To: Principals of the Consent Decree

Dan Kimball, Superintendent, Everglades National Park
Mark Musaus, Manager, A.R.M. Loxahatchee National Wildlife Refuge
Robert Carpenter, District Engineer, U.S. Army Corps of Engineers
Colleen Castille, Secretary, Florida Department of Environmental Protection
Carol Wehle, Executive Director, South Florida Water Management District

From: Representatives of the Technical Oversight Committee

Nicholas Aumen, Everglades National Park
Mike Walden, A.R.M. Loxahatchee National Wildlife Refuge
Paul DuBowy, Jacksonville District, U.S. Army Corps of Engineers
Frank Nearhoof, Florida Department of Environmental Protection
Garth Redfield, South Florida Water Management District

Date: July 13, 2005

Re: Recommendations to Principals for Water Management Activities Relating to Water Quality

This letter report responds to the request from the Principals of the Consent Decree on November 9, 2004 to provide recommendations on water management and water quality. Specifically, the Principals requested "among those measures, at its November 30, 2004 meeting the TOC should analyze the relationship between the current water management practices and water quality compliance, as well as opportunities to alter water management to improve water quality while maintaining water quantity benefits. The Principals anticipate further recommendations from the TOC regarding these additional measures."

After discussion of the many suggested water management activities that could improve water quality in the Refuge, the TOC Representatives at the May 17, 2005 meeting decided on four candidate water management actions to be further investigated for possible recommendation to the Principals. These topics are outlined in the TOC working document (**Attachment 1**) along with agency responsibilities for follow-up. As a result of TOC deliberations at the May 17, June 13, and July 12, 2005 TOC meetings, the TOC Representatives propose the following to the Principals on water management activities relating to water quality.

1. The TOC recommends that the Principals consider a feasibility study to address the potential for constructing a project similar to that described in the briefing paper contributed by Patrick Martin of the Lake Worth Drainage District (LWDD) (**Attachment 2**). This project would involve the construction of a low-level berm and a downstream structure and would allow the delivery of a minimum of 100,000 gallons per minute of water to be used for water supply purposes. The basic value of this project would be to allow water supply deliveries with potentially little impact to ecological resources of the Refuge and there may be ancillary benefits as well. Such a feasibility study should include:

- Consideration of the legal issues involved with the use of lands within the Everglades Protection Area for these purposes.
- Analysis of the quantitative benefit of water supply deliveries through this bermed canal on the management and operations of the Stormwater Treatment Areas (STAs).
- Assessment of the impacts on overall Refuge hydrology.
- Evaluation of environmental impacts – estimation of direct and indirect impacts to the Refuge from the construction and operation of the project.
- Exploration of potential costs and funding sources for construction, operation and maintenance.
- Study of the effects of the operation of the project of the Regulation Schedule on the Refuge.
- Examination of various alternatives of structural length and height and the terminal location of the project.
- Consideration of recreational use impacts and impediment of navigation, including those currently used by the Refuge areas east of the proposed levees.

2. In response to the first topic of the TOC working document (**Attachment 1**), the TOC recommends that the Principals consider increasing the number of grab samples taken routinely at the S-10 and S-39 structures. TOC finds that increasing sampling frequency to biweekly at all structures regardless of flow will provide additional information on water quality moving through these structures. During its deliberations, TOC reviewed the current sampling protocols (see Executive Summary of **Attachment 3**) and resulting data from the three S-10 structures (S-10A, C, and D) and S-39 structure summarized by the District in **Attachment 3**. Appendix B of this document provides cost estimates for this change as Option E.

3. In response to the topics 2, 3, and 4 of the TOC working document (**Attachment 1**), the TOC recommends that the Principals consider studies to provide the information outlined in each topic of this document.

4. In addition to these three topics, the TOC recommends that the Principals consider initiating the technical analyses and other activities involved in revision of the Regulation Schedule for Water Conservation Area 1 (WCA-1). This effort will involve two complimentary dimensions. The first is to examine short-term operational changes that can be implemented either under the current Regulation Schedule or through temporary deviations. The second is a traditional process to do a major revision to the Regulation Schedule.

The TOC is slated for a quarterly meeting on August 16, 2005 and for a special session on September 20, 2005. We look forward to the Principals' response on these topics, preferably prior to the September meeting.

Attachment 1

TOC WORKING DOCUMENT

Action Items Towards Recommendations to Principals on Water Management Practices and Water Quality in the Refuge
May 17, 2005

The following bullets are issues that the interagency teams should address at a minimum to provide information to support TOC recommendations.

1. **More frequent outflow structure water quality sampling.**
    - Characterize existing data and permit requirements.
    - Estimate the cost of upgrading the monitoring the systems on S-10s, including personnel and laboratory costs. Provide implementation schedule.
    - Assess the potential reduction in uncertainty by increasing information.
    - Characterize the use of the resultant data.
    - Analyze the effect of sampling frequency (power analysis).

The team will be lead by SFWMD with Refuge technical staff.

2. **Improved coordination of inflow pump and outflow gate operations.**
    - Determine the feasibility under current Regulation Schedule and other constraints.
    - Conduct cost benefit analysis.
    - Quantify the expected benefits of the operational recommendations.
    - Consider the potential water quality and quantity impacts on receiving water bodies.
    - Evaluate potential for constraining STA operations.

The Refuge and the Corps will be the lead agencies.

3. **Delay stage rise until after wet-season rain on Refuge begins.**
    - Determine the feasibility under current Regulation Schedule and other constraints.
    - Conduct cost benefit analysis.
    - Quantify the expected benefits of the operational recommendations.
    - Consider the potential water quality and quantity impacts on receiving water bodies.
    - Evaluate potential for constraining STA operations.

The Refuge and the Corps will be the lead agencies.

4. **Re-distribution of flows through Refuge outflows with water quality as a consideration.**
    - Determine the feasibility under current Regulation Schedule and other constraints.
    - Conduct cost benefit analysis.
    - Quantify the expected benefits of the operational recommendations.
    - Consider the potential water quality and quantity impacts on receiving water bodies.
    - Evaluate potential for constraining STA operations.

The Refuge and the Corps will be the lead agencies.

Attachment 2

Briefing Paper to the T.O.C.
Patrick A. Martin, P.E., Director of Engineering
Lake Worth Drainage District

Lake Worth Drainage District has secured from South Florida Water Management District a Consumptive Use Permit for 61.0 BGY. This quantity of water is necessary for the public health, safety and welfare of Southeastern Palm Beach County. Both wellfields and agriculture in the region depend on this resource.

LWDD receives its water from the regional system. Flow is provided from to two major regional water sources; C-51 and WCA-1 (Refuge). Refuge water is diverted to project culverts in the L-40 then to LWDD pump stations. The L-40 further routes water to the Hillsboro Canal via the S-39 structure. The Hillsboro Canal supplies other consumptive users, i.e. Broward County, Boca Raton, (as well as LWDD), etc.

LWDD has pump stations located on the C-51 (and E-4) Canals, the Hillsboro Canal, and the Refuge via the connection from L-40 to the project culverts then to the LWDD E-1W.

The point of greatest demand for LWDD is located near the pump stations withdrawing from the Refuge. While the C-51 and Hillsboro stations are important, they cannot, in any way, satisfy the demands; and certainly, in the location where the demands are greatest.

During average annual conditions, all parties coexist helping one another with water supply, as well as excess runoff removal from time to time. The problem at hand is during the later part of the dry season when both the Refuge demands (to maintain a biological balance for bird nesting as well as other biological factors), and the water supply demands for Southeastern Palm Beach County may compete for the same water.

This paper is an attempt to offer a solution to the above. LWDD suggests a low-level berm be constructed on the Western side of the L-40 Borrow Canal and the construction of a control structure (Obermeyer or like kind) at some location South of the G-94B project culvert.

The following points are offered as reasoning for such a project:

- As stated earlier, when the water elevation is at or above 15.0’ NGVD, both LWDD and the Refuge coexist managing both our resources. It is only when water elevations begin to fall below this point, that both parties become concerned. This elevation could be debated; but is used in this paper to provide a reference point.

- Construct a low level berm at elevation 15.0’ NGVD on the Western side of the L-40 Borrow Canal.

- Construct an Obermeyer (or equal) Water Control Structure South of the G-94B Project culvert. This will enable flow to occur at low stages to the LWDD pump stations without the canal runoff intermingling with the Refuge.

- This separation will allow SFWMD to meet its water supply commitments to LWDD and not adversely impact the Refuge with phosphorus tainted Lake Okeechobee water.

- An operational protocol would be established between SFWMD and LWDD (with Refuge oversight) to ensure all Lake Okeechobee water is withdrawn from the Borrow Canal prior levels exceeding the berm elevation.

- This allows water levels above 15.0' NGVD to again commingle, providing water supply to both parties. It should be noted again that other users exist and depend on Lake Okeechobee water and this route. They are Broward County (and possible parties within Broward that have separate Consumptive Use Permits) and the City of Boca Raton.

- This project could also aid in the stress reduction to the STAs 1 West and East (once on line).

- Excess runoff from Lake Okeechobee can be diverted to Lake Worth Drainage District providing relief to the Caloosahatchee and St. Lucie Estuaries.

Attachment 3

WORKING DOCUMENT

TOTAL PHOSPHORUS SAMPLE COLLECTION AT THE S-10 AND S-39 STRUCTURES AND RECOMMENDATIONS FOR FUTURE SAMPLING

Water Quality Assessment Division
South Florida Water Management District
For June 13, 2005 Technical Oversight Committee (TOC) Meeting

Executive Summary

Flow and water quality (total phosphorus) data were retrieved for the S-10 (S-10A, S-10C, S-10D, and S-10E) and S-39 structures for the period from January 1, 2000 through December 31, 2004. The data was used to identify whether the present monitoring protocols were adequate to characterize water quality at these structures during flow events. Water quality data was also used to identify any total phosphorus (TP) gradient across these structures.

The monitoring protocols differ for the five structures and are summarized below:

- S-10A and S-10C: biweekly sampling if flowing.
- S-10D and S-39: biweekly sampling if flowing, otherwise a monthly sample is collected regardless of flow.
- S-10E: biweekly sampling if flowing, otherwise a monthly sample is collected regardless of flow; during the five-year monitoring, flow at this structure totaled 14 acre-feet (ac-ft) [Note that water quality monitoring at this site was terminated in February 2005].

Time series plots of TP and flow for each of the five structures suggest that grab samples were collected during most of the flow events (**Figures 1** through **3**). Typically, flow events lasting seven consecutive days or less were missed by the present sampling schedule at the S-10A, S-10C, and S-10D structures. However, due to the sampling protocol at S-10D, fewer of these events were missed. Flow events were more efficiently sampled at the S-39 structure. The average number of samples collected for the structures ranged from 7 per year at S-10A and S-10C to 16 per year at S-39.

Another part of the data analysis examined whether the sampling protocol was observed for these five structures. To determine whether a site was only visited with no sample collected, an additional parameter known as the "No Bottle Sample" (NOB) needed to be retrieved from the District's database, DBHYDRO. The NOB parameter provides information when a site was visited with no sample collected. By using the NOB with the TP data, the total number of visits (or sampling opportunities) at each site can be calculated. These results are presented for each month in **Figures 4** through **6** and summarized annually in **Table 1**. With the exception of S-10E, each structure should have at least two sampling opportunities per month.

By comparing the number of sampling opportunities with the sampling protocol for each of the structures, the number of missed sampling opportunities can also be calculated (**Table 1**). The total number of missed sampling opportunities for each of the structures over the five years was three or less (**Table 1**). With the exception of these missed opportunities, the sampling protocol was observed during the entire period from 2000 through 2004.

