D R A F T

Analysis of Water Quality & Hydrologic Data from the C-111 Basin

prepared for

U.S. Department of the Interior
Everglades National Park

by

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Introduction

Canals in the C-111 basin (Figure 1) are operated to provide water supply and flood protection for agricultural and urban areas and to the deliver flows to Taylor Slough and coastal basins of Everglades National Park (ENP). West-to-east hydraulic gradients between the adjacent ENP marsh and basin canals induce large horizontal groundwater flows through relatively permeable substrates. Resulting diversions of water from Northeast Shark Slough and Taylor Slough to the southern C-111 basin cause reductions in marsh hydroperiod and associated ecological impacts. These diversions may also have significant negative impacts on Florida Bay. Major alterations to the canal system are planned by the Corps of Engineers to reduce these impacts while continuing to provide water-supply and flood-protection benefits. A buffer strip will be constructed between the ENP marsh and the main drainage canals. Flows will be pumped from the drainage canals to raise water levels in the buffer, flatten regional hydraulic gradients, and thereby reduce groundwater flows. Overflows of surface water from the buffer into ENP may occur during periods of high flows. There are currently three direct outlets from basin canals into ENP (S332, S175, and S18C). Protection of water quality in these and any new surface or groundwater discharges created by the project is a high priority.

Monitoring efforts by the South Florida Water Management District (SFWMD), U.S. Geological Survey (USGS) and ENP have generated substantial water-quality and hydrologic data, which date primarily back to 1983. The Florida Department of Environmental Protection (1997) has compiled and analyzed the broad spectrum of water-quality data available from the basin. This report analyzes portions of the data pertaining primarily to canal phosphorus concentrations and loads. Historical variations in phosphorus concentration at monitored points in the basin are summarized and correlated with hydrologic factors. Results are discussed in the relation to conceptual models describing sources and sinks of flow and phosphorus under historical and future conditions. The report provides a foundation for future development of quantitative models to evaluate water-quality aspects of specific buffer designs.

Settlement Agreement Phosphorus Limit

Figure 2 shows yearly flow-weighted-mean phosphorus concentrations in the combined discharges into ENP through S332, S175, and S18C in relation to the 11-ppb Limit specified in the Everglades Settlement Agreement (1991). If year-to-year variance is similar to that observed in 1984-1990, a long-term, flow-weighted-mean concentration of 6 ppb or less would be required in order to comply with the 11 ppb yearly Limit in 90% of the years. The 12-month flow-weighted-mean concentration has been below the Limit since November 1995. Current monitoring data provide a basis for tracking basin inflows in relation to the 11 ppb annual Limit. Under the terms of the Settlement Agreement, compliance with the limit is not required until 2006.

The importance of seepage from NE Shark Slough and Taylor Slough as a component of flows discharged through S332, S175, and S18C is indicated in previous reports (Fennema et al, 1993; Johnson et al.,1994; Ley, 1995; NPS, 1994,1995ab; VanLent et al., 1993). As demonstrated below, seepage from ENP provides dilution of other phosphorus sources in the basin. Future concentrations in the canals, buffer, and ENP inflows will depend partially upon the extent to which existing concentrations in the L31N, L31W, and C111 canals are influenced by seepage. These influences are evaluated below by formulating water and phosphorus balances and by investigating correlations between canal phosphorus concentrations and hydrologic factors.

Hydrologic influences were considered in deriving Settlement Agreement phosphorus limits for inflows to ENP Shark River Slough and for marsh stations in Loxahatchee National Wildlife Refuge. The Shark River Slough Limits vary with basin flow and the Refuge marsh Levels vary with marsh stage. Hydrologic influences were based from statistical relationships derived from 1978-1990 monitoring data. Hydrologic influences were not factored into the Limit for the Taylor Slough / C111 basin because a significant correlation between concentration and basin flow was not detected. In light of the analysis below, however, correlations between concentration and stage (or stage differential) would provide a basis for revising the Limit to account for hydrologic variations. Such a revision may increase the accuracy, realism, and power of the tracking procedure and is suggested for consideration by the Everglades Technical Oversight Committee (TOC).

Structure Flows & Loads

Monthly flows, phosphorus loads, and flow-weighted-mean concentrations have been computed for each structure monitored by SFWMD since October 1983 (S174, S175, S176, S177, S332, and S18C). Since water-quality samples have not been collected at S174, concentrations at S176 have been used to estimate loads and concentrations at S174. Since samples have been collected at S175 only since 1995, concentration data from S332 have been used to estimate loads and concentrations at S175. Loads and concentrations have been calculated by interpolating concentration values between adjacent sampling dates with positive flow. Figures 3 and 4 show daily flows and sample concentrations used in these calculations, respectively. Flows and loads reflect positive discharges only; negative flows reported infrequently at some structures (Figure 3) are treated as zero flows.

Figure 4 indicates that the highest phosphorus concentrations in the basin are measured at S178 (median = 21ppb vs. 4-9 ppb at other stations). Lack of flow data precludes computation of loads at S178, however. (Flow values are reported in SFWMD's hydrologic data base, but are nearly all negative. A valid flow data set should be compiled for this structure to provide a basis for load calculations.)

Water and phosphorus balances have been developed for three canal reaches:

1. L31W (between S174 and S332 / S175)
2. C111-North (between S176 and S177)

3. C111-South (between S177 and S18C)

Outputs from L31N at S174 and S176 are treated as input terms in these calculations. Formulation of phosphorus balances on L31N (between the S334 / S335 inflows at the Tamiami Trail and S174 / S176) would require additional data compilation and / or assumptions because water quality data are not routinely collected at S334 or S335. Extension of the calculations to include this reach is recommended for future work.

Table 1 contains water and mass balances for the canal system in Water Years 1984 through 1996 (October 1983 – September 1996). Table 2 shows results for a dry year (1989). Table 3 shows results for a wet year (1993). Results are summarized in the following categories:

1. Structures (directly monitored; S176, S174, S332, S175, S177, S18C);

2. Net Inflows to three canal reaches, computed by difference from adjacent structure values (L31W, C111 North, C111 South); positive net inflows are attributed to seepage or runoff from adjacent areas; negative net inflows are attributed to seepage out of the canal or withdrawal for water supply / irrigation; computed in this manner, net inflows of phosphorus would also reflect any non-conservative behavior (sedimentation, algal uptake, etc.); negative net inflows are labeled as "retention".

3. Total Inflows from L31N (S174 + S176) and each of the three reaches described above;

4. Structure Outflows (directly monitored; S332, S175, S18C).

5. Net Retention (negative net inflows, attributed to outflow seepage, withdrawal, & phosphorus removal mechanisms).

Calculations have been performed at a yearly time step and subsequently averaged over the 13-year period of record. Structure flows and loads for each year are listed in Table 4. Water and mass balances for each year are listed in Table 5. Calculations ignore direct rainfall on and evaporation from the canal surfaces.

Sources of flow and phosphorus over the 13-year period are summarized below:

Source	Description	Flow cfs	Flow kac-ft / yr	Load kg / yr	Conc ppb
L31N	S174+S176	324.0	234.7	3443	11.9
L31W	S174 to S332 / S175	93.3	67.6	1258	15.1
C111 North	S176 to S177	15.2	11.0	97	7.1
C111 South	S177 to S18C	61.8	44.8	937	17.0
Total		494.3	358.1	5735	13.0

The combined outflows through S332, S175, and S18C amounted to 316 kac-ft / yr and 4270 kg / yr and had a flow-weighted-mean phosphorus concentration of 11 ppb. Retention averaged 12% of the inflow volume and 26% of the inflow load.

Yearly variations in total inflow and outflow terms are shown in Figure 5. Average inflow concentrations range from 6 to 23 ppb. Average outflow concentrations range from 6 to 21 ppb. Retention of flow and phosphorus were higher in drought years (85, 89, 90), when irrigation demands would have been higher (primarily, C111 North Reach) and when seepage from L31W towards ENP probably occurred (see below). Because of retention mechanisms operating in dry years with relatively low inflow seepage volumes from ENP, the higher inflow concentrations measured at S174 / S176 in these years were substantially reduced before discharge to ENP through S332, S175, and S18C.

Seepage Magnitudes & Impacts on Canal Water Quality

The magnitudes and impacts of seepage on phosphorus concentrations and loads at monitored structures are evident in relationships described below:

1. Correlation between measured P concentrations and estimates of seepage inflow volume derived from canal water balances (Figure 9).

2. Correlations between net seepage inflow volume and head differential (ENP marsh stage – canal stage, Figures 11-16);

3. Correlations between yearly flow-weighted-mean P concentration and head differential (Figures 17-22); and

4. Correlations between monthly flow-weighted-mean P concentration and head (Figures 23-31).

Daily stage data used in the analysis are plotted in Figure 6 (marsh stations) and Figure 7 (canal stations).

<u>P Concentration vs. Seepage Inflow Volume</u>

Ley (1995) provides direct estimates of seepage inflow (or outflow) to sections of the L31N, L31W, and C111 canals for calendar years 1987 – 1993. As demonstrated in Figure 8 (results for 1991), most of the inflow seepage typically occurs in the northern reach between S334 / S335 (inflows from North) and S331. Seepage is estimated based upon measured structure flows and canal water balances. Results do not distinguish between seepage inflows from ENP and seepage (or runoff) inflows from the local watershed (other than those passing through gauged structures shown in Figure 8).

Figure 9 correlates the yearly flow-weighted-mean phosphorus concentration measured at the outflow from L31N (S174 + S176) against the fraction of the total canal inflow attributed to seepage. Total seepage inflow is calculated as the sum of positive net inflows over each canal reach (S335->G211, G211->S331, S332->S176). The total inflow is calculated as the total inflow from the North (releases from S334 & S335) and the total seepage inflow. Most of the flows delivered from the North were dry-season water-supply releases through S335 (VanLent et al., 1993). Releases through S334 were infrequent. (SFWMD, DBHYDRO data). Results are summarized by the following regression equation:

$$C = 27.6 - 21.9\, f_{seep} \qquad (r^2 = .74\ ,\ \text{s.e.} = 3.7\ \text{ppb})$$

where,

C = flow-weighted-mean concentration at S174+S176 (ppb)

f_{seep} = fraction of L31N inflow attributed to seepage

This result suggests that local inflows (regardless of source) had a flow-weighted-mean concentration of 6 ± 3 ppb and inflows from the S334 / S335 had a concentration of 28 ± 4 ppb. Water-balance calculations do not distinguish between seepage from ENP and other local canal inflows (runoff or seepage). As demonstrated below, local inflows also have low chloride concentrations which are similar to those measured in the ENP marsh. Groundwater chloride concentrations in adjacent developed areas are expected to higher. This suggests that seepage from ENP is the primary source of local inflows to L31N.

<u>Net Seepage Inflows vs. Head Differential</u>

Seepage inflows are driven by head differential (difference between marsh stage and canal stage). The latter can be estimated for various reaches of the canal using marsh and canal monitoring stations shown in Figure 1. Figure 10 shows monthly stage differentials computed from various station pairs and rainfall measured at S331. For some periods, missing marsh stage data have been estimated by regression against data from adjacent marsh stations. Variations in head reflect climatologic and water-management factors. Generally higher heads observed in later years reflect higher rainfall.

Correlations between net seepage inflow volumes (Ley, 1995) and head for calendar years 1987-1993 are summarized below:

Figure	Canal Reach	Marsh Stage	Canal Stage	Intercept kac-ft / yr	Slope kac-ft / yr / ft	r^2	S.E.
11	L31N	G1502	S176_H	-253.3	280.9 ± 76.6	0.729	71.1
12	L31N	NE2	S176_H	-760.3	419.6 ± 58.9	0.910	40.9
13	L31N	NE2	S331	-245.5	244.9 ± 97.3	0.559	90.8
14	L31W	NP206	S175_H	-71.9	84.2 ± 11.5	0.914	15.4
15	L31W	R3110	S175_H	-1.8	133.9 ± 22.4	0.877	18.5

16	C111-South	R127	S18C_H	32.9	128.8 ± 21.9	0.873	11.4

The following regression model has been calibrated in each case:

Seepage (kac-ft / yr) = Intercept + Slope (Marsh Stage – Canal Stage)

For the L-31 N canal (above S176), the strongest correlation (r^2= 0.910, Figure 12) is observed with head estimated using marsh stage at station NE2 in Northeast Shark River Slough and canal stage above S176. The correlation based upon G1502 and S176 stages is similar (r^2 = 0.729, Figure 11). Observed seepage rates in 1992 and 1993 fall below the regression lines in Figures 11-13. This possibly reflects benefits of interim measures designed to reduce seepage (operation of G211 starting in 1991, which raised canal stages by approximately 1 foot above that structure).

For the L31 W canal, net seepage is estimated based upon the difference between inflow at S174 and outflows at S332 and S175. The strongest correlation (r^2 = 0.914, Figure 14) is observed using marsh stage at NP206 and canal stage above S175. The correlation using marsh stage at R3110 (closer to L31W) is similar (r^2 = 0.877, Figure 15). In the C111 South reach (between S177 and S18C), net seepage is correlated with head differential calculated from marsh stage at station R127 and canal stage above S18C (r^2 = 0.873, Figure 16).

A negative head differential apparently caused net seepage out of L31W in 1989. This may have occurred in other periods, as well, based upon the fact that negative differentials were observed in several months prior to 1993, based upon the R3310 and S175 stages (Figure 10). This outflow seepage may be of significance from a water quality perspective, because it provides a potential mechanism for transporting phosphorus from the canal to the adjacent marsh during periods when the inflow concentrations from the L-31 N tend to be highest (26 ppb in 1989, Figure 9). Seepage losses are primarily responsible for retention of flow and phosphorus in L31W during dry years.

The extent to which phosphorus in outflow seepage from L31W actually reaches the marsh is unknown. Some portion of the output seepage is directed east towards the Frog Pond and probably reflects irrigation demands (VanLent et al, 1993). Phosphorus in seepage moving west may be retained in soils before reaching the marsh. This mechanism may cause enrichment in soils and vegetation in marsh areas adjacent to the canal. Direct observations of soil phosphorus levels and vegetation patterns in marsh areas adjacent to the canal would help to determine whether this enrichment mechanism is important. The hydraulic mound created by the buffer will tend to alleviate this type of problem, depending upon the extent which phosphorus concentrations in the buffer are below those in the canal and upon the phosphorus retention capacity of soils beneath the buffer.

Yearly Structure Concentrations vs. Head Differential

Correlations between structure flow-weighted-mean phosphorus concentrations and head differentials for calendar years 1984 – 1996 are summarized below:

Figure	Canal	Marsh	Canal	Intercept ppb	Slope ppb / ft	r^2	SE
17	S174+S176	G1502	S176_H	34.1	-13.4 ± 2.4	0.735	3.3
18	S174+S176	NE2	S176_H	59.6	-20.9 ± 3.4	0.778	3.0
19	S332+S175	NP206	S175_H	20.3	-4.3 ± 6.5	0.038	15.2
20	S332+S175 excl. 87-88	NP206	S175_H	11.6	-1.9 ± 0.7	0.464	1.6
21	S177	G1502	S176_H	18.5	-5.9 ± 1.7	0.526	2.3
22	S18C	R127	S18C_H	9.4	3.2 ± 5.1	0.034	4.1

The following regression model has been calibrated in each case:

Concentration = Intercept + Slope (Marsh Stage – Canal Stage)

Significant correlations are identified for L31N outflow (S174+S176, r^2 = 0.735-0.778) and S177 (r^2 = 0.526). Predicted L31N concentrations range from 6 to 25 ppb over a head range of 1.7 to 2.6 feet (Figure 18). The range is similar to that obtained based upon direct correlation of concentration with seepage volume (Figure 9).

The lack of significant correlation between concentration at S332+S175 and head differential (Figure 19) is attributed to the following factors:

1. As discussed above, retention mechanisms operating in L31W cause reductions in S332+S175 outflow volumes and loads in dry years, relative to inflows through S174 (Tables 4 & 5). These mechanisms operate in periods when inflow concentrations to L31W are relatively high (because of less dilution from seepage into L31N) and when L31W stage is above marsh stage.

2. The S332 concentration data for 1987 and 1988 include a few extremely high values which have large influences on the annual flow-weighted-mean concentrations. These samples are rejected (p<.05) when the outier detection algorithm used in developing baseline data set for the EAA Regulatory Rule is applied to the entire flow / concentration data set. for S332. Soluble reactive phosphorus concentrations in these samples were at or below the limit of detection (4 ppb). When 1987 and 1988 are excluded from the regression, a significant correlation between concentration and head is indicated (r^2 = 0.464, Figure 20). The range of predicted concentrations (6 to 10 ppb) is narrow relative to that observed for L31N outflows (6 to 25 ppb, Figure 18), however, because of retention mechanisms in L31W.

<u>Monthly Structure Concentrations vs. Head Differential</u>

Correlations between head differential and flow-weighted-mean structure concentrations calculated on a monthly basis are summarized below:

Figure	Variable	Location	Marsh Stage	Canal Stage	Slope (%/ft)	r^2
23	TP	S174+S176	G1502	S176	-64%	.42
24	TN	S174+S176	G1502	S176	-17%	.15
25	CL	S174+S176	G1502	S176	-34%	.62
26	TP	S332+S175	NP206	S175	-27%	.16
27	TN	S332+S175	NP206	S175	-15%	.18
28	CL	S332+S175	NP206	S175	-29%	.39
29	TP	S18C	R127	S18C	-9%	.01
30	TN	S18C	R127	S18C	-23%	.07
31	CL	S18C	R127	S18C	-27%	.27

The following regression model has been calibrated to the monthly data:

$$\ln(\text{Concentration}) = \text{Intercept} + \text{Slope}\ (\text{Marsh Stage} - \text{Canal Stage})$$

The regression slope estimates the percent change in concentration per foot of head. Results for phosphorus (Figures 23,26, & 29) are spread over three pages:

A. Scatter plot of concentration vs. stage with regression results.

B. Diagnostic time-series plots (concentration, load, flow, rainfall, stage, & stage difference vs. year).

C. Diagnostic residuals plots (residuals [ln (observed / predicted) concentration] vs. flow, stage, rainfall, month, & year).

Regression slopes are significantly different from zero ($p<.05$) in every case except for phosphorus at S18C. Phosphorus slopes are –64% at S174+S176 ($r^2 = 0.42$) and –27% at S332+S175 ($r^2 = 0.16$). Total nitrogen and chloride concentrations also decrease with head differential at each location at rates of –15 to –23%/ft and –27 to –34%/ft, respectively. Further analysis indicates that phosphorus concentrations are also negatively correlated with head differential on a daily basis at S176 ($r^2 = 0.42$) and S332 ($r^2 = 0.20$).

The relatively low r^2 values (vs. yearly analysis discussed above) reflect the fact that each monthly concentration value is based upon between 0 samples (interpolated from adjacent months, if sampling dates in a given month did not fall on days with positive flow) and 2 samples (biweekly sampling frequency). As described below, the lack of correlation between phosphorus concentration and head at S18C is explained by influences of runoff from the C111-South watershed.

Phosphorus residuals at S174+S176 appear to be independent of flow, stage, rainfall, month, and year (Figures 23BC). Residuals at S332+S175 are positively correlated with rainfall and flow (Figure 26C). It is possible that these patterns reflect local inputs to the L31W from the Frog Pond area under high rainfall conditions, although they are also influenced by the suspected outliers discussed above.

Ranges of predicted monthly-mean L31N outflow concentrations are summarized below:

Variable	Low-Head	High-Head	ENP Marsh (TSB)
Phosphorus (ppb)	29	5	8
Nitrogen (ppb)	1687	1049	910
Chloride (ppm)	98	39	36

The low-head values estimate L31N inflow concentrations from sources other than seepage. The high-head values estimate L31N inflow concentrations from seepage. Apparent concentrations at high head are similar to median concentrations measured in the ENP marsh at Taylor Slough Bridge (period of record = 1985 – 1996). Similarities of the marsh and canal concentrations under high head conditions further indicates that the correlations between head differential and concentration primarily reflect influences of seepage from ENP (vs. seepage or runoff inflows from local watersheds).

Structure Flows & Loads vs. Head Differential & Rainfall

Since marsh water levels are influenced by rainfall, the apparent correlations between concentration and head differential described above may be influenced by variations in rainfall. Under future conditions, overflows from the buffer to ENP would be most likely to occur during periods of high rainfall. For these reasons, it is useful to investigate rainfall and head influences simultaneously. Cross-tabulations of monthly flow-weighted-mean concentration, flow, and phosphorus load vs. head differential and rainfall interval are shown in Figure 32 (S174+S176), Figure 33 (S332+S175), and Figure 34 (S18C). Head and rainfall intervals have been defined to reflect lower, middle, and upper thirds of monthly values over the 1984-1996 period.

Flow generally increases with both head and rainfall at each location. Under low-head conditions, flows at S174+S176 are relatively independent of rainfall interval (range 195 to 244 cfs). Under high-head conditions, flows increase with rainfall from 325 to 604 cfs). Under low-head conditions, when seepage out of the L31W canal is likely, flows at S332+S175 increase with rainfall from 20 to 98 cfs. Flows are also low at S18C under low-head conditions (26 to 119 cfs) because of seepage out of the C111 canal between S176 and S177.

Concentration at S174+S176 decreases with head over a range of 21 to 8 ppb, but is relatively independent of rainfall. Concentration at S332+S175 is highest in the medium-head, high-rainfall interval (26 ppb vs. 7-14 ppb for other intervals). It is possible that this pattern reflects contributions from the Frog Pond area, although results for this interval are controlled largely the suspected outliers in the 1987 and 1988 phosphorus data for S332.

Figure 34 suggests that concentrations at S18C are independent of both head and rainfall (8 – 12 ppb). When examined over a shorter time scale, however, higher concentrations at S18C are associated with large storm events in recent years. Figure 35 plots sample concentrations at S176, S332, and S18C against 7-day antecedent rainfall at S331. There is no indication that concentrations at S176 or S332 increase systematically following large storm events. Such increases are suggested in S18C data from 1991-1996, however. Higher phosphorus concentrations following large storms are primarily responsible for higher phosphorus concentrations and loads computed for local inflows to the C111-South reach in 1992-1996 (Table 5). This suggests that runoff sources are important in this reach. Compilation of S178 flows and calculation of loads are suggested to provide a basis for further evaluation of factors controlling S18C concentrations and loads.

Discussion

The following summary and discussion of results for each canal segment rely heavily on yearly water and mass balances listed in Table 5. Figure 36 shows yearly total inflow volumes and phosphorus loads to each canal segment, using results extracted from 5. These inflows reflect the sum of seepage, runoff, and drainage inflows. Refinement of these calculations to separate ENP seepage inflows from local watershed inflows would be needed for model calibration and is suggested for future work.

<u>L31N Outflows</u>

Average outflows from L31N through S174 and S176 in Water Years 1984-1996 were 235 kac-ft / yr and 3443 kg / yr at a flow-weighted-mean concentration of 12 ppb. The following observations are made regarding sources of flow and phosphorus to the L31N canal between S335 and S176:

1. The negative correlation between seepage inflow fraction and phosphorus concentration at S174 / S176 in 1987-1993 (Figure 9) suggests that inflows from the S335 had a flow-weighted-mean concentration of ~28 ppb and that the combined inflows to the L31N between S335 and S176 had a flow-weighted-mean concentration of ~6 ppb.

2. Figures 11 and 12 indicate that local volumes to this reach are strongly correlated with head differential (marsh stage – canal stage). This suggests that seepage from ENP accounts for most of the local inflows to L-31N.

3. Direct correlations between annual-mean stage differentials and S174/S176 concentrations (Figure 17 & 18) indicate concentrations ranging from 2-6 ppb under high-head conditions to 23-25 ppb under low-head conditions.

4. Direct correlations between monthly-mean stage differential and S174/S176 concentration (Figure 23A) indicate a range of 5 to 29 ppb.

5. Cross-tabulation of flow-weighted-mean concentrations at S174/S176 against head differential and rainfall (Figure 32) indicates that concentration at S174/S176 does not increase with rainfall under low, medium, or high-head conditions. Increases in discharge volume with rainfall within each head interval probably reflect drainage and runoff from local watersheds. Since concentrations do not increase with rainfall (Figures 32, 35, it is likely that concentrations in local watershed inflows are low (similar to seepage inflows from ENP) and that local inflows are primarily in the form of seepage (vs. direct runoff).

Local inflows to L31N originate from the 8.5 mi^2 residential area, Rocky Glades agricultural area, and agricultural areas east of L31N. Impacts of runoff and seepage from these areas on phosphorus concentrations at S176 are apparently not detectable in the presence of large volumes of seepage inflow from ENP and deliveries from the North. Direct monitoring of groundwater and runoff from these areas would be needed to provide a basis for calibrating a model of the basin.

L31W / Frog Pond Reach

Local inflows to L31W (between S174 and S332/S175) averaged 68 kac-ft/yr and 1258 kg/yr at a concentration of 15 ppb. These results are heavily influenced, however, by data from 1987 and 1988, when a few high sample concentrations at S332. In 1991-1996 (years which are more representative of current land uses in the Frog Pond area), local inputs averaged 104 kac-ft/yr and 899 kg/yr at a concentration of 7 ppb. These inputs reflect the sum of seepage inflows from ENP and runoff/drainage from the local watershed.

As for L31N, local inflow concentrations to L31W in recent years appear small and/or not detectable in the presence of the large volumes of seepage inflow from ENP. This would be expected to continue in the future, unless substantial development occurs in the region. Resumption of farming in the area would increase local input volumes, loads, and concentrations. These impacts could be evaluated with a more detailed modeling effort.

This reach apparently acts as a net sink for flow and phosphorus in dry years (Table 5). In water years 1989 and 1990, ~36% of the inflow volume from S174 was lost due to seepage or water supply in the Frog Pond and ~73% of the phosphorus load was lost due to volume loss and other retention mechanisms (sedimentation, algal uptake, etc.). Under future conditions, these retention mechanisms would be displaced to the buffer. To the extent that retention reflects seepage from the canal to ENP, the buffer project would be expected to provide significant benefits by separating the canal from the Park, assuming that future phosphorus concentrations in the buffer are below those which occurred historically in the canal.

