Preliminary Evaluation of Proposed Methodology for Determining Compliance with the Numeric Phosphorus Criterion in WCA-2A

prepared for
U.S. Department of the Interior
by
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Introduction

At the April 1999 meeting of the Everglades Technical Advisory Committee (ETAC), the Florida Department of Environmental Protection distributed a draft document describing a monitoring network for determining compliance with the numeric phosphorus criterion in WCA-2A (FDEP, 1999). The marsh was divided into "impacted" and "unimpacted" zones based upon 600 mg/kg, 0-10 cm soil total phosphorus contours developed from historical soil surveys. The proposed monitoring network consisted of 10 stations in the impacted zone and 14 stations in the unimpacted zone (Figure 1). Using data from these stations, the impacted zone would be tested for "net improvement" (decreasing phosphorus trend) and the unimpacted zone would be tested for exceedence of the phosphorus criterion. Monitoring frequency would be one or more times per month. Fundamental assumptions and statistical details for testing compliance were unspecified or left for future development.

The network may have been revised since the April ETAC meeting. Presumably, FDEP will describe any changes and provide more details at the next ETAC meeting. This document evaluates the draft monitoring network. Inherent assumptions and limitations are discussed. Spatial variations in soil and water-column phosphorus concentrations in WCA-2A are summarized. Potential impacts of discharges from STA-2 on phosphorus concentrations in the unimpacted area are evaluated for alternative discharge concentrations and monitoring scenarios. Alternative designs for the monitoring program are discussed.

Basic Concepts

To provide a rational basis for designing a compliance methodology, numerical interpretation of the narrative nutrient standard should consider following aspects:

- **Numeric Threshold Value**. The "default" value specified under the Everglades Forever Act (EFA) is 10 ppb. The actual value may differ, depending upon FDEP's interpretation of research results.

- **Summary Statistic**. The EFA default is a geometric mean. This approximates the median or 50th percentile. Impacts on marsh communities may be more accurately reflected by other statistics (e.g., 90th percentile, frequency of values > 10 ppb). Since these alternative summary statistics are inter-correlated, it is not clear whether research will be able to distinguish among the alternatives. With sufficient quality control, the geometric mean can be measured more precisely than other summary statistics based upon a given number of samples.

- **Hydrologic Condition**. The EFA, as well as the Refuge Levels and ENP Inflows Limits specified in the Settlement Agreement, allow for hydrologic and other background variations. Stage (water level) is the most important hydrologic variable in this case. It not clear whether research will be able to determine whether a numeric criterion determined under a given stage regime (generally high during the 1993-1998 period) is applicable under low-stage conditions. Correlations between phosphorus concentration and stage derived from historical data could be used to adjust measured concentrations to a reference stage that corresponds to average conditions under which the threshold value was determined.

- **Temporal scale**. The EFA default scale is "long-term". The true long-term geometric mean cannot be directly measured, but confidence intervals can be estimated based upon data from time intervals ranging from one to several years. An annual time step is the shortest that could be used without the added complexity of seasonal adjustment.

- **Spatial scale.** The draft network implies a spatial scale covering the entire unimpacted area (Figure 1) monitored at stations typically spaced at ~3 km apart. According to this scheme, "imbalance" would not occur unless the geometric mean over the entire area exceeds the numeric criterion. Biological impacts of nutrient enrichment have been observed on smaller spatial scales (e.g., along S10 transects & in dosing experiments). The choice of an area-wide scale appears to be driven by interpretation of certain language in the EFA, rather than research results or other scientific evidence.

Research and discussions have focused on the numeric threshold. For any threshold value, the choices of summary statistic, hydrologic conditions, temporal scale, and spatial scale can have major impacts on the design of the compliance test, upon the extent to which it protects against imbalance, and upon resulting effluent limits in a permitting context. It is unlikely that all of these parameters will follow directly from research results. Some will be based upon reasonable technical assumptions. Others (in particular, spatial scale) may be more a matter of policy. The process of developing an appropriate monitoring network and compliance test should involve explicit consideration of each parameter. This process does not seem to have taken place as yet.

The spatial scale is one of the more sensitive design parameters. The concept of using the geometric mean of a station grid distributed over a large area is borrowed from the compliance methodology used for Interim phosphorus levels at interior marsh stations in Loxahatchee National Wildlife Refuge under the Settlement Agreement. If the objective is to protect the entire marsh, the Refuge compliance methodology is not adaptable to other WCA's. Averaging over a number of stations has the advantage of providing a robust general indicator; however, this approach can be used without risking degradation of specific regions of the grid only if spatial variations are random (i.e. no consistent spatial pattern).

Because of the Refuge's unique hydrologic features (rim canal & rain-driven interior), variations among internal marsh stations are approximately random, although a relatively weak northwest-to-southeast gradient has been detected in recent monitoring data (Walker, 1999). In WCA regions with sheet-flow hydraulics (e.g., S10 inflow region of WCA-2A, discharge zones for STA-2 & STA-34), gradients are expected to develop downstream of phosphorus inputs and spatial variations are not expected to be random, unless external inflow concentrations are at marsh background levels. In such situations, measuring compliance based upon the area-wide geometric mean would allow elevated concentrations and resulting biological impacts in areas immediately downstream of phosphorus inputs. The magnitude and spatial extent of such impacts would depend upon discharge flow and concentration, phosphorus removal ("settling") rate, marsh background concentration, and the threshold criterion. Furthermore, when a gradient exists, the determination of compliance based upon an area-wide geometric mean will depend upon arbitrary station placements, as shown below.

Soil & Water-Column Data

Figure 2 shows the compliance monitoring grid for the unimpacted area in relation to soil phosphorus measurements reported by Reddy et al (1991) and baseline surveys conducted by SFWMD in 1998 within the STA-2 discharge zone, as required under the ECP 404 permit. The map shows stations with 0-10 cm soil total phosphorus levels above and below 600 mg/kg, the criterion used by FDEP in defining the unimpacted region of the marsh (Figure 1). The point values in Figure 2 agree reasonably with the 600 mg/kg contour derived by FDEP based upon a larger data set (including Duke Wetland Center results and excluding SFWMD 404 permit results). One exception is that a region of elevated TP levels immediately adjacent to STA-2 is shown on the contour map (Figure 1), but not on the data map (Figure 2). The difference apparently reflects data provided by Duke Wetland Center. Given the absence of an historical discharge, it would be difficult to explain elevated soil phosphorus levels in this vicinity. It seems likely that soil P levels that "impacted" regions along L-6 are restricted to the extreme northern end (S10E discharge zone) and extreme southern end (S7 discharge zone), as represented in Figure 2.