Total phosphorus concentrations varied from structure to structure (**Figures 7** and **8**) with structures located on the northern portion of the L-39 canal (i.e., S-10E and S-10D) exhibiting higher mean TP concentrations than those in the southern portion. During the period from January 2000 through December 2004, average TP concentrations ranged from 32 µg/L at S-39 to 60 µg/L at S-10D. This gradient was also observed under flow conditions with mean TP concentrations of 30 μg/L at S-39 compared with 86 μg/L at S-10D (**Figure 8**). Additional statistical summaries of the TP data for the S-10 and S-39 structures are provided in Appendix A.

Based on the data review, additional sample collection would provide more total phosphorus information at each of the structures and would improve chances of collecting samples during short-term flow events. Cost estimates for this change are provided in Appendix B. However, there does not appear to be enough information to be gained from auto-sampling to justify this major change in approach. It is important to note that flow through the three S-10 structures occurs only a few days per month (Appendix C).

In light of these facts, consideration should be given to modifying the present sampling protocol for S-10A, S-10C, S-10D, and S39. Such a modification will require that samples be collected biweekly at each structure regardless if the structure is flowing. These changes should increase the number of samples collected at S-10A and S-10C by an average of four times and samples collected at S-10D and S-39 by twofold. In view of the relatively infrequent flow events at these structures, consistent biweekly sampling is a reasonable strategy to improve water quality information for discharges from the Refuge.

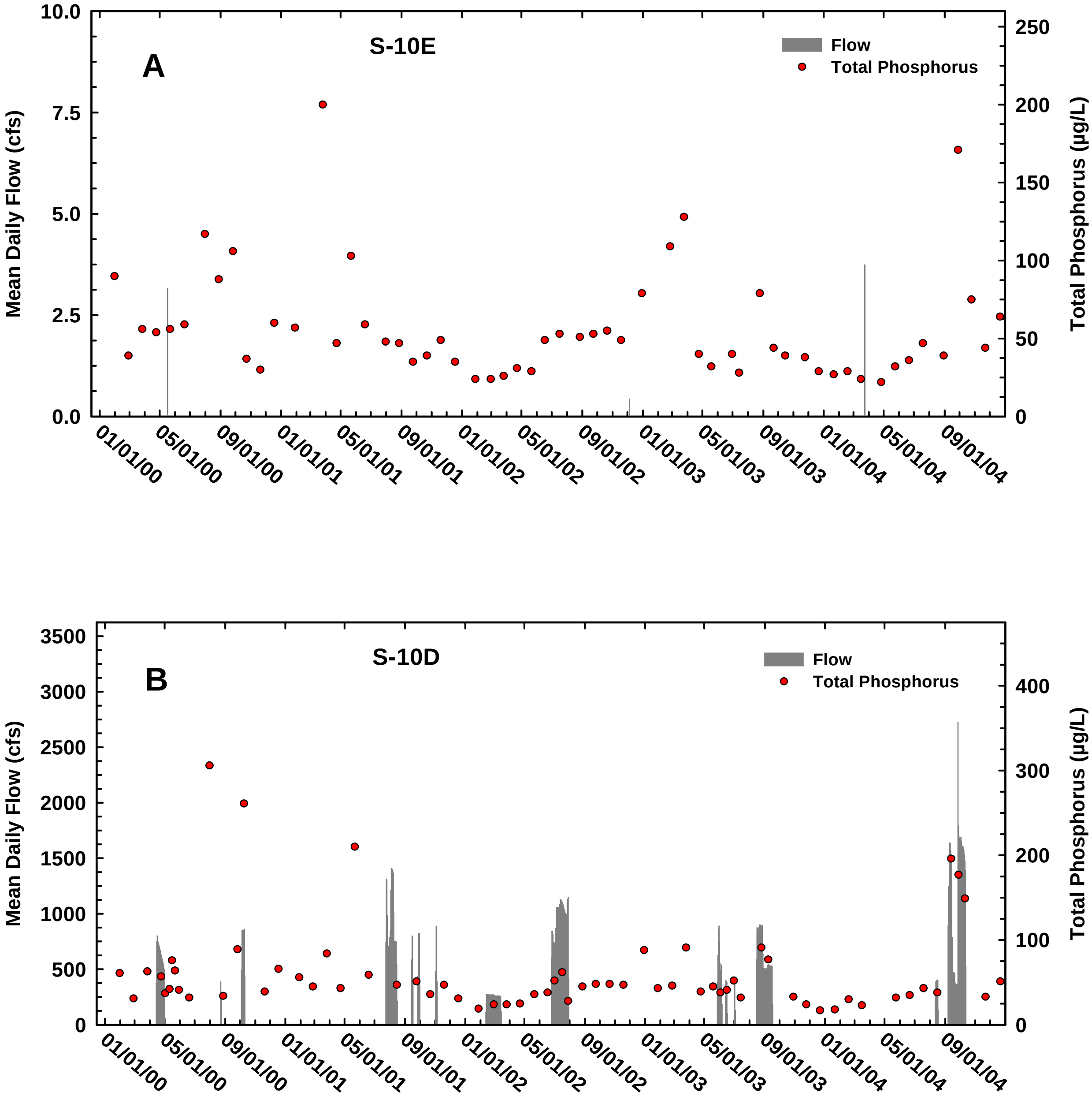
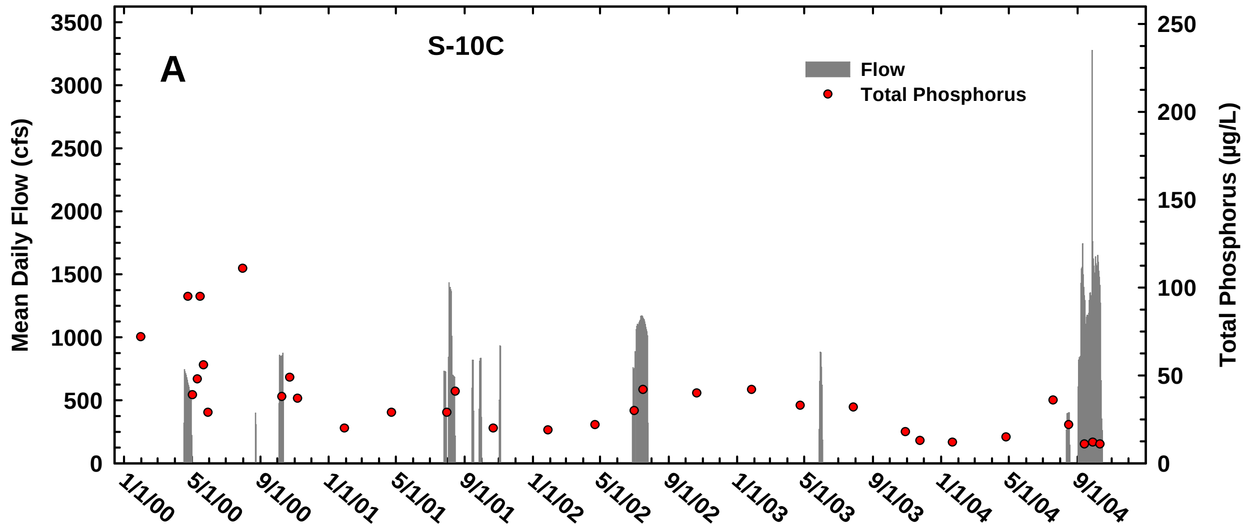


Figure 1. Mean daily flows and total phosphorus grab sample concentrations collected from January 1, 2000 through December 31, 2004 at: (**A**) S-10E and (**B**) S-10D.



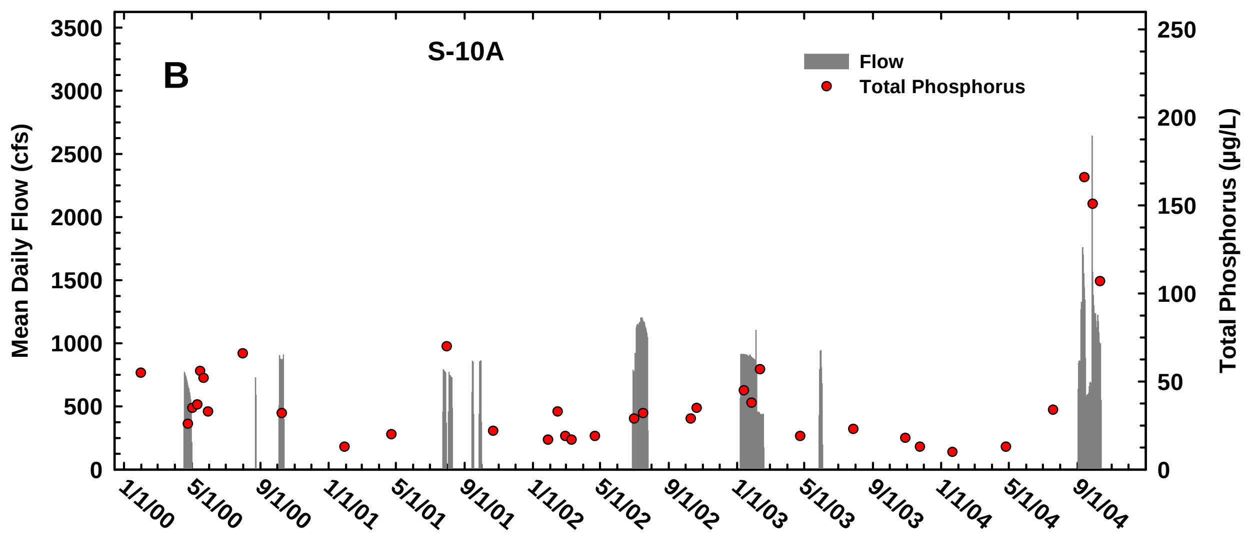


Figure 2. Mean daily flows and total phosphorus grab sample concentrations collected from January 1, 2000 through December 31, 2004 at: (**A**) S-10C and (**B**) S-10A.

