A.R.M. Loxahatchee National Wildlife Refuge

Enhanced Water Quality Monitoring and Modeling Program – 3rd Annual Report

LOXA07-005

October 2007

Acknowledgments

The authors thank the following contributors, without whom this report would not have been possible: Bruce Arrington, A. Camille Darby, Rebekah Gibble, Angela Markovich, Serena Rinker, Robert Smith, and Tiffany Trent for water quality sample collection and sonde deployments and collections; SFWMD and Columbia Analytical Services for water chemistry analyses; and SFWMD for the use of DBHYDRO for data availability; Leslie MacGregor for GIS assistance; Paul Conrads, Rebekah Gibble, Guoqing He, Callie Oblinger, Dilip Shinde and Hongqing Wang for extensive review of earlier versions of this report; and finally, Refuge Manager Mark Musaus and Deputy Manager Rolf Olson for their continuing support and leadership throughout this project. Funds to conduct the expanded monitoring network at A.R.M. Loxahatchee NWR were provided by the U.S. Congress in P.L. 108-108, the Department of the Interior and Environment Appropriations Act of 2004.

This report should be cited as:

USFWS, 2007. A.R.M. Loxahatchee National Wildlife Refuge - Enhanced Water Quality Monitoring and Modeling Program – 3rd Annual Report – October 2007. LOXA07-005, U.S. Fish and Wildlife Service, Boynton Beach, FL. 116 pp.

Acronyms and Abbreviations

A_C	area of canal
ACME	Special Drainage District
acre-ft	acre-feet (volume reported as one acre in size by one foot in depth)
A_M	area of marsh
ATLSS	Across Trophic Level System Simulation
CERP	Comprehensive Everglades Restoration Plan
cfs	cubic feet per second
Cl	chloride
cm	centimeter
CMF	completely-mixed flow
DBHYDRO	SFWMD's web portal for water quality data
DCS	depth to consolidated substrate
DD	dry deposition
DMSTA	Dynamic Model of Stormwater Treatment Areas
E	evaporation
EAA	Everglades Agricultural Area
EDEN	Everglades Depth Estimation Network
EFA	Everglades Forever Act
ELM	Everglades Landscape Model
ET	evapotranspiration
EVPA	Federal Consent Decree compliance network for Refuge
ft	feet
G	groundwater recharge
G_C	groundwater loss in canal
G_M	groundwater loss in marsh
ha	hectare
HSI	Habitat Suitability Indices
I_H	high inflow
I_L	low inflow
I_{L-M}	low to moderate inflow
km	kilometer
L	liter
LOXA	Refuge's expanded water quality monitoring network
m	meter
mg	milligram
MIKE-FLOOD	coupled one and two-dimensional finite difference model
mm	millimeter
NAD	North American Datum
NGVD	National Geodetic Vertical Datum
NO_x	oxides of nitrogen (e.g., NO_2 and NO_3)
O_H	high outflow
O_L	low outflow
O_{L-M}	low to moderate outflow
P	precipitation

ppb	parts per billion (micrograms per liter)
Q	outflow
Q_{in}	volumetric flow into the canal
Q_{MC}	volumetric flow between the marsh and canal
Q_{out}	volumetric flow out of the canal
R	correlation coefficient
Refuge	A.R.M. Loxahatchee National Wildlife Refuge
RMSE	root mean square error
s	second
SFWMD	South Florida Water Management District
SO_4	sulfate
STA	Stormwater Treatment Area
T	transpiration
Tdepth	depth of clear water column
TN	total nitrogen
TP	total phosphorus
µg	microgram
µS	microSiemen (measure of conductivity)
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WASP	Water Quality Analysis Simulation Program
WCA	Water Conservation Area
XYZ	monitoring and research transect in southwest Refuge

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Executive Summary

Congress appropriated funds to the U.S. Fish and Wildlife Service in 2004 to develop an enhanced water quality monitoring network and hydrodynamic and water quality models to improve the scientific understanding of water quality in the Arthur R. Marshall Loxahatchee National Wildlife Refuge[1] (Refuge). The network and models provide information that will be used in management decisions to better protect Refuge resources. The enhanced water quality monitoring network complements the existing water quality compliance network created under the 1992 Federal Consent Decree (Case No. 88-1886-CIV-MORENO) by characterizing the water quality of a larger Refuge area, particularly the fringe area potentially impacted by canal water intrusions. The expanded monitoring network, initiated in June, 2004, consists of monthly grab samples collected at 39 canal and marsh stations, and continuous measurements of conductivity along seven transects, four of which extend from the canal near surface water discharge points into the interior. This report is the third annual report, and focuses primarily on the period from January 2006, through December 2006.

Although only a limited range of climatic and hydrological conditions has been experienced during this study, data collected document intrusion of rim canal water into the Refuge interior, adding to a growing information base about canal water impacts to the Refuge. Intrusion of nutrient-rich and high conductivity water from the canal has the potential to negatively impact Refuge plants and animals. Analyses of these data continue to support previously identified management practices that have the potential to minimize such intrusion.

Based on the water quality data, the Refuge was classified into four geographic zones: (1) Canal Zone; (2) Perimeter Zone, located from the canal to 2.5 km (1.6 miles) into the marsh; (3) Transition Zone, located from 2.5 km (1.6 miles) to 4.5 km (2.8 miles) into the marsh; and (4) Interior Zone, greater than 4.5 km (2.8 miles) into the marsh. Overall, water quality conditions in the Perimeter and Transition zones of the Refuge marsh were different from, and more impacted than, the Interior Zone. The Transition Zone had instances where canal water penetration may have functionally altered the Refuge ecosystem as supported by a previous study of cattail expansion measurements along a single transect across the Refuge.

This report continues to document previous findings that water movement between the canals and the marsh is influenced by the canal-marsh stage difference, structure-controlled water inflow and outflow into perimeter canals, marsh elevation, and rainfall. When inflows to Refuge canals were greater than outflows from Refuge canals, and when canal stages were greater than marsh stages, intrusion extended more than 1 km (0.6 miles) into the marsh interior. Even with a minimal difference between the canal and marsh stage and when marsh stage was greater than canal stage, canal water still intruded into the marsh interior. Additionally, this report documents a positive relationship between structure inflows and canal total phosphorus concentrations, reflecting both stormwater treatment area discharges and bypass inflows into the Refuge. When combined with our understanding of the influence of the canal water intrusion into the marsh, these data suggest an impact of high-nutrient water on the Refuge marsh.

[1] Public Law 108-108; see House Report No. 108-195, p. 39-41 (2004)

A simple water budget model was developed to predict canal compartment and marsh compartment volumes and stages. Statistical analyses demonstrate the applicability of this model to predict temporal variation of water levels in both the marsh and the Refuge perimeter canal. This model already is being used for examining regional water management scenarios. A more complex hydrodynamic model allows examination of Refuge hydrology at a scale of 400 m by 400 m (1,312 ft by 1,312 feet) – a much higher resolution than the 2-miles by 2-miles hydrodynamic model presently available for the Refuge. Water quality constituents are being incorporated into both models, allowing for both a better understanding of water movement within the marsh and understanding phosphorus levels in the water column. An independent model advisory review panel has provided valuable insights that have been incorporated into the modeling program. Finally, a series of management scenarios has been identified for application of these modeling tools.

Chapter 1. Introduction[2]

The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), located in Palm Beach County, Florida, includes approximately 58,300 ha (144,000 acres) of northern Everglades habitats (Figure 1). Approximately 57,085 ha (141,000 acres) of interior marsh is Water Conservation Area 1 (WCA-1), an impounded marsh established in the 1950s and 1960s for water supply, flood protection, and wildlife habitat. It is managed by the U.S. Fish and Wildlife Service (USFWS) under a License Agreement with the South Florida Water Management District (SFWMD). The Refuge once was part of the contiguous Everglades that extended from the Kissimmee Chain of Lakes south to Florida Bay. Now, the Refuge interior marsh is impounded and surrounded by agriculture to the north and west, and urban areas and agriculture to the east. Water Conservation Area 2 lies immediately to the south.

The Refuge was established in 1951 under the Migratory Bird Conservation Act of 1929 which states that the Refuge is "…for use as an inviolate sanctuary, or for any other management purposes, for migratory birds." (16 USC. 715d). The Refuge provides habitat for over 300 vertebrate species including the endangered snail kite and wood stork. A current goal of the Refuge is to restore and conserve the natural diversity, abundance and ecological function of Refuge flora and fauna.

Hydrologic inputs once came solely from direct rainfall and overland sheet flow. Today, the Refuge is isolated hydrologically by levees and canals, receives no sheet flow, and inflows now occur as rainfall and discharges into perimeter canals from water management structures (gates and pumps) (Figure 1-1). Water delivered through structures from runoff of adjacent agricultural and urban areas is treated, in part, by Stormwater Treatment Areas (STA-1W and STA-1E) designed to reduce phosphorus inputs. Untreated water enters from structures on the east side (ACME-1 and ACME-2), or as bypass (untreated) through the G-300 and G-301 at the north end (Figure 1-1). Water entering through structures and in canals has different characteristics than rainfall or water from natural wetlands and may flow into the marsh under certain canal stages or flow regimes. Hydrologic outflows through structures are for stage regulation and flood protection (S-10 structures and S-39 at the south), and water supply (G-94 structures and S-39 on the east). Evapotranspiration and seepage loss are other sources of water outputs from the Refuge. Location, amount, and timing of inflows and outflows may affect marsh water flow, depths, and nutrient and other ion concentrations.

Areas of pristine marsh throughout the Everglades have been impacted to various degrees by water with high nutrients and other constituents. Information from the Refuge and other wetlands indicates that increases in phosphorus and major ions cause undesirable ecological changes in flora and fauna. A large amount of research conducted by state, federal and private entities has demonstrated the impacts of small increases in total phosphorus concentrations (Richardson et al. 1990; Childers et al. 2003; McCormick and Crawford 2006). Changes in Everglades flora and fauna begin to occur at total phosphorus concentrations slightly higher than 10 $\mu g\ L^{-1}$ (10 ppb) (Payne and Weaver 2004). Recognition that increases in total phosphorus

[2] Prepared by Matthew C. Harwell, and Nicholas G. Aumen

concentrations have caused changes in Everglades communities led to the establishment of legal mandates including a Federal Consent Decree in 1992 that established phosphorus levels and a compliance methodology for the Refuge. Interim levels for the Refuge have been in effect since February 1999 and long-term levels took effect December 31, 2006. In 1994, Florida's Everglades Forever Act (EFA) was passed which led to the establishment of a numeric criterion for total phosphorus.

The Everglades, including the Refuge, developed as a rainfall-driven system with surface waters low in nutrients and inorganic ions such as chloride, sodium, and calcium. Conductivity was, therefore, naturally low. Conductivity is a field measurement that provides a good surrogate for concentrations of major ions compared to the naturally low conductivity Refuge marsh interior. In addition to elevated phosphorus concentration, canal water has high conductivity. Although there is no appropriate state water quality numerical criterion for conductivity for the northern Everglades, there are concerns that increases in canal water intrusion into the Refuge interior marsh may cause negative ecological consequences because canal water is high in conductivity as well as nutrients.

The highest soil elevation in the Refuge interior is approximately 5.6 m (18.5 ft), and the lowest interior elevation is roughly 3.2 m (10.6 ft) (1929 NGVD unless expressed otherwise). The Refuge interior exhibits a general slope in elevation from north to south, with typical wet prairie or slough elevations as high as 5.0 m (16.3 ft) in the north, and as low as 3.9 m (12.5 ft) in the south. Average interior marsh soil surface elevation is approximately 4.6 m (15.0 ft). Historically, water flowed generally from north to south following the natural elevation gradient. Impoundment of the area has altered flow magnitude and direction. Water discharged into the Refuge perimeter canals now either stays in the canals and eventually passes out through discharge structures on the east or south or flows in and out of the marsh from the east and west.

Water levels are managed by the U.S. Army Corps of Engineers (USACE) and SFWMD under a Water Regulation Schedule. The current schedule (Figure 1-2) has an upper level of 5.3 m (17.5 ft) and a floor of 4.3 m (14 ft). Under this schedule, outflows are determined based on stage and the need for water supply and flood protection.

The marsh is a mosaic of habitats including slough, wet prairie, sawgrass, brush, tree islands, and cattail. Community location and type is determined by elevation, hydrology, and soil and water quality. Hydroperiods near canals in the central and north part of the marsh are shorter than in the center and southern marsh. In general, water depths are shallower in the north and deeper in the south. Hydroperiod and water depth are key factors in determining vegetation patterns in the marsh. Conditions that are drier result in predominance of brush or sawgrass. Areas that are wetter are characterized by slough or open water.

To protect Refuge resources, resource managers must be able to identify potential threats to Refuge resources, keep unimpacted areas from becoming impacted, and maximize the potential for the recovery of impacted areas. Hydrology and water quality information is critical for making management decisions to meet the multiple purposes of the Refuge and for overall Everglades restoration. In 2004, as a result of this recognition, Congress appropriated funds specifically to the Refuge for development of an enhanced water quality monitoring network and hydrodynamic and water quality models. The appropriation was intended to improve the scientific understanding of water quality issues in the Refuge and to provide information for better water management decisions to protect Refuge resources.

A work plan was developed (Brandt et al. 2004) outlining studies to provide scientifically supported management recommendations. The original list of questions is below – these have subsequently been refined since this program was initiated:

- What are the water quality characteristics in the fringe marsh adjacent to inflows?
- Under what operational or environmental conditions does canal water flow (intrude) into the marsh and how far does it intrude?
- How does relative flow through different structures affect water flow and water quality within the interior marsh?
- If there are potential negative impacts of pump, structure, or STA operations, how can they be minimized/eliminated?
- What impacts of STA-1E on Refuge water quality and ecological resources are projected?
- When canal stages are below typical interior marsh elevation, what are the impacts of water supply releases on interior surface water and groundwater conditions?
- When water supply releases from the eastern Refuge boundary are made-up by water deliveries, what is the optimal pattern of structure operations? Should we continue to require that all make-up water first be provided prior to water supply releases?
- What factors contribute to water column phosphorus values that are above the limits established in the Consent Decree?
- What can be done to eliminate exceedances to the interim and long-term levels of the Consent Decree?
- What hydroperiods and depths will occur in the marsh under different operational and water management conditions?

Three areas of study were developed to provide information to address the above questions:

1. additional monthly water quality sampling sites;
2. continually monitored conductivity transects to provide a better understanding of how and when water from the canals moves into the interior marsh; and
3. application of hydrodynamic and water quality modeling to the Refuge.

The original extent of the project was two years. However, additional funds have allowed for the continuation of the projects for an additional two years. This report is the third annual report and includes data collected and analyzed from January 2004 through December 2006, building upon information presented in the first and second annual reports (Harwell et al. 2005; USFWS 2007). This report is intended to provide a better understanding of the hydrological and water quality conditions of the Refuge. The intended audience for this report are those interested in tracking the implementation of the project, those interested in the technical details of the work, and resource managers who can use the information as support for future management decisions. Other information about this program can be found at http://sofia.usgs.gov/lox_monitor_model/.

The report is organized into five chapters. Chapter 1 (this chapter) provides background and a summary of overall project implementation written for a general audience. Chapter 2 presents a descriptive summary of surface water quality in the Refuge. Chapter 3 presents analyses of canal water intrusion into the Refuge interior utilizing data from conductivity sondes. Chapter 4 presents an update on the hydrodynamic and water quality modeling efforts. Chapter 5 provides a summary of the management implications of the technical chapters and discusses unanswered questions and future monitoring and research needs.

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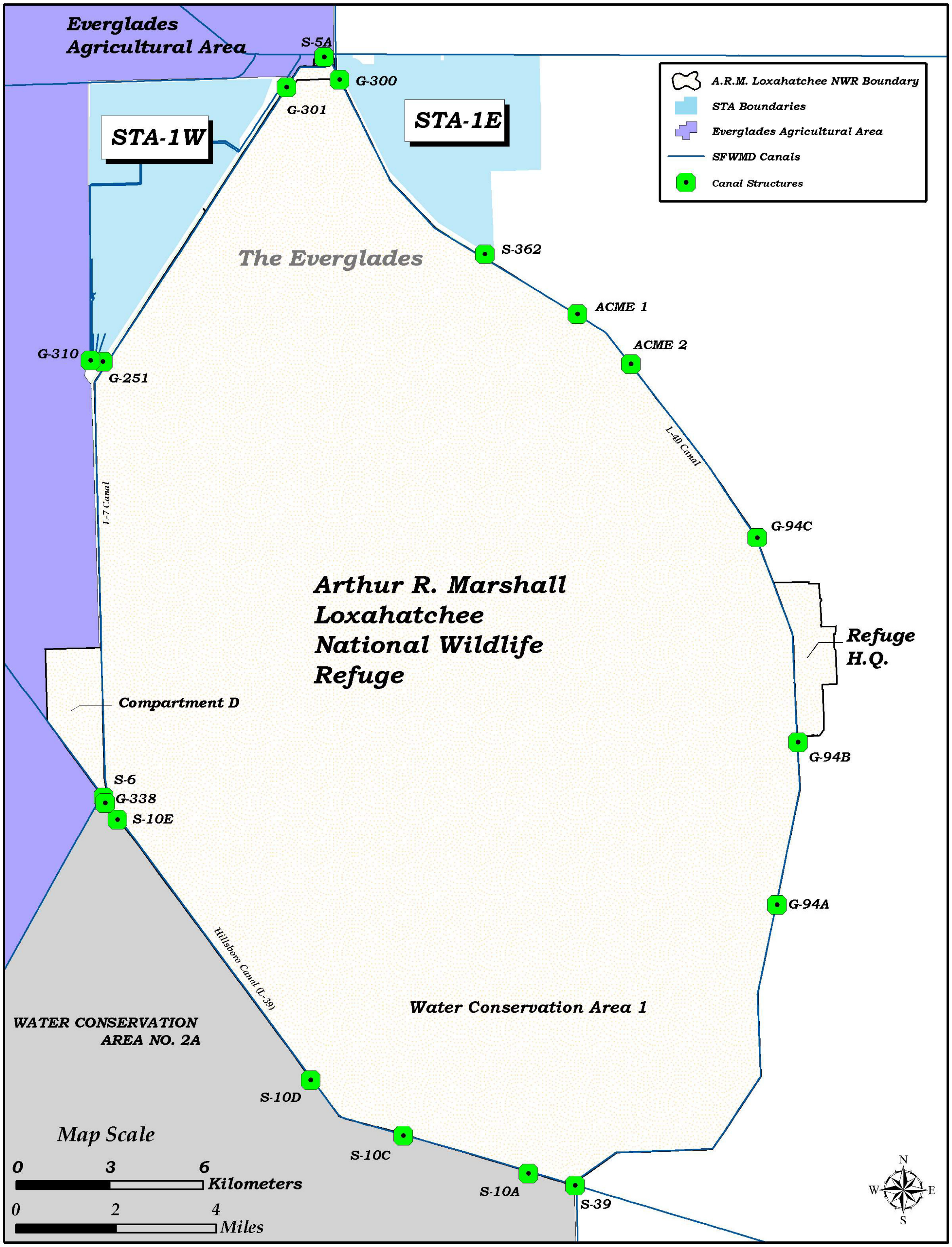
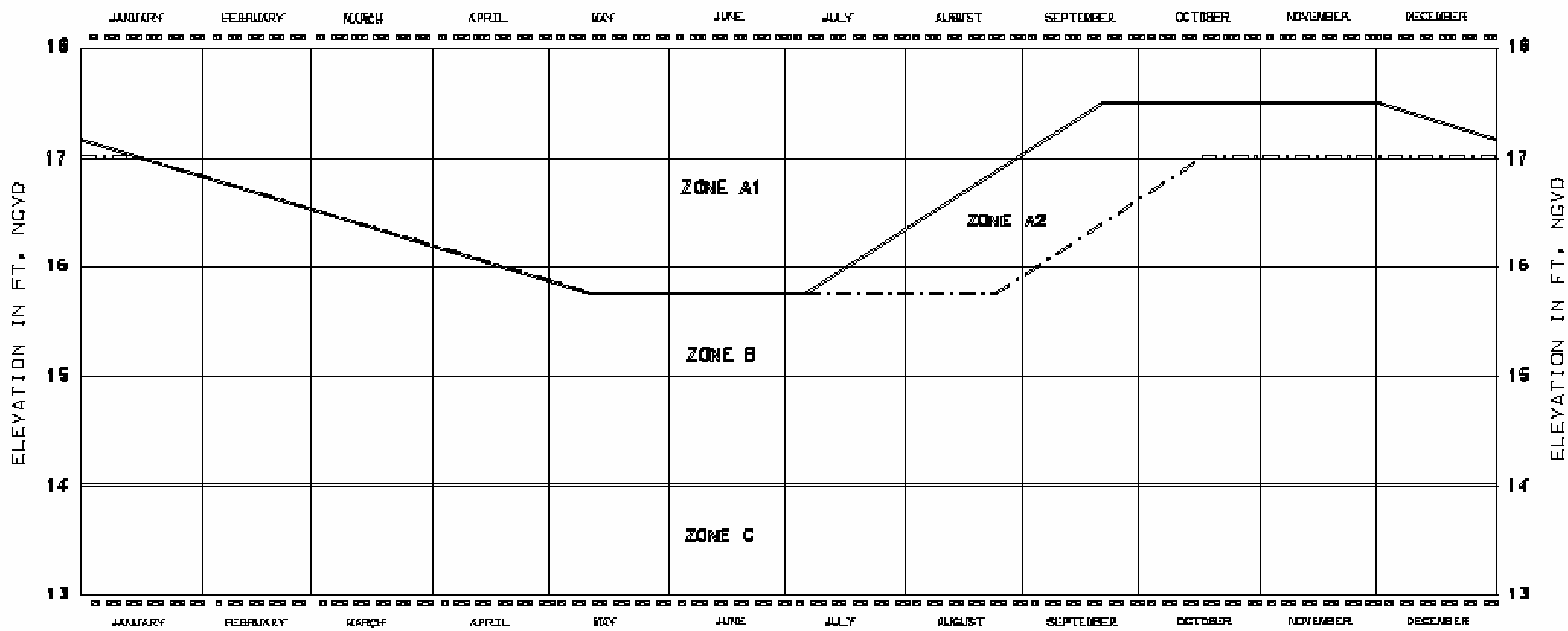


Figure 1-1. The Arthur R. Marshall Loxahatchee National Wildlife Refuge.



