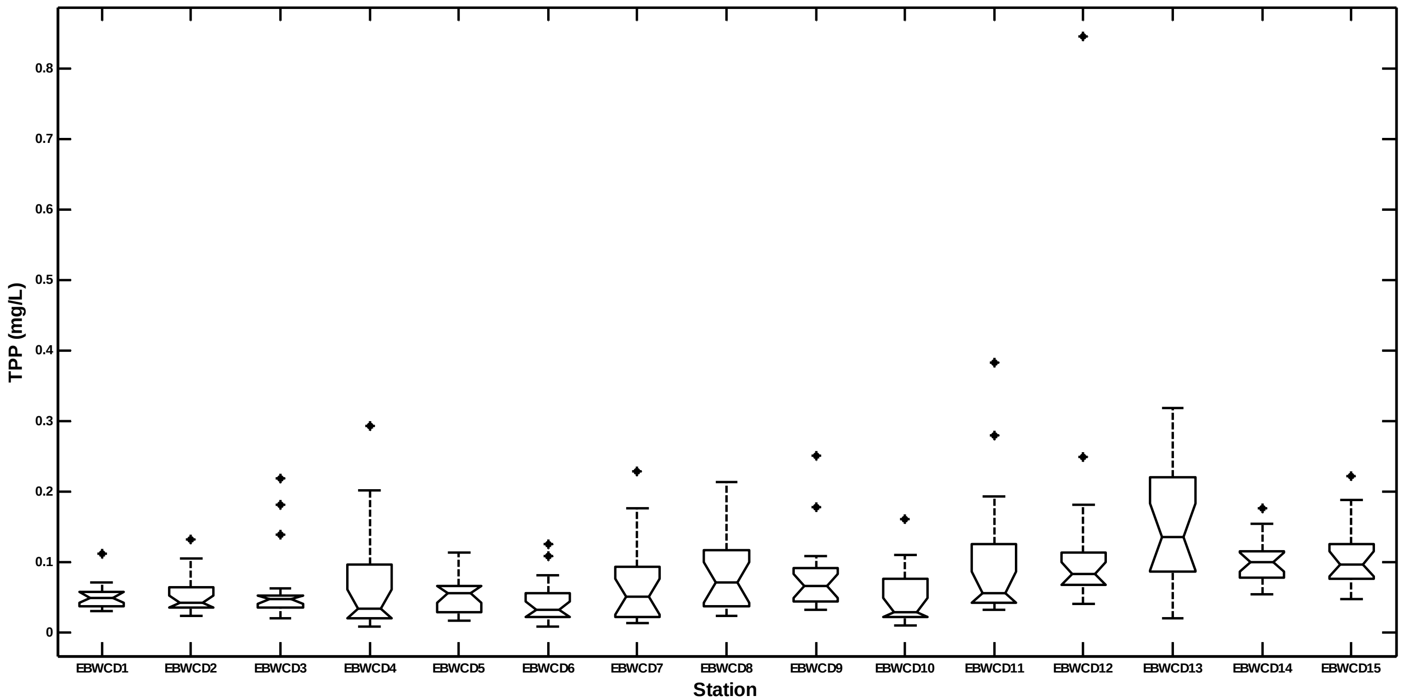

Figure 7 Notched-box plot of TPP concentrations at all the stations

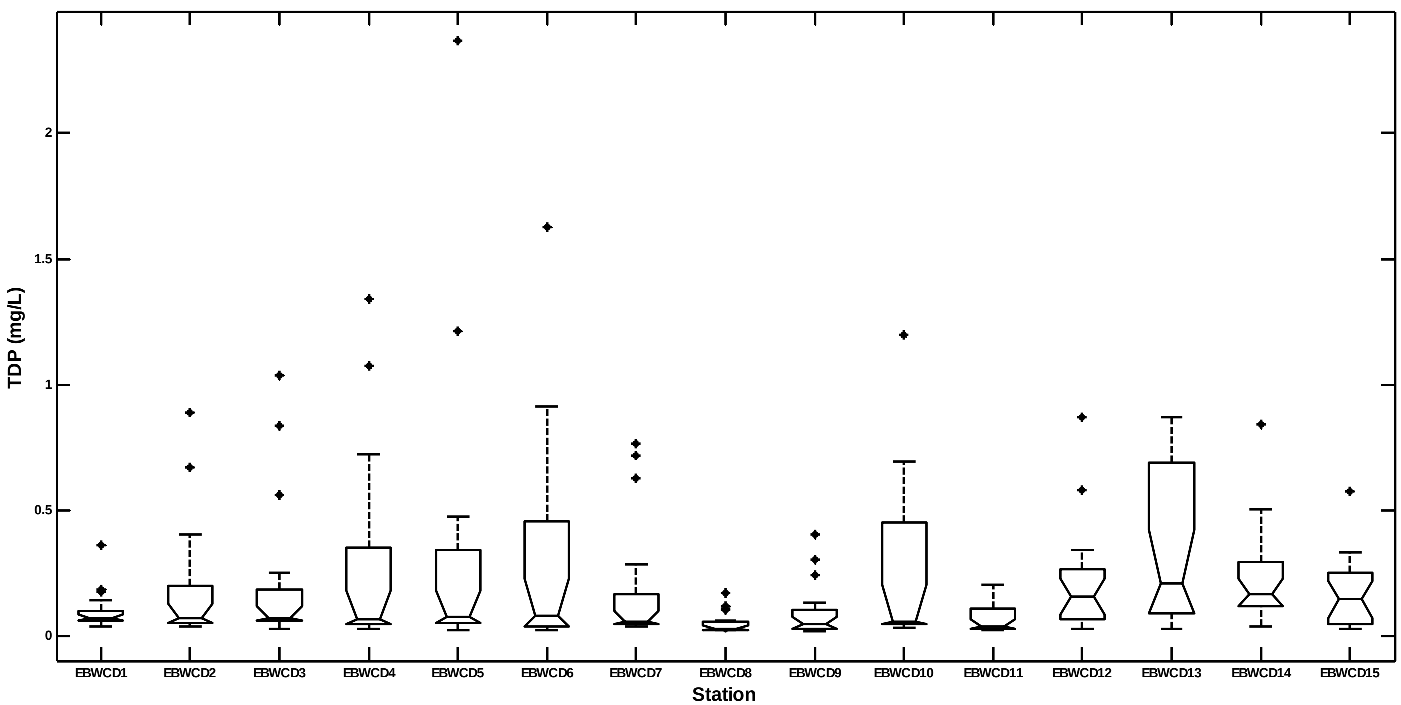

Figure 8 Notched-box plot of TDP concentrations at all the stations

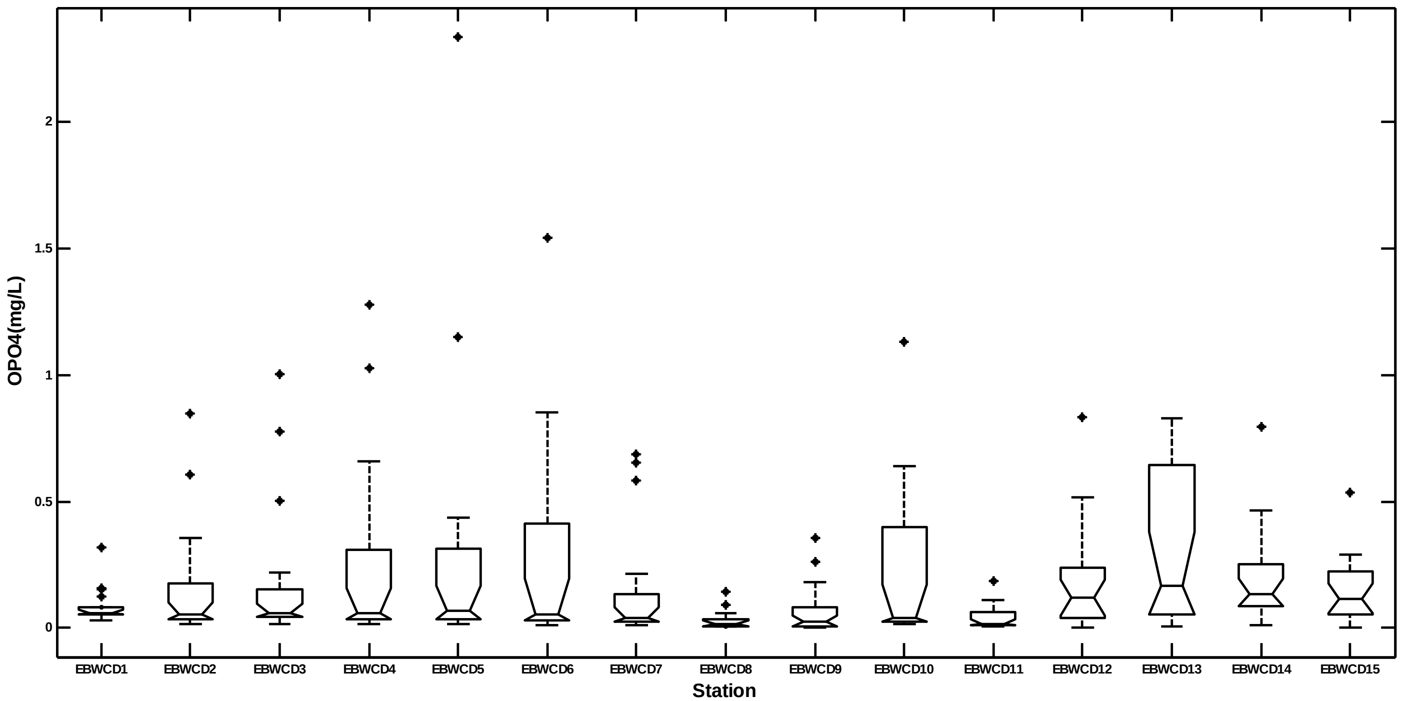

Figure 9 Notched-box plot of SRP concentrations at all the stations

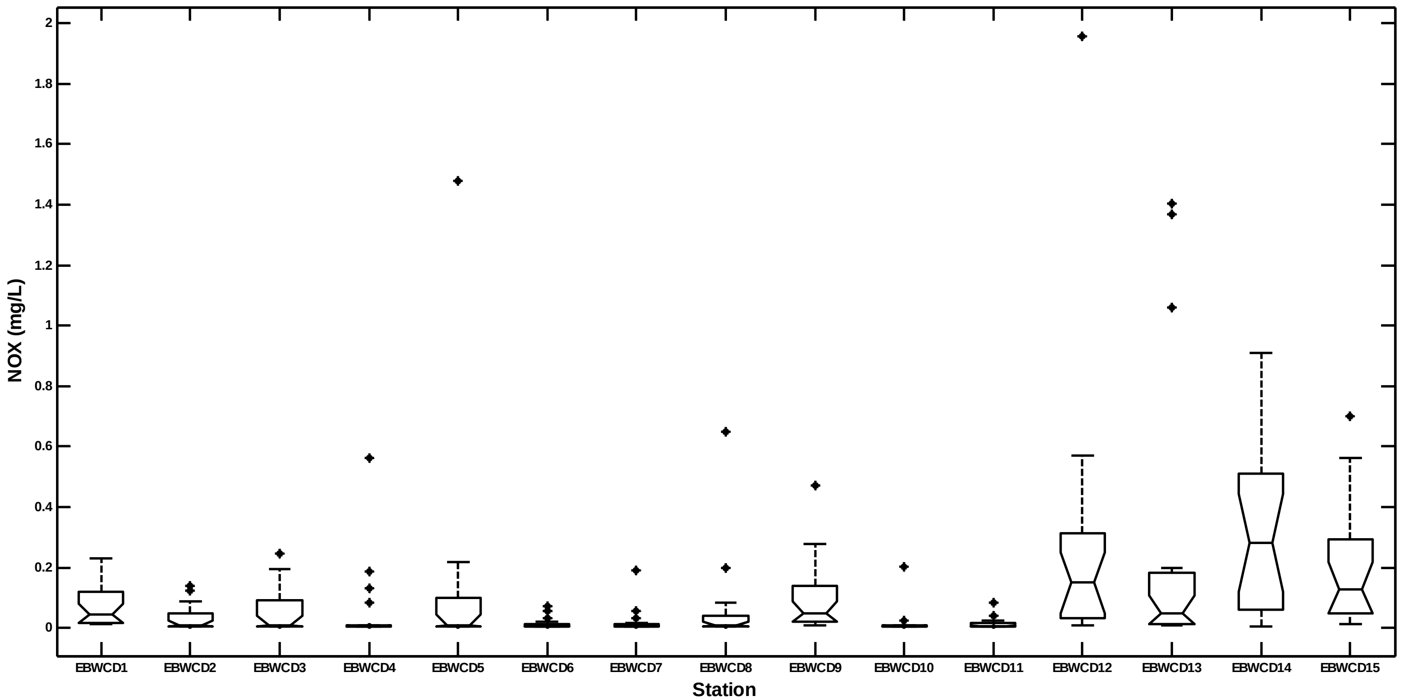

Figure 10 Notched-box plot of NOX concentrations at all the stations

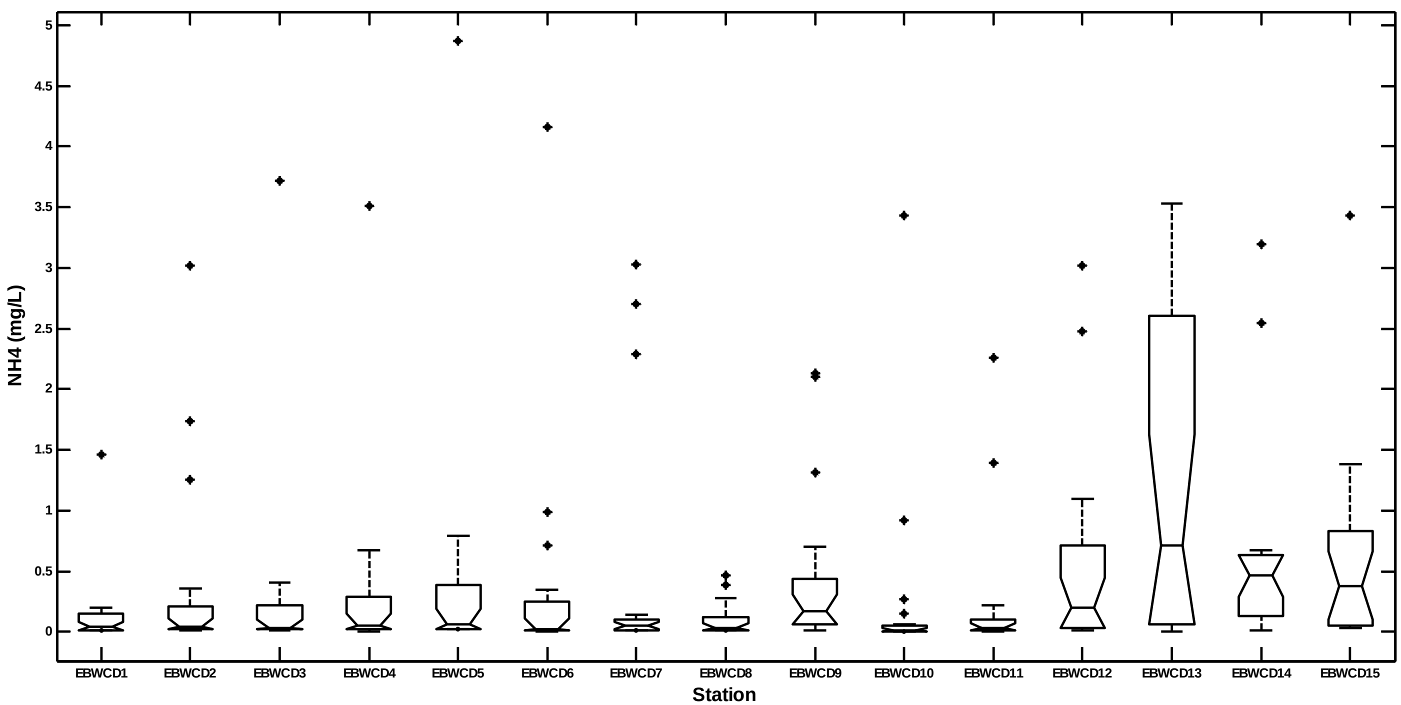

Figure 11 Notched-box plot of NH4 concentrations at all the stations

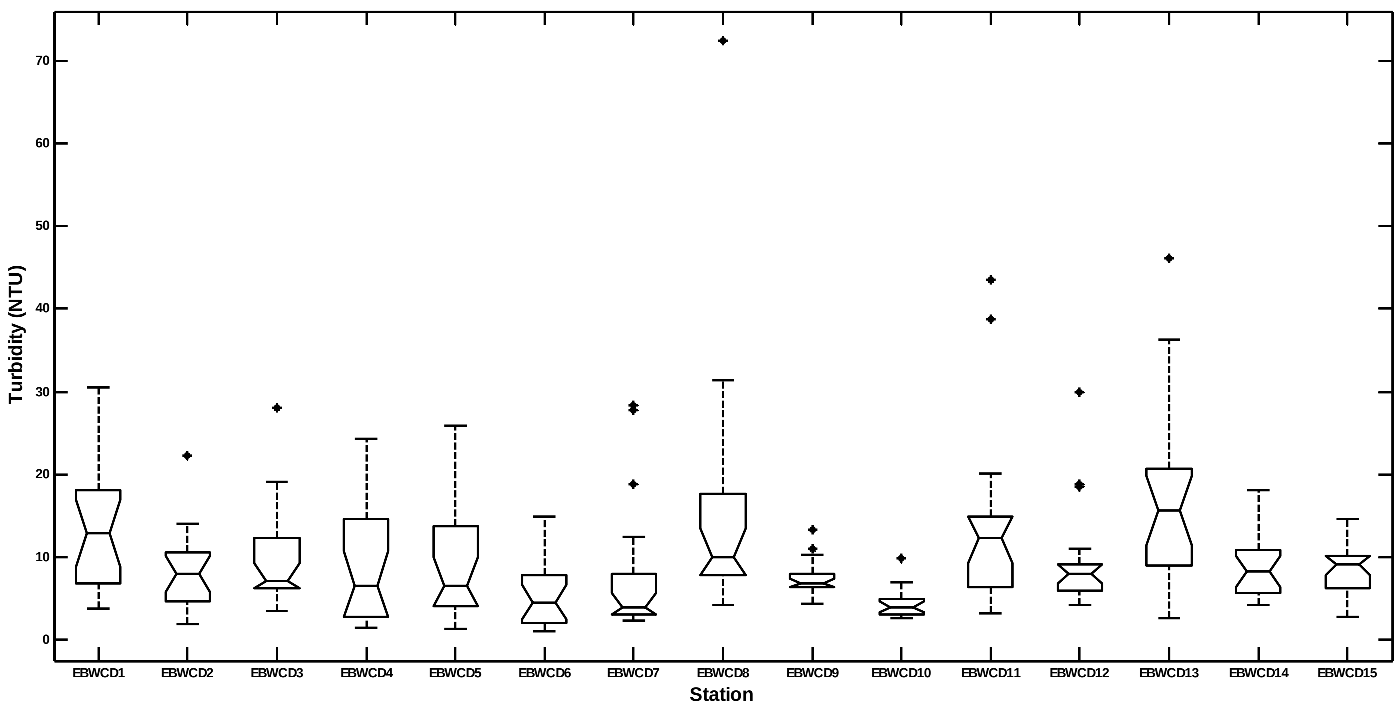

Figure 12 Notched-box plot of turbidity values at all the stations

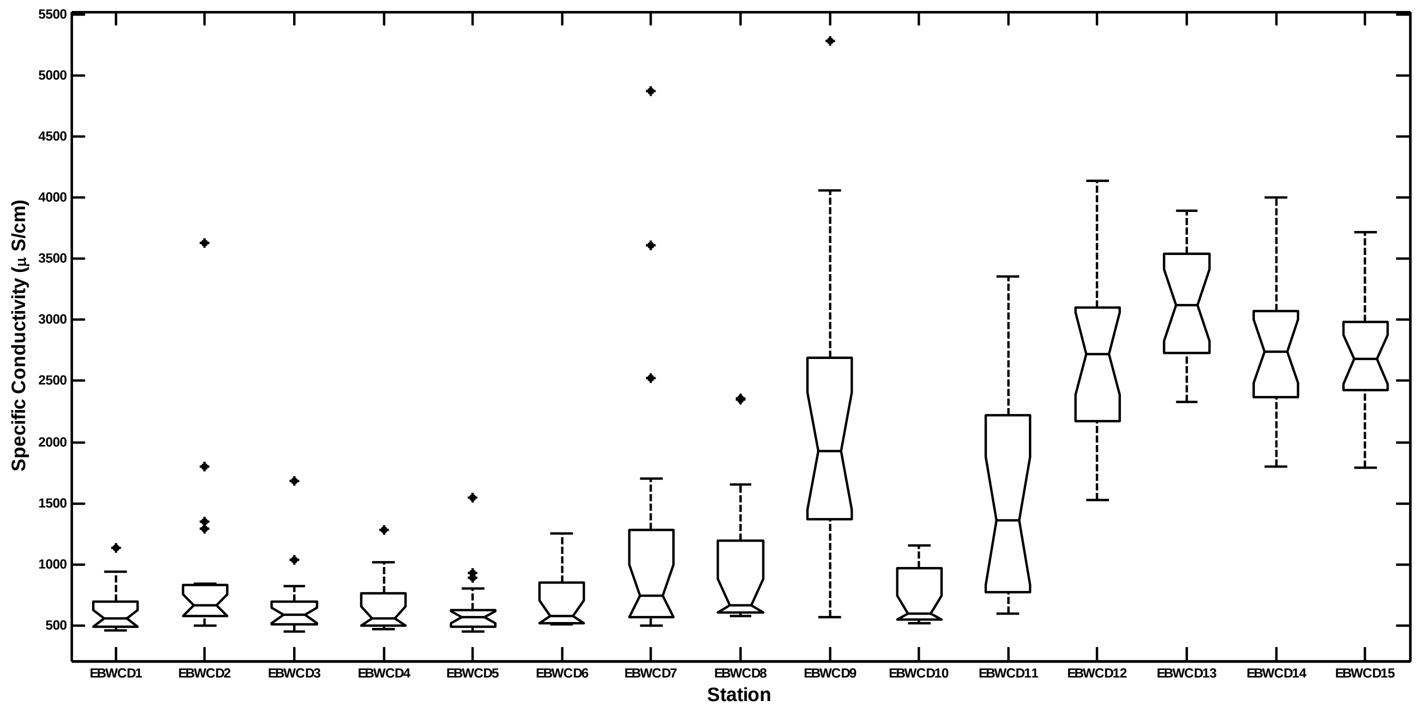

Figure 13 Notched-box plot of specific conductivity values at all the stations

Significant positive correlation was noticed between specific conductivity measurements and SO4 concentrations. This may be suggestive of a typical drainage from landfills, which needs to be further investigated. Extremely high specific conductivity values were observed in dry and wet seasons at sampling stations EBWCD9, 12, 13, 14 and 15. Again, the topography of the area in which these stations are located is conducive to contribution from ground water sources.

TEMPORAL ANALYSIS

The temporal variations in constituent concentrations were analyzed for each station. These temporal trends are summarized in Table 6. Mean concentrations for all constituents have exhibited an increasing trend over the study period (January 2007 through September 2007) at all the monitoring stations. Trends were delineated using visual observation of the plotted data and slopes of the linear trend lines fitted to the data.

Table 6 Temporal trends in different constituents and parameters

	Water Quality Constituent Concentrations and Parameter Value Trends								