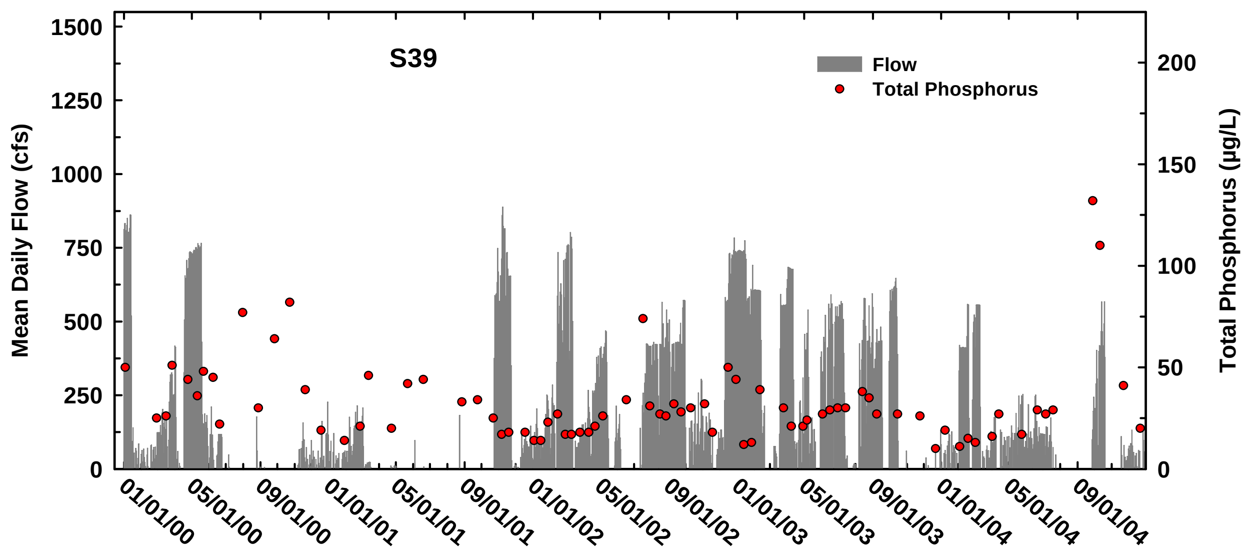
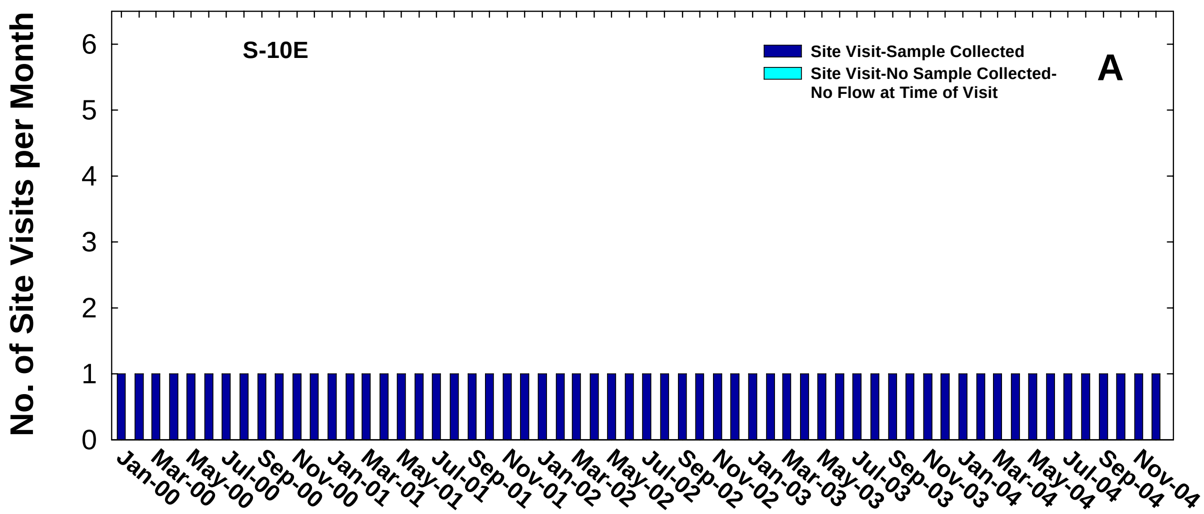


Figure 3. Mean daily flows and total phosphorus grab sample concentrations collected from January 1, 2000 through December 31, 2004 at S-39.



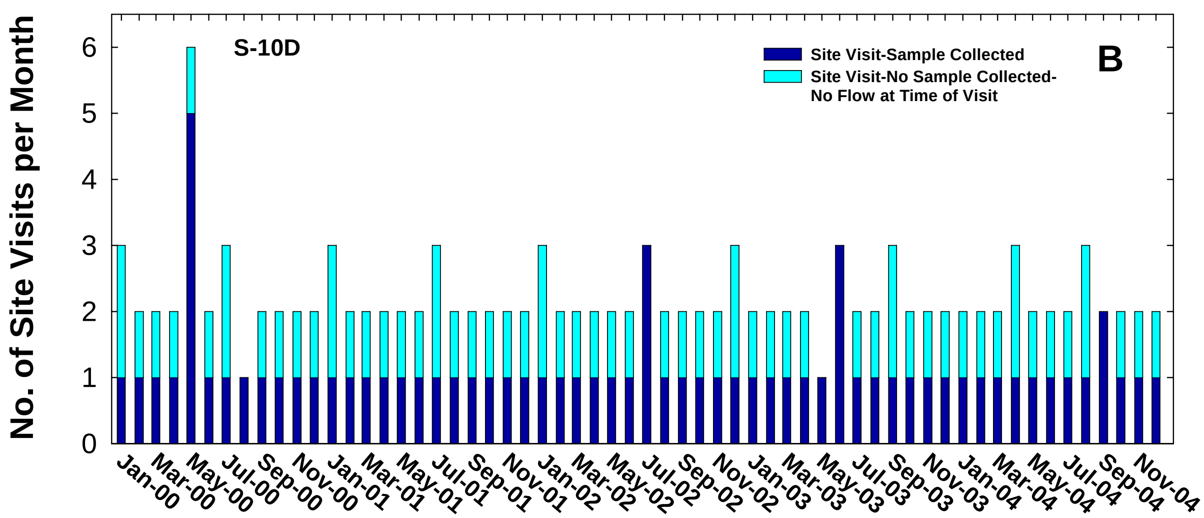


Figure 4. Stacked bar graph identifying total number of times per month Stations S-10E (**A**) and S-10D (**B**) were visited by field sampling crew from January 2000 through December 2004. The dark colored bars indicate the number of samples collected at the sites each month while the light colored bars indicate the number of times the sites was visited but no sample was collected because there was not flow at the time of the sample collection visit.

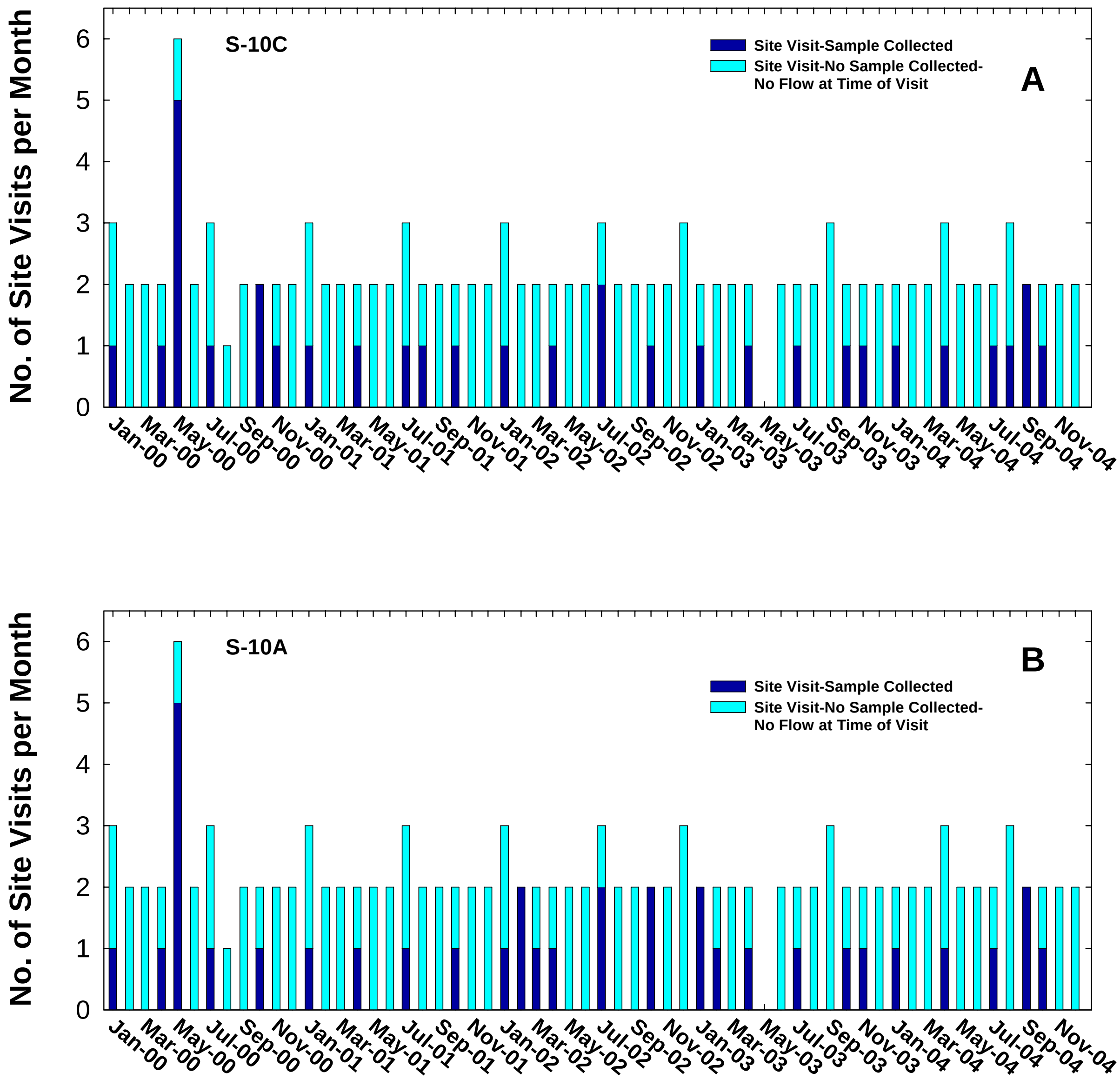


Figure 5. Stacked bar graph identifying total number of times per month Stations S-10C (**A**) and S-10A (**B**) were visited by field sampling crew from January 2000 through December 2004. The dark colored bars indicate the number of samples collected at the sites each month while the light colored bars indicate the number of times the sites was visited but no sample was collected because there was not flow at the time of the sample collection visit.

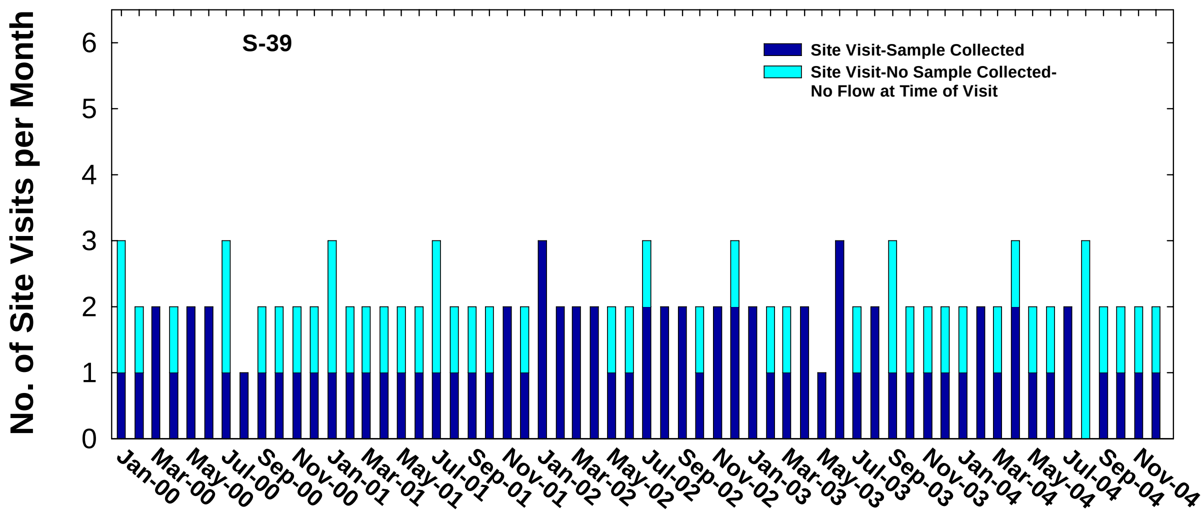


Figure 6. Stacked bar graph identifying total number of times per month Station S-39 was visited by field sampling crew from January 2000 through December 2004. The dark colored bars indicate the number of samples collected at the site each month while the light colored bars indicate the number of times the site was visited but no sample was collected because there was not flow at the time of the sample collection visit.

Table 1. Summary of flow events and monitoring performed annually at the S-10 and S-39 structures from the period from January 2000 through December 2004.

