Responses to
NRC Everglades Committee Follow-Up Questions
on Mass Balances and STA's

Prepared for
U.S. Department of the Interior
by
William W. Walker, Jr., Ph.D
bill@wwwalker.net

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My initial responses to NRC questions in September 2009 are attached. Following are responses to two additional questions received from Stephanie Johnson on Nov 10:

1) In your responses, you said: "At recent basin runoff concentrations and lake concentrations, it is estimated that total treatment area would have to be doubled in order to meet QBEL levels while providing flows currently contemplated under the ROG initiative. Reducing source TP concentrations (additional BMPs) would reduce treatment area requirements."

Could you elaborate on this statement, and the assumptions involved?? What are the "flows currently contemplated" compared to current flows? What is your assumed treatment effectiveness per acre of STA (lb P removed per acre or some other metric?)? What is this based upon?"

My statements were based upon a preliminary evaluation performed for the Department of the Interior (DOI) regarding treatment capacity needed to support hydrologic restoration. The analysis was based upon flows and P loads projected by SFWMD, updated to reflect recent increasing trends in the phosphorus concentrations in Lake Okeechobee and runoff from one EAA basin (S5A, discharging into WCA-1 on eastern side of EAA).

Three basic flow scenarios were considered:

A. Florida's Long-Term Plan, 2003, updated in 2007; adjusted to reflect all flows discharging into the northern WCAs; design flows include ~240 kac-ft/yr of additional Lake Okeechobee release to the Everglades above historical values.

B. Base planning scenario considered in the "River of Grass" (ROG) initial planning process ("Test 0", approximates current conditions, no additional Lake releases)

C. Hypothetical Restoration Scenario ("Performance Plan"), as developed by the Everglades Foundation in the initial ROG Planning Process; comes closest to meeting restoration flow targets within various constraints; similar to DOI's initial design concepts with respect to objectives and scope (see attached figure)

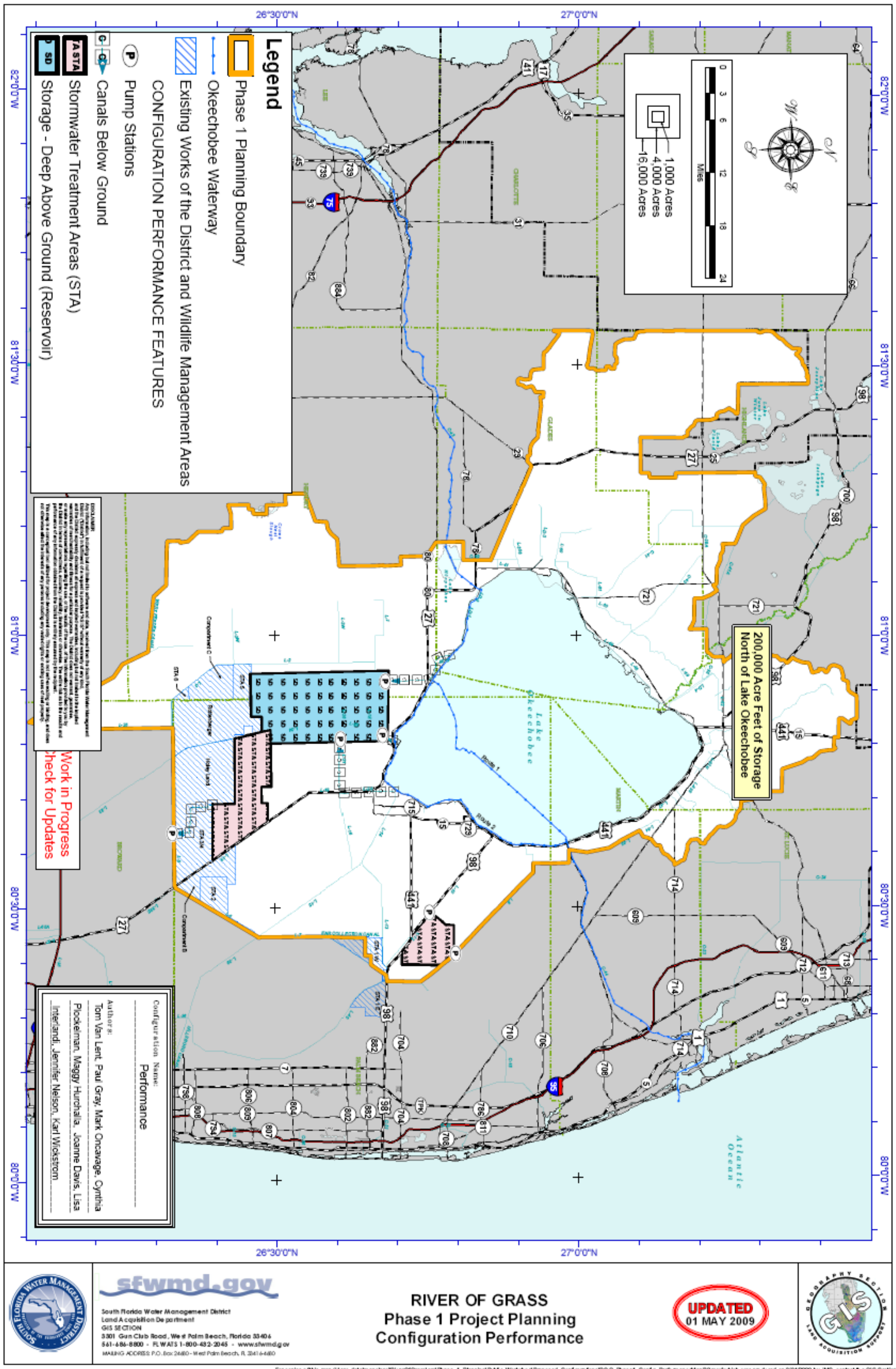
The analysis was performed by basin. Flow assumptions and overall treatment area requirements are summarized below:

Variable	Units	Long-Term Plan	Restoration Base	Restoration Plan
Flow to Everglades	kac-ft/yr	1,860	1,380	1,910
Effective Treatment Area				
Currently Planned	k-acres	57	57	57
To Meet QBEL (17 ppb)	k-acres	111	82	116

While STA inflow concentrations and loads vary by basin and scenario, the combined inflow TP concentration is approximately 145 ppb for each scenario. The average unit area TP load (inflow load / effective treatment area) is ~0.74 g/m^2-yr for each scenario.

Treatment area estimates are based upon a simplified version DMSTA that predicts long-term performance based upon average inflow volumes and loads. The screening model was calibrated to output from DMSTA daily simulations and observed STA performance data. It was developed to support rapid screening of alternatives that would be subsequently evaluated with more detailed basin hydrologic modeling and full DMSTA simulations.

Model standard error is on the order of 12%. Forecast uncertainty is greater because of uncertainty in the assumed inflow volumes and P loads. Treatment area requirements would also be influenced by other factors not considered in the screening exercise, such as variations in assumed BMP performance, assumed Lake P concentrations, reservoir design and operation to reduce variability in STA inflows, additional capacity for STA maintenance, land requirements for STA engineering components, trends in basin TP concentrations, etc.



Restoration Scenario Developed by the Everglades Foundation in ROG Planning Process.
Existing STAs & Wildlife Management Areas (cross hatch), Expanded STAs (pink), Reservoir (blue).

https://my.sfwmd.gov/portal/page/portal/common/newsr/rog_config_data/rog_phase1_config_performance_r2.pdf

"2) In your final paragraph, you mentioned the issue of Ca and it's relationship with STA performance. The committee would like to understand this better and exactly why Ca is decreasing in inflows. What is the mechanism of Ca in P uptake? Why are the Ca levels decreasing in inflows? Is this a major concern? Can it be remedied?"

See discussion of STA performance relative to calcium at http://wwwalker.net/dmsta/calibration.htm#results.

Co-precipitation with calcite is an important mechanism for P removal in the STAs, particularly for submersed vegetation and periphyton communities that perform best at low TP concentrations. The mechanism was also important historically in Lake Okeechobee, where loss of P assimilative capacity has been partially attributed to a decrease in calcium levels following diversion of calcium-rich runoff from the EAA south the Everglades.
http://wwwalker.net/okee/okee_tmdl_report_www_final_dec2000.pdf

Average inflow calcium levels vary from ~70 to ~100 ppm across the STAs. They depend primarily on the percentage of inflow from EAA runoff (Ca ~ 100 ppm) vs. other sources (Ca ~ 40 ppm, Lake Okeechobee, C-139 agricultural basin). Calcium concentrations above ~40 ppm are needed to drive calcite precipitation.

While "trends" in STA inflow calcium have not been observed historically, it is likely that they will decrease in the future as additional flows are released from Lake Okeechobee for restoration purposes. Further decreases could result from calcium removal in storage reservoirs. Future decline in calcium is a particular concern for STA-34, which treats nearly all of the Lake releases. Despite that, STA-34 P removal performance has been superior to the others, both with respect to outflow concentration and effective P settling rate. Good performance is likely to reflect operation at relatively low inflow TP concentrations and loading rates, which may be masking any detrimental effects treating low-calcium lake water.