Figure 3 shows the compliance monitoring grid for the unimpacted area in relation to water- column phosphorus measurements by SFWMD & Duke Wetland Center between 1994 and 1998. The data set was provided by FDEP and contains only stations that are in the unimpacted area, as defined based upon soil P levels (Figure 1). The FDEP data set has been supplemented with SFWMD/404 transects in the STA-2 discharge zone , which reflect both impacted and unimpacted regions. Figure 3 shows geometric-mean phosphorus concentrations above and below 10 ppb at stations with at least 3 samples. In the eastern portion of WCA-2A (south of S10 discharges), there is a considerable north-to-south decreasing gradient in water-column phosphorus concentration within the region defined as unimpacted based upon soil phosphorus . Concentrations range from ~12 ppb at 7 km to ~8 ppb at 11-15 km. Generally, stations below 10 ppb are located further than 10 km south of L-39, where the compliance stations are also located. The 1994-1998 geometric mean of all samples collected in this region (>10 km) between 1994 and 1998 was 8.1 ppb. Given the concentration gradient and placement of compliance stations, the geometric mean for the station grid would under-estimate the true geometric mean over the entire unimpacted area.

The existence of a water column phosphorus gradient in regions with soil P levels less than 600 mg/kg soil P suggests that these areas may not in fact be unimpacted. A lower soil P criterion corresponding to the water-column threshold may be appropriate for differentiating impacted and unimpacted areas.

Modeling

Previous reports describe applications of the model used for STA design to predict phosphorus gradients in marsh areas downstream of STA discharges (Walker & Kadlec (1996), Kadlec & Walker(1999)). The model is used below to evaluate the sensitivity of phosphorus concentrations in the proposed monitoring grid to discharges from STA-2 and to evaluate the performance of the compliance test under various conditions.

Figure 4 shows the station grid for the unimpacted marsh in relation to the STA-2 discharge zone. The analysis assumes uniform sheet flow with a constant width of 12.1 km. This scenario represents the conceptual design for STA-2 with hydropattern restoration facilities in place. The station grid for the unimpacted area is represented as a series of 6 stations spaced 3 km apart over a total distance of 21 km. The actual grid contains 14 stations, with 2-3 stations at ~3 km intervals from the discharge. The hydraulic assumptions (constant width and direction of sheet flow) are assumed to apply for a distance of at least 6 km into the marsh (the second pair of monitoring stations). Since concentrations approach background levels beyond this point, the predicted geometric mean over the entire grid is insensitive to the actual flow path beyond ~6 km.

The effects of deviations from the simplified one-dimensional flow assumption could be more fully explored using SFMWD's two-dimensional model. Preliminary simulations using the steady-state version of that model indicate that the STA-2 discharge moves out into the marsh in a direction perpendicular to L-6 and results in phosphorus concentration contours that are parallel to L-6 (Fontaine, 1999). This pattern is generally consistent with the one-dimensional approximation used here.

A threshold value of 10 ppb is assumed for illustration purposes. Concentrations predicted by the model represent long-term-average, flow-weighted-means.

Theoretically, these values would not be not directly comparable to a threshold expressed as a geometric mean. Geometric and flow-weighted means at WCA marsh and outflow stations have been shown to converge at low concentration levels (Walker, 1993). For the purpose of this analysis, they are assumed to be equivalent.

When implementing the test, the threshold would be compared with measured geometric means, as opposed to model predictions. Some allowance would be made for uncertainty in the measured geometric means, so that the measured value would have to exceed the threshold by some tolerance before it would be considered a violation of the standard. For example, the measured geometric mean might have to exceed 12 ppb in order for it to be significantly above 10 ppb at a specified confidence level. Methods are available for estimating the appropriate tolerance levels based upon measurement variability and monitoring network design (Walker, 1999). Stage-dependence of concentration may also be factored into the tolerance levels. Measurement variability does not have to be considered in comparing model predictions with the threshold. For purposes of the following analysis, a violation of the standard is assumed to occur when the predicted value exceeds the threshold (i.e. zero tolerance).

Base simulations assume a settling rate of 10.2 m/yr, as estimated for the S10 inflow zone of WCA-2A and used as a basis for STA design (Walker, 1995). Phosphorus concentrations at the at the eastern end of the grid may be controlled more by historical and future discharges from the S10's than by discharges from STA-2. As discussed above, the 1994-1998 geometric mean concentration in this region was 8.1 ppb. To reflect alternative responses in this region, the model has been run with background concentrations of 8 and 4 ppb. The 8 ppb value essentially assumes that concentrations in this region are unchanged relative to 1994-1998 conditions. To some extent, these may reflect residual effects of historical loads from the S10's. The 4 ppb value assumes "recovery" of concentrations to values controlled by atmospheric phosphorus loads alone. The actual response may be a hybrid of these two cases. Since areas in the STA discharge zone are previously unimpacted, a background concentration of 4 ppb may be appropriate there, whereas a background concentration of 8 ppb would be appropriate in eastern WCA-2A to reflect residual impacts of S10 phosphorus loads.

Figure 5 shows typical results for an STA-2 discharge concentration of 50 ppb. Phosphorus concentrations are plotted as a function of distance from the inflow for background concentrations of 8 and 4 ppb. The approximate locations of 10, 20, & 30 ppb contours are plotted on a WCA-2A map for a background concentration of 8 ppb. The predicted geometric concentration over monitoring grid is 10.6 ppb for a background concentration of 8 ppb and 6.4 ppb for a background concentration of 4 ppb. The sensitivity to assumed background concentration indicates that determination of compliance with this grid would depend strongly upon concentration changes in the eastern portion of WCA-2A, which would not be significantly influenced by the STA-2 discharge. Potential localized impacts within the grid are indicated by the fact that 38% and 26% of the grid area exceeds the threshold for background concentrations of 8 and 4 ppb, respectively. Maximum concentrations detected at the monitoring stations are 13.6 and 10.9 ppb, respectively. As a consequence of the coarse station grid, these values severely under-estimate the actual maximum concentration within the previously unimpacted area (50 ppb immediately below the STA-2 discharge).

Figure 6 shows corresponding results for a discharge concentration of 25 ppb. Grid geometric mean concentrations are 9.2 and 5.3 ppb for background concentrations of 8 and 4 ppb, respectively. Even though the system would "pass" the compliance test, the threshold would be exceeded in 27% and 16% of the grid area, respectively.

Figure 7 plots the distance below the STA-2 discharge exceeding the threshold as a function of discharge concentration and assumed background concentration. The distance ranges from 5.5 to 8.1 km with a discharge concentration of 50 ppb and from 3.4 to 5.7 km with a discharge concentration of 25 ppb. The corresponding area percentage impacts can be estimated by dividing the predicted distances by the total grid length (21 km).

