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Investigation of Sampling Methodologies for Monitoring Water Quality at Inflows to Everglades National Park

prepared for

U.S. Department of the Interior
Everglades National Park

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Introduction

The extensive hydrologic and water quality monitoring network operated by South Florida Water Management District (SFWMD) since the late 1970's has provided essential data for characterizing Everglades nutrient enrichment problems, devising solutions, and tracking responses to management efforts. The spatial scope and intensity of monitoring have increased substantially in recent years as other agencies, institutions, and laboratories have become involved. Interpretation of the data, particularly with respect to long-term trends, requires consistency over time and space with respect to monitoring and data-reduction techniques.

As a consequence of the increased sampling intensity and utilization of the data in recent years, a number of factors have been identified that contribute to inconsistencies in historical and recent data. Various investigations have been undertaken to characterize and correct them. For example, the Everglades Round Robin Program was implemented by the Florida Department of Environmental Protection to address inconsistencies in phosphorus analyses across laboratories. A replicate sampling program was undertaken by the Everglades Technical Oversight Committee to investigate problems related to sample collection at marsh sites and to develop a consistent marsh sampling protocol. The SFWMD has taken substantial measures to improve the consistency, accuracy, and accessibility of hydrologic and water quality data in its DBHYDRO database.

This study evaluates sampling techniques for characterizing water quality at inflows to Everglades National Park (ENP) in the Taylor Slough, Coastal, and Shark River Slough basins (Figure 1). There is a particular emphasis on developing monitoring strategies to support estimation of phosphorus mass balances in the canal systems and detention areas discharging into the Park and obtaining samples that are more representative of storm events. The spatial scale of marsh impacts caused by discharge of water with elevated phosphorus concentrations into Everglades marshes is related to the mass discharge of phosphorus or load, typically reported in metric tons per year. Load estimates are also critical to the design and evaluation of source-control and treatment measures.

Currently, data are collected under 8 different monitoring projects (Figure 1) involving various sampling methods, frequencies, and parameters. The cost-effectiveness of the monitoring program can be enhanced by improving sampling methods and by eliminating redundancies and inconsistencies. Further evaluation of sampling methodologies (in particular, apparent discrepancies between grab and auto sampling results) is needed to support this effort.

The study will provide improved information to support management decisions with respect to:

1. Operation of canals and detention basins in the C111 region, particularly to provide flood control benefits in addition to primary benefits associated with reduction in seepage losses from ENP;

2. Ongoing design of treatment and hydropattern restoration facilities in the lower C111 basin;

3. Evaluation and management of phosphorus and contaminant loads from agricultural and urban areas adjacent to the L31N and C111 canals;

4. Regional water management affecting the location and timing of ENP inflows in all basins (e.g., Interim Operations Plan);

5. Interpretation of data collected for determination of compliance with inflow P limits under the State/Federal Consent Decree; and

6. Development of cost-effective long-term monitoring strategies.

To the extent possible, the study will be integrated with SFWMD's routine monitoring program and ongoing evaluations of sampling methodologies in other South Florida basins.

Background

Estimation of loads at a monitored site requires integration of daily flow and periodic concentration data. Various sampling methods and computation algorithms have been utilized for this purpose. Historical load estimates for ENP inflow points are based upon daily mean flow and periodic (biweekly-monthly) grab samples, with occasional data gaps. Integration of these data requires estimation of concentrations on the days that were not sampled. A variety of computation techniques have been utilized for this purpose, including:

1. Application of the yearly total flow to the flow-weighted-mean concentration on sampled dates;

2. Linear interpolation of concentrations between sampling dates, usually excluding samples collected on days without flow;

3. Application of regression models relating sampled concentration to flow and/or season and calibrated to the sampling dates.

These methods will not necessarily yield the same annual load estimates when applied to a given dataset. The extent of correlation between concentration and flow is one factor contributing to differences in the estimates. Further sampling and computational complications arise from bidirectional flows at some structures.

To reduce the uncertainty associated with estimation of concentrations on unsampled dates, there has been an increased emphasis on continuous automated sampling in recent years. With this technique, sample aliquots are composited on a flow-proportionate (or time-proportionate) basis over a weekly time frame. Weekly grab samples are also collected to provide consistency checks and a basis for estimation of loads in periods with missing auto-samples. Time-proportional auto-sampling (8-hour discrete composites) was utilized in monitoring performed by the Corps of Engineers at several sites in the C111 region between 1999 and 2003.

One advantage of auto-sampling is that is simplifies annual load computations because they do not involve estimation or interpolation algorithms. There is also less risk that short-term increases in concentration and load (“spikes”) will go undetected.

The major disadvantages of auto-sampling are higher equipment cost, higher operating cost, and an increased risk of sample contamination and artifacts related to equipment malfunction, as compared with grab samples collected periodically by trained staff using a standard protocol. Weekly composite sampling does not provide resolution of concentration spikes occurring on an hourly or daily basis. Another significant limitation of weekly composite sampling is that it cannot be used reliably for measuring concentrations and loads of nutrient fractions (SRP, dissolved, particulate) or other water quality components that cannot be preserved over a weekly composite interval. Auto-sampling has generally been limited to measurement of total phosphorus and total nitrogen concentrations (NOX + TKN).

Because of lower cost, greater reliability, and broader parameter coverage, grab sampling at biweekly or higher frequency, possibly supplemented during periods of high flow, may be a preferred method for estimating loads in some cases. If appropriate computation algorithms are employed, grab samples may provide unbiased load estimates with acceptable precision. Grab sampling may be inadequate as sites with infrequent flow events because of the logistics of deploying sampling crews.

Recent (1999-2003) results have revealed significant differences in phosphorus loads computed from grab vs. composite samples collected simultaneously at ENP inflow points (see below). At other SFWMD sites, an adjustment factor has been typically applied in periods with loads estimated from grab samples to compensate for apparent differences in results based upon the two techniques. Problems with this algorithm arise from variations in the adjustment factors over time as additional data are accumulated and/or as sampling equipment is changed. Generally, the adjustment factors have been applied regardless of whether the differences between grabs and auto-samples are statistically significant and without a fundamental understanding of the reasons for the differences.

It is not clear whether grab/composite differences reflect true temporal variations or whether they reflect artifacts in the sample collection or data-reduction procedures. Comparison of results using each technique potentially provides a basis for evaluating the uncertainty and robustness of load estimates derived from recent data.

While auto-sampling began on a limited basis in the late 1970's at WCA inflow points, the technique was first applied to an ENP inflow structure (S332D) in 1999 by both the Corps of Engineers and SFWMD. One general pattern across all regional datasets is a tendency for the grab/composite ratio to be lower at sites with lower average phosphorus concentrations, specifically including two ENP inflow points with auto-samplers (S332D and S18C) currently being operated by SFWMD (Figure 2). It is not clear whether these differences are real or due to sampling artifacts. They have potentially important implications for interpretation of historical (1978-2002) loads and flow-weighted-mean inflow concentrations in each ENP basin, which are based exclusively on grabs. Grab samples are used exclusively in tracking compliance with the Consent Decree ENP inflow P limits. It is possible that these values significantly under-estimate the actual inflow concentrations and loads entering the Park. Changes in flow and concentration dynamics resulting from operation of new pump stations and detention areas in the C111 basin further necessitate improvements in sampling networks and techniques to evaluate detention area performance and estimate nutrient transport via surface and groundwater, especially during and following storm events.