ZONE	RELEASES
A1	UP TO MAXIMUM AT S-10 (AND S-39 WHEN AGREED BETWEEN CORPS AND SFWMD). WATER SUPPLY RELEASES AS NEEDED.
A2	S-10 RELEASES BASED ON CORPS FORECASTS. WATER SUPPLY RELEASES AS NEEDED. IF LAKE OKEECHOBEE STAGE IS ABOVE WCA-1 STAGE OR NO MORE THAN ONE FOOT BELOW WCA-1 STAGE, THEN WATER SUPPLY RELEASES FROM WCA-1 MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW.
B	WATER SUPPLY AS NEEDED. IF LAKE OKEECHOBEE STAGE IS ABOVE WCA-1 STAGE OR NO MORE THAN ONE FOOT BELOW WCA-1 STAGE, THEN WATER SUPPLY RELEASES FROM WCA-1 MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW.
C	NO NET RELEASES FROM WCA-1. ANY WATER SUPPLY RELEASES MUST BE PRECEEDED BY AN EQUIVALENT VOLUME OF INFLOW.

DATES	USE GAGE	CONDITIONS
1 JAN - 30 JUN	1-8 CANAL	ALL
1 JUL - 31 DEC	1-8 CANAL	EXCEPT AS NOTED BELOW
	AVG. 1-7, 1-8T, 1-9	DURING RISING STAGES WHEN CANAL STAGE EXCEEDS AVERAGE.

CENTRAL AND SOUTHERN FLORIDA
INTERIM REGULATION SCHEDULE
WATER CONSERVATION AREA NO. 1
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA
DATED: 03 MAY 1995

Figure 1-2. Water regulation schedule for the Arthur R. Marshall Loxahatchee National Wildlife Refuge. For more information see: USFWS, 2000. Arthur R. Marshall Loxahatchee National Wildlife Refuge Comprehensive Conservation Plan. available at http://loxahatchee.fws.gov, U.S. Fish and Wildlife Service, Boynton Beach, Florida.

Chapter 2. Water Quality in the A.R.M. Loxahatchee National Wildlife Refuge: 2004-2006[3]

Abstract

The Everglades, including the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), developed as a rainfall-driven system with surface waters low in nutrients including total phosphorus and total nitrogen, and inorganic ions such as chloride, sodium, and calcium. There are concerns that increases in nutrient- and ion-enriched canal water intrusion into the Refuge interior may have negative ecological consequences (i.e., altered periphyton communities; displacement of sawgrass with cattails; sawgrass expansion into slough-wet prairies; impaired growth of yellow-eyed grass; etc.) because canal water is higher in nutrients and other ionic constituents. Changes in Everglades flora and fauna occur at total phosphorus (TP) concentrations above Florida's numerical phosphorus criterion of 10 $\mu g\ L^{-1}$. In addition to elevated TP concentrations, canal water has high conductivity compared to the marsh interior of the Refuge as a result of mineral enrichment from agricultural and urban runoff. Short pulses of high conductivity canal water into the Refuge interior have been shown to adversely impact Refuge vegetative species in laboratory studies. This report is an update to the 2007 report on water quality in the Refuge, which covered the period from January 2004 through December 2005.

During the period from January through December 2006, input volumes, rainfall and canal inflows, were slightly lower (7%) than in 2005, and both years were much lower (18%) than in 2004. This pattern suggests a decrease in inputs to the Refuge with the larger decrease in inflows. Inflows were 50% of the input volume in 2004 and 35% of the input volume in 2005. Although canal waters were clearly impacting the Perimeter and Transition Zone in 2006, the variability in water quality parameters in these zones and the Interior Zone was lower than observed in 2004 and 2005. Average TP concentrations across the Refuge were equal to or below 10 $\mu g\ L^{-1}$ in 2006, which were lower than 2004 and 2005 average concentrations. The major ions analyzed in 2006 across the marsh had levels similar to those observed in 2004 and 2005.

Lower Refuge TP concentrations in 2006, relative to 2005 and 2004, were associated with the reduced occurrence of TP flow-weighted mean spikes greater than 100 $\mu g\ L^{-1}$ and the reduced occurrence of canal inflow rates greater than 1,000 cfs in 2006. Drought and management decisions in 2006 have decreased marsh stages for more extensive periods of time relative to 2004, with conditions drying areas of the northern Refuge in 2006. Because dry conditions create the potential for further habitat degradation through the introduction and spread of woody vegetation and exotics and increased threat of fire, further investigation into the impacts of reduced water quantity needs to be pursued.

[3] Prepared by: Donatto D. Surratt, Matthew C. Harwell, James A. Entry, Nicholas G. Aumen

Background

Prior to June 2004, water quality in the Refuge interior was monitored primarily using the 1992 Federal Consent Decree (Case No. 88-1886-CIV-MORENO) compliance network (EVPA). These 14 stations (Figure 2-1), monitored since 1978, characterize the central region of the interior marsh, leaving a relatively large region uncharacterized, predominantly in the outer, impacted fringe of the wetland.

In June 2004, the Refuge began the establishment of an enhanced water quality monitoring network (LOXA) intended to improve the scientific understanding of water movement in and out of the Refuge, water quality in the marsh, and to provide information that can be incorporated into water management decisions to better protect Refuge resources (Brandt et al. 2004). The enhanced monthly sampling focuses on areas near surface water discharge sites and areas uncharacterized by the EVPA network (Figure 2-1).

The objective of this chapter is to provide a general descriptive summary of environmental conditions, including select water quality parameters, in the Refuge from January through December 2006 (2006) following the approaches presented in 2007 annual report (USFWS 2007). Further, we compare results in 2006 to results from the previous water quality report covering the period from January 2004 through December 2005. Thus this chapter serves as an update to the 2006 annual report (USFWS 2007). This chapter presents the following: characterization of water quality and related environmental parameters in the canal, perimeter, transition, and interior regions of the Refuge marsh; and characterization of external environmental conditions, including canal water stage, water movement in perimeter canals, rainfall, and evapotranspiration.

Methods

Surface water grab samples were collected monthly as part of two monitoring networks (EVPA and LOXA) encompassing a total of 48 marsh stations, and 5 stations in the perimeter canals. Water quality laboratory analysis was performed by the South Florida Water Management District (SFWMD) from January 2004 through May 2006, and by Columbia Analytical Services from June 2006 through December 2006.

Twenty-nine parameters were analyzed for samples collected when depth of clear water column (Tdepth) was greater than 20 cm (0.66 ft) in depth (Table 2-1). To reduce sediment entrainment into the water column during sampling of water with depths less than 20 cm, smaller sampling bottles are used for sample collections. Only total phosphorus (TP), chloride (Cl), and sulfate (SO_4) are analyzed from smaller volumes collected when Tdepth was between 10 and 20 cm (0.33-0.66 ft). When reported concentrations were below minimum detection limits, a value of one-half of the minimum detection limit was applied in data analyses (Weaver and Payne 2006).

Stage, flow, rainfall, wet deposition chemistry, and evapotranspiration (ET) data were downloaded from the SFWMD data web portal, DBHYDRO (http://www.sfwmd.gov/org/ema/dbhydro/). Data from the USGS 1-7 stage gage (Figure 2-1) were used as estimates of marsh stage values; canal stage data from the headwater gage of the G-94C outflow spillway structure (Figure 2-1) were used because the 1-8C canal gage had periods of missing data. Refuge inflow and outflow were aggregated as the total daily average flow. Inflow records for ACME-1, ACME-2, G-310, G-251, S-362, G-300 and G-301 were used for daily average inflow into the canals; outflow records at G-300, G-301, G-94A, G-94B, G-94C, S-10A, S-10C, S-10D and S-39 were used for daily average outflow out of the canals (Figure 2-1). Daily rainfall data were averaged from the G-300, S-6, S-39 and S-5A weather stations (Figure 2-1). Rainfall volumes were computed using a Refuge marsh area of 150,000 acres. Wet deposition of TP, TN, Cl and SO_4 was estimated (median values) from the ENRWET site located in Stormwater Treatment Area (STA) 1W, northwest of the Refuge. Evapotranspiration (ET) was calculated at the ENRWET site using a calibrated model dependent on solar radiation and latent heat of water vaporization (Abtew et al. 2004). Seepage was not considered here.

Marsh water quality was characterized using monthly values for TP, TN, conductivity, Cl, SO_4, Tdepth and depth to consolidated substrate (DCS) following the methods presented in USFWS (2007). The geometric mean of TP concentrations for the entire marsh network (all 53 stations) also was summarized (Appendix 2-1). Gaps in data for any parameter were treated as missing data.

The Refuge interior was classified into several geographic zones based upon conductivity data variability and changes in median conductivity as a function of distance from the perimeter canal as presented in USFWS (2007). For the analyses presented here, the following zones were identified:

- Canal: sites located in the canal
- Perimeter: sites located from the canal to 2.5 km (1.6 miles) into the marsh
- Transition: sites located from 2.5 km to 4.5 km (1.6 to 2.8 miles) into the marsh
- Interior: sites located greater than 4.5 km (2.8 miles) into the marsh

Results and Discussion

Water Quality Summary Statistics

Depth of clear water column: In 2006, depth of clear water column (Tdepth) varied over time, with generally similar relationships among zones (Figure 2-2a). Unlike in 2005 and 2004, Tdepth in the Interior Zone was higher than in the Transition Zone for most of the year, but lower than in the Perimeter Zone (Table 2-2). The Tdepth variability in all zones observed through 2006 was similar to 2005.

Depth to consolidated substrate: Depth to consolidated substrate (DCS) is a measure of the total water column (clear water and any bottom floc layer). As with Tdepth, DCS varied over time, with similar relationships among zones (Figure 2-2b). In general, Perimeter Zone DCS was higher than the other zones, except the highly unusual event in May 2006, when DCS was 26 inches in the Interior Zone. The May 2006 period was characterized with low flow (inflow/outflow) rates and marsh stages much greater than canal stage. Rainfall spiked in mid-May 2006 to 1.9 inches for two days, and marsh stage increased by 0.26 ft during this time. The rationale for this rapid increase in marsh stage is not obvious based on the environmental data, but changes in the DCS zone relationship were not isolated to 2006. Interior Zone DCS was higher than Transition Zone DCS in December 2004 and January 2005 and again in June and July 2005. Further, Transition Zone DCS was higher than Perimeter Zone DCS in August 2004, March 2005 and 2006. None of the reported environmental conditions consistently explain these changes in DCS zone relationship and further investigation is required.

TP: Average monthly flow-weighted mean TP concentrations entering the Refuge from STA-1W (G-310 and G-251) was 106 ± 29 $\mu g\ L^{-1}$ (mean ± 1 standard deviation, unless other wise specified); this is similar to 2005 (Figure 2-3), but higher than in 2004 (60 ± 47 $\mu g\ L^{-1}$ TP). STA-1W flow-weighted mean TP concentrations were greater than average 2006 flow-weighted mean TP concentrations in February 2006, late June through July 2006, and again from September through October 2006, corresponding to inflow events that exceeded 2,000 cfs. In general, the flow-weighted mean concentrations from STA-1E followed a similar, but lower pattern when compared with concentrations from STA-1W. However, STA-1E (S-362) flow-weighted mean TP discharges in January and February 2006 were higher than values observed from STA-1W. In 2006, discharges from the G-300 and G-301 occurred less frequently, but were higher in magnitude than in 2005 and 2004. Flow-weighted mean TP concentrations from the G-300 and G-301 in February 2006 were around 300 $\mu g\ L^{-1}$ (Figure 2-3).

In general, TP concentration at the canal sites reflected STA discharges in 2006. The patterns of TP concentrations in the Canal Zone were on average lower than STA-1W flow-weighted mean TP concentrations, but higher than concentrations from STA-1E. Perimeter and Transition Zones followed the same pattern of increases and decreases in TP levels as the Canal Zone after May 2006, but had lower variability prior to May. Perimeter Zone TP levels (11 ± 3 $\mu g\ L^{-1}$; mean ± 1 standard deviation) were, generally, higher than levels in the Transition (8 ± 2 $\mu g\ L^{-1}$) and Interior (9 ± 3 $\mu g\ L^{-1}$) Zones through 2006, unlike in 2005 when there were periods that the Transition and Interior Zones TP concentrations were higher than TP in the Perimeter Zone (Figure 2-3; Table 2-2).

Throughout the marsh zones in 2006, July was the only month with geometric mean TP concentrations above 10 $\mu g\ L^{-1}$, a numerical criterion concentration above which negative impacts to marsh vegetation communities occur (Payne and Weaver 2004). The low frequency of TP increasing above 10 $\mu g\ L^{-1}$ in 2006 was not consistent with previous years, when TP geometric mean frequently were above 10 $\mu g\ L^{-1}$.

TN: Total nitrogen (TN) is the sum of total Kjeldahl nitrogen (organic nitrogen plus free ammonia) and oxidized nitrogen (NO_2 and NO_3). In 2006, TN levels (Figure 2-4a) in the canals and the marsh never exceeded 2.2 mg L^{-1} and had reduced variability (20 to 35% coefficient of variation unless other wised specified) when compared to 2005. In 2005, TN increased to greater than 8 mg L^{-1} in the Canal and Interior Zones, and the TN variability (45%) for the year was higher than 2006. In general, TN levels in the Perimeter and Interior Zones were higher than Transition Zone levels through 2006, similar to previous years (Table 2-2).

Conductivity: Conductivity variability was highest in the Canal, followed by the Perimeter Zone. The Transition and Interior Zones had the lowest variability (Figure 2-4b). There was a clear delineation in conductivity between the Canal (901 ± 125 μS cm^{-1}; mean ± 1 standard deviation), Perimeter (386 ± 58 μS cm^{-1}), and Transition (182 ± 48 μS cm^{-1}) Zones in 2006 (Figure 2-4b; Table 2-2). There also was a significant difference (Mann Whitney U; $p < 0.001$) between the Transition and Interior (149 ± 43 μS cm^{-1}) Zones. Conductivity levels in 2006 in all zones were similar to 2005, but lower than 2004 conductivity levels in the marsh zones (Appendix 2-2). In May and June 2006, conductivity levels across the three marsh zones were very similar, with elevated levels in the Interior and Transition Zones and decreased levels in the Perimeter Zone unlike previous periods. The elevated conductivity levels in the Interior and Transition Zones may just be an artifact of the small Interior and Transition Zone sample size during these two months ($n = 3$ in May; $n = 3$ in June of 18 sites) or mixing of Perimeter and Interior Zones.

Cl: The patterns of Cl concentrations (Figure 2-4c) were similar to the conductivity patterns. There was a clear difference in Cl between the Canal (123 ± 20 mg L^{-1}), Perimeter (57 ± 10 mg L^{-1}), and Transition (30 ± 7 mg L^{-1}) Zones in 2006; however there was no clear difference between the Transition and Interior (30 ± 10 mg L^{-1}) Zones. Average Cl concentrations in 2006 were similar to concentrations in 2005 and 2004 (Table 2-2). In 2006, similar to conductivity, variability was lowest in the Canal and the Perimeter Zones and highest in the Transition and Interior Zones.

SO_4: There were clear differences among SO_4 concentrations in the Canal (47 ± 14 mg L^{-1}; mean ± 1 standard deviation), Perimeter (8 ± 6 mg L^{-1}), and Transition (1.0 ± 0.9 mg L^{-1}) Zones (Table 2-2). The 2006 SO_4 pattern in the Perimeter Zone followed the Canal Zone SO_4 pattern (Figure 2-4d). Transition and Interior Zone SO_4 concentrations were uniformly low.

Descriptive statistics tables for all the water quality parameters analyzed for the Refuge's LOXA and EVPA monitoring sites (2004 - 2006) are presented in Appendix 2-1.

Atmospheric Deposition Chemistry

Median TP wet deposition concentration (Table 2-3) in 2006 (3 μg L^{-1}) was dramatically lower than concentrations in 2005 and 2004. Median TN wet deposition concentration in

2006 (0.3 mg L^{-1}) was similar to 2005 and 2004 levels (Table 2-3). Median Cl wet deposition concentration in 2006 (0.6 mg L^{-1}) was similar to 2005 and 2004 (Table 2-3). Median SO_4 wet deposition concentration in 2006 (0.6 mg L^{-1}) was similar to levels in 2005 and 2004 (Table 2-3).

Marsh and Canal Stages

Average 2006 canal stage was 16.3 ft with a range of 14.6 to 17.3 ft; this average was slightly higher than both 2005 (16.2 ft) and 2004 (15.9 ft) averages (Figure 2-5). The canal stage was higher than the marsh stage for the majority of 2006 (58%), unlike in 2005 and 2004, when the marsh stage exceeded the canal stage for the majority of the year. Canal stage was greater than 17 ft for 9% of 2006; most of this time was in September after large and continued rainfalls began in July 2006. The occurrence of canal stages greater than 17 ft was less extensive in 2005 (3%) and 2004 (3%). Consequences of these elevated September 2006 canal stages are explored further in Chapter 3.

Average stage in the marsh was 16.3 ft with a range of 15.6 to 17.1 ft and the average was similar to 2005 (16.3 ft) and 2004 (16.4 ft) averages (Figure 2-5). Variability in the marsh stages in 2006 was similar to 2005, but lower than 2004. Maximum (17.1 ft) and minimum (15.6 ft) marsh stages in 2006 were similar to 2005 and 2004 maximum and minimum marsh stages. Canal stages were greater than marsh stages for a longer continuous period (4 months) from mid-July through late October 2006, when, as in both 2005 and 2004, canal stages exceeded marsh stage no more than three months continuously. Marsh stages were below 16.5 ft for more than 70% of the year, which suggests that most of the marsh in the north was dry in 2006. The percent of water stages below 16.5 ft in 2006 was greater than 2004 (54%), but slightly less than in 2005 (78%). Extended dry periods have been documented to have negative impacts the marsh of the Refuge. The most obvious impact is a shift from submerged vegetation to shrubby vegetation (Richardson et al. 1990). Further, the increase in marsh dry downs increase the threat of exotic and invasive vegetation spread (USFWS 2000).

2006 Inflow and Outflow Management Changes

In 2006, STA-1E discharged into Refuge canals more frequently (43% of days in 2006) than in 2005 (33%) and 2004 (5%) (Figure 1-6a, b). The increase in STA-1E discharges was, in part, to reduce hydraulic loads on STA-1W, which was partially off-line for much of the year for regrowth, maintenance, repair, and construction (Pietro et al. 2007). Inflow volumes through STA-1E increased by approximately 20% in 2006 relative to 2005 inflows, while inflows through STA-1W decreased by 20%. Increased inflows on the east side of the Refuge resulted in increased distance of canal water intrusion into the marsh on the east side, while the decrease in inflows on the west side resulted in a decrease in canal water intrusion distance on the west side of the Refuge (Chapter 3).

