DRAFT - TOC Preliminary Recommendations for Further Investigations of the Relationship Between Water Management and Water Quality

May 17, 2005

Direction from Principals: Analyze 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.

Time frame: Prepare a report to the Principals by June 2005

Outline with Insertions from Contributing Agencies

1. Backdrop: Settlement Agreement water quality compliance
    a. Refuge
        i. Interim levels
        ii. Long-tem levels
        iii. load reduction targets
    b. ENP
        i. Shark River Slough
            1. interim limits
            2. long-term limits
        ii. Taylor Slough and Coastal Basins
            1. long-term limit
    c. WCAs
        i. load reduction targets

2. Analyze current water management practices that influence Settlement Agreement water quality compliance
    a. Lake Okeechobee regulation schedule – Water Supply and the Environment (WSE)
    b. WCA-1 regulation schedule
    c. WCA-2A regulation schedules
    d. WCA-3A regulation schedule
    e. Everglades National Park
        i. Operations for the modified water deliveries to ENP
        ii. C-111 operations
        iii. Interim Operating Plan (IOP)
        iv. Combined Structural and Operational Plan (CSOP) - Cape Sable seaside sparrow

Background document contributed by Mike Zimmerman on ENP water quality

In 1989, Congress passed the ENP Protection and Expansion Act. The purpose of the Act was twofold: (1) Purchase and incorporate the 109,000 acres of Northeast Shark Slough (NESS) into ENP and (2) implement structural modifications to the C&SF Project to restore the natural hydrologic conditions within ENP. This became the Modified Water Deliveries Project that is designed to restore the Shark Slough basin. A major objective of this project is to improve water deliveries to ENP by restoring WCA-3B and NESS as a functioning component of the historical Shark Slough hydrologic system. Two gated levees (S-355A and S-355B) have already been built within the L-29 levee on the southern boundary of WCA-3B. Other components of this project include a hydrologic connection between WCA-3A and WCA-3B, rising of Tamiami Trail, and the flood mitigation component for the 8.5 SMA.

In 1994, Congress authorized modifications to the C&SF Project features within the C-111 basin (C-111 Project) to address problems associated with water deliveries on the east side of ENP. The primary purpose of the C-111 Project, according to the C-111 General Reevaluation Report is restoration of the ecosystem in Taylor Slough and the Eastern Panhandle of ENP while maintaining the level of flood protection existing prior to construction of the features associated with the C-111 Project recommended plan. The concept was to build features in the C-111 Canal and adjacent areas to contain the seepage losses from ENP. Two pumps (S-332B and S-332C) have been constructed into the C-111 canal, and one pump (S-332D) has been constructed into the L-31W canal. Associated reservoirs and flow ways to the pumps have been constructed; some of which discharge into ENP.

In response to the drought conditions of the 1960's, Congress authorized a set minimum allocation of water from the C&SF Project for Shark Slough (ENP), as well as Taylor Slough and the Eastern Panhandle drainage Basins within ENP. This management approach, often referred to as the minimum delivery schedule, was active from 1970-1983. The minimum allocations were based on average monthly flow volumes from 1939-1960 that existed prior to the construction of the WCAs. However, these minimum volumes were routinely exceeded due to regulatory discharges designed to ensure that water levels in the upstream reservoirs were maintained within the range necessary to meet water supply and flood control requirements. Large regulatory water releases, in great excess of the prescribed minimum, resulted and caused rapid changes in hydrologic conditions within the downstream ENP and disastrous ecological consequences, including the flooding of eggs within alligator nests, and the abandonment of nestlings within wading bird colonies.

Since many of the problems associated with the management of water deliveries to ENP reflect the fact that the jurisdictional boundaries of ENP were not coincident with the historic drainage patterns in South Florida. Congress authorized the establishment of "The Experimental Program of Water Deliveries to Everglades National Park" which lasted from 1984 to 1999. The goal of this experimental program was to modify the schedule of delivery of water to ENP and conduct experimental deliveries for the purpose of determining an improved schedule of water deliveries.