The study has been developed in response to the following patterns identified in recent monitoring data:

1. An apparent tendency for the ratio of grab to composite sample concentrations to be lower at regional monitoring sites with lower average phosphorus concentrations, especially the two ENP inflow sites with auto-samplers (Figure 2).

2. Spikes in phosphorus concentration at Shark River Slough inflow points associated with reflooding of WCA-3A after drought periods and with possible transport of storm-driven loads from WCA-3A inflows along the Miami Canal and L67 to ENP inflow structures (Figure 3). Biweekly grab sampling may not be sufficient to capture significant loading events. For example, a phosphorus concentration of 40 ppb was measured at S333 in August 2001 following storm-driven loading events to WCA-3A and reflooding of the marsh after an extended drought. Exclusion of a single grab sample in Water Year 2002 (May 2001-April 2002) would reduce the yearly flow-weighted concentration at S333 from 16 to 13 ppb.

3. Significant differences in phosphorus loads computed from grab vs. composite samples at S18C, where composite sampling was initiated in December 2002 (Figure 4). The Water Year 2004 load computed from

grab samples was 0.8 metric tons and the flow-weighted-mean concentration was 4.3 ppb, as compared with 1.8 mtons and 9.4 ppb computed from composite samples. Occasional phosphorus spikes were observed in historical (>=1984) grab samples in association with high rainfall and/or flows.

4. Significant differences in phosphorus loads at S332D computed from grab vs. weekly composite samples (Figure 4). The Water Year 2004 load computed from grab samples was 0.9 metric tons and the flow-weighted-mean concentration was 5.8 ppb, as compared with 3.0 mtons and 19.3 ppb computed from composite samples. Similarly, the Water Year 2002-2003 load computed from SFWMD grab samples was 0.8 mt/yr (5.6 ppb), as compared with 1.4 mt/yr (10.0 ppb) from SFWMD composites, and 1.1 mt/yr (7.0 ppb) from Corps of Engineer composites. Agreement between SFWMD grabs and composites was better in Water Year 2003, as compared with 2002 and 2004 (Figure 4). It is unclear the apparent drift in the consistency is attributed to changes in sampling methods (e.g., auto-sampler malfunction) or changes in the actual loading dynamics.

5. Flow at S18C increases rapidly following rainfall events and generally on a time scale that is short relative to the historical biweekly sampling frequency (Figure 5). Yearly and long-term average loads may be controlled by infrequent large events that are not reflected in the historical biweekly samples. Coverage of peak flows increased significantly when the sampling frequency was increased from biweekly to weekly in December 2002 for total phosphorus. The frequency for other parameters remained at biweekly (quarterly for pesticides).

6. Daily-average concentrations ranging from 50 to 800 ppb were recorded by COE at S331, S332B, and S332D in high-frequency (3 per day) composite samples following a major storm event (~6 inches) that occurred between October 2 and 6, 2000 (Figure 6). This event was not captured by the routine biweekly grab sampling program, which recorded concentrations ranging from 4 to 20 ppb at these structures on September 27 and October 11.

7. The more intensive COE monitoring program also detected spikes in concentration in the eastern canals (C102, C103, C113) tributary to the L31N and C111 canals during October 2000 event, as well as others in the November 2000-March 2003 period. These may reflect runoff loads from agricultural and urban watersheds that are not captured in the SFWMD grab sampling program. Potential nutrient sources include several nurseries that have recently appeared in the watersheds east of the L31N/C111 canals. The SFWMD monitoring network (Figure 1) does not

include C113; samples have been collected historically at C102 and C103 under project BISC, but no data exist in DBHYDRO after March 2003.

8. Loadings of water quality components other than phosphorus (e.g., nitrogen and pesticides) are also of concern, especially given the adjacent agricultural areas and storm-driven hydrographs in the basin. The probability of detecting loading events is small given the existing grab-sampling network (biweekly, quarterly for pesticides). Furthermore, such events would not be detected at sites currently equipped with auto-samplers because only total phosphorus concentrations are measured.

9. It is possible that apparent discrepancies between the relatively low phosphorus concentrations typically measured at ENP inflow sites in the C111 basin and FIU observations of soil enrichment and apparent biological impacts in the marsh downstream of these structures may be related to undetected storm-driven loads of phosphorus and/or other water quality components that occurred between historical grab sampling events.

Hypotheses

The study will test the following causal hypotheses potentially explaining observed differences between grab and composite results in the C111 basin, with an initial emphasis on the S18C and S332D sites:

A. Differences are related to contamination of the auto-sampler device. This will be tested by continuing to analyze field blanks in accordance with SFWMD's routine QA/QC protocols. Investigations of existing data and equipment by SFWMD have not identified problems related to contamination or other obvious equipment artifacts.

B. Differences are related to concentration/flow dynamics and inaccuracies in the load-computation algorithm. At sites with a positive correlation between concentration and flow, interpolated grab-sample concentrations are expected to yield lower load estimates as compared with flow-weighted composite samples, even if sampling artifacts are absent. This hypothesis can be tested using existing and new data by computing loads from grab samples using methods that account for correlations between concentration and flow and/or antecedent rainfall in place of the simple interpolation algorithm that has been routinely used.

C. Differences are related to short-term events (spikes) that are not captured in grab samples. This will be tested by collecting discrete composite samples at a daily frequency (or more frequently during storm event periods). These results will be compared with weekly composites and daily grab samples collected at the same monitoring site. Comparing daily grabs and daily composites during dry and wet weather will also provide a means of detecting differences related to systematic diel variations in concentration. Increased spatial and temporal monitoring frequency in the mainstem and tributary canals upstream of the site will help to identify sources of loading spikes.

D. <u>Differences are related to horizontal and/or vertical gradients in concentration combined with differences in grab vs. auto-sampler intake locations.</u> Grab samples are typically collected 0.5 feet from the surface. While the standard protocol is to collect grabs that are representative of water flowing through the structure, this protocol is not always followed because of site access constraints. Similarly, auto-sampler intake locations relative to channel geometry and velocity profiles vary depending upon site constraints. For example, S18C grabs are collected at 0.5 foot depth on the east side of the structure. Composite samples are collected at variable water depths (fixed elevation) on the west side of the structure. In the June 23, 2004 sampling event, only the west gate of the S18C structure was open. Flow was passing underneath the auto-sampler intake adjacent to the open gate and the grab was collected in an area of relatively stagnant water adjacent to the closed gate. During periods of low stage, the auto-sampler intake is located relatively close to the channel bottom in a region that may contain relatively high concentrations of particulate phosphorus (bed load) that may not be representative of water flowing through the structure. This hypothesis that the differences are related to spatial variations will be tested by:

   a. collecting grab samples at multiple vertical and horizontal locations relative to the auto-sampler intake with fractionation of phosphorus species and with simultaneous velocity measurements on at least three sampling dates and at three locations (upstream, at, and downstream of the S18C).

   b. deploying an additional auto-sampler and platform upstream of S18C that will enable collection of grab and composite at the same location (0.5 depth in the center of the channel) and in a region where horizontal and vertical gradients in velocity would be less affected by structure operation. This will be similar to the auto-sampler configuration at S332D.