Station	TP04 (mg/L)	TPP (mg/L)	TDP (mg/L)	OPO4 (mg/L)	NH4 (mg/L)	NOX (mg/L)	Sulfate (mg/L)	Turbidity (NTU)	Specific Conductivity (µS/cm)
EBWCD1	Increase	Increase	Increase	Increase	Increase	Decrease	Increase	Decrease	Increase
EBWCD2	Increase	Increase	Increase	Increase	Increase	Decrease	Increase	Decrease	Increase
EBWCD3	Increase	Increase	Increase	Increase	Increase	Decrease	Increase	Decrease	Increase
EBWCD4	Increase	Increase	Increase	Increase	Increase	No trend	Increase	No trend	Increase
EBWCD5	Increase	Increase	Increase	Increase	Increase	No trend	Increase	Decrease	Increase
EBWCD6	Increase	Increase	Increase	Increase	Increase	Decrease	Increase	Increase	Increase
EBWCD7	Increase	Increase	Increase	Increase	Increase	No trend	Increase	Increase	Increase
EBWCD8	Increase	Increase	Decrease	No Trend	Increase	Decrease	Increase	Decrease	Increase
EBWCD9	Increase	Increase	Increase	Increase	Increase	Decrease	Increase	Increase	Increase
EBWCD10	Increase	Increase	Increase	Increase	Increase	Decrease	Increase	Increase	Increase
EBWCD11	Increase	Increase	Increase	Increase	Increase	Decrease	Increase	Increase	Increase
EBWCD12	Increase	Increase	Increase	Increase	Increase	Decrease	Increase	Increase	Increase
EBWCD13	Increase	Increase	Increase	Increase	Increase	Decrease	Decrease	No Trend	Decrease
EBWCD14	Increase	Increase	Increase	Increase	Increase	Decrease	Decrease	No Trend	Decrease
EBWCD15	Increase	Increase	Increase	Increase	Increase	Decrease	Decrease	No Trend	Decrease

EVENT-BASED ASSESSMENT

Classification of sampling events into wet and dry events provides more insight into concentration variations associated with precipitation events. The study utilizes several scenarios to assess event-based concentration assessments and they include: 1) wet season – wet event; 2) wet season – dry