We don't have a model to evaluate this issue. It is possible that calcium releases from the initial soil substrates will supplement the inflows. We plan to continue tracking STA performance relative to DMSTA predictions and inflow calcium levels. If a significant effect of calcium is identified, the probable remedy would be to adjust the control program (better BMPs and/or larger STAs). The concept of supplementing the inflows with calcium has been investigated but found to be impractical on this scale. Research on periphyton treatment technology has also involved substrate preparations with lime rock or other calcium-rich materials, but results have not been conclusive.

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bill@wwwalker.net

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The following comments provide further elaboration on the topics discussed at the June 2009 meeting of the NRC Everglades Committee.

What are the phosphorus and water balances of the Everglades?

An overview of this topic was presented at the meeting. The average mass balances of the WCAs provide useful background information, but do not have sufficient spatial resolution to define Everglades nutrient problems. The most heavily impacted areas are located downstream of inflows with elevated P concentrations, where the phosphorus budgets are dominated external inflows, as opposed to atmospheric deposition. System-wide mass balances that represent each WCA as a "stirred tank" tend to overstate the importance of atmospheric deposition as a factor contributing to the nutrient enrichment problem.

How are the STAs performing in terms of removal of P, N, S, and other contaminants of interest?

See Deb Drum's presentation. P removal rates are also summarized in DMSTA calibration datasets http://www.wwwalker.net/dmsta/calibration.htm Data on N, S, and other components have been collected and summarized in various reports, which could be located if the committee is interested in pursuing this topic. A table from the 2010 SFER is attached.

What model tools are available to design and assess the performance of STAs?

Dynamic Model for Stormwater Treatment Areas (DMSTA) and its precursors, as discussed at meeting. http://www.wwwalker.net/dmsta

Can you explain the variability in performance between the different STAs?

Described in presentation. DMSTA explains >90% of the variance in outflow concentrations in STA cells used for calibration & testing. ttp://www.wwwalker.net/dmsta/testing/scatter.htm

Linked Questions addressed together:

- ***How does STA performance affect current efforts and near-term plans to restore flow in the Everglades ecosystem?***
- ***What are the latest plans for STA expansion, and how is this additional STA acreage expected to influence the performance of the other STAs and the overall treatment capacity?***
- ***Can the planned STAs meet the P water quality performance expectations of the CERP in all parts of the Everglades? What acreage would be needed to address increased flows being considered in light of the US Sugar purchase?***

Hydrologic restoration involves changing the amounts, spatial distribution, and timing of inflows to the Everglades along the northern boundaries of the Water Conservation Areas. If the inflows are not sufficiently "treated", hydrologic restoration measures could have adverse water quality impacts, particularly if they attempt to restore sheet flow in marsh areas that have not been previously impacted by external inflows.

With sheet flow hydraulics, water quality at the edge of the marsh is determined by quality of the inflows; i.e. there is no "assimilative capacity" or "mixing zone". Therefore, WCA inflow (STA outflow) concentrations approaching the 10 ppb long-term geometric mean criterion would be required to restore and protect the entire marsh downstream of the STA discharges. Initial CERP planning efforts assumed that inflows would be treated to that level. In permit land, that degree of treatment is reflected in the Water Quality-Based Effluent Limit (QBEL) included in the most recent discharge permit for STA-34 (maximum yearly flow-weighted-mean concentration of 17 ppb), which is thought to be consistent with the Clean Water Act, State/Federal Consent Decree, and CERP Performance Measures. Based upon statistical analyses of historical STA outflow data, achieving the 17 ppb QBEL discharge concentration in >90% of years would limit the long-term geometric mean concentration in the marsh to the 10 ppb criterion. Modeling results and correlations between marsh soil and water column P concentrations indicate that achieving CERP performance measures for soil phosphorus throughout the Everglades would also require inflow P concentrations at or below QBEL levels.

The currently-planned phosphorus control program (BMPs, STAs, flow management) does not have sufficient capacity for treating the currently-planned flows or the additional flows under the River-of-Grass (ROG) initiative. Based upon the most recent forecast of STA performance without additional restoration flows (Compartment B EIS, 2007), the combined outflow concentration from all STAs will exceed the QBEL by a wide margin (90th percentile yearly FWM = 32 ppb vs. QBEL =17 ppb). The predicted range for individual STAs is 18 to 38 ppb. Those forecasts are optimistic because they do not account for increasing trends in Lake Okeechobee and farm runoff TP concentrations.