C111-North Reach

Local inflows to C111 North (S176 → S177) averaged 11 kac-ft / yr and 97 kg / yr at a concentration of 7 ppb. Historically, this reach acted as a net sink for flow and phosphorus in most years. Local outflows (retention) averaged 39 kac-ft / yr and 1095 kg / yr at a concentration of 23 ppb (Table 5). Apparent retention in this reach reduced flows, loads, and concentrations reaching S18C, particularly in dry years, when inflow concentrations at S176 were highest (22 – 24 ppb in water years 1989-1990). Van Lent et al (1993) suggested that apparent decreases in flow between S176 and S177 in most years could be attributed to errors in flow measurements. While such errors are possible, the fact that flow decreases are higher in dry years (1989-1990) is consistent with the hypothesis that they result from irrigation demand from the Frog Pond and / or areas to the East. Additional QA / QC work on flow data sets may help to resolve this situation.

C111-South Reach

Local inputs to the C111-South reach (S177→S18C) contributed an average of flow of 45 kac-ft / yr and phosphorus load of 937 kg / yr at an average concentration of 17 ppb in water years 1983-1996 (Table 5). Inputs from this reach had the highest average phosphorus concentration (17 ppb vs. 12 ppb for S174 / S176, 15 ppb for L31W, and 7 ppb for C111-North). More importantly, local inflow concentrations have been highest in recent years (28 ppb 1994 and 25 ppb in 1995). Since the computed local inflow concentrations represent the sum of seepage from ENP (Figure 16) and runoff / drainage from the local watershed, it is likely that concentrations in the latter are much higher. Figure 36 shows that this basin was the largest source of phosphorus over the 1994-1996 period.

In contrast to other reaches, C111-South contains a more substantial agricultural watershed. Discharges through S178 constitute one known source; phosphorus concentrations at S178 are generally higher than those measured elsewhere in the basin (median = 21 ppb vs. 4-7 ppb, Figure 4). Recent increases in phosphorus loads may be attributed partially to drainage improvements made upstream of S178. Compilation of a valid flow data set is needed to estimate phosphorus loads through this structure. It is clear that treatment of runoff / drainage from this reach should be a high priority in developing a future plan for the basin.

Conceptual Model

The above results can be interpreted in the context of conceptual models shown in Figure 37 (historical conditions) and Figure 38 (future conditions). These figures identify important flows and phosphorus fluxes under different hydrologic conditions.

A modeling effort would be required to quantify flows and fluxes and to predict future concentrations and loads of phosphorus in surface and groundwater discharges from the buffer into ENP. The model structure is similar to that developed for evaluating treatment options for the S9 discharge in the C11 basin (Walker, 1997a). The above analyses provide information which could be used to calibrate and apply a model. Despite lack of a calibrated model at this point, Figures 37 and 38 provide a basis for discussing and ranking important sources of flow and phosphorus under historical and future conditions, respectively.

It is assumed that the buffer design concept (Figure 38) applies to the L31N, L31W, C111-South segments. The latter reflects full-scale implementation of continuous buffer between ENP and the L31N / C111 canals extending from the Tamiami Trail to S18C. Depending upon local flow-control objectives and constraints, the actual project may differ from this idealized concept.

Based above results, an average concentration of ~30 ppb can be assigned to deliveries from the North under historical conditions. These deliveries have been primarily dry-season water-supply releases through S335. Because of canal linkages to WCA's described above, phosphorus concentrations in flows delivered from the North will eventually decrease as a consequence of load-control measures (BMP's & STA's) being implemented at inflows to the WCA's. The 30 ppb value would be a conservative estimate if applied to future scenarios (Figure 38). More realistic estimates could be derived by tracking S335 flows back up into the system and evaluating concentration sensitivity to upstream load controls. These deliveries may not be important in modeling buffer response under high-flow conditions, because the would occur in the dry season and would be mostly diverted to the C1, C102, and C103 basins.

Based upon the concentration / head relationships described above, an average concentration of ~6 ppb would characterize seepage from ENP under historical and future conditions. Although it is likely that concentrations in seepage from the local watershed are higher than this, the effects of such seepage on concentrations at S176 are not detectable in the presence of the large volumes of seepage from ENP and deliveries from the North. Compilation of groundwater monitoring data from the region would be needed to select appropriate concentration values for modeling.

As shown in Figure 38, diversions from western portions of the C1, C-102, and / or C103 basins (urban watersheds immediately to the East) would represent potential additional inflows to the L31N under future conditions. Since these are urban basins, they could represent significant sources of phosphorus . If such diversions are actually planned under the East Coast Buffer project, relevant water quality data from these basins should be compiled to provide a basis for assigning appropriate phosphorus concentrations.

From a mass-balance perspective, impacts of the project on net phosphorus loads **to** ENP would depend the extent to which its design and / or operation:

1. Creates new sources of phosphorus (promotes new development, provides more aggressive drainage of existing developed areas, promotes diversion of flows from other basins).

2. Provides treatment within the buffer and / or associated treatment areas (reduction in load attributed to phosphorus retention in vegetation and soils);

3. Reduces phosphorus transport in groundwater flows from the canals to ENP, which probably occurred historically during dry periods, particularly adjacent to L31W.

A modeling approach similar to that applied to the C11 / S9 basin could be applied to develop quantitative predictions, subject to uncertainties involved in simulating buffer hydraulics and phosphorus uptake mechanisms (Walker, 1997a).

If significant new sources of phosphorus are not created (1), it is not unlikely that the project will cause a net increase in phosphorus *loads* to ENP. Under historical conditions, phosphorus loads to L31N and L31W were apparently dominated by deliveries through S335 and seepage from ENP, particularly in 1991-1996. Substantial load reductions relative to historical conditions may occur as a consequence of the reduced volume of recycled seepage from ENP. Phosphorus controls implemented at inflows to the WCA's may reduce concentrations and loads in releases through S335. Further load reductions may occur as a result of phosphorus uptake in soils and vegetation within and below the buffer. Given current understanding of phosphorus dynamics in vegetative treatment systems with this type of hydrology and substrate, uptake rates could only be estimated within broad ranges. In any case, the buffer is likely to retain more phosphorus than the existing canal system.

Impacts of the buffer project on phosphorus ***concentrations*** in flows discharged to ENP would be more difficult to predict, particularly if estimates on a short time step are required. Reductions in the dilution historically provided by recycled seepage from ENP would tend to cause increases in basin outflow concentration. These concentration increases may be offset by the load reduction mechanisms discussed above.

ENP inflow concentrations may be highest in overflows from the buffer during and following intense rainfall periods. During overflow events, water residence time in the buffer would be short, so that outflow concentrations would be largely determined by inflow concentrations. There is no indication that canal concentrations at S176 or S332 increase systematically following large storm events (Figure 35), however.

Given uncertainties involved in predicting future inflow concentrations to ENP, various phases of the project should be designed to provide operational flexibility. Both design and operating decisions would be made based upon monitoring data and current hydrologic and water-quality management objectives. As project phases become functional, much will be learned about inflow dynamics, buffer hydraulics, phosphorus uptake rates, and responses to storm events. If current operations result in frequent overflows with unacceptably high phosphorus concentrations, adjustments could be made (e.g., changes in the design of future phases, changes in inflow pumping strategies, operating levels, chemical treatment (liming) of soils, harvesting of soils and vegetation, isolation and separate treatment of upstream phosphorus sources). Project designs should be reviewed to insure that they provides operational flexibility to the maximum feasible extent.

It is not clear to the author whether the existing buffer design incorporates flows from the C111-South basin (between S177 and S18C). As discussed above, this portion of the basin represented the largest source of phosphorus in the 1994-1996 period. Further evaluations of this basin are suggested to identify requirements and appropriate components of a phosphorus-control strategy. Experience in the Everglades Agricultural Area has demonstrated that BMP's can be effective in reducing phosphorus loads. The Everglades Nutrient Removal Project has demonstrated that vegetated treatment systems can also be effective. Translating these experiences to the C111 is not straight-forward, however, because of the vastly different forms of agriculture, geology, and hydrology.

Initial Phase – S332D

The initial phase of the C111 project calls for construction and operation of the S332D pump station near the location of the current S174 gated structure. This will provide a capability for diverting flows from L31N into L31W and the headwaters of Taylor Slough at higher rates (maximum 500 cfs) and at higher marsh stages than are currently possible through S174. Hydrologic simulations required for evaluating water-quality impacts of this interim measure are not currently available. Potential mechanisms to be considered in evaluating water-quality impacts are discussed below.

Hydrologic effects on L31W would include an increase in flow from the L31N and decrease in seepage inflow from ENP. The latter would result from higher canal stages in L31W (Figures 14-15). Discharges to ENP would potentially occur in the form of outflow seepage, overflow from the L31W, and point discharge through S332. Discharge through S175 is unlikely. Maximum hydrologic benefits to ENP may be derived by eliminating discharge through S332 altogether (VanLent, T., pers. com.) , in which case most of the outflow would occur in the form of overflow from L31W.

Given the shift in ENP inflow distribution, adjustments to the procedures for evaluating compliance with the Settlement Agreement phosphorus Limit may be required. This matter should be considered by the TOC. Given potential difficulties in monitoring diffuse overflows and seepage from L31W, monitoring data from S332D could be used to reflect inflows to Taylor Slough. Based upon historical data for the combined discharges through S176 and S174, annual flow-weighted-mean concentrations would range from ~6 ppb to ~25 ppb, depending upon head differential (Figures 17-18). Concentrations may be higher if pumping at S332D induces more flow into the L31N from the East. Concentrations may be lower if inflows to L31N from the North decrease as a result phosphorus load controls at inflows to the WCA's. Since the 11 ppb annual limit applies to the combined inflows to Taylor Slough and Coastal basins (S18C), the basin could still (theoretically) be in compliance even if inflows through S332D exceed 11 ppb.

Provision of a flow-through treatment area in western sections of the Frog Pond may help to reduce concentrations and loads to Taylor Slough. Depending upon design and operation, such a measure may reduce hydrologic benefits, however. As noted above, the L31W has apparently provided some ”treatment” of S174 inflows in dry years (reductions in flow and load attributed to outflow seepage and / or phosphorus uptake mechanisms operating in the canal). More quantitative evaluations of treatment needs, options, and hydrologic impacts in the Frog Pond area would be based upon hydrologic simulation results.

Hydrologic effects on the C111-North and C111-South reaches would include a decrease in flow from L31N. An increase in seepage inflow from ENP into the C111-South reach may occur as a result of higher marsh stages in Taylor Slough (Figure 16). If the increase in seepage inflow from ENP does not offset the decrease in inflow from L31N, a higher percentage of the volume discharged through S18C would originate in the local watershed draining into the C111-South reach. As discussed above, phosphorus concentrations in local inflows to this reach have been relatively high in recent years (Figure 38). Because there would be less dilution by inflows from L31N, phosphorus concentrations at S18C may increase as a result of S332D operation, unless measures are taken to reduce phosphorus loads from the C111-South watershed.

Conclusions

1. Water and phosphorus balances have been developed for the C111 basin using monitoring data from 1984-1996. Inflows have been partitioned into four sources: outflows from L31N (S174+S176) and local inflows to each of three canal reaches (L31W between S174 and S332 / S175, C111-North between S176 and S177, and C111-South between S177 and S18C). Outflows and retention (net losses) have also been quantified for each reach.

2. Local inflows to the L31N, L31W, and C111-South are strongly correlated with head differentials between the adjacent ENP marsh and the respective canal segments. Seepage rate estimates per foot of head differential are 281-420 kac-ft / yr / ft for L-31N, 84-134 kac-ft / yr / ft for L31W, and 129 kac-ft / ft / yr for C111-South. These correlations reflect a direct linkage between seepage losses from ENP and canal design / operation. They generally support the buffer design concept as an effective means for controlling seepage losses.

3. Effects of dilution by seepage from ENP are reflected in negative correlations between phosphorus concentrations measured at the outflow from L31N (S174+S176) and upstream head differential (marsh stage – canal stage) evaluated on a yearly, monthly or daily basis. Flow-weighted-mean concentrations at S176 vary systematically from ~30 ppb during periods of low head differential, when L31N inflows are dominated

by deliveries through S335, to ~ 6 ppb during periods of high head differential, when L31N inflows are dominated by seepage from ENP. Total nitrogen and chloride concentrations at this location are also negatively correlated with head differential.

4. Phosphorus loads and concentrations in the L31N and L31W canals are controlled largely by deliveries from the North (S334/S335) and seepage from ENP. Impacts of local watershed contributions are difficult to detect in the presence of large volumes of recycled seepage from ENP. Based upon the apparent lack of response in canal phosphorus concentrations to rainfall events in recent years, it is likely that most of the local watershed contributions are in the form of seepage instead of direct runoff. Compilation of additional canal and groundwater quality data would provide an improved basis for estimating phosphorus concentrations in local inflows to the L31N and L31W.

5. Relatively low phosphorus concentrations measured at L31N and L31W structures in recent wet years reflect high ENP stages and high volumes of seepage from ENP. Over the short term, concentrations at ENP inflow points S332 and S175 may increase above current levels when normal or dry rainfall years are encountered. Over the long term, concentrations may decline as a result of phosphorus load controls being implemented at inflows to the Water Conservation Areas.

6. The L31W canal acted as a net sink for flow and phosphorus during dry years (1989-1990). These losses partially reflect seepage out of the canal into the adjacent ENP marsh, which occurred during a period when phosphorus concentrations at inflows to the L31W canal were highest (25-30 ppb). An inventory of soils and vegetation in marsh areas adjacent to the canal would help to determine whether enrichment resulting from such seepage is a valid water-quality concern.

7. Phosphorus loads and concentrations at S18C are influenced by contributions from the northern C111 and by drainage from local watersheds. Concentrations in local drainage show an increasing response to rainfall. Compared with outflows from L31N and local inflows to L31W and C111-North, local inflows to the C111 South reach accounted for the largest source of phosphorus to the C111 canal over the 1991-1994 period. The flow-weighted-mean phosphorus concentration in local inflows to this reach averaged 24 ppb, compared with a range of 6 – 10 ppb for the other reaches. Development of a phosphorus-control strategy for this portion of the basin is suggested.

8. If the C111 buffer project does not create new sources of phosphorus (by promoting development, providing more aggressive flood control for existing areas, or promoting diversion of flows from other basins), it is unlikely that the full-scale project will cause net increase in phosphorus ***load*** to ENP relative to historical conditions. Reductions in phosphorus load may occur as a consequence of reduced seepage, implementation of phosphorus controls at inflows to the WCA's, and phosphorus uptake within the buffer.

9. Impacts of the buffer project on phosphorus ***concentrations*** in flows discharged to ENP would be more difficult to predict, particularly if estimates on a short time step are required. Reductions in the dilution historically provided by recycled seepage from ENP would tend to cause increases in basin outflow concentration. These concentration increases may be offset by the load reduction mechanisms discussed above.

10. ENP inflow concentrations may be highest in overflows from the buffer during and following intense rainfall periods. Consistent increases in phosphorus concentrations following large storm events are not evident in historical data from S176 and S332, however. This suggests that most of the canal inflows from local watersheds following storms are in the form of seepage instead of surface runoff. Assuming that the buffer itself does not represent a significant source of phosphorus, there is no indication that dramatic spikes of flow with high phosphorus concentrations water would be discharged into or out of the buffer during overflow periods.

11. The various phases of the buffer design should be reviewed to insure that they provide operational flexibility to the maximum feasible extent. Changes to the designs of future phases and / or operations can be made in response to monitoring results and current hydrologic and water-quality management objectives.

12. If operation of S332D (initial project phase) does not induce additional groundwater inflow to the L31N from the East, this phase is not likely to cause a net increase in phosphorus load discharged to ENP. As a consequence reduced seepage recycling in L31W, there may be a net overall increase in inflow concentration. Provision of a flow-through treatment area in western sections of the Frog Pond may help to reduce concentrations and loads to Taylor Slough. Depending upon design and operation, such a measure may reduce hydrologic benefits, however. Further analyses of treatment requirements and options for the Frog Pond area are needed.

13. Because of reduced dilution of local inflows to the C111-South canal, increases in phosphorus concentration (not load) may occur at S18C as a consequence of S332D operation, unless adequate load-control measures are implemented in the C11-South watershed.

14. Various project phases will change the locations and forms (surface vs. groundwater) of basin outflows to ENP. Appropriate adjustments in current procedures for monitoring compliance of basin discharges with the Settlement Agreement should be developed by the Technical Oversight Committee. Potential revisions to the fixed 11 ppb annual limit to account for the substantial hydrologic variance components identified above (relationships between canal P concentration and head) should also be considered by the TOC.

15. Development of a water-quality model is suggested to provide a basis for evaluating specific designs for each phase of the buffer project. The model would rely heavily upon output from independent hydrologic simulations defining the water balances of canal and buffer segments. Water-quality predictions would necessarily reflect uncertainties in the hydrologic simulations, as well as uncertainties in simulating phosphorus retention mechanisms in the buffer water column and soils. Evaluation of these uncertainties will provide a basis for identifying needs for additional monitoring and / or experimental data to provide an adequate foundation for predicting water quality impacts and developing control strategies.

16. The following future work is proposed for refining the analysis of historical conditions and developing more quantitative predictions of future conditions:

    (a) Delineation of watersheds and land uses tributary to each canal segment.

    (b) Compilation of a flow data set and calculation of phosphorus loads for S178.

    (c) Extension of the water-balance and mass-balance calculations to include L31N between the Tamiami Trail and S176.

    (d) Compilation and analysis of regional groundwater quality data.

    (e) Compilation and analysis of regional surface-water quality data from drainage canals east of the L31N / C111.

    (f) Refinement of the calculations to partition local inflows into ENP seepage and local watershed contributions

    (g) Refinement and application of the C-11 / S9 model framework (Walker, 1997a) to further evaluate buffer designs and to assist in developing phosphorus-control strategies for the southern C111.

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List of Tables

C111 Canal Water & Mass Balances, Water Years 1984-1996

Dates: Oct-83 to Sep-96 Avg Rain: 4.8 in/mo Head (G1502-S176): 1.63 ft

	Flow cfs	Flow kac-ft/mo	Load kg/mo	Conc ppb	Notes
Canal Fluxes					
S176	219.6	13.3	197.8	12.1	Directly Monitored
S174	104.3	6.3	89.1	11.5	Directly Monitored, Conc. @ S176
S332	108.3	6.5	73.6	9.1	Directly Monitored
S175	84.5	5.1	97.3	15.4	Directly Monitored, Conc. @ S332
S177	181.1	10.9	114.6	8.5	Directly Monitored
S18C	242.9	14.7	185.0	10.2	Directly Monitored
L31W Reach					
Measured Inputs	104.3	6.3	89.1	11.5	S174
Measured Outputs	192.8	11.6	170.8	11.9	S332 + S175
Net Inputs	88.5	5.3	81.7	12.4	Measured Outputs - Measured Inputs
Local Inputs	93.3	5.6	104.8	15.1	Max (Net Inputs, 0), Min Conc = 6 ppb
Local Retention	4.8	0.3	23.2	64.5	Net Inputs - Local Inputs
C111 North Reach					
Measured Inputs	219.6	13.3	197.8	12.1	S176
Measured Outputs	181.1	10.9	114.6	8.5	S177
Net Inputs	-38.5	-2.3	-83.2	29.0	Measured Outputs - Measured Inputs
Local Inputs	15.2	0.9	8.1	7.1	Max (Net Inputs, 0), Min Conc = 6 ppb
Local Retention	53.7	3.2	91.3	22.8	Net Inputs - Local Inputs
C111 South Reach					
Measured Inputs	181.1	10.9	114.6	8.5	S177
Measured Outputs	242.9	14.7	185.0	10.2	S18C
Net Inputs	61.8	3.7	70.5	15.3	Measured Outputs - Measured Inputs
Local Inputs	61.8	3.7	78.1	17.0	Max (Net Inputs, 0), Min Conc = 6 ppb
Local Retention	-0.0	0.0	7.7	NA	Net Inputs - Local Inputs
Total Inputs					
L31N	324.0	19.6	286.9	11.9	S174+S176
L31W	93.3	5.6	104.8	15.1	L31W Local Inputs
C111 North	15.2	0.9	8.1	7.1	C111 North Local Inputs
C111 South	61.8	3.7	78.1	17.0	C111 South Local Inputs
Total	494.3	29.8	477.9	13.0	Sum of Above
Canal Outputs					
S332	108.3	6.5	73.6	9.1	Directly Monitored
S175	84.5	5.1	97.3	15.4	Directly Monitored
S18C	242.9	14.7	185.0	10.2	Directly Monitored
Total	435.7	26.3	355.9	11.0	Sum of Above
Net Retention					Seepage Out, Irrigation, Sedimentation
L31W	4.8	0.3	23.2	64.5	L31W Local Retention
C111 North	53.7	3.2	91.3	22.8	C111 North Local Retention
C111 South	-0.0	0.0	7.7	NA	C111 South Local Retention
Total	58.5	3.5	122.1	28.0	Sum of Above
Summary					
Total Inputs	494.3	29.8	477.9	13.0	From Above
Canal Outputs	435.7	26.3	355.9	11.0	From Above
Net Retention	58.5	3.5	122.1	28.0	From Above
Net Retention	12%	12%	26%		Net Retention / Total Inputs

C111 Canal Water & Mass Balances, Water Year 1989

Dates: Oct-88 to Sep-89 Avg Rain: 3.1 in/mo Head (G1502-S17(0.99 ft

	Flow cfs	Flow kac-ft/mo	Load kg/mo	Conc ppb	Notes
Canal Fluxes					
S176	174.1	10.5	284.4	21.9	Directly Monitored
S174	78.4	4.7	166.0	28.4	Directly Monitored, Conc. @ S176
S332	43.1	2.6	39.1	12.2	Directly Monitored
S175	9.3	0.6	5.6	8.0	Directly Monitored, Conc. @ S332
S177	102.4	6.2	127.4	16.7	Directly Monitored
S18C	117.3	7.1	111.8	12.8	Directly Monitored
L31W Reach					
Measured Inputs	78.4	4.7	166.0	28.4	S174
Measured Outputs	52.4	3.2	44.6	11.4	S332 + S175
Net Inputs	-26.0	-1.6	-121.3	62.7	Measured Outputs - Measured Inputs
Local Inputs	0.0	0.0	0.0	NA	Max (Net Inputs, 0), Min Conc = 6 ppt
Local Retention	26.0	1.6	121.3	62.7	Net Inputs - Local Inputs
C111 North Reach					
Measured Inputs	174.1	10.5	284.4	21.9	S176
Measured Outputs	102.4	6.2	127.4	16.7	S177
Net Inputs	-71.7	-4.3	-157.0	29.4	Measured Outputs - Measured Inputs
Local Inputs	0.0	0.0	0.0	NA	Max (Net Inputs, 0), Min Conc = 6 ppt
Local Retention	71.7	4.3	157.0	29.4	Net Inputs - Local Inputs
C111 South Reach					
Measured Inputs	102.4	6.2	127.4	16.7	S177
Measured Outputs	117.3	7.1	111.8	12.8	S18C
Net Inputs	14.9	0.9	-15.6	-14.0	Measured Outputs - Measured Inputs
Local Inputs	14.9	0.9	6.7	6.0	Max (Net Inputs, 0), Min Conc = 6 ppt
Local Retention	0.0	0.0	22.3	NA	Net Inputs - Local Inputs
Total Inputs					
L31N	252.5	15.2	450.4	23.9	S174+S176
L31W	0.0	0.0	0.0	NA	L31W Local Inputs
C111 North	0.0	0.0	0.0	NA	C111 North Local Inputs
C111 South	14.9	0.9	6.7	6.0	C111 South Local Inputs
Total	267.4	16.1	457.0	22.9	Sum of Above
Canal Outputs					
S332	43.1	2.6	39.1	12.2	Directly Monitored
S175	9.3	0.6	5.6	8.0	Directly Monitored
S18C	117.3	7.1	111.8	12.8	Directly Monitored
Total	169.7	10.2	156.4	12.4	Sum of Above
Net Retention					Seepage Out, Irrigation, Sedimentatio
L31W	26.0	1.6	121.3	62.7	L31W Local Retention
C111 North	71.7	4.3	157.0	29.4	C111 North Local Retention
C111 South	0.0	0.0	22.3	NA	C111 South Local Retention
Total	97.7	5.9	300.6	41.3	Sum of Above
Summary					
Total Inputs	267.4	16.1	457.0	22.9	From Above
Canal Outputs	169.7	10.2	156.4	12.4	From Above
Net Retention	97.7	5.9	300.6	41.3	From Above
Net Retention	37%	37%	66%		Net Retention / Total Inputs