Figure 8 plots the grid geometric mean as a function of STA-2 outflow concentration and assumed background concentration. This illustrates potential difficulties in using the compliance test to calculate the maximum acceptable inflow concentration (i.e., that corresponding to a grid geometric mean equal to the threshold). The result would be strongly dependent on the assumed background concentration because most of the stations are out of the influence of the STA-2 discharge. With a background concentration of 8 ppb, the compliance test would support an inflow concentration of 39 ppb. With background concentration of 4 ppb, the test would support an inflow concentration of 157 ppb (off the graph scale). Both of these scenarios would be in compliance, despite significantly elevated concentrations in the STA discharge zone.

Figure 8 further illustrates that the station grid provides a biased estimate of the true geometric mean downstream of the discharge. The solid lines show geometric means over the monitoring stations (from 3 to 18 km downstream of the discharge). The dashed lines show actual geometric means over the entire transect (from 0 to 21 km, computed at 0.1 km increments). Because of the steepness of the gradient below the discharge and the coarse station grid, the station geometric mean will always under-estimate the actual geometric mean over the entire area. This bias would decrease with a finer station grid (smaller distances between stations). One way to reduce bias and dependence on station spacing would be to include stations immediately below the discharge (X = 0 km) and at the far downstream end (X = 21 km). These would be given weights of 50% in computing the geometric mean. In this way, the geometric mean would be computed by interpolation and would capture the entire zone. This would be preferable to excluding regions at arbitrary distances from the upstream and downstream edges of the monitored zone.

Table 1 summarizes results for a broader range of parameters, including settling rates of 10.2 and 15 m/yr, grid spacings of 3 and 1 km, background concentrations of 4 and 8 ppb, and discharge concentrations of 50 and 25 ppb. Geometric means are computed for the station grid, the entire transect, and for an expanded grid. Results show that an expanded grid would largely eliminate bias and dependency on arbitrary grid spacing.

Based upon water-column concentrations, the size of the impacted areas below the STA discharge would decrease with a higher settling rate (15 vs. 10.2 m/yr). This would not be entirely beneficial, since higher settling rates would also be associated with more rapid buildup of soil phosphorus levels in these areas. Soil impacts could be explored using the Everglades Phosphorus Gradient Model (Walker & Kadlec,1996).

Alternative Designs

Aside from the conceptual difficulties discussed above, the proposed station grid for the unimpacted (and impacted) areas would require tremendous monitoring effort. Most (practically all) of the effort would be spent at locations remote from phosphorus inputs. Transect monitoring downstream of phosphorus inputs, similar to that currently being conducted in the future discharge zone of STA-2 under the ECP 404 permit, would be more effective for determining the extent to which the marsh as a whole is being protected from adverse impacts of nutrient inputs. Given the problems associated with and lack of a scientific basis for averaging over large areas, the condition of the marsh would be evaluated spatially by comparing the threshold value with the geometric mean at each monitored location, with appropriate allowance for measurement variability.

In the event that a practical treatment technology to achieve inflow concentrations below the threshold is not identified and implemented before 2007, transect monitoring and modeling would be used to measure and project the spatial extent of impact zones for alternative discharge scenarios. Subsequent research and refinements of treatment technology would work towards shrinking the size of such impact zones and/or developing and implementing other mitigation measures. Transects would be supplemented by continued monitoring at a few remote stations in the marsh with long-term records to support trend analysis.

Differentiating impacted and unimpacted areas would be important for interpreting future monitoring data. In marsh areas within or downstream of previously impacted areas, release of historical P loads stored in the soils may delay the response to reductions in external P loads and make it more difficult to reach water-column concentrations below the threshold. Given the uncertainties in forecasting marsh response in previously impacted areas and given typical variability in the monitoring data, it is not clear that compliance should require detection of a significant decreasing phosphorus trend in these areas. Long time scales may be required to detect significant trends, particularly if they are small. Research and monitoring in impacted areas would promote understanding of restoration/recovery processes and possibly lead to development of management methods to accelerate them.

A demonstration of reductions in external loads to previously impacted areas may be sufficient to show a "net improvement" in previously impacted areas, as apparently required under the EFA. The threshold criterion would still be used as a restoration objective for these areas, however, and external loads would be reduced to the extent required to achieve that objective, regardless of uncertainties in the time scale required for marsh response.

The monitoring design for impacted would involve continued operation of a few stations in impacted areas with long-term records (possibly along transects). If the objective is to measure changes, adding new stations to the impacted areas does not seem useful, since it would take several years to accumulate sufficient data to support a valid trend analysis.

References

Florida Department of Environmental Protection, "Development of a Phosphorus Criteria Compliance Test for WCA-2", Draft Distributed at Meeting of Everglades Technical Advisory Committee, April 22, 1999.

Fontaine, T., Preliminary Simulations of Phosphorus Concentrations in WCA-2A Using SFWMD's Two-Dimensional Model, Personal Communication, Everglades Research Department, SFWMD, June 1999.

Kadlec, R. H., & W.W. Walker, "Management Models to Evaluate Phosphorus Impacts on Wetlands", in Reddy, K.R., G.A. O-Connor, & C.L. Schelske, eds., Phosphorus Biogeochemistry in Sub-Tropical Ecosystems, Lewis Publishers, pp. 565-584, 1999.

Walker, W.W., "Statistical Procedures for Tracking STA Performance", prepared for U.S. Department of Justice, November 1993.

Walker, W.W., "Design Basis for Everglades Stormwater Treatment Areas", Water Resources Bulletin, Volume 31, No. 4, pp. 671-685, August 1995.

Walker, W.W. & R.H. Kadlec, "A Model for Simulating Phosphorus Concentrations in Water Column and Soil Downstream of Everglades Stormwater Treatment Areas", prepared for U.S. Department of the Interior, August 1996

Walker, W.W, "Analysis of Marsh Phosphorus Data from Loxahatchee National Wildlife Refuge", prepared for U.S. Department of the Interior, March 1999.