In 2006, the G-301 bypass structure, which bypasses untreated water around STA-1E (Figure 2-1) and thus serves as another source of inflows to the Refuge, was operated mostly for outflow purposes (Figure 2-6d). The frequency of outflows through G-301 (26% of days in 2006) was 2.5 and five times greater than in 2004 and 2005, respectively. Outflow volume through the G-301 was approximately 30,000 acre-ft in 2006, which was eight times greater than outflow volume through the G-301 in 2005, but similar to G-301 2004 outflow volumes. The result of this change reduced the distance of intrusion on the east side of the Refuge, particularly when elevated conductivity levels (approximately 500 $\mu S\ cm^{-1}$ or more) were observed approximately 2 km or more into the marsh (see Chapter 3).

Total inflow in 2006 was slightly lower (5%) than inflow in 2005. Although outflow increased through G-301, 2006 total outflow was less than 50% of 2005 outflows.

Net Flow in Canals

Net flow (Figure 2-7) is defined as inflow minus outflow. Inflow structures are located in the northern region of the Refuge, and the outflow structures are primarily located in the southern and eastern regions (Figure 2-1). Positive net flow reflects higher inflow to the canals relative to outflow from the canals. Average net flows in 2006 were positive at 187 cfs with a range of daily average flows from -500 to 3,083 cfs (Figure 2-7). The average net flow in 2006 was greater than in 2005 (23 cfs) and 2004 (84 cfs) (Figure 2-7). In 2006, average inflow to the perimeter canals was 385 cfs with a range of daily average flows from 0 to 3,532 cfs. Average inflow in 2006 was similar to 2005, but inflows through 2005 and 2006 were almost half the rates in 2004. More than 17% of the 2006 inflow events were greater than 500 cfs (defined as high inflow rates; Chapter 3), which was lower than the 26% observed in 2005 and comparable to 15% observed in 2004.

In 2006, net flows were largest in early February, late July through early August, and again from late August through early October 2006 (Figure 2-7). Net flows were lowest (most negative) shortly after these high positive events, particularly in late February through early April and again in early October 2006 (Figure 2-7). Each of the high net flow events were preceded by rainfall events that were greater than 1.5 inches for a few days.

Rainfall

The rainfall pattern in 2006 was similar to the historic average, with heavy frequent rainfalls occurring from May through October and low infrequent rainfalls occurring from January through May (Figure 2-8). Average monthly rainfall in 2006 was 3.6 inches with a range of 0.3 inches in January to 7.0 inches in July (Figure 2-8). Average monthly rainfall in 2006 was similar to the 2004 average (3.5 inches), but lower than the 2005 average (4.0 inches). Cumulative rainfall for 2006 was 43.7 inches, similar to 2004, but slightly lower than 2005 (48.4 inches). Drought conditions within the drainage basin in areas north of the Refuge began in late-October 2005 and increased in severity through 2006 (NDMC 2007). These drought conditions affected the relationship between Refuge rainfall and Refuge canal inflows in 2006 likely because the drought conditions in these northern areas reduced discharge to the Refuge.

Evapotranspiration

Evapotranspiration in South Florida is driven primarily by solar radiation, while vegetation type, wind speed, atmospheric pressure, temperature, and humidity play smaller roles (Abtew et al. 2006). Average monthly ET in 2006 was 4.5 inches with a range of 2.6 inches in December to 5.9 inches in May (Figure 2-9). Cumulative ET for 2006 was 53.5 inches and was slightly higher than ET in 2005 (50 inches) and 2004 (52 inches).

Overall Hydrologic Inputs and Outputs

Hydrologic inputs are defined as the sum of canal water inflows and rainfall (Figure 2-10). Hydrologic outputs are defined as the sum of canal outflows and ET:

Rainfall total monthly volumes ranged from 4,250 acre-ft in January 2006 to 87,750 acre-ft in July 2006. The greatest rainfall occurred between June and September 2006 similar to the two previous years and the rainfall monthly volumes were around 80,000 acre-ft. The lowest rainfall monthly volumes occurred between January and April and again in October and November 2006. Total rainfall volumes during these months were lower than 30,000 acre-ft.

Total monthly *canal inflow* volumes were greatest between July and September 2006 with volumes ranging 60,000 to 75,000 acre-ft. These higher inflow volumes began one month after the increased rainfall events in June 2006. The lowest inflow occurred between January and June 2006 and again between October and December 2006, regardless of the period of higher inflows. The inflows during the periods were generally lower than 30,000 acre-ft, except in February when they were 37,000 acre-ft.

Total monthly *ET* volumes were less variable than inflows and rainfall volumes. Monthly ET lows were all greater than 30,000 acre-ft, unlike rainfall and inflows. The range of total monthly ET volumes was 32,000 to 74,000 acre-ft and was lowest in December 2006 and the December of the two previous years.

Total monthly *outflow volumes* ranged from 900 to 30,000 acre-ft, which is generally the range of the lows for the inflows and rainfall, but much lower than monthly total ET volumes. Outflows were highest in August and September 2006, following the higher inflows initiated in July 2006. Outflow total volumes during these months ranged from 21,000 acre-ft in August to 30,000 acre-ft in September 2006.

In 2006, total inputs were 851,996 acre-ft and total outputs were 786,225 acre-ft (Figure 2-10). The 2006 values were lower than in 2005 (input 911,642 acre-ft; output 856,258 acre-ft) and 2004 (input 1,036,735 acre-ft; output 1,092,126 acre-ft). The condition of lower total input in 2006 is associated with lower TP levels and lower variability in the other water quality parameters observed through 2006. The lower TP concentrations and water constituent variability occurred in 2006, even though net inputs were similar between 2006 and 2005 and net inputs for both years were much higher than net input in 2004.

From January through May 2006, and again in October and November 2006, outputs were greater than inputs, with ET having the highest volumes (Figure 2-10). Input volumes were higher than output volumes from June through September 2006 and rainfall had the highest volumes during these periods.

In general, the temporal pattern of high and low inputs and outputs in 2006 was similar to 2005 and 2004 patterns; however, the maximum monthly volumes of total input were much lower than maximums observed in the previous two years (Figure 2-10). Through most of the year, total monthly rainfall was higher than total monthly canal inflows (Figure 2-10). Total monthly inflows were higher than rainfall volumes between August and October 2004; however, this shift in input contribution was not observed in 2005 and 2006 (Figure 2-10). Further, total monthly ET was higher than total monthly canal outflows through 2006, unlike in 2004 and 2005, when canal outflows were greater than ET in one to two months. (Figure 2-10). The lack of canal inflow volume exceeding rainfall and the lack of canal outflow volume exceeding ET provides further indication that less water was delivered to the Refuge in 2006, relative to 2004 and 2005.

Summary

This chapter describes the 2006 environmental and water quality monitoring data for the Refuge, and compares them to results from 2005 and 2004. In 2005 and 2004, we demonstrated that the approach of classifying the Refuge into zones (Canal, Perimeter, Transition, and Interior) was useful in identifying marsh response to impacts from canal water penetration. In 2005 and 2004, we determined that water quality in the Perimeter and Transition Zones were different and more impacted than in the Interior Zone. These findings in 2005 and 2004 were also observed in 2006, when there again was a clear difference in most of the water quality parameters between the Perimeter and Transition Zones. However, unlike 2004 and 2005, 2006 TP concentrations in the Transition Zone decreased below levels in the Interior Zone. Identifying the specific mechanism for these zone shifts may be challenging with monthly grab data and further investigation of these zone shifts is necessary.

Because TP concentrations greater than 10 $\mu g\ L^{-1}$ alter the ecology of the Refuge, it is important to understand the degree of canal water impact on the Refuge water quality. In the marsh, TP was observed above 10 $\mu g\ L^{-1}$ in only a few months in 2006, and only in the Perimeter Zone. This observation differed from 2005 and 2004, when geometric mean TP was observed above 10 $\mu g\ L^{-1}$ several times in each year. It is clear that water quality in the Perimeter Zone was more impacted by canal water intrusion in 2006, than either the Transition or Interior Zones. This pattern was also observed for conductivity, Cl, and SO_4 for most of 2006, when concentrations of these constituents were greater in the Perimeter Zone than either the Transition or Interior Zone.

Although rainfall patterns in 2006 were similar to 2004 patterns, the Refuge 2006 inflows, when compared to 2005, were slightly reduced and split between STA-1W and STA-1E, and outflows were less than half the volume observed in 2005. Daily-averaged canal stages increased to greater than 17 ft for 9% of 2006, longer than occurred in 2004 or 2005. During the period of high canal stages, increases in water quality parameters were only observed in the Canal Zone, with little to no response to these elevated canal stages in the marsh zones. We hypothesize that the occurrence of canal water intrusion into the marsh was reduced by elevated marsh rainfall, particularly during high canal and marsh stage conditions (i.e., a flat-pool conditions). The results here provide a preliminary indication that the frequency, magnitude, and extent of canal water intrusion events into the interior of the Refuge summed over 2006 were reduced relative to previous years.

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Table 2-1. Water quality monitoring parameters for the A.R.M. Loxahatchee National Wildlife Refuge Enhanced Water Quality Program. Parameter descriptions, IDs, and Methods are as listed in the SFWMD's DBHYDRO database and at SFMWD (2006).

PARAMETER	ID[1]	Units	MDL	Method
ALKALINITY, TOTAL as CACO3	ALKA	mg L^{-1}	1	EPA 310.1
CALCIUM	Ca	mg L^{-1}	0.2	SM3120B
CHLORIDE	Cl	mg L^{-1}	0.1	EPA 300.0
DISSOLVED OXYGEN	DO	mg L^{-1}		FIELD[2]
DISSOLVED ORGANIC CARBON	DOC	mg L^{-1}	1.0	EPA 415.1
NITRATES and NITRITES as N	NOX	mg L^{-1}	0.006	SM4500NO3F
PHOSPHATE, ORTHO as P	OPO_4	mg L^{-1}	0.004	SM4500PF
pH	pH	UNITS		FIELD[2]
SILICA	SiO_2	mg L^{-1}	0.05	SM4500SID (MODIFIED)
SULFATE	SO_4	mg L^{-1}	0.1	EPA 300.0
SP CONDUCTANCE	SpCond	µS cm^{-1}		FIELD[2]
TOTAL DISSOLVED SOLIDS	TDS	mg L^{-1}	22	SM2540C
TEMPERATURE	TEMP	Deg. C		FIELD[2]
KJELDAHL NITROGEN, TOTAL	TKN	mg L^{-1}	0.05	EPA 351.2-MOD
CARBON, TOTAL ORGANIC	TOC	mg L^{-1}	1	EPA 415.1
PHOSPHATE, TOTAL AS P	TPO_4	mg L^{-1}	0.002	SM4500PF
TOTAL SUSPENDED SOLIDS	TSS	mg L^{-1}	3	EPA 160.2
TURBIDITY	TURB	NTU	0.1	SM2130B

[1] ID is the descriptor used in Appendix 2-1
[2] These values reflect the smallest reporting interval from field instruments.

Table 2-2. Summary statistics for TP, conductivity, Cl, SO_4, TN, and Tdepth classified by zone from January 2006-December 2006. Summary statistics are based on monthly arithmetic means for each zone. n = total number of monthly values available.

	Canal Zone[A]							Transition Zone[C]						
Parameter	Mean	Median	Minimum	Maximum	n	25th percentile	75th percentile	Mean	Median	Minimum	Maximum	n	25th percentile	75th percentile
Total Phosphorus ($\mu g\ L^{-1}$)	69	61	34	125	12	51	86	8	7	6	13	12	6	8
Conductivity ($\mu S\ cm^{-1}$)	902	906	737	1123	12	808	983	182	173	131	281	12	144	199
Chloride ($mg\ L^{-1}$)	123	121	95	153	12	108	140	30	29	21	43	12	25	32
Sulfate ($mg\ L^{-1}$)	47	51	24	65	12	38	56	1	0.6	0.5	3.0	12	0.5	1.0
Total Nitrogen ($mg\ L^{-1}$)	1.6	1.6	1.1	2.0	10	1.3	1.8	1	1.0	0.3	1.6	12	0.8	1.2
Tdepth (inches)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	10	10	3	19	12	8	12

	Perimeter Zone[B]							Interior Zone[D]						
Parameter	Mean	Median	Minimum	Maximum	n	25th percentile	75th percentile	Mean	Median	Minimum	Maximum	n	25th percentile	75th percentile
Total Phosphorus ($\mu g\ L^{-1}$)	11	10	7	18	12	9	12	9	8	6	14	12	7	11
Conductivity ($\mu S\ cm^{-1}$)	386	389	292	467	12	341	435	149	141	95	118	12	119	165
Chloride ($mg\ L^{-1}$)	57	54	44	74	12	50	66	30	28	18	49	12	25	34
Sulfate ($mg\ L^{-1}$)	8	6	2	17	12	4	13	0.1	0.1	0.07	0.3	12	0.1	0.2
Total Nitrogen ($mg\ L^{-1}$)	1.2	1.1	0.8	2.2	12	1.0	1.3	1.3	1.3	0.7	2.1	11	1.1	1.6
Tdepth (inches)	11	10	5	18	12	9	12	11	10	6	17	12	9	13

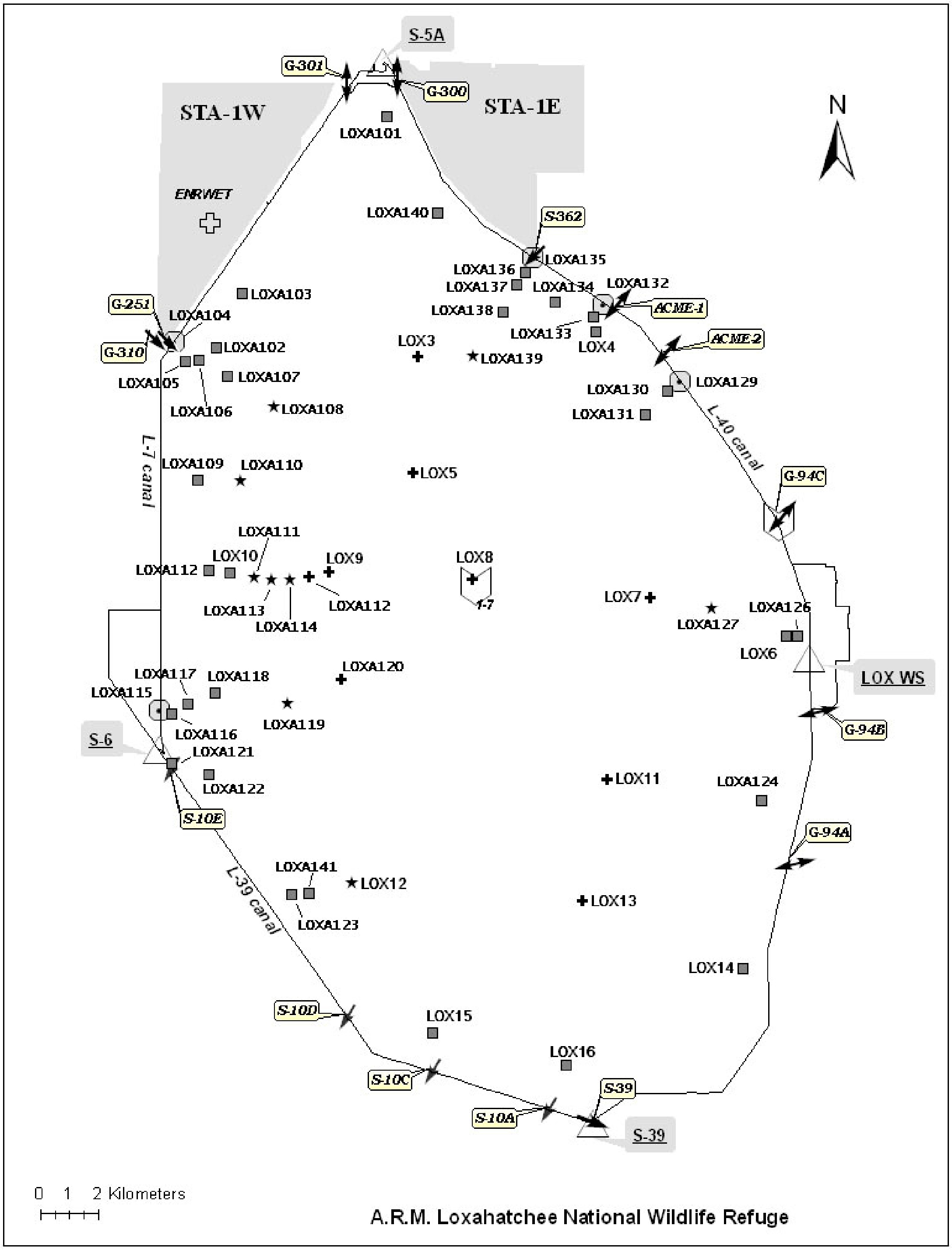
[A] Five stations.
[B] Thirty stations.
[C] Nine stations.
[D] Nine stations.

Table 2-3. Summary statistics for wet deposition concentration of TP, TN, Cl, and SO_4, for 2004, 2005, and 2006. Data from ENRWET station (Figure 2-1).

Atmospheric Deposition Chemistry								
Parameter	Year	n	Mean	Std	Max	Min	C.V.	Median
TP ($\mu g\ L^{-1}$)	2004	12	33.3	77.8	276.0	2.0	2.3	6.6
	2005	10	14.7	17.7	58.0	2.0	1.2	8.0
	2006	20	3.8	42.0	14.0	1.0	11.2	3.0
TN ($mg\ L^{-1}$)	2004	11	0.5	0.3	1.3	0.2	0.7	0.4
	2005	10	0.3	0.2	0.8	0.2	0.5	0.3
	2006	18	0.4	0.4	1.5	0.1	1.1	0.3
CL ($mg\ L^{-1}$)	2004	11	1.1	1.0	3.0	0.2	0.9	0.9
	2005	11	2.1	3.1	11.3	0.5	1.5	1.0
	2006	18	1.3	1.9	8.6	0.1	1.5	0.6
SO_4 ($mg\ L^{-1}$)	2004	11	1.1	0.7	3.0	0.6	0.6	0.8
	2005	11	1.0	0.6	2.4	0.6	0.6	0.8
	2006	19	0.9	0.8	2.6	0.1	0.9	0.6

C.V. = coefficient of variation
Max = maximum
Min = minimum
n = number samples

Figure 2-1. Water quality stations and operational structures in the A.R.M. Loxahatchee National Wildlife Refuge classified by zone: Canal (rounded squares with dot in center); Perimeter (filled squares); Transition (solid stars); Interior (solid crosses). Inflow and outflow structures are represented with arrows; double arrows indicate bidirectional flow. Weather stations are represented with hollow triangle; ET station represented by hollow cross. Footprint of Stormwater Treatment Areas (STAs) are shown in gray shading. The map is projected in NAD 1983.


S-5A
G-301
G-300
STA-1W
STA-1E
N
LOXA101
ENRWET
LOXA140
S362
LOXA135
LOXA136
LOXA137
LOXA134
LOXA132
LOXA103
G-251
LOXA104
LOXA138
ACME-1
LOXA133
ACME-2
LOX3
LOX4
G-310
LOXA102
LOXA139
LOXA105
LOXA107
LOXA130
LOXA129
LOXA106
LOXA108
LOXA131
L-7 canal
L-40 canal
LOXA109
LOXA110
LOX5
G-94C
LOXA111
LOX10
LOX9
LOX8
LOXA112
LOXA113
LOXA114
LOXA112
1-7
LOX7
LOXA126
LOXA127
LOX6
LOXA120
LOX WS
LOXA117
LOXA118
LOXA115
LOXA119
LOXA116
G-94B
S-6
LOXA121
LOXA122
LOX11
LOXA124
S-10E
G-94A
LOXA141
LOX12
L-39 canal
LOX13
LOXA123
LOX14
S-10D
LOX15
LOX16
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S-10A
S-39
0 1 2 Kilometers
A.R.M. Loxahatchee National Wildlife Refuge

Figure 2-1.