C111 Canal Water & Mass Balances, Water Year 1995

Dates: Oct-94 to Sep-95 Avg Rain: 6.5 in/mo Head (G1502-S17(2.38 ft

	Flow cfs	Flow kac-ft/mo	Load kg/mo	Conc ppb	Notes
Canal Fluxes					
S176	210.2	12.7	127.7	8.2	Directly Monitored
S174	149.3	9.0	68.5	6.2	Directly Monitored, Conc. @ S176
S332	286.8	17.3	143.7	6.7	Directly Monitored
S175	135.9	8.2	64.1	6.3	Directly Monitored, Conc. @ S332
S177	305.8	18.5	139.7	6.1	Directly Monitored
S18C	461.2	27.8	428.8	12.5	Directly Monitored
L31W Reach					
Measured Inputs	149.3	9.0	68.5	6.2	S174
Measured Outputs	422.7	25.5	207.9	6.6	S332 + S175
Net Inputs	273.4	16.5	139.3	6.8	Measured Outputs - Measured Inputs
Local Inputs	273.4	16.5	139.3	6.8	Max (Net Inputs, 0), Min Conc = 6 ppt
Local Retention	0.0	0.0	0.0	NA	Net Inputs - Local Inputs
C111 North Reach					
Measured Inputs	210.2	12.7	127.7	8.2	S176
Measured Outputs	305.8	18.5	139.7	6.1	S177
Net Inputs	95.7	5.8	12.0	1.7	Measured Outputs - Measured Inputs
Local Inputs	95.7	5.8	42.7	6.0	Max (Net Inputs, 0), Min Conc = 6 ppt
Local Retention	0.0	0.0	30.7	NA	Net Inputs - Local Inputs
C111 South Reach					
Measured Inputs	305.8	18.5	139.7	6.1	S177
Measured Outputs	461.2	27.8	428.8	12.5	S18C
Net Inputs	155.4	9.4	289.1	25.0	Measured Outputs - Measured Inputs
Local Inputs	155.4	9.4	289.1	25.0	Max (Net Inputs, 0), Min Conc = 6 ppt
Local Retention	0.0	0.0	0.0	NA	Net Inputs - Local Inputs
Total Inputs					
L31N	359.5	21.7	196.2	7.3	S174+S176
L31W	273.4	16.5	139.3	6.8	L31W Local Inputs
C111 North	95.7	5.8	42.7	6.0	C111 North Local Inputs
C111 South	155.4	9.4	289.1	25.0	C111 South Local Inputs
Total	883.9	53.3	667.4	10.1	Sum of Above
Canal Outputs					
S332	286.8	17.3	143.7	6.7	Directly Monitored
S175	135.9	8.2	64.1	6.3	Directly Monitored
S18C	461.2	27.8	428.8	12.5	Directly Monitored
Total	883.9	53.3	636.7	9.7	Sum of Above
Net Retention					Seepage Out, Irrigation, Sedimentatio
L31W	0.0	0.0	0.0	NA	L31W Local Retention
C111 North	0.0	0.0	30.7	NA	C111 North Local Retention
C111 South	0.0	0.0	0.0	NA	C111 South Local Retention
Total	0.0	0.0	30.7	NA	Sum of Above
Summary					
Total Inputs	883.9	53.3	667.4	10.1	From Above
Canal Outputs	883.9	53.3	636.7	9.7	From Above
Net Retention	0.0	0.0	30.7	NA	From Above
Net Retention	0%	0%	5%		Net Retention / Total Inputs

Yearly Flows & Loads at Structures in the C111 Basin

	---S174---			---S176---			---S332---			---S175---			---S177---			---S18C---		
Water Year	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb
84	55.4	357	5.2	112.4	808	5.8	38.2	237	5.0	65.5	426	5.3	91.7	590	5.2	137.5	1090	6.4
85	25.0	275	8.9	192.8	3869	16.3	33.2	390	9.5	31.6	344	8.8	121.0	1369	9.2	147.6	1861	10.2
86	64.2	588	7.4	266.4	2310	7.0	36.0	267	6.0	88.6	669	6.1	231.5	1858	6.5	263.1	2688	8.3
87	16.3	309	15.4	129.5	2264	14.2	40.9	899	17.8	14.3	340	19.3	87.2	1460	13.6	88.1	1315	12.1
88	73.5	718	7.9	374.5	3607	7.8	31.5	1187	30.5	112.2	8304	60.0	330.4	3434	8.4	352.4	3295	7.6
89	56.8	1992	28.4	126.0	3413	21.9	31.2	469	12.2	6.8	67	8.0	74.1	1529	16.7	84.9	1342	12.8
90	67.4	1726	20.8	196.4	5285	21.8	37.9	431	9.2	2.9	30	8.3	39.6	371	7.6	56.7	396	5.7
91	65.1	1018	12.7	143.7	2201	12.4	37.9	395	8.4	63.8	748	9.5	81.4	1273	12.7	115.4	1153	8.1
92	121.5	1748	11.7	110.3	1332	9.8	63.3	662	8.5	91.7	1037	9.2	121.6	1613	10.7	161.0	2261	11.4
93	160.1	2360	11.9	105.8	1618	12.4	138.7	1759	10.3	122.8	1467	9.7	84.9	887	8.5	171.4	1959	9.3
94	95.4	1480	12.6	94.7	2176	18.6	177.1	2236	10.2	59.5	757	10.3	114.9	1154	8.1	210.0	4444	17.1
95	108.1	823	6.2	152.2	1532	8.2	207.6	1725	6.7	98.4	770	6.3	221.4	1676	6.1	333.9	5146	12.5
96	74.5	513	5.6	63.8	437	5.5	146.4	818	4.5	38.2	212	4.5	106.5	662	5.0	166.5	1915	9.3
84-96	75.6	1070	11.5	159.1	2373	12.1	78.5	883	9.1	61.3	1167	15.4	131.3	1375	8.5	176.0	2220	10.2
91-96	104.1	1324	10.3	111.7	1549	11.2	128.5	1266	8.0	79.1	832	8.5	121.8	1211	8.1	193.0	2813	11.8

Water Years ending September 30

Yearly Flow & Mass Balances

Inputs

	S174+S176			L31W			C111 North			C111 South			Total		
Water Year	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb
84	167.8	1165	5.6	48.4	358	6.0	0.0	0	NA	45.7	501	8.9	261.9	2024	6.3
85	217.8	4144	15.4	39.9	459	9.3	0.0	0	NA	26.6	493	15.0	284.2	5095	14.5
86	330.7	2898	7.1	60.5	448	6.0	0.0	0	NA	31.6	830	21.3	422.7	4176	8.0
87	145.8	2573	14.3	38.9	930	19.4	0.0	0	NA	0.9	7	6.0	185.6	3510	15.3
88	447.9	4325	7.8	70.2	8773	101.2	0.0	0	NA	22.0	163	6.0	540.1	13261	19.9
89	182.8	5404	23.9	0.0	0	NA	0.0	0	NA	10.8	80	6.0	193.6	5484	22.9
90	263.8	7011	21.5	0.0	0	NA	0.0	0	NA	17.1	127	6.0	280.9	7137	20.6
91	208.8	3220	12.5	36.6	271	6.0	0.0	0	NA	34.1	252	6.0	279.5	3744	10.9
92	231.8	3080	10.8	33.5	248	6.0	11.3	281	20.2	39.4	648	13.3	316.0	4257	10.9
93	265.8	3978	12.1	101.5	867	6.9	0.0	0	NA	86.5	1072	10.0	453.8	5917	10.6
94	190.1	3656	15.6	141.3	1513	8.7	20.2	149	6.0	95.1	3290	28.0	446.6	8609	15.6
95	260.2	2354	7.3	197.9	1672	6.8	69.2	513	6.0	112.5	3470	25.0	639.9	8009	10.1
96	138.3	949	5.6	110.1	816	6.0	42.7	317	6.0	60.0	1252	16.9	351.1	3334	7.7
Mean	234.7	3443	11.9	67.6	1258	15.1	11.0	97	7.1	44.8	937	17.0	358.2	5735	13.0

Structure Outputs

	S332			S175			S18C			Total				
Water Year	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Rainfall inches	Head ft
84	38.2	237	5.0	65.5	426	5.3	137.5	1090	6.4	241.2	1754	5.9	62.6	1.69
85	33.2	390	9.5	31.6	344	8.8	147.6	1861	10.2	212.4	2595	9.9	49.6	1.34
86	36.0	267	6.0	88.6	669	6.1	263.1	2688	8.3	387.8	3625	7.6	49.9	1.95
87	40.9	899	17.8	14.3	340	19.3	88.1	1315	12.1	143.3	2555	14.4	53.6	1.33
88	31.5	1187	30.5	112.2	8304	60.0	352.4	3295	7.6	496.1	12786	20.9	61.5	1.89
89	31.2	469	12.2	6.8	67	8.0	84.9	1342	12.8	122.9	1877	12.4	37.4	0.99
90	37.9	431	9.2	2.9	30	8.3	56.7	396	5.7	97.5	856	7.1	54.6	1.06
91	37.9	395	8.4	63.8	748	9.5	115.4	1153	8.1	217.1	2296	8.6	62.7	1.44
92	63.3	662	8.5	91.7	1037	9.2	161.0	2261	11.4	316.0	3960	10.2	68.3	1.58
93	138.7	1759	10.3	122.8	1467	9.7	171.4	1959	9.3	432.9	5186	9.7	47.3	1.99
94	177.1	2236	10.2	59.5	757	10.3	210.0	4444	17.1	446.6	7437	13.5	67.7	1.58
95	207.6	1725	6.7	98.4	770	6.3	333.9	5146	12.5	639.9	7640	9.7	77.7	2.38
96	146.4	818	4.5	38.2	212	4.5	166.5	1915	9.3	351.1	2945	6.8	55.6	2.04
Mean	78.4	883	9.1	61.2	1167	15.4	175.9	2220	10.2	315.5	4270	11.0	57.6	1.63

Retention

	L31W			C111 North			C111 South			Total			Percent of Inflow	
Water Year	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow kacft	Load kg	Conc ppb	Flow %	Load %
84	0.0	51	NA	20.7	218	8.5	0.0	0	NA	20.7	270	10.5	8%	13%
85	0.0	0	NA	71.8	2500	28.2	0.0	0	NA	71.8	2500	28.2	25%	49%
86	0.0	99	NA	34.9	451	10.5	0.0	0	NA	34.9	551	12.8	8%	13%
87	0.0	0	NA	42.3	804	15.4	0.0	151	NA	42.3	955	18.3	23%	27%
88	0.0	0	NA	44.0	174	3.2	0.0	301	NA	44.0	475	8.7	8%	4%
89	18.8	1456	62.7	51.9	1884	29.4	0.0	267	NA	70.7	3607	41.3	37%	66%
90	26.6	1265	38.6	156.8	4914	25.4	0.0	102	NA	183.4	6281	27.7	65%	88%
91	0.0	147	NA	62.4	928	12.1	0.0	373	NA	62.4	1448	18.8	22%	39%
92	0.0	297	NA	0.0	0	NA	0.0	0	NA	0.0	297	NA	0%	7%
93	0.0	0	NA	20.9	731	28.4	0.0	0	NA	20.9	731	28.4	5%	12%
94	0.0	0	NA	0.0	1172	NA	0.0	0	NA	0.0	1172	NA	0%	14%
95	0.0	0	NA	0.0	368	NA	0.0	0	NA	0.0	368	NA	0%	5%
96	0.0	298	NA	0.0	91	NA	0.0	0	NA	0.0	389	NA	0%	12%
Mean	3.5	278	64.5	38.9	1095	22.8	0.0	92	NA	42.4	1465	28.0	12%	26%

Reach: L31W = S174 to S332/S175
C11 North = S176 to S177
C11 South = S177 to S18C

Head = Average Marsh Stage @ G1502 - Average Canal Stage Above S176

List of Figures

C111 Canal & ENP Marsh Stations

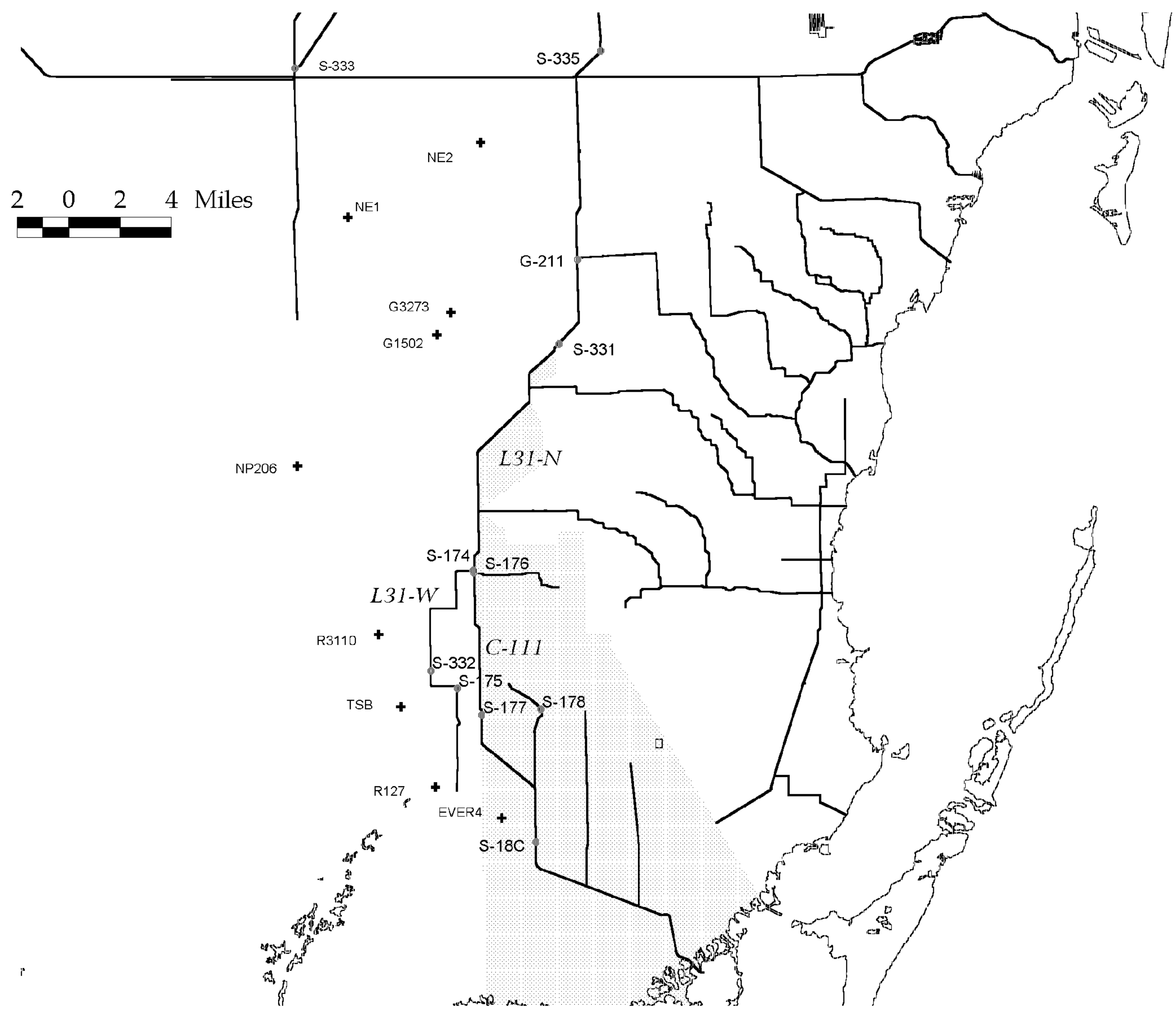


Figure 1

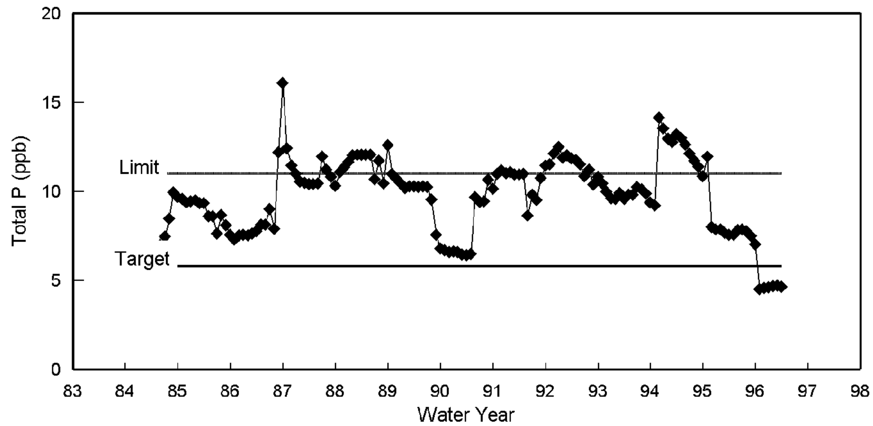
Inflow P Limits	**ENP Taylor Slough & Coastal Basins** **Combined Inflows from S18C, S332, & S175**				**09/22/97**

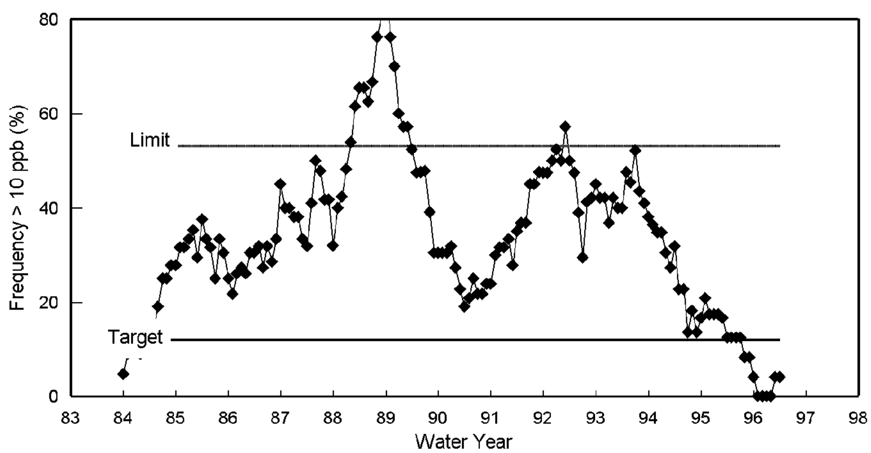
Results for 12-Month Pd **9604** **thru** **9703**

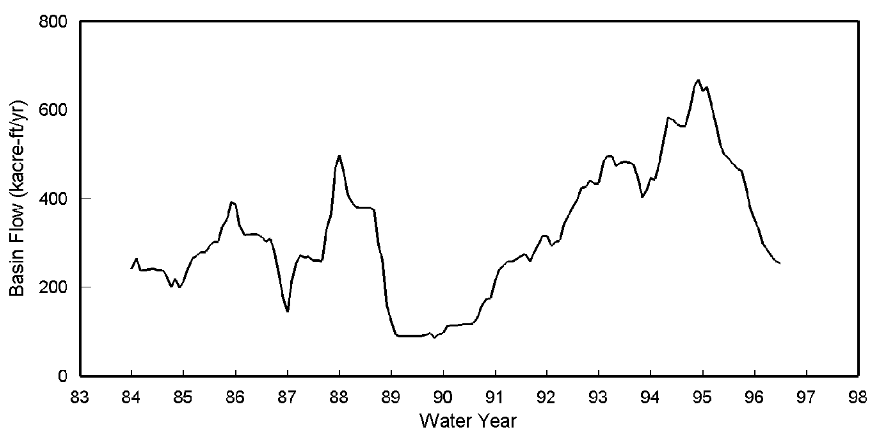
Basin Total Flow	254.8 kac-ft/yr		Sample Dates:	24	
Sampled Flow	15.7 kac-ft/yr				

Variable	Units	Observed	Target	Limit	
Flow-Wtd-Mean Conc.	ppb	4.6	5.8	11.0	OK
Frequency > 10 ppb	%	4.2	12.1	53.1	OK

Longterm Limits

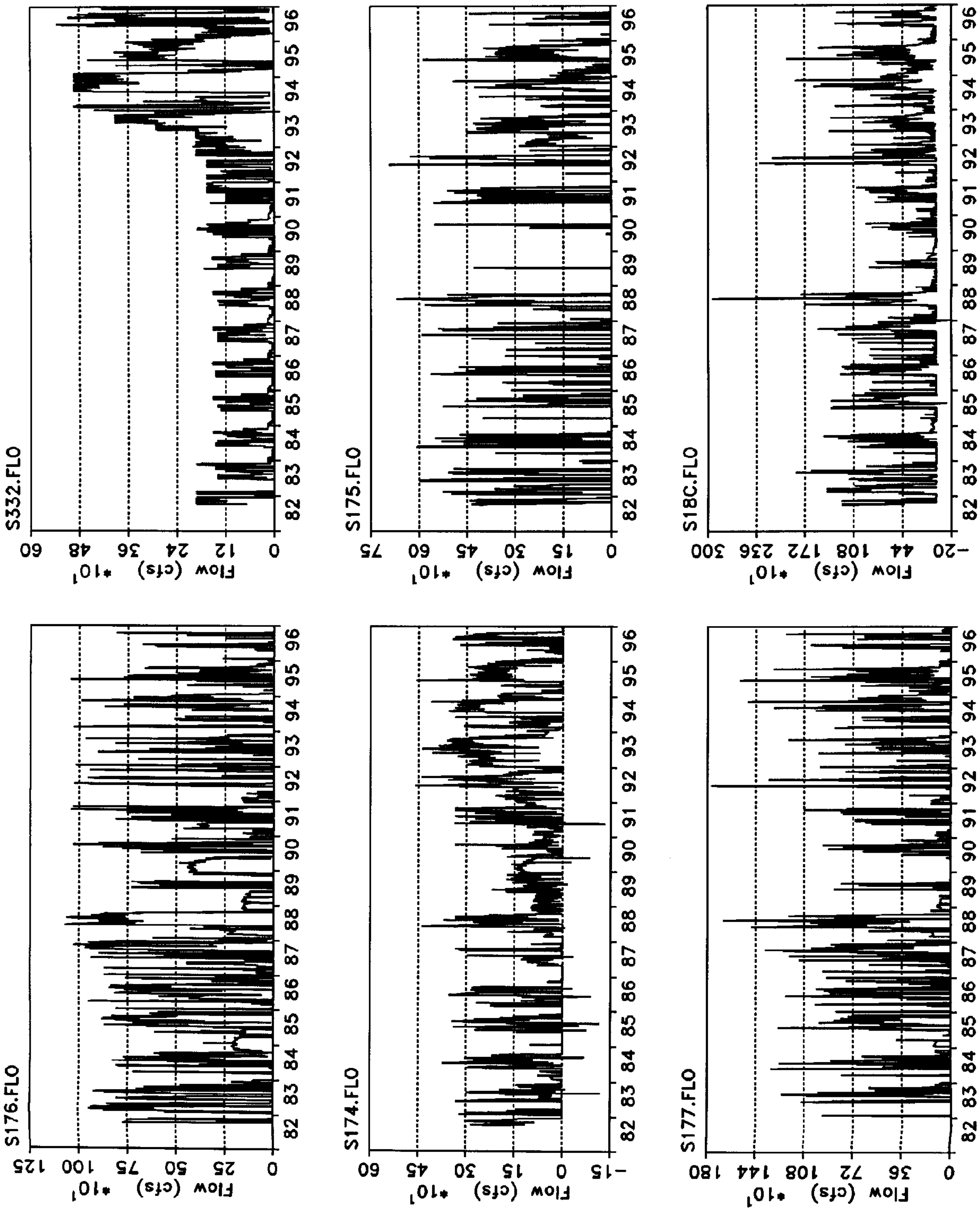






12-Month Rolling Values, Water Years Ending September 30

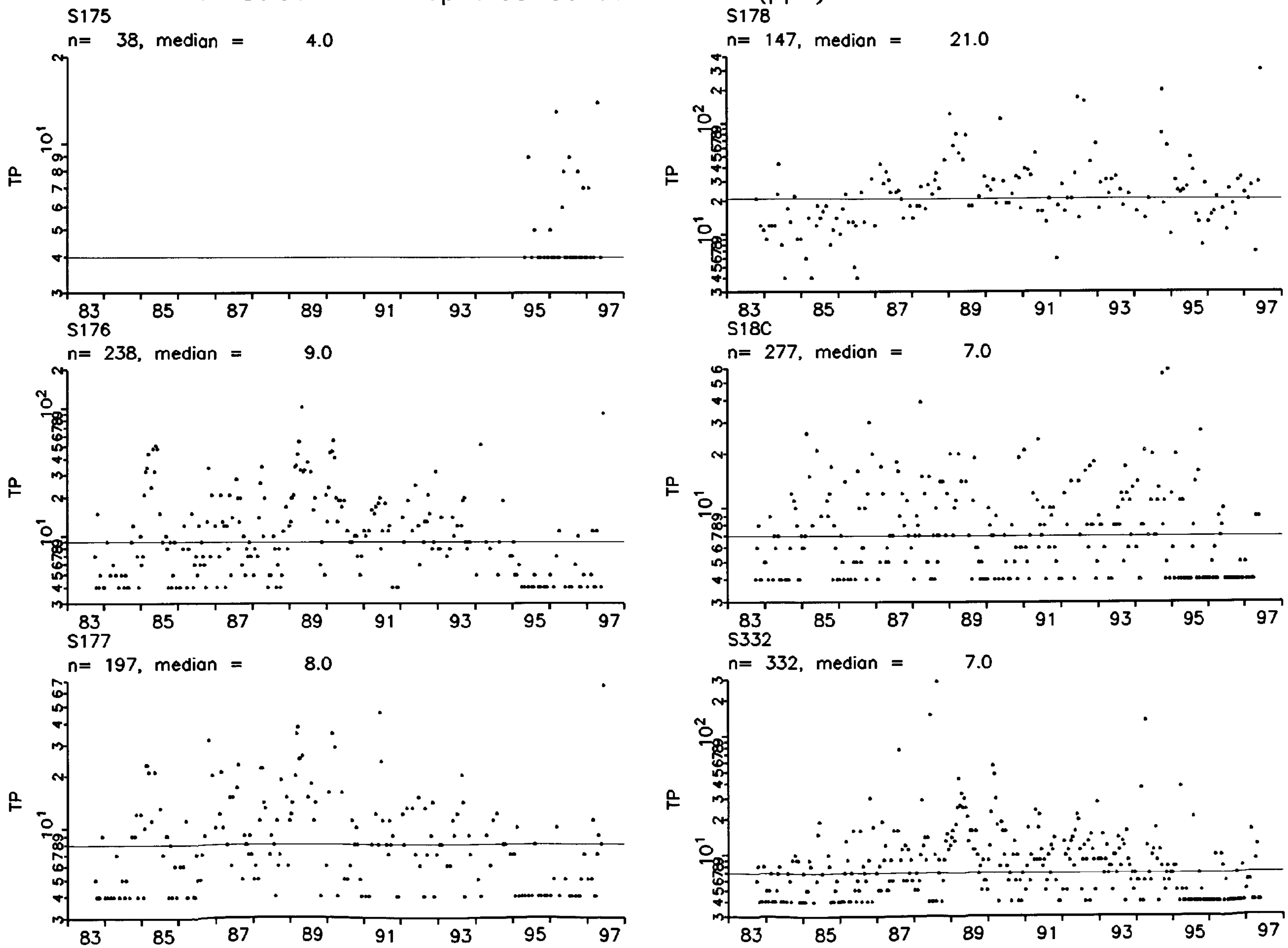
Figure 3



S332.FLO
S175.FLO
S18C.FLO
S176.FLO
S174.FLO
S177.FLO
Flow (cfs) *10^1

Figure 4

C111 Basin Structure Phosphorus Concentrations (ppb)



