Technical Support Document on Data Quality of Water Quality Data Collected During the May and June 2005 Monitoring Events for the SFWMD EVPA (LOX) and Refuge LOXA Projects

BACKGROUND

Figure 1 shows the total phosphorus (TP) data for the last 12 months at the 14 LOX marsh sites located in the Arthur R. Marshall Loxahatchee Wildlife Refuge (Refuge) as part of the EVPA (LOX) Project. These data indicate that the May and June 2005 data are significantly higher than the preceding month. The elevated values prompted the South Florida Water Management District (SFWMD) to perform an assessment of the data and monitoring processes for the EVPA (LOX) Project (Ivanoff, 2005a, b). The Department has reviewed the available information relative to assessing the quality and validity of the data collected during the May and June 2005 sampling events. The information evaluated during this review included the 1) data (lab and field data) collected during the referenced monitoring events as well as preceding and subsequent monitoring events, 2) field notes collected by the samplers, 3) the Marsh Field Sampling Protocol prepared in 1996 by Frank Nearhoof of FDEP, 4) the 8/11/05 and 9/8/05 Assessment documents prepared by D. Ivanoff of the SFWMD, 5) notes from interviews with SFWMD helicopter pilots participating in May and June 2005 sampling events with Refuge staff, 6) FDEP observations of SFWMD staff sampling at three Loxahatchee stations on 9/7/05, and 7) FDEP observations during the marsh sampling training workshop on 9/26/05 with SFWMD, the Loxahatchee Refuge, and Everglades National Park staff.

SFWMD ASSESSMENTS

The SFWMD's 8/11/05 and 9/8/05 assessments were prepared to assess the validity of the data collected during May and June 2005 and to determine if further action is needed to ensure that the data generated for this project are of acceptable and verifiable quality. In this assessment, the SFWMD evaluated the data for the referenced events, and after finding abnormally high TP values, that were unexpected based on conditions that existed during the May – June 2005 time period, proceeded to evaluate possible causes, including possible errors. The SFWMD report provides information regarding the methods utilized for data and sample collection obtained through interviews with the sampling personnel. This information was then used to determine if required sampling standard operating procedures (SOPs) and protocols were followed during the monitoring events in question and to evaluate whether poor sampling technique caused the elevated TP results obtained for these events.

SFWMD staff conducted a thorough evaluation of the May and June 2005 EVPA monitoring events and provided Refuge management and staff with sufficient opportunity to comment and provide feedback. An initial draft of the SFWMD report was made available by District management to Refuge staff on July 21, 2005. D. Ivanoff met with Refuge sampling personnel on August 10, 2005 and received comments regarding the 7/21/05 draft report. The suggested revisions subsequently made to the report were reflected in the 8/11/05 version (Ivanoff, 2005a).

The SFWMD report concluded that the high phosphorus concentrations observed during the May and June 2005 sampling events were the result of high solids content (total suspended solids, or TSS) also reported for the samples. The source of the high levels could not be

determined definitively, but poor sampling technique by inexperienced samplers was identified as the likely cause.

FDEP EVALUATION

The Department has conducted an independent evaluation of the data and other supporting information. The Department also requested an opportunity to interview the Refuge field sampling personnel, but was told by the Refuge that they were unavailable at that time (on 8/27/05). The Department subsequently performed a field review of the sample collection procedures of SFWMD personnel (Bob Stickler) at three Loxahatchee sites (LOX 3, 11, and 16) on 9/7/05, and conducted training on marsh sampling on 9-26-05 with SFWMD, the Loxahatchee Refuge, and Everglades National Park. The Department also conducted telephone interviews with SFWMD helicopter pilots, Terry Jones and Alex Brostek.

During the 9/7/05 field audit, the Department auditor (Russel Frydenborg) noted that collecting representative water column samples in the Refuge marsh was exceedingly difficult. Any small disturbance (e.g., a shift in weight while standing in the unstable substrate) resulted in plumes of floc dispersing into the water column. At times, the sampler had to resort to crawling on hands and knees to move through the unstable sediment. Vegetation at the sites was dense, and loosely attached periphyton was very prevalent. The sampler had a very narrow window of opportunity to collect a sample that was free of any non-target media, such as resuspended floc and periphyton.

These observations reinforce the importance that the sampling team have an understanding of the types of conditions and/or activities that impede efforts to collect representative samples, firm knowledge of site conditions, and demonstrated experience collecting water column samples under these very demanding conditions, as was emphasized in the Department's marsh field sampling protocol (Nearhoof, 1996).