While comparability of data across labs and sampling agencies will be evaluated in the historical data, this topic will not be investigated experimentally to limit the scope of the study. Inter-laboratory comparisons are being addressed under the

FDEP Everglades Round Robin Program and routine split sampling. To the extent possible, the study will be integrated with ongoing and planned studies by SFWMD addressing sampling methodologies at other sites in South Florida. This will provide a larger database for analysis, ensure consistency of sampling and analytical techniques, and contribute to development of system-wide improvements in monitoring strategies.

Monitoring Network Design

Grab and auto-sample stations in the existing monitoring network are shown in Figure 7. A preliminary network design for the 3-year study period is shown in Figure 8. Table 1 lists monitoring sites and compares the sampling effort under each program. The design includes components necessary to test the above hypotheses, as well as other changes that work towards optimizing the network by eliminating redundancies and increasing spatial coverage to provide basic data for tracking storm events and developing phosphorus mass balances on the regional canal system and C111 detention areas. This design will be modified to incorporate cost constraints, logistical constraints, and reviewer comments. The monitoring strategy will adapted over the course of the study as new data are acquired and analyzed.

Changes to the monitoring network include:

1. Eliminate 9 sites on the L29 east of S333 currently monitored under project TAMB; these appear to be redundant.

2. Eliminate the S332 and S175 sites, which no longer discharge into Taylor Slough after degradation of L31W and removal of S332 pump station

3. S332DFW – new site at mouth of the flow-way downstream of the S332D detention area at ENP boundary north of S332; event grab samples;

4. BERMB3E – new site east side of BERMB3 (for comparison with existing site BERMB3 on the west side); event grab samples;

5. S335 – new grab site at outflow from L30, which delivers water to the L31N/C111 region from the WCA's; previously unsampled

6. G211 – reactivate grab site on L31N, previously sampled 1997-2002; grab & event sampled; while historical grab concentrations were similar to those at measured at S331, comparisons have not been made specifically during storm event periods.

7. S333, S12C – new auto-samplers; weekly flow-weighted composites for comparison with existing grab samples; possibly add 2 autosamplers along the L67A upstream and downstream of the proposed weirs discharging into WCA3B under CSOP to track source of flow to S333 and provide baseline data for evaluating CSOP impacts.

8. S331-173, S176, S177, C102, C103, C113 – new auto-samplers on L31N/C111 mainstem and tributary; to establish L31N/C111 canal mass balances and evaluate sources of spikes observed at S332B, S332D, and S18C auto-samplers; weekly flow-weighted-composites for Total P; in some periods operated to provide time-proportionate, daily composites to capture short-term spikes; biweekly grab samples for nutrient and inorganic species normally monitored under projects CAMB and ENP.

9. S18CUS1 – new auto-sampler upstream of S18C; weekly flow-weighted composites and grabs; grab & composite intake from platform extending out to middle of canal and sufficiently far upstream to eliminate cross-sectional variations in velocity associated with gate operation; similar to S332D autosampler deployment.

10. S18CUS2 – new auto-sampler adjacent to S18CUS1; time-proportionate, daily composites; samples analyzed routinely (max 365 / yr) with compositing during periods of low rainfall and flow; to detect short-term spikes and for comparison with S18CU1 & S18C weekly composites;

11. S18CDS – grab site downstream of S18C (for comparison with S18CUS & S18C, cross-sectional & biweekly grab sampling for TP only)

The possibility of consolidating monitoring efforts at the junction of the L31N, L31W, and C111 canals will be investigated. Currently, outflows from this junction are monitored separately at S176 (grab), at S174 (grab + time-proportional auto-sampler) and at the S332D pump station (grab + flow-proportional auto-sampler). Given the close proximity of these sites and their common source of flow, it is possible that all data needs would be met by a single grab/auto-sampler station in the vicinity of S176 or on L31N just upstream of the junction. The new auto-sampler will be operated in a time-proportionate mode to provide daily (or 8-hour) discrete composite samples. Under the assumption that water moving in each direction has the same concentration, the same daily samples can be used to compute loads through each structure. Historical grab-sample data from S174, S176, and S332D can be analyzed to test this assumption. This procedure would not provide true yearly flow-weighted concentrations at each structure if with-day variations in concentration are significant. Field testing will be based upon direct comparison of computed loads through S332D with values derived from the existing weekly flow-proportionate auto-sampler.

The network will enable testing of three strategies for capturing event flows:

A. Existing biweekly grab sampling with weekly composites at a few stations;

B. Event-oriented grab sampling throughout the C111 basin; grab samples collected within 1-2 days of significant rainfall event; target ~8 events per year; strategy consistent with S18C rainfall response (see Figure 5); where possible, consolidate with routine sampling (i.e., a biweekly periodic sample would be counted as an event if it happens to occur in a high-rainfall period); include broad range of water quality parameters; possibly include selected pesticides for some stations & events;

C. Addition of several new autosamplers along the L31N/C111 mainstem & tributary canals; test operation in (a) weekly, flow-proportional composite mode and (b) daily, time-proportional composite mode, with samples possibly further composited or discarded in weeks with low rainfall and/or flow; total P, possibly add TKN & NOX at some sites.

Tasks & Timetable

The above preliminary design will be refined following agency review and a workshop. Quarterly reports will summarize the incoming data and study progress. Yearly interim reports and workshops will analyze the data and refine the study plan. A final report and workshop will analyze and interpret all of the data and include recommendations for enhancement of the long-term monitoring network and use of the data for computation of loads.