Yearly Flow & Mass Balances

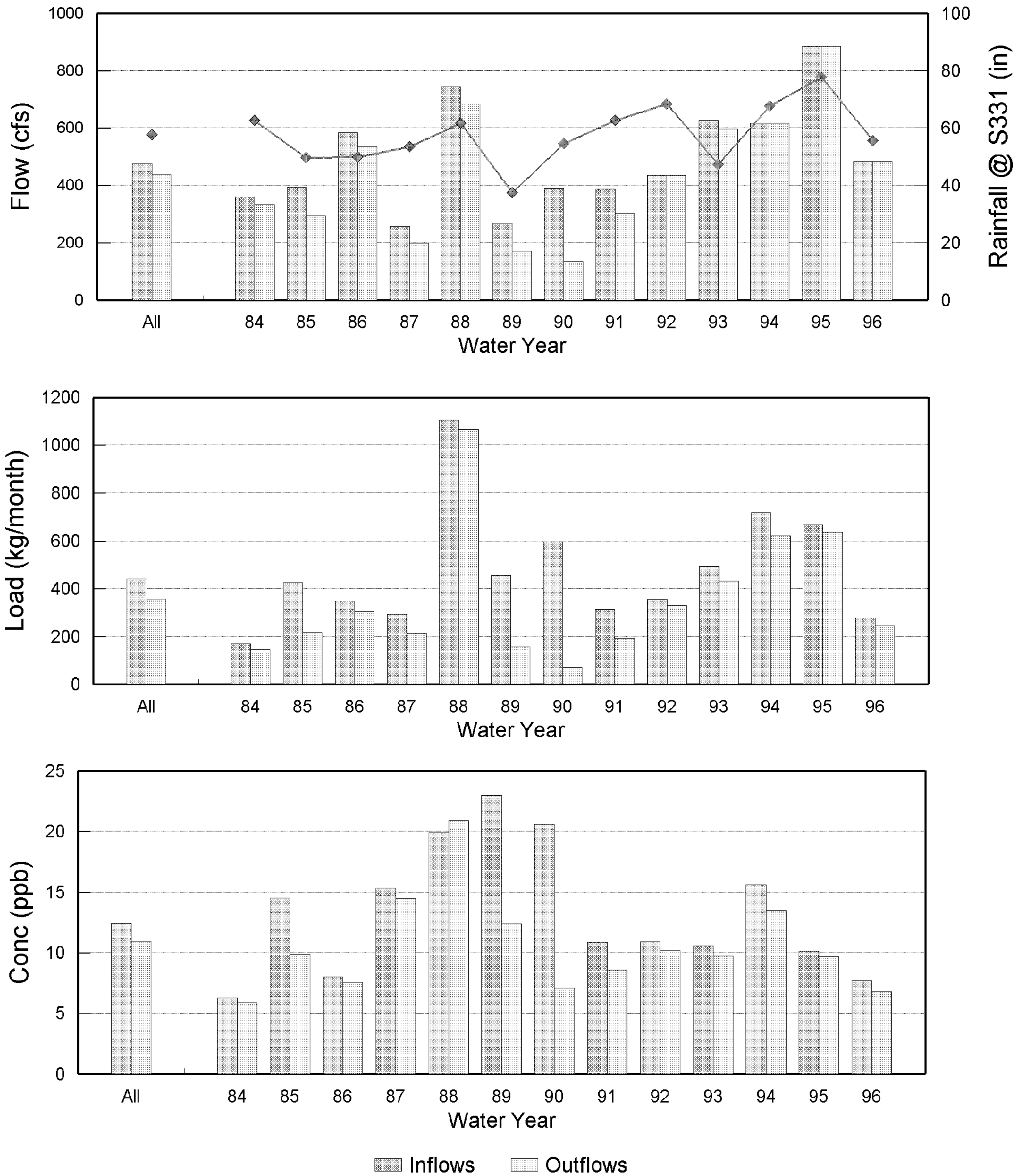


Figure 6

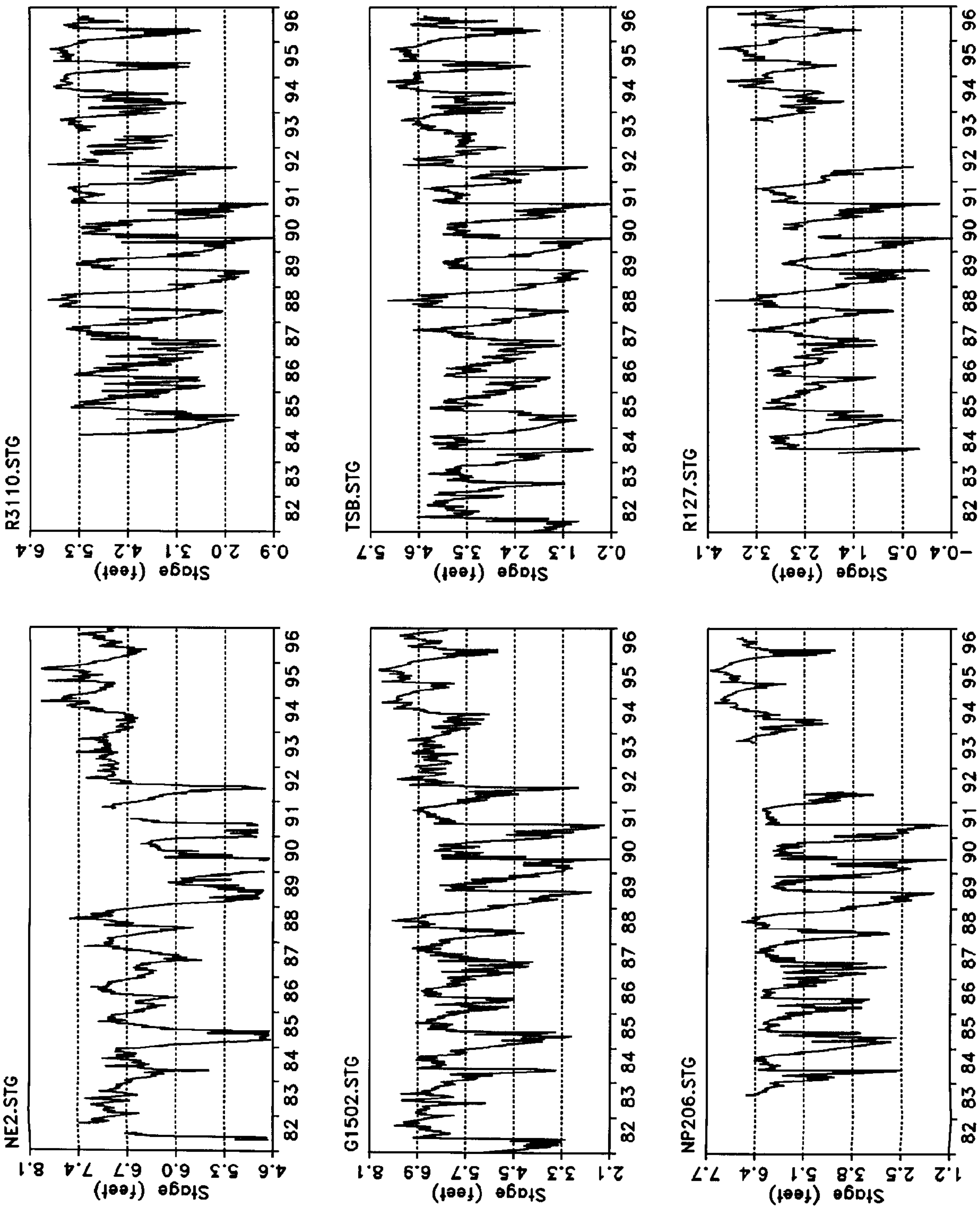
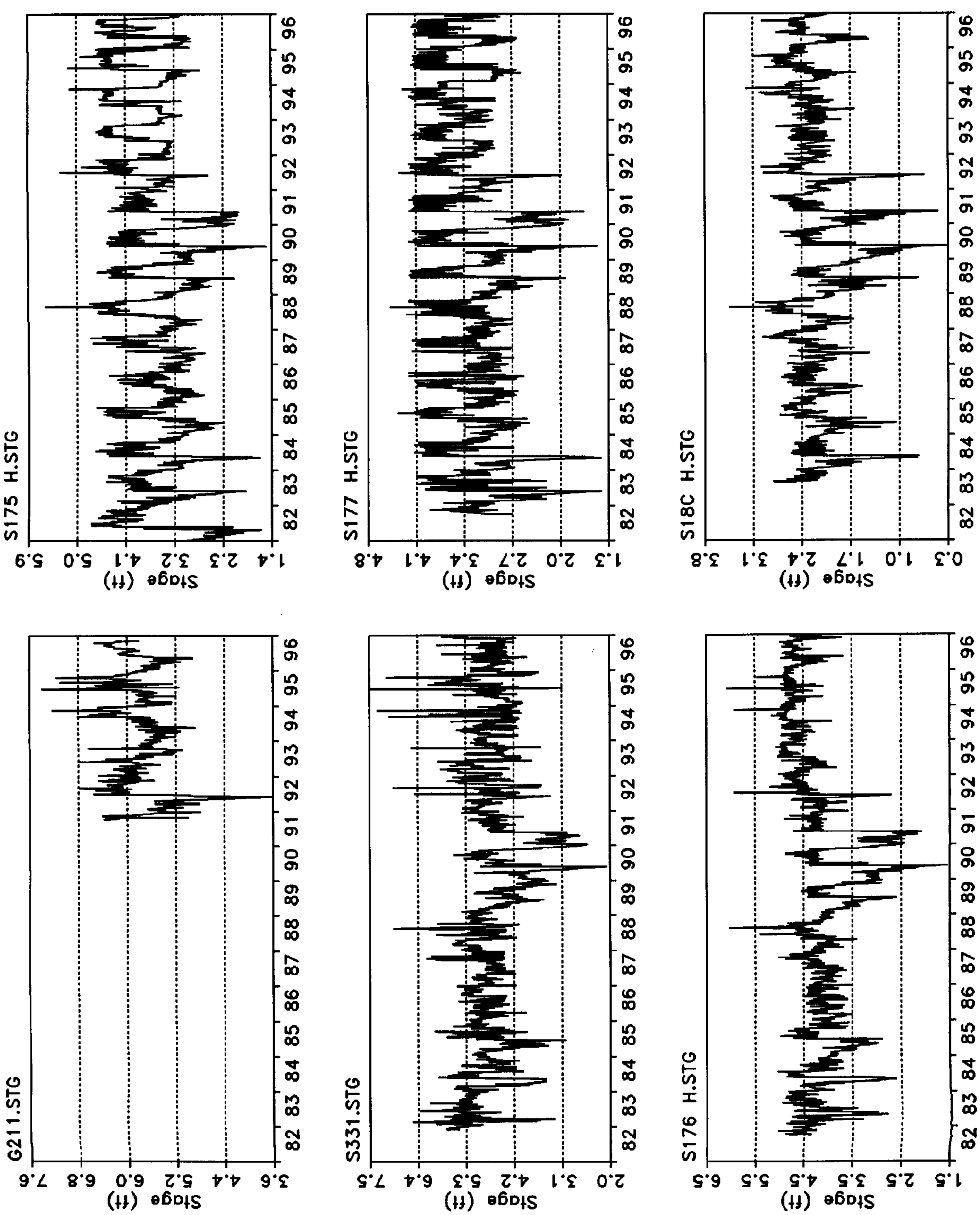
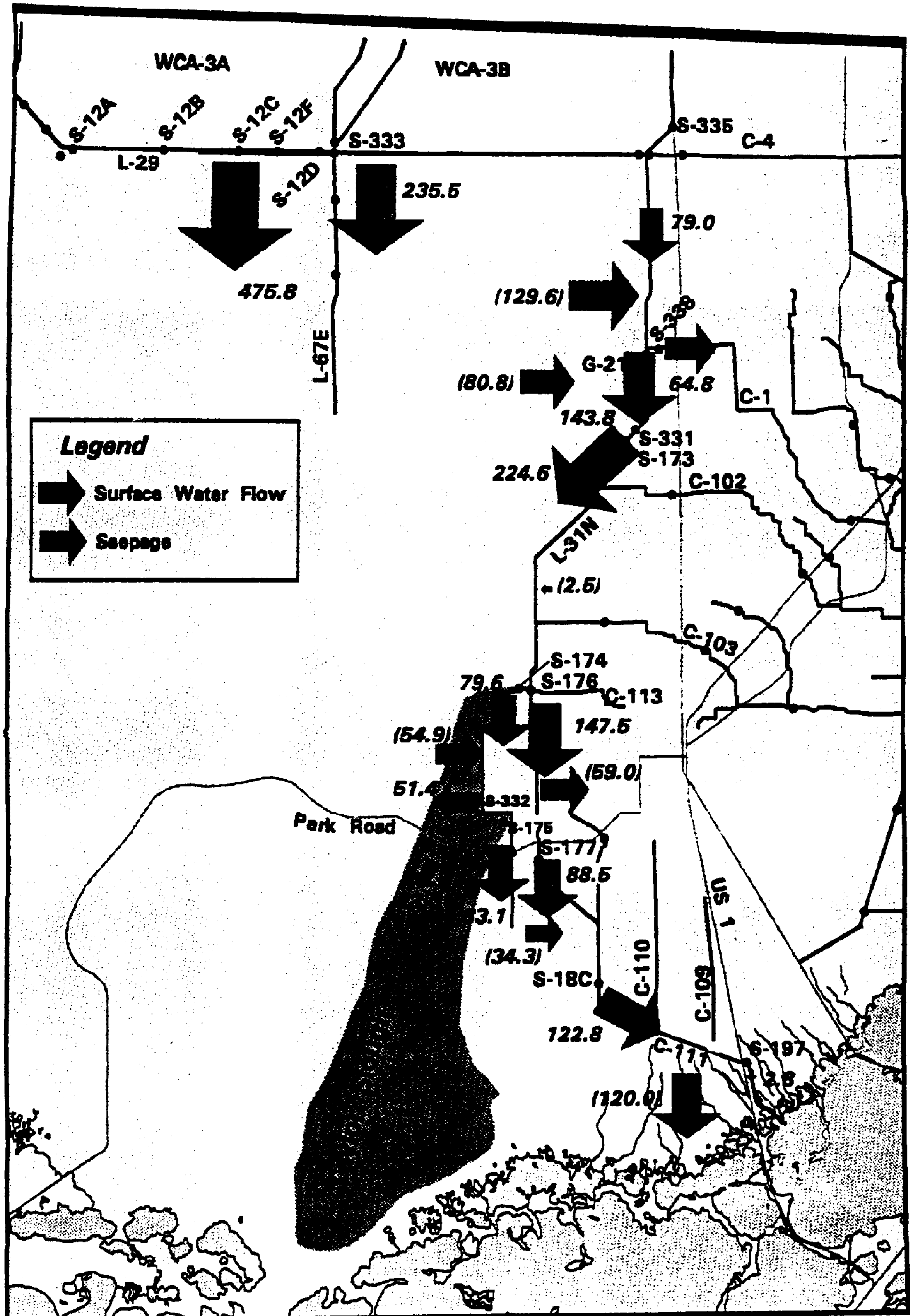
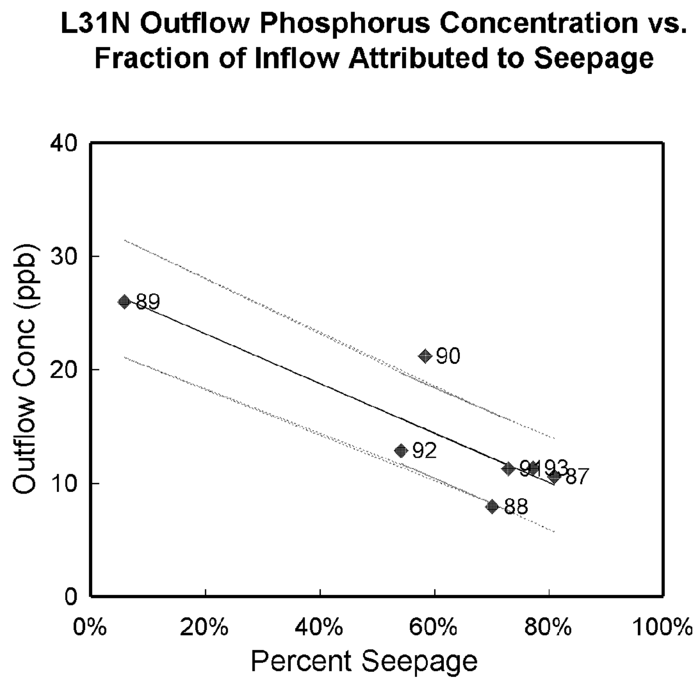

R3110.STG
TSB.STG
R127.STG
NE2.STG
G1502.STG
NP206.STG
Stage (feet)

Figure 7


G211.STG
S331.STG
S176 H.STG
S175 H.STG
S177 H.STG
S18C H.STG
Stage (ft)



Total Flows* for the 1991 Calendar Year



Regression Output:

Constant		27.56
Std Err of Y Est		3.70
R Squared		0.735
No. of Observations		7
Degrees of Freedom		5
X Coefficient(s)	-21.88	
Std Err of Coef.	5.87	

Seepage Conc: 5.7 +/- 2.6 ppb

Non-Seepage Conc: 27.6 +/- 3.9 ppb

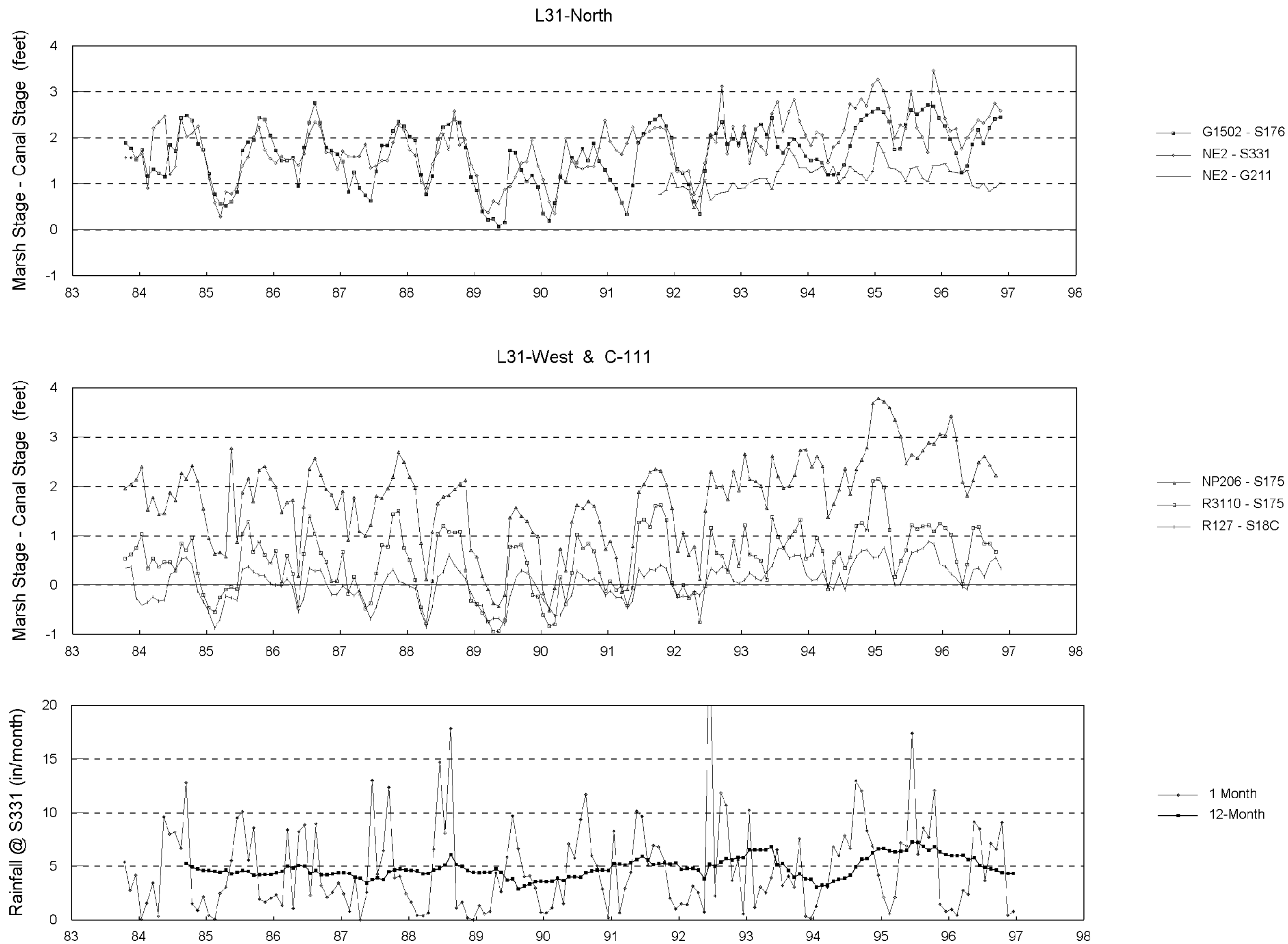
Calendar Year	Qother kac-ft/yr	Qseep kac-ft/yr	Qtotal kac-ft/yr	Seepage %	Conc ppb	Predicted ppb
87	68.6	290.9	359.5	80.9%	10.6	9.9
88	127.4	299.4	426.8	70.1%	7.9	12.2
89	260.0	16.3	276.3	5.9%	26.0	26.3
90	103.4	145.2	248.6	58.4%	21.2	14.8
91	79.0	212.9	291.9	72.9%	11.2	11.6
92	112.8	133.5	246.3	54.2%	12.9	15.7
93	87.8	298.6	386.4	77.3%	11.3	10.6
Mean	119.9	199.5	319.4	62.5%	13.6	13.9

Outflow = Combined Discharge through S176 & S174.