Based on the Department's review of the data, other supporting information, and on-site observations, the Department concurs with the conclusions from the SFWMD 8/11/05 and 9/8/05 Assessment Reports (Ivanoff, 2005a,b) regarding the representativeness and utility of the May and June 2005 Refuge EVPA data and the likely cause of the elevated phosphorus concentrations.

Training and Experience of Refuge Sampling Staff

The three Loxahatchee staff involved in the sampling for May and June 2005 were Robert Smith, Serena Rinker, and Donato Suratt. The contract between SFWMD and Loxahatchee for sampling services includes a requirement that SFWMD staff provide field sampling training and sample processing training to Loxahatchee staff. Due to miscommunication, the SFWMD did not provide training to these staff in field sampling, but provided training only in laboratory-based sample processing. According to verbal interviews with Delia Ivanoff (SFWMD QA Officer), a Loxahatchee employee, Bruce Arrington, who was previously trained by SFWMD, conducted limited training (two occasions: 3-15-05 and 3-23-05) for Mr. Smith and Mr. Suratt, but not for Ms. Rinker. Prior to the May and June 2005 sampling events under scrutiny, where they acted as lead samplers, the March 2005 training is the only known field sampling training received by these staff in what can be considered among the most difficult sampling situations encountered by field crews in Florida . In contrast, SFWMD requires up to a year of training and

apprenticeship in marsh sampling, including a demonstration of proficiency, before staff may serve as lead samplers.

Mr. Arrington was no longer employed by the Loxahatchee by the May, 2005 sampling trip. Training records for Mr. Smith and Mr. Suratt are incomplete in many areas and contradictory on one issue. Written documents show that Mr. Arrington verified that only Mr. Smith received training in field sampling on 3-23-05. Mr. Smith did not enter a date for several other areas of his training records, such as having read and understood the EVPA SOP and FDEP EVPA sampling guidance. Although Mr. Suratt entered in his training records that he received training on 3-15-05, this was not verified by the instructor, who was presumably at the time, Mr. Arrington. Although it has been established that SFWMD did not provide sampling training to these staff, Mr. Suratt indicated that on his training checklist that he had "completed training and documentation as specified by SFWMD (attach copy of training documentation)" on 3-15-05. This raises questions regarding the accuracy of other entries in Mr. Suratt's training records. In addition, Mr. Suratt initialed many of Mr. Smith's undated training records without Mr. Smith's initials in that category.

The lack of experience by the sampling staff is also reflected in the field notes collected during the May and June 2005 sampling events that exhibited deficiencies and provided little information about the site conditions. The majority of the entries in the field notes concerned the appearance of the sample during processing at the laboratory. Information about the vegetation appeared to have been pre-written (numerous instances where vegetation information appeared with samples that were either not collected or were different, such as a field equipment blank). No observations were made about site conditions other than "sampled from float". Although the samplers stated that they used smaller bottles for some of the sites, neither the size of the sampling container nor its use were documented in the field notes. Some notes were extremely messy, difficult to read, and had numerous errors that required correction.

Notes taken in August and September 2005, after SFWMD staff had trained Loxahatchee staff, showed many improvements. Staff recorded more detail about site conditions, the fact that an intermediate container was used to collect samples, the approximate size of the open water portion of the marsh from which samples were collected, a description of vegetation that included more than the names of the plants, the site coordinates, and the location of where field measurements were conducted. This suggests staff improvements in record taking associated with training and experience.

In summary, the evidence indicates that the sampling staff involved in the May and June 2005 sampling events received limited instruction (during 2 previous events) for extremely difficult sampling conditions and techniques. In addition, there was no documented demonstration of competency, prior to the May and June events which were their first trips serving as lead samplers.

FDEP Data Analysis

As mentioned previously, May and June 2005 TP values are significantly higher than those for the adjacent April and July 2005 sampling events, for which we have confidence that the proper sampling methodology was followed. The laboratory records indicated that, for the reviewed phosphorus data, all laboratory quality control measures were well within the acceptable limits. This eliminates the analytical procedure as a potential source of the elevated

phosphorus values. In addition, the high TP levels during May and June 2005 appear to be unrelated to marsh inflows. As shown in Figure 2, no extreme inflow events were observed directly preceding either the May or June 2005 EVPA sampling events. Further, even though extreme inflow events associated with the passage of multiple hurricanes occurred during the September and October, 2004 sampling events when experienced samplers performed the sample collections, marsh TP levels were not found to be elevated. Thus, impacts from inflows can be eliminated as an influence on marsh TP levels.