List of Figures

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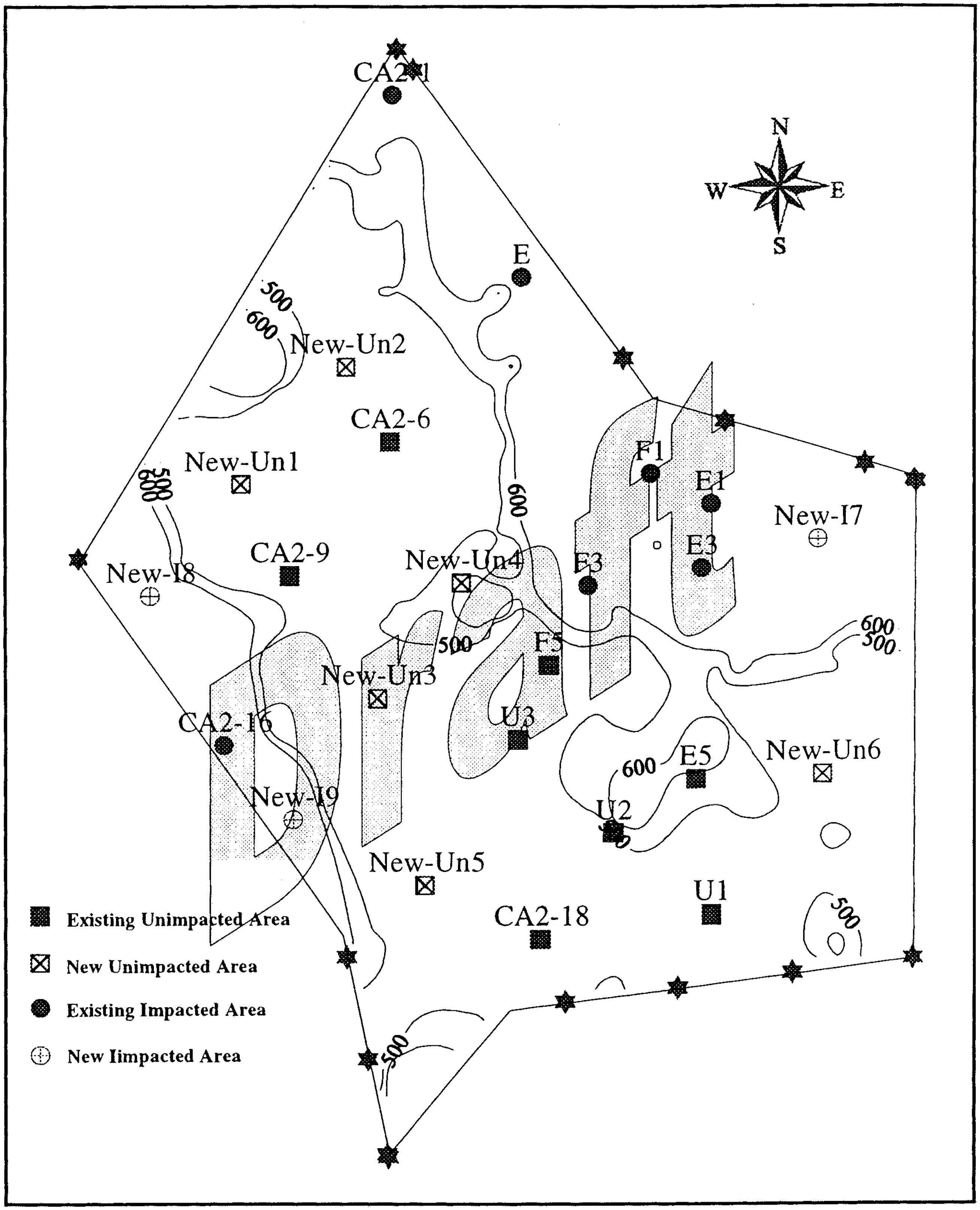


Figure 6. Map of WCA-2A Showing the 500 and 600 mg/kg Total Sediment Phosphorus Contours and the Location of Proposed Compliance Test Sampling Sites.