Non-Seepage Inflows from North (S331, Tamiami Trail)

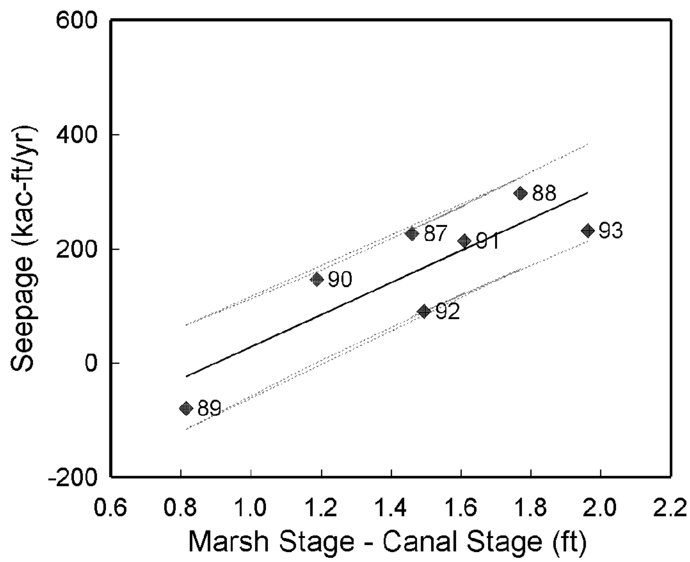
Figure 10

Monthly Stage Differentials & Rainfall



Net Seepage Inflow to L31N vs. Head

Marsh Stage: G1502 Canal Stage: S176_H
Seepage: L31N



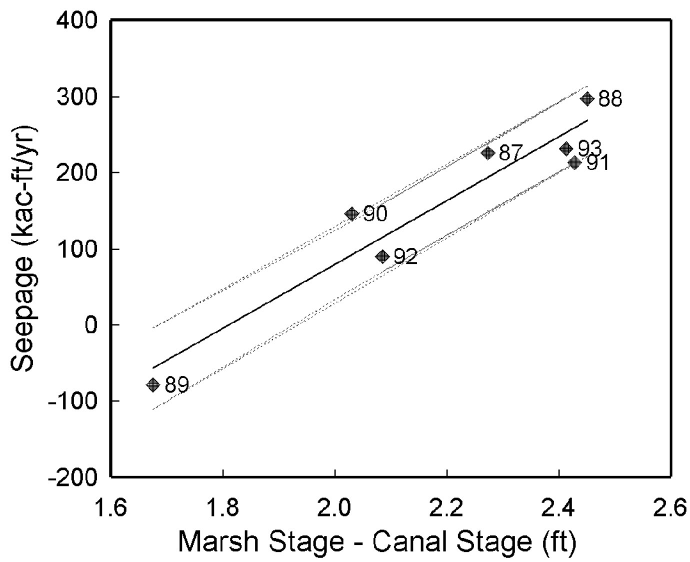
Regression Output:		
Constant		-253.32
Std Err of Y Est		71.14
R Squared		0.729
No. of Observations		7
Degrees of Freedom		5
X Coefficient(s)	280.92	
Std Err of Coef.	76.61	

Predicted Seepage @ Zero Head = -253.3 kac-ft/yr
Head Corresponding to Zero Seepage = 0.9 ft

Calendar Year	Marsh G1502 feet	Canal S176_H feet	Head feet	Seepage kac-ft/yr	Predicted kac-ft/yr
87	5.64	4.18	1.46	225.4	157.1
88	6.04	4.27	1.77	296.5	244.2
89	4.53	3.72	0.81	-79.6	-24.5
90	4.68	3.50	1.19	145.2	80.3
91	5.26	3.65	1.61	212.9	199.1
92	5.84	4.34	1.50	89.4	166.8
93	6.57	4.60	1.96	231.0	297.9
Mean	5.51	4.04	1.47	160.11	160.11

Net Seepage Inflow to L31N vs. Head

Marsh Stage:	NE2	Canal Stage:	S176_H
Seepage:	L31N		



Regression Output:

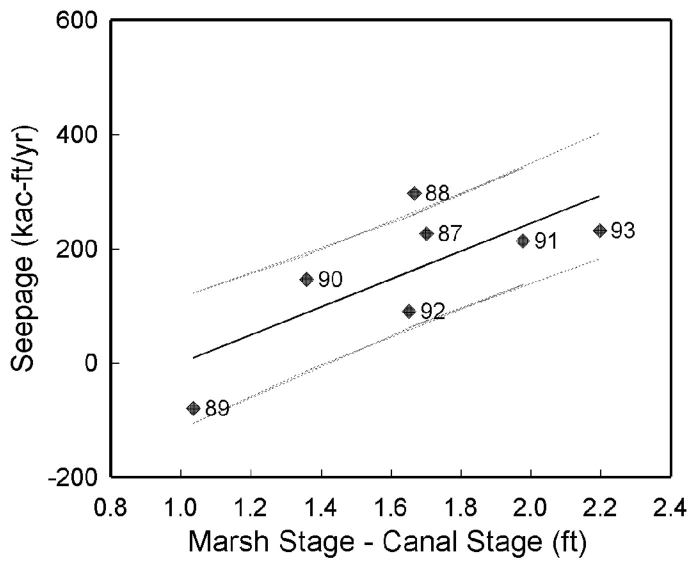
Constant		-760.28
Std Err of Y Est		40.92
R Squared		0.910
No. of Observations		7
Degrees of Freedom		5
X Coefficient(s)	419.58	
Std Err of Coef.	58.90	

Predicted Seepage @ Zero Head = -760.3 kac-ft/yr
Head Corresponding to Zero Seepage = 1.8 ft

Calendar Year	Marsh NE2 feet	Canal S176_H feet	Head feet	Seepage kac-ft/yr	Predicted kac-ft/yr
87	6.45	4.18	2.27	225.4	193.4
88	6.72	4.27	2.45	296.5	267.9
89	5.39	3.72	1.68	-79.6	-57.4
90	5.53	3.50	2.03	145.2	91.6
91	6.08	3.65	2.43	212.9	258.6
92	6.43	4.34	2.08	89.4	114.4
93	7.02	4.60	2.41	231.0	252.3
Mean	6.23	4.04	2.19	160.11	160.11

Net Seepage Inflow to L31N vs. Head

Marsh Stage:	NE2	Canal Stage:	S331
Seepage:	L31N		



Regression Output:

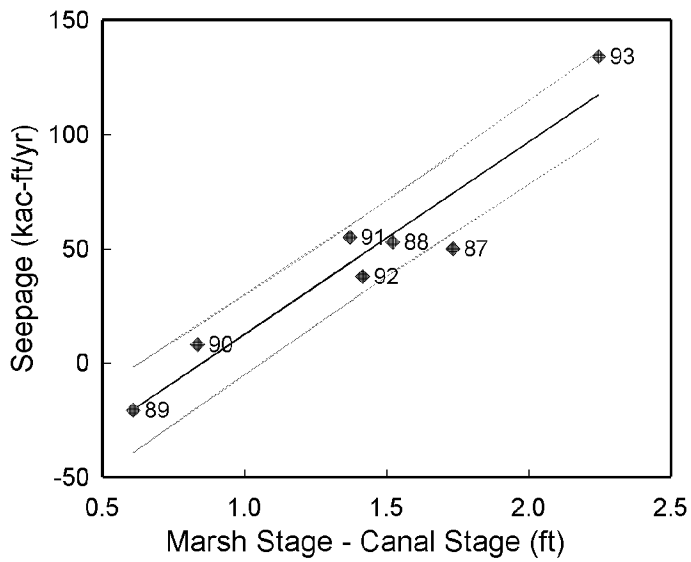
Constant		-245.45
Std Err of Y Est		90.76
R Squared		0.559
No. of Observations		7
Degrees of Freedom		5
X Coefficient(s)	244.94	
Std Err of Coef.	97.33	

Predicted Seepage @ Zero Head = -245.5 kac-ft/yr
Head Corresponding to Zero Seepage = 1.0 ft

Calendar Year	Marsh NE2 feet	Canal S331 feet	Head feet	Seepage kac-ft/yr	Predicted kac-ft/yr
87	6.45	4.75	1.70	225.4	171.4
88	6.72	5.05	1.67	296.5	162.9
89	5.39	4.36	1.04	-79.6	8.4
90	5.53	4.17	1.36	145.2	87.5
91	6.08	4.10	1.98	212.9	238.8
92	6.43	4.78	1.65	89.4	159.3
93	7.02	4.82	2.20	231.0	292.6
Mean	6.23	4.57	1.66	160.11	160.11

Net Seepage Inflow to L31W vs. Head

Marsh Stage:	NP206	Canal Stage:	S175_H
Seepage:	L31W		



Regression Output:

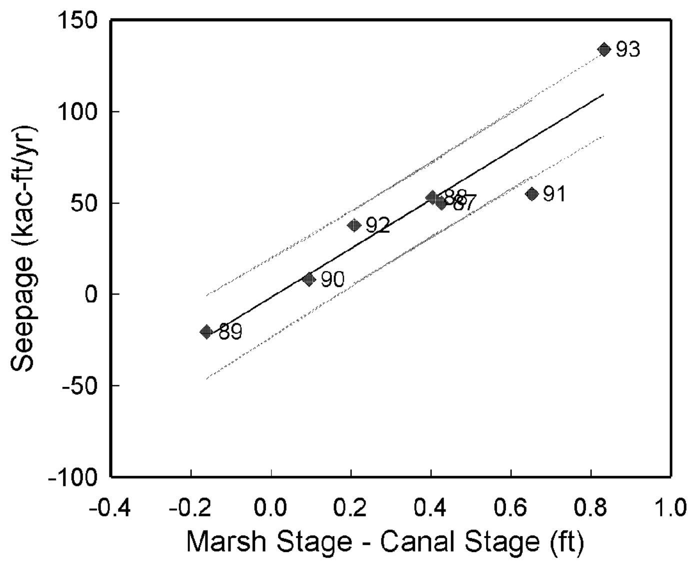
Constant		-71.87
Std Err of Y Est		15.42
R Squared		0.914
No. of Observations		7
Degrees of Freedom		5
X Coefficient(s)	84.19	
Std Err of Coef.	11.53	

Predicted Seepage @ Zero Head = -71.9 kac-ft/yr
Head Corresponding to Zero Seepage = 0.9 ft

Calendar Year	Marsh NP206 feet	Canal S175_H feet	Head feet	Seepage kac-ft/yr	Predicted kac-ft/yr
87	5.19	3.46	1.73	49.9	74.0
88	5.26	3.74	1.52	52.7	56.3
89	3.98	3.37	0.61	-20.8	-20.5
90	4.16	3.33	0.83	7.9	-1.6
91	4.63	3.26	1.37	54.9	43.5
92	5.23	3.81	1.42	37.8	47.4
93	6.04	3.79	2.25	134.0	117.3
Mean	4.93	3.54	1.39	45.20	45.20

Net Seepage Inflow to L31W vs. Head

Marsh Stage:	R3110	Canal Stage:	S175_H
Seepage:	L31W		



Regression Output:

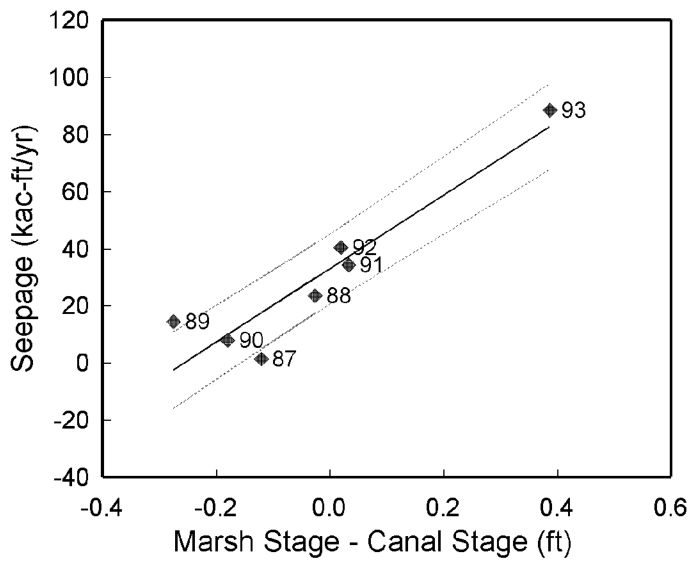
Constant		-1.82
Std Err of Y Est		18.48
R Squared		0.877
No. of Observations		7
Degrees of Freedom		5
X Coefficient(s)	133.87	
Std Err of Coef.	22.44	

Predicted Seepage @ Zero Head = -1.8 kac-ft/yr
Head Corresponding to Zero Seepage = 0.0 ft

Calendar Year	Marsh R3110 feet	Canal S175_H feet	Head feet	Seepage kac-ft/yr	Predicted kac-ft/yr
87	3.89	3.46	0.43	49.9	55.3
88	4.14	3.74	0.40	52.7	52.2
89	3.21	3.37	-0.16	-20.8	-23.3
90	3.42	3.33	0.10	7.9	11.0
91	3.91	3.26	0.65	54.9	85.5
92	4.02	3.81	0.21	37.8	26.1
93	4.62	3.79	0.83	134.0	109.7
Mean	3.89	3.54	0.35	45.20	45.20

Net Seepage Inflow to C111-South vs. Head

Marsh Stage:	R127	Canal Stage:	S18C_H
Seepage:	C111-South		



Regression Output:

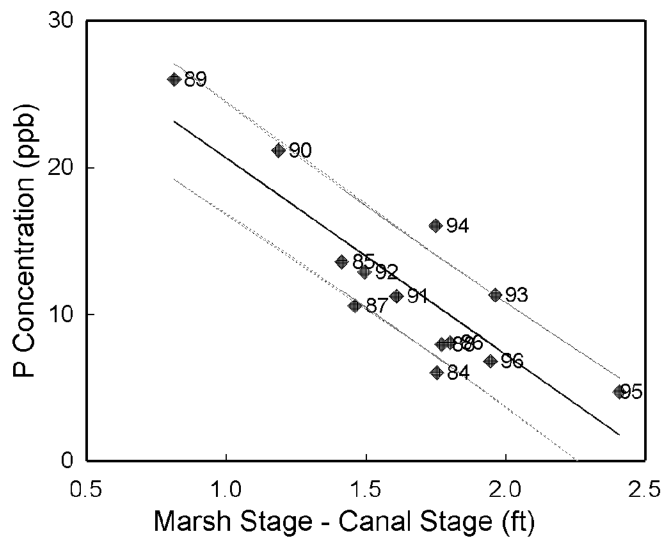
Constant		32.93
Std Err of Y Est		11.42
R Squared		0.873
No. of Observations		7
Degrees of Freedom		5
X Coefficient(s)	128.79	
Std Err of Coef.	21.94	

Predicted Seepage @ Zero Head = 32.9 kac-ft/yr
Head Corresponding to Zero Seepage = -0.3 ft

Calendar Year	Marsh R127 feet	Canal S18C_H feet	Head feet	Seepage kac-ft/yr	Predicted kac-ft/yr
87	2.16	2.28	-0.12	1.2	17.4
88	2.28	2.30	-0.03	23.5	29.6
89	1.59	1.87	-0.27	14.4	-2.5
90	1.63	1.81	-0.18	7.8	9.8
91	2.05	2.01	0.03	34.3	37.2
92	2.17	2.15	0.02	40.4	35.5
93	2.67	2.28	0.39	88.4	82.8
Mean	2.08	2.10	-0.02	30.00	30.00

Phosphorus Concentration at S174+S176 vs. Head

Marsh Stage:	G1502	Canal Stage:	S176_H
Location:	S174+S176		



Regression Output:

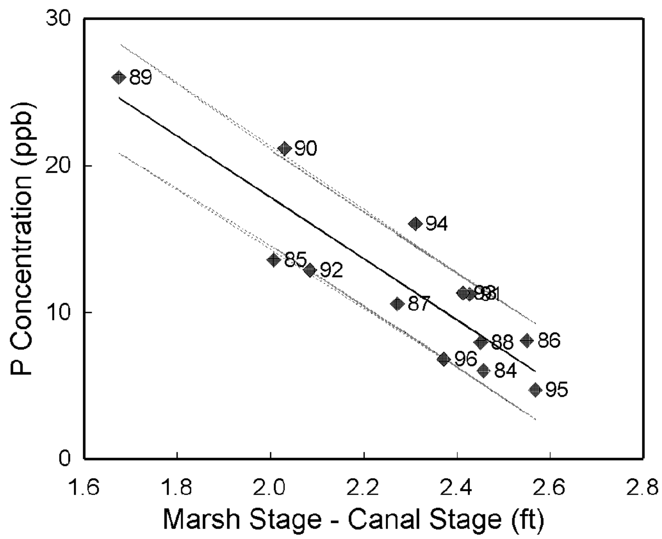
Constant		34.06
Std Err of Y Est		3.30
R Squared		0.735
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	-13.41	
Std Err of Coef.	2.43	

Predicted Concentration @ Zero Head 34.1 ppb
Predicted Concentration @ Min. Head : 23.1 ppb
Predicted Concentration @ Max. Head 1.8 ppb

Calendar Year	Marsh G1502 feet	Canal S176_H feet	Head feet	Conc ppb	Predicted ppb
84	5.84	4.08	1.75	6.0	10.5
85	5.33	3.92	1.41	13.6	15.1
86	5.87	4.07	1.80	8.1	9.9
87	5.64	4.18	1.46	10.6	14.5
88	6.04	4.27	1.77	7.9	10.3
89	4.53	3.72	0.81	26.0	23.1
90	4.68	3.50	1.19	21.2	18.1
91	5.26	3.65	1.61	11.2	12.5
92	5.84	4.34	1.50	12.9	14.0
93	6.57	4.60	1.96	11.3	7.8
94	6.46	4.71	1.75	16.0	10.6
95	7.14	4.74	2.41	4.7	1.8
96	6.49	4.54	1.95	6.8	8.0
Mean	5.82	4.18	1.64	12.0	12.0

Phosphorus Concentration at S174+S176 vs. Head

Marsh Stage:	NE2	Canal Stage:	S176_H
Location:	S174+S176		



Regression Output:

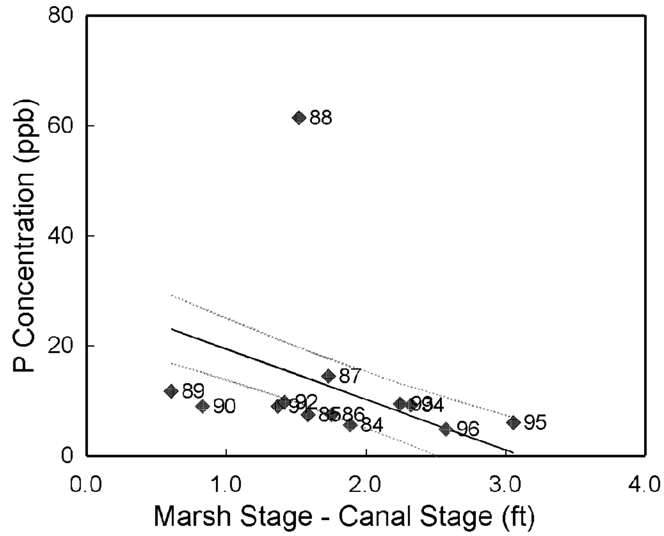
Constant		59.57
Std Err of Y Est		3.02
R Squared		0.778
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	-20.87	
Std Err of Coef.	3.36	

Predicted Concentration @ Zero Head	59.6 ppb
Predicted Concentration @ Min. Head :	24.6 ppb
Predicted Concentration @ Max. Head	6.0 ppb

Calendar Year	Marsh NE2 feet	Canal S176_H feet	Head feet	Conc ppb	Predicted ppb
84	6.54	4.08	2.46	6.0	8.3
85	5.93	3.92	2.01	13.6	17.7
86	6.62	4.07	2.55	8.1	6.3
87	6.45	4.18	2.27	10.6	12.1
88	6.72	4.27	2.45	7.9	8.4
89	5.39	3.72	1.68	26.0	24.6
90	5.53	3.50	2.03	21.2	17.2
91	6.08	3.65	2.43	11.2	8.9
92	6.43	4.34	2.08	12.9	16.1
93	7.02	4.60	2.41	11.3	9.2
94	7.02	4.71	2.31	16.0	11.3
95	7.31	4.74	2.57	4.7	6.0
96	6.92	4.54	2.37	6.8	10.1
Mean	6.46	4.18	2.28	12.0	12.0

Phosphorus Concentration at S332+S175 vs. Head

Marsh Stage:	NP206	Canal Stage:	S175_H
Location:	S332+S175		



Regression Output:

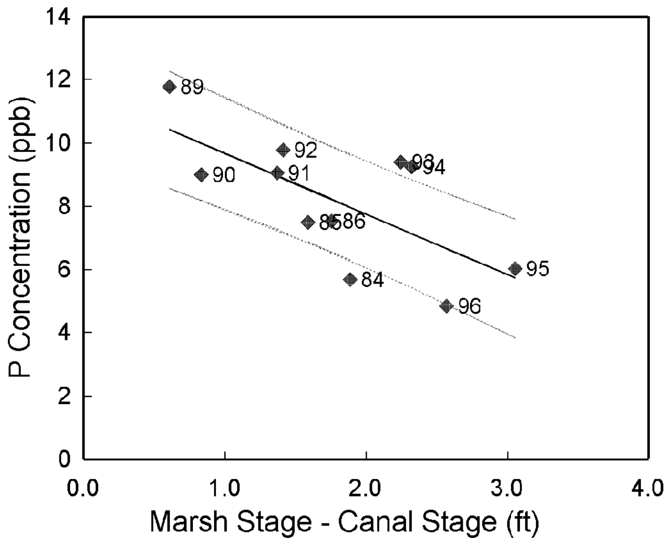
Constant		28.65
Std Err of Y Est		4.80
R Squared		0.439
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	-9.19	
Std Err of Coef.	3.13	

Predicted Concentration @ Zero Head 28.6 ppb
Predicted Concentration @ Min. Head : 23.0 ppb
Predicted Concentration @ Max. Head 0.6 ppb

Calendar Year	Marsh NP206 feet	Canal S175_H feet	Head feet	Conc ppb	Predicted ppb
84	5.32	3.43	1.89	5.7	11.3
85	4.94	3.35	1.59	7.5	14.1
86	5.13	3.37	1.76	7.5	12.5
87	5.19	3.46	1.73	14.5	12.7
88	5.26	3.74	1.52	61.4	14.7
89	3.98	3.37	0.61	11.8	23.0
90	4.16	3.33	0.83	9.0	21.0
91	4.63	3.26	1.37	9.0	16.1
92	5.23	3.81	1.42	9.8	15.6
93	6.04	3.79	2.25	9.4	8.0
94	6.17	3.85	2.32	9.2	7.3
95	6.96	3.90	3.06	6.0	0.6
96	6.33	3.75	2.57	4.8	5.0
Mean	5.33	3.57	1.76	12.7	12.4

Phosphorus Concentration at S332+S175 vs. Head
Excluding 1987& 1988

Marsh Stage:	NP206	Canal Stage:	S175_H
Location:	S332+S175		



Regression Output:

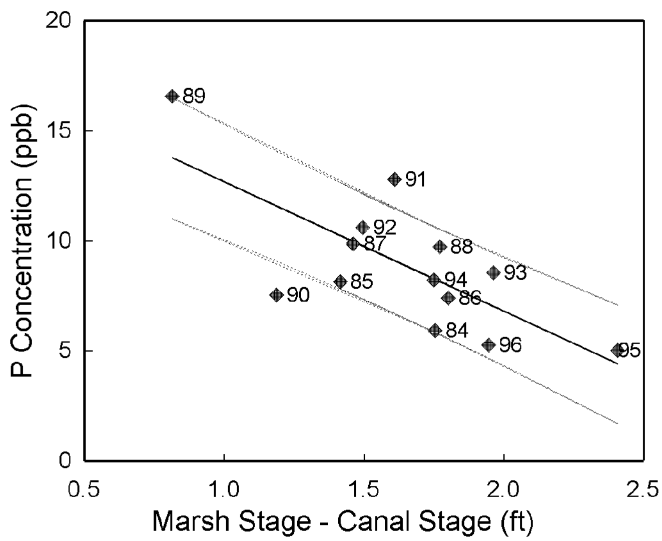
Constant		11.57
Std Err of Y Est		1.59
R Squared		0.464
No. of Observations		11
Degrees of Freedom		9
X Coefficient(s)	-1.91	
Std Err of Coef.	0.69	

Predicted Concentration @ Zero Head =	11.6 ppb
Predicted Concentration @ Min. Head =	10.4 ppb
Predicted Concentration @ Max. Head =	5.7 ppb

Calendar Year	Marsh NP206 feet	Canal S175_H feet	Head feet	Conc ppb	Predicted ppb
84	5.32	3.43	1.89	5.7	8.0
85	4.94	3.35	1.59	7.5	8.5
86	5.13	3.37	1.76	7.5	8.2
89	3.98	3.37	0.61	11.8	10.4
90	4.16	3.33	0.83	9.0	10.0
91	4.63	3.26	1.37	9.0	8.9
92	5.23	3.81	1.42	9.8	8.9
93	6.04	3.79	2.25	9.4	7.3
94	6.17	3.85	2.32	9.2	7.1
95	6.96	3.90	3.06	6.0	5.7
96	6.33	3.75	2.57	4.8	6.6
Mean	5.35	3.56	1.79	8.1	8.1

Phosphorus Concentration at S177 vs. Head

Marsh Stage:	G1502	Canal Stage:	S176_H
Location:	S177		



Regression Output:

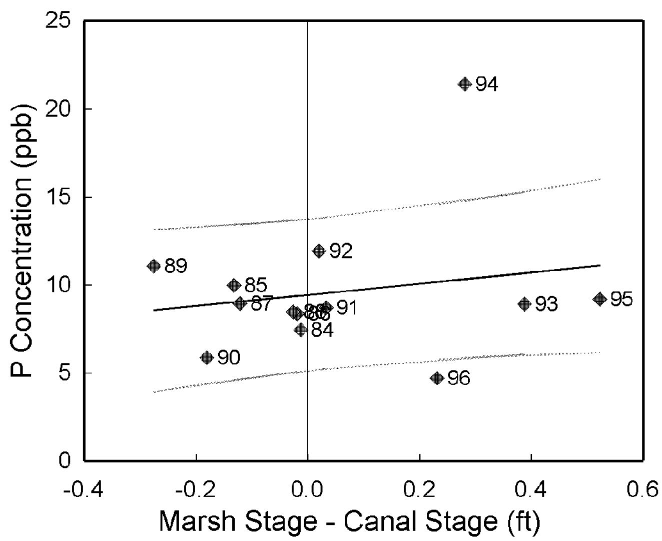
Constant		18.55
Std Err of Y Est		2.28
R Squared		0.526
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	-5.88	
Std Err of Coef.	1.68	

Predicted Concentration @ Zero Head 18.5 ppb
Predicted Concentration @ Min. Head : 13.8 ppb
Predicted Concentration @ Max. Head 4.4 ppb

Calendar Year	Marsh G1502 feet	Canal S176_H feet	Head feet	Conc ppb	Predicted ppb
84	5.84	4.08	1.75	5.9	8.2
85	5.33	3.92	1.41	8.1	10.2
86	5.87	4.07	1.80	7.4	8.0
87	5.64	4.18	1.46	9.9	10.0
88	6.04	4.27	1.77	9.7	8.1
89	4.53	3.72	0.81	16.6	13.8
90	4.68	3.50	1.19	7.5	11.6
91	5.26	3.65	1.61	12.8	9.1
92	5.84	4.34	1.50	10.6	9.8
93	6.57	4.60	1.96	8.5	7.0
94	6.46	4.71	1.75	8.2	8.3
95	7.14	4.74	2.41	5.0	4.4
96	6.49	4.54	1.95	5.3	7.1
Mean	5.82	4.18	1.64	8.9	8.9

Phosphorus Concentration at S18C vs. Head

Marsh Stage:	R127	Canal Stage:	S18C_H
Location:	S18C		



Regression Output:		
Constant		9.42
Std Err of Y Est		4.13
R Squared		0.034
No. of Observations		13
Degrees of Freedom		11
X Coefficient(s)	3.18	
Std Err of Coef.	5.09	