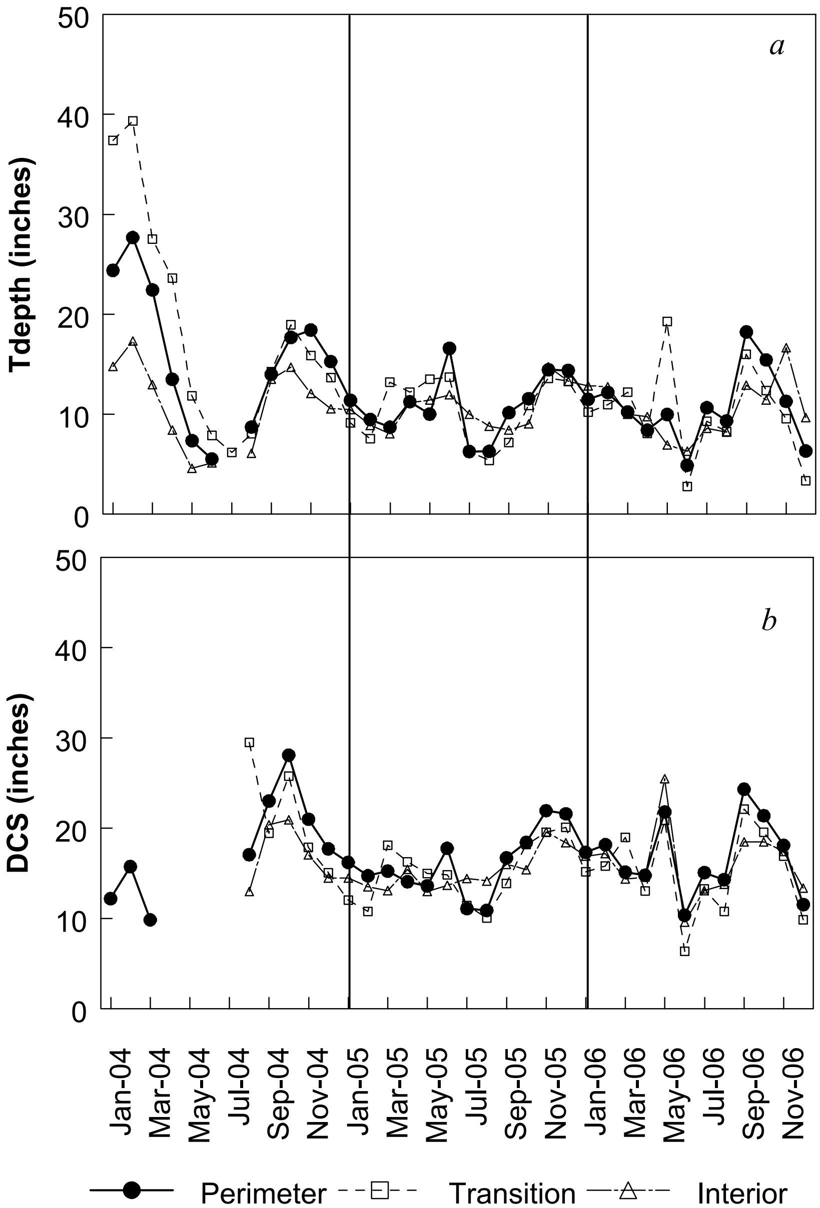
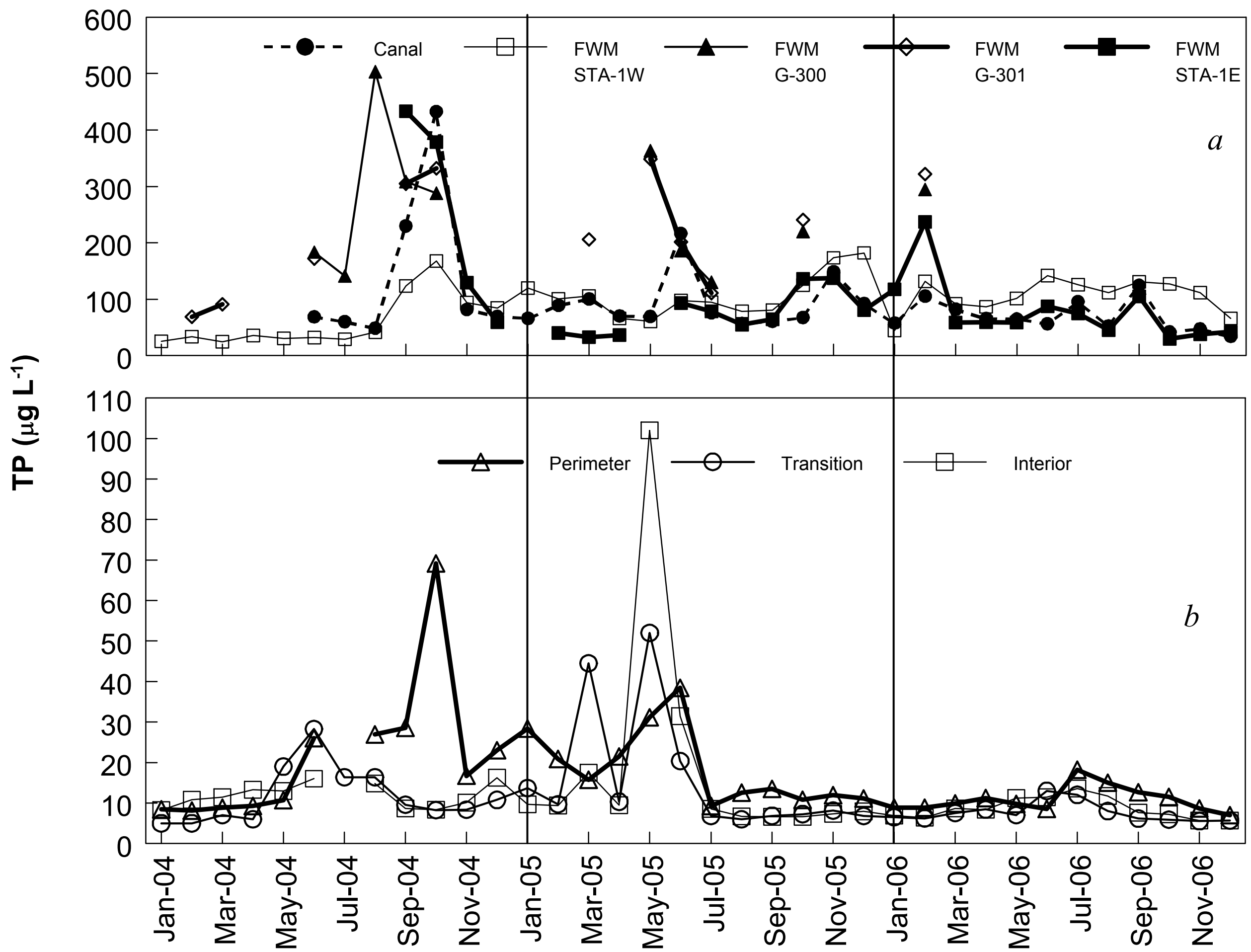


Figure 2-2. Time series of (a) clear water column depth (Tdepth in inches; arithmetic mean of all stations in each zone), and (b) depth to consolidated substrate (DCS in inches; arithmetic mean of all stations in each zone). Perimeter Zone (solid circles and thick line); Transition Zone (hollow squares and thin line); Interior Zone (hollow triangles and thin line).

Figure 2-3. (a) Flow-weighted mean TP concentration (μg L^{-1}) over time for STA-1W inflows (G-251 plus G-310; hollow square), STA-1E inflows (S-362; solid squares), G-300 (solid triangle), G-301 (hollow diamond), and mean TP in the Canal Zone (solid circles and dashed line). (b) Monthly arithmetic mean TP concentration (μg L^{-1}) for the Perimeter Zone (hollow triangles), Transition Zone (hollow circle), and Interior Zone (hollow square). Monthly values are summarized in Appendix 2-1.



TP (μg L-1)
600
500
400
300
200
100
0
Canal
FWM STA-1W
FWM G-300
FWM G-301
FWM STA-1E
a
110
100
90
80
70
60
50
40
30
20
10
0
Perimeter
Transition
Interior
b
Jan-04
Mar-04
May-04
Jul-04
Sep-04
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Jan-06
Mar-06
May-06
Jul-06
Sep-06
Nov-06

Figure 2-3.

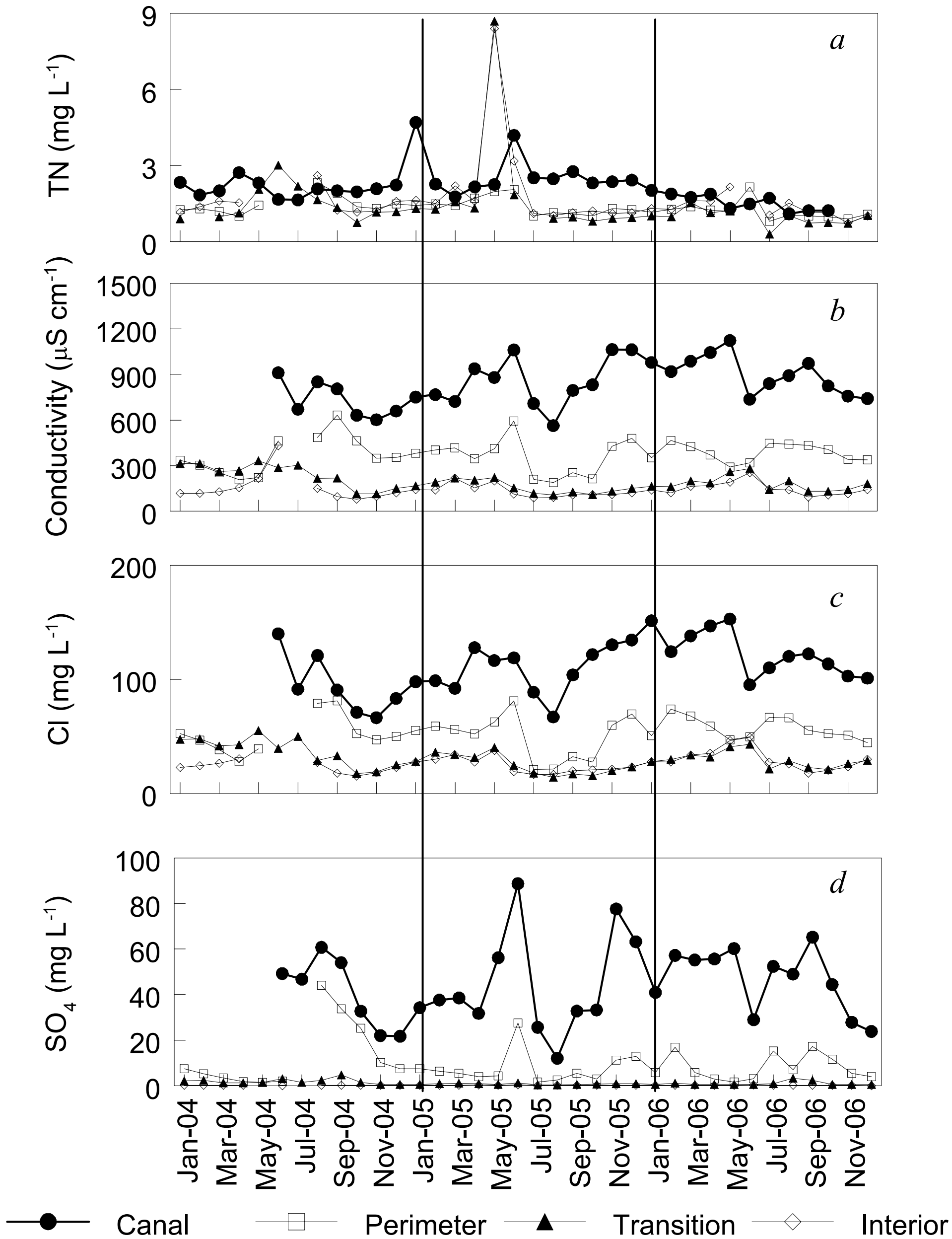


Figure 2-4. a) TN (mg L^{-1}), b) conductivity (µS cm^{-1}), c) Cl (mg L^{-1}), and d) SO_4 (mg L^{-1}) as arithmetic mean of all stations in each zone through time. Refuge Canal (solid circles), Perimeter (hollow squares), Transition (solid triangles), and Interior (hollow diamonds) Zone values are presented for each parameter in the individual panels.

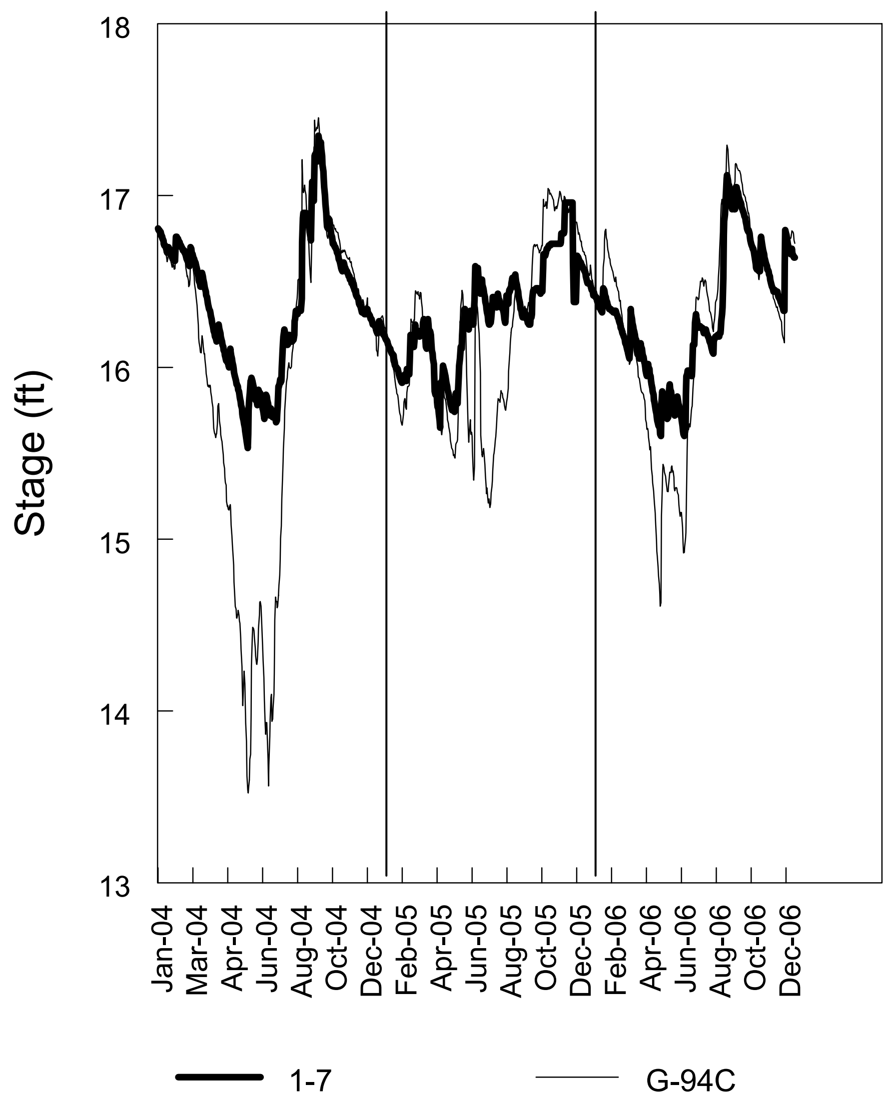


Figure 2-5. Marsh (1-7: thick line) and canal (G-94C: thin line) stages (reported in feet) from January 2004 through December 2006.

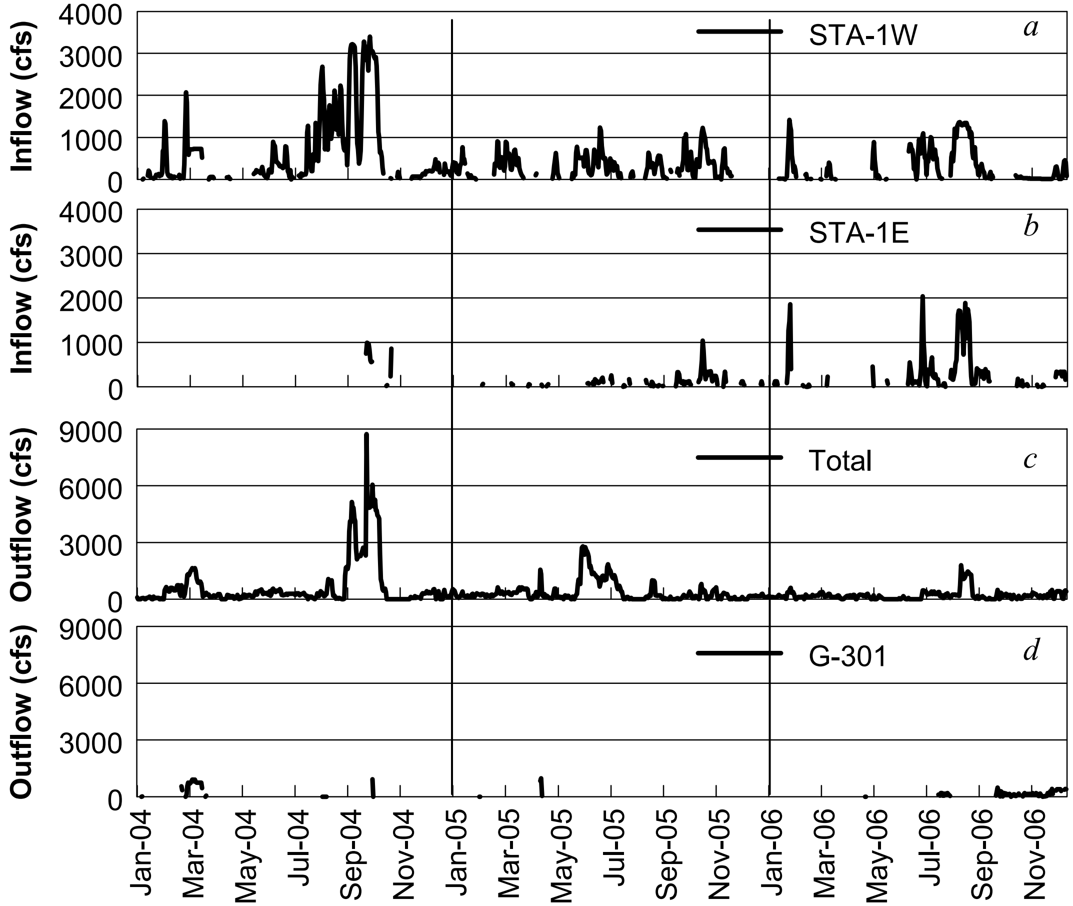


Figure 2-6. Inflows and outflows (in cfs) from January 2004 through December 2006. (a) STA-1W inflows; (b) STA-1E inflows; (c) Total outflows; and (d) G-301 outflows.

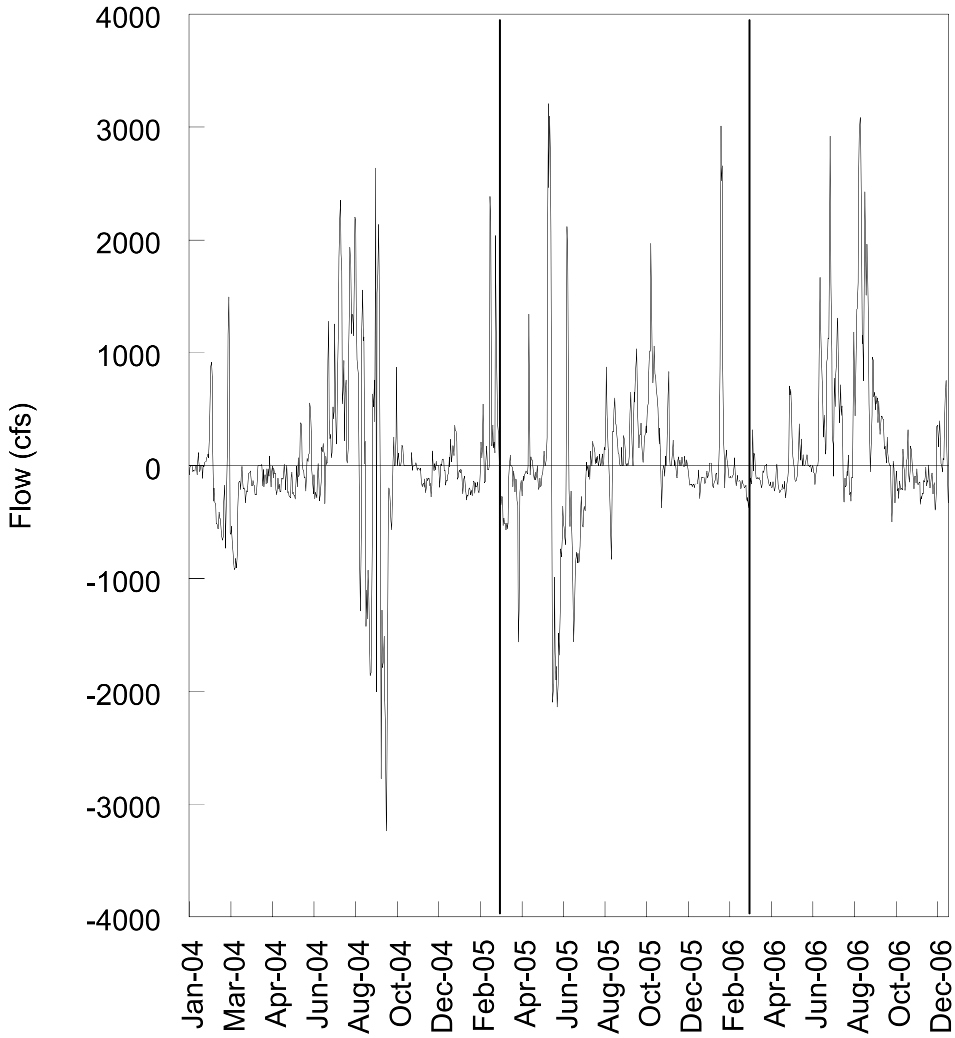


Figure 2-7. Daily-average net flows (calculated as the difference between inflow and outflow from all structures) for the Refuge from January 2004 through December 2006. Positive values indicate net inflow and negative values indicate net outflow.