The comments associated with the laboratory records included many observations about the samples or sampling event, such as "sondes partly in floc", "heavy susp. Solids" and "suspended flocc (sic) in water column". The laboratory data, field notes, and SFWMD interviews with the field samplers indicate that the elevated values are due to high particulates in the samples, which FDEP believes were not representative of the actual water column conditions. The elevated particulates are most likely a result of sampling errors by inexperienced samplers participating in their first two sampling events as the primary collectors in challenging sampling conditions.

Total Suspended Solids (TSS) are solids in water that can be trapped by a filter. Due to the affinity of particulate matter for phosphorus, TSS is strongly correlated with phosphorus concentrations at the LOX EVPA sampling sites in the Refuge (Figure 3). Due to the strong influence of TSS on measured phosphorus concentrations, the accepted Everglades marsh sampling protocols (as well as FDEP SOPs) warns that it is essential that every precaution be made to prevent disturbance at a sampling location that would result in the inclusion of excess TSS. This precaution is especially important when water levels are low (as during these events) or when wading to a sampling site or attempting to sample from an air-boat or helicopter. In fact, sampling at or near an airboat or helicopter is not generally recommended due to the high level of disturbance they cause due to prop wash, disturbance to vegetation, disturbance of floc and sediment, and compaction of the sediment. It is also important to note that TSS can be composed of disturbed floc/sediment or epiphytic or floating periphyton disbursed into the water column through excess agitation of the vegetation or the water's surface. Therefore, TSS can serve as a useful cross check to indicate situations where the high TP levels are likely due to particulates in the samples.

Figure 4 shows that TSS levels for the May/June 2005 sample events are significantly elevated compared to the historic (June 1994 – April 2005) data. In fact, the two highest TSS levels recorded for the LOX sites during the 1994-2005 period of record were reported for the May and June 2005 sampling events. In addition, the inclusion of abnormally large amounts of particulate matter in selected samples collected during the May and June 2005 sampling events were also noted by the SFWMD laboratory staff during sample processing. The high TSS levels can not be attributed to extreme climatic conditions (i.e., wind or rain). Figures 5 and 6 show that wind speeds and rainfall during and immediately preceding the May and June 2005 sampling events were in no way extreme and were in fact well within normal ranges. The lack of alternative explanations for the extreme values further supports the conclusion that errors occurred during the sampling. Thus, the TSS data serves to confirm that contamination from non-target media (sediment floc, algae) were the cause of the elevated phosphorus levels in the May/June 2005 sample events. Given the extreme difficulty of collecting water samples in the marsh without inadvertently entraining floc and periphyton into the water sample, inappropriate sampling technique is the most likely cause for the TSS contamination.

Supporting Evidence

Helicopter Pilot Observations

The Department interviewed two of the helicopter pilots who transported the sample collectors for the May and June 2005 sampling events. Both were asked about their experience in flying sampling teams into the Everglades, how they would characterize an experienced sampling team and their impressions about the sampling teams for the May and June sampling events. Both pilots have over 5 years experience, and fly sampling teams into the Everglades at least twice a week. Alex Brostek stated that experienced samplers assessed the depth of water upon landing, and either made the decision not to sample or used smaller bottles. He stated that the sampling teams during the May and June sampling events were "trying hard" to get a sample, when past samplers would not have attempted collection. In one instance, the sampler made a concerted effort to find a pool of water because the surrounding depths were shallow. Terry Jones characterized experienced sampling teams being very particular about performing the activities in the same way each time they collected samples. He described the May and June sampling teams as "struggling to get their procedures in line" and being on a "learning curve."

Department of Interior Analysis

Department of Interior staff (Waldon, 2005) performed an independent examination of the Refuge TP concentrations in May and June 2005. The objective of this examination was to compile information related to answering the question – *"Is there substantial evidence that the May and/or June excursions were due to error or extraordinary natural phenomena?"* The majority of Waldon's findings are consistent with the Department's findings, presented herein. This examination concluded that there is considerable evidence that some values are outliers and represent very unusual or exceptional values. Furthermore, Waldon (2005) found no evidence that loading, unusual meteorological, fire, or canal water intrusion caused the unusual TP levels in May and June 2005. The only point of disagreement among the FDEP, SFWMD, and DOI evaluations is on the issue of sample contamination. Waldon concluded that there was little evidence, beyond speculation, of sample contamination. However, given the weight of evidence that the Department reviewed, including the clear lack of necessary experience and training of the field sampling staff, the evidence of sampling contamination in the phosphorus and TSS data, and the exclusion of all other tangible explanations for the elevated data, sample contamination is the most likely cause for the unusual TP and TSS values in some EVPA samples during May and June 2005.