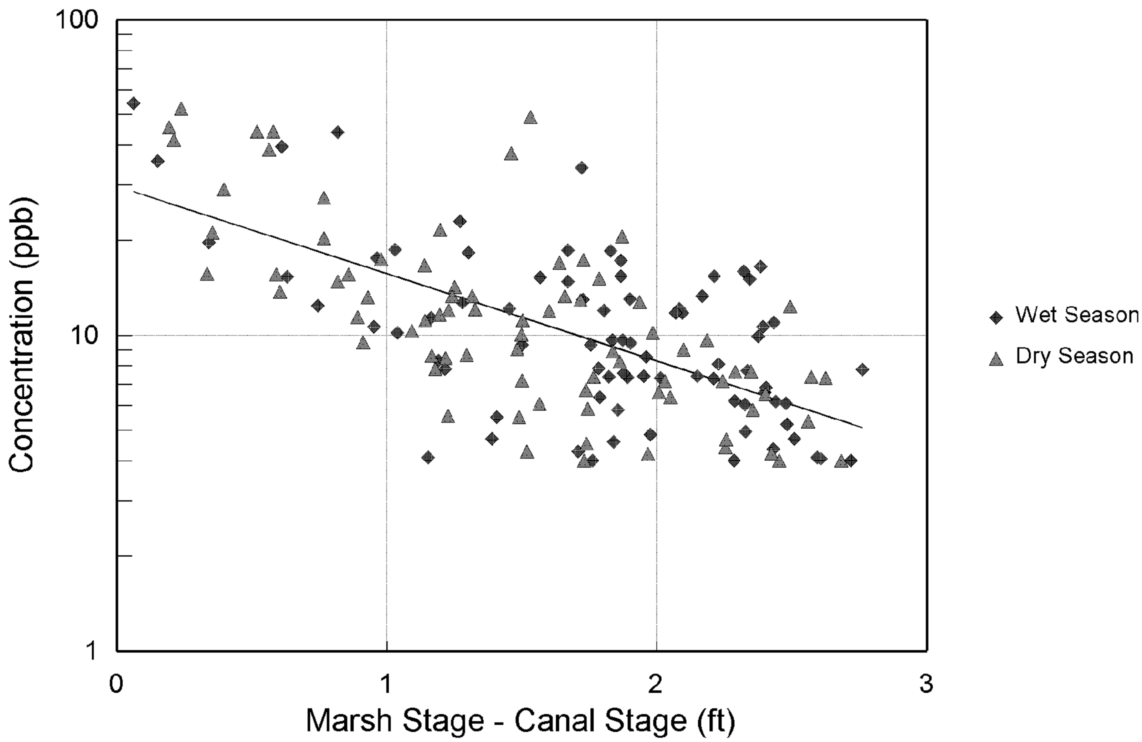
Predicted Concentration @ Zero Head	9.4 ppb
Predicted Concentration @ Min. Head :	11.1 ppb
Predicted Concentration @ Max. Head	8.6 ppb

Calendar Year	Marsh R127 feet	Canal S18C_H feet	Head feet	Conc ppb	Predicted ppb
84	2.03	2.05	-0.01	7.4	9.4
85	2.00	2.14	-0.13	9.9	9.0
86	2.21	2.23	-0.02	8.3	9.4
87	2.16	2.28	-0.12	8.9	9.0
88	2.28	2.30	-0.03	8.4	9.3
89	1.59	1.87	-0.27	11.0	8.6
90	1.63	1.81	-0.18	5.8	8.9
91	2.05	2.01	0.03	8.7	9.5
92	2.17	2.15	0.02	11.9	9.5
93	2.67	2.28	0.39	8.9	10.7
94	2.61	2.33	0.28	21.4	10.3
95	2.92	2.40	0.52	9.2	11.1
96	2.50	2.27	0.23	4.7	10.2
Mean	2.22	2.16	0.05	9.6	9.6

Monthly Concentration vs. Stage Differential A

Location: **S174S176** Conc: TP Marsh Stage = G1502

Canal Stage = S176_H



Marsh Stage = G1502
Canal Stage = S176_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

Regression Output:

Constant	3.3902
Std Err of Y Est	0.4816
R Squared	0.4239
No. of Observations	158
Degrees of Freedom	156

Stage Diff. feet	Predicted Concentration (ppb)
0	30
0.1 (min)	29
2.8 (max)	5

X Coefficient(s)	-0.637
Std Err of Coef.	0.059
t-statistic	-10.713
Significance:	0.000

Slope = -63.7 +/- 5.9 % per foot

Diagnostic Plots - Time Series B

Location: S174S176 Conc: TP Marsh Stage = G1502
Canal Stage = S176_H

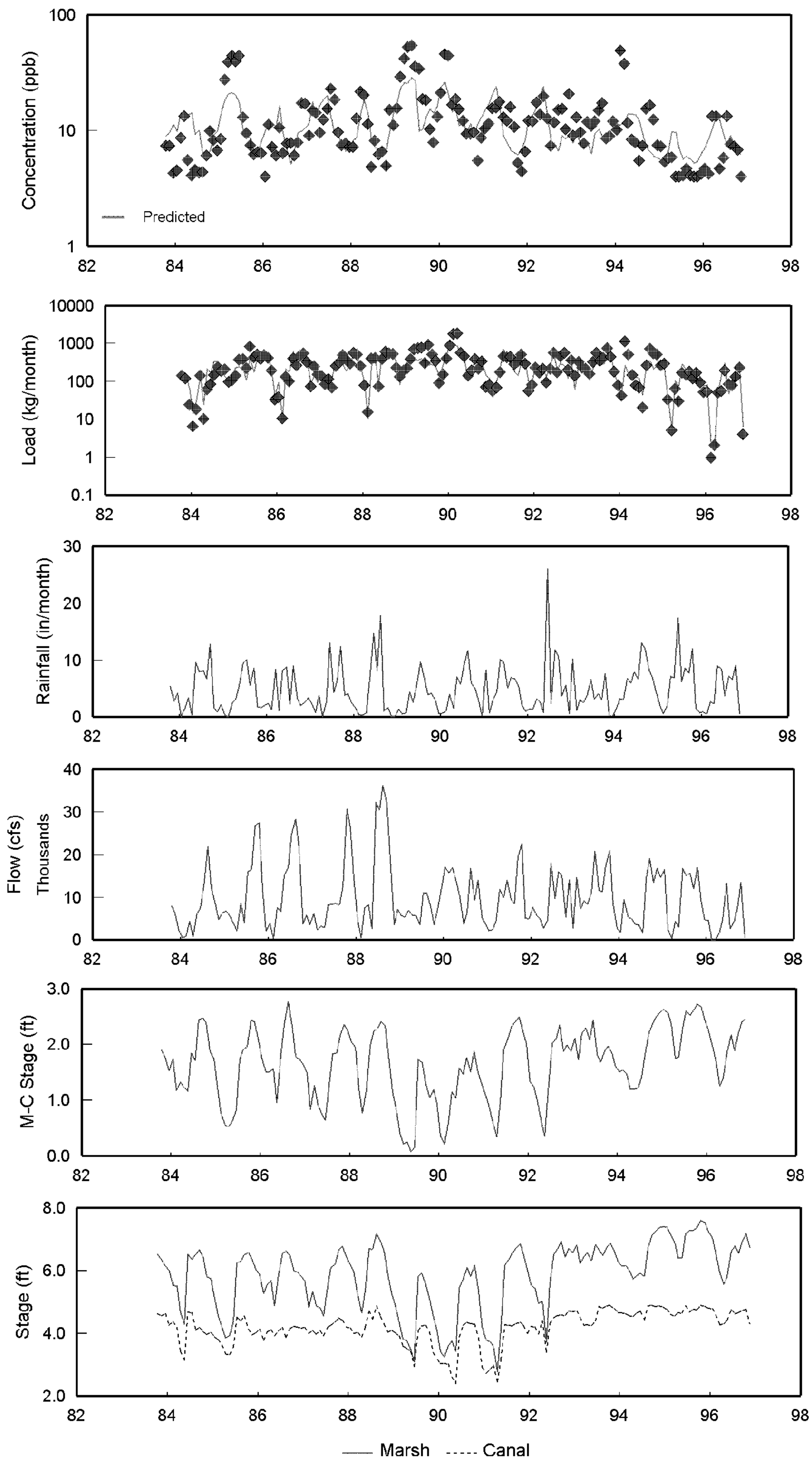
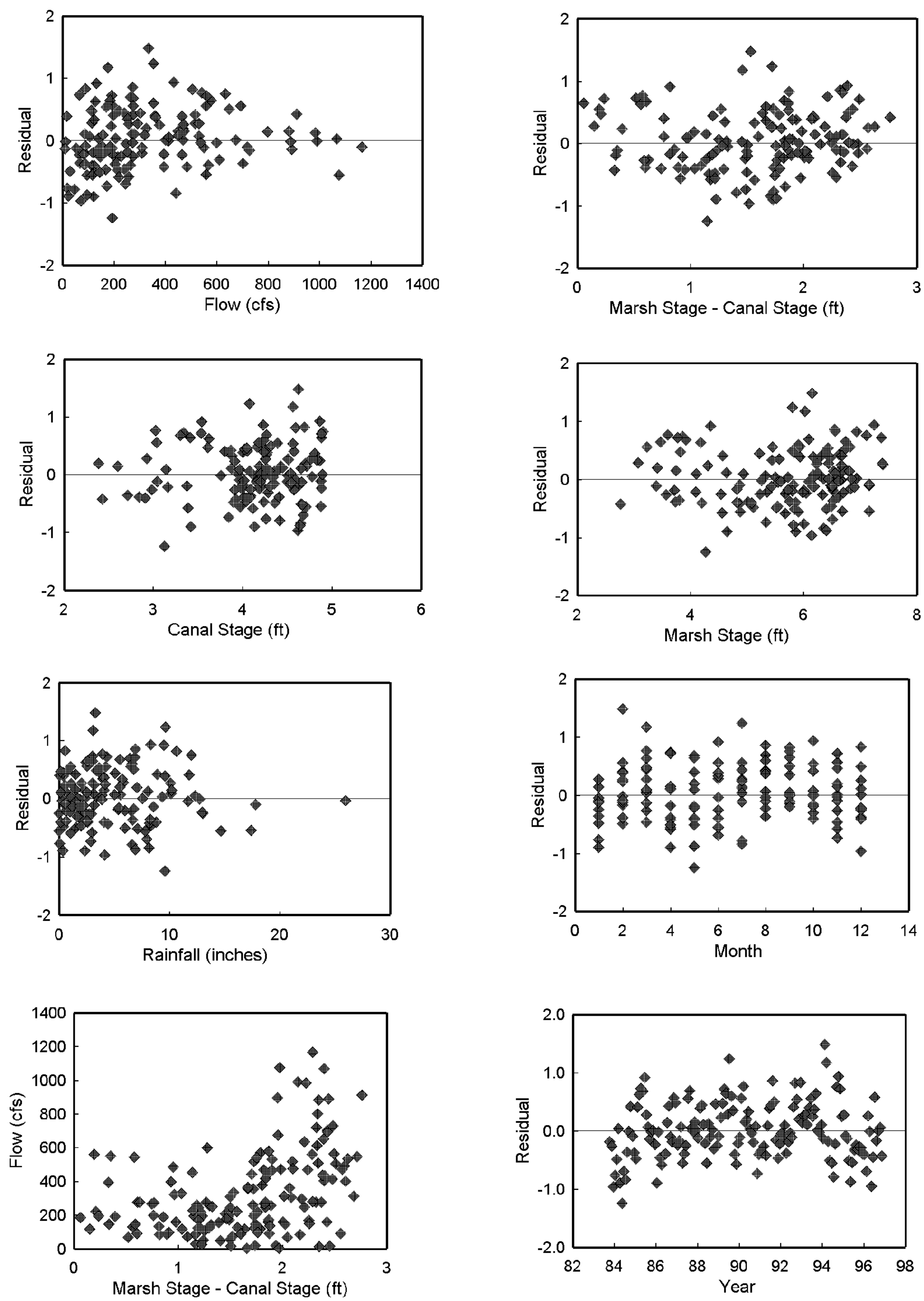


Figure 23 C

Diagnostic Plots - Residuals C

Location: S174S176 Conc: TP Marsh Stage = G1502

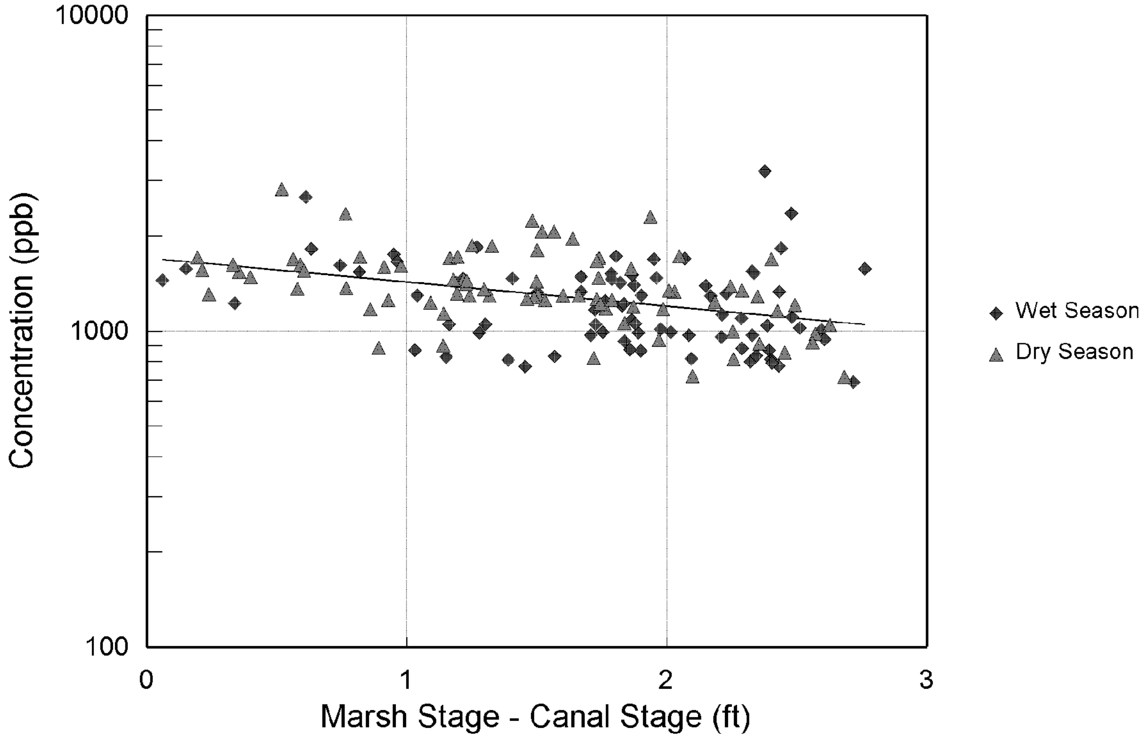
Residual = Ln (Observed / Predicted Conc.) Canal Stage = S176_H



Monthly Concentration vs. Stage Differential A

Location: **S174S176** Conc: TN Marsh Stage = G1502

Canal Stage = S176_H



Marsh Stage = G1502
Canal Stage = S176_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

Regression Output:

Constant	7.4421
Std Err of Y Est	0.2708
R Squared	0.1512
No. of Observations	158
Degrees of Freedom	156

Stage Diff. feet	Predicted Concentration (ppb)
0	1706
0.1 (min)	1687
2.8 (max)	1049

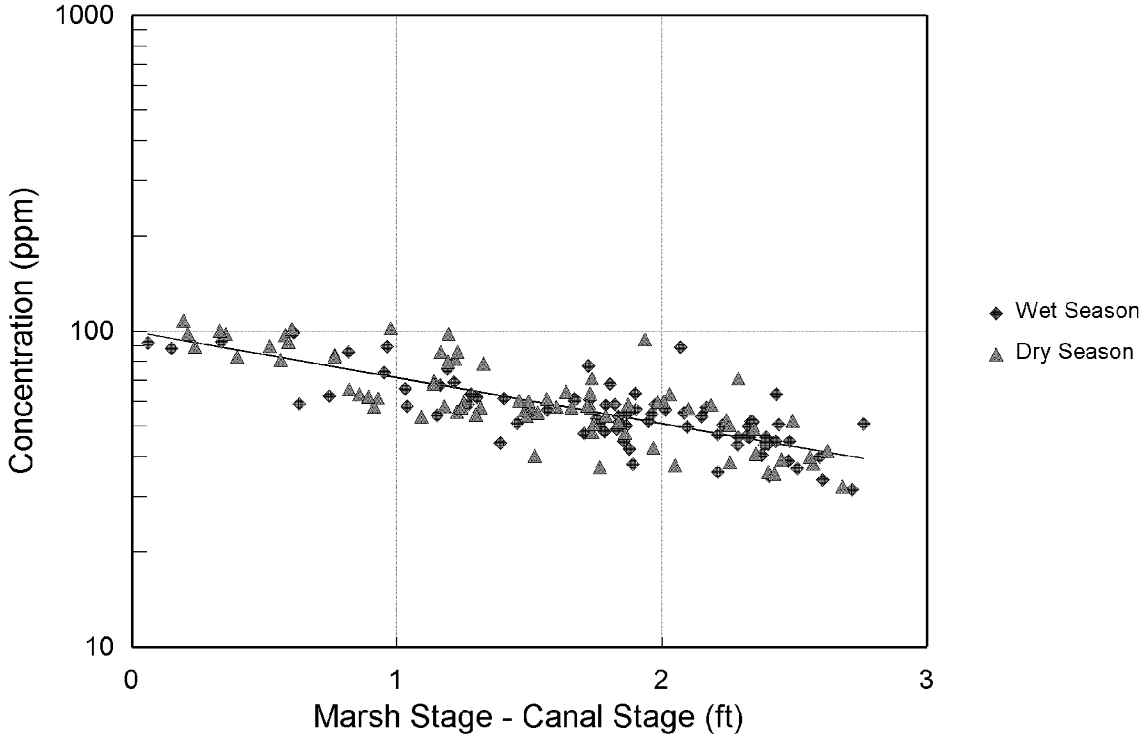
X Coefficient(s)	-0.176
Std Err of Coef.	0.033
t-statistic	-5.272
Significance:	0.000

Slope = -17.6 +/- 3.3 % per foot

Monthly Concentration vs. Stage Differential A

Location: **S174S176** Conc: CL Marsh Stage = G1502

Canal Stage = S176_H



Marsh Stage = G1502
Canal Stage = S176_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

Regression Output:	
Constant	4.6021
Std Err of Y Est	0.172
R Squared	0.6155
No. of Observations	158
Degrees of Freedom	156

Stage Diff. feet	Predicted Concentration (ppm)
0	100
0.1 (min)	98
2.8 (max)	39

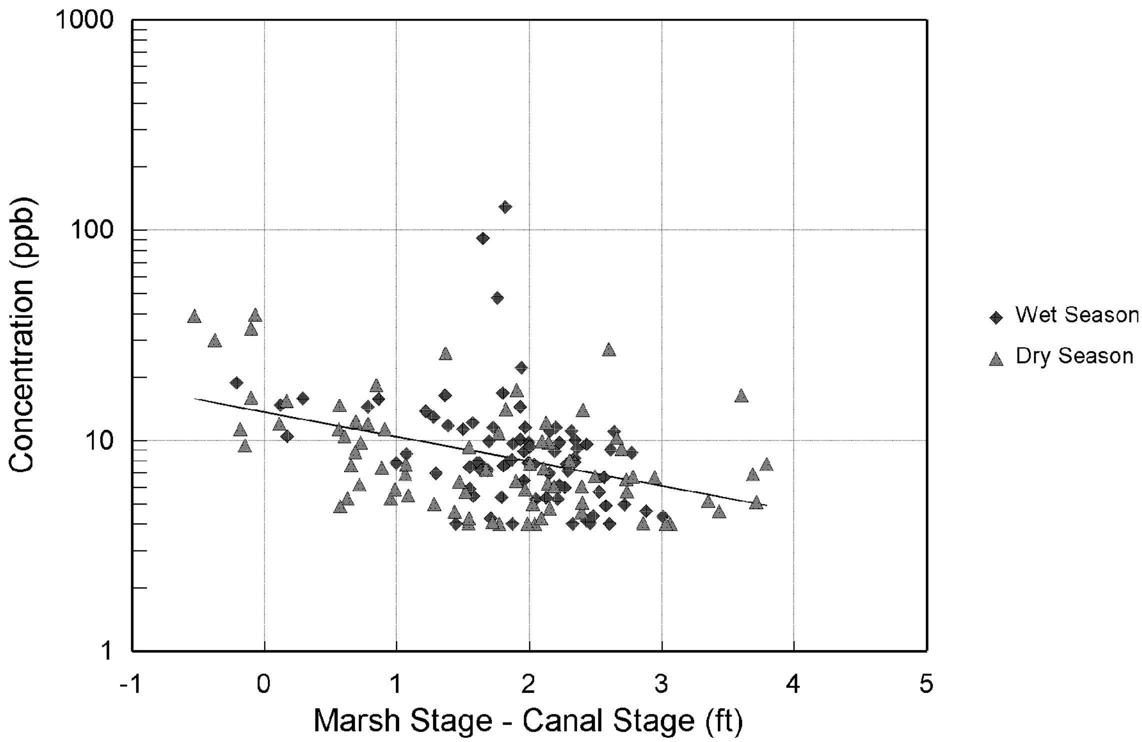
X Coefficient(s)	-0.336
Std Err of Coef.	0.021
t-statistic	-15.802
Significance:	0.000

Slope = -33.6 +/- 2.1 % per foot

Monthly Concentration vs. Stage Differential A

Location: **S332S175** Conc: TP Marsh Stage = NP206

Canal Stage = S175_H



Marsh Stage = NP206
Canal Stage = S175_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

Regression Output:

Constant	2.6161
Std Err of Y Est	0.547
R Squared	0.1581
No. of Observations	156
Degrees of Freedom	154

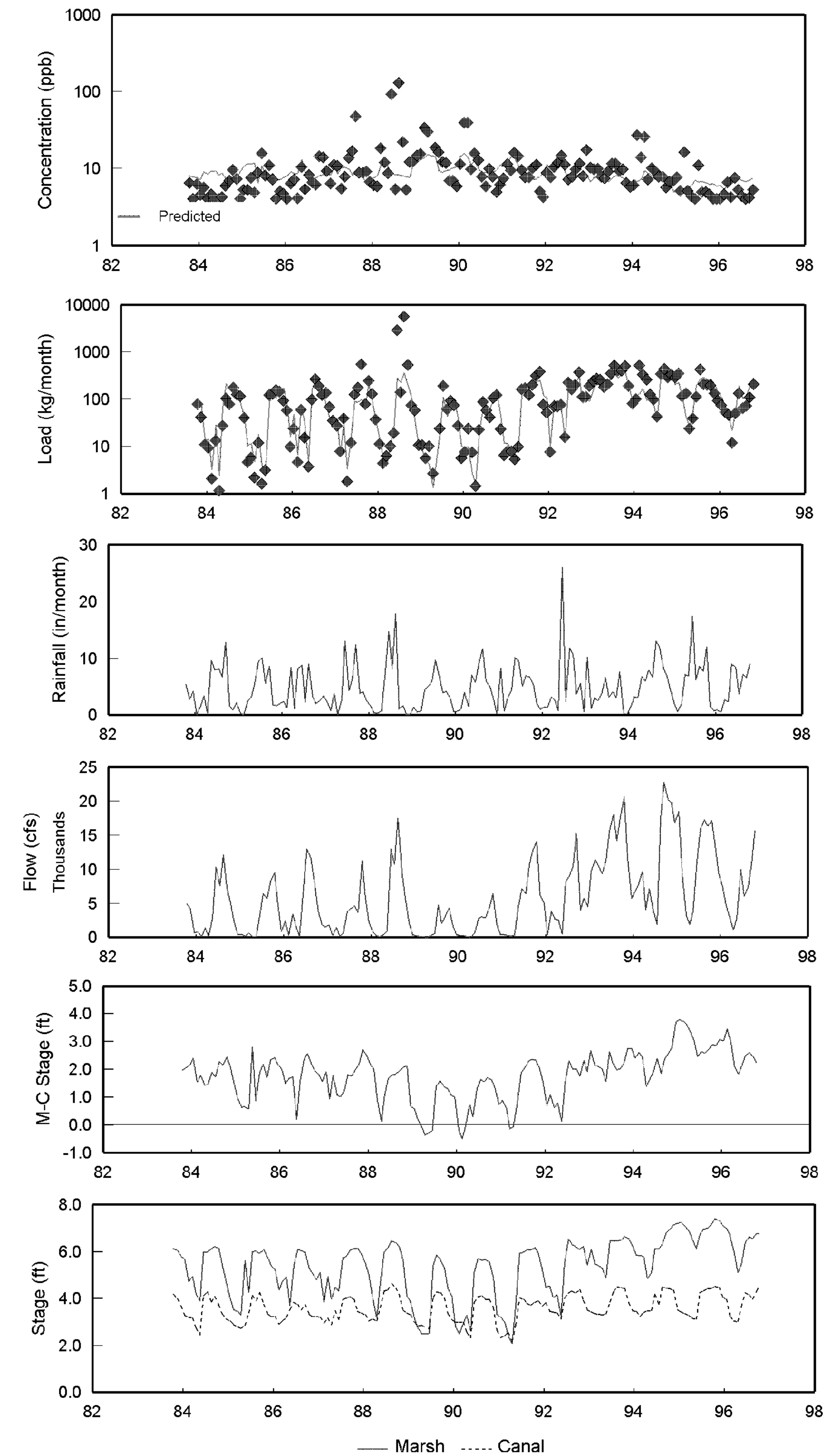
Stage Diff. feet	Predicted Concentration (ppb)
0	14
-0.5 (min)	16
3.8 (max)	5

X Coefficient(s)	-0.270
Std Err of Coef.	0.050
t-statistic	-5.378
Significance:	0.000