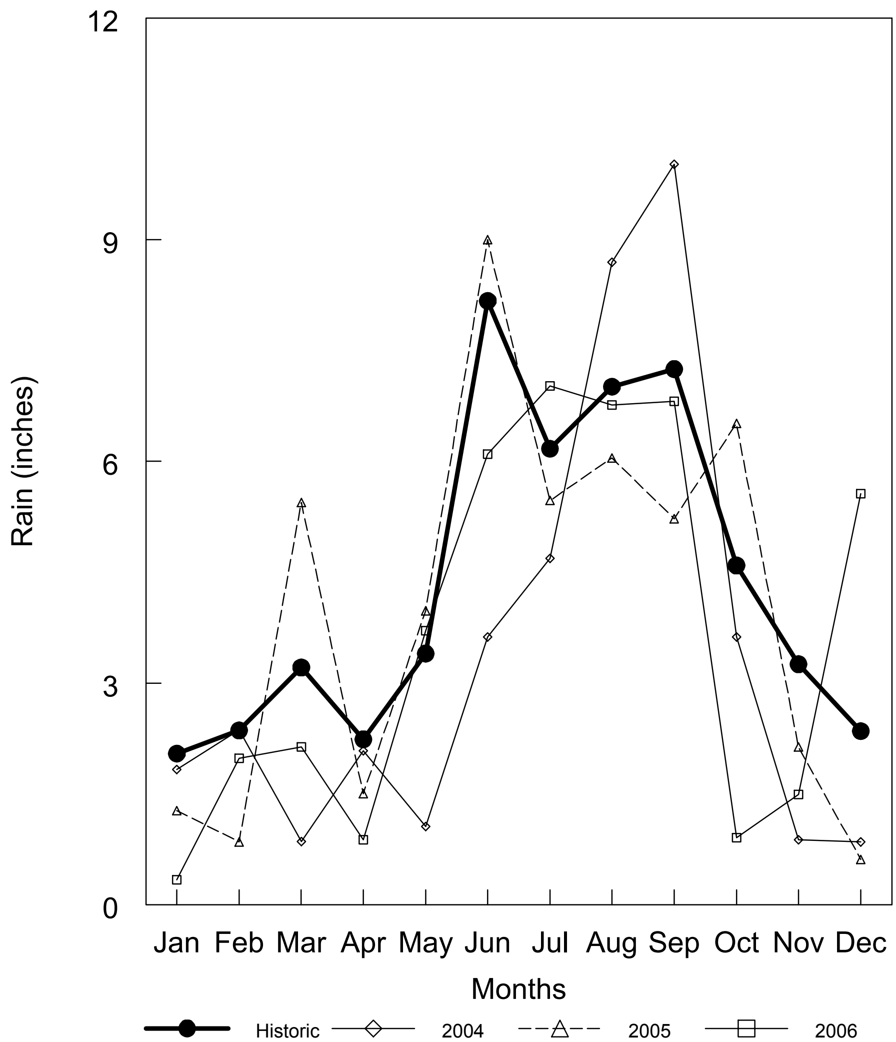


Figure 2-8. Monthly rainfall for 2004 (hollow diamonds), 2005 (hollow triangles), 2006 (hollow squares), and historic average (1999 - 2006; solid black line) recorded at different stations (gages S-5A, LOXWS, S-39 and S-6) around the Refuge.

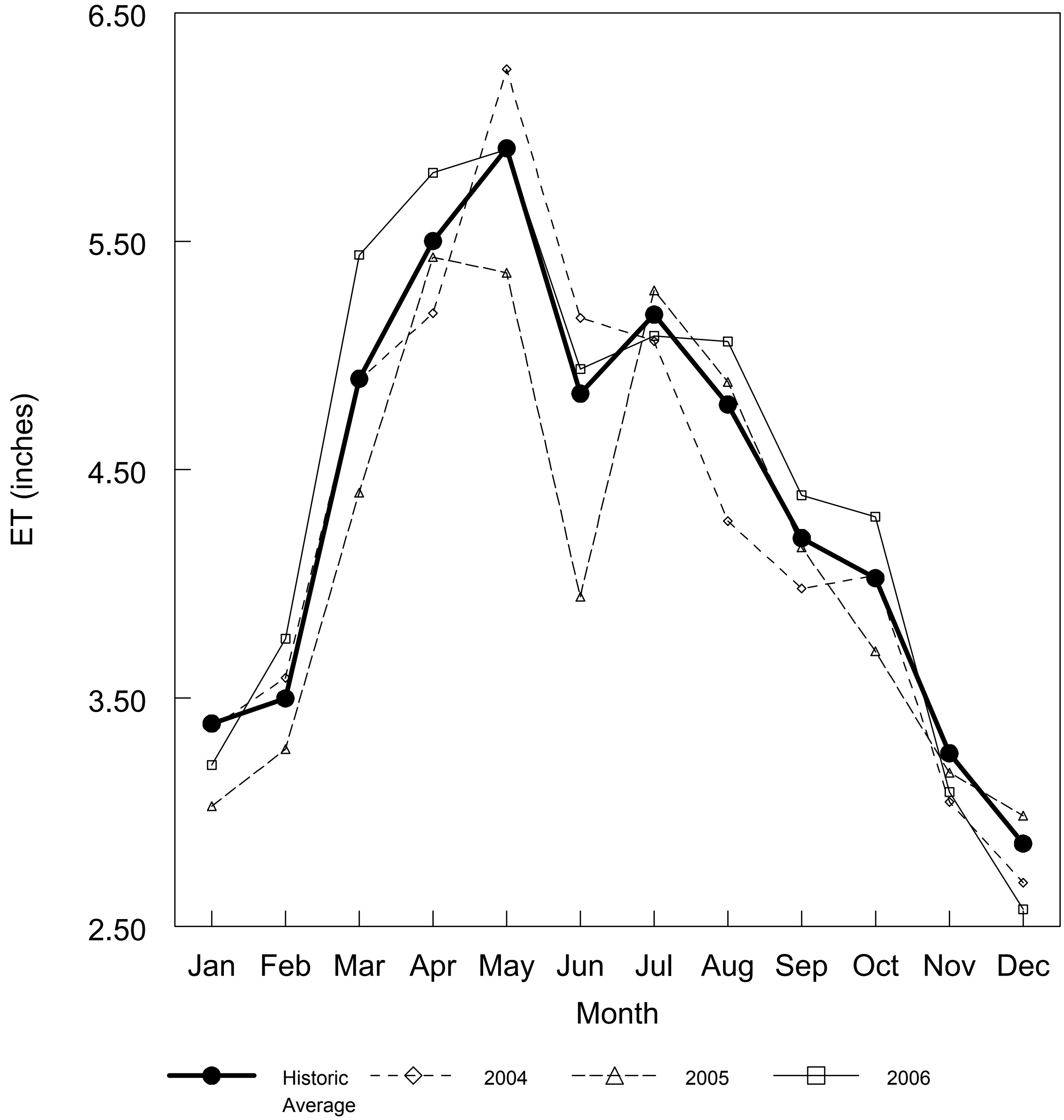


Figure 2-9. Monthly ET for 2004 (hollow diamonds), 2005 (hollow triangles), 2006 (hollow squares), and historic average (1999 - 2006; solid black line). Data from the ENRWET station.

Figure 2-10. Total monthly water inputs (rainfall and canal inflows) and outputs (evapotranspiration and canal outflows) for the Refuge from January 2004 to December 2006. Rainfall was the average of four weather stations (S-5A, S-6, LOXWS, and the S-39) summed for each month. Canal inflows were the daily sum from all the inflow structures (STA-1W: G-251 and G-310; STA-1E: S-362; bypass: G-300 and G-310; and ACME-1 and ACME-2) summed over each month. Evapotranspiration was the monthly total determined from the ENRWET station. Canal outflows were the daily sum from all the outflow structures (bypass: G-300 and G-301; S-10A, S-10C, S-10D, G-94A, G-94B, ACME-1 and ACME-2) summed over each month.

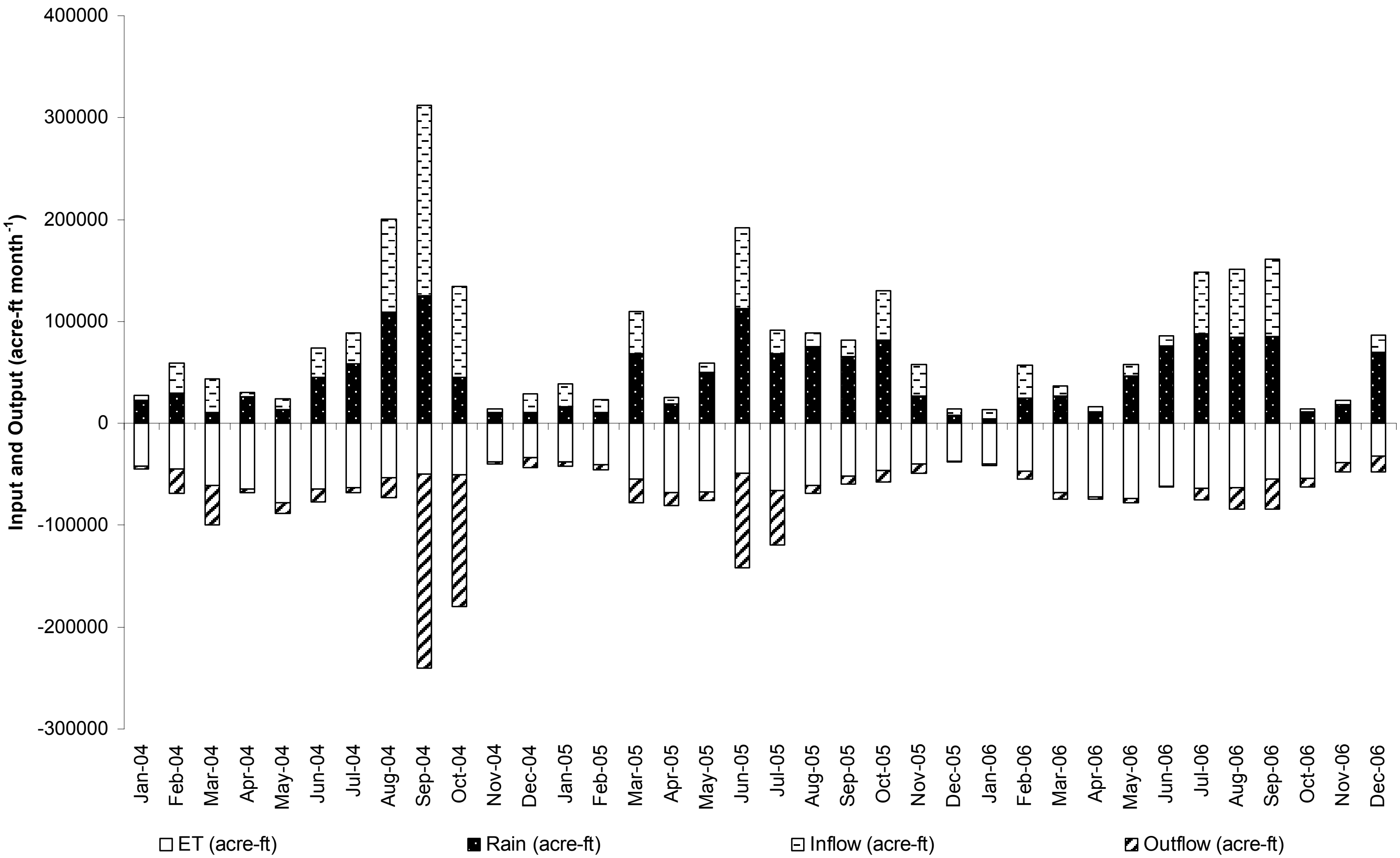

400000
300000
200000
100000
0
-100000
-200000
-300000
Input and Output (acre-ft month-1)
Jan-04
Feb-04
Mar-04
Apr-04
May-04
Jun-04
Jul-04
Aug-04
Sep-04
Oct-04
Nov-04
Dec-04
Jan-05
Feb-05
Mar-05
Apr-05
May-05
Jun-05
Jul-05
Aug-05
Sep-05
Oct-05
Nov-05
Dec-05
Jan-06
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Jul-06
Aug-06
Sep-06
Oct-06
Nov-06
Dec-06
ET (acre-ft)
Rain (acre-ft)
Inflow (acre-ft)
Outflow (acre-ft)

Figure 2-10.

Chapter 3. Transect Conductivity Monitoring: Canal Water Intrusion[4]

Abstract

The Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge) developed as a rainfall-driven system and is part of the continuous Greater Everglades ecosystem. Presently, the Refuge is impounded by canals that deliver nutrient and ion-enriched waters south from the Everglades Agricultural Area, as well as from Lake Okeechobee and urban drainage. These waters intrude into the interior of the Refuge and cause ecosystem alterations including sawgrass conversion to cattail stands. The Refuge is one of the last remaining pristine areas of the Everglades, therefore, ecosystem protection is an important management goal and intrusion of nutrient and ion-enriched waters to the marsh is a potential threat to this goal.

Thirty-two conductivity monitors (sondes) were deployed in the Refuge. Sondes were deployed along six transects perpendicular to the perimeter canal. Additional sondes also were deployed at sites perpendicular to the main transects to document conductivity parallel to the canal alignment within the marsh. Sondes continuously collected temperature and conductivity data hourly.

We used the location of the 300, 350 and 500 µS cm^{-1} conductivity isopleths as indicators of canal water intrusion into the marsh for the period from January through December 2006 and compared the results to 2005 results. These conductivity levels were determined through interpolating conductivity between sites that bracket each of the three conductivity values.

Each transect had different magnitudes of canal water intrusion into the marsh. Canal water intrusion into the marsh was consistently between 0.5 and 3 km in 2006, similar to 2005. Three major differences in canal water intrusion between 2006 and 2005 were observed. One major change observed in 2006 was that the extent canal water intruded on the east side of the Refuge was greater than in 2005. Another key difference observed in 2006 was that intrusion on the west side of the Refuge was less than in 2005. A third major difference observed in 2006 was that across the Refuge, the length in time that intrusion was extensive following high inflow events was greater than in 2005.

On the east side of the Refuge, particularly in the northeast, intrusion was higher through 2006 than 2005. The increased intrusion appeared to be a result of increased inflows through the structures on the east side of the Refuge (STA-1E, G-94s and G-300). East-side inflows in 2006 increased by more than 20% compared to 2005. These intrusion events were still evident when hydrologic conditions (net flow, canal-marsh stage differences and rainfall) were favorable for water movement away from the marsh interior towards the canals.

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[4] Prepared by: Donatto D. Surratt, Matthew C. Harwell, Michael G. Waldon

In 2006, the extent of intrusion on the west side of the Refuge, particularly in the northwest, was less than in 2005. Generally, inflows on the east and west sides of the Refuge occurred simultaneously, with more water coming through the east than the west. The 2006 inflow pattern reduced the volume and rate of water directly discharged to the west side of the Refuge relative to 2005, resulting in a reduction in the distance of canal water intrusion into the marsh, although the frequency and duration of intrusions was slightly higher in 2006 than 2005. Also, the lower conductivity levels along the west side of the Refuge in 2005 were not observed in 2006, and the minimum conductivity level observed in 2006 were approximately 15% higher than levels observed in 2005.

Overall, canal water intrusion into the marsh for both sides of the Refuge had longer durations following high inflow events. Canal outflow rates in 2006 decreased by almost 50% compared to 2005 outflow rates. The increased duration of canal water intrusion likely was because of a reduction in outflows in 2006 compared to 2005.

Finally, the hydrologic management changes coupled with decreased rainfall in 2006, resulted in reductions in both canal inflows and outflows. One impact to the Refuge was an increase in the duration of Refuge exposure to the nutrient-enriched canal water. The long term effects of this may have negative consequences including increased dry periods in the northern marsh and extended exposure of the marsh to these nutrient-enriched waters in the southern, flooded areas of the Refuge. Both of these consequences have the potential to alter the trophic status of the Refuge ecosystem.

Background

Water high in nutrient and mineral content is pumped into the Refuge (Figure 3-1) perimeter canals from stormwater runoff and other sources. There is a concern that when canal stages are greater than marsh stages, enriched water from perimeter canals may intrude into the Refuge interior, resulting in eutrophication and elevated ion concentrations in the Refuge wetlands (Swift 1981; Swift 1984; Richardson et al. 1990; McCormick and Crawford 2006). A gradient of surface water exist with elevated nutrient and mineral content with concentrations ranging from higher values near canals to lower values in the most interior regions of the Refuge (Richardson et al. 1990; Stober et al. 1998; Scheidt et al. 2000; Stober et al. 2001; Harwell et al. 2005; USFWS 2007). The primary source of these elevated concentrations in the fringe wetlands has been shown to be canal water flowing toward the Refuge interior (Richardson et al. 1990; Newman et al. 1997; USFWS 2007).

Water discharged into the Refuge included both treated and untreated water from January 2005 to December 2005 (2005). Untreated waters came from the Everglades Agricultural Area (EAA), the L-8 basin east of the EAA, and Lake Okeechobee via bypass structures (G-300 and G-301), or the Village of Wellington via the ACME-1 and ACME-2 water control structures (Figure 3-1). Treated waters came from the EAA, the L-8 basin and Lake Okeechobee via stormwater treatment areas (STAs). Both untreated and treated water were higher in nutrients and other ions than water in the Refuge interior (Chapter 2). Temperature-compensated conductivity (specific conductance) is used here as a conservative tracer of canal water (USFWS 2007).

The objective of this study was to understand canal water intrusion into the marsh by:

- Describing and quantifying conductivity patterns;
- Examining conductivity changes along transects at selected times; and
- Examining specific effects of water inflow or outflow on the marsh

Analyses presented here are an update to the information presented in USFWS (2007) by examination of conductivity time-series graphs, distance of water movement across the canal-marsh interior gradient and mapping of this movement relative to distance from the canals and positions around the canal. The site locations and methods of spatial analysis presented in this chapter were intended to minimize problems of contouring conductivity data by using a transformed coordinates system (distance around perimeter canal and distance from canal; USFWS 2007). All of the analysis methods applied in this paper were focused on the northern portion of the Refuge because surface water inflow points are concentrated in the northern portion.

Methods

Data acquisition and monitoring

Sonde Data: Thirty-two conductivity monitors (sondes) were deployed (Table 3-1) along six transects (STA-1W, STA-1E, ACME-1, ACME-2, S-6 and Central; Figure 3-1) from the canal to 9 km (5.6 miles) into the marsh interior following methods described in USFWS (2007). The period of record analyzed in this chapter is from January through December 2006 (2006) and is compared to 2005.

Average, standard deviations, minimum, and maximum summary statistics were reported for the non-transformed data presentation. The rank-based Mann-Whitney statistical test was applied for data comparisons. Statistics presented in this chapter reflect midnight values for all days that data were available from the sondes.

Stage, flow, and rainfall data were downloaded from the SFWMD data web portal, DBHYDRO (http://www.sfwmd.gov/org/ema/dbhydro/). Analyses of these data were directed to understand natural conditions and management operation impact on canal water movement into and out of the marsh.

Stage Data: Data from the USGS 1-7 stage gage (Figure 3-1) were applied as estimates of marsh stage following methods described in USFWS (2007). Canal stages were characterized using the headwater gage of the G-94C spillway structure (Figure 3-1) located on the L-40 Canal (east side of the Refuge). When the Refuge has a high water stage (> 5.15 m; 17 ft) a flat-pool condition exists during which all stage readings should be equal. Because of small inconsistencies among Refuge gages observed during high stages we adjusted the G-94C gage readings by adding 2.83 cm (0.093 ft) to equalize the stage readings to the 1-8C stage gage (USFWS 2007).