Costs

To be developed…

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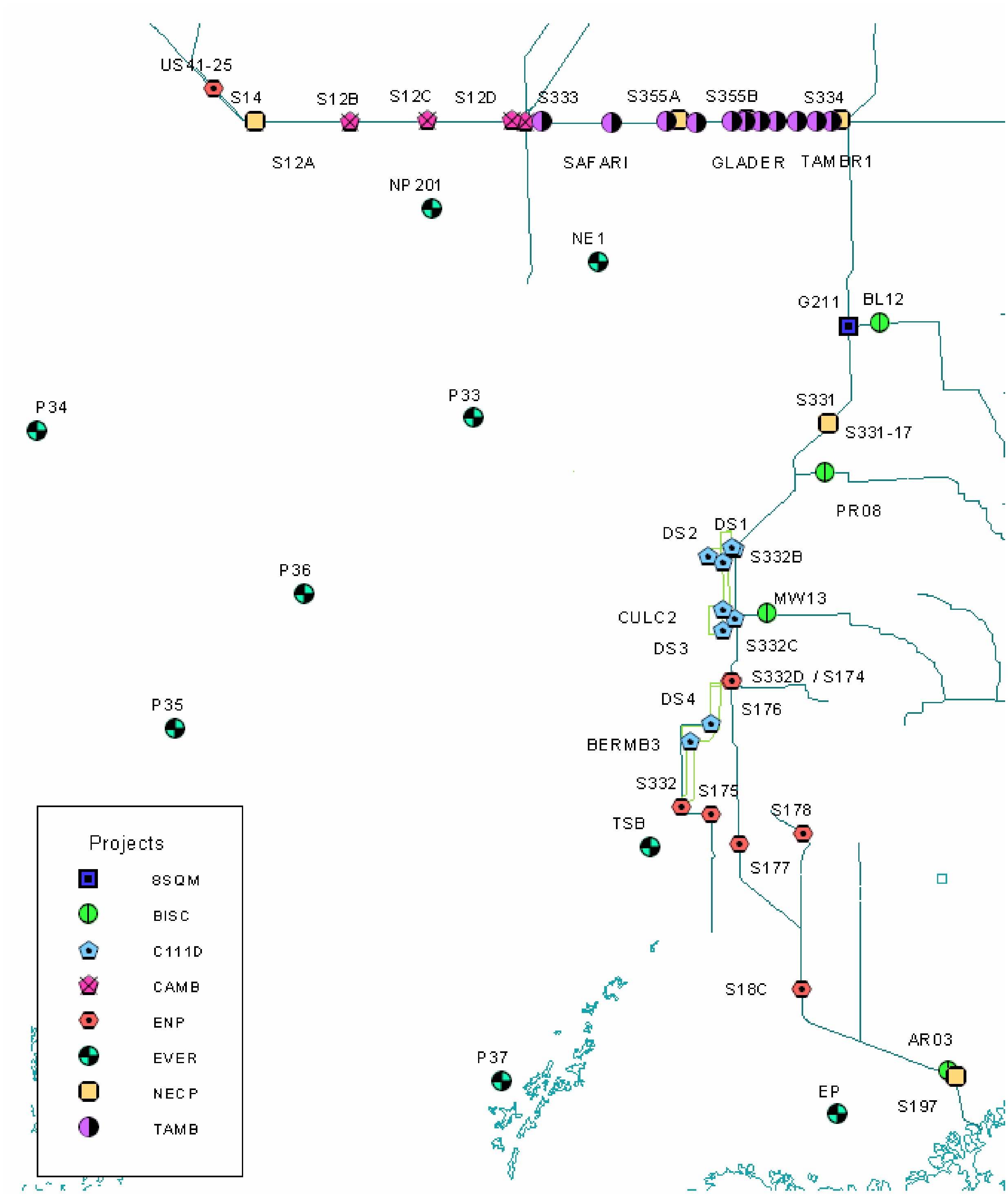


Figure 1 – Existing Monitoring Projects in ENP Vicinity

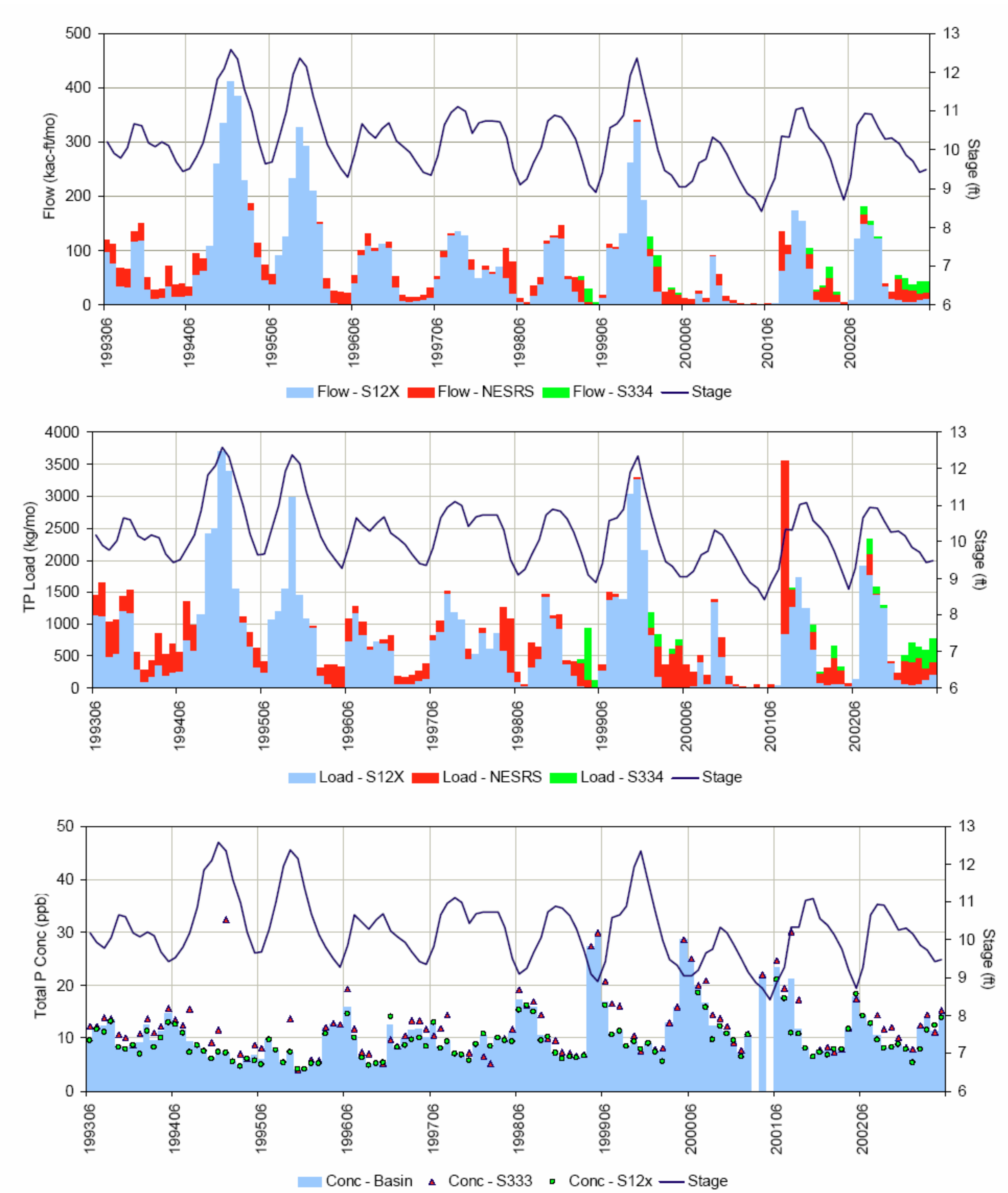
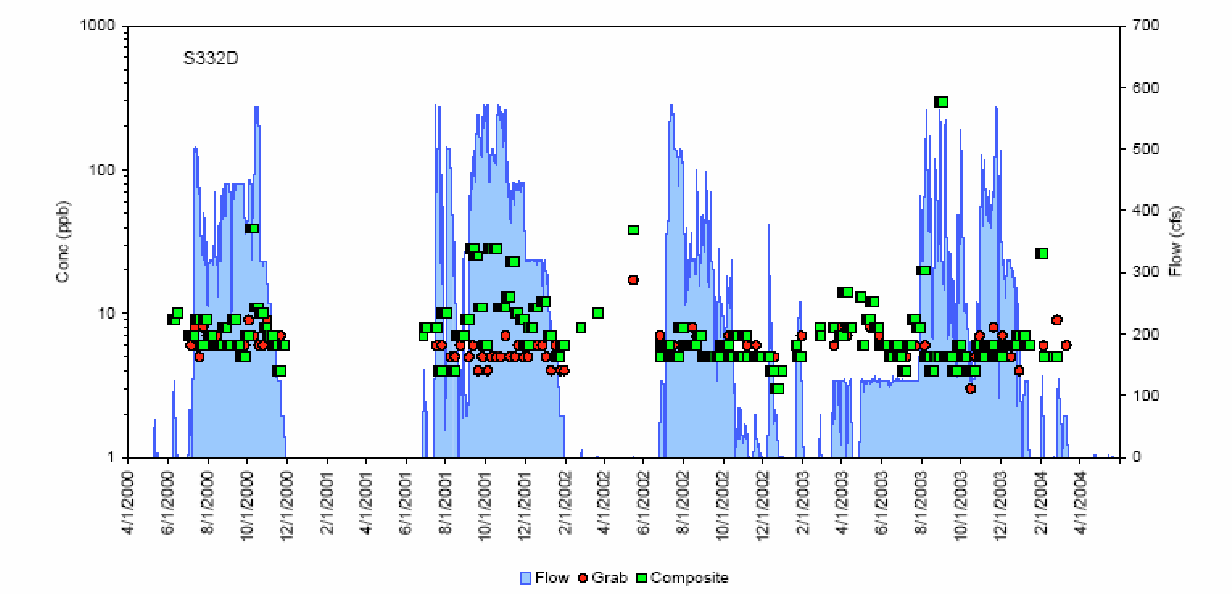