In February 1999, the U.S. Fish and Wildlife Service (FWS) issued the final Biological Opinion for the Modified Water Deliveries Project, the C-111 Project, and the Experimental Program of water deliveries to ENP. The FWS found that the hydrological impacts associated with the Experimental Program if continued, would likely jeopardize the continued existence of the Cape Sable Seaside Sparrow (CSSS) and adversely modify its critical habitat. In response, the USACOE initiated two plans designated Interim Structural and Operational Plan (ISOP) 2000 and 2001, followed by the Interim Operational Plan (IOP), designed to protect the endangered CSSS until completion of the Modified Water Deliveries and C-111 Projects. The purpose of the ISOP and IOP structural and operational modifications was to move water away from western Shark Slough, which was too wet for CSSS nesting, to regions of the Rocky Glades and Taylor Slough on the east side of ENP, which were too dry for maintenance of CSSS habitat. Shark Slough water in WCA-3A was diverted through S-333 and S-334 into L-31N Canal. These waters were then subsequently discharged through new pump stations, S-332B, S-332C, and S-332D into newly constructed detention areas of the C-111 Project entering Taylor Slough and the Coastal Basin of ENP.

At present, FWS, USACOE, ENP, and SFWMD staff are developing a Combined Structural and Operational Plan (CSOP). This plan will integrate and possibly modify the structural components of Modified Water Deliveries and C-111 Projects into an operational plan that will protect the CSSS and complete the restoration objectives of these projects.

End Zimmerman document on ENP water quality

- f. Other C&SF practices
  - i. flood control
    1. EAA interim action plan
    2. C-51W basin
    3. L-8 basin
    4. Other basins' operations
  - ii. water supply
    1. meeting environmental water supply demands of WCAs
    2. meeting water supply demands of Lower East Coast (LEC)
       - a. agreements with local drainage districts
- g. STA operations
  - i. STA-1E/STA-1W
  - ii. STA-2
  - iii. STA-3/4
  - iv. STA-5
  - v. STA-6
- h. CERP components
  - i. L-8 basin rock pits

3. Analyze opportunities to alter water management to improve water quality while maintaining water quantity benefits
   - a. Near-term initiatives
     - i. Integrated STA-1E/STA-1W operations
       1. Finalize DEP permit *(DEP to lead effort)*
       2. Develop phased STA-1E operation plan *(DEP/SFWMD to lead effort)*
          - a. Flexibility to incorporate future operations

b. Integrate with STA-1W (and G-311) operation
c. S-155A divide structure operation plan
d. Integrate with L-8 basin operation (CERP project)

The following is from Gary Goforth based on multiple meetings and telephone conferences with Refuge staff, ENP staff, Corps staff and consultants.

Draft - Critical Components of the Interim Operation of STA-1E – 4/5/5

Objective: To develop a set of principles for operating STA-1E that integrates the water quality, flood control and water supply needs of the region, and recognizes the anticipated changes in the regional water management system over the next 10 years. ***Without such a set of principles, instead of improving the present water quality conditions in the Refuge, the operation of STA-1E could actually worsen the situation.***

Background: Flows and phosphorus loads entering the Everglades through the A. R. M. Loxahatchee National Wildlife Refuge have been higher than anticipated in the 1994 Conceptual Design of the Everglades Construction Project. This is due in part to a delay in the diversion of L-8 Basin runoff away from the Everglades, more releases from Lake Okeechobee for water supply and regulatory purposes, and more inflows than anticipated from sources upstream of S-5A. STA-1E was designed to work in concert with STA-1W and capture approximately 100,000 AF/yr of water that is presently lost to tide. The integrated STA-1E & STA-1W operation plan should contain the following:

1. Discharge of untreated water into the Refuge through the G-300 & G-301 structures should be terminated to the maximum extent practical by diverting the flow through the G-311 structure for treatment in STA-1E prior to discharge to the Refuge, or for discharge to the C-51W canal by gravity through the S-319 pump station and discharge to tide or meet downstream water supply demand.