LOXA Data Review

The LOXA monitoring program is another monitoring program being conducted in the Refuge and involves the collection of water quality samples at numerous sites under the same conditions as experienced during the EPVA (LOX) monitoring project. In addition, the LOXA monitoring employs the same samplers as the EPVA (LOX) project. A field cleaned equipment blank (a QA/QC sample collected to assure sampling equipment is being cleaned properly and that samples are not being contaminated) collected by the same sampling staff as for the May/June EVPA samples during the May 16, 2005 LOXA Program sampling event was determined to be highly contaminated. This is another indication that either improper sampling techniques, confusion in bottle labeling, and/or contaminated equipment or preservatives were associated with the sampling staff during this time period and that the sampling staff lacked sufficient experience to reliably collect appropriate samples from this difficult environment.

Waldon (2005) hypothesized that the failure of the May 16, 2005 equipment blank was due to a mislabeled bottle. The actual cause of the failure, whether it was due to contaminated sampling equipment or poor sample handling, is ultimately irrelevant. The salient point is the fact that control samples, such as equipment blanks, are components of a quality assurance program designed to produce data of known and defensible quality. Failure of these control samples calls into question the accuracy of any associated environmental samples. The May 16, 2005 field cleaned equipment was clearly contaminated through sample container mishandling and/or contaminated sample equipment. It is unknown whether the marsh samples were similarly mishandled or contaminated, thus the data are not of known and defensible quality. Furthermore, the failed blank is an additional indictor of the samplers' inexperience.

Further evaluation of the data from the LOXA monitoring project (collected by the same samplers as the EPVA project) for the May – June 2005 period also indicate there are several instances in which abnormally elevated TP values were associated with very high TSS levels . These results further confirm that the lack of experience by the samplers involved in these projects resulted in errors during sample collection that strongly biased the results of subsequent analyses. The LOXA results also indicate that the apparent sampling problems discussed for the EPVA project are not isolated occurrences and warrant immediate corrective actions as discussed below. Prior to the use of the LOXA data collected during May and June 2005 (and other periods when the sampling was not conducted by experienced staff) in further water quality assessments, a thorough QA/QC evaluation of the data should be performed to determine if the data can be expected to be representative of true ambient marsh conditions or if sampling errors likely introduced unacceptable biases into the data.

FDEP RECOMMENDATIONS

Based on their assessment, the District's report makes recommendations regarding the handling of the data from the May and June 2005 sampling events and corrective actions that need to be taken to prevent a reoccurrence in the future. The District's recommendations are:

1) Flag all data for the May and June 2005 sampling events with a "?" qualifier; add a comment: sampling quality is questionable based on sampling assessment findings.
2) Require improved training and demonstration of capability by sampling personnel prior to being involved in the project.
3) Require routine collection and analysis of TSS samples to be used as a step in the data validation process.
4) Finalize the development of a project specific Monitoring Plan that would identify and communicate the details, goals and objectives, and protocols to project participants.
5) Develop and implement SOPs covering various aspects of the project including sampling methods, data verification and validation, field project management, and data assessment.

Based on the Department's evaluation, we concur with the District's recommendations concerning the needed corrective actions and would urge the District and Refuge staff to implement the corrective actions as soon as possible. However, we do recommend making the modifications/clarifications described below.

The Department concurs that all data for all water quality parameters for the May and June 2005 sampling events should be flagged with a "?" qualifier. Due to the strong probability that the invalid data resulted from improper sampling techniques utilized by inexperienced personnel presumably throughout the entire monitoring events in question, serious questions exist concerning the validity of all the data (including field data) collected in this manner, since parameters other than phosphorus are definitely affected by the inclusion of high levels of TSS in the sample. Furthermore, the Department concurs with the use of the "?", which conveys the magnitude of the error; the fact that a large portion of the data are clearly not representative of ambient marsh conditions; and, indicates that the data should be rejected from use in any further assessments.