Figure 2 – Shark River Slough Monthly Inflow Dynamics



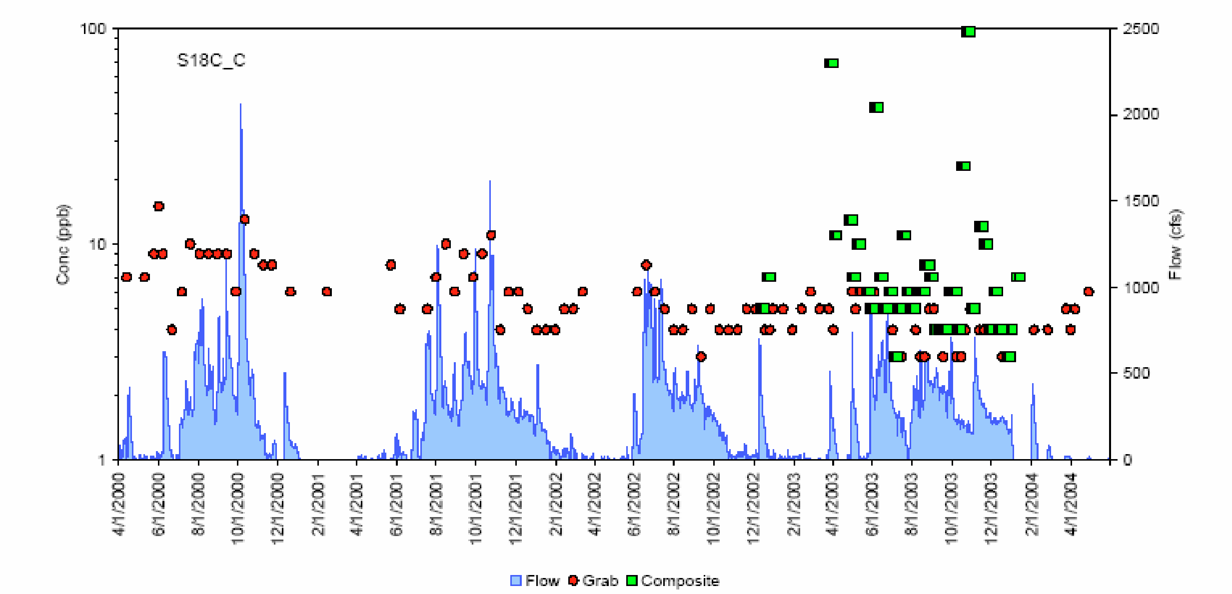
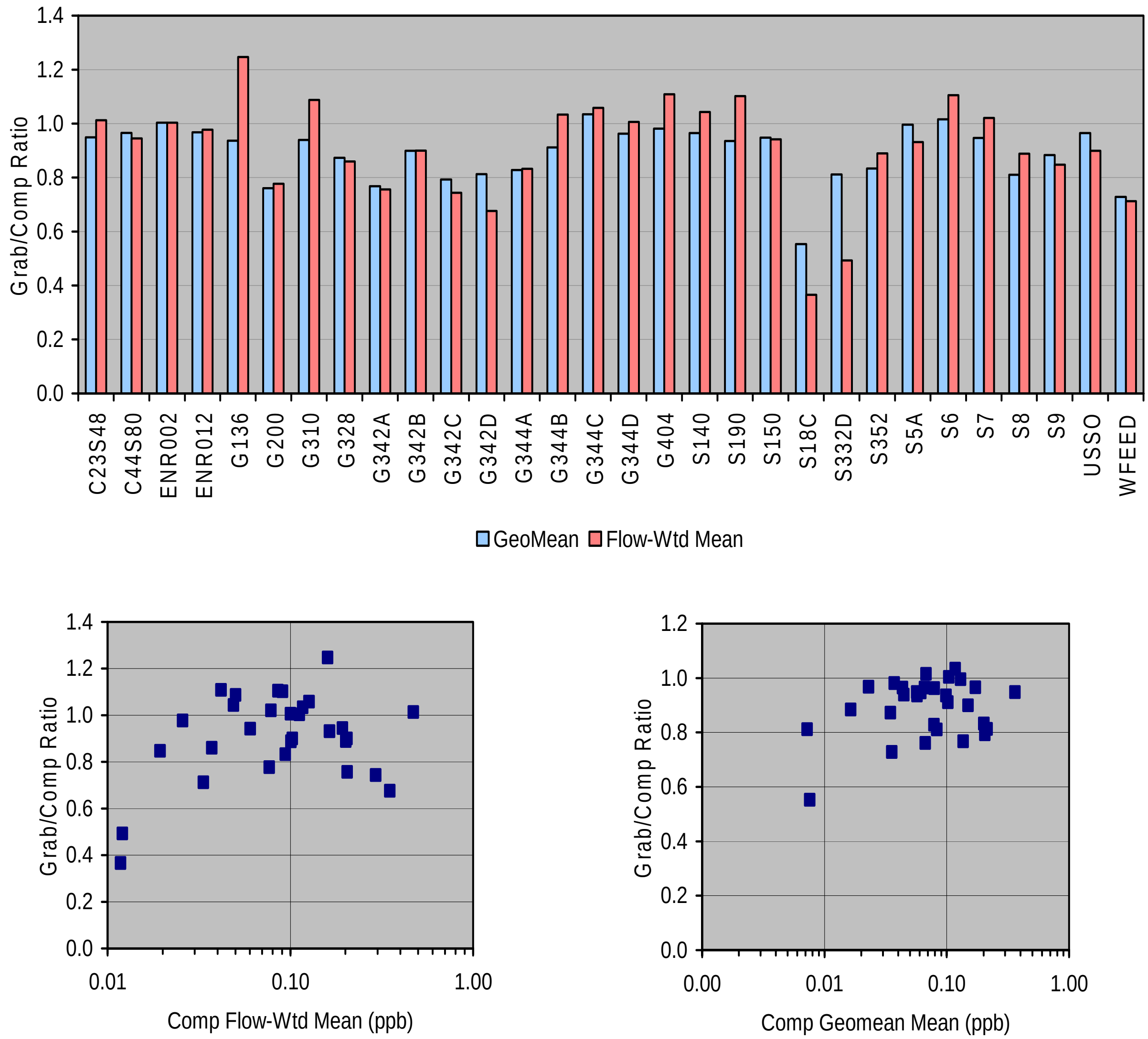