2. Presently about 50,000 AF/yr of L-8 Basin is being discharged to the Refuge, either after treatment or untreated. In addition, about 150,000 AF/yr is discharged to tide through the C-51 Canal. Until the L-8 basin runoff is diverted north into the proposed CERP project, the S-155A divide structure should be operated to pass at least the same volume of stormwater to tide as L-8 presently discharges to C-51. This will be a mixture of L-8 and C-51W basin runoff.

3. STA-1E and STA-1W should be operated in an attempt to keep their inflows within the range anticipated in the design of enhancements, with an expected mean inflow of ~ 165,000 AF/yr for STA-1E and ~ 180,000 AF/yr STA-1W. These mean inflows include the anticipated diversion of approximately 35,000 AF/yr of runoff from the Acme Basin B into STA-1E. ***Until L-8 is fully diverted, flows to STA-1E and STA-1W will likely exceed their design range.***

4. The PSTA demonstration project constructed in Cell 2 will be operated in an attempt to treat the same hydraulic and nutrient unit loading that STA-1E was designed for.

5. Until the L-40 improvements are completed *and shown to be effective*, and except under upstream flooding conditions, discharges from STA-1E should be limited to minimize impacts to presently unimpacted area of the Refuge.

6. **There is uncertainty surrounding the expected performance of the proposed L-40 canal/bank improvements to minimize movement of STA-1E discharges into the unimpacted areas of the Refuge. Additional modeling is needed to estimate this benefit. In order to better understand potential water quality impacts associated with the intrusion of treated water into the interior marsh of the Refuge, collection and analysis of hydrological and certain water quality data will be conducted by the USFWS and the South Florida Water Management District before and during the initial operation of STA-1E. The STA-1E operation plan should be reviewed and revised periodically based on downstream monitoring and upstream levels of service.**

3. Inflow and outflow pump station operation – more continuous instead of 8-hr peak pumping. (*SFWMD to continue working with upstream landowners to implement continuous pump operation. No data analysis anticipated beyond routine monitoring associated with STAs and enhanced monitoring and hydrodynamic modeling of Refuge.)*
4. Meeting water supply demands of LEC by moving more water around the Refuge to the C-51 canal – limited at the present time to ~500 cfs. (via G-311) (*DEP/SFWMD to lead effort)*

ii. Temporary deviation fromWCA-1 regulation schedule *(effort underway led by Corps; Corps to provide estimates of time frames)*

1. Reduce the time period for preceding water supply deliveries. Under some conditions, the refuge water regulation schedule requires that an equivalent volume of water be supplied to the refuge must preceding water supply deliveries from the refuge. There is now a concern that under high stage conditions this process may enhance movement of phosphorus into and across the impacted fringe marsh as a result of water level fluctuations. At present, water supply accounting is routinely performed on a seven-day cycle. It has been suggested that this period be reduced to a daily accounting, or that the regulation schedule be revised to allow simultaneous inflow with water supply deliveries. However, the shorter time frame may impose the requirement to send untreated water to the Refuge, in recognition that the residence time of water going through the STA is generally a week or more. Since December 2004, Calvin J. Neidrauer, Chief Engineer in the Water Control Operations Section, South Florida Water Management District, has been providing regular detailed water supply accounting to refuge and SFWMD personnel. These reports will support an evaluation of the need for alteration of water delivery procedures. *Note – The above*

item could be part of the evaluation described in A.4. in the draft Progress Report.
SFWMD to report on feasibility of reduced accounting time frame

2. Avoid water supply releases in the periods when the regulation schedule is increasing. This practice forces replenishment of the release by new inflows from the rim canal in order to satisfy the regulation schedule. *In Section A.1.a.#6., an update was given on the request for a temporary deviation from the Regulation Schedule.*

On April 22, 2005, based on the information analyzed in the Environmental Assessment and Finding Of No Significant Impact and pertinent data obtained from Federal and State agencies having jurisdiction by law and/or special expertise, and information obtained from the interested public, Col. Carpenter of the US Army Corps of Engineers concluded that the considered action would have no significant impact on the quality of the human environment and does not require an Environmental Impact Statement.