event; 3) dry season – wet event and 4) dry season – dry event. According to the SFWMD, the dry and wet seasons are defined from November to April and May to October respectively. Also, a dry event in a wet season is defined based on the cumulative value of precipitation realized in the two days prior and including the day of sampling. An event is classified as dry even if the cumulative value of precipitation is less than 0.5 inches. The dry and wet seasons were based on the sampling period from January to September 2007 for this study.

Daily rainfall data (area-weighted for the EBWCD study area) is shown in Figure 14. Monthly and 30 year average rainfall values are shown in the Figure 15. Based on 30-year data for the East EAA region provided by SFWMD all months except for the months of July, October and December during the monitoring period resulted in lower than average rainfall depths. The 30 year average annual rainfall depth is 48.82 inches and rainfall amount for year 2007 is 40.25 inches.

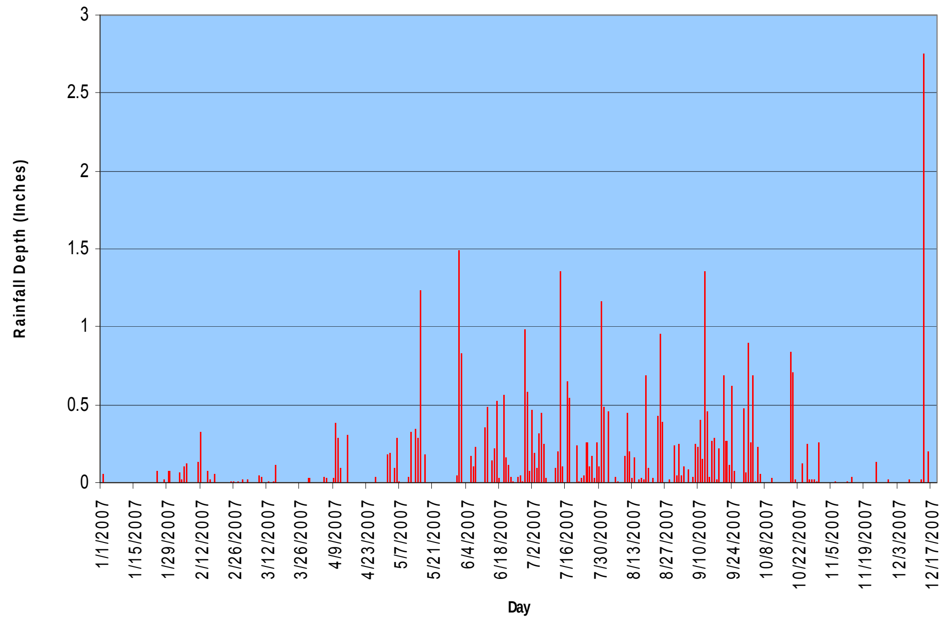

Figure 14 Observed daily rainfall depth during the monitoring period

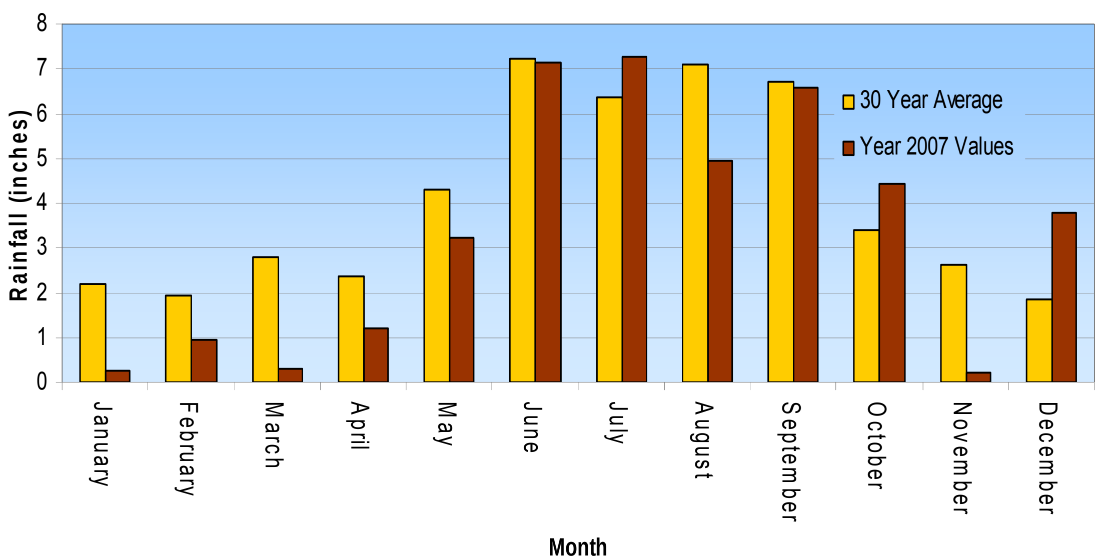

Figure 15 Monthly rainfall depth values and 30 year average rainfall amounts

Flow records are not available at monitoring sites because no monitoring of surface water flow is on-going at these monitoring stations. However, flow and concentration data are available at EBPS3 (EBWCD Pump Station #3, a.k.a. WP16.8TS). The wet and dry event characterizations can be designated by data relevant to the pumping out of the basin. The EBWCD basin discharged only through the EBPS3 structure during the upstream monitoring period, and the basin flow, TP Load, and TP FWMC are presented in Figure 16. Historical EBWCD discharges are summarized in Appendix B.