Figure 3 – Grab and Composite Sampling Results at S332D and S18C



Paired Samples, >= 5 Dates / Site, 1994-2004

Figure 4 – Comparison of Grab & Composite Total P Concentrations at SFWMD Monitoring Sites

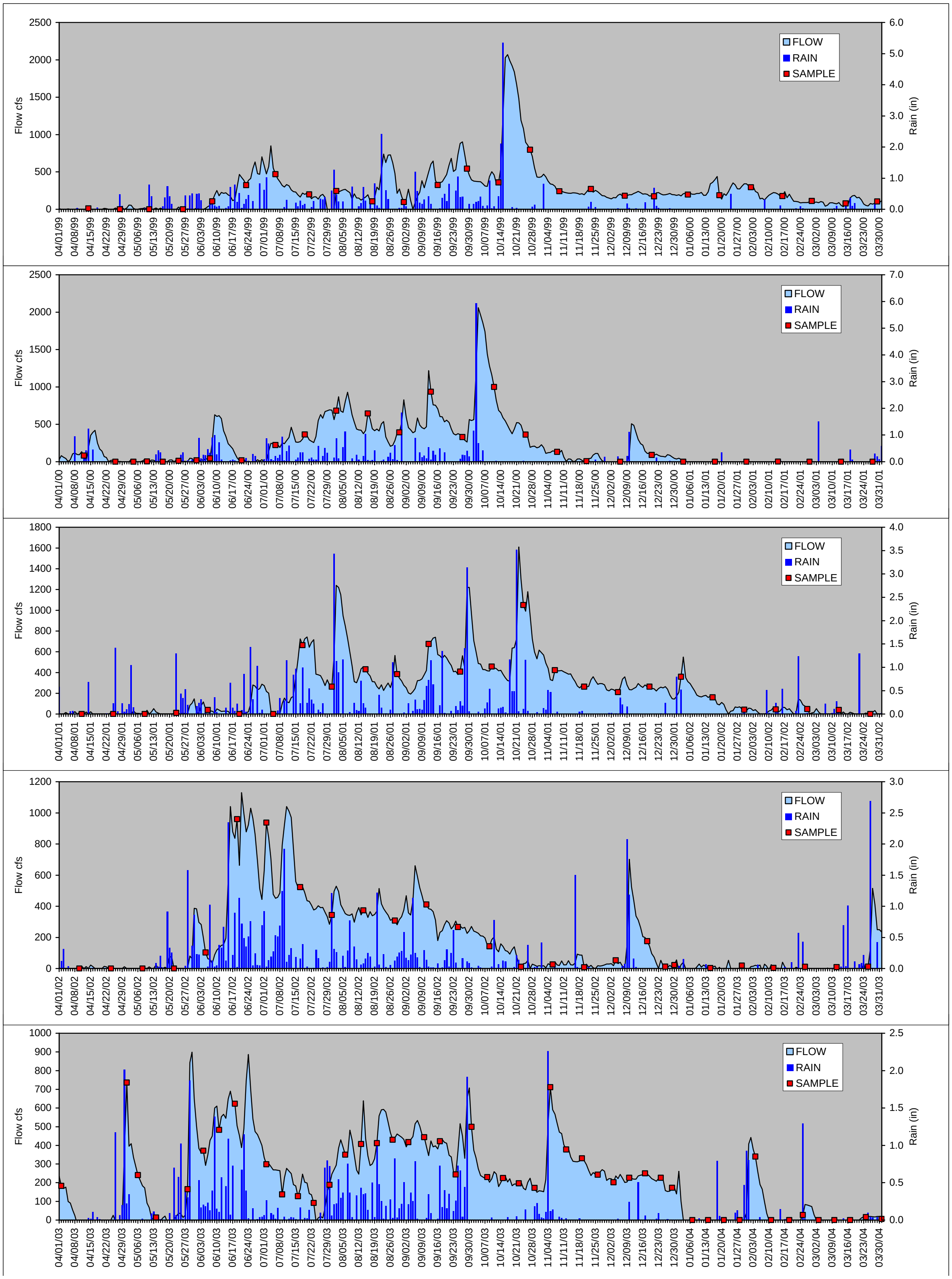


Figure 5 – S18C Sampling Events, Daily Flows, & Rainfall

Squares = dates when grab samples for Total P were collected. Coverage of peak flow events improved significantly when sampling frequency was increased from biweekly to weekly after December 2002. Sampling frequencies were biweekly for other nutrients and inorganic water quality components and quarterly for pesticides.