Structure	Monitoring Year	Total Number of Flow Days	Total Number of Visits to Structure	Total Number of TP Samples Collected	Number of Missed Sampling Opportunities
S10A	2000	27	29	9	1
	2001	24	26	4	0
	2002	28	27	9	0
	2003	50	23	7	2
	2004	42	26	6	0
S10C	2000	26	29	11	1
	2001	30	26	5	0
	2002	28	27	5	0
	2003	7	23	5	2
	2004	51	26	7	0
S10D	2000	28	29	16	1
	2001	37	26	12	0
	2002	67	27	14	0
	2003	52	25	14	1
	2004	44	26	13	0
S10E	2000	1	12	12	0
	2001	0	12	12	0
	2002	1	12	12	0
	2003	0	12	12	0
	2004	1	12	12	0
S39	2000	193	25	15	1
	2001	136	26	13	0
	2002	295	27	22	0
	2003	236	25	17	1
	2004	224	26	14	0

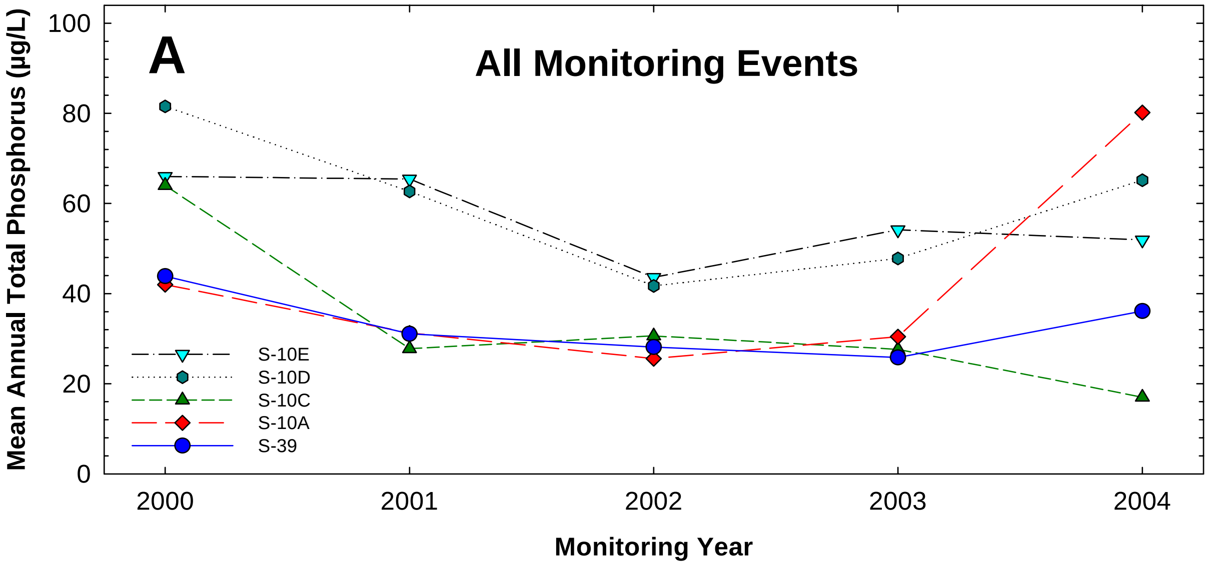
Note:

Total Number of Flow Days – Count of days during a year that flow was reported for the structure.

Total Number of Visits to the Structure – Total number of scheduled sampling events during the year that a structure was visited.

Total Number of TP Samples Collected – Number of scheduled sampling events during the year that water quality samples were collected at each structure.

Number of Missed Sampling Opportunities – Number of missed sampling events based on the monitoring protocol at each structure.



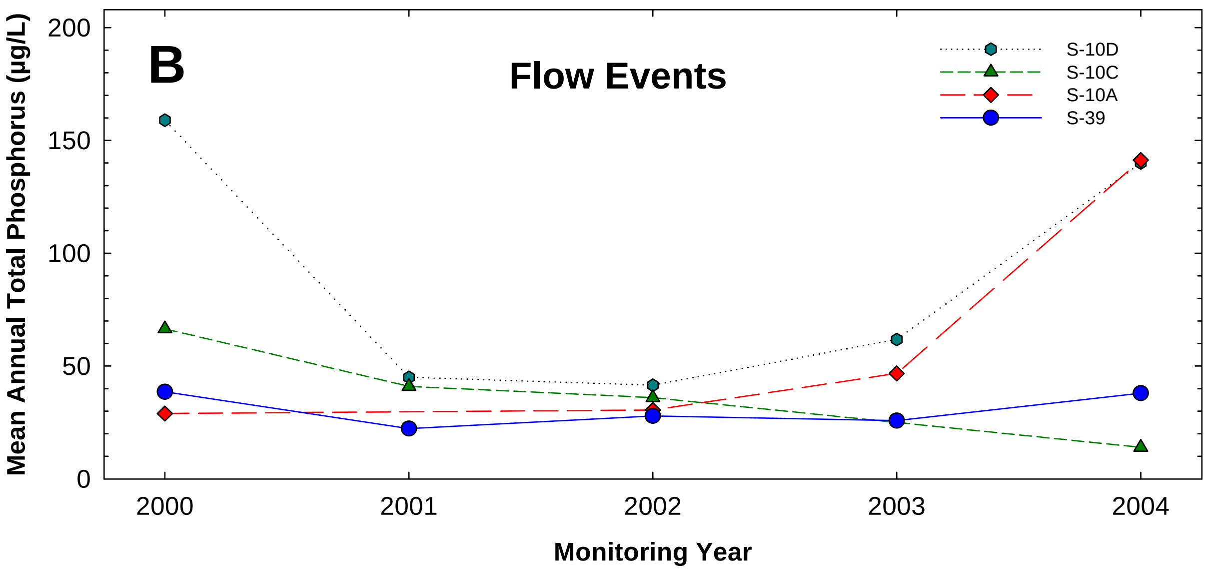


Figure 7. Mean annual total phosphorus concentrations at S-10 and S39 structures for all monitoring events (**A**) and flow events (**B**) during the period from January 2000 through December 2004.

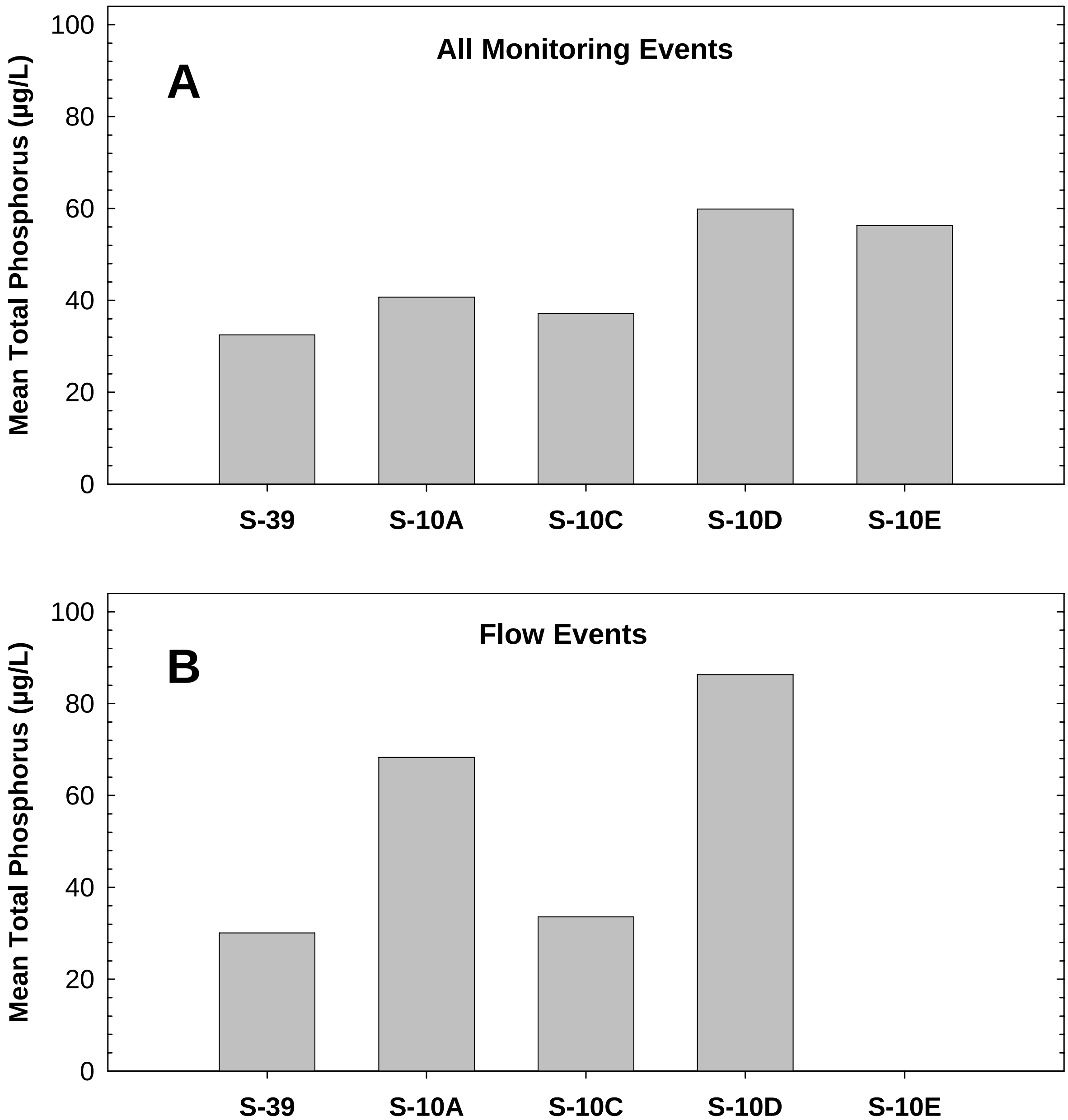


Figure 8. (**A**) Mean total phosphorus concentrations at the S-39 and S10 structures for samples collected under all monitoring conditions during the period from January 2000 through December 2004. (**B**) Mean total phosphorus concentrations at the S-39 and S10 structures for samples collected under conditions when flow was reported in DBHYDRO during the period from January 2000 through December 2004.

APPENDIX A

Summary Statistics of Flow and Total Phosphorus at the S-10 and S-39 Structures for the period from 2000 through 2004

2000-2004
Flow Data

Station	Year	No. of Flow Days	Minimum	Maximum	Median	Mean	Std. Deviation	Annual Volume (ac-ft)
			(cfs)					
S10E	2000	1	0	3	0	0	0	6
	2001	0	0	0	0	0	0	0
	2002	1	0	0	0	0	0	1
	2003	0	0	0	0	0	0	0
	2004	1	0	4	0	0	0	7
S10D	2000	28	0	859	0	49	176	35,345
	2001	37	0	1,409	0	91	281	61,339
	2002	67	0	1,147	0	126	304	83,538
	2003	52	0	899	0	82	218	59,375
	2004	45	-1622	2,724	0	122	417	88,548
S10C	2000	26	0	873	0	45	170	32,618
	2001	31	-59	1,433	0	70	246	47,562
	2002	28	0	1,169	0	84	284	55,392
	2003	7	0	883	0	12	91	8,422
	2004	52	-726	3,276	0	163	461	118,435
S10A	2000	27	0	908	0	50	185	36,530
	2001	25	-58	861	0	47	178	32,079
	2002	28	0	1,201	0	86	293	57,080
	2003	50	0	1,101	0	101	268	73,160
	2004	43	-1337	2,641	0	118	374	85,408
S39	2000	193	0	862	8	132	241	95,739
	2001	136	0	888	0	74	185	53,265
	2002	295	0	802	154	240	223	173,443
	2003	236	0	774	173	264	265	190,956
	2004	224	0	567	46	101	149	73,339