The current Long-Term Plan (LTP) provides a total treatment area of 57 kac with all planned expansions. The most recent STA expansions were initiated primarily to accommodate runoff flows and loads that were under-estimated in previous design calculations. At recent basin runoff concentrations and lake concentrations, it is estimated that total treatment area would have to be doubled in order to meet QBEL levels while providing flows currently contemplated under the ROG initiative. Reducing source TP concentrations (additional BMPs) would reduce treatment area requirements.

Achieving ROG flow targets will increase the total flow volume by a small percentage (~5-7%) relative to the flow assumed in the current Long-Term Plan, which already provides for additional lake releases above historical values. From a treatment perspective, the primary impacts of ROG would be to increase the year-to-year variability in flows and decrease the seasonal variability in flows, relative to those in the current LTP. These changes could have positive or negative impacts on treatment efficiency, depending on how ROG storage components are designed and operated. Additional factors to be considered in design would include flow balancing across reservoirs and STAs to attenuate peak flows and optimize treatment efficiency, provision of excess treatment capacity to allow for STA maintenance, and uncertainties associated with projected flows, inflow concentrations, and model forecasts. Looking ahead, tools and opportunities exist for engineering a plan to meet hydrologic and water quality objectives using an appropriate mix of source controls, storage, and treatment. Previously, these objectives have considered in separate planning/design efforts that have been operating on different time scales with little or no coordination.

What are the capital and operating costs of STAs?

See Deb Drum’s presentation.

What can we expect in terms of long term sustainability of STA performance?

The accretion of peat and associated soil phosphorus provides a long-term, sustainable mechanism for phosphorus removal in the STAs. Cycling of phosphorus between the water column and biological storage compartments occurs regularly and is enhanced by seasonal dryout/reflood events. Net mobilization of phosphorus stored in the soil may occur under extreme drought sufficient to promote peat oxidation. Based upon simulation of historical hydrologic time series (1965-2005), those conditions are not projected to occur to a significant degree with the existing STA designs or with designs consistent with achieving QBEL levels. Should they occur due to extreme drought, peat oxidation events would be expected to cause a temporary spike in STA outflow concentrations after re-flooding, followed by recovery as the plants and phosphorus cycles are re-established. Management of STA water depths and allocation of lake outflows for STA irrigation would reduce risk of extreme dry-out. Other management measures, such as re-grading or dryout to promote soil/floc consolidation, may be implemented to offset impacts of soil mass buildup on water depths and STA hydraulics.

What research is needed to advance the effectiveness of STAs?

See Drum & Walker presentations.

Calcium plays a role in phosphorus removal by SAV. Implementation of restoration measures (increased lake outflows & reservoirs) will tend to decrease calcium concentrations in STA inflows. These effects have not been considered in STA performance forecasts and are an important research & modeling topic.

421 **Table 5-6**. Summary of annual flow-weighted mean concentrations (FWMC) for parameters other than total phosphorus (TP) at inflow and outflow of STAs to the Everglades Protection Area (EPA) during WY2009. Excursions occurred when FWMC at outflows are greater than those at inflows. There were no excursions in WY2009.

Stormwater Treatment Area	Data Classification	Flow-Weighted Mean Concentrations							
		Alkalinity (mg $CaCO_3$/L)	Chloride (mg/L)	Sulfate (mg/L)	Un-ionzied Ammonia (mg NH_3/L)	Nitrate+Nitrite (mg N/L)	Total Dissolved Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Dissolved Phosphorus (mg/L)
STA-1E	Inflow	174	----	42.5	----	1.296	----	3.26	----
	Outflow	139	----	29.4	----	0.068	----	1.25	----
	Excursions	No	----	No	----	No	----	No	----
STA-1W	Inflow	275	----	81.0	----	0.596	----	3.67	----
	Outflow	201	----	61.6	----	0.044	----	2.19	----
	Excursions	No	----	No	----	No	----	No	----
STA-2	Inflow	333	----	77.5	----	0.605	----	3.40	----
	Outflow	265	----	58.3	----	0.137	----	2.32	----
	Excursions	No	----	No	----	No	----	No	----
STA-3/4	Inflow	263	88	61.5	0.004	1.931	4.22	4.41	0.069
	Outflow	207	87	49.3	0.001	0.009	1.78	1.81	0.007
	Excursions	No	No	No	No	No	No	No	No
STA-5	Inflow	----	----	6.1	----	0.037	----	1.74	----
	Outflow	----	----	4.7	----	0.009	----	1.36	----
	Excursions	----	----	No	----	No	----	No	----
STA-6	Inflow	143	----	8.6	----	0.096	----	1.67	----
	Outflow	140	----	3.7	----	0.011	----	1.31	----
	Excursions	No	----	No	----	No	----	No	----