The 1-7 stage gage was established in the center (from north to south and east to west) of the marsh. Because of micro-scale topographic variations across the marsh, marsh stages calculated at the 1-7 gage may not sufficiently represent areas away from the center of the marsh. Further, there may be differences in canal stage elevation between the east and west sides of the Refuge, most likely associated with differences in inflow volumes between the east and west sides of the Refuge. The G-94C gage serves as a good proxy of canal stages on the east side, but the gage values may not sufficiently represent canal stages on the west side of the Refuge. However, to enhance our understanding of canal water movement into the marsh interior, the canal and marsh gages applied in this study provide a general understanding of canal stages relative to marsh stages as the difference between these two water levels may have some influence on canal water movement into the marsh.

Flow Data: Daily average inflow and outflow rates ($m^3 s^{-1}$) ($ft^3 s^{-1}$, cfs) were used in this study. Inflow records for ACME-1, ACME-2, G-310, G-251, S-362, G-300 and G-301 were summed for daily average inflow; outflow records at G-300, G-301, G-94A, G-94B, G-94C, S-10A, S-10C, S-10D and S-39 were used for daily average outflow (Figure 3-1) following methods described in USFWS (2007). The G-338 had no significant flows reported over the study period. Net flow was determined as the difference between inflow to the canals and outflow from the canals. Positive net flow occurred when inflow to the canals was greater than outflow from the canals and negative net flow occurred when outflow from the canals was greater than inflow to the canals.

Rainfall and ET Data: Data from the S-6, S-39, LOXWS and S-5A weather stations (Figure 3-1) were used in this analysis following methods described in USFWS (2007). Evapotranspiration (ET) plays a nontrivial role in the overall Refuge water budget (Meselhe et al. 2006). Generally, ET remains consistent through the year, decreasing to the lowest levels in December (see Chapter 2).

In the USFWS (2007) report, we performed a sensitivity analysis for the impacts of rainfall and ET on intrusion, using several simple steps. First, we added the net rainfall (difference between total rainfall and ET) to the total water depth for each period. The potential conductivity values associated with the change in volume resulting from the addition of net rainfall using a simple mass balance approach was then calculated. Next, the percent difference between the actual conductivity level (350 $\mu S\ cm^{-1}$) and the estimated conductivity level was used to determine the upper and lower limits of the conductivity range associated with the contribution of net rainfall. We determined the distance into the marsh of the upper and lower limits of each conductivity range by interpolation, as presented in the Distance of Intrusion method section of USFWS (2007). These minimum and maximum distances of intrusion represent the variability of intrusion distance that could be caused by rainfall and ET for the high and low water depths examples examined here.

Based on analyses presented in USFWS (2007), intrusion of the 350 $\mu S\ cm^{-1}$ isopleth on August 25, 2005 extended to 3.5 km into the marsh, water depth was 0.35 ft, and total net rainfall for the period August 22 – 26, 2005 was 0.07 ft (0.05 ft ET; 0.12 ft rainfall). The addition of net rainfall to the water column increased the water depth to 0.42 ft and the range of conductivity associated with this change was 292 to 420 $\mu S\ cm^{-1}$. Intrusion for these conductivity values ranged between 3.8 and 3.1 km, respectively.

Intrusion of the 350 $\mu S\ cm^{-1}$ isopleth on November 11, 2005 extended to 3.7 km into the marsh, water depth was 2.38 ft, and total net rainfall for the period November 1 – 16, 2005 was -0.09 ft (0.15 ft ET; 0.06 ft rainfall). The amount decreased the water depth to 2.29 ft and the range of conductivity associated with this change was 337 to 364 $\mu S\ cm^{-1}$. Intrusion for these conductivity values ranged between 3.9 and 3.6 km, respectively.

Using these examples, we demonstrate that effects of rainfall and ET are greater when water depths are low. The extent of how much the effect of rainfall and ET may influence the distance of intrusion ranges between 2 and 12%. In the examples of intrusion described throughout this report, issues with rainfall and ET were minimized by selecting periods with little or no rain, and selecting periods sufficiently short to minimize the influence of evapotranspiration. The reader should be aware, however, that some scenarios examined here had high rainfall by design.

Mathematical and graphical analysis

Data exploration and analyses were performed using three complementary methods as described in USFWS (2007):

Method 1 - Time-series conductivity transect analysis: Time-series data were graphed and visually examined for each monitoring site (USFWS 2007).

Method 2 - Distance of intrusion: We determined the general level of intrusion by interpolating conductivity isopleths (contour lines between points of similar value) along four selected conductivity transects (STA-1W, STA-1E, ACME-2 and S-6). Methodologies for analysis are described in USFWS (2007).

Method 3 - Distance of Intrusion: A transformed coordinate system approach: Interpolated distances of canal water intrusion using all transects (STA-1W, S-6, West-Central, East-Central, ACME-2, ACME-1 and STA-1E) were plotted as distance of intrusion into the marsh versus distance around the perimeter canal, going clockwise from LOXA116 (western Refuge) to LOXA126 (eastern Refuge). We refer to this presentation of the interpolated distances as a transformed-coordinates system approach (see USFWS 2007).

We selected periods representative of specific canal-marsh stage relations (e.g., canal stage greater than marsh stage and vice-versa) and hydrologic natural drivers (e.g., large rainfall events) for this analysis. Stage relationships and storm events were considered for conditions of: (1) high canal water inflow with high outflow (I_H-O_H); and (2) low canal inflow with high outflow (I_L-O_H) rates. Low flow rates are less than 200 cfs, moderate flow rates are between 200 and 500 cfs, while high flow rates are defined as flows greater than 500 cfs. Analytical approaches are described in USFWS (2007).

Results and Discussion

Conditions during the study period

Total 2006 rainfall in the Refuge was 43.7 inches (546,385 acre-ft), which was about 4.5 inches (54,562 acre-ft) lower than in 2005. In 2006, rainfall contributed to 67 percent of the total volume of water entering the area (273,122 acre-ft canal inflow and 819,507 acre-ft total inflow). The lower 2006 rainfall is notable because it is about two times greater than the 2006 inflow volume (299,242 acre-ft).

Average inflow rate in 2006 (385 ± 739 cfs; mean ± 1 standard deviation) was more than twice average 2005 inflow rate. However, 2006 median inflow (149 cfs) was closer to the 2005 average and median value. The frequency of inflow rates greater than 1,000 cfs in 2006 was almost two times greater than the 2005 period, and these extended high inflows contributed to the higher average 2006 inflow rates. Further, these higher inflow rates began shortly after and continued through heavy, extended rainfall events, similar to inflow events in 2005. Unlike the 2005 period, STA-1E contributed more than 35% of the canal inflows to the Refuge in 2006, approximately 20% greater than in 2005. Even though 2006 inflow rates were greater than 2005 inflow rates, the total volume of canal inflow in 2006 was lower than 2005 inflow volumes (see Chapter 2).

Total 2006 evapotranspiration in the Refuge was 53.5 inches (668,750 acre-ft), which was slightly higher than 2005 ET value. Average outflow rates in 2006 (198 ± 257 cfs; mean ± 1 standard deviation) were almost two times lower than the 2005 outflow rates. Total outflow for 2006 was 140,594 acre-ft.

Average canal stage at the G-94C headwater stage gage for 2006 was 16.26 ft with a range of 14.61 to 17.29 ft. The average G-94C stage for 2006 and 2005 was the same, however, the range of stages differed, with the larger range observed in 2006. Average marsh stage at the 1-7 stage gage was 16.32 ft with a range of 15.60 to 17.12 ft in 2006. The average 1-7 stage for the periods 2006 and 2005 was the same, but the maximum stage in 2006 was 0.16 ft higher than 2005 period.

Canal stage exceeded marsh stage by a maximum of 0.68 ft in 2006 which was 0.2 ft higher than the 2005 period. Canal stage variability (4% coefficient of variation) was 1% higher than the 2005 period. Periods when canal stages were much higher than marsh stages in 2006, generally, were centered on high inflow and rainfall events. Marsh stage exceeded canal stage by a maximum of 1 ft in 2006 and was very similar to the 2005 period. Periods when marsh stages were much higher than canal stages in 2006, generally, occurred when low and sparse rainfall occurred in combination with low inflows for periods of a week or longer. In 2006, the average canal and marsh stages were similar.

Conductivity in the interior zone during 2006 typically was less than 190 $\mu S\ cm^{-1}$ for more than 75% of the year. Conductivity at canal sites typically ranged from 700-1000 $\mu S\ cm^{-1}$.

<u>Transect time-series and isopleth analysis</u>

STA-1E transect: The STA-1E transect incorporates a set of sondes that extend from the northeast marsh perimeter canals to an intermediate area within the perimeter zone (Figure 3-1) of the marsh. Sondes along this transect include LOXA135 (canal), LOXA136 (0.6 km), LOXA137 (1.1 km), LOXA138 (2.1 km) and LOXA139 (3.9 km).

STA-1E transect average conductivity in the canal (868 ± 131 $\mu S\ cm^{-1}$) was similar to average conductivity in 2005 (Figure 3-2; Table 3-2). However, conductivity levels in 2006 never decreased below 590 $\mu S\ cm^{-1}$, unlike conductivity values in 2005 that declined below 370 $\mu S\ cm^{-1}$. In February 2006, conductivity from the canal to about 1.1 km into the marsh ranged between 1,092 and 607 $\mu S\ cm^{-1}$, respectively, and the spike was associated with inflow rates greater than 3,000 cfs and canal stages higher than marsh stages. Following the September 2006 inflow spike (> 3,000 cfs), conductivity levels across most of this transect (from 0.6 to 1.1 km into the marsh) increased to between 900 and 500 µS cm^{-1}. These levels of conductivity remained high for the most extended period of time (> one month) observed through the entire period of record (January 2005 through December 2006).

Average intrusion following the 500 µS cm^{-1} isopleth in 2006 was 1 ± 0.49 km, more than twice the 2005 average intrusion, and the median 500 µS cm^{-1} isopleth distance from canal in 2006 (1 km) was significantly greater than the median distance from canal of 0.5 km in 2005 (Mann-Whitney U, $p \ll 0.001$; Figure 3-3c; Table 3-3). Ninety percent of the available 500 µS cm^{-1} isopleth record was 0.5 km or more into the marsh in 2006 verses 0.1 km in 2005. The 500 µS cm^{-1} isopleth generally intruded more than 1.5 km into the marsh when inflows were greater than 2,000 cfs and canal stages were higher than marsh stage, particularly in February and again in September 2006. During these periods, the 350 µS cm^{-1} isopleth intruded more than 1.7 km into the marsh. The 350 µS cm^{-1} intruded an average of 1.72 ± 0.73 km and a maximum of 3.3 km in September 2006, which was 1 km greater than in 2005. Maximum intrusion on the 500 µS cm^{-1} isopleth was 2.7 km at the beginning of September 2006. During this 2006 maximum intrusion event, canal stages increased to more than 0.6 ft higher than marsh stages, unlike during the maximum intrusion event in 2005, when marsh stages were higher than canal stages and outflows were higher than inflows. This change in intrusion response to canal water changes was likely a result of the much higher inflow volumes entering the canals on the east side of the Refuge in 2006.

ACME-2 transect: The ACME-2 transect incorporates a set of sondes that extend from the northeast (south of STA-1E transect) marsh perimeter canals to an intermediate area within the perimeter zone of the marsh (Figure 3-1). The sondes along this transect include LOXA129 (canal), LOXA130 (0.5 km) and LOXA131 (1.5 km).

ACME-2 transect average conductivity in the canal (808 ± 129 µS cm^{-1}) was higher than conductivity in 2005 (696 µS cm^{-1}), but similar to values at the STA-1E canal site (Figure 3-4; Table 3-2). The ACME-2 transect canal conductivity in 2006 never decreased below 488 µS cm^{-1} (98 µS cm^{-1} less than at the STA-1E canal site), unlike conductivity levels in 2005 that declined below 300 µS cm^{-1}. Half a kilometer into the marsh, conductivity levels did not decrease below 320 µS cm^{-1}, more than twice the minimum in 2005. Following the February 2006 inflow spike, conductivity ranged from 1,060 to 880 µS cm^{-1} from the canal to 0.5 km into the marsh, respectively. Alternatively, conductivity levels at 1.5 km into the marsh slowly increased from February (230 µS cm^{-1}) through April 2006 (394 µS cm^{-1}), along with conductivity values in the canal. Further, conductivity levels at 1.5 km into the marsh exceeded 400 µS cm^{-1} when inflows increased above 3,000 cfs and canal stages were more than 0.5 ft higher than marsh stages beginning in late August 2006. Conductivity levels along this transect between August and October 2006 did not decrease to levels observed during the same period in 2005. The elevation in conductivity levels observed across the ACME-2 transect in 2006 reflect the increased inflow through the STA-1E discharge structure.

Average intrusion following the 500 $\mu S\ cm^{-1}$ isopleth in 2006 was 0.8 ± 0.3 km, 0.2 km further than 2005 average intrusion following the 500 $\mu S\ cm^{-1}$ isopleth (Figure 3-3d). The maximum intrusion in 2006 was 1.2 km at the beginning of September and flow and stage conditions were the same as those for the STA-1E transect during this period. Average intrusion following the 350 $\mu S\ cm^{-1}$ isopleth extended 1.2 ± 0.2 km into the marsh and the maximum intrusion of 1.5 km occurred in early April 2006. Interestingly, net flows were approximately -146 cfs and marsh stages were more than 0.5 ft higher than the canal stages. These conditions, generally, create a marsh configuration that leads to water moving from the marsh towards the canals (USFWS 2007). The ACME-2 transect is highly sensitive to canal water movements, because of its lower elevation relative to surrounding areas (USFWS 2007). ACME-2 canal conductivity levels often were greater than 900 $\mu S\ cm^{-1}$ and were associated with the elevated conductivity levels at 1.5 km into the marsh along the transect (Figure 3-4d). Evaporation may have contributed to the elevated conductivity levels along this transect in April 2006, but the contribution did not increase intrusion by more than 0.2 km considering that the water depth was greater than 10 cm, which is the water depth at which evaporation processes could extend the distance of canal water intrusion by 12% (USFWS 2007). The more likely source of these elevated conductivity levels across this transect in April and through most of the year was the elevated canal discharge from the STA-1E structure.

It should be noted that the 350 $\mu S\ cm^{-1}$ isopleth maximum intrusion distances may be truncated as a function of the linear interpolation model used to fit the ACME-2 transect, particularly because this transect only extends 1.5 km into the marsh and the model does not estimate intrusion beyond the transect end points. Considering this limitation, the maximum intrusion along the ACME-2 transect is likely much further than 1.5 km following the 350 $\mu S\ cm^{-1}$ isopleth, because actual conductivity values at 1.5 km occasionally exceeded 400 $\mu S\ cm^{-1}$.

STA-1W transect: The STA-1W transect incorporates a set of sondes that extend from the northwest marsh perimeter canals to an intermediate area within the marsh transition zone (Figure 3-1). Sondes along this transect include LOXA104 (canal), LOXA105 (0.7 km), LOXA106 (1.1 km), LOXA107 (2.2 km) and LOXA108 (3.9 km).

STA-1W transect average conductivity in the canal (962 ± 153 $\mu S\ cm^{-1}$) was similar to average conductivity in 2005 (Figure 3-5; Table 3-2). However, conductivity levels in 2006 never decreased below 560 $\mu S\ cm^{-1}$, unlike conductivity values in 2005 that declined below 300 $\mu S\ cm^{-1}$. Conductivity spikes across most of this transect occurred during or several days following spikes in canal water inflow. Conductivity levels at 0.7 km were greater than average in late January/early February (> 900 $\mu S\ cm^{-1}$), late July (> 600 $\mu S\ cm^{-1}$), and late August/early September 2006 (> 500 $\mu S\ cm^{-1}$). With the exception of late January/early February 2006, conductivity patterns at 1.1 km were similar to those at 0.7 km into the marsh, but conductivity levels were lower, ranging between 300 and 550 $\mu S\ cm^{-1}$ during the peak inflow periods. Beyond 2.2 km, little change in conductivity levels was observed through 2006.

Average intrusion following the 500 µS cm^{-1} isopleth in 2006 was 0.70 ± 0.18 km, about 0.2 km less than 2005 intrusion (Figure 3-3e). The maximum intrusion was 1.3 km at the end of August 2006 and occurred two weeks after inflows increased to and remained greater than 1,000 cfs. Maximum intrusion following the 500 µS cm^{-1} isopleth in 2006 was less than half the distance of the maximum intrusion observed in 2005 (2.7 km), but both maximum intrusion events occurred at the end of August, similar to the STA-1E transect. During this time, canal stage was as much as 0.68 ft greater than the marsh stage, unlike in 2005, when marsh stages were greater than canal stage and outflows were higher than inflows. In August 2006, rainfall totaled 3.9 inches nine days before the maximum intrusion event was observed, as where in August 2005, rainfall for the nine days leading to the maximum intrusion event totaled 2.8 inches. Further, in August 2006, stages in the marsh increased to the highest stages observed in 2005 or 2006. The higher rainfall in August 2006 most likely diluted conductivity in the marsh, preventing canal water intrusion from extending to the maximum intrusion observed in 2005.

In general, the 500 µS cm^{-1} isopleth intruded more than 1 km into the marsh, when inflows were greater than 2,000 cfs and canal stages were higher than marsh stage, particularly in February and again in late August/early September 2006. During these periods, the 350 µS cm^{-1} isopleth intruded more than 1.5 km into the marsh and the 2006 average was 0.94 ± 0.28 km.

S-6 transect: The S-6 transect incorporates a set of sondes that extend from the southwest marsh perimeter canal near the site of the now-diverted S-6 outfall, to an intermediate area within the interior marsh zone (Figure 3-1). Sondes along this transect include LOXA115 (canal), LOXA116 (0.4 km), LOXA117 (0.9 km), LOXA118 (1.8 km), LOXA119 (4.3 km) and LOXA120 (6.1 km).

S-6 transect average conductivity in the canal (958 ± 135 µS cm^{-1}) was similar to average conductivity in 2005 (Figure 3-6; Table 3-2). However, the 2006 conductivity levels never decreased below 600 µS cm^{-1}, unlike conductivity levels in 2005 that declined below 330 µS cm^{-1}. Conductivity values from the canal (> 950 µS cm^{-1}) to at least 1 km (> 700 µS cm^{-1}) were elevated from January through early March 2006. These high conductivity levels were associated with the high inflows and low canal-marsh stage difference observed at the end of 2005 and the elevated inflows in February 2006. Further, because the S-6 has some of the lowest ground elevations of the analyzed transects, this transect is more sensitive to canal water inflows at lower canal stages than other transects and less sensitive to canal water outflows draining water from the marsh (USFWS 2007). The lower elevations allow canal water to move further into the marsh and when the canal-marsh gradient is small or marsh stage become higher than canal stage, these lower elevations tend to retain higher conductivity levels longer than the other transects. Following the July and August 2006 elevated inflows (> 3,000 cfs), conductivity levels across most of this transect increased to between 1,000 and 550 µS cm^{-1} from 0.4 to 1.8 km into the marsh, respectively. Canal-marsh stage difference for this period increased to greater than 0.6 ft. The high inflows coupled with canal stage much higher than marsh stage created conditions conducive to extensive canal water intrusion during each of the observed elevated intrusion events in 2006.

Average 500 µS cm^{-1} isopleth intrusion in 2006 was 1.1 ± 0.3 km, 0.2 km further than in 2005 (Figure 3-3f). Average intrusion following the 350 µS cm^{-1} isopleth extended 1.5 ± 0.4 km into the marsh and was similar to average intrusion in 2005. The 500 µS cm^{-1} and 350 µS cm^{-1} isopleth intrusion extent increased to the 2006 maximum (1.6 and 2.4 km, respectively) by mid-February 2006, following the inflow spike (> 3,000 cfs) at the beginning of the month. Even though canal-marsh stage difference (approximately 0.25 ft) and rainfall (< 0.01 ft) was similar to 2005 during the maximum 350 µS cm^{-1} intrusion event, the 2005 maximum intrusion event occurred in November 2005 and was preceded with 42 days of inflows averaging 760 cfs, where as the February 2006 inflow event was preceded only with five days of flow that exceeded 700 cfs. Based on these two different events (350 µS cm^{-1} maximum intrusion events in 2005 and 2006), it is clear that the extent and volume of inflows has an important influence on canal water intrusion in the marsh. Further, limiting the extent of high inflows to a few days, particularly when the canal stage is higher than the marsh stage reduces intrusion.