One potential long term solution to the problem of obtaining representative water samples involves the construction of small platforms at the sites. These platforms would enable staff to more effectively sample the water column without the unavoidable disturbance to the floc layer caused by wading and/or vehicular disturbances such as prop wash. With a platform, samplers would have a stable area from which they could carefully collect only the water column without entraining the ubiquitous floc and periphyton into the sample bottle. Switching to smaller bottles (100 mL to 250 mL) is another potential solution to the floc contamination problem. During the 9-26-05 marsh sampling training, the FDEP instructor noted that sampling staff had great difficulty in collecting a non-contaminated sample using the 2 L bottles in the relatively shallow (28 cm) water. Several staff from SFWMD and the Refuge attempted multiple grab samples, yet they entrained several (5-10) visible pieces of floc in the 2 L bottles, although it was clear that floc was not present in the water column. However, all staff could collect a water sample uncontaminated with floc, sediment, or algae when they used the 125 mL bottles. Therefore, if large volumes of water are needed for the analyses (currently, 4 L are collected) a method other than a direct grab (such as a variable flow peristaltic pump) should be employed. The Department recommends the use of a variable speed peristaltic pump, which can be adjusted to a low flow rate. Use of this technique would ensure that surrounding algae and floc were not disturbed, and would prevent non-target media (sediment, tissue) from inappropriately entering the water sample bottle..

We believe some discussion is needed about the District's recommendation to require that TSS sampling and analyses be performed on a routine basis to aid in the assessment of data validity. The concept is sound, but there are logistical considerations, which should be discussed during the upcoming marsh sampling training workshop. Additionally, changes in the marsh sampling strategy (pumps deployed from boardwalks) could eliminate the grab sampling method, so the following comments are provided with those considerations in mind:

We agree that ideally, TSS should be collected from the same grab sample as that used for TP; however, there is merit in collecting a discrete TSS sample as an ending sample since high levels of TSS would be an indication that the water column has been disturbed during the collection event.

Collecting two separate bottles in the field (one for nutrients and one for TSS) creates several possible sources of error: (1) a disturbance of the floc during the period between collecting these two bottles could mean that the collected samples are not identical in composition; (2) if the TSS was collected first, and the sediment was disturbed prior to collecting

the TP sample and the TP results were high, one would erroneously conclude that the high TP results were valid.

Collecting a single grab sample may be problematic, since a large bottle may be impractical to use during low water events or when vegetation is dense at a site, because the inflow volume and the size of the sampling container may cause unintended entrainment of particulates. To minimize disturbance to the water column, a small bottle could be used as an intermediate sampling device if the samplers took precautions to avoid disturbing the water column during the repetitive sampling. We believe that use of a peristaltic pump from a platform would clearly be superior.

Whether the sample is collected using a single large bottle or is a composite of multiple volumes from a smaller container, the samples must be divided into different sample containers for the applicable preservation technique (acid preservatives in some, thermal preservation in others). It is critical that the original grab sample be thoroughly mixed while aliquoting the sample into different containers. The Department recommends the use of a churn splitter or a magnetic stirrer to ensure that the sample is evenly distributed in all containers.

Only highly trained and experienced field staff, exercising due caution and sampling according to the SOPs, can ensure that a representative marsh water sample is obtained. While the extraordinarily high TSS measurements during the May and June samplings indicated problems, relying only on "after the fact" TSS measurements to assess how well staff are sampling is not a long term solution. A multi-tiered approach, involving evaluating changes to the current sampling strategy (switching to peristaltic pumps deployed from platforms), comprehensive training, field performance testing, documentation, and data assessment and validation is needed to address ongoing and future QA concerns.