2000-2004
Total Phosphorus Data (µg/L)
All Data

STATION	YEAR	No. of Measurements	Mean	Median	Maximum	Minimum	Std Deviation
S10E	2000	12	66.0	57.5	117	30	27.9
	2001	12	65.4	48.5	200	35	46.2
	2002	12	43.6	49	79	24	16.8
	2003	12	54.2	40	128	28	33.0
	2004	11	51.9	36	171	22	42.9
S10D	2000	15	81.5	57	306	31	84.0
	2001	12	62.7	47	210	31	48.3
	2002	14	41.7	41.5	88	19	18.5
	2003	14	47.8	42	91	17	22.9
	2004	13	65.2	35	196	18	63.4
S10C	2000	10	64.0	52.5	111	37	27.4
	2001	5	27.8	29	41	20	8.6
	2002	5	30.6	30	42	19	10.3
	2003	5	27.6	32	42	13	11.8
	2004	7	17.0	12	36	11	9.2
S10A	2000	8	42.0	36	66	26	13.9
	2001	4	31.3	21	70	13	26.1
	2002	9	25.6	29	35	17	7.4
	2003	7	30.4	23	57	13	16.4
	2004	6	80.2	70.5	166	10	70.2
S39	2000	15	43.9	44	82	19	19.1
	2001	13	31.1	25	72	14	16.6
	2002	21	28.1	26	74	14	14.1
	2003	17	25.8	27	39	10	8.4
	2004	14	36.1	23.5	132	11	37.1

Note: There was one flagged TP value in 2004 at S-10E

2000-2004
Total Phosphorus Data (µg/L)
Flow Events

STATION	YEAR	No. of Measurements	Mean	Median	Maximum	Minimum	Std Deviation
S10D	2000	2	159	159	261	57	144.2
	2001	2	45	45	47	43	2.8
	2002	4	41.5	40	62	24	18.4
	2003	4	61.8	59	91	38	26.3
	2004	4	140	163	196	38	70.7
S10C	2000	2	66.5	66.5	95	38	40.3
	2001	1	41	41	41	41	
	2002	2	36	36	42	30	8.5
	2003	0	--	--	--	--	--
	2004	4	14	11.5	22	11	5.4
S10A	2000	2	29	29	32	26	4.2
	2001	0	--	--	--	--	--
	2002	2	30.5	30.5	32	29	2.1
	2003	3	46.7	45	57	38	9.6
	2004	3	141.3	151	166	107	30.7
S39	2000	9	38.6	44	51	22	11.6
	2001	6	22.3	18	46	14	11.8
	2002	20	27.9	26	74	14	14.4
	2003	16	25.8	27	39	10	8.7
	2004	11	38	19	132	11	41.8

Note: No significant flow was observed at S-10E during the period from January 2000 through December 2004. Total volume of water during this period was approximately 14 ac-ft.

2000-2004
Total Phosphorus Data (μg/L)
No Flow

STATION	YEAR	No. of Measurements	Mean	Median	Maximum	Minimum	Std Deviation
S10E	2000	12	66.0	57.5	117	30	27.9
	2001	12	65.4	48.5	200	35	46.2
	2002	12	43.6	49	79	24	16.8
	2003	12	54.2	40	128	28	33.0
	2004	11	51.9	36	171	22	42.9
S10D	2000	13	69.6	42	306	31	73.1
	2001	10	66.2	49	210	31	52.6
	2002	10	41.8	41.5	88	19	19.5
	2003	10	42.2	41	91	17	20.2
	2004	9	31.9	32	51	18	10.4
S10C	2000	8	63.4	52.5	111	37	27.1
	2001	4	24.5	24.5	29	20	5.2
	2002	3	27.0	22	40	19	11.4
	2003	5	27.6	32	42	13	11.8
	2004	3	21.0	15	36	12	13.1
S10A	2000	6	46.3	44.5	66	33	13.3
	2001	4	31.3	21	70	13	26.1
	2002	7	24.1	19	35	17	7.9
	2003	4	18.3	18.5	23	13	4.1
	2004	3	19.0	13	34	10	13.1
S39	2000	6	51.8	51.5	82	19	26.1
	2001	7	38.6	34	72	20	17.0
	2002	1	34.0	34	34	34	0.0
	2003	1	26.0	26	26	26	0.0
	2004	3	29.3	27	41	20	10.7

Note: There was one flagged TP value in 2004 at S-10E

APPENDIX B
Cost Estimates for Sampling the S-10 and S-39 Structures

Options	Structure	Frequency	Collection Method	List of Parameters	Cost		
					Initial Cost	Annual Cost	Total Cost
Option A	Culvert S10 A	7 events (based on 5 year average) and Quarterly	Grab	Events (based on 5 years average) : ALK, CL,Color,NH4,NO2,NOX,OPO4,TKN,TPO4,TSS,TURB Quarterly : CA,K,MG,NA,SIO2,SO4,TOTFE	$0	$32,037	$32,037
	Culvert S10 C	7 events (based on 5 year average) and Quarterly	Grab				
	Culvert S10 D	14 events (based on 5 year average) and Quarterly	Grab				
	S39	16 events (based on 5 year average) and Quarterly	Grab				
Option B	Culvert S10 A	Weekly	Flow Proportional Autosampler	TP	$337,000	$45,213	$382,213
	Culvert S10 C	Weekly	Flow Proportional Autosampler				
	Culvert S10 D	Weekly	Flow Proportional Autosampler				
Option C	Culvert S10 A	Weekly	Time Autosampler	TP	$81,090	$45,213	$126,213
	Culvert S10 C	Weekly	Flow Proportional Autosampler				
	Culvert S10 D	Weekly	Time Autosampler				
Option D	Culvert S10 C	Weekly	Flow Proportional Autosampler	TP	$27,000	$30,733	$57,733
Option E	Culvert S10 A	Every other week	Grab	Every other week: ALK, CL,Color,NH4,NO2,NOX,OPO4,TKN,TPO4,TSS,TURB Quarterly : CA,K,MG,NA,SIO2,SO4,TOTFE	$0	$39,486	$39,486
	Culvert S10 C	Every other week	Grab				
	Culvert S10 D	Every other week	Grab				
	S39	Every other week	Grab				

Option A

Existing water quality monitoring program - Grab samples	**Frequency of sampling :**	Culvert 10A	7 events (based on 5 years average) and Quarterly
		Culvert 10C	7 events (based on 5 years average) and Quarterly
		Culvert 10D	14 events (based on 5 years average) and Quarterly

Culvert	Annual Data Collection cost	Annual Analytical Cost	Annual QA/QC Cost	Annual Reporting Cost	Total Annual Cost
Culvert 10A		$823	$400	$400	
Culvert 10C		$823	$400	$400	
Culvert 10D		$1,403	$400	$400	
S39		$2,295	$400	$400	
Total Cost	$23,493	$5,344	$1,600	$1,600	$32,037

Annual Cost **$32,037**

Parameters	
(Qrtly)	Every other Week /F or BWF/M
CA	ALK
K	CL
MG	Color
NA	NH4
SIO2	NO2
SO4	NOX
TOTFE	OPO4
	TKN
	TPO4
	TSS
	TURB

Option B

Installation of Three Flow Proportional Autosampler units at S10A, S10C, and S10D

Frequency of sampling : Weekly

Culvert	Instrumentation Cost	Installation cost	Annual Maintenance cost	Platform	Electricity cost	List of parameters	Annual Data Collection Cost	Annual Analytical Cost	Annual QA/QC Cost	Annual Reporting Cost
Culvert 10A	$3,500	$10,000	$5,000	$13,500	$80,000	TP		$640	$800	$800
Culvert 10C	$3,500	$10,000	$5,000	$13,500	$0	TP		$640	$800	$800
Culvert 10D	$3,500	$10,000	$5,000	$13,500	$176,000	TP		$640	$800	$800
Total Cost	$10,500	$30,000	$15,000	$40,500	$256,000		$23,493	$1,920	$2,400	$2,400

One time Cost	**$337,000**
Annual Cost	**$45,213**

Option C

Installation of one Flow Proportional Autosampler unit at S10C and two time auto sampler units at S10A and S10 D

Frequency of sampling : Weekly

Culvert	Instrumentation Cost	Installation Cost	Annual Maintenance cost	Platform	Electricity Cost	Parameter	Annual Data Collection Cost	Annual Analytical Cost	Annual QA/QC Cost	Annual Reporting Cost	Total Cost
Culvert 10A	$3,500	$10,000	$5,000	$13,500	$0	TP		$640	$800	$800	
Culvert 10C	$3,500	$10,000	$5,000	$13,500	$0	TP		$640	$800	$800	
Culvert 10D	$3,500	$10,000	$5,000	$13,500	$0	TP		$640	$800	$800	
Total Cost	$10,500	$30,000	$15,000	$40,500	$0		$23,493	$1,920	$2,400	$2,400	$126,213

One time cost **$81,090**
Annual Cost **$45,213**

Option D

Installation of one Flow Proportional Autosampler unit at S10C

Frequency of sampling: Weekly

Culvert	Instrumentation Cost	Installation cost	Annual Maintenance Cost	Platform	Parameter	Annual Data Collection Cost	Annual Analytical Cost	Annual QA/QC Cost	Annual Reporting Cost	Total Cost
Culvert 10C	$3,500	$10,000	$5,000	$13,500	TP		$640	$800	$800	
Total Cost	**$3,500**	**$10,000**	**$5,000**	**$13,500**	**TP**	**$23,493**	$640	**$800**	**$800**	**$57,733**

One time cost **$27,000**
Annual Cost **$30,733**

Option E

Grab sample collection every other week

Frequency of sampling:		
	Culvert 10A	Every other week
	Culvert 10C	Every other week
	Culvert 10D	Every other week

Culvert	Annual Data Collection cost	Annual Analytical Cost	Annual QA/QC cost	Annual Reporting cost	Total Annual Cost
Culvert 10A		$2,398	$800	$800	
Culvert 10C		$2,398	$800	$800	
Culvert 10D		$2,398	$800	$800	
S39		$2,399	$800	$800	
Total Cost	$23,493	$9,593	$3,200	$3,200	$39,486

Annual Cost **$39,486**

Parameters	
(Qrtly)	Every other Week
CA	ALK
K	CL
MG	Color
NA	NH4
SIO2	NO2
SO4	NOX
TOTFE	OPO4
	TKN
	TPO4
	TSS
	TURB

S10 A

Parameters	Unit Cost	Frequency of Sampling			Cost Analytical	
					Average for 5 years	Purposed
		Average for 5 years	Purposed			
ALK	$6.53	7	26		$46	$169.78
CL	$8.07	7	26		$56	$209.82
COLOR	$6.53	7	26		$46	$169.78
NH4	$6.53	7	26		$46	$169.78
NOX	$6.53	7	26		$46	$169.78
NO2	$6.53	7	26		$46	$169.78
OPO4	$6.53	7	26		$46	$169.78
TKN	$12.26	7	26		$86	$318.76
TPO4	$9.14	7	26		$64	$237.64
TSS	$7.77	7	26		$54	$202.02
TURB	$6.53	7	26		$46	$169.78
CA	$8.13	4	4		$33	$32.52
K	$8.13	4	4		$33	$32.52
MG	$8.13	4	4		$33	$32.52
NA	$8.13	4	4		$33	$32.52
SIO2	$8.25	4	4		$33	$33.00
TOTFE	$19.73	4	4		$79	$78.92
Total Cost					$823	$2,398.70

S10 C

Parameters	Unit Cost	Frequency of Sampling			Cost Analytical	
					Average for 5 years	Purposed
		Average for 5 years	Purposed			
ALK	$6.53	7	26		$46	$169.78
CL	$8.07	7	26		$56	$209.82
COLOR	$6.53	7	26		$46	$169.78
NH4	$6.53	7	26		$46	$169.78
NOX	$6.53	7	26		$46	$169.78
NO2	$6.53	7	26		$46	$169.78
OPO4	$6.53	7	26		$46	$169.78
TKN	$12.26	7	26		$86	$318.76
TPO4	$9.14	7	26		$64	$237.64
TSS	$7.77	7	26		$54	$202.02
TURB	$6.53	7	26		$46	$169.78
CA	$8.13	4	4		$33	$32.52
K	$8.13	4	4		$33	$32.52
MG	$8.13	4	4		$33	$32.52
NA	$8.13	4	4		$33	$32.52
SIO2	$8.25	4	4		$33	$33.00
TOTFE	$19.73	4	4		$79	$78.92
Total Cost					$823	$2,398.70