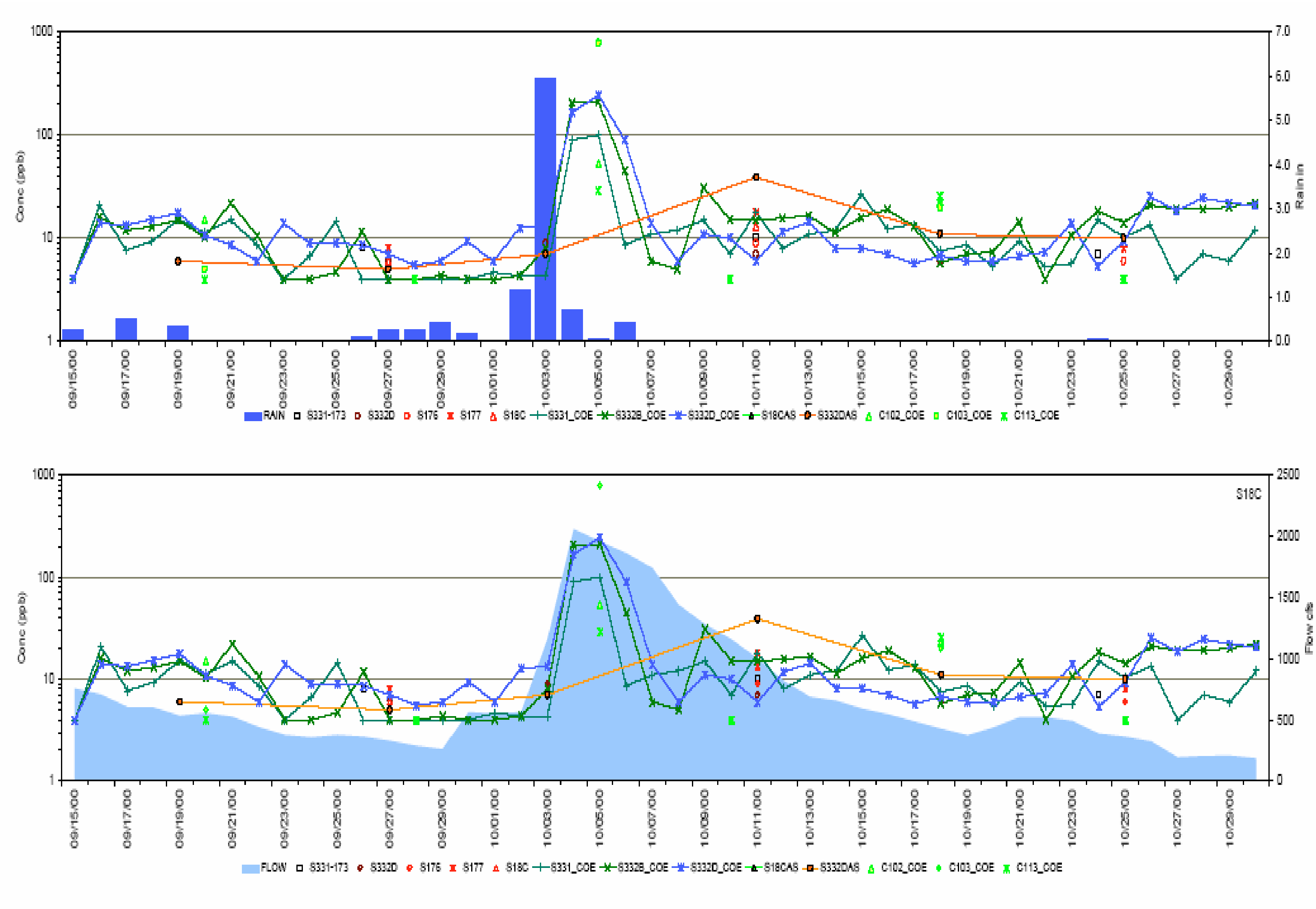


Figure 6 - C111 Phosphorus Data, S18C Flow, and Basin Rainfall, September- Cctober 2000