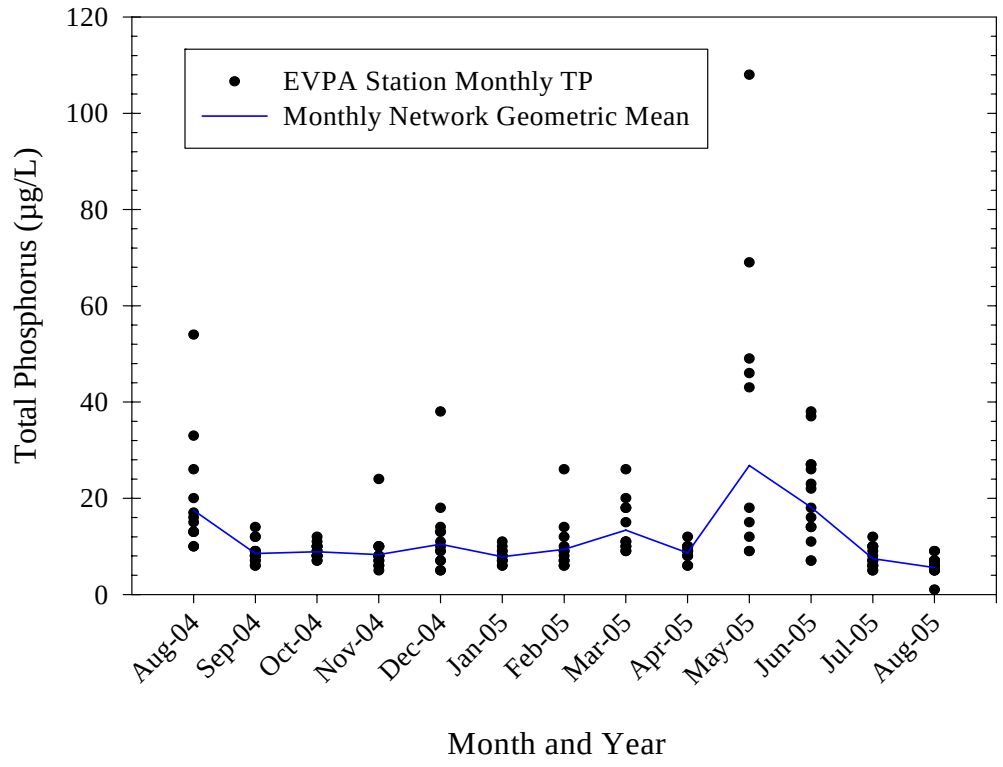

Figure 1. Total phosphorus concentrations in EVPA samples from the Refuge for the period from August 2004 through August 2005. The points are measured concentrations at individual monitoring stations. The blue line is the monthly geometric mean averaged across all stations.

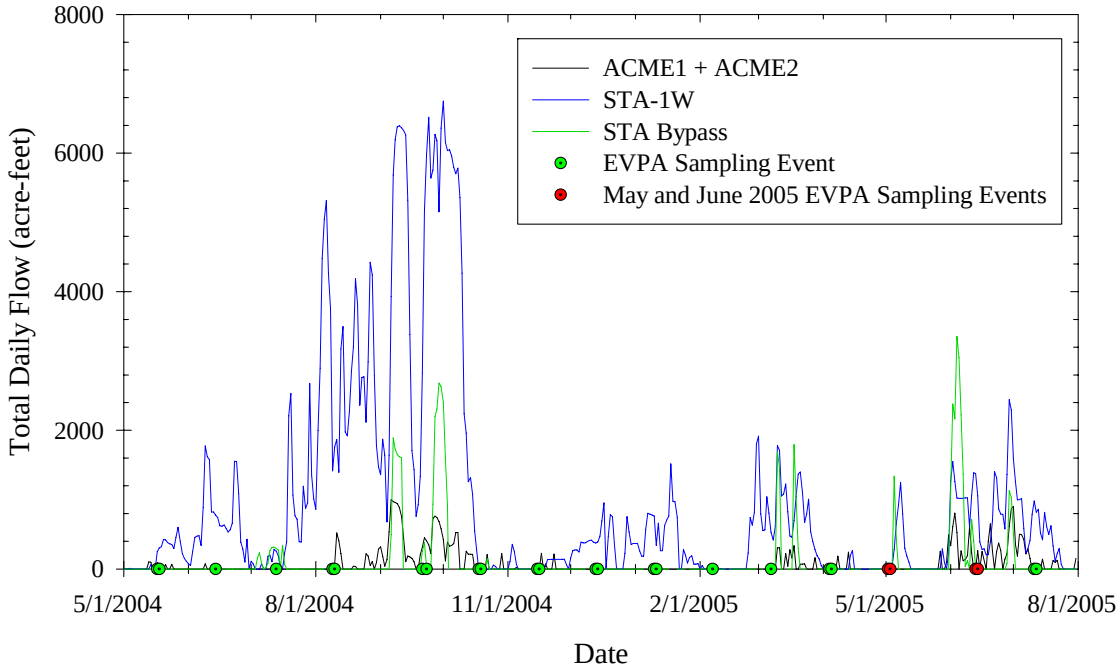

Figure 2. Total daily inflow to Refuge during the period from May 2004 through July 2005. Red points indicate the dates of the May and June 2005 EVPA sampling events.