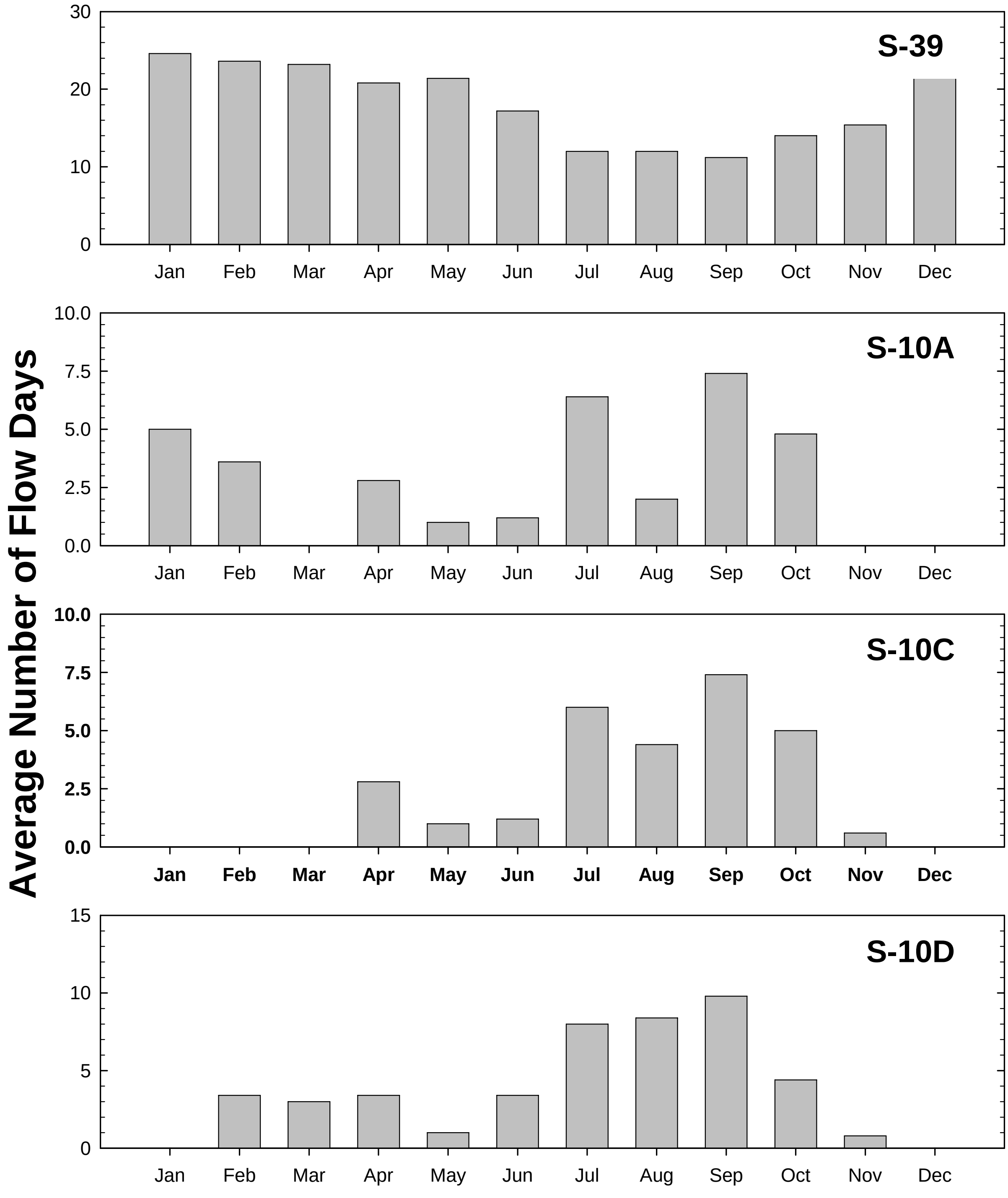
S10 D

Parameters	Unit Cost	Frequency of Sampling			Cost Analytical	
					Average for 5 years	Purposed
		Average for 5 years	Purposed			
ALK	$6.53	14	26		$91	$169.78
CL	$8.07	14	26		$113	$209.82
COLOR	$6.53	14	26		$91	$169.78
NH4	$6.53	14	26		$91	$169.78
NOX	$6.53	14	26		$91	$169.78
NO2	$6.53	14	26		$91	$169.78
OPO4	$6.53	14	26		$91	$169.78
TKN	$12.26	14	26		$172	$318.76
TPO4	$9.14	14	26		$128	$237.64
TSS	$7.77	14	26		$109	$202.02
TURB	$6.53	14	26		$91	$169.78
CA	$8.13	4	4		$33	$32.52
K	$8.13	4	4		$33	$32.52
MG	$8.13	4	4		$33	$32.52
NA	$8.13	4	4		$33	$32.52
SIO2	$8.25	4	4		$33	$33.00
TOTFE	$19.73	4	4		$79	$78.92
Total Cost					$1,403	$2,398.70

S39

Parameters	Unit Cost	Frequency of Sampling			Cost Analytical	
					Average for 5 years	Purposed
		Average for 5 years	Purposed			
ALK	$6.53	16	26		$104	$169.78
CL	$8.07	16	26		$129	$209.82
COLOR	$6.53	16	26		$104	$169.78
NH4	$6.53	16	26		$104	$169.78
NOX	$6.53	16	26		$104	$169.78
NO2	$6.53	16	26		$104	$169.78
OPO4	$6.53	16	26		$104	$169.78
TKN	$12.26	16	26		$196	$318.76
TPO4	$9.14	16	26		$146	$237.64
TSS	$7.77	16	26		$124	$202.02
TURB	$6.53	16	26		$104	$169.78
CA	$8.13	16	4		$130	$32.52
K	$8.13	16	4		$130	$32.52
MG	$8.13	16	4		$130	$32.52
NA	$8.13	16	4		$130	$32.52
SIO2	$8.25	16	4		$132	$33.00
TOTFE	$19.73	16	4		$316	$78.92
Total Cost					$2,295	$2,398.70

APPENDIX C
Flow Days for the
S-10 and S-39 Structures



Average number days flow was recorded at the S-10 and S-39 structures over the period from January 2000 through December 2004.

DOI-TOC Briefing Paper: Alternative Operational Strategies to Reduce Refuge Impacts

BACKGROUND

Objective - This briefing paper presents suggested operational approaches that might be adopted to reduce the risk of elevated phosphorus concentrations in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge). These changes should additionally reduce the risk of excursions beyond interim and long-term total phosphorus levels defined in the Consent Decree. It is important to note that these changes alone are unlikely to achieve our goals of protection and restoration within the Refuge. When compared to construction of major infrastructure additions, these and other operational changes might provide some benefits within a relatively short time frame at relatively modest costs. It is important to consider these operational strategies in the near-term, while STA performance is not yet reliably meeting goals and STA optimization is underway. In the long-term, after STA performance is fully optimized, these strategies can continue to provide an added layer of protection from treatment system disruptions and unusual events.

Timeline - STA-1W became fully operational around June 2000, discharging via pump station G-310 and, to a smaller extent, through pump station G-251. In May 2001, the S-6 pump station discharge was diverted away from the Refuge for treatment by STA-2 and final discharge to WCA-2. This diversion removed a significant source of both water and phosphorus mass loading from the Refuge, and also reduced the demand for water deliveries to WCA-2 through the S-10 gates. The net impacts of this treatment and diversion on refuge hydrology and water quality are not well understood and should be a topic for future hydrologic and water quality modeling analysis. Although the impacts of these changes are not completely understood, it is clear that water quality in the Refuge within the L-39 (Hillsboro) Canal greatly improved following these changes (Figure 1).

Much of STA-1E is now flooded, and STA-1E is nearing or is in a startup status. Soon, the maximum pump capacity discharging to the Refuge will approximately double as pump station S-362, the STA-1E discharge pump station, begins routine operation. Completion of STA-1E represents a significant milestone in the effort to clean up Everglades inflows and restore the Everglades. However, the doubling of instantaneous pumping capacity directed into the Refuge, and the location of the new S-362 discharge adjacent to pristine marsh, coupled with the present reduced efficiency of STA-1W and startup concentration anticipated in proposed permits for STA-1E all serve to heighten concerns about potential increased risk of impact from canal water intrusion. It is, therefore, timely to now consider additional measures that may reduce canal water intrusion and therefore reduce impacts in the Refuge interior.

Conceptual framework - A working hypothesis upon which the proposed operational changes are based is that much of the deleterious impact from pumped stormwater results from intrusion of canal water, often in relatively short-term events. Walker (2004) suggested that these events are analogous to estuarine rising and falling tide events.

Time-series plots of chloride concentration at selected sites in the southern area of the Refuge (Figure 2) are utilized here to examine patterns of canal water intrusion. Chloride concentration provides a useful tracer for canal water movement and mixing because it is, to a close approximation, a conservative material, and because it is elevated in canal water (Figure 2a) and quite low in rain water and rainfall dominated interior sites such as LOX11 and LOX13 (Figure 2b). Patterns of chloride concentration at more impacted sites, LOX12 and LOX14 (Figure 2b), support the hypothesis that canal water does at times intrude into Consent Decree monitoring sites. Qualitative examination of Figure 2b suggests that intrusion may have actually increased in recent years at sites LOX12 and LOX14.

CANDIDATE OPERATIONAL STRATEGIES

This section describes four specific operational strategies that potentially may reduce canal water intrusion and reduce related deleterious impact on the Refuge. Further consideration might identify additional candidate strategies. Prior to implementation, a candidate strategy should undergo a more rigorous evaluation in terms of practical and regulatory constraints, and anticipated positive and negative impacts on the Refuge, other areas of the Everglades, and other stakeholder needs.

- **More frequent outflow structure water quality sampling**

Water quality monitoring at the S-10 and S-39 gates is required by permit conditions. These data are used, however, for a number of non-regulatory purposes. Current sampling relies on grab samples taken at an irregular frequency depending on structure discharge. The sampling protocol at most permitted sites requires grab sampling at least every four weeks, and sampling on the intermediate 2-week date if the structure is flowing on that intermediate date. This protocol results in missing the sampling of many flow events, and results in most samples being collected under no-flow conditions.

From June 1, 2001, to the most recently available DBHYDRO sampling record collected on January 18, 2005, the number of total phosphorus values in DBHYDRO vary from 21 to 63 for these individual sites (see table). This averages from 6 to over 16 samples per year.

Table 1. Total phosphorus sampling history at L-39 structures.

	S-39	S-10A	S-10C	S-10D	S-10E
Number of TP samples in DBHYDRO (6/1/2001 through 1/18/2005)	61	25	21	49	43
Average number of samples per year	16.5	6.7	6.1	13.2	11.6

Data from these sites are used for water quality model calibration and verification, and for loading estimates. Loads of total phosphorus leaving the Refuge are calculated and published each year in the *South Florida Environmental Report* (formerly the *Everglades Consolidated Report*). Because of the frequency of sampling and the fact that most sampling occurs under no-flow conditions, there is considerable uncertainty associated with these load estimates.

Although general spatial and temporal patterns of water quality in terms of total phosphorus and other constituents can be clearly identified from the historic monitoring data collected at structures along the L-39 Levee, the data are not collected at a frequency that supports more detailed studies, including studies targeting development of a better understanding of mechanisms of canal water intrusion. Both SFWMD and Refuge staff have commented that the sampling frequency at these structures results in a high degree of uncertainty in estimates of the concentration time-series.