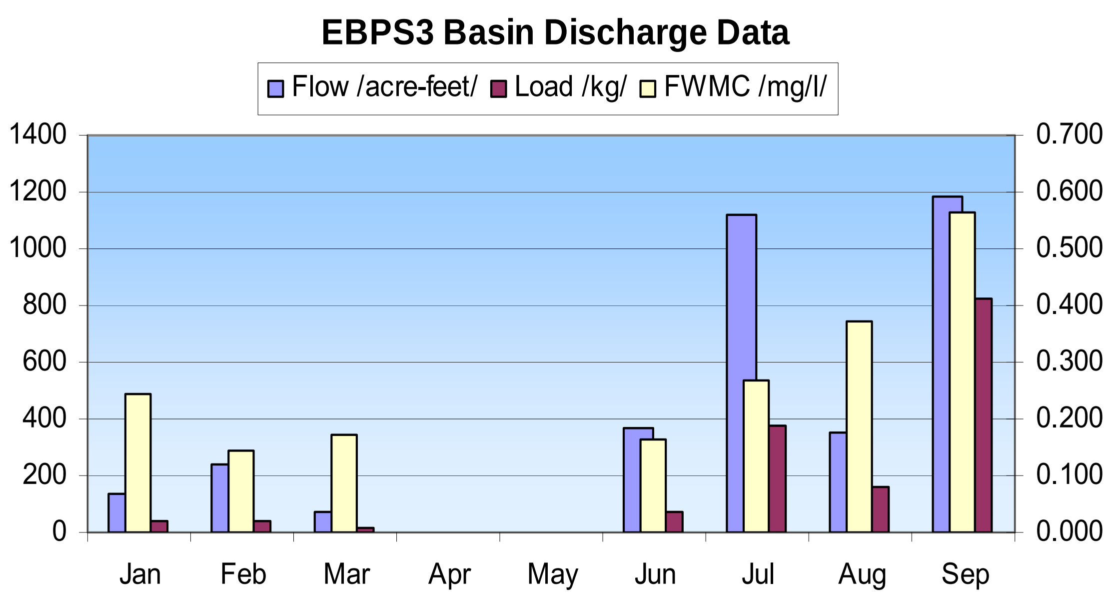

Figure 16 Monthly EBPS3 Flow, TP Load and TP FWMC

The precipitation totals within the monitoring period for dry and wet season were 2.7 and 29.1 inches respectively. The mean constituent concentrations and parameter values for dry and wet seasons are shown in Tables 7 and 8.

Table 7 Seasonal Variations (Dry and Wet Seasons)

	Water Quality Constituent Concentrations and Parameter Values								
Station	**TP (mg/L)**	**TPP (mg/L)**	**TDP (mg/L)**	**SRP (mg/L)**	**NH4 (mg/L)**	**NOX (mg/L)**	**Sulfate (mg/L)**	**Turbidity (NTU)**	**Specific Conductivity (µS/cm)**
EBWCD1									
Dry Season	0.111	0.044	0.066	0.056	0.046	0.107	35.475	19.288	481.625
Wet Season	0.175	0.053	0.121	0.102	0.218	0.044	52.691	10.191	704.709
EBWCD2									
Dry Season	0.113	0.037	0.076	0.061	0.046	0.066	40.925	11.875	561.250
Wet Season	0.318	0.066	0.251	0.219	0.614	0.005	78.455	5.900	1186.909
EBWCD3									
Dry Season	0.105	0.040	0.065	0.054	0.026	0.079	37.063	14.225	505.000
Wet Season	0.382	0.080	0.302	0.273	0.474	0.052	53.736	7.145	785.964
EBWCD4									
Dry Season	0.080	0.029	0.051	0.040	0.029	0.036	36.350	9.163	497.625
Wet Season	0.541	0.101	0.440	0.405	0.548	0.086	48.964	8.400	751.045
EBWCD5									
Dry Season	0.117	0.053	0.064	0.053	0.033	0.066	35.413	14.663	484.250
Wet Season	0.554	0.054	0.501	0.471	0.711	0.204	52.191	5.155	752.409
EBWCD6									
Dry Season	0.062	0.022	0.046	0.033	0.021	0.027	37.088	3.663	517.375
Wet Season	0.504	0.057	0.447	0.407	0.618	0.006	51.673	7.000	818.818
EBWCD7									
Dry Season	0.079	0.021	0.058	0.042	0.029	0.018	43.200	3.900	602.500
Wet Season	0.373	0.107	0.266	0.225	0.774	0.025	103.655	10.827	1731.018

Table 8 Continuation of Seasonal Variations for Wet and Dry Events (Dry and Wet Seasons)

	Water Quality Constituent Concentrations and Parameter Values								
Station	**TP (mg/L)**	**TPP (mg/L)**	**TDP (mg/L)**	**SRP (mg/L)**	**NH4 (mg/L)**	**NOX (mg/L)**	**Sulfate (mg/L)**	**Turbidity (NTU)**	**Specific Conductivity (µS/cm)**
EBWCD8									
Dry Season	0.123	0.060	0.053	0.034	0.109	0.021	72.200	20.750	998.000
Wet Season	0.168	0.099	0.059	0.026	0.127	0.113	73.391	14.900	1115.555
EBWCD9									
Dry Season	0.094	0.053	0.055	**0.032**	0.169	0.087	130.700	7.325	1659.000
Wet Season	0.244	0.097	0.137	0.093	0.746	0.117	192.545	7.509	2579.636
EBWCD10									
Dry Season	0.097	0.020	0.077	0.061	0.046	0.040	46.763	3.438	621.125
Wet Season	0.428	0.066	0.362	0.322	0.424	0.006	58.736	5.018	815.282
EBWCD11									
Dry Season	0.079	0.051	0.032	0.010	0.021	0.025	75.300	9.638	1073.875
Wet Season	0.230	0.137	0.093	0.061	0.405	0.013	137.400	16.955	1927.273
EBWCD12									
Dry Season	0.189	0.067	0.122	0.093	0.212	0.275	285.625	6.863	2829.625
Wet Season	0.467	0.181	0.286	0.247	0.821	0.272	228.545	11.564	2679.000
EBWCD13									
Dry Season	0.346	0.153	0.193	0.156	0.675	0.229	252.571	14.100	3316.375
Wet Season	0.639	0.141	0.483	0.400	1.792	0.310	212.636	20.500	3030.455
EBWCD14									
Dry Season	0.210	0.076	0.134	0.105	0.300	0.371	309.125	7.638	2942.625
Wet Season	0.401	0.116	0.285	0.249	0.830	0.263	244.545	10.045	2680.455
EBWCD15									
Dry Season	0.202	0.077	0.125	0.098	0.520	0.288	301.000	7.838	2896.375
Wet Season	0.354	0.118	0.224	0.176	0.750	0.157	243.364	9.218	2533.364

Regional values of mean concentrations for constituent and parameters are given in Table 9. Figures 16 and 17 provide the variations of TPP and TDP for all the stations. The concentrations and parameter values are consistently higher in the wet season compared to the dry season.

Table 9 Regional Means of Wet and Dry Events

All Stations	TP (mg/L)	TPP (mg/L)	TDP (mg/L)	SRP (mg/L)	NH4 (mg/L)	NOX (mg/L)	Sulfate (mg/L)	Turbidity (NTU)	Specific Conductivity (µS/cm)
	Water Quality Constituent Concentrations and Parameter Values								
Dry Season	0.134	0.054	0.081	0.062	0.152	0.115	115.920	10.291	1332.442
Wet Season	0.385	0.098	0.284	0.245	0.657	0.112	122.168	10.022	1606.126

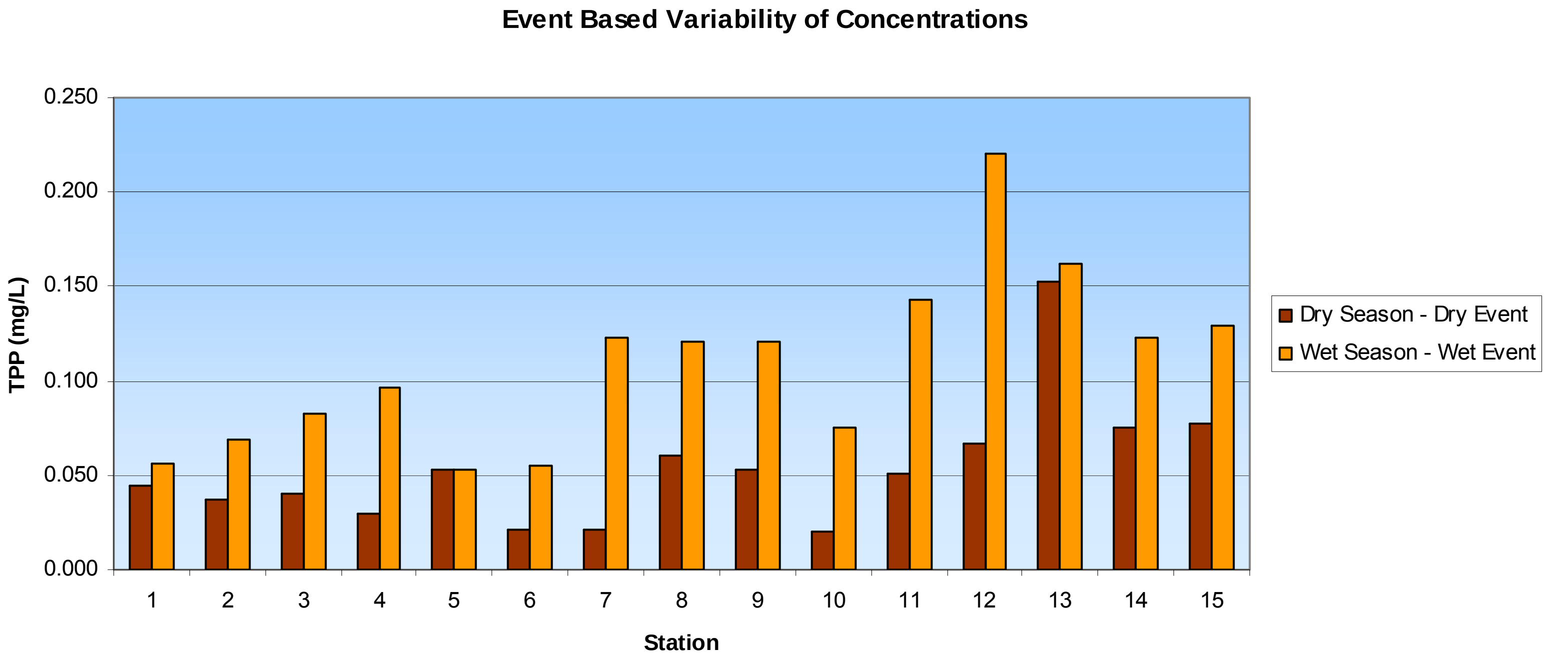

Figure 17 Event Based Variability of Total Particulate Phosphorous for All Stations