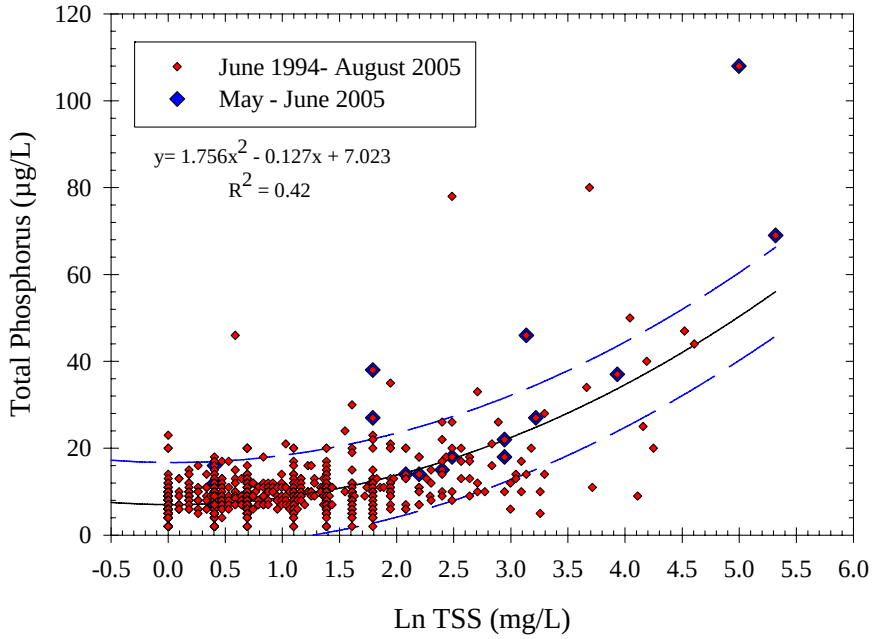

Figure 3. Relationship between TSS and TP concentrations at 14 LOX sites in the Refuge during the period from June 1994 to June 2005. Note: samples with two highest TSS concentrations were collected during the May and June 2005 monitoring events.

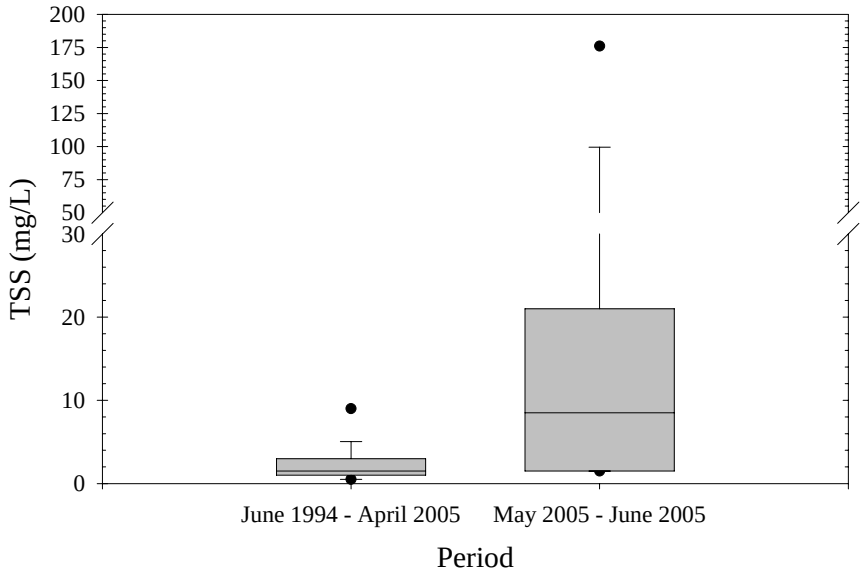

Figure 4. Boxplots of total suspended solids (TSS) concentrations at Refuge EVPA monitoring stations during the May and June 2005 sample events and all previous sampling events (June 1994 – April 2005). The 25th and 75th percentiles are shown by the bottom and top of each box, respectively. Medians are shown as solid horizontal lines through each box. Whiskers indicate 10th and 90th percentiles. Black circles indicate the 5th and 95th percentiles.