Reasons for this conclusion are, in summary:

a. The goal of the temporary deviation is to minimize the potential increase of phosphorus load in the Arthur R. Marshall Loxahatchee National Wildlife Refuge, which may result from the current WCA-1 regulation schedule.
b. The action will not adversely affect the balance of authorized purposes of the Central and Southern Florida Project for flood control, water supply, fish and wildlife conservation, and recreation.
c. The action will not adversely affect the overall existing habitat in the area.
d. The action will not adversely affect any endangered or threatened species or critical habitat under the Endangered Species Act.

iii. More frequent operation of S-10 gates (*DOI to prepare paper describing anticipated benefit/operation. If TOC agrees, COE will report back on the feasibility of these operations.)*
See attached briefing paper from DOI, April 2005

iv. More frequent water quality sampling at the S-10 gates
(DOI to prepare briefing paper describing anticipated benefits.)
See attached briefing paper from DOI, April 2005

v. A related water quality/operations issue deals with the distribution of flow through the individual S-10 gates. Water quality monitoring in the headwater area of the gates reveals a strong 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. 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 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. STA-2 discharges to the area historically "fed" by S-10E, and a system-wide balance is needed. The refuge 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. It has also been suggested that intensive field studies associated with controlled gate opening events might support better understanding.

Note – The above items could be part of the evaluation described in A.4.in the draft Progress Report.

(*DOI to prepare briefing paper describing anticipated benefits.)*

See attached briefing paper from DOI, April 2005

vi. Investigate, and if appropriate, avoid "reversal" in the stage. In some years (1999, for one), the stage was suddenly dropped during a period with the regulation schedule was still increasing and then subsequently increased back to the original stage to satisfy the schedule. This could effectively double the intrusion of canal water in some years. The reasons for this are unclear (possibly draw-down in anticipation of large storm events so that the Refuge can function as a flood storage facility?). (*DOI to prepare briefing paper.)*

See attached briefing paper from DOI, April 2005

vii. Water supply

viii. Place holder for balancing flows and loads EPA wide, including role of EAA Feasibility Study

Action items: future topic

b. Long-term initiatives

i. Revisions to regulation schedules

Action item: COE to provide summary of time frames associated with revisions to regulation schedules

1. WCA-1 *(Action item – Susan Sylvester)*

a. Consider deferring the seasonal increase in stage until later in the wet season? The objective would be to "rinse" the marsh fringe areas with rainfall for a period of time and export the initial flush of elevated P water to the rim canal (vs. interior marsh).

(The Refuge will develop a briefing paper)

See attached briefing paper from DOI, April 2005

Explore developing a rain-driven regulation schedule, under which the seasonal maximum stage would be related to rainfall (vs. fixed). A fixed stage requires more inflow from the rim canal in dry years, whereas rainfall satisfies more of the demand in wet years. This is probably the only way to deal with marsh water quality impacts associated with hardness, chloride, and other conservative substances that cannot be reduced by BMP's or STA's. *(SFWMD to provide technical report in support of this.)*

Status of Rainfall Driven Regulation Schedule for the Refuge (Scott Huebner, 4/7/05)

There have been no technical investigations undertaken by the SFWMD to explore development of a regulation schedule for the Refuge (WCA-1) that would establish seasonal maximum stages based on rainfall amounts. The only known work for WCA-1 was over ten years ago and was done as part of hydrological modeling tests associated with the SF Water Management Model. Future development using this approach as not sought at that time by Refuge staff. However, modeling work similar to this has been done for WCA-2 and WCA-3 in conjunction with CERP planning, specifically the without project conditions projection for 2050.

The foregoing is based on personal communications to Scott Huebner with C. Neidrauer, A. Ali, D. Swift and L. Cadavid, SFWMD, and M. Waldon, USFWS. Cal Neidrauer also suggests that 'Everglades Rainfall-Driven Operations' (ERDO) is the term used in CERP and Water Supply Planning. The concept is to base inflow and releases for an area on rainfall level at selected gage sites called 'trigger gages'. This is a significant departure from the current calendar-stage driven regulation schedules.

b. Synchronized operation of the S-10 gates and the WCA-1 inflow structures, which will require remote operation capability of the S-10 gates. Would require synchronized operation of structure on the east and west side of the Refuge. (*DOI to prepare briefing paper.)*

See attached briefing paper from DOI, April 2005

ii. Explore L-40 low berm extension on west side of L-40 and/or enhancement from G-300 to south of the G94A structure (or S-39); structure at this point to allow delivery of water either to LWDD or into L-40. This enhancement would allow for (~500 cfs) water supply deliveries to southeast Palm Beach County without impacting the Refuge interior. (*Lake Worth Drainage District to develop briefing paper.)*

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.