Slope = -27.0 +/- 5.0 % per foot

Diagnostic Plots - Time Series B

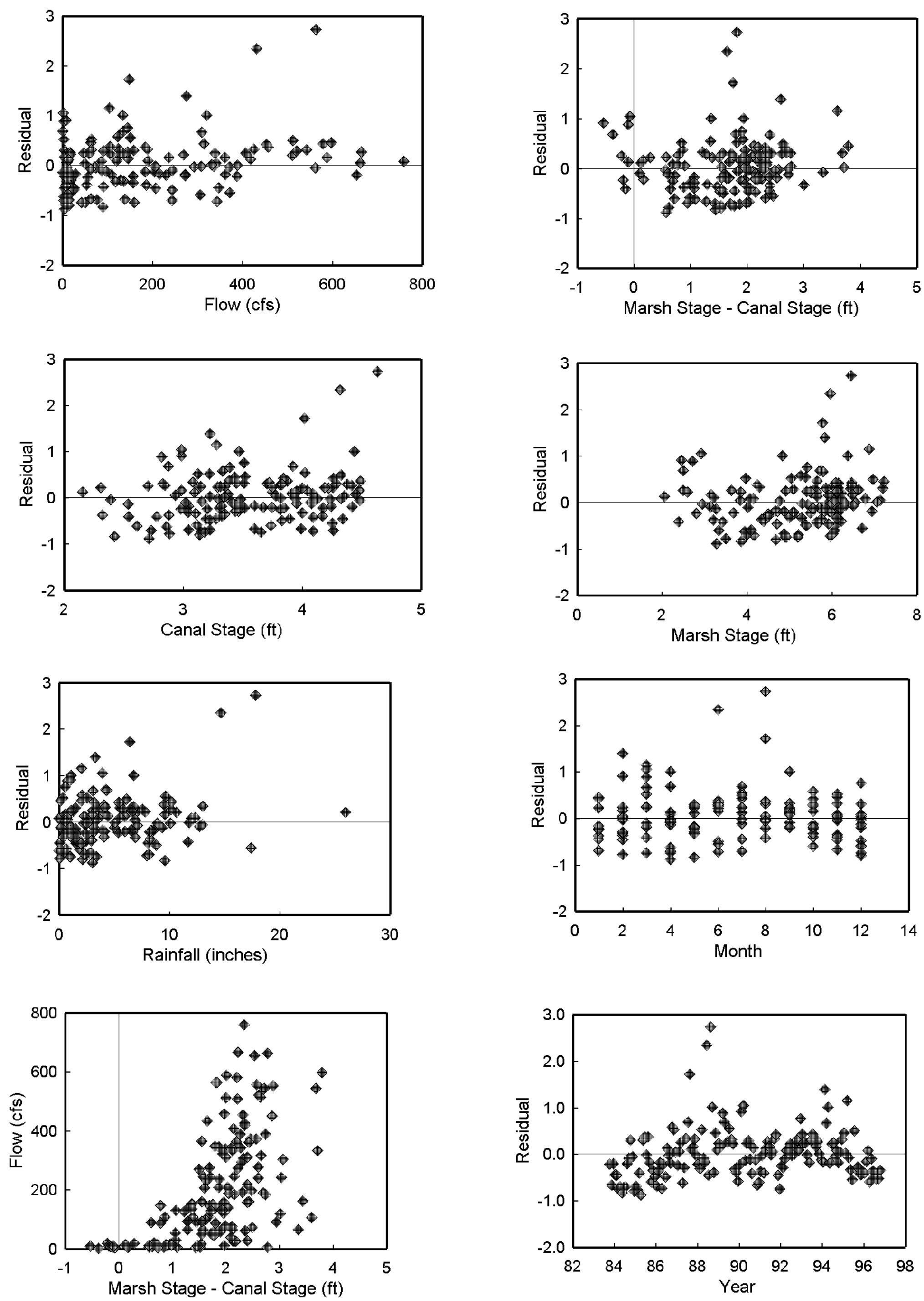
Location: S332S175 Conc: TP Marsh Stage = NP206
Canal Stage = S175_H



Diagnostic Plots - Residuals C

Location: S332S175 Conc: TP Marsh Stage = NP206

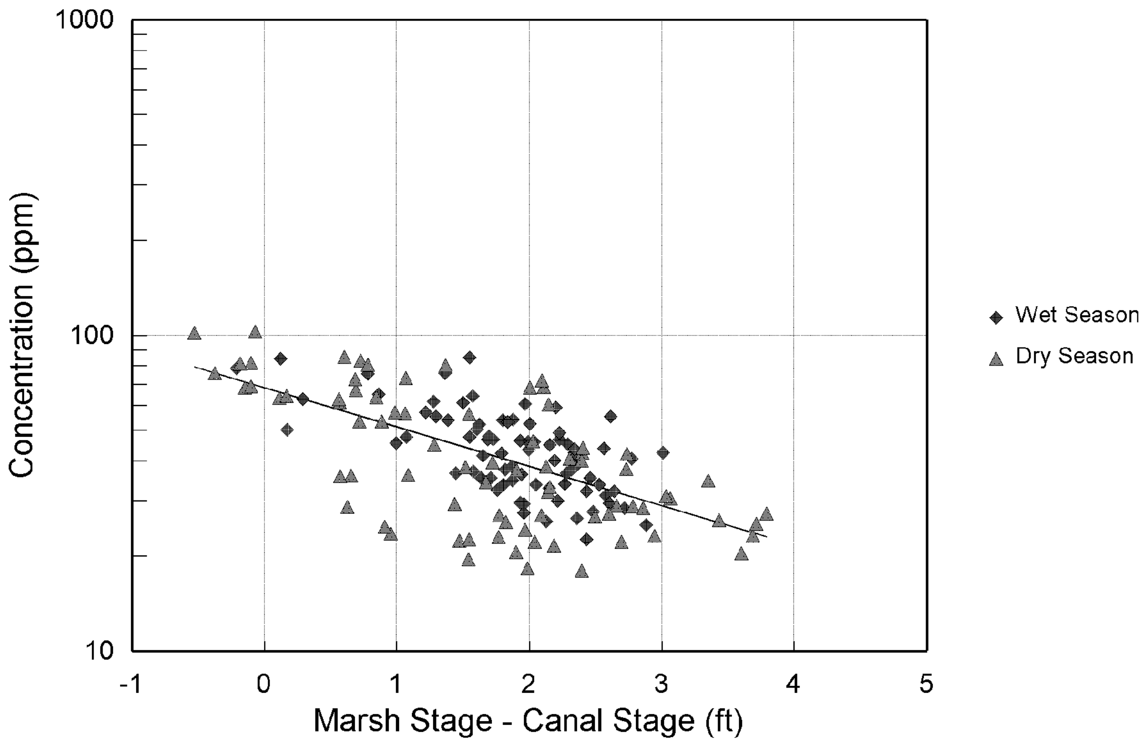
Residual = Ln (Observed / Predicted Conc.) Canal Stage = S175_H



Monthly Concentration vs. Stage Differential A

Location: **S332S175** Conc: CL Marsh Stage = NP206

Canal Stage = S175_H



Marsh Stage = NP206

Canal Stage = S175_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

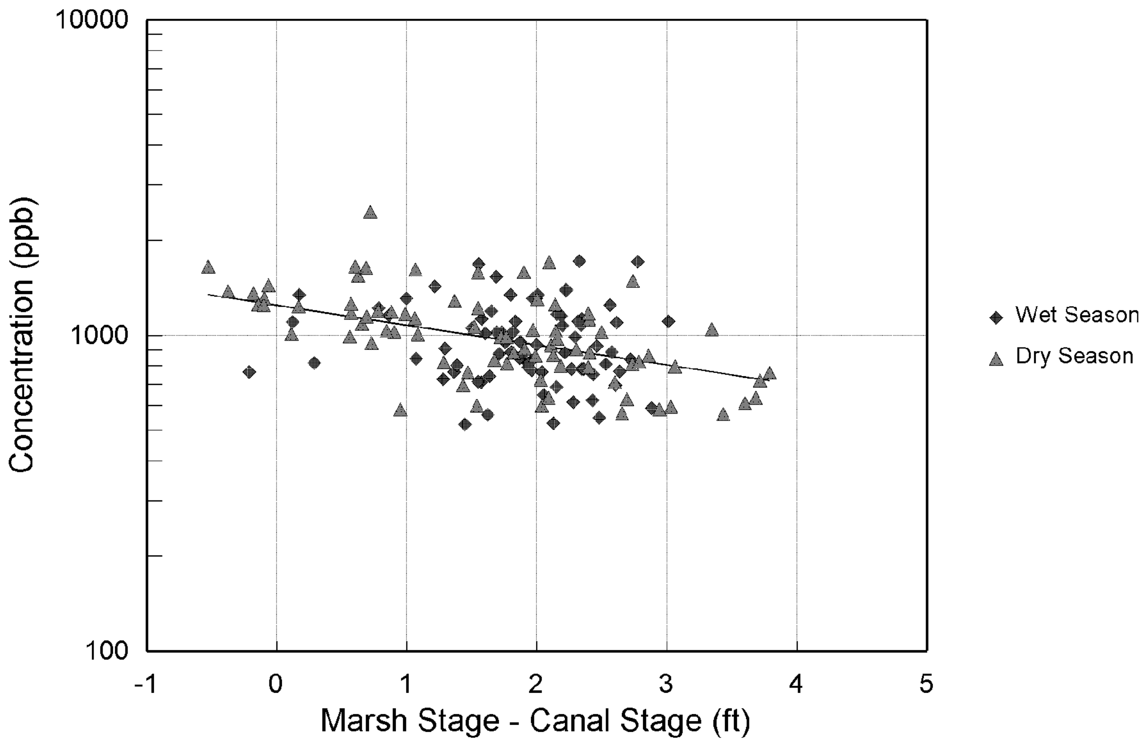
Regression Output:			Stage Diff. feet	Predicted Concentration (ppm)
Constant		4.2253		
Std Err of Y Est		0.3136		
R Squared		0.3927	0	68
No. of Observations		156	-0.5 (min)	80
Degrees of Freedom		154	3.8 (max)	23
X Coefficient(s)	-0.287			
Std Err of Coef.	0.029			
t-statistic	-9.979			
Significance:	0.000			

Slope = -28.7 +/- 2.9 % per foot

Monthly Concentration vs. Stage Differential A

Location: S332S175 Conc: TN Marsh Stage = NP206

Canal Stage = S175_H



Marsh Stage = NP206

Canal Stage = S175_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

Regression Output:

Constant	7.1276
Std Err of Y Est	0.2741
R Squared	0.1779
No. of Observations	156
Degrees of Freedom	154

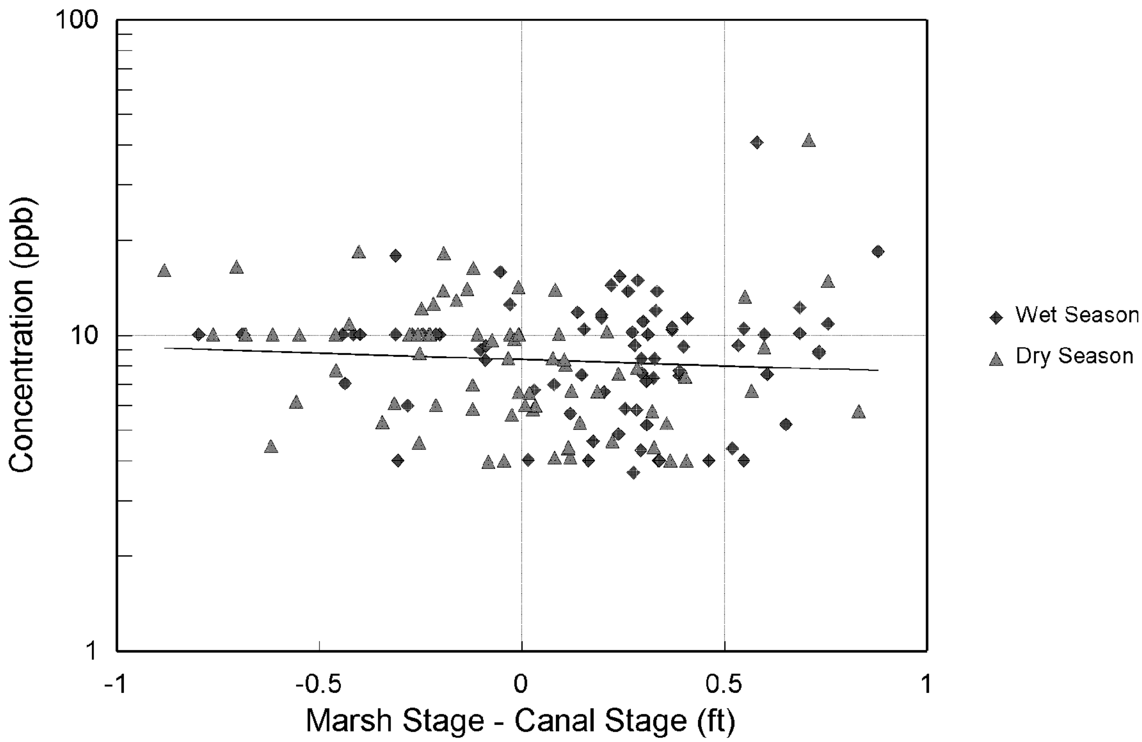
Stage Diff. feet	Predicted Concentration (ppb)
0	1246
-0.5 (min)	1345
3.8 (max)	718

X Coefficient(s)	-0.145
Std Err of Coef.	0.025
t-statistic	-5.772
Significance:	0.000

Slope = -14.5 +/- 2.5 % per foot

Monthly Concentration vs. Stage Differential A

Location: **S18C** Conc: TP Marsh Stage = R127
Canal Stage = S18C_H



Marsh Stage = R127
Canal Stage = S18C_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

Regression Output:		Stage Diff. feet	Predicted Concentration (ppb)
Constant	2.1264		
Std Err of Y Est	0.4476		
R Squared	0.0059	0	8
No. of Observations	152	-0.9 (min)	9
Degrees of Freedom	150	0.9 (max)	8

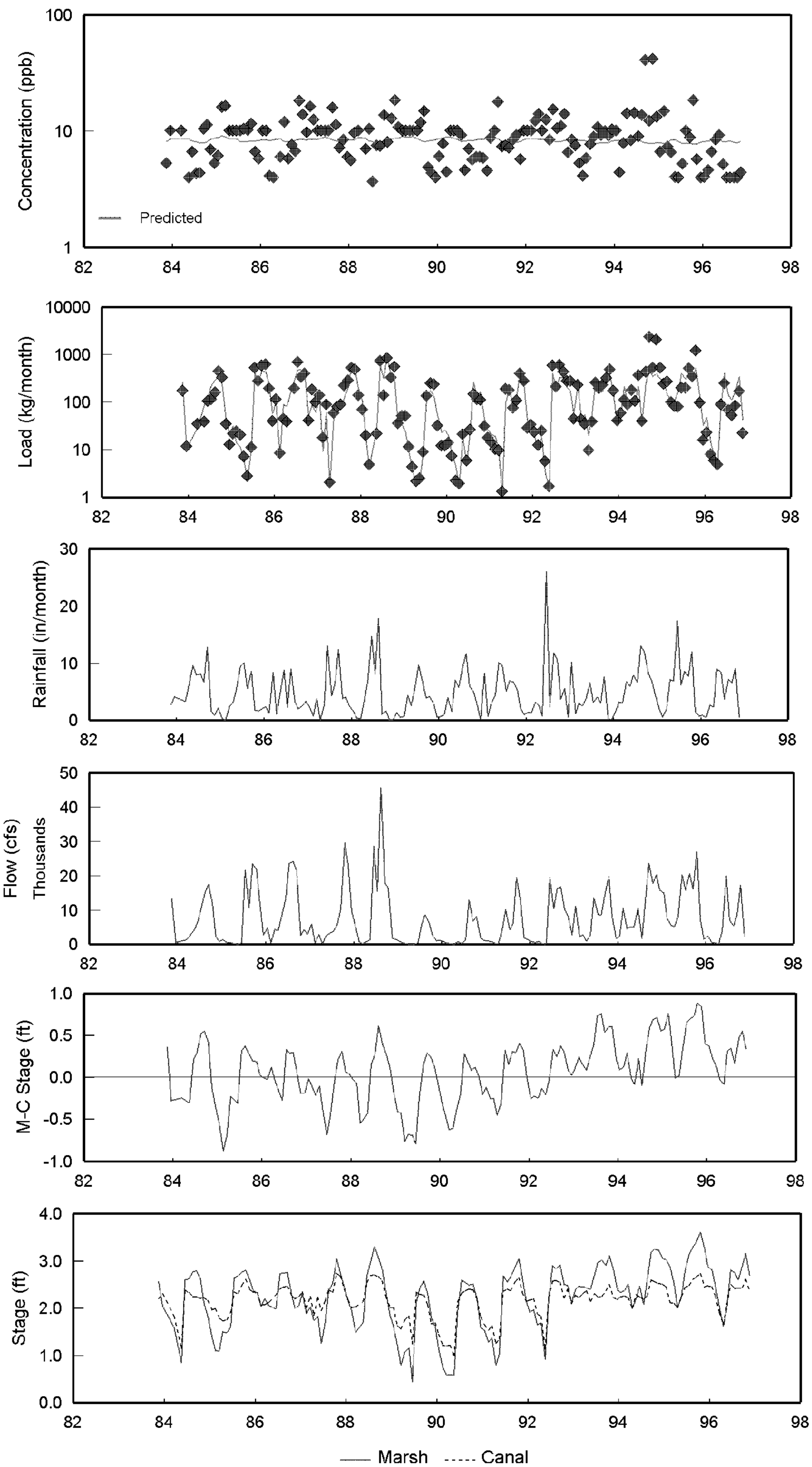
X Coefficient(s)	-0.092
Std Err of Coef.	0.098
t-statistic	-0.944
Significance:	0.347

Slope = -9.2 +/- 9.8 % per foot

Diagnostic Plots - Time Series B

Location: S18C Conc: TP Marsh Stage = R127

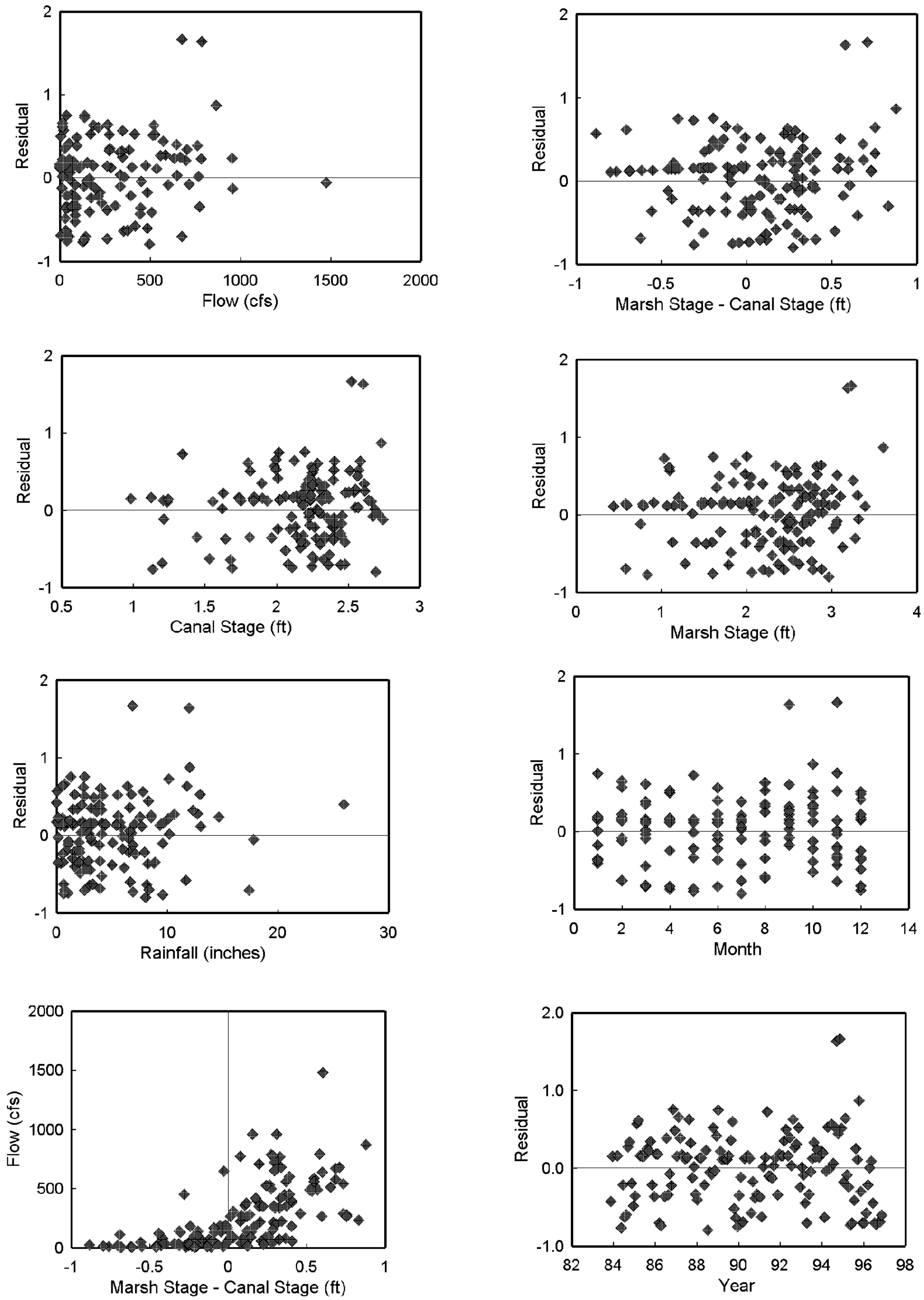
Canal Stage = S18C_H



Diagnostic Plots - Residuals C

Location: S18C Conc: TP Marsh Stage = R127

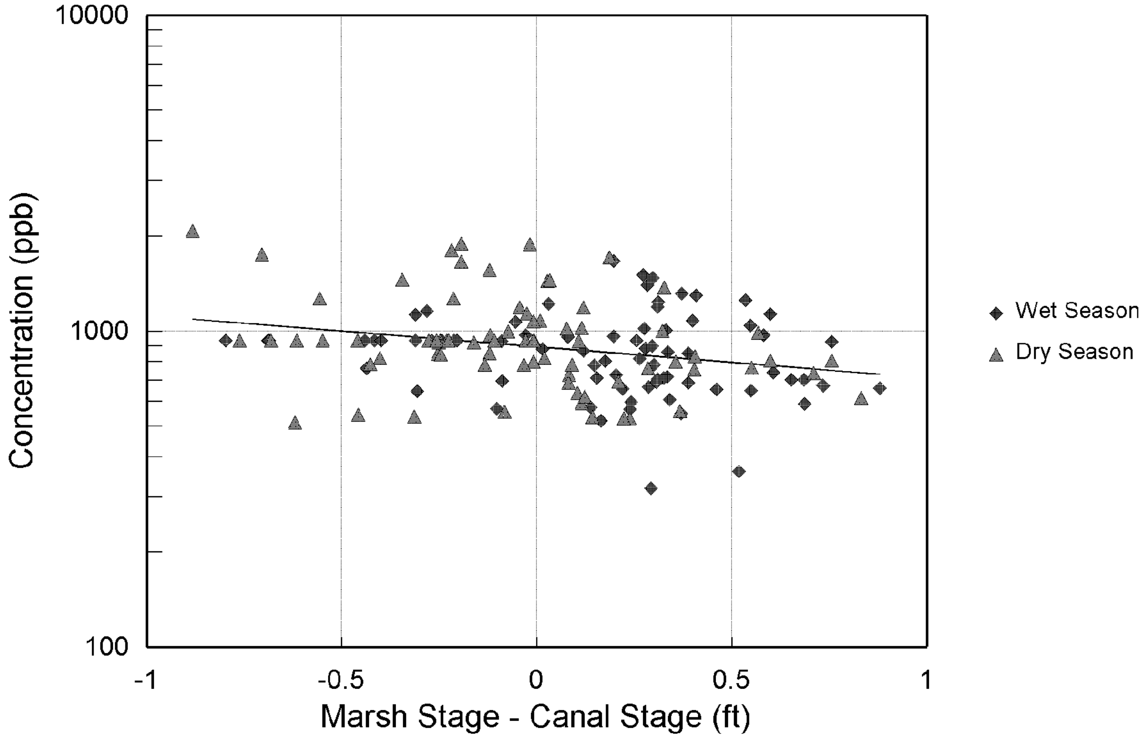
Residual = Ln (Observed / Predicted Conc.) Canal Stage = S18C_H



Monthly Concentration vs. Stage Differential A

Location: S18C Conc: TN Marsh Stage = R127

Canal Stage = S18C_H



Marsh Stage = R127
Canal Stage = S18C_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

Regression Output:

Constant	6.794
Std Err of Y Est	0.3109
R Squared	0.07
No. of Observations	152
Degrees of Freedom	150

Stage Diff. feet		Predicted Concentration (ppb)
0		892
-0.9	(min)	1091
0.9	(max)	730

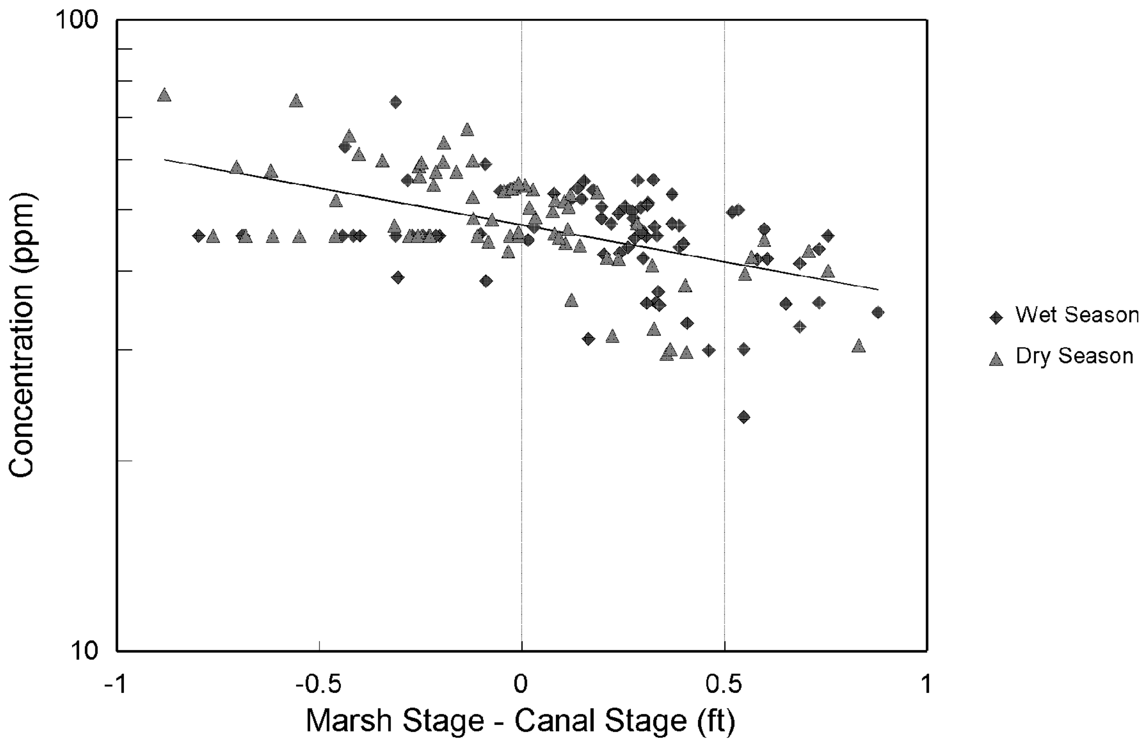
X Coefficient(s)	-0.228
Std Err of Coef.	0.068
t-statistic	-3.359
Significance:	0.001