Figure 2

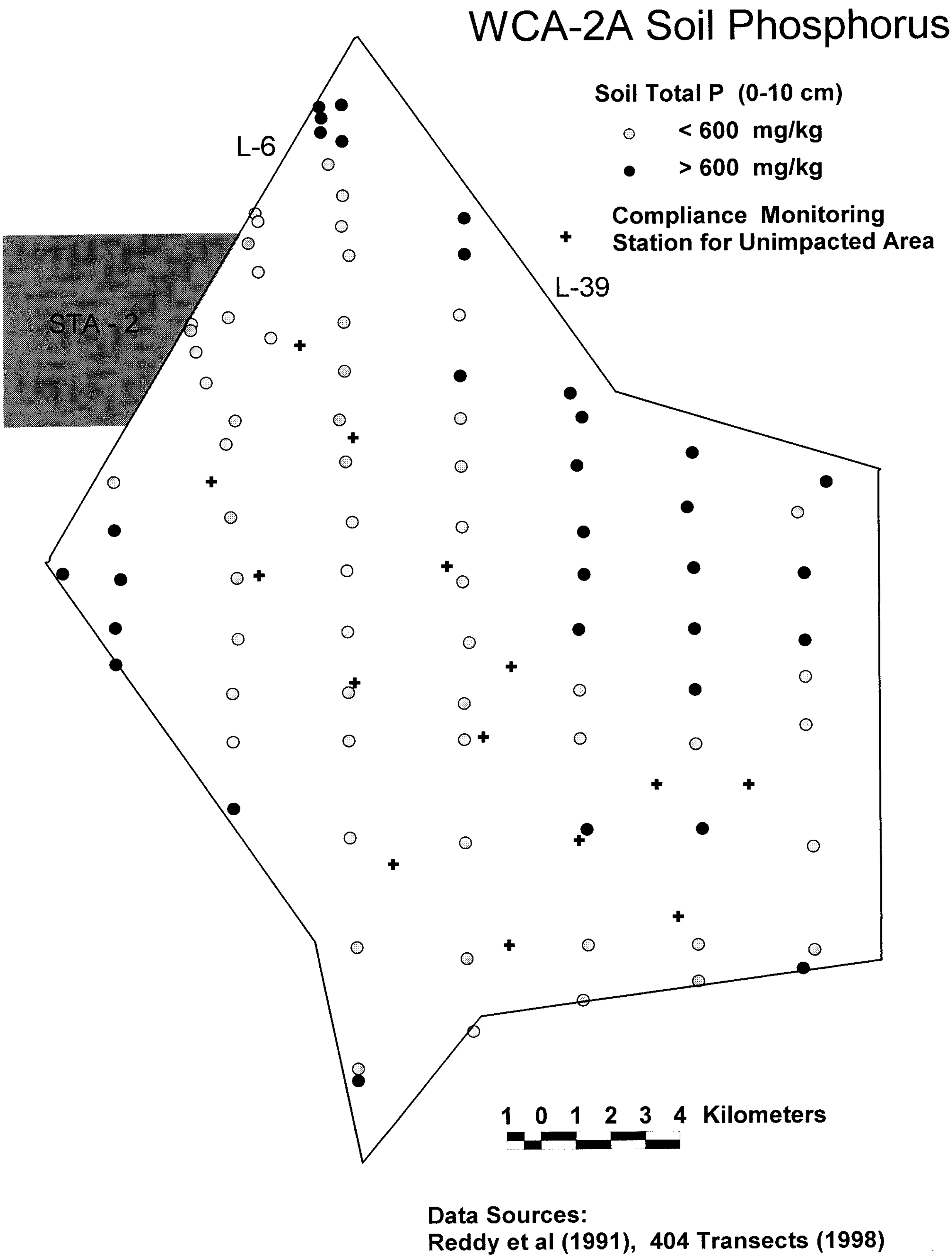
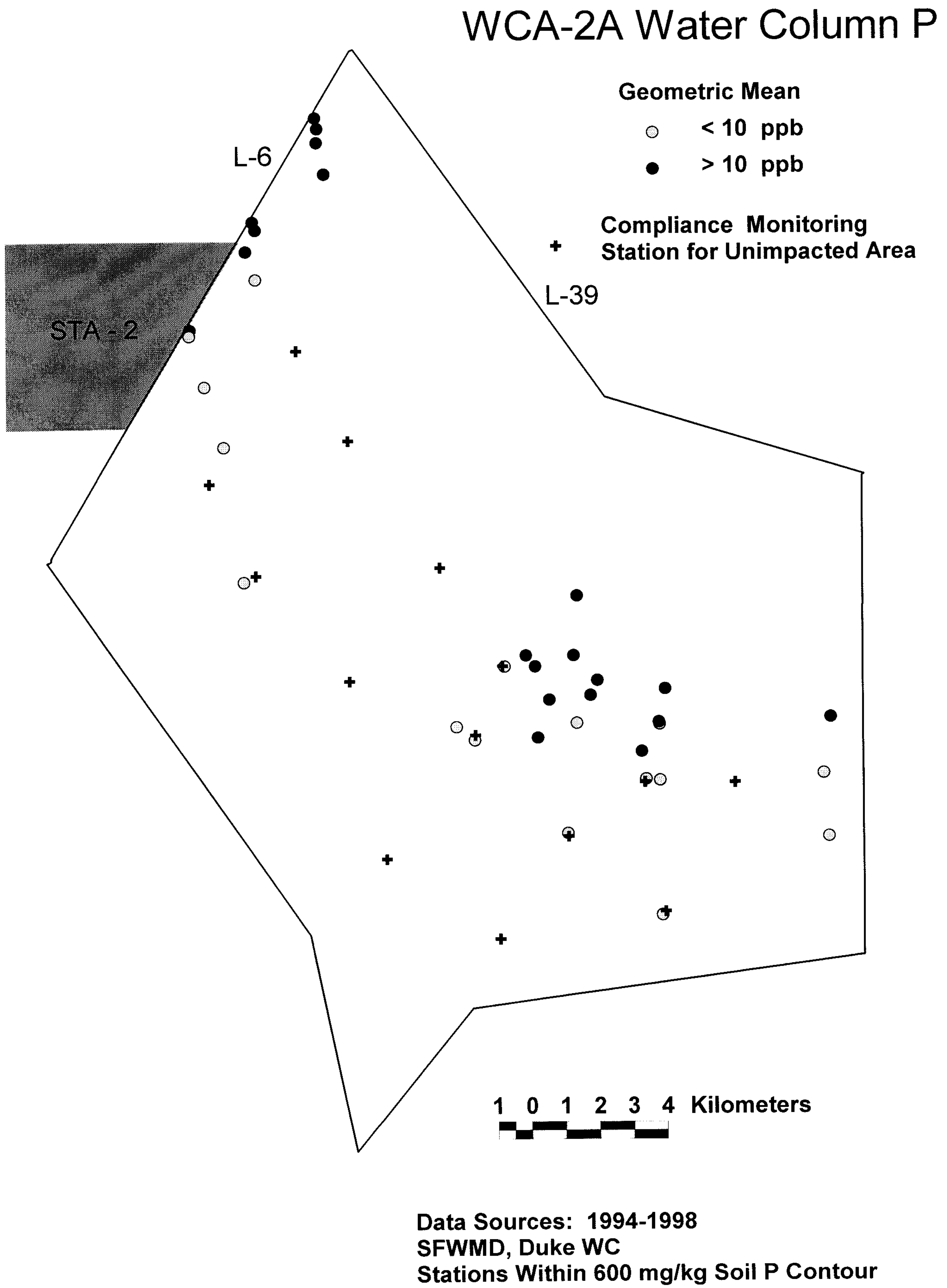
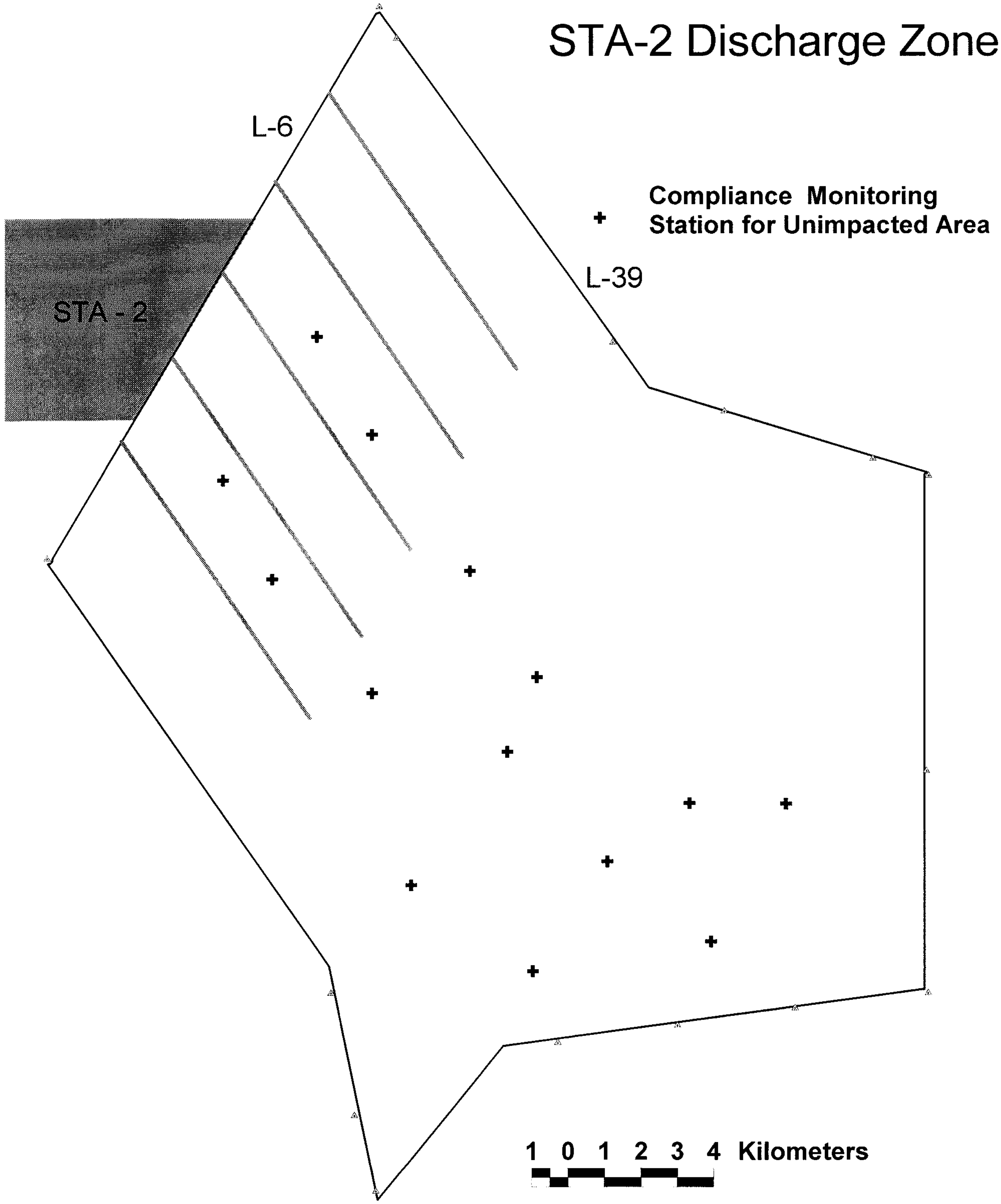