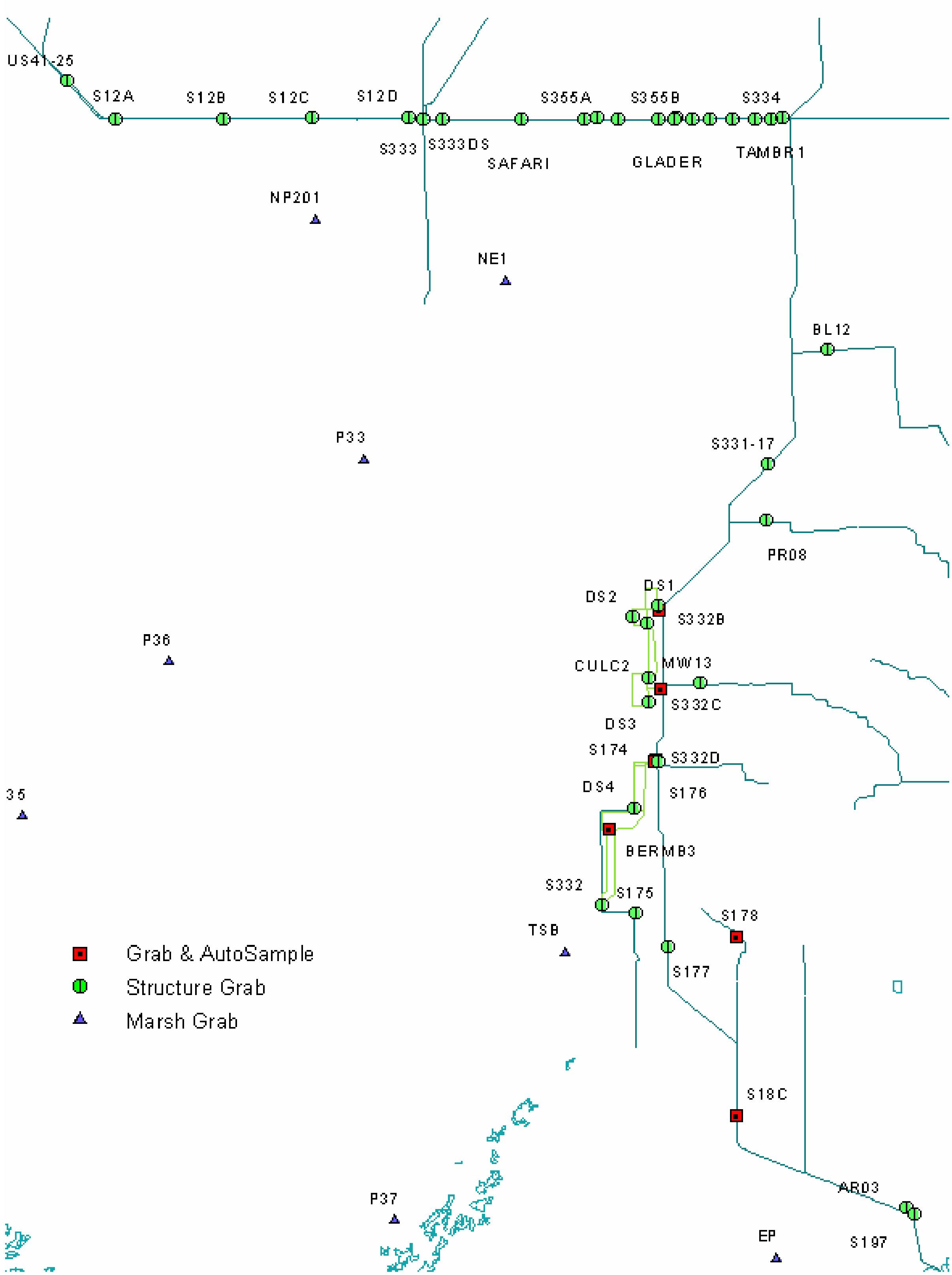


Figure 7 – Existing Monitoring Network

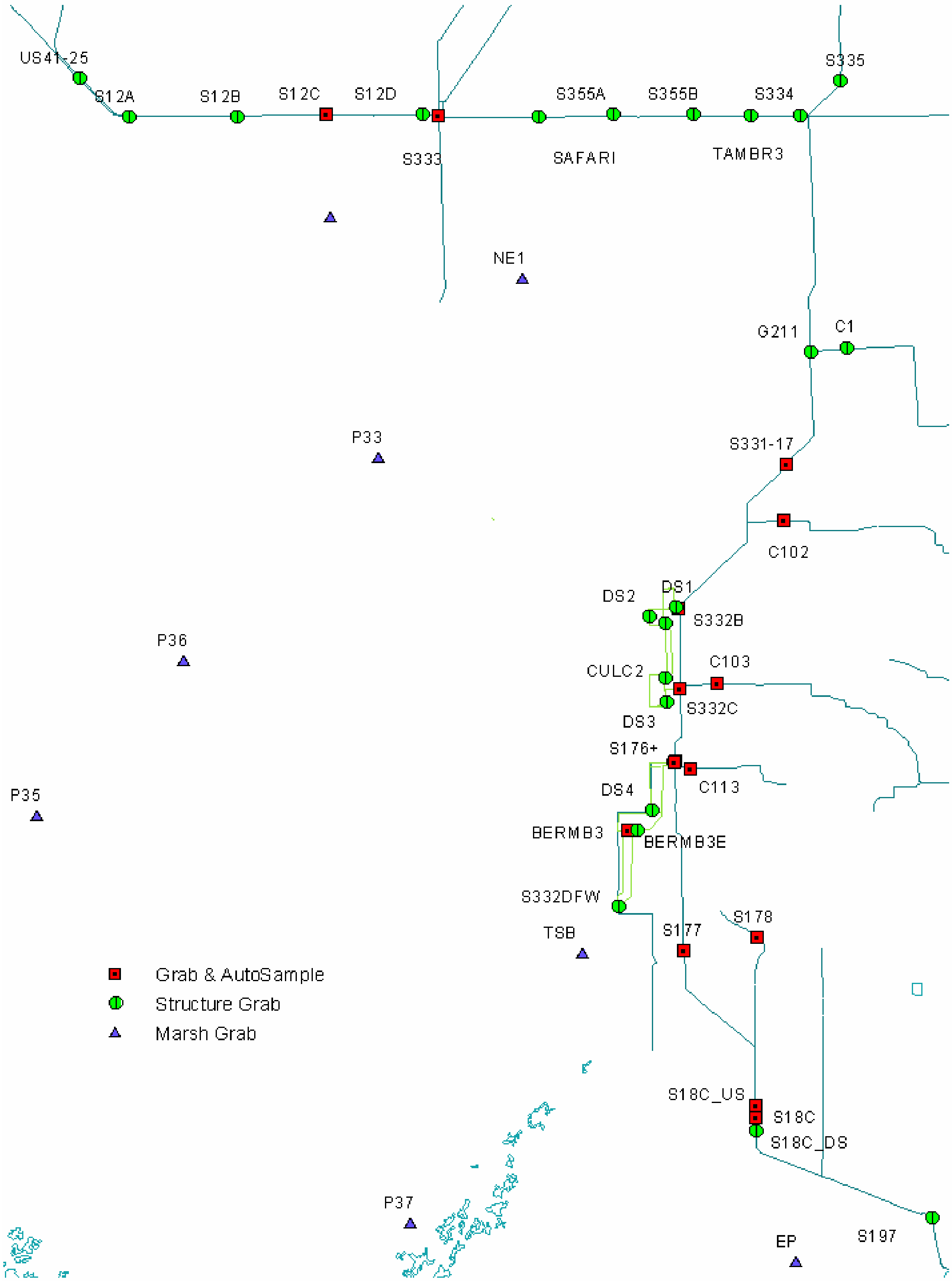


Figure 8 – Proposed Future Monitoring Network

		EXISTING PROGRAM -->						PROPOSED PROGRAM -->					
VARIABLES			ALL	ALL	TP	ALL	TP	ALL	TP	ALL	TP	TP	TP
FREQUENCY		Inactive	Monthly	Biweekly	Biweekly	Event	Weekly	Biweekly	Biweekly	Event	Weekly	Discrete	Cross-Sec
SITE	PROJECT		Grab	Grab	Grab	Grab	Comp	Grab	Grab	Grab	Comp	Comp	Grab
S12A	CAMB			o				o					
S12B	CAMB			o				o					
S12C	CAMB			o				o			**x**		
S12D	CAMB			o				o					
S333	CAMB			o				o			**x**		
S333DS	TAMB				o								
SAFARI	TAMB				o				o				
FROGCITY	TAMB				o								
GLADER	TAMB				o								
COOPERTN	TAMB				o								
TAMBR6	TAMB				o								
TAMBR5	TAMB				o								
TAMBR4	TAMB				o								
TAMBR3	TAMB				o				o				
TAMBR2	TAMB				o								
TAMBR1	TAMB				o								
S355A	NECP			o	o			o					
S355B	NECP			o	o			o					
S334	NECP			o	o			o					
S335	NEW							**x**					
G211	8SQM	o							**x**	**x**			
C1 (BL12)	BISC	?	o						**x**	**x**			
S331-173	NECP			o				o		**x**	**xx**	**xx**	
C102 (PR08)	BISC	?	o					**x**		**x**	**xx**	**xx**	
S332B	C111D			o			o	o		**x**	o		
C103 (MW13)	BISC	?	o					**x**		**x**	**xx**	**xx**	
S332C	C111D			o			o	o		**x**	o		
S332D / S332DAS	ENP			o			o	o			o		
S174	ENP			o			o	o			o		
S176	ENP			o				x		**x**	**xx**	**xx**	
CULC1	C111D					o				o			
CULC2	C111D					o				o			
DS1	C111D					o				o			
DS2	C111D					o				o			
DS3	C111D					o				o			
DS4	C111D					o				o			
BERMB3	C111D			o		o	o			o		**x**	
BERMB3E	NEW									o			
S332DFW	NEW									**x**			
S332	ENP			o									
S175	ENP			o									
C113	NEW							**x**		**x**	**xx**	**xx**	
S177	ENP			o				o		**x**	**xx**	**xx**	
S178	ENP			o			o	o		**x**	o		
S18CUS1	NEW							**x**			**x**		**x**
S18CUS2	NEW											**x**	
S18C	ENP			o			o	o		**x**	o		**x**
S18CDS	NEW								o				**x**
AR03	BISC	?	o										
S197	NECP			o				o					
Site Count		5	4	21	14	7	7	23	5	21	15	8	3
Samples/Event/Site			1	1	1	1	1.5	1	1	1	1.5	7	9
Events/Yr			12	26	26	6	52	26	26	8	26	26	3
Samples/Yr			48	546	364	42	546	598	130	168	585	1456	81

SYMBOLS

- o existing monitoring design
- **x** new or modified component
- **xx** autoasamplers operated in weekly flow-wtd composite or daily, time-weighted discrete composite mode

SAMPLE COUNTS:	ALL	TP	Total
Existing	636	910	1546
Proposed	766	2252	3018
Increase	130	1342	1472
% Increase	20%	147%	95%

VARIABLES

ALL	suite of parameters monitored under projects ENP & CAMB; possible reduction in field parameters to save field time
TP	Total P; possibly including TKN & NOX

SAMPLE TYPES & FREQUENCIES

Biweekly	biweekly grab samples (similar to existing projects CAMB, ENP, NECP)
Weekly Comp	weekly flow-weighted composite + biweekly grab; possibly operated in discrete composite mode in some periods
Discrete Comp	daily time-weighted composite; possibly operated in weekly flow-wtd composite mode in some periods analysis of separate bottles in autosampler; each bottle representing 1 day; samples possibly composited across days or not analyzed in extended periods with no flow and/or rainfall
Event	grab samples collected within 1-2 days during/after heavy rainfall event possibly include selected pesticides for some sites & events
Cross-Sec	grabs collected at 9 points in channel cross-section to assess spatial variations in concentration 3 events (low, medium, high flows) include field measurements of velocity & particulate P in cross-section

Total Samples per year over-estimated because of reduced sampling during periods with no flow.
Sample counts do not include normal QA/QC samples.

D R A F T 8/6/2004

Table 1 – Existing & Proposed Monitoring Program