End Briefing Paper from Patrick Martin

iii. Other initiatives

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.

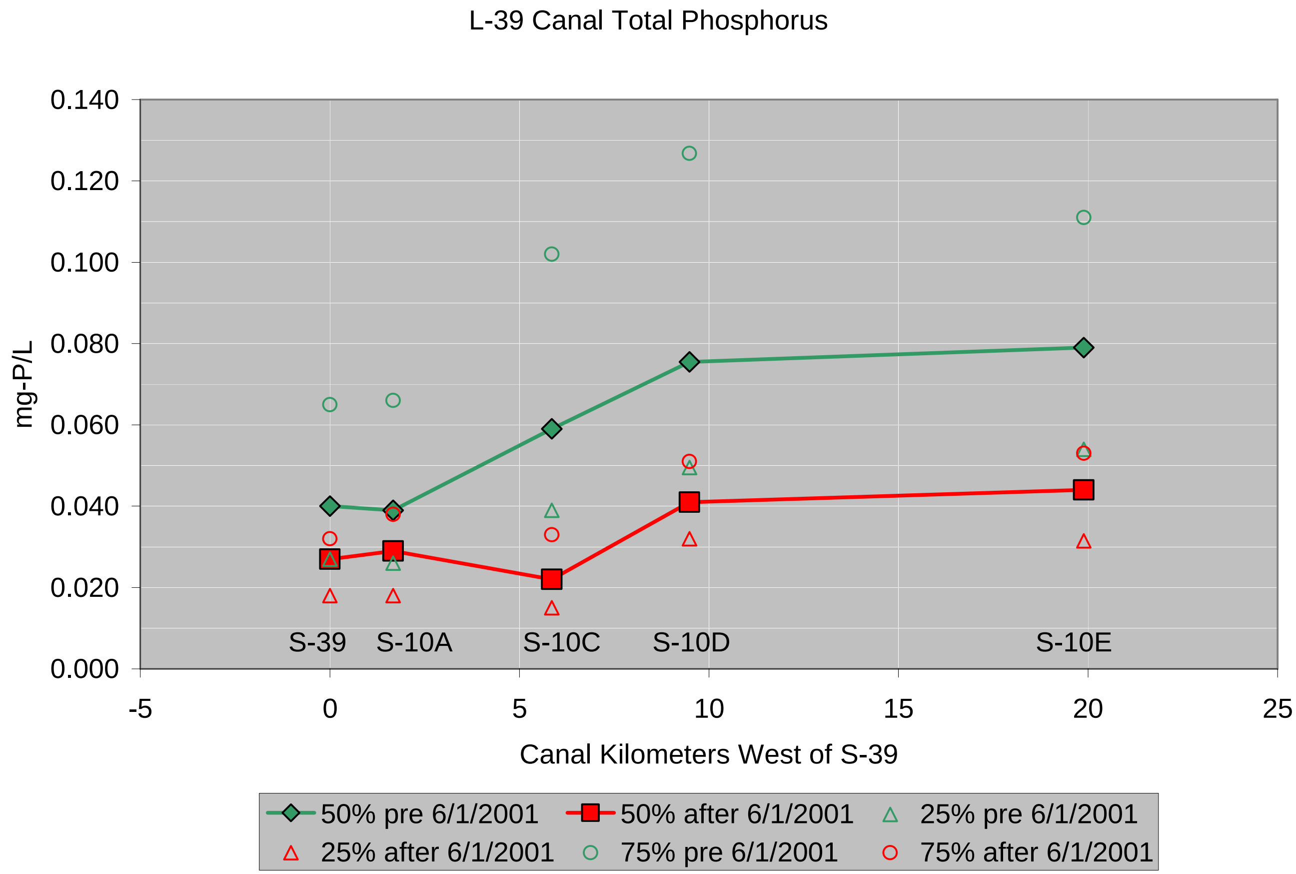

Figure 1. Historic patterns of total phosphorus concentration along the L-39 Canal measured at outflow structures. The figure presents the 50 percentile (median), 25 percentile (1st quartile), and 75 percentile (3rd quartile) for sampling prior-to and after diversion of the S-6 pump (data from DBHYDRO).