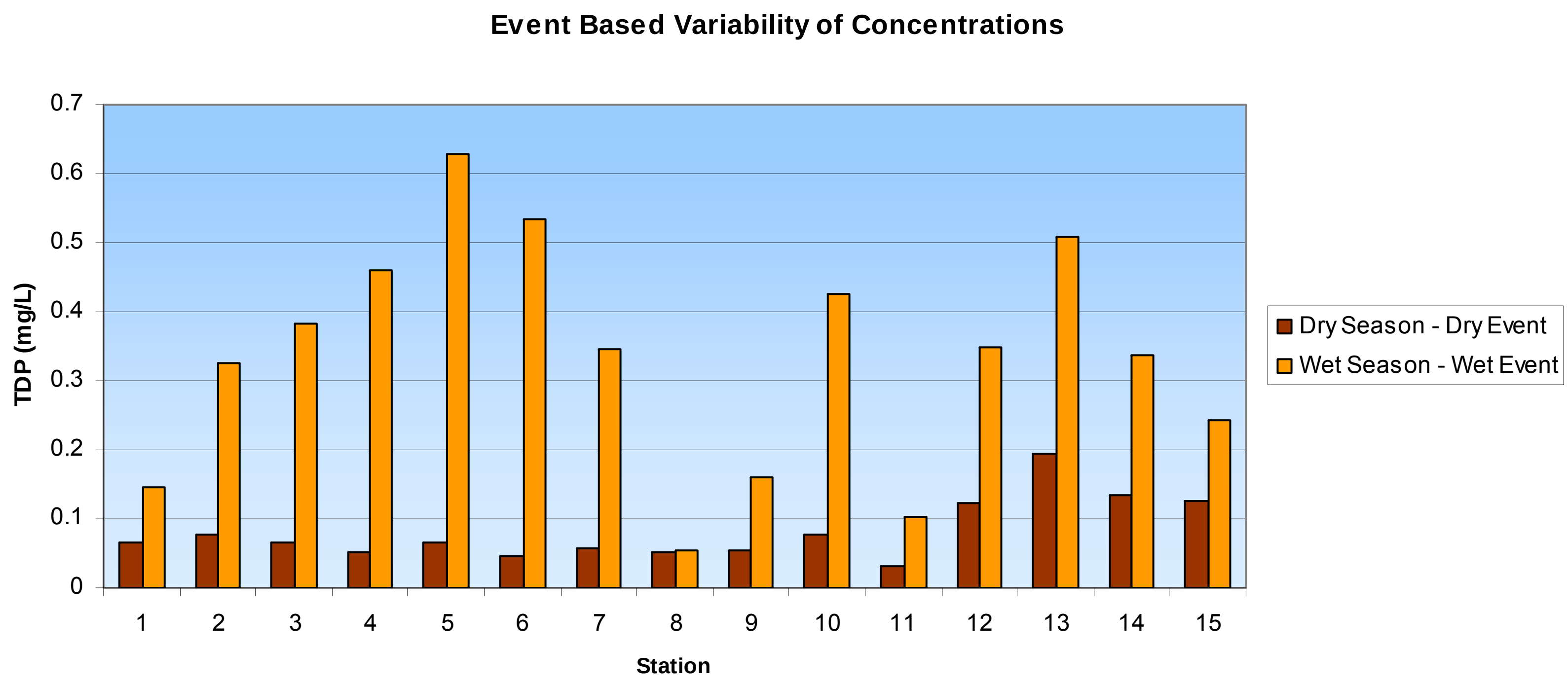

Figure 18 Event Based Variability for Total Dissolved Phosphorous for All Stations

Very high phosphorus and ammonia levels coincident with rainfall and flow in the southern region of EBWCD indicate of surface water runoff contribution. Phosphorus levels were lower in the dry than wet period adjacent to urban and WWTP; indicating point source is likely not a significant contributor to TP load.

FORMS OF PHOSPHORUS

Identification of the sources of phosphorus with a high level of certainty in canals is difficult based on the limited amount of sampling conducted for this study. One method of determining useful source tracking information is comparing dissolved vs. particulate phosphorus content (Daroub, et al. 2002). In the current study the dissolved phosphorus exceeded the particulate phosphorus at almost all stations excepting at stations EBWCD 8, 9 and 11. The ratios of total dissolved phosphorus (TDP) and total phosphorus (TP) and total particulate phosphorus (TPP) and total phosphorus (TP) are provided in Table 10.

Table 10 Mean and Standard Deviation values of dissolved, particulate and total phosphorus ratios

	TDP/TP		TPP/TP	
Station ID	Mean	Standard Deviation	Mean	Standard Deviation
EBWCD1	0.631	0.105	0.369	0.105
EBWCD2	0.660	0.157	0.340	0.157
EBWCD3	0.663	0.138	0.337	0.138
EBWCD4	0.718	0.147	0.282	0.147
EBWCD5	0.687	0.185	0.313	0.185
EBWCD6	0.734	0.202	0.266	0.202
EBWCD7	0.647	0.159	0.353	0.159
EBWCD8	0.376	0.148	0.624	0.148
EBWCD9	0.421	0.225	0.579	0.238
EBWCD10	0.733	0.164	0.267	0.164
EBWCD11	0.405	0.175	0.595	0.175
EBWCD12	0.590	0.218	0.410	0.218
EBWCD13	0.573	0.298	0.427	0.278
EBWCD14	0.612	0.198	0.388	0.198
EBWCD15	0.531	0.243	0.469	0.230

The mean and standard deviations for the ratio of total dissolved phosphorus (TDP) and total particulate phosphorus (TPP) is provided in Table 11.

Table 11 Mean and Standard Deviation of Dissolved Phosphorus and Particulate Ratios

	TDP/TPP	
Station ID	**MEAN**	**STANDARD DEVIATION**
EBWCD1	1.951	0.930
EBWCD2	3.019	2.921
EBWCD3	2.982	3.548
EBWCD4	4.503	6.528
EBWCD5	5.826	10.019
EBWCD6	5.670	8.012
EBWCD7	2.533	1.859
EBWCD8	0.709	0.497
EBWCD9	1.064	0.871
EBWCD10	5.479	7.081
EBWCD11	0.930	0.853
EBWCD12	2.218	1.720
EBWCD13	3.307	3.088
EBWCD14	2.368	1.898
EBWCD15	1.938	1.653

The ratio of TDP/TPP values at almost all of the stations is higher than 1.0 suggesting that the dissolved phosphorus is elevated compared to the particulate phosphorus. The average TDP/TPP ratios for each station are shown in Figure 18. Ratios provided in Tables 10 and 11 suggest that dissolved phosphorus is the dominant form of phosphorus enrichment at most (13 out 15) of the sampling stations. Daroub et al. (2002) indicate that the primary sources for dissolved phosphorus are soil mineralization and fertilizer application in the EAA. They also suggest that mineralization of the organic soils of the EAA is accelerated by excessive draining, which exposes the subsoil to aerobic conditions, causing oxidation and solubilization of organically bound phosphorus. Several management practices have been implemented by the agricultural growers in the EAA to control water tables and reduce the opportunity for fertilizer-sourced phosphorus to reach the waterways

(Bottcher et al. 1995). However, dissolved phosphorus still appears to be a major concern in the study region based on results from the sampling effort.

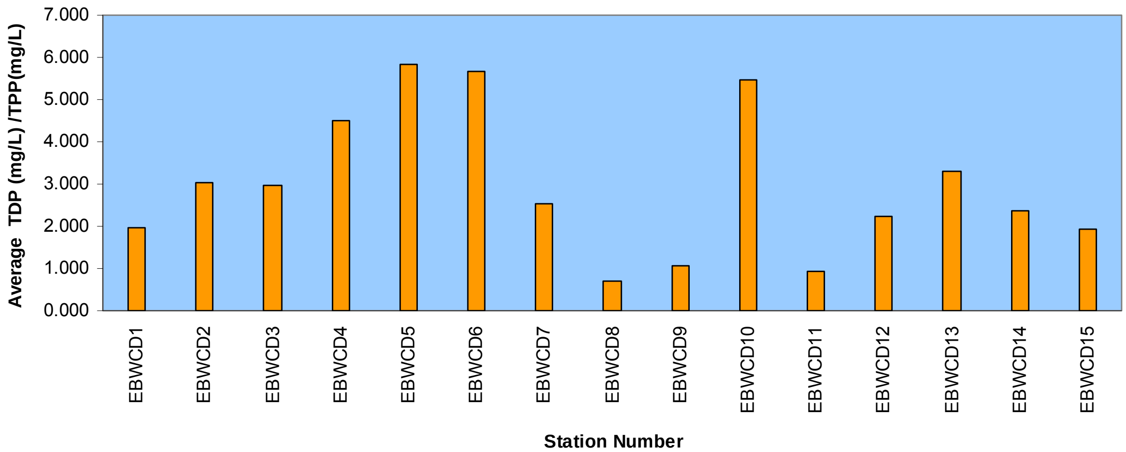

Figure 19 Average Values of TDP/TPP Ratios

LIMITATIONS OF DATA ANALYSIS AND ASSESSMENT FRAMEWORK

The spatial and temporal data collection effort was based on objectives set forth by SFWMD to identify potential sources of phosphorus in EBWCD. Approximately 18-20 grab samples were collected from each of the monitoring sites. While the length and frequency of data collection effort were adequate for preliminary assessment of spatial and temporal variation of phosphorus and its forms in the basin, follow-up effort specifically targeted to source assessment needs to be established. The limited amount of data also puts a constraint on analysis of the data to develop inferences about the sample values. Statistical analysis requires more numbers of samples (at least 30) to make these inferences using parametric tests and also characterizing the distributions.