It is proposed here to initiate a sampling regimen at each of the S-10 gates and at the S-39 gate consisting of flow proportional composite sampling and weekly grab sampling. This enhanced sampling program will result in improved load estimates leaving WCA-1 and entering WCA-2. It will also support model calibration and analysis of canal water intrusion events that transport elevated phosphorus concentrations into the Refuge marsh. Improved understanding of the conditions that lead to intrusion will support future management decisions that optimally protect the Refuge while meeting constraints of water supply and flood control.

- **Improved coordination of inflow pump and outflow gate operations**

It is reasonable to assume that optimal control of outflow gates should be related to real-time pumping and rainfall, and that outflow gate adjustments should be made before significant stage changes have occurred in the Refuge. The desirable speed of reaction to a pumping event can be estimated for specific cases. Consider a situation with the Refuge stage at 15.5 feet (NGVD 29). At this stage, roughly 97,000 acres of the Refuge is inundated (estimated from Fig. 6a in Trimble 1986). If we desire a reaction in gate opening to happen before 0.05 feet of stage change occurs, then the time for 4,850 acre-feet to be pumped into the Refuge provides the critical gate adjustment reaction time. These times are presented in the following table:

Table 2. Relationship between desirable reaction time and total inflow pumping rate at 15.5-foot stage.

Pump rate (cfs)	**Time (Days)**
500	4.9
1000	2.4
2000	1.2

4000	0.6
8000	0.3

Inflow pump capacity from STA-1W is approximately 4000 cfs. With STA-1E added, capacity approaches 8000 cfs. At these inflow rates it may be impossible to manually operate the outflow gates to coordinate flows during future major storm events. Efficient synchronized operation of the S-10 and S-39 gates and the WCA-1 inflow pumps and structures may necessitate installation of remote operation capability at the S-39 and S-10 gates. It is also recognized that there are significant logistical constraints and organizational obstacles to interagency coordination of operations that must be considered in implementation of this strategy.

- **Delay stage rise until after wet-season rain on Refuge begins**

After examining historic patterns of excursions of the Consent Decree levels, Walker (2004) described mechanisms that may lead to canal water intrusion and circumstances that result in highest probability of excursions (Figure 3). Especially at the beginning of the wet season during rising stages, it is conjectured that phosphorus concentration in the impacted marsh may be elevated by the combination of high phosphorus canal water flowing toward the interior and mixing with water that has elevated concentration due to prior evaporative concentration (distillation) and re-wetting of the soil surface.

It is proposed to consider deferring seasonal increase in stage at the beginning of the wet season to a slightly later time. The objective would be to (1) "rinse" the marsh fringe areas with rainfall for a period of time and either export the initial flush of elevated P water to the rim canal (vs. interior marsh) or allow added time for biotic uptake, and (2) collect rainwater in the interior to a slightly higher water surface elevation (stage) which should counter canal water intrusion (e. g. inflowing tide analogy). Under this operational scheme, the S-10 and/or S-39 gates would operate to hold Refuge stage constant during the first major storm event of the wet season. After interior stage had risen (e.g. 0.2 feet at the 1-9 gage), operations would return to normal.

One potential “rule-of-thumb” that could be used as a basis for an operational rule would be to release water during a drainage basin storm event such that rainfall dominates net inflow to the Refuge. Neglecting evapotranspiration and groundwater recharge, this is:

$$V_{in} - V_{out} < A\ R / 12 \qquad (1)$$

where V_{in} is pumped stormwater inflow volume (acre-ft), V_{out} is outflow volume through structures (acre-feet), R is Refuge rainfall (inches), and A is Refuge inundated area (acres). Rearranging this inequality provides the outflow management rule that at all times during a storm event in the early wet season

$$V_{out} > V_{in} - (A\ R / 12) \qquad (2)$$

Prior to adopting this or a similar altered operational strategy, several factors would need to be fully considered:

- Feasibility – Capacity of the outflow structures is a constraint that should be considered. For example, avoidance of 0.2 feet of stage rise when 1/3 of the Refuge (roughly 50,000 acres) is inundated would require the release of 10,000 acre-feet of water. Over a 10-day period, this would require a 500 cfs release. This is well within the capacity of the outflow structures.
- Water quality in WCA-2 or the Eastern Hillsboro Canal – It is not anticipated that this operational change would have a significant effect on downstream water quality. However, these impacts should be quantified prior to implementation of this strategy.
- Ecological impacts – Impacts on Refuge plant and animal communities should be analyzed prior to implementation.
- Relationship to regulation schedule – It is not envisioned, at this time, that this candidate strategy will require amending or deviating from the Refuge regulation schedule. In order to be implemented as quickly as possible, operations proposed here must be shown to be consistent with the current regulation schedule (Neidrauer 2004). Future consideration of regulation schedule revision should consider additional operational alternatives as described here.

➢ **Re-distribution of flows through the S-10 gates**

Four gated structures, S10A, C, D, and E deliver water from the Refuge to WCA-2. Historically, total annual flow through these gates (Figure 4a) has varied depending on basin rainfall, water management decisions, and infrastructure changes such as the 2001 diversion of the S-6 pump station discharge. Although the total flow via the S-10 gates must be consistent with a number of constraints including the Refuge and other regulation schedules, the distribution of flow among the gates is not prescribed. The pattern of utilization of the 4 gates has varied (Figure 4b). The S-10E gate was constructed by the State of Florida to provide water to western WCA-2. After the S-10E began discharging in 1985, this additional volume of canal water was delivered to WCA-2 from the western portion of the L-39 Canal. Since mid 1997, these deliveries to WCA-2 using the S-10E have stopped. Since 1997, the S-10A and C gates have delivered slightly more of the volume of discharge than was the case in years when the S-10E was used.

Distribution of flow through the S-39 and individual S-10 gates may influence Refuge marsh water quality. Water quality monitoring in the headwater area of the gates reveals a gradient of total phosphorus often exists from the highest values at the more western S-10E and S-10D, to lowest values at the more eastern S-10A (Figure 1). That is, it appears from water quality monitoring data, that the S-10D discharges more pumped stormwater while the S-10A discharges more rainwater drawn for the Refuge interior. This observed pattern implies that preferentially discharging from the S-10D might reduce impact on the pristine areas of the refuge by bypassing more stormwater south into the already impacted area of WCA-2. The Refuge's hydrodynamic and water quality model will be used, when available, to evaluate alternative gate operation scenarios that may be more protective of pristine Refuge areas. Further analyses associated with this candidate strategy must estimate not only the positive impact on the Refuge, but also quantify any negative impact on WCA-2.

It has also been suggested that intensive field studies associated with controlled gate opening events might support better understanding. Such studies should be considered as soon as practical. When STA-1E becomes fully operational, this proposed strategy should be reexamined and adapted to fit this new condition.

CONCLUSIONS AND ADDITIONAL RECOMMENDATIONS

Operational strategies selected within constraints to reduce water quality impacts and enhance restoration may provide timely benefits without necessitating large financial investments. Although such strategies are unlikely to provide more than a small part of needed improvements, further investigation of these strategies is clearly warranted. It is important to now pursue these strategies aggressively because recent performance of STA-1W has been degraded, and total phosphorus concentration in discharges from STA-1W and STA-1E in the near future are unlikely to be close to the 10 ppb goal.

This paper has not exhaustively examined all operational strategies that may be beneficial. Future consideration should, for example, be given to the possibility of coordinating discharge from STA-1W and STA-1E in an effort to minimize intrusion. Both modeling and monitoring will support this deliberation. Before implementation of any of the candidate strategies presented here, consideration should be given to the adequacy of the monitoring network and models for assessment of the success or failure of the strategy.

Adaptive management is dependent on monitoring and analysis. The initial analyses presented here would not be possible without the legacy of monitoring that is available. As we move forward in efforts to protect and restore the Everglades it is essential that monitoring and modeling efforts continue, and in some cases expand, to support the best management decisions within constraints of practicality and budget.

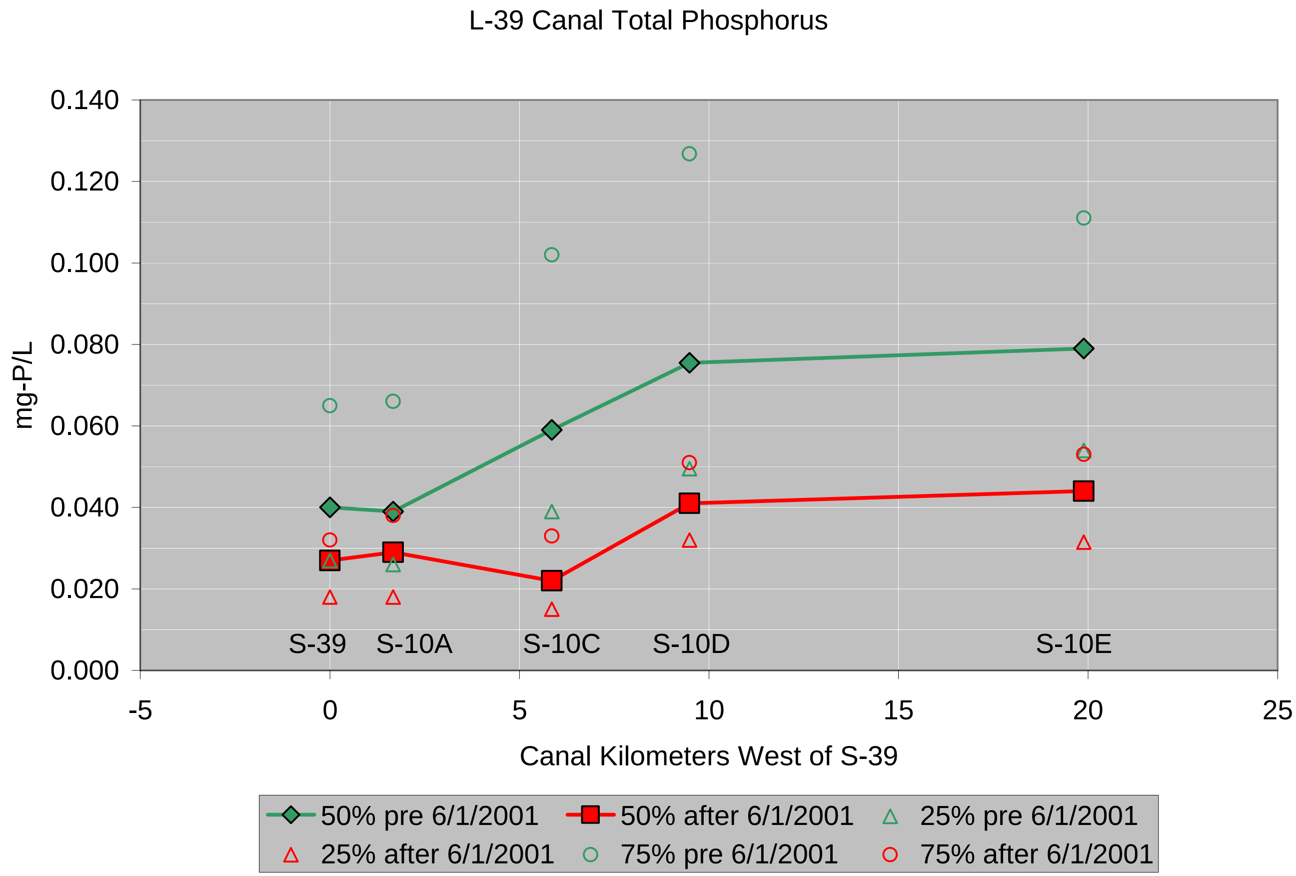


Figure 1. Historic patterns of total phosphorus concentration along the L-39 Canal measured at outflow structures. The figure presents the 50 percentile (median), 25 percentile (1st quartile), and 75 percentile (3rd quartile) for sampling prior-to and after diversion of the S-6 pump (data from DBHYDRO).