Slope = -22.8 +/- 6.8 % per foot

Monthly Concentration vs. Stage Differential A

Location: **S18C** Conc: CL Marsh Stage = R127

Canal Stage = S18C_H



Marsh Stage = R127
Canal Stage = S18C_H

Regression: ln(Concentration) vs. (Marsh - Canal Stage)

Regression Output:

Constant	3.8567	Stage Diff. feet	Predicted Concentration (ppm)
Std Err of Y Est	0.165		
R Squared	0.2709	0	47
No. of Observations	152	-0.9 (min)	60
Degrees of Freedom	150	0.9 (max)	37

X Coefficient(s)	-0.269
Std Err of Coef.	0.036
t-statistic	-7.465
Significance:	0.000

Slope = -26.9 +/- 3.6 % per foot

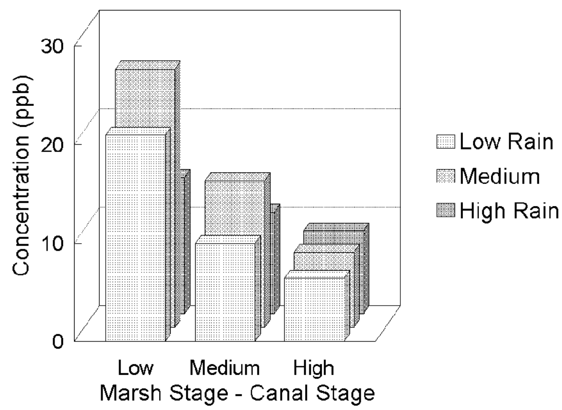
Stage / Rainfall Cross-Tabulation

Location: S174S176 Var: TP Marsh Stage: G1502
Canal Stage: S176_H

Dates: Oct-83 to Nov-96

Frequency (months)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	21	13	19	53
Medium	20	19	13	52
High	12	20	21	53
All	53	52	53	158

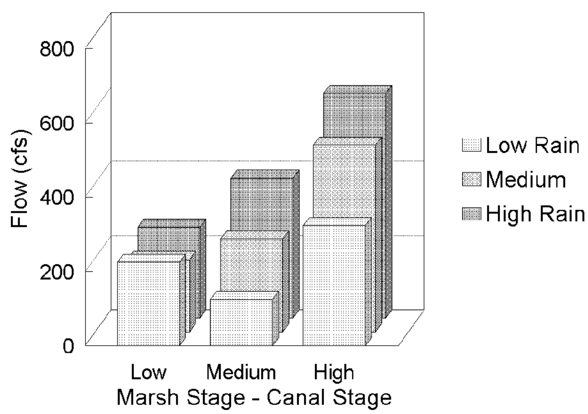


Concentration (ppb)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	21.0	10.0	6.4	12.3
Medium	26.2	14.9	7.6	14.7
High	13.8	10.3	8.4	9.7
Both	20.9	11.8	7.7	11.8

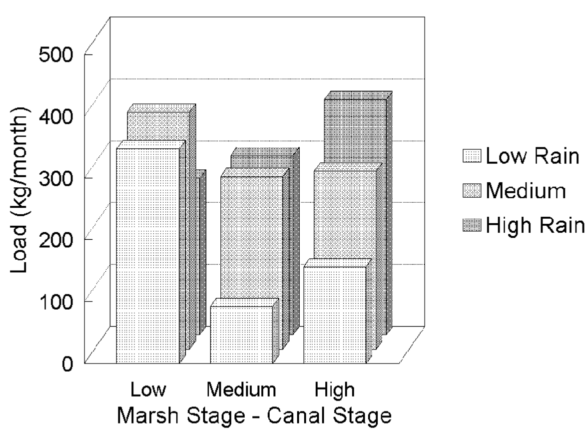
Flow (cfs)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	226	126	325	237
Medium	195	251	503	292
High	244	376	604	437
All	218	268	479	322



Load (kg/month)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	348	92	157	217
Medium	383	279	288	321
High	253	289	380	317
All	340	236	277	285



Marsh Stage - Canal Stage (ft)
Low: <=1.40
High: > 1.97

Rainfall (inches/month)
Low: <=2.3
High: > 6.3

Results for Months with Positive Flow

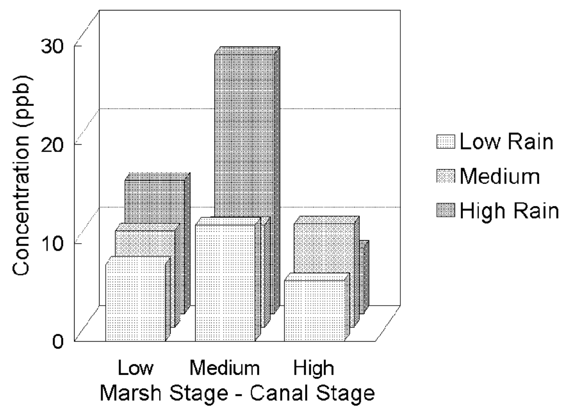
Stage / Rainfall Cross-Tabulation

Location: S332S175 Var: TP Marsh Stage: NP206
Canal Stage: S175_H

Dates: Oct-83 to Oct-96

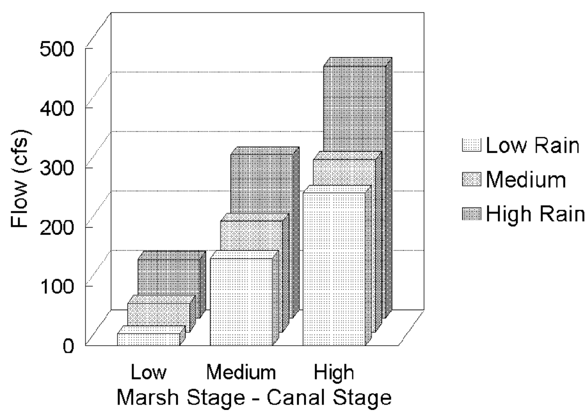
Frequency (months)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	24	11	17	52
Medium	16	22	14	52
High	12	20	20	52
All	52	53	51	156



Concentration (ppb)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	7.9	11.8	6.2	7.7
Medium	9.8	10.4	10.5	10.4
High	13.6	26.3	6.6	14.3
Both	11.3	18.4	7.5	11.8

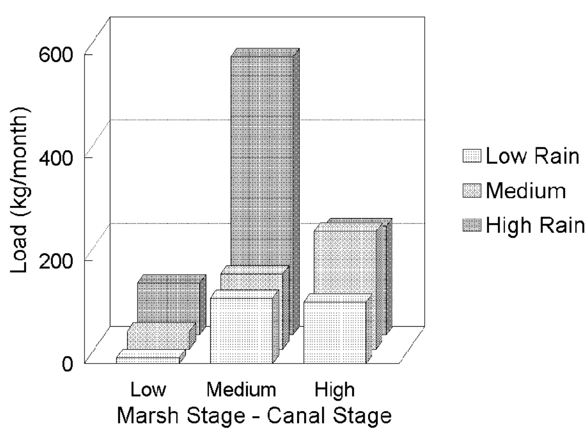


Flow (cfs)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	20	147	257	124
Medium	48	186	290	171
High	98	275	424	291
All	47	211	331	196

Load (kg/month)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	12	127	119	71
Medium	35	146	228	134
High	100	540	210	311
All	39	290	185	172



Marsh Stage - Canal Stage (ft)
Low: <=1.55
High: > 2.16

Rainfall (inches/month)
Low: <=2.3
High: > 6.5

Results for Months with Positive Flow

Stage / Rainfall Cross-Tabulation

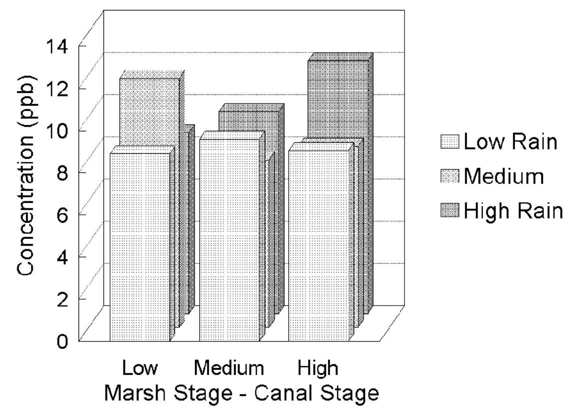
Location: S18C Var: TP Marsh Stage: R127

Canal Stage: S18C_H

Dates: Nov-83 to Nov-96

Frequency (months)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	20	18	13	51
Medium	20	16	14	50
High	11	16	24	51
All	51	50	51	152

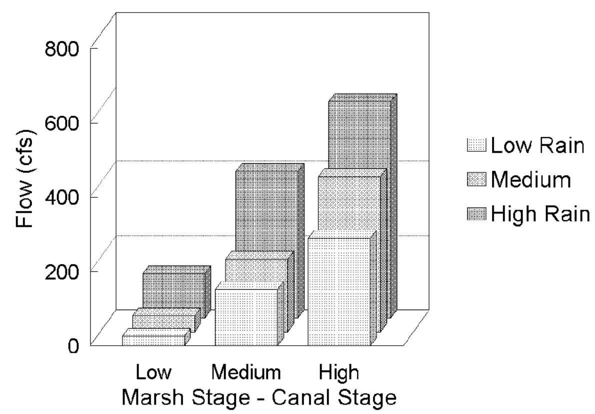


Concentration (ppb)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	8.9	9.6	9.0	9.2
Medium	11.8	7.9	8.6	8.7
High	8.6	9.6	12.0	11.1
Both	9.7	9.2	10.7	10.1

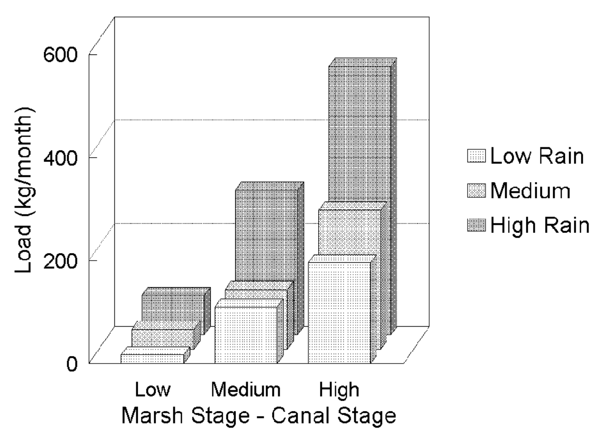
Flow (cfs)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	26	152	290	138
Medium	43	196	418	197
High	119	394	582	423
All	53	243	462	253



Load (kg/month)

Rainfall	Marsh - Canal Stage Low	Med	High	All
Low	17	110	196	95
Medium	39	115	270	128
High	76	280	520	349
All	38	166	369	191



Marsh Stage - Canal Stage (ft)

Low: <=-0.08

High: > 0.28

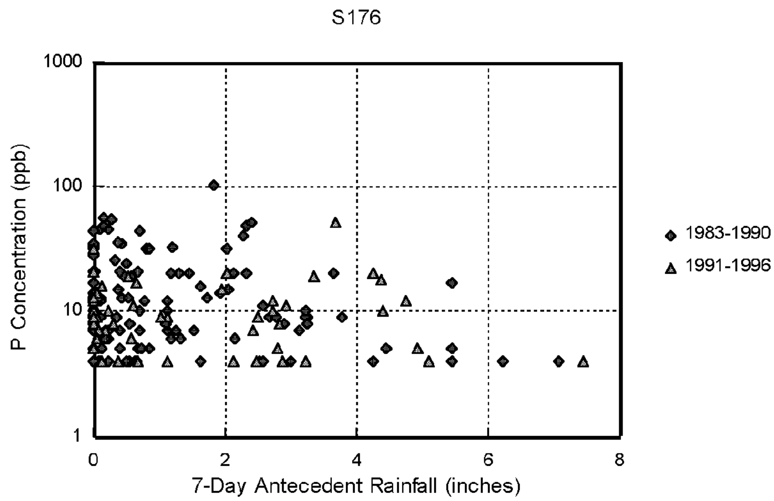
Rainfall (inches/month)

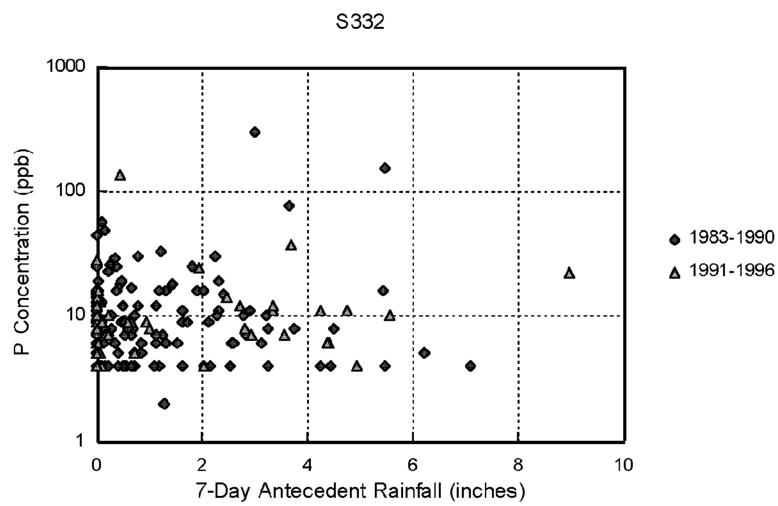
Low: <=2.4

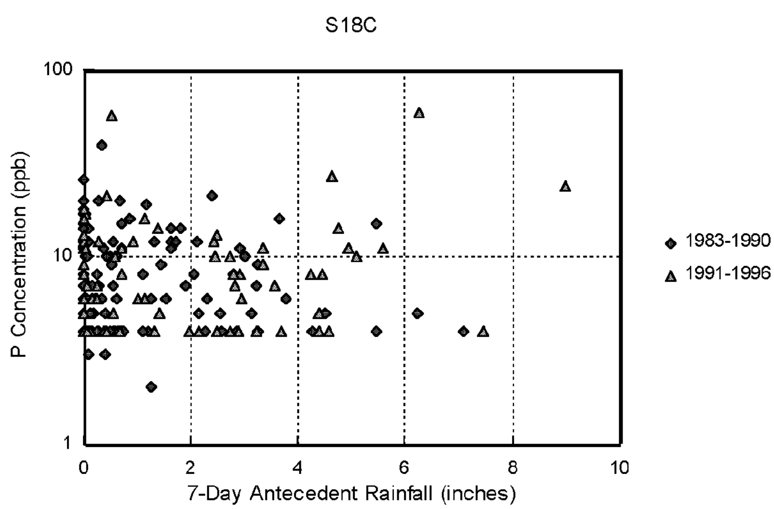
High: > 6.5

Results for Months with Positive Flow

Sample Phosphorus Concentrations vs. 7-Day Antecedent Rainfall at S331

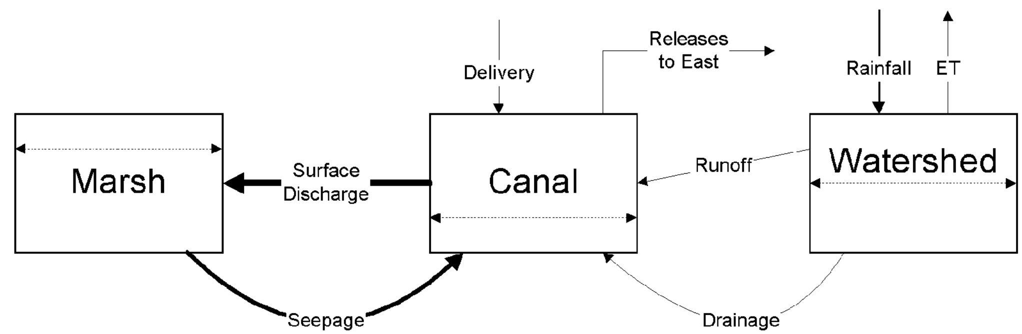




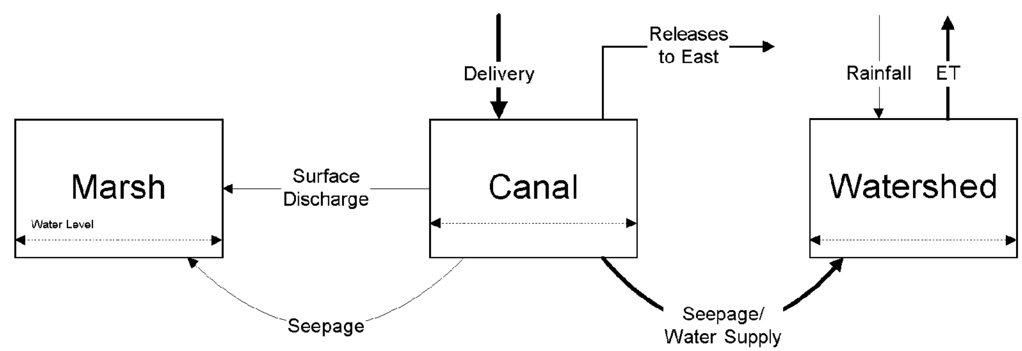


Conceptual Model - Historical Conditions

Normal to Wet Conditions, Marsh Stage > Canal Stage

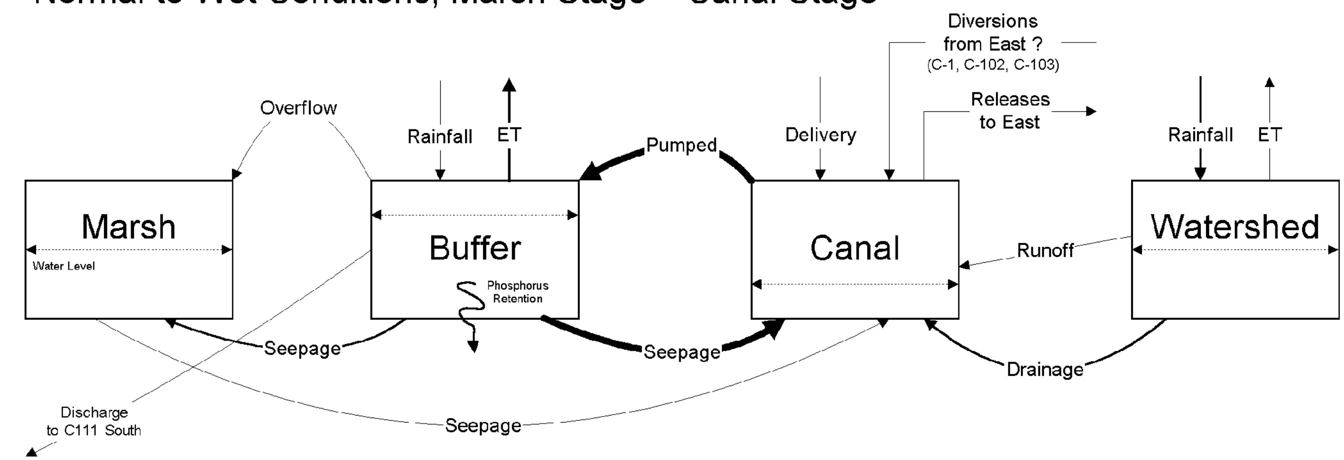


Dry Conditions, Marsh Stage < Canal Stage



Conceptual Model - Future Conditions

Normal to Wet Conditions, Marsh Stage > Canal Stage



Dry Conditions, Marsh Stage < Canal Stage

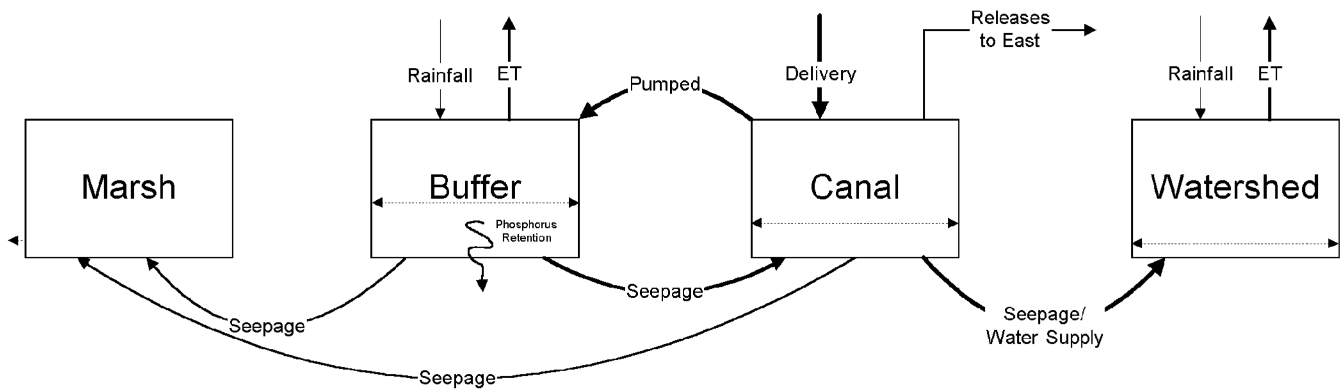
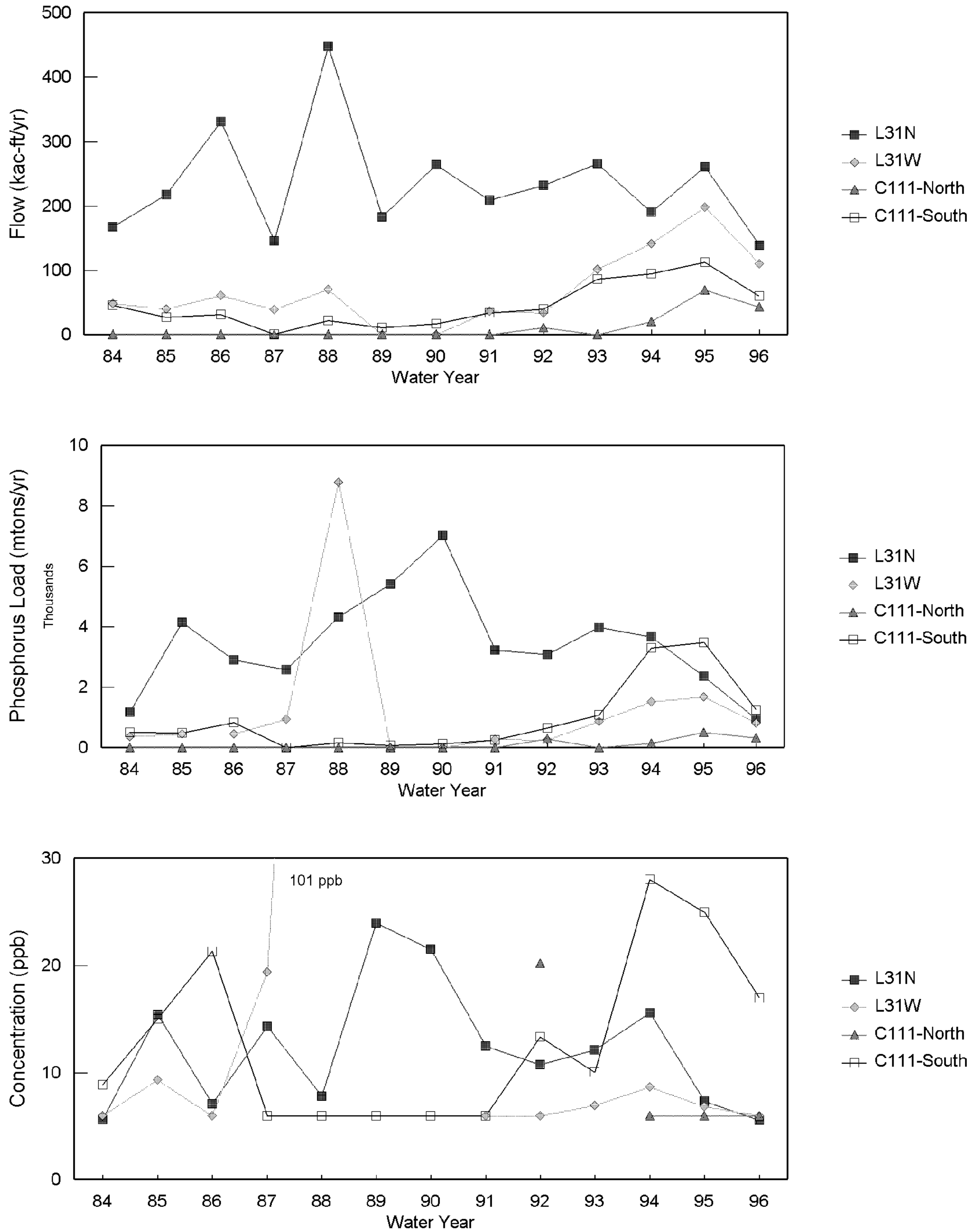


Figure 37

Yearly Flows & Phosphorus Loads to Each Canal Segment



Combined inflows attributed to seepage & runoff into each canal segment.

L31N = S174+S176 L31W = S332 + S175 - S174 C111-North = S177 - S176 C111-South = S18C - S177