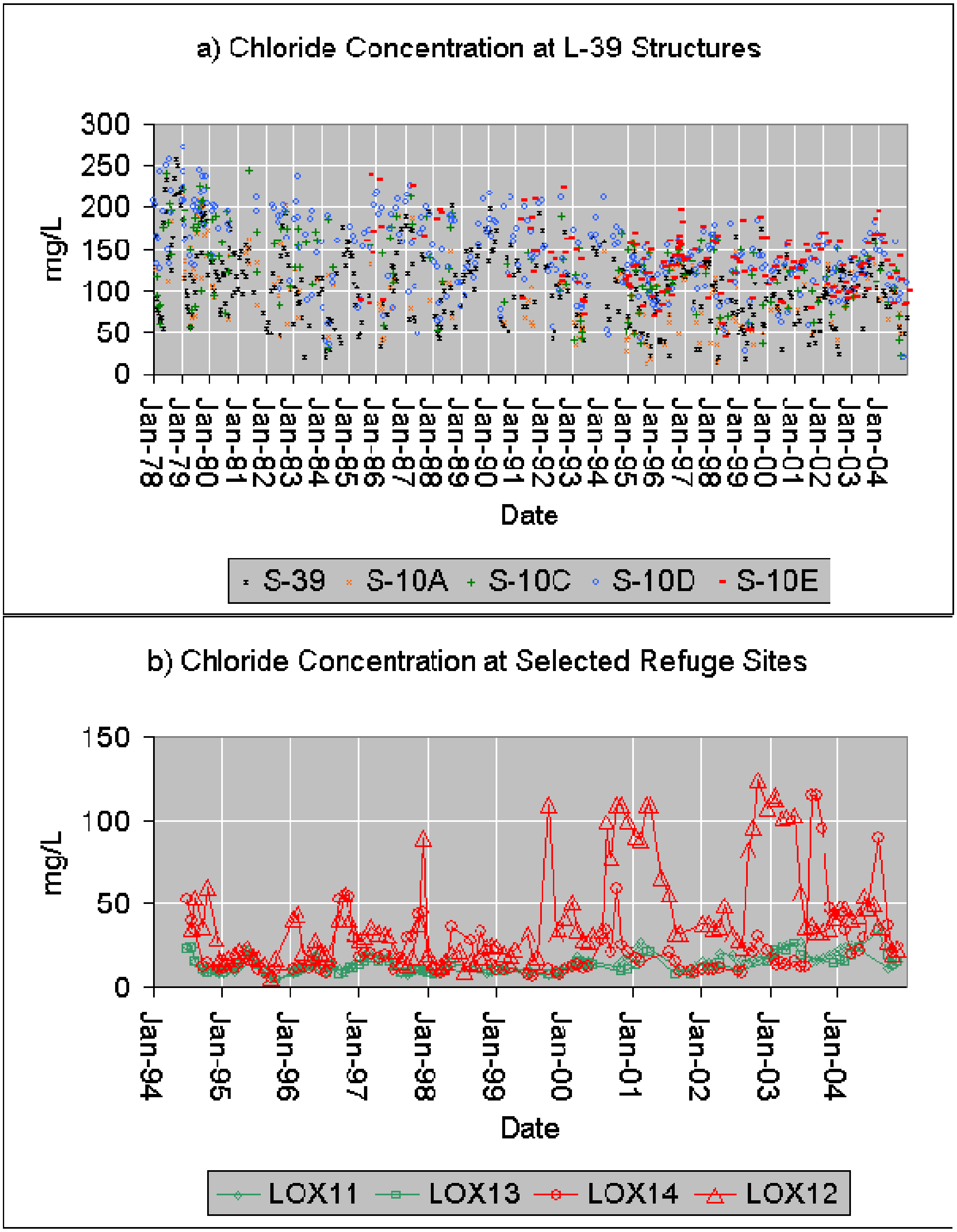

Figure 2. Time series plots of chloride concentration at (a) 5 outflow structures along the L-39 Levee, and (b) at two sites relatively unimpacted by intrusion (LOX 11 and 13), a moderately impacted (LOX 14), and a more heavily impacted site (LOX 12). All sites are in the southern area of the Refuge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

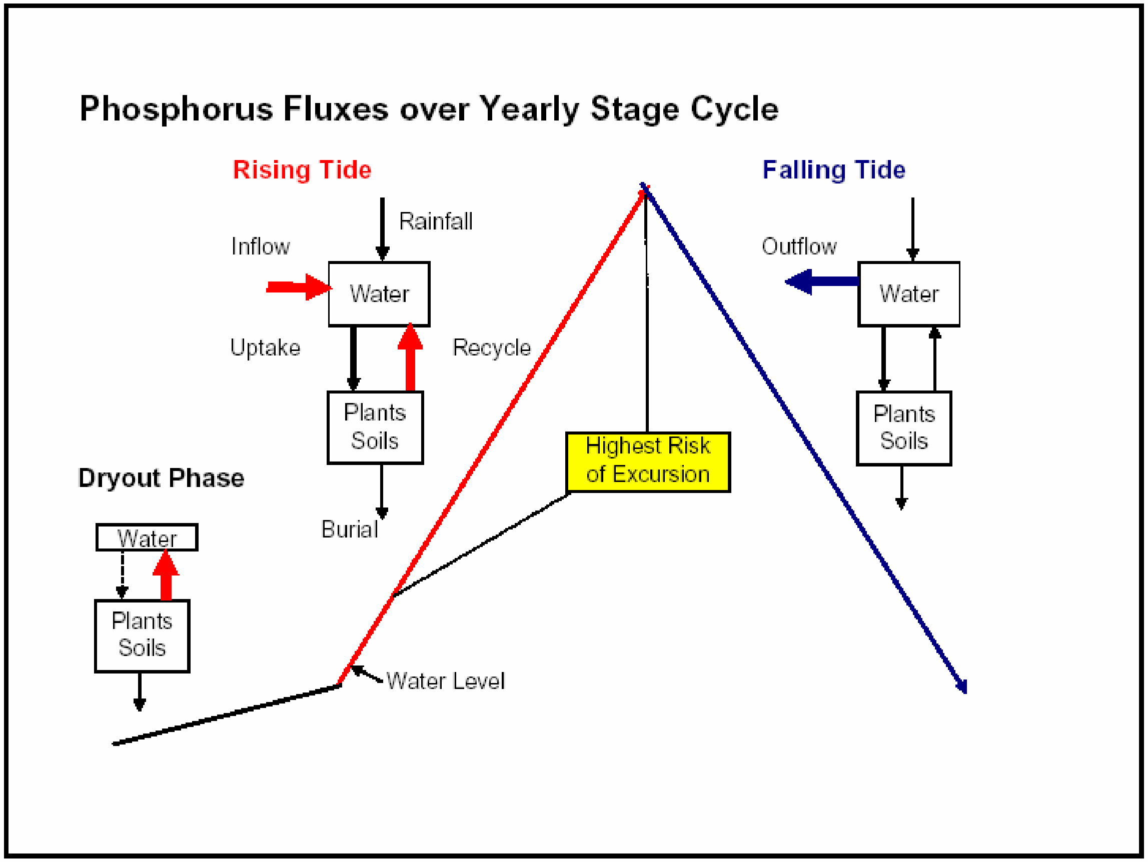

Figure 3. Conceptualization of mechanisms of canal-interior phosphorus exchange, cycling, and excursion risk (Walker 2004).