Storm-Event Driven Refuge-Wide Intrusion

In early February 2006, rainfall increased to more than 1.5 inches per day for two days. A few days following these elevated rainfalls, canal inflows and outflows were I_H-O_H and inflows were greater than 700 cfs (with maximums greater than 3,000 cfs) for seven days, while outflows were closer to 500 cfs. During this inflow spike, canal stage increased by more than 0.3 ft higher than marsh stages. Prior to this time, inflows and outflows were low and the 500 µS cm^{-1} and 300 µS cm^{-1} conductivity isopleths were less than 0.8 km and between 1 and 1.2 km, respectively, into the marsh across the characterized zone, except in the west where conductivity levels were 2.6 and 3.6 km, respectively (Figure 3-7a). Following the maximum inflows in February 2006, the 300 µS cm^{-1} isopleth intrusion increased to 2 km in the northeast and east areas of the Refuge, while intrusion increased to 1.8 km in the northwest and 3.8 km in the west areas of the Refuge (Figure 3-7b). These levels of intrusion remained until at least the end of March 2006, when inflows were low and the continuous low to moderate outflows decreased the canal stage to levels similar to the marsh. The length of time (more than three weeks) for this February-March 2006 intrusion event was unusual, considering that in most areas of the Refuge, the February-March 2005 intrusion had a shorter duration and less extensive penetration than the 2006 intrusion.

High rainfall (> 1 inch) events lasting one to two days and occurring at three to five day intervals began in late June 2006 and increased in frequency through early October 2006. Following the initiation of the high rainfalls, high inflow (> 500 cfs; maximum > 3,000 cfs) persisted for one and half months (mid August through September 2006) prior to the inflow reduction in October 2006. Management operations in October 2006 were I_L-O_H. During this time, the 500 and 300 µS cm^{-1} conductivity isopleth extended greater than 1.2 and 3 km into the marsh, respectively, particularly in the northeast and east areas of the marsh, and in the west, the 500 and 300 µS cm^{-1} isopleths extended 1.7 and 3 km, respectively (Figure 3-8a). These higher levels of intrusion were likely legacy from the high inflows (I_H-O_{L-M}) from mid-August through September 2006 and did not decline until early November for the 500 $\mu S\ cm^{-1}$ isopleth (Figure 3-8b) and the mid-December 2006 (Figure 3-8c) for the 300 $\mu S\ cm^{-1}$ isopleth. The continued 300 $\mu S\ cm^{-1}$ isopleth intrusion through mid-December was most likely exacerbated by the low inflows (I_L-O_L) that ensued through November when canal and marsh stages were similar, while the low to moderate outflows (I_L-O_{L-M}) at the end of November through mid-December decreased the canal stage, resulting in decreased intrusion. Long periods of high inflow increased intrusion and these intrusion events were generally reduced when outflow rates were either higher than inflows for a period of time similar to the inflows or low to moderate for a much longer time than the high inflow period.

In 2005, we examined the impact of Refuge outflows to the south on the extent of intrusion and observed a strong decrease in intrusion when these outflows occurred at combined rates above 1,000 cfs for five or more days. In 2006, however, we examine intrusion extents as they are affected by outflows to the north through the G-301 structure, which rarely delivers water out of the Refuge. For a period of approximately one month, from October to November 2006, the G-301 structure had the highest outflow rates of all structures, but these outflow rates were low to moderate. The effect of these outflows was only observed for the 500 $\mu S\ cm^{-1}$ isopleth. Prior to the initiation of the outflows, intrusion, following the 500 $\mu S\ cm^{-1}$ isopleth, was most extensive in the northeast and west (1.8 to 2 km; October 1, 2006; Figure 3-9a). The extent of the 500 $\mu S\ cm^{-1}$ isopleth intrusion declined slowly through October 2006 and decreased to 0.8 km in the northeast by November 12, 2006, while the remainder of the intrusion across the characterized zone of the Refuge, following the 500 $\mu S\ cm^{-1}$ isopleth, was mostly constant (Figure 3-9b; west sondes failed). Based on these data, outflows through the G-301 have a potential to reduce intrusion, particularly when inflows were low and the marsh stage (approximately 15.6 ft) was much greater than the canal stage (approximately 15.1 ft). However, the operation of the G-301 with low to moderate outflow rates allowed intrusion to remain for a longer period than when outflows were much higher through the southwest in 2005. Also, outflows through G-301 did not appear to decrease intrusion throughout the marsh, unlike the higher outflows observed through the southwest in 2005. Further, the outflows through G-301 did not appear to decrease intrusion following the 300 $\mu S\ cm^{-1}$ isopleth, unlike the higher outflows through the southwest structures in 2005, which reduced intrusion of the 300 $\mu S\ cm^{-1}$ isopleth across the entire characterized zone of the Refuge.

Water management in 2006 following these high inflow events was unsuccessful in reducing inflow to a short amount of time (two to three weeks). These high inflows can result in negative impacts to native marsh vegetation productivity (USFWS 2007). However, in June 2005, following a high inflow event when outflow structures were operated with two and three times the outflow rates used in the February-March 2006 intrusion event, intrusion declined to average levels within ten days. Outflow rates during the June 2005 event were higher than 2,200 cfs. Based on the February-March 2006, October-December 2006, and the June 2005 events, it appears that canal outflow rates should equal, or at least approach, inflow rates to reduce the extent of intrusion. One impact of these high and extended outflows was that the marsh water levels were reduced below the marsh sediment surface, which can also threaten native marsh vegetation that are generally submerged through the year (USFWS 2000).

Summary

Canal water intrusion into the marsh was influenced principally by canal-marsh stage differences, the balance between canal water inflow and outflow rates, and rainfall conditions. We used the 300, 350, and 500 $\mu S\ cm^{-1}$ isopleths to determine when and where intrusion occurred throughout 2006 and for comparison to intrusion in 2005. Further, each conductivity level was selected because they have been shown to alter the ecosystem (e.g., periphyton communities, vegetative growth rates) of the marsh under different levels of exposure (USFWS 2007).

Combined, these approaches show frequent and persistent intrusion of canal water between 0.5 and 3 km in 2006, similar to 2005. Three major differences in canal water intrusion between 2006 and 2005 were observed. One major change observed in 2006 was that the extent canal water intrusion on the east side of the Refuge was greater than in 2005. Another key difference observed in 2006 was that intrusion on the west side of the Refuge was less than in 2005. A third major difference observed in 2006 was that across the Refuge, the length in time that intrusion was extensive following high inflow events was greater than in 2005.

On the east side of the Refuge, particularly in the northeast, intrusion was higher through 2006 than 2005. The increased intrusion appeared to be a result of increased inflows through the structures on the east side of the Refuge (STA-1E, G-94s and the G-300). East-side inflows in 2006 increased by more than 20% compared to 2005. Intrusion in 2006, following the 500 and 350 $\mu S\ cm^{-1}$ isopleths, never declined to levels observed in 2005. Based on the comparison of 2006 and 2005 intrusion levels, it is likely that the 2006 increase in canal water inflows on the east side of the Refuge have increased intrusion on the east side of the Refuge, even when canal-marsh stage difference, net flow, and rainfall conditions were in a configuration conducive for movement of marsh water towards the canals.

On the west side of the Refuge in 2006, particularly in the northwest, the extent of intrusion was less than in 2005. Generally, inflows on the east and west sides of the Refuge occurred concurrently, with more water coming through the east than the west. This inflow pattern reduced the volume and rate of water directly discharged to the west side of the Refuge, which resulted in a reduction in the distance of canal water intrusion into the marsh. Although the distance of intrusion was reduced on the west side, the frequency and duration of intrusions was slightly higher in 2006 than 2005. Also, the lower conductivity levels along the west side of the Refuge in 2005 were not observed in 2006, and the minimum conductivity level observed in 2006 were approximately 15% higher than levels observed in 2005. Further, even though there is obvious mixing of east and west discharges in the canals, the direct discharge from the west appears to cause canal waters to intrude farther into the marsh on the west side than waters introduced to the system through STA-1E. Coupling this observation with the opposite effect observed when inflows increased on the east side of the Refuge, there is a direct relation between canal water intrusion and the volume and rate of structure discharge, such that as discharges increase, intrusion near the discharge point is likely to increase.

The importance of canal-marsh stage differences and rainfall conditions, increased when considering canal water intrusion for areas far from direct inflow discharge. We observed increased intrusion across the Refuge when inflows occurred (low, moderate, and high rates) and canal-marsh stage difference was small. Also, because of the increased inflow on the east side, we observed increased intrusion from northeast to the central east for much longer periods (three to five weeks) in 2006 than in 2005. Alternatively, we determined that when rainfall is high and extended, canal water intrusion can be buffered or reduced. We suspect that this was a result of rain water with natural conductivity levels ($< 150\ \mu S\ cm^{-1}$) mixing with interior waters, and increasing the stage in the marsh, causing water to move from the marsh interior towards the canals. This pattern was most evident when outflows were lower than inflows for several weeks and canal stage was increased substantially. Because water in the canal was not moving out and the canal stages were not decreasing, we suspect that the increased canal stage created a situation for water in the marsh to stay in the marsh, increasing the marsh stage, and reducing conductivity levels closer to the perimeter of the marsh.

Finally, outflows north through the G-301 did not have as strong of an influence as outflows through the southwest structures. Particularly, the G-301 outflows had little to no impact on conductivity at or below $300\ \mu S\ cm^{-1}$, and these outflows only were associated with reduced intrusion in the northeast area of the Refuge. Conversely, outflows through the south and southwest reduced intrusion throughout the characterized areas of the Refuge at all levels of conductivity. However, it should be noted that the southwest outflows were much higher than outflows observed through the G-301 structure and there is the potential that higher outflows through the G-301 may decrease intrusion in other areas of the Refuge.

One notable impact to the Refuge in 2006 was an increase in the duration the Refuge marsh was exposed to the eutrophic canal waters relative to 2005. The long term effects of this may have negative consequences including increased dry periods in the northern portion of the Refuge and extend exposure of the marsh to higher-nutrient waters in flooded areas of the southern marsh. Both of these effects result in the potential of altering the trophic structure of the Refuge ecosystem.

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Table 3-1. Site distances from the canal into the marsh and around the canal with the LOXA116 as the starting point (highlighted in table). Sites are grouped by transects in the A.R.M. Loxahatchee National Wildlife Refuge (Figure 3-1).

Transect	Site ID	Distance from canal (km)	Distance around canal (km)	Transect	Site ID	Distance from canal (km)	Distance around canal (km)
STA-1W	LOXA104	canal	12.8	STA-1E	LOXA135	canal	33.8
	LOXA105	0.7	12.9		LOXA136	0.6	34.0
	LOXA106	1.1	13.4		LOXA137	1.1	34.1
	LOXA107	2.2	14.4		LOXA138	2.1	34.8
	LOXA108	3.9	11.1		LOXA139	3.9	36.2
S-6	LOXA115	canal	0.1	ACME 1	LOXA132	canal	36.7
	LOXA116	0.4	0.0		LOXA133	0.6	36.7
	LOXA117	0.9	0.5		LOX4	1.2	36.7
	LOXA118	1.8	1.3				
	LOXA119	4.3	3.2	ACME 2	LOXA129	canal	40.5
	LOXA120	6.1	5.2		LOXA130	0.5	40.6
					LOXA131	1.5	41.2
West-Central	LOX10	1.2	5.5	East-Central	LOX6	1.1	50.8
	LOXA112	1.6	5.0		LOXA126	0.4	50.5
	LOXA111	3.1	5.4		LOXA127	3.1	50.0
	LOXA113	3.8	5.6		LOX7	5.5	47.4
	LOXA114	4.4	6.0		LOX8	9.7	48.4
	LOXA128	5.1	6.4				
	LOX9	5.5	7.4				

Table 3-2. Time-series conductivity summary statistics and distance from the canal for all transects.

				Conductivity (μS cm^{-1})								
Transect	Site	Distance around canal (km)	Distance from canal (km)	Average 2006	Median 2006	Standard Deviation	Maximum	Minimum	25th Percentile	75th Percentile	Average 2005	Median 2005
STA-1W	A104	12.8	0.0	962	992	153	1260	568	857	1088	998	1011
	A105	12.9	0.7	480	483	138	785	197	363	595	469	471
	A106	13.4	1.1	291	249	94	625	185	233	313	295	297
	A107	14.4	2.2	181	184	30	230	129	153	209	189	211
	A108	11.1	3.9	185	189	37	257	87	150	216	174	176
S-6	A115	0.1	0.0	958	995	135	1213	601	878	1051	961	1007
	A116	0.0	0.4	768	781	232	1115	134	621	975	708	708
	A117	0.5	0.9	547	555	187	890	264	364	694	435	404
	A118	1.3	1.8	250	260	83	540	72	174	312	260	270
	A119	3.2	4.3	158	146	58	352	89	113	180	179	184
	A120	5.2	6.1	164	145	55	326	89	130	177	120	109
West-Central	A126	50.5	0.4	368	307	150	780	111	272	456	290	233
	LX06	50.8	1.1	274	260	104	520	109	224	338	272	296
	A127	50.0	3.1	157	156	35	473	101	134	171	123	106
	LX07	47.4	5.5	171	162	57	474	76	144	184	132	109
	LX08	48.4	9.7	159	145	55	471	86	124	183	156	128
STA-1E	A135	33.8	0.0	868	842	131	1156	591	775	950	809	796
	A136	34.0	0.6	609	638	138	943	164	537	702	366	402
	A137	34.1	1.1	445	482	154	871	108	273	546	250	266
	A138	34.8	2.1	302	282	108	631	53	211	346	182	171
	A139	36.2	3.9	159	164	31	248	75	135	180	121	102
ACME-1	A132	36.7	0.0	822	789	126	1103	593	727	912	762	747
	A133	36.7	0.6	533	581	152	898	54	377	631	387	430
	LX04	36.7	1.2	417	425	82	568	122	388	455	360	318
ACME-2	A129	40.5	0.0	808	784	129	1121	488	734	884	696	710
	A130	40.6	0.5	575	563	122	881	323	460	668	438	511
	A131	41.2	1.5	314	310	70	439	131	270	369	286	276
East-Central	LX10	5.5	1.2	150	130	53	476	71	116	192	194	150
	A112	5.0	1.6	205	209	68	535	100	147	252	238	244
	A111	5.4	3.1	140	129	45	479	83	106	171	113	111
	A113	5.6	3.8	155	154	63	468	77	100	188	168	134
	A114	6.0	4.4	142	142	48	468	56	110	167	267	135
	A128	6.4	5.1	137	121	47	282	74	101	161	-	-
	LX09	7.4	5.5	158	162	58	453	77	114	192	112	118

Table 3-3. Summary of intrusion events using (A) the 500 µS cm^{-1} and (B) 350 µS cm^{-1} isopleths for four transects (STA-1W, S-6, ACME-2 and STA-1E).

2004-2005			2006						
Transect	Maximum 500 µS cm^{-1} Intrusion (km)	Date	Average 500 µS cm^{-1} Intrusion (km)	Maximum 500 µS cm^{-1} Intrusion (km)	Date	Canal-Marsh Stage Difference	Canal-Marsh Stage Difference (ft)	Net Inflow (cfs)	Hypothesized Cause of Intrusion Event
STA-1W	2.7	26-Aug-05	0.69±0.18	1.3	30-Aug-06	Marsh > Canal	0.55	445	Extended high inflows
STA-1E	0.7	9-Nov-05	1.06±0.49	2.7	9-Sep-06	Canal > Marsh	0.15	1137	Extended high inflows
ACME-2	1.4	17-May-05	0.77±0.28	1.2	9-Sep-06	Canal > Marsh	0.18	1137	Extended high inflows
S-6	2.5	30-Nov-05	1.1±0.33	1.6	19-Feb-06	Canal > Marsh	0.27	75	*CS > MS and low to moderate flows
Transect	Maximum 350 µS cm^{-1} Intrusion (km)	Date	Average 350 µS cm^{-1} Intrusion (km)	Maximum 350 µS cm^{-1} Intrusion (km)	Date	Canal-Marsh Stage Difference	Canal-Marsh Stage Difference (ft)	Net Inflow (cfs)	Hypothesized Cause of Intrusion Event
STA-1W	3.5	25-Aug-05	0.94±0.28	1.8	7-Aug-06	Canal > Marsh	0.21	-171	Preceded by extended high inflows and CS > MS
STA-1E	1.3	4-Nov-05	1.72±0.73	3.3	9-Sep-06	Canal > Marsh	0.15	1137	Extended high inflows
ACME-2	1.5	13-Apr-05	1.2±0.22	1.5	6-Apr-06	Marsh > Canal	0.1	84	Small stage difference and low net inflow
S-6	3.9	30-Nov-05	1.46±0.39	2.4	19-Feb-06	Canal > Marsh	0.27	75	CS > MS and low to moderate net flows

* CS = canal stage; MS = marsh stage

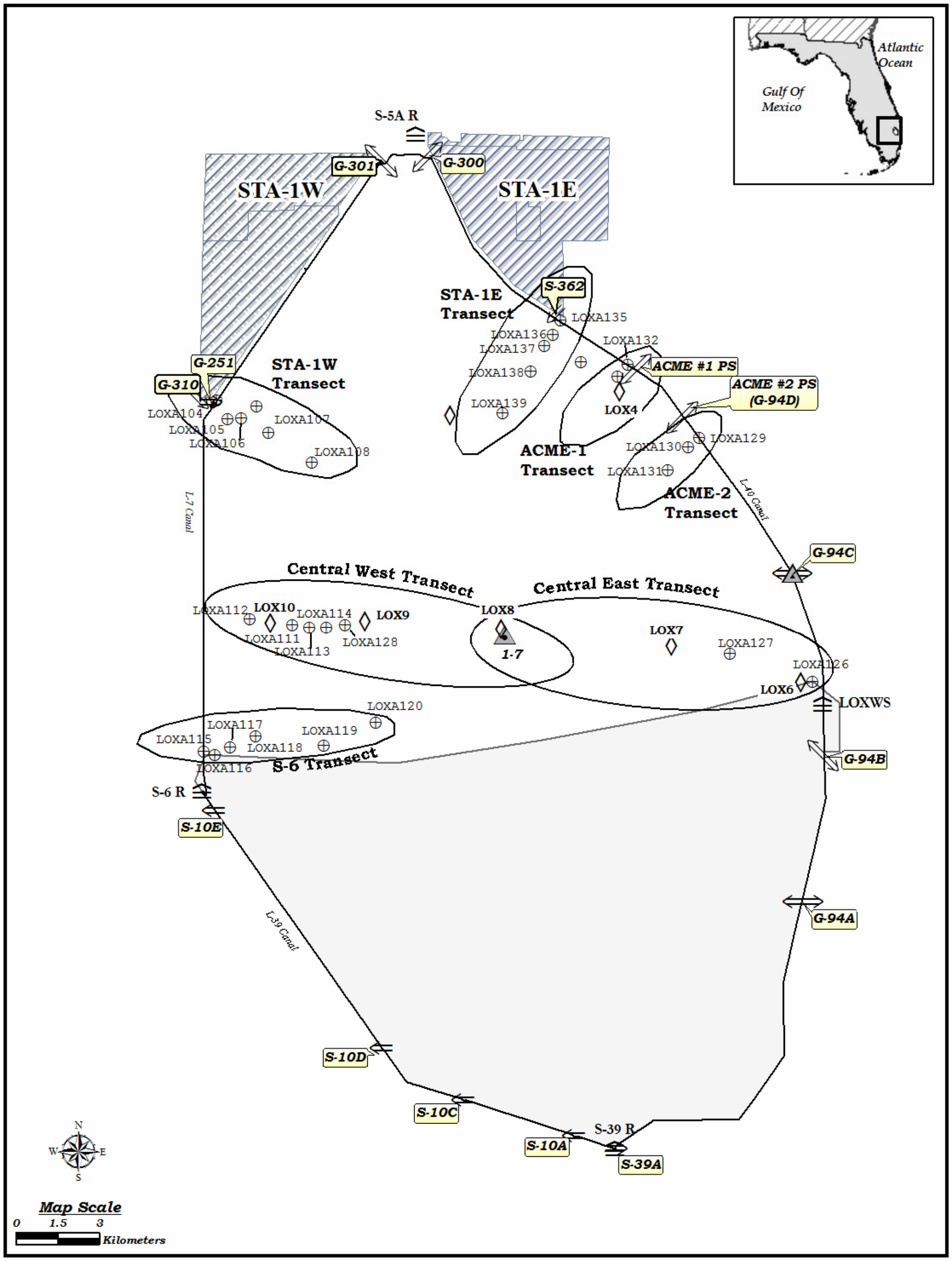

Figure 3-1. A.R.M. Loxahatchee National Wildlife Refuge map of the LOXA (circles with crosses) and EVPA (hollow diamonds) water quality monitoring sites, canal and marsh stage gages (solid trangles), inflow and outflow structures (arrows), transects (hollow polygons) and stormwater treatment areas (STAs – diagonal lines) used in this report.