WCA-2A Soil Phosphorus
Soil Total P (0-10 cm)
< 600 mg/kg
> 600 mg/kg
Compliance Monitoring
Station for Unimpacted Area
L-6
L-39
STA - 2
1 0 1 2 3 4 Kilometers
Data Sources:
Reddy et al (1991), 404 Transects (1998)

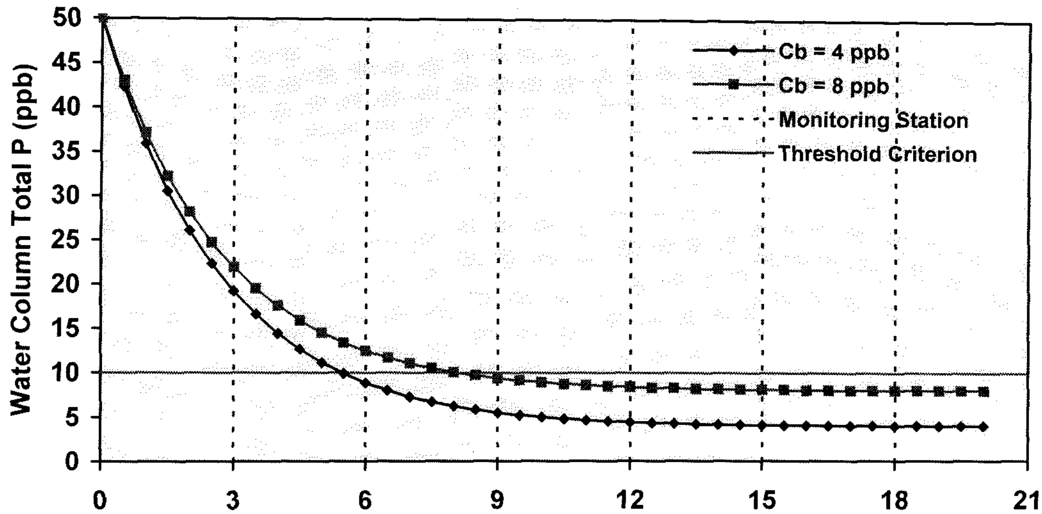
Figure 3

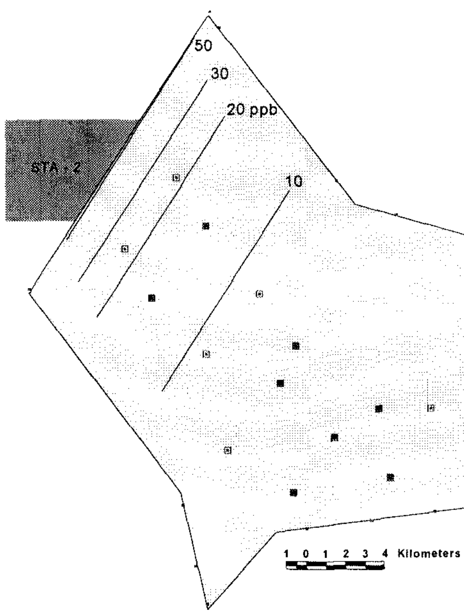

WCA-2A Water Column P
Geometric Mean
< 10 ppb
> 10 ppb
Compliance Monitoring
Station for Unimpacted Area
L-6
L-39
STA - 2
1 0 1 2 3 4 Kilometers
Data Sources: 1994-1998
SFWMD, Duke WC
Stations Within 600 mg/kg Soil P Contour



Data Sources: 1994-1998
SFWMD, Duke WC
Stations Within 600 mg/kg Soil P Contour

Phosphorus Concentration Profile Downstream of STA-2
Case: Discharge Conc = 50 ppb