Some limitations of the data collected are associated with the lack of sampling considering already identified potential sources, flow monitoring, detailed source assessment; land-use based monitoring effort, specific tests that can attempt to link phosphorus to point and non-point sources in the basin. All of these limitations are noted and considered while interpreting the available data and for planning of future action. One significant limitation is that the period of data collection (i.e. January – September) may not be typical in rainfall and runoff patterns due to drought conditions. To address the limitations identified with the completed monitoring efforts, a set of recommendations concerning source inventory, monitoring, and modeling efforts are provided in this report.

CONCLUSIONS

This study reports the results of an analysis conducted based on the water quality data collected from the East Beach Water Control District's 15 sampling sites from January 2007 to September 2007. The analysis revealed spatial and temporal trends in water quality constituents and parameters measured. All of the monitoring sites showed very high concentrations of TP, TPP, TDP, and NH_4^+. Few sites, particularly EBWCD13, EBWCD14 and EBWCD15, showed extremely high concentrations for TDP and TPP. The spikes in concentrations of several specific constituents at sites EBWCD4, EBWCD5, and EBWCD6 during wet periods indicate that surface water runoff is likely a primary source. High ratios of dissolved to particulate phosphorus and high concentrations of SRP combined with the knowledge that agriculture is the predominant land use in this area indicate that fertilizer application is a likely source.

Temporal variations of concentrations at all of the sites indicate a general increasing trend for most water quality parameters as the sampling activities moved from the dry season to the wet season. Event-based analysis indicated that the dry season-wet event and wet season-wet event mean concentrations of phosphorus tended to be higher than the respective dry season-dry event and wet season-dry event mean concentrations for almost all of the constituents. The dry season and dry event concentrations observed suggested no indication of sewer and septic system leaks.

Similar conclusions can be made for urban areas in the western region of the EBWCD that includes the treatment plants, although however, phosphorus from sewage disposal is rapidly removed by chemisorption in the subsurface (Corbett et al. 1999), and thus phosphorus tracers are difficult to interpret for sewer leaks and OSTDS. Few monitoring sites that registered high phosphorus concentrations were located in close proximity to the NDPES facilities in the study area. The ratio of TDP/TPP (total dissolved phosphorus/total particulate phosphorus) was consistently above 1.0 for almost all of the sampling stations, which is suggestive of an important contribution from fertilizer application and/or soil erosion processes.

Another important observation is the elevated specific conductance at stations EBWCD9 and 11-15 throughout the dry and wet periods. High specific conductance is an indicator of high total dissolved solids. As stated earlier, dissolved minerals are more likely finding their way into the canal network via industrial operations such as the rock pit mining activities and landfills. Both of these land uses would tend to generate extremely elevated levels of dissolved constituents that can migrate into the nearby canals through a subsurface ground water flow connection.

ADDITIONAL MONITORING RECOMMENDATIONS

Based on the synoptic data collected at the 15 monitoring sites in the East Beach Water Control District, assessment of the sources causing nutrient impairment is complicated. The following general recommendations are made based on the data analysis that was conducted:

1. Increase monitoring stations to cover locations that have shown consistently high nutrient concentrations through more focused efforts.
2. Increase sampling frequency to capture variability in pollutant loads associated with all wet and dry events.

3. Identify indicators for accurate assessment of sources that are causing high nutrient concentrations in the EBWCD
4. Develop an organized monitoring plan for specific project sites that received state and federal funds to assess improvements achieved through Best Management Practices (BMPs).
5. Measure or estimate discharge at all the sampling locations.

SPECIFIC RECOMMENDATIONS

Over the course of the investigation, a great deal of information has been collected and analyzed. The findings indicate that to resolve the potential different sources of pollution, the following additional work is recommended:

SOURCE IDENTIFICATION

Establish a comprehensive list of known or potential sources in the area.

To accomplish this, a series of site visits must be conducted to inspect current land use activities in the affected areas. Interviews with regulatory officials (Department of Environmental Protection, County Environmental Resource Management, South Florida Water Management District, East Beach Water Control District, Town of Pahokee, etc.) and landowners with knowledge and experience in the affected region should be conducted to better understand potential contributions and local issues. To assist with this information gathering step, EBWCD BMP permits, MS4 permits, NPDES permits, verification visit reports, and permitee-provided data should be collected. Existing historic data related to monitoring wells for landfills and Bryant Mill sites also needs to be collected and evaluated.

Sewer leaks in the newly installed areas must be cataloged to remove this possibility as a confounding factor.

Investigation into the land application of sludge, timing, frequency and location if applicable in the case study needs to be carried out in addition to evaluation of sewer and septic system leaks.

Potential contribution associated with the landfill sites.

Class III landfills contain construction and demolition (C&D) waste. In the past, one of the large portions of the C&D waste stream involved CCA-treated wood. These waste materials were treated with copper, chromium, and arsenic to counteract the natural rotting process. Older landfills that accepted waste prior to 1984 may not have a liner. Therefore, the leachate generated in the landfill will mobilize these metals, particularly the arsenic, and allow them to enter into the surrounding ground water in the form of the oxyanions, arsenate and arsenite. Thus, monitoring for copper, chromium, and arsenic will potentially indicate if those landfills are contributing to the nutrient pollution observed. Another item routinely found in C&D landfills is gypsum board (dry wall). This material contains high amounts of sulfates, which could also be used as a conservative tracer, but it is not unique to landfills.

Contribution from historical rock pit mining activities or other industrial activities.

Rock pit ponds are loaded with enormous quantities of total phosphorus (1700 – 12,000 mg/L as P), sulfate (4000 – 10,000 mg/L), fluoride (200 – 15,000 mg/L), and ammonia (40-1500 mg/L as N). Any of these tracers could be used for source tracking. In conjunction with microbial indicators and molecular techniques, differences between industrial contributions and residential wastewater can be expected. The sugar mill's contribution would be much different than the mining operation's contribution, and this should be investigated further, particularly in regards to seasonal impacts due to the timing of harvesting/replanting activities vs. the growing season.

Agricultural activities.

Agricultural sources can be distinguished using: 1) nitrogen isotopic ratios to signal fertilizer usage, 2) specific broad spectrum persistent pesticides, such as arsenic and halogenated organo-pesticides, 3) elevated levels of nitrates vs. ammonia, and 4) particulate phosphorus vs. dissolved phosphorus content.

MONITORING

Monitor upstream-downstream impacts with strategically placed sampling locations.

Many of the trends established in the previous round of sampling were used to pinpoint potential sources of contamination in the study area. Now that these areas have been more or less identified through the first round of sampling, background stations and upstream-downstream sampling sites must be selected to establish source linkages. To better accomplish this, it is recommended to add more representative background sites, with considerations given to prior land use and location relative to potential sources. Also more station density may be required in these areas to help resolve upstream-downstream influences. More station density would allow the investigators to potentially triangulate the possible location of the source.

Conduct monitoring activities that coincide with the seasonal high water table (SHWT) elevation event and the seasonal low water table (SLWT) elevation event.

In previous work conducted by FAU Lab.EES in Dania Beach, Boynton Beach, and Taylor County, FL this technique has been used to differentiate between sewered areas and those serviced by on-site treatment and disposal systems (OSTDS). If certain portions of the study area are serviced by OSTDS, this would be highly recommended. The first step is to establish the timing of the historical SHWT and SLWT events. It has been suggested that OSTDS failure is more likely when the water table elevation is near the ground surface (<0.6 m), since insufficient distance between the drainfield and the ground water level leads to inadequate treatment (Meeroff and Morin 2005). In many areas in Florida, the water table is constantly high, reaching ground surface level elevations during periods of high rainfall. Thus, the drainfield piping network may become submerged. Because of this fact, it is necessary to determine when the seasonal high water table (SHWT) and the seasonal low water table (SLWT) events occur in the study area. To that end, several approaches must be utilized. These include an analysis of ground water monitoring well measurements, precipitation records, canal water level stage heights, lake water elevations, historical water quality monitoring data, potable water usage statistics from utility billing records, soil surveys, and tidal considerations, where applicable.

It is recommended that nitrogen isotopic ratios be monitored to separate fertilizer inputs from wastewater-related inputs.

Nitrogen isotopic ratios of water samples with high levels of nitrate or ammonia can be analyzed to determine if the signatures are consistent with runoff or fertilizer inputs. The resolution can be improved by providing duplicate samples: one filtered with pre-combusted GFF filter disks and acidified with HCl prior to freezing and the other syringe-filtered and frozen. This will allow the assay to determine if preservation methods are causing changes in the results.

Microbiological parameters must be monitored.

One potential source of nutrient pollution is wastewater from OSTDS or sewer leaks or other wastewater-related discharges. It is recommended to add *E. coli* (or fecal coliforms) and *Enterococcus* to the list of parameters in the monitoring program. These two indicators have different die-off rates in the environment, depending upon salinity, solar radiation, and other parameters, and also both are found in natural sources as well as human sources but in different relative concentrations. That is why both are necessary. In addition, both are sometimes capable of regrowth in shallow sediments as a potential legacy reservoir of microbial pathogens. Thus, studies of shallow sediments are recommended to determine if regrowth patterns of microbial indicators is a confounding issue.

Molecular techniques are extremely informative and highly recommended for pollution source tracking.