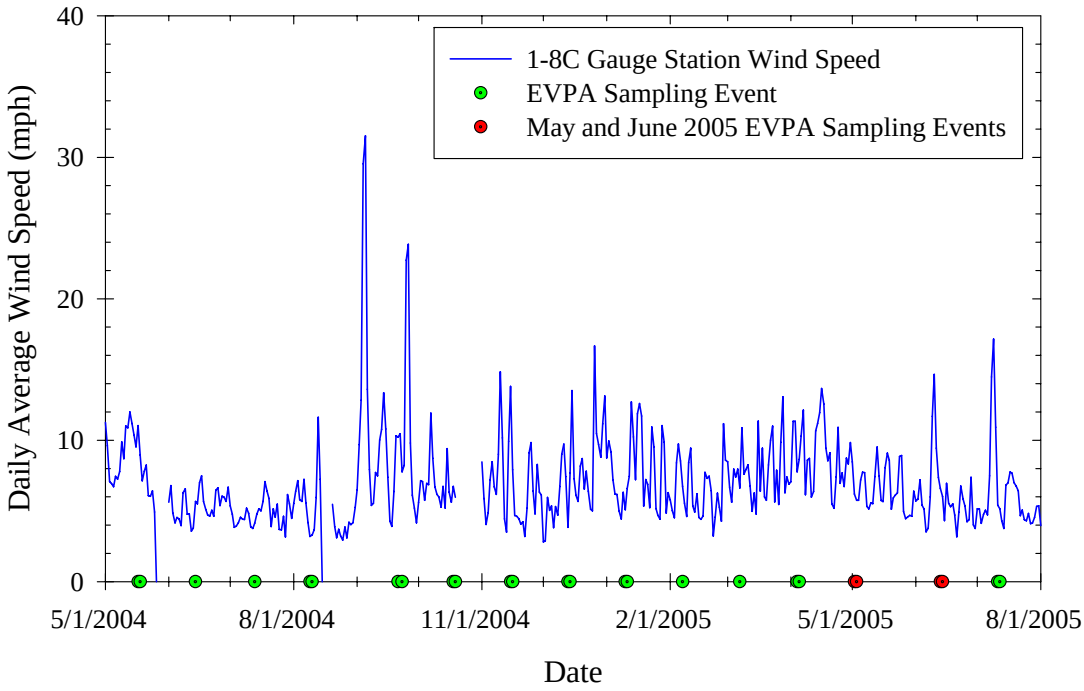

Figure 5. Average daily wind speed at station 1-8C during the period from May 2004 through July 2005. Red points indicate the dates of the May and June 2005 EVPA sampling events.

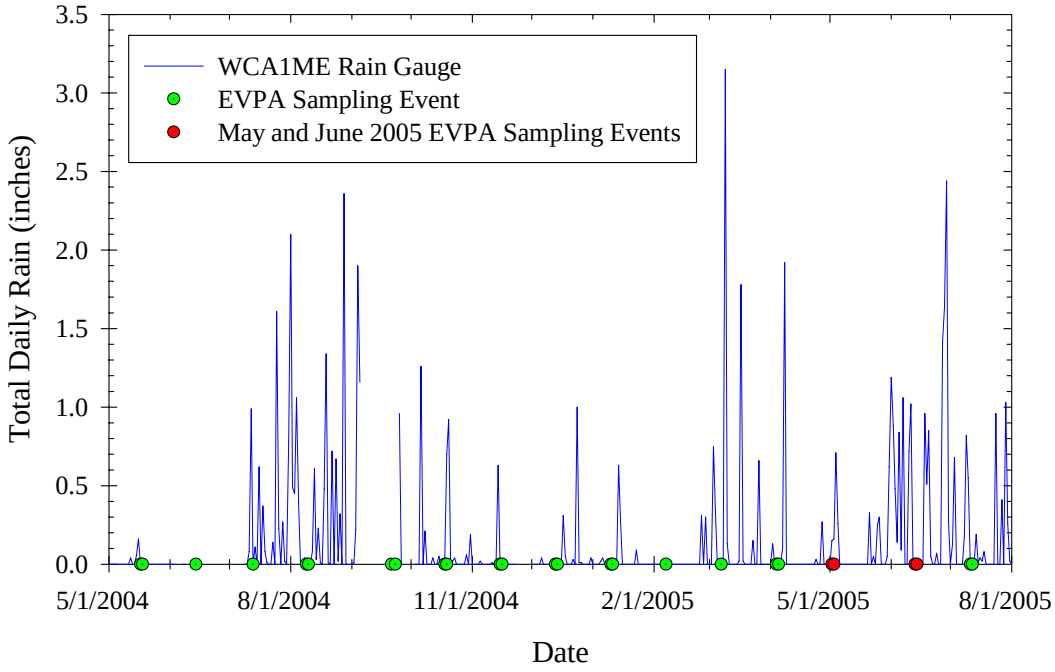

Figure 6. Total daily rainfall at station WCA1ME during the period from May 2004 through July 2005. Red points indicate the dates of the May and June 2005 EVPA sampling events.

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Nearhoof, F. 1996. A Protocol for Collecting Surface Water Sample in Marshes of the Florida Everglades. Water Quality Technical Series, Volume 3, Number 25. FDEP, Tallahassee, FL.

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