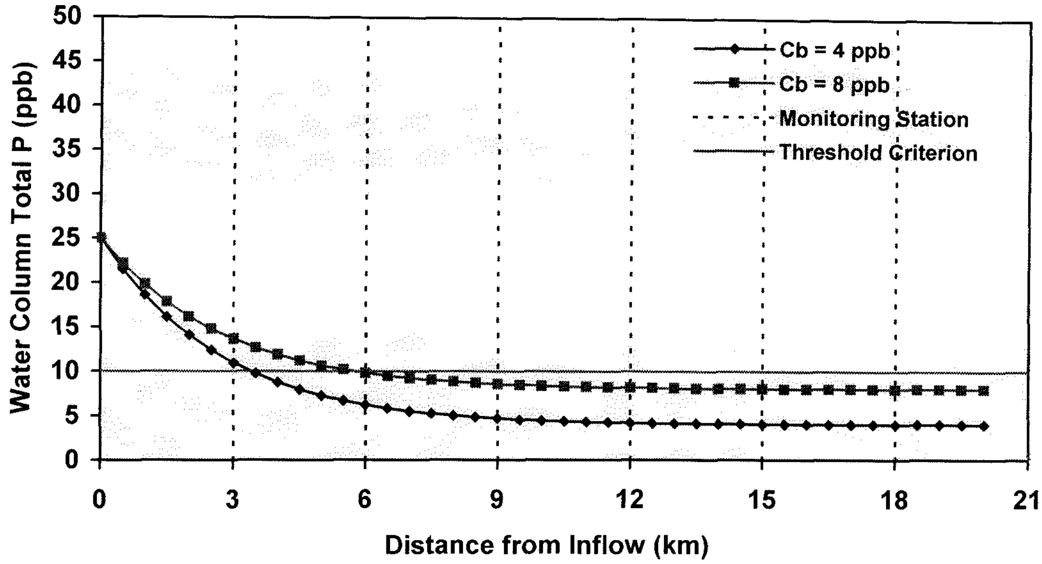
Area Map

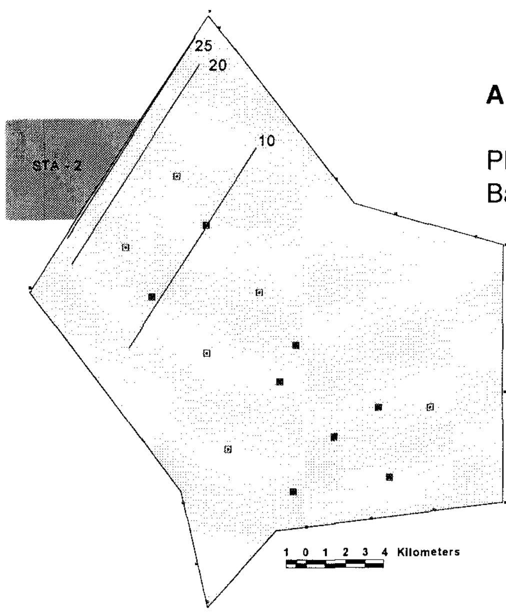
Phosphorus Contours
Background Conc = 8 ppb

Input Values	Units	
Inflow Conc	ppb	50
Inflow Volume	kac-ft/yr	303
Discharge Width	km	12.1
Threshold Criterion	ppb	10
Settling Rate	m/yr	10.2
Hydroperiod	-	0.91
Station Spacing	km	3
Station Grid Length	km	21

Output Values	Units		
Background Conc	ppb	8	4
Distance > Criterion	km	8.1	5.5
Area > Criterion	km2	97.6	66.1
Grid Geometric Mean	ppb	10.6	6.4
Grid Maximum Conc.	ppb	21.9	19.2
% of Grid > Criterion	%	38%	26%
Distance > 20 ppb	km	3.4	2.9
Distance > 30 ppb	km	1.8	1.6

Phosphorus Concentration Profile Downstream of STA-2
Case: Discharge Conc = 25 ppb