These techniques have been employed with promising results by FAU Lab.EES in work conducted in Dania Beach, Boynton Beach, and Taylor County, FL. Analyses have been developed that can distinguish between microbial indicators associated with humans, dogs, cows, and even swimmers (aquatic recreational activities). The assay requires much larger sample sizes (>1.0 L) than first anticipated. It is recommended to attempt additional tests with greater sensitivity to help resolve the human vs. animal input issue. One way to potentially improve sensitivity would be to move the assays from a PCR/electrophoresis detection system (which is the traditional method of amplification) to a fluorescent real-time qPCR detection system. The drawback is that reagents for qPCR are more expensive than for regular PCR and gel electrophoresis. Independent qPCR assays based on commercially-available proprietary primers for human enterococci markers, a dog enterococci marker, a human *Bacteroides* marker, a cow *Bacteroides* marker, and a dog *Bacteroides* marker would be recommended. Also, direct DNA filters used in molecular techniques allow for the testing of a wide range of targets from the same filters, but it also limits detection sensitivity, especially if targets are in low abundance in relation to a large background microbial assemblage. Sensitivity can potentially be increased with culture pre-enrichment before extraction (this is basically the approach with the MFC and mEI media filters).

Basically, in addition to direct DNA filters, MFC filters and mEI filters, two more filters could be collected. One from an azide dextrose broth culture incubated overnight to enrich for enterococci (while limiting enzyme inhibition due to media dyes as can happen with mEI), and the other from a filter that is incubated under anaerobic conditions on BBE plates to enrich for *Bacteroides*. Another recommendation to improve the sensitivity of molecular techniques would be to consider using media enrichment filters in addition to direct DNA extraction filters. For instance, a *Bacteroides* specific media filter could be added, although this would require anaerobic incubation. This can be accomplished inexpensively in the field using small disposable GasPak EZ pouches.

Expanding the microbial screening tests to include other known human pathogens such as *Giardia*, *Cryptosporidium*, and viruses could potentially be added to the investigation.

These tests are progressively more expensive and labor intensive. *Giardia* and *Cryptosporidium* testing requires filtering on site with a pump filter rig for water volumes ranging from 60 to 100 liters, then the filters are analyzed for IMS/IMF capture and enumeration. Tissue culture *Cryptospordium* viability/infectivity analysis is required after enumeration to determine how many of the oocysts are actually alive. Screening for viruses also involves filtering a large volume of water sample; however, qPCR enumeration of viruses does not take into account infectivity. Enumeration for noroviruses, enteroviruses, human adenovirus, and Hepatitis A can be done simultaneously. However, the expense and labor for these tests is partly why protozoans and viruses are not routinely measured in environmental water quality monitoring programs.

Other optional parameters to monitor for wastewater-related inputs include: caffeine and optical brighteners.

Both parameters are associated with human wastewater discharged to the environment. The resolution must be improved to successfully employ these methods in the field. To increase the resolution of caffeine testing, it is recommended to collect much larger sample sizes (2-4 L) and perform sample extraction/concentration in the field. The optical brighteners test looks for compounds used in laundry applications. This method is also currently under development and requires higher resolution for useful results. To improve the optical brighteners technique, it is proposed to investigate specific wavelength matrices that can act as spectrophotometric fingerprints of optical brighteners using a flow-through fluorometer system with multiple wavelength scanning capabilities. This work is ongoing in studies supported by the FDOH.

MODELING

Subdivide the analysis areas into sub-watersheds to better understand the storm water contribution to each of the monitoring sites.

First, a map including major culvert connections and general flow directions must be created. Then sub-watershed delineation can be accomplished by constructing a watershed model with estimated runoff coefficients, or by tracking the contributions of conservative tracers such as specific conductance and back-calculating the appropriate flows and directions. This runoff contribution must be analyzed in the context of wet event – dry event data.

Development of conceptually simple pollutant loading models at a watershed scale to model point and non-point sources

Pollutant loading models at a watershed scale such as WAM (USPEA) and PLOAD (BASINS, USPEA) can be used to obtain site specific nutrient loadings based on land use and water quality data available from different sources. Few limitations associated with this modeling effort can be recognized as they relate to the study area. The topography and canal structure are not conducive to accurate delineation of watersheds. However, the suggested models can be used for assessment of phosphorus loadings. The WAM model is highly appropriate for ranking the phosphorus loading by source and watershed.

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GLOSSARY

DBHYDRO	SFWMD's Water Quality and Hydrology Database
DGPS	Differential Global Positioning System
District	South Florida Water Management District
EAA	Everglades Agricultural Area
EBPS3	EBWCD Pump Station #3, a.k.a. WP16.8TS
EBWCD	East Beach Water Control District
EFA	Everglades Forever Act
ERP	Environmental Resource Permit
FAC	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
FSQM	Field Sampling Quality Manual
GPS	Global Positioning System
HARN	High Accuracy Reference Network
LABEES	Laboratory for Engineered Environmental Solutions
LIMS	Laboratory Information Management System
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NPDES	National Pollutant Discharge Elimination System
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/ Quality Control
SFWMD	South Florida Water Management District
TP	Total Phosphorus, a.k.a. TPO4
WQMD	Water Quality Monitoring Division
WWTP	Waste Water Treatment Plant

APPENDIX A

Discharge Summary for EBWCD

Excerpts from Section 9.1 of Goforth, 2007, document:

Stepping Up the Pace ACCELER8 evergladesnow.org

the journey to restore America's Everglades

Updated Flow and Phosphorus Data Sets for the ECP Basins

Covering the Period May 1, 1994 – April 30, 2007

Work Order No. CN040902-WO03R2

Prepared for

US Army Corps of Engineers

South Florida Water Management District

Prepared by

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10924 SW Hawkview Circle
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Stuart, FL 34994
(772) 781-3400

FINAL REPORT - REVISED

October 2007

APPENDIX B

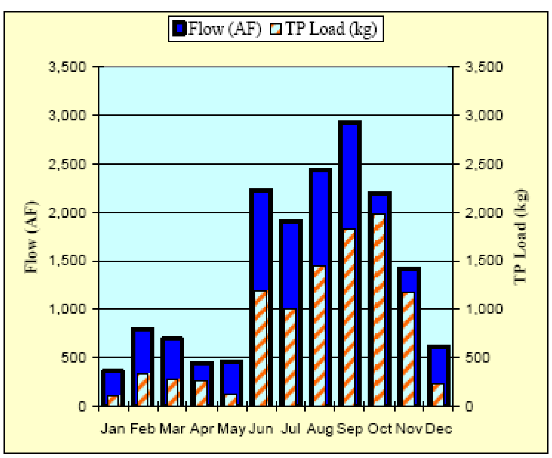
Discharge Summary for EBWCD

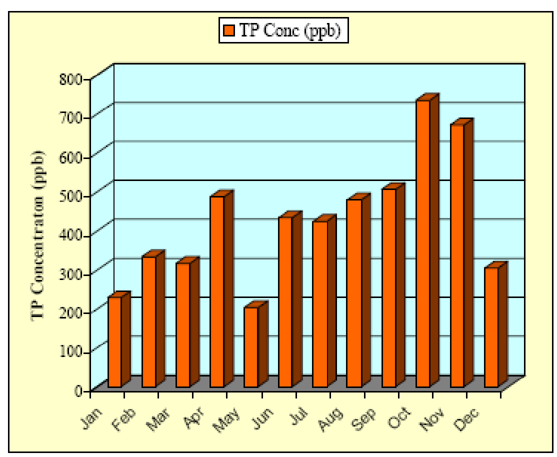
Water Year	Annual Data[1] Volume		TP Load	TP Conc
	ac-ft	hm^3	kg	ppb
1995	12,857	15.858	8,917	562
1996	11,269	13.900	10,869	782
1997	3,551	4.380	677	155
1998	10,040	12.385	6,707	542
1999	18,596	22.938	16,643	726
2000	29,283	36.120	21,058	583
2001	5,227	6.447	6,546	1015
2002<	20,328	25.074	9,431	376
2003	20,419	25.186	8,024	319
2004	23,744	29.288	8,710	297
2005	28,215	34.803	15,282	439
2006	18,162	22.402	10,770	481
2007	12,438	15.342	5,557	362
Min.	3,551	4.380	677	-
Max.	29,283	36.120	21,058	-
Ave.	16,150	19.921	9,980	501

Month	Monthly Data[2] Volume		TP Load	TP Conc
	ac-ft	hm^3	kg	ppb
Jan	359	0.443	101	229
Feb	799	0.985	328	333
Mar	695	0.857	272	317
Apr	438	0.541	264	488
May	456	0.563	115	204
Jun	2,224	2.743	1,190	434
Jul	1,908	2.353	999	424
Aug	2,434	3.003	1,442	480
Sep	2,933	3.617	1,831	506
Oct	2,191	2.703	1,988	736
Nov	1,422	1.754	1,178	672
Dec	613	0.756	230	305
Annual	16,471	20.317	9,938	489

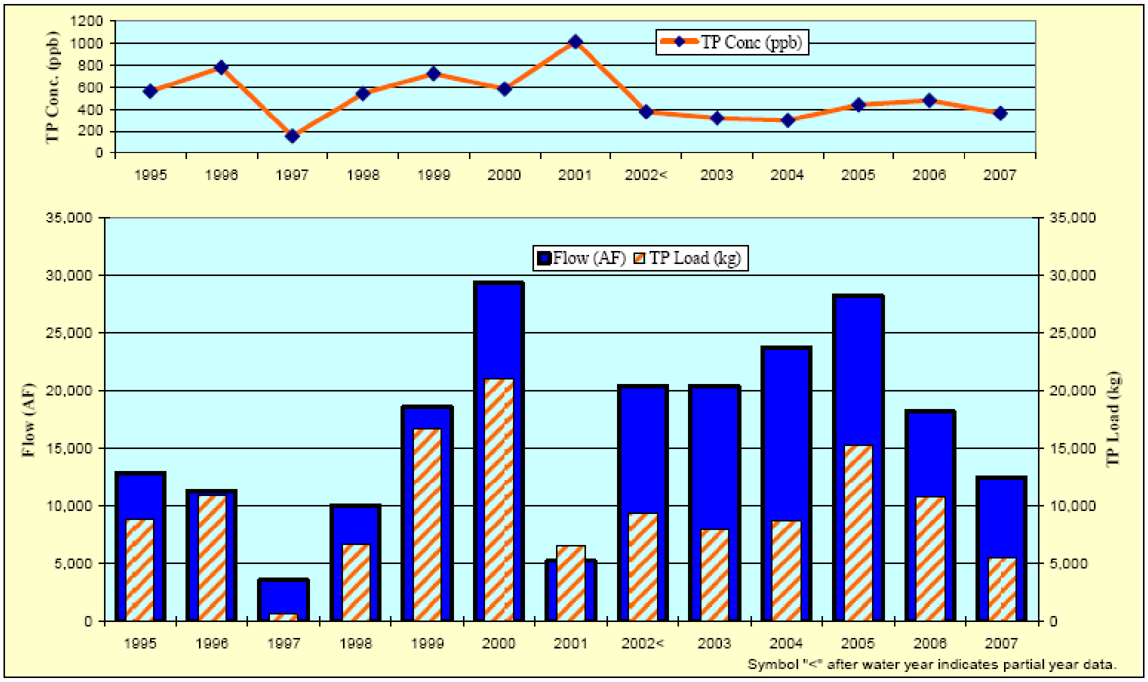
*Runoff for this basin is underreported prior to July 2001.