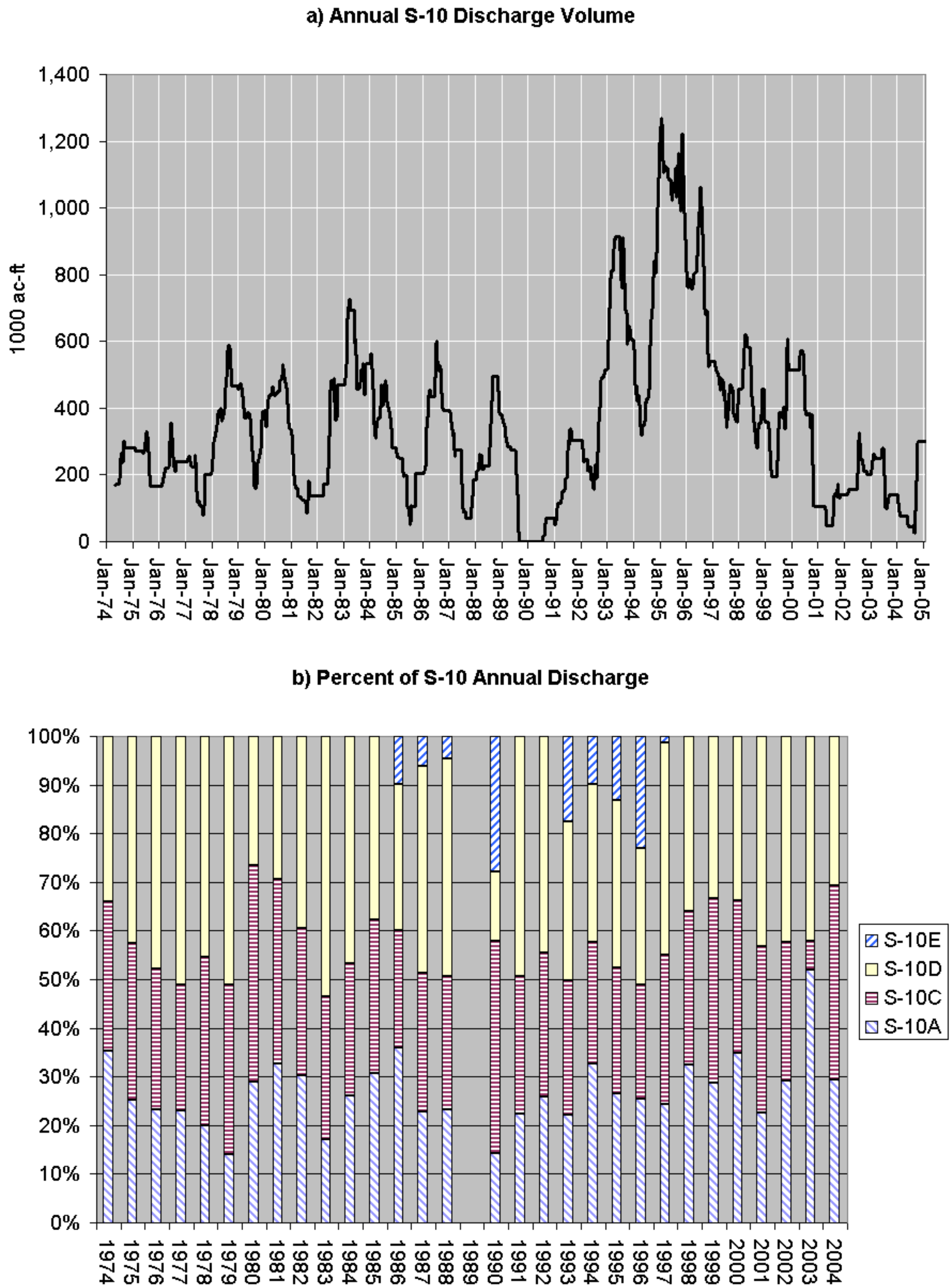

Figure 4. Discharge through the S-10 gated structures over the available period-of-record (data from DBHYDRO). (a) One year rolling total volume, and (b) percent of calendar year discharge volume by gate.

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.