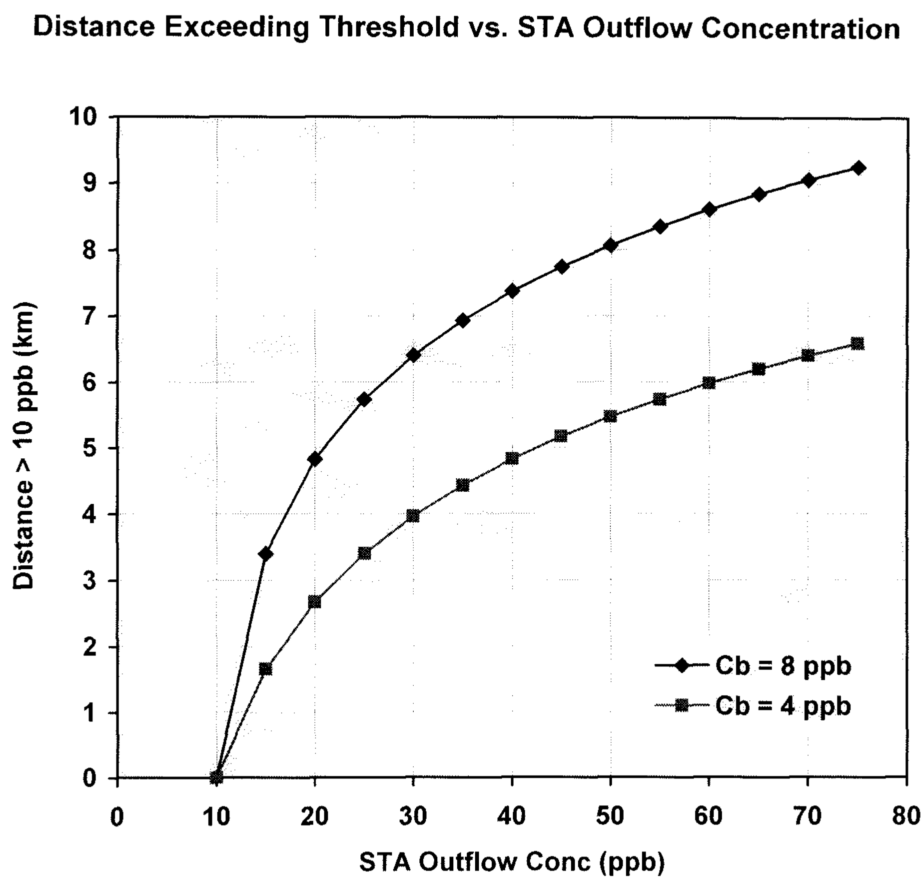


Area Map

Phosphorus Contours
Background Conc = 8 ppb

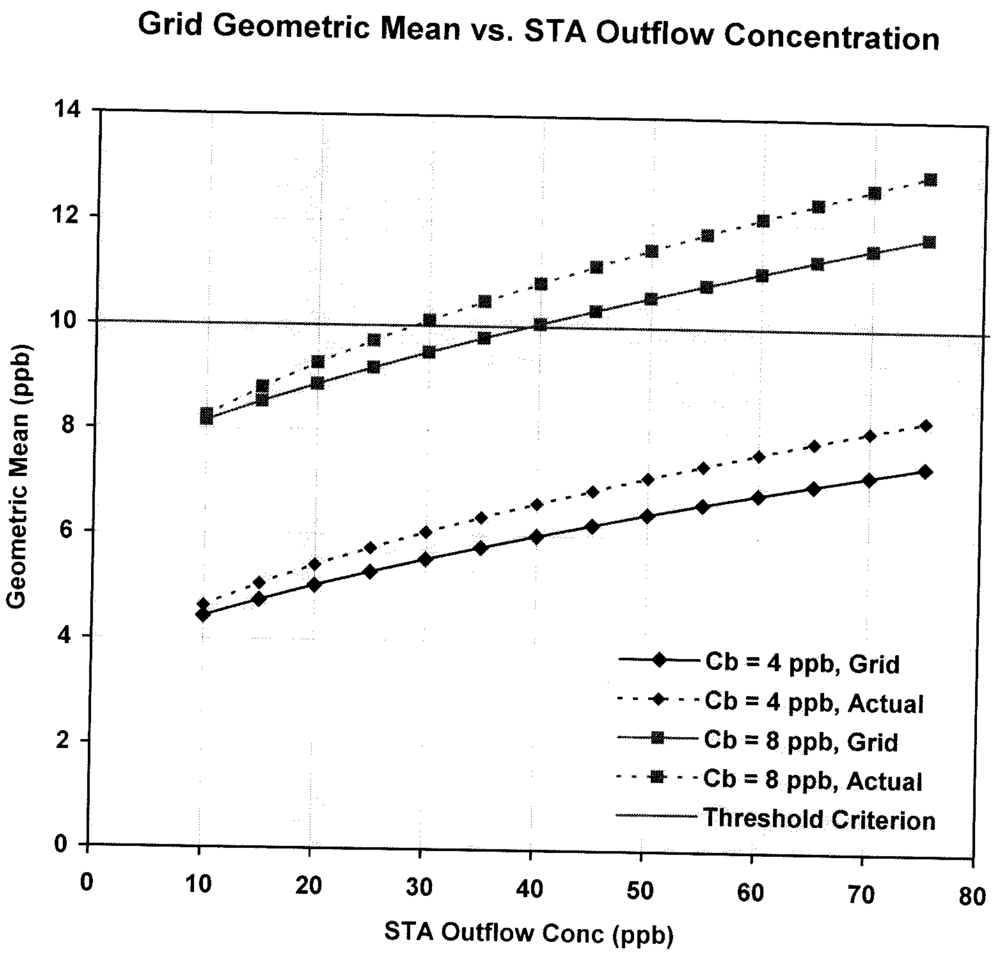
Input Values	Units	
Inflow Conc	ppb	25
Inflow Volume	kac-ft/yr	303
Discharge Width	km	12.1
Threshold Criterion	ppb	10
Settling Rate	m/yr	10.2
Hydroperiod	-	0.91
Station Spacing	km	3
Station Grid Length	km	21

Output Values	Units		
Background Conc	ppb	8	4
Distance > Criterion	km	5.7	3.4
Area > Criterion	km2	69.4	41.0
Grid Geometric Mean	ppb	9.2	5.3
Grid Maximum Conc.	ppb	13.6	10.9
% of Grid > Criterion	%	27%	16%
Distance > 20 ppb	km	1.0	0.7
Distance > 30 ppb	km	0.0	0.0



Total Grid Length =	21	km
Settling Rate =	10.2	m/yr
Cb =	Background Concentration (ppb)	

Figure 8



Cb	Background Conc (ppb)	Grid Length	21 km
Grid	GM over Stations (3 to 18 km)	Station Spacing	3 km
Actual	GM over Entire Area (0 to 21 km)	Settling Rate	10.2 m/yr

Sensitivity Analysis

Settling Rate = 10.2 m/yr

		Grid Spacing = 3 km				Grid Spacing = 1 km			
Case	Units	1	2	3	4	5	6	7	8
Settling Rate	m/yr	10.2	10.2	10.2	10.2	10.2	10.2	10.2	10.2
Background Conc	ppb	8	4	8	4	8	4	8	4
Grid Spacing	km	3	3	3	3	1	1	1	1
Grid Length	km	21	21	21	21	21	21	21	21
Inflow Conc	ppb	50	50	25	25	50	50	25	25
Test Result		Fail	Pass	Pass	Pass	Fail	Pass	Pass	Pass
Grid Geometric Mean	ppb	10.6	6.4	9.2	5.3	11.2	6.9	9.5	5.6
Expanded Grid Geo Mean	ppb	11.6	7.2	9.8	5.8	11.5	7.1	9.7	5.7
Actual Geometric Mean	ppb	11.5	7.1	9.7	5.7	11.5	7.1	9.7	5.7
Grid Maximum Conc	ppb	21.9	19.2	13.6	10.9	37.1	35.9	19.8	18.6
Actual Max. Conc	ppb	50.0	50.0	25.0	25.0	50.0	50.0	25.0	25.0
Distance > Threshold	km	8.1	5.5	5.7	3.4	8.1	5.5	5.7	3.4
Total Area > Threshold	km2	97.6	66.1	69.4	41.0	97.6	66.1	69.4	41.0
% of Grid > Threshold	%	38%	26%	27%	16%	38%	26%	27%	16%
Maximum Inflow Conc	ppb	38.9	156.5	38.9	156.5	31.7	131.1	31.7	131.1

Settling Rate = 15 m/yr

		Grid Spacing = 3 km				Grid Spacing = 1 km			
Case	Units	9	10	11	12	13	14	15	16
Settling Rate	m/yr	15.0	15.0	15.0	15.0	15.0	15.0	15.0	15.0
Background Conc	ppb	8	4	8	4	8	4	8	4
Grid Spacing	km	3	3	3	3	1	1	1	1
Grid Length	km	21	21	21	21	21	21	21	21
Inflow Conc	ppb	50	50	25	25	50	50	25	25
Test Result		Pass	Pass	Pass	Pass	Pass	Pass	Pass	Pass
Grid Geometric Mean	ppb	9.3	5.2	8.6	4.7	9.9	5.7	8.9	5.0
Expanded Grid Geo Mean	ppb	10.4	6.0	9.2	5.2	10.2	5.9	9.1	5.1
Actual Geometric Mean	ppb	10.3	5.9	9.1	5.1	10.3	5.9	9.1	5.1
Grid Maximum Conc	ppb	16.2	12.9	11.3	8.1	32.4	30.8	17.9	16.2
Actual Max. Conc	ppb	50.0	50.0	25.0	25.0	50.0	50.0	25.0	25.0
Distance > Threshold	km	5.5	3.7	3.9	2.3	5.5	3.7	3.9	2.3
Total Area > Threshold	km2	66.6	45.0	47.2	27.8	66.6	45.0	47.2	27.8
% of Grid > Threshold	%	26%	18%	19%	11%	26%	18%	19%	11%
Maximum Inflow Conc	ppb	78.6	468.6	78.5	468.6	52.8	336.2	52.8	336.2

Terms

Expanded Grid	Includes additional stations at inflow and downstream end (X = 0 & 21 km)
Actual Geometric Mean	Geometric Mean over entire transect (0 to 21 km at 0.1 km increments)
Maximum Inflow Conc.	Inflow concentration resulting in grid geometric mean of 10 ppb