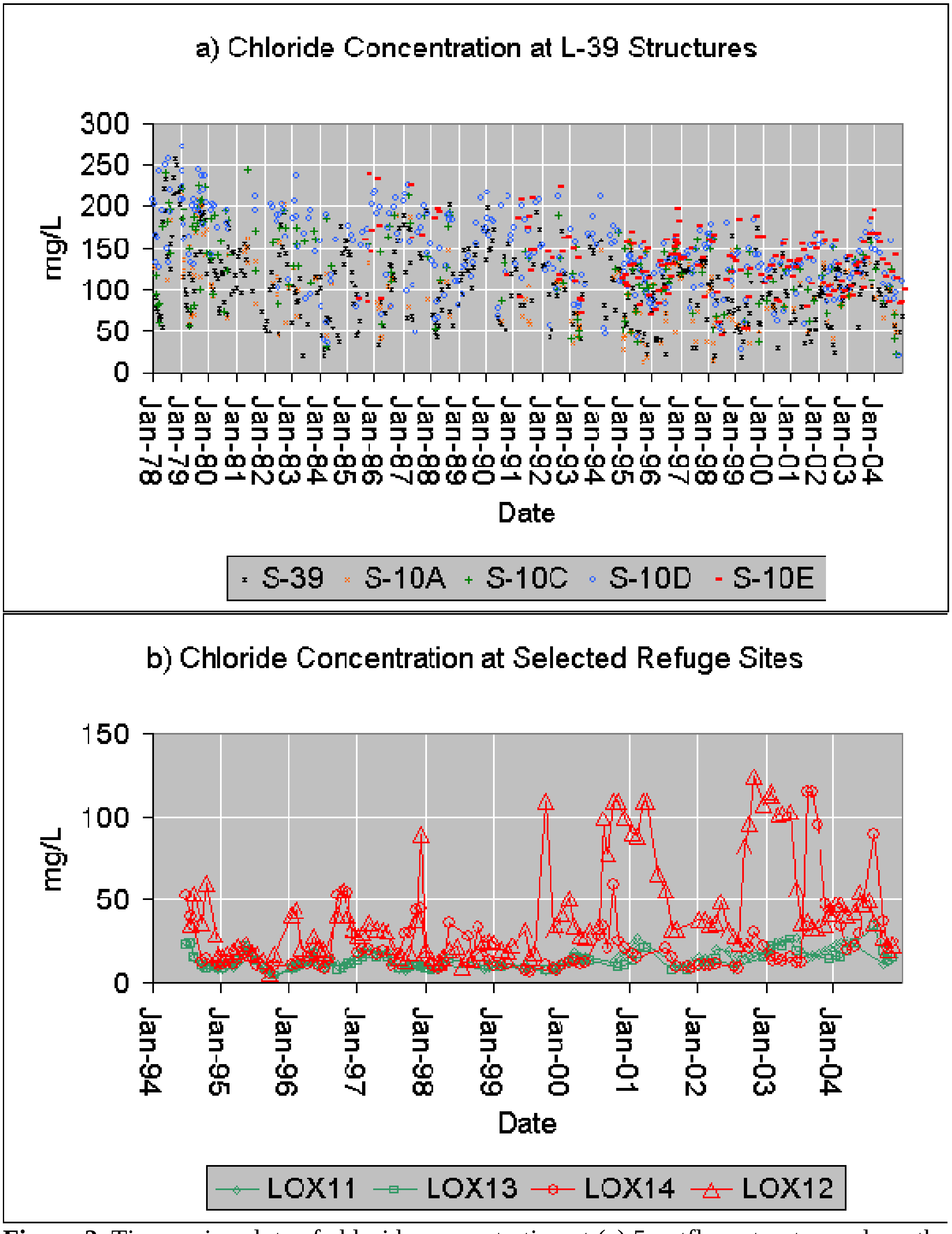


Figure 2. Time series plots of chloride concentration at (a) 5 outflow structures along the L-39 Levee, and (b) at two sites relatively unimpacted by intrusion (LOX 11 and 13), a moderately impacted (LOX 14), and a more heavily impacted site (LOX 12). All sites are in the southern area of the Refuge (data from DBHYDRO).

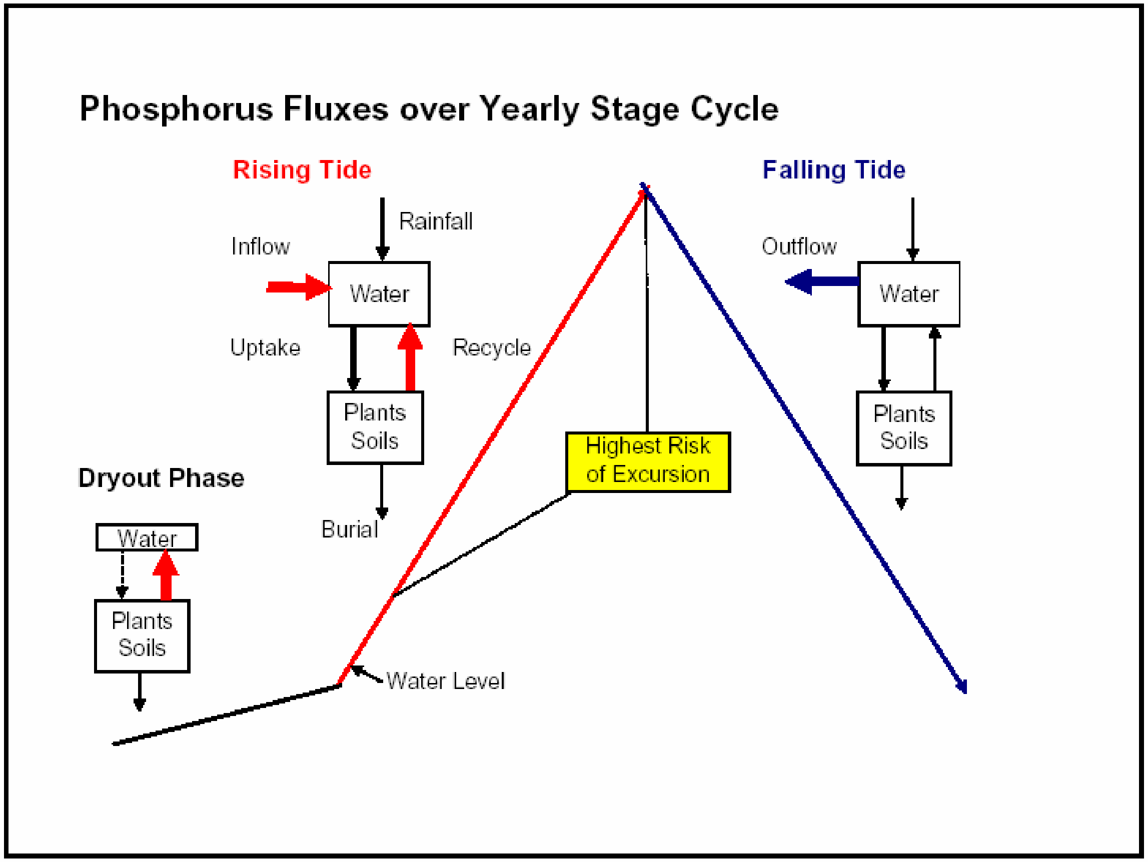


Figure 3. Conceptualization of mechanisms of canal-interior phosphorus exchange, cycling, and excursion risk (Walker 2004).

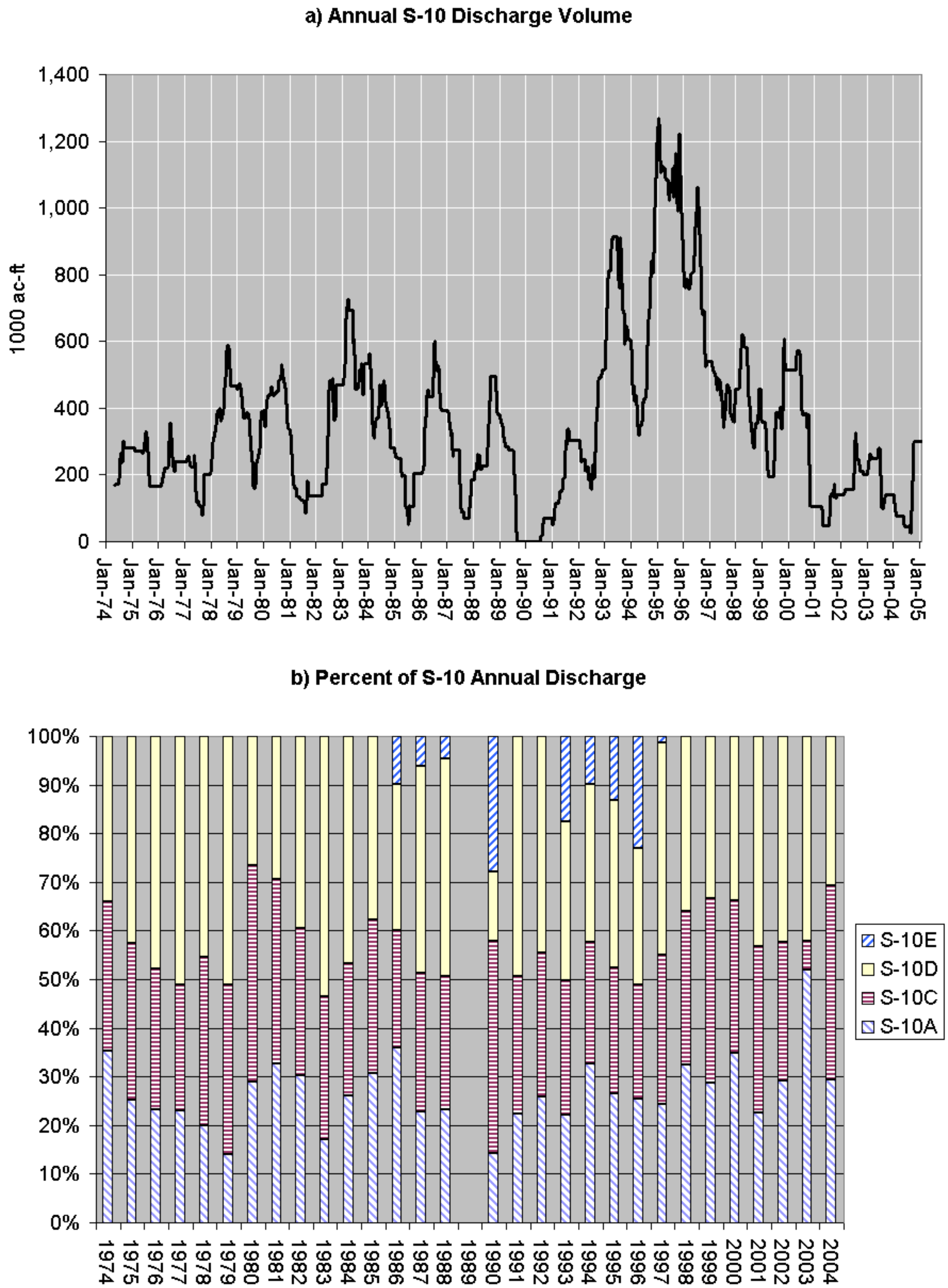


Figure 4. Discharge through the S-10 gated structures over the available period-of-record (data from DBHYDRO). (a) One year rolling total volume, and (b) percent of calendar year discharge volume by gate.

CITATIONS

Neidrauer, C. J. (2004). "Water Conservation Area Regulation Schedules." *available at* <*http://www.sfwmd.gov/org/ema/toc/archives/082604/wca_schedules_082604.pdf*>.

Trimble, P. (1986). "South Florida Regional Routing Model." *Technical Publication 86-3*, South Florida Water Management District, West Palm Beach, FL.

Walker, W. W. (2004). "Analysis of Refuge Interim P Level Excursions September 2003 & August 2004." *available at* <*http://www.sfwmd.gov/org/ema/toc/archives/110804/refuge_excursions_110804.pdf*>, prepared for the US Department of Interior.