1. Symbol "<" after water year indicates partial year data. Missing and partial year data are excluded from annual statistic calculations.
2. Average monthly statistics are calculated using all available data, including those for partial water years; therefore, annual total of monthly averages may not match average of annual totals.





Average Monthly Flows and Phosphorus Levels in EBWCD Runoff



WY1995-2007 Flows and Phosphorus Levels for EBWCD Runoff.

APPENDIX C

Table 12 Solid Waste Facilities in the EBWCD study area

Site	Status	Site Location	Class Description	Class - General
Palm beach county Land Fill #4 (Pahokee)	Closed No monitoring	Rock Pit Road & Bay Bottom Road	Class 1 landfill	General disposal
City of Pahokee incinerator/class 3	Inactive	1001 Rim Canal Road	Other disposal facility	General disposal
City of Pahokee incinerator/class 3	Inactive	1001 Rim Canal Road	Incineration	Processing facility
Shredtex, inc	Inactive	700 St Rd 15-a	Auto/white Goods shredder	Processing facility

APPENDIX D

Bay Bottom Road filling violation documentation provided by FDEP staff

Excerpts from the document:

12/04/02 14:40 FAX

Page 1 of 3

DEC - 2 2002

United States District Court

Southern District of Florida

WEST PALM BEACH DIVISION

UNITED STATES OF AMERICA

v.

EMI-SAR TRUCKING & EQUIPMENT, INC.

JUDGMENT IN A CRIMINAL CASE
(For Offenses Committed On or After November 1, 1987)

Case Number: 01-8100-CR-RYSKAMP

Counsel For Defendant: Anthony Natale
Counsel For The United States: Kenneth Noto
Court Reporter: Stephen Franklin

The defendant was found guilty on Counts 1, 2 and 3 of the Indictment on January 14, 2002. Accordingly, the court has adjudicated that the defendant is guilty of the following offenses:

TITLE/SECTION NUMBER	NATURE OF OFFENSE	DATE OFFENSE CONCLUDED	COUNT
33 U.S.C. §§ 1311(a), 1319(c)(2)(A), 1344 and 18 U.S.C. § 2	Discharging pollutants in the wetlands	May 2001	1 and 2
18 U.S.C. §§ 1361 and 2	Damage to government property	October 1999	3

The defendant is sentenced as provided in the following pages of this judgment. The sentence is imposed pursuant to the Sentencing Reform Act of 1984.

IT IS FURTHER ORDERED that the defendant shall notify the United States attorney for this district within 30 days of any change of name, residence, or mailing address until all fines, restitution, costs and special assessments imposed by this judgment are fully paid. If ordered to pay restitution, the defendant shall notify the court and United States attorney of any material change in the defendant's economic circumstances.

Defendant's FEI#:65-0369153

Defendant's Address:
2814 E. Main Street
Pahokee, FL 33476

Defendant's Mailing Address:
P. O. Box 202
Pahokee, FL 33476

Date of Imposition of Sentence:
November 22, 2002

KENNETH L. RYSKAMP
United States District Judge

December 2, 2002

DEFENDANT: EMI-SAR TRUCKING & EQUIPMENT, INC.
CASE NUMBER: 01-8100-CR-RYSKAMP

PROBATION

The defendant is hereby sentenced to probation for a term of **Five (5) years**, as to Counts One, Two and Three, to run concurrently with each other.

While on probation, the defendant shall not commit another federal, state, or local crime.
The defendant shall not illegally possess a controlled substance.

For offenses committed on or after September 13, 1994:

The defendant shall refrain from any unlawful use of a controlled substance. The defendant shall submit to one drug test within 15 days of placement on probation and at least two periodic drug tests thereafter.

The defendant shall not possess a firearm, destructive device, or any other dangerous weapon.

If this judgment imposes a fine or a restitution obligation, it shall be a condition of supervised release that the defendant pay any such fine or restitution in accordance with the Schedule of Payments set forth in the Criminal Monetary Penalties sheet of this judgment.

The defendant shall comply with the standard conditions that have been adopted by this court (set forth below).

The defendant shall also comply with the additional conditions on the attached page.

STANDARD CONDITIONS OF SUPERVISION

1. The defendant shall not leave the judicial district without the permission of the court or probation officer;
2. The defendant shall report to the probation officer as directed by the court or probation officer and shall submit a truthful and complete written report within the first five days of each month;
3. The defendant shall answer truthfully all inquiries by the probation officer and follow the instructions of the probation officer;
4. The defendant shall support his or her dependents and meet other family responsibilities;
5. The defendant shall work regularly at a lawful occupation unless excused by the probation officer for schooling, training, or other acceptable reasons;
6. The defendant shall notify the probation officer at least ten (10) days prior to any change in residence or employment;
7. The defendant shall refrain from the excessive use of alcohol and shall not purchase, possess, use, distribute, or administer any controlled substance or any paraphernalia related to any controlled substances, except as prescribed by a physician;
8. The defendant shall not frequent places where controlled substances are illegally sold, used, distributed, or administered;
9. The defendant shall not associate with any persons engaged in criminal activity, and shall not associate with any person convicted of a felony unless granted permission to do so by the probation officer;
10. The defendant shall permit a probation officer to visit him or her at any time at home or elsewhere and shall permit confiscation of any contraband observed in plain view by the probation officer;
11. The defendant shall notify the probation officer within seventy-two (72) hours of being arrested or questioned by a law enforcement officer;
12. The defendant shall not enter into any agreement to act as an informer or a special agent of a law enforcement agency without the permission of the court;
13. As directed by the probation officer, the defendant shall notify third parties of risks that may be occasioned by the defendant's criminal record or personal history or characteristics, and shall permit the probation officer to make such notifications and to confirm the defendant's compliance with such notification requirement.

DEFENDANT: EMI-SAR TRUCKING & EQUIPMENT, INC.
CASE NUMBER: 01-8100-CR-RYSKAMP

SPECIAL CONDITIONS OF SUPERVISION

The defendant shall also comply with the following additional condition(s) of probation:

The defendant shall provide complete access to financial information to the U.S. Probation Officer upon request.

The defendant shall immediately submit a restoration plan to be reviewed and approved by the U.S. Army Corps of Engineers and the Environmental Protection Agency. The restoration plan shall include removal of all unauthorized fill and restoring both the Bay Bottom and Sand Cut sites to pre-existing grades. If natural vegetation does not occur within one year of the date of fill removal, native wetlands plant species should be planted.

The defendant shall work, cooperate, and provide annual education to all employees and subcontractors concerning basic wetlands identification and dumping requirements.

DEFENDANT: EMI-SAR TRUCKING & EQUIPMENT, INC.
CASE NUMBER: 01-8100-CR-RYSKAMP

CRIMINAL MONETARY PENALTIES

The defendant shall pay the following total criminal monetary penalties in accordance with the schedule of payments set forth in the Schedule of Payments.

Total Assessment	Total Fine	Total Restitution
$1,200.00	$25,000.00	$9,100.00

The defendant shall make restitution (including community restitution) to the following payees in the amount listed below. Restitution is ordered joint and several in the amount of $9,100.00

If the defendant makes a partial payment, each payee shall receive an approximately proportioned payment, unless specified otherwise in the priority order or percentage payment column below. However, pursuant to 18 U.S.C. § 3664(i), all nonfederal victims must be paid in full prior to the United States receiving payment.

Name of Payee	Total Amount of Loss	Amount of Restitution Ordered	Priority Order or Percentage of Payment
To victims as listed in presentence report	$9,100.00	$9,100.00	

*Findings for the total amount of losses are required under Chapters 109A, 110, 110A, and 113A of Title 18, United States Code, for offenses committed on or after September 13, 1994 but before April 23, 1996.

DEFENDANT: EMI-SAR TRUCKING & EQUIPMENT, INC.
CASE NUMBER: 01-8100-CR-RYSKAMP

SCHEDULE OF PAYMENTS

Having assessed the defendant's ability to pay, payment of the total criminal monetary penalties shall be due as follows:

Payment to begin immediately.

Unless the court has expressly ordered otherwise in the special instructions above, if this judgment imposes a period of imprisonment, payment of criminal monetary penalties shall be due during the period of imprisonment. All criminal monetary penalties, except those payments made through the Federal Bureau of Prisons' Inmate Financial Responsibility Program, are made to the clerk of the court, unless otherwise directed by the court, the probation officer, or the United States attorney.

The defendant shall receive credit for all payments previously made toward any criminal monetary penalties imposed.

The assessment/fine/restitution is payable to the U.S. COURTS and is to be addressed to:

U.S. CLERK'S OFFICE
ATTN: FINANCIAL SECTION
301 N. MIAMI AVENUE, ROOM 150
MIAMI, FLORIDA 33128

The assessment/fine/restitution is payable immediately. The U.S. Bureau of Prisons, U.S. Probation Office and the U.S. Attorney's Office are responsible for the enforcement of this order.

Payments shall be applied in the following order: (1) assessment, (2) restitution principal, (3) restitution interest, (4) fine principal, (5) community restitution, (6) fine interest (7) penalties, and (8) costs, including cost of prosecution and court costs.

APPENDIX E

Table 13 Typical composition of leachate in Florida landfills

Parameters	Concentrations Range	Average
COD in mg/L as O_2	55 - 14,000	3,000
Conductivity in µS/cm	1,000 - 95,000	11,600
TDS in mg/L	900 - 88,000	9,300
BOD_5 in mg/L	BDL - 445	150
Ammonia in mg/L as NH_3-N	BDL - 1,350	500
Lead in mg/L	BDL - 0.1	0.03
TSS in mg/L	*	*
pH	2.0 - 11.3	7.5

* No data were available.