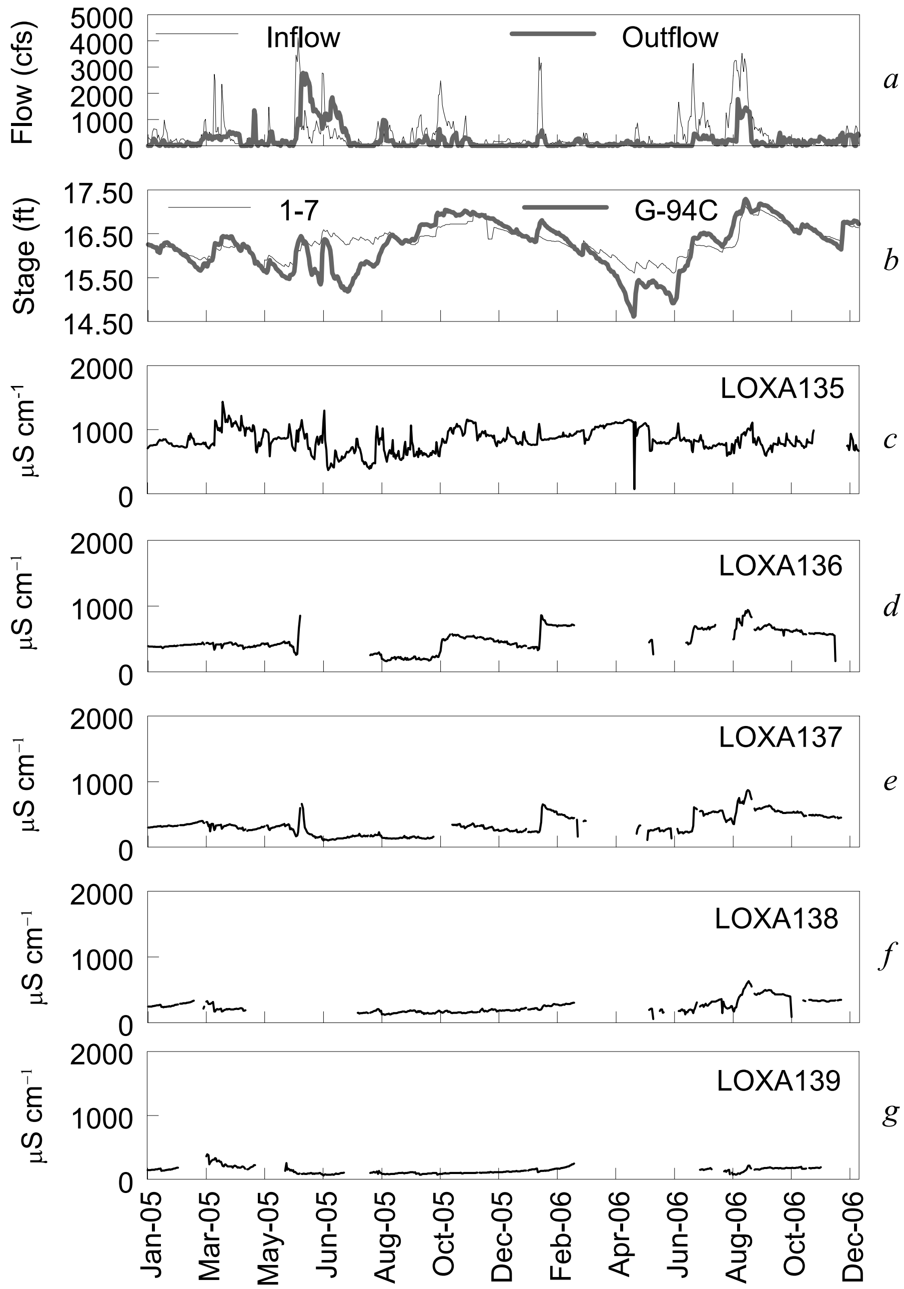

Figure 3-2. a) Inflow and outflow rates (cfs) summed for all structures through 2006. b) Marsh (thin line) and canal (thick line) stage reading from the 1-7 and G-94C stage gages, respectively. Panels c-g are the time-series of conductivity values from the STA-1E transect: c) LOXA135, canal site; d) LOXA136, 0.7 km into the marsh; e) LOXA137, 1.1 km into the marsh; f) LOXA138, 2.1 km into the marsh; and g) LOXA139, 3.9 km into the marsh.

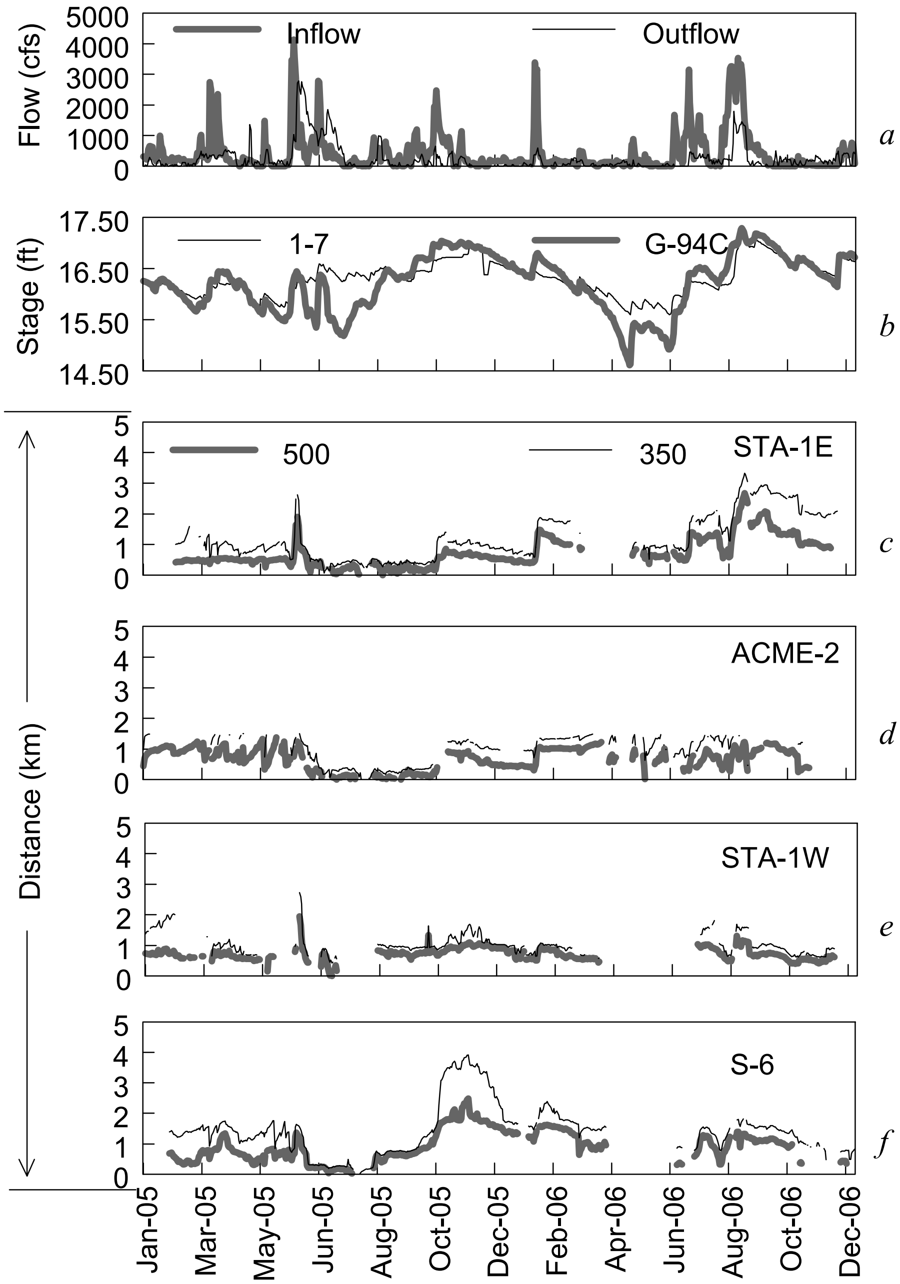

Figure 3-3. a) Inflow and outflow rates (cfs) summed for all structures through 2006. b) Marsh (thin line) and canal (thick line) stage reading from the 1-7 and G-94C stage gages, respectively. The 500 and 350 $\mu S\ cm^{-1}$ conductivity isopleths used to track canal water movement into and out of the marsh interior for: c) STA-1E; d) ACME-2; e) STA-1W; and f) S-6 transects.

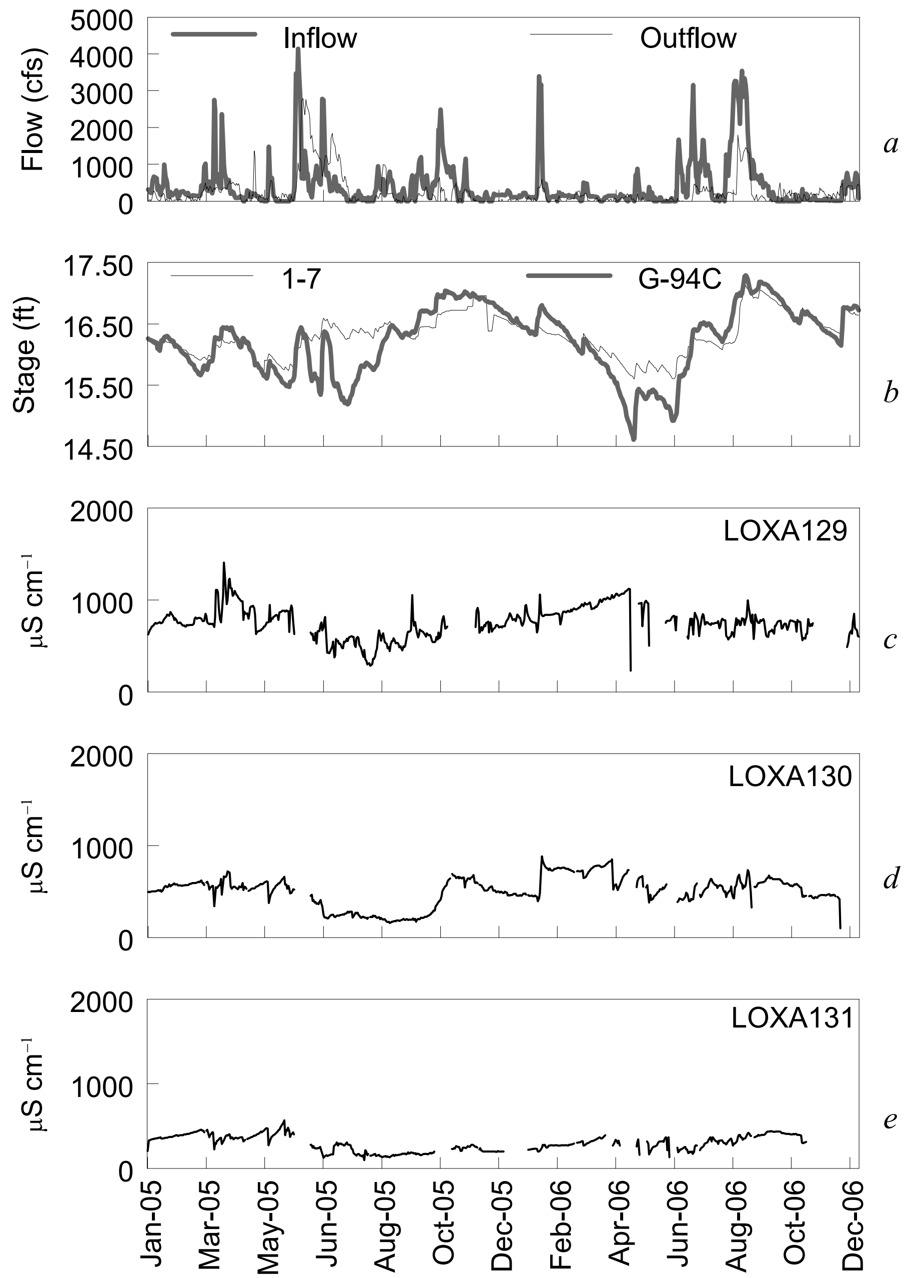

Figure 3-4. a) Inflow and outflow rates (cfs) summed for all structures through 2006. b) Marsh (thin line) and canal (thick line) stage reading from the 1-7 and G-94C stage gages, respectively. Panels c-e are the time-series of conductivity values from the ACME-2 transect: c) LOXA129, canal site; d) LOXA130, 0.5 km into the marsh; and e) LOXA131, 1.5 km into the marsh.

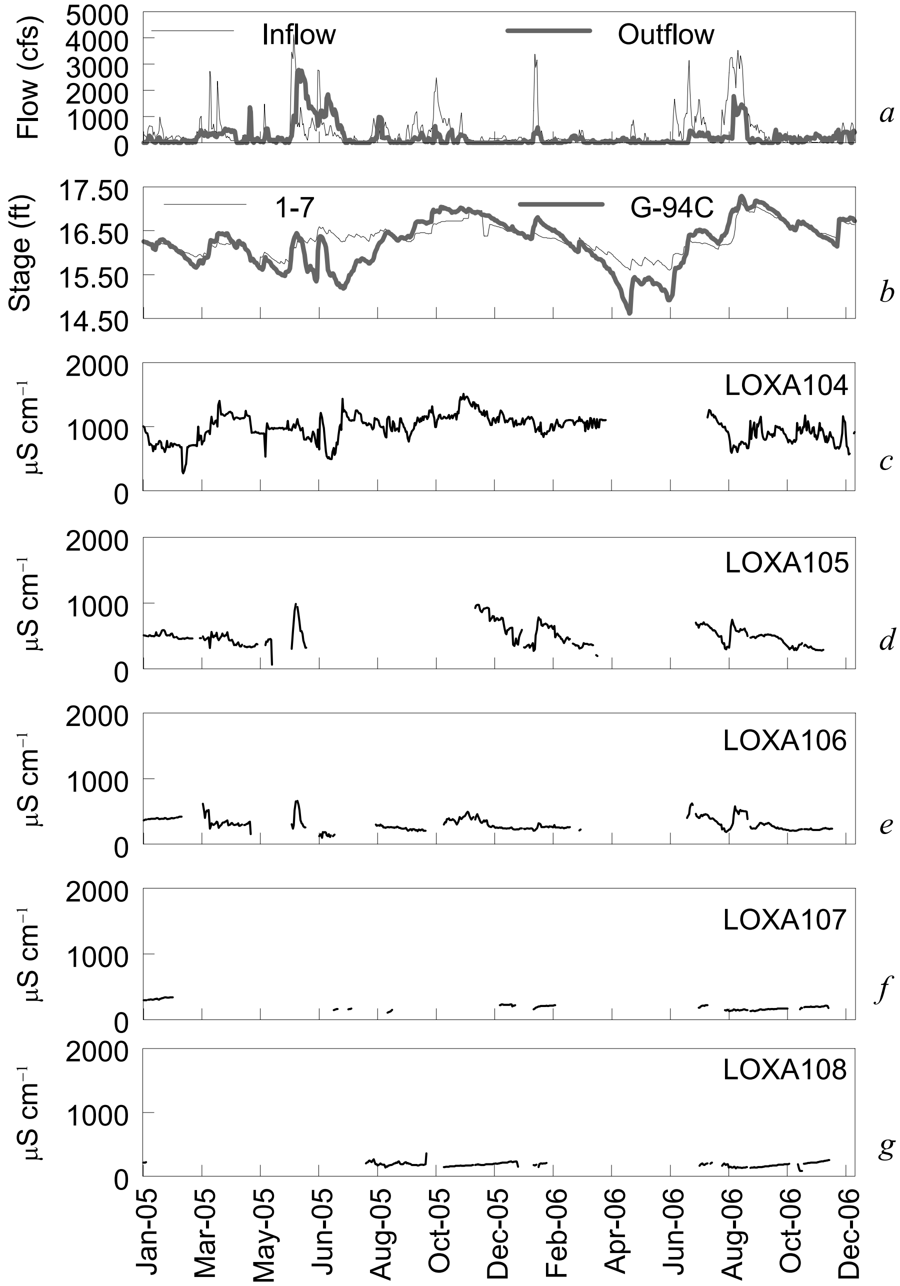

Figure 3-5. a) Inflow and outflow rates (cfs) summed for all structures through 2006. b) Marsh (thin line) and canal (thick line) stage reading from the 1-7 and G-94C stage gages, respectively. Panels c-g are the time-series of conductivity values from the STA-1W transect: c) LOXA104, canal site; d) LOXA105, 0.7 km into the marsh; e) LOXA106, 1.1 km into the marsh; f) LOXA107, 2.2 km into the marsh; and g) LOXA108, 3.9 km into the marsh.

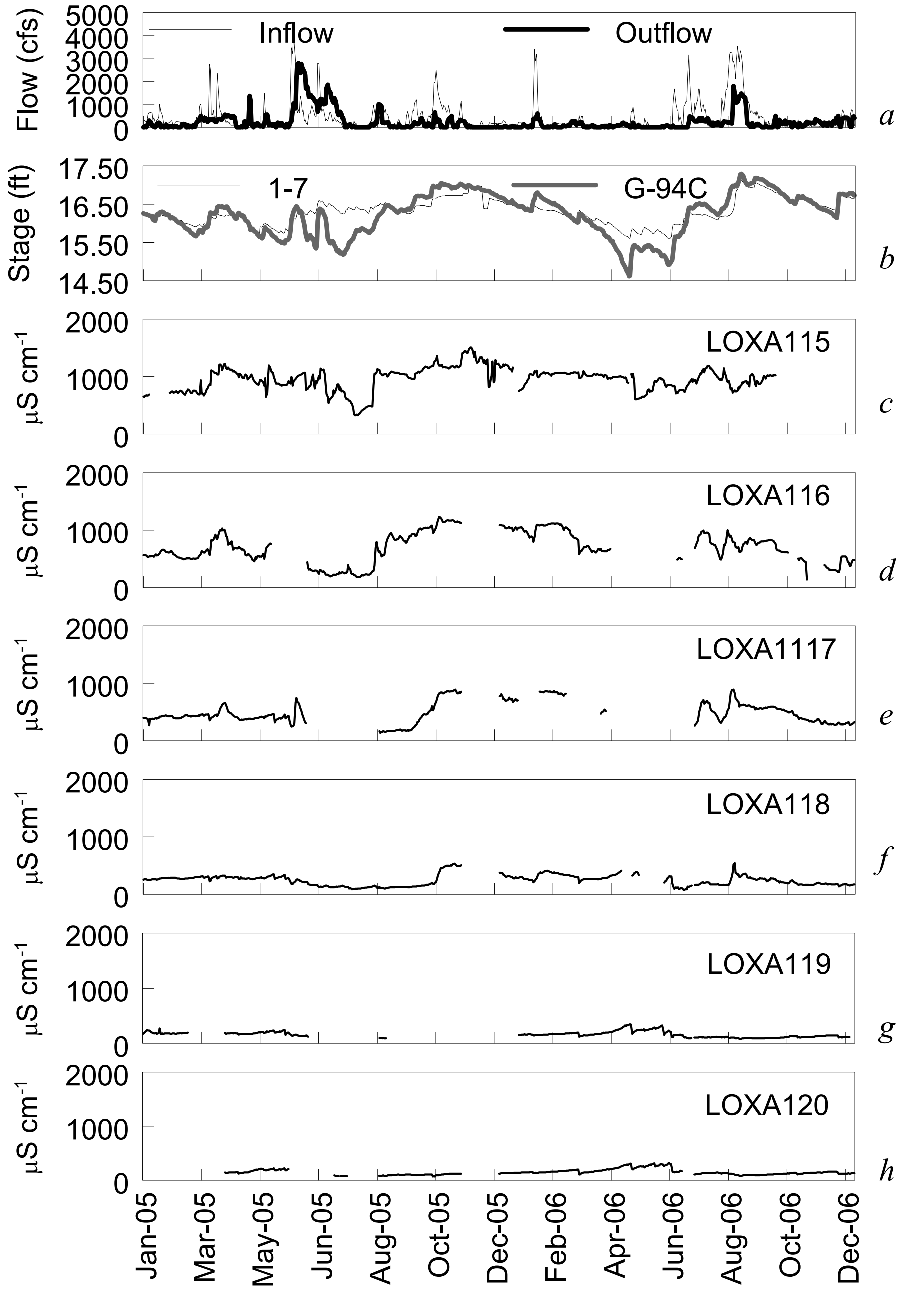

Figure 3-6. a) Inflow and outflow rates (cfs) summed for all structures through 2006. b) Marsh (thin line) and canal (thick line) stage reading from the 1-7 and G-94C stage gages, respectively. Panels c-h are the time-series of conductivity values from the S-6 transect: c) LOXA115, canal site; d) LOXA116, 0.4 km into the marsh; e) LOXA117, 0.9 km into the marsh; f) LOXA118, 1.8 km into the marsh; g) LOXA119, 4.3 km into the marsh; and h) LOXA120, 6.1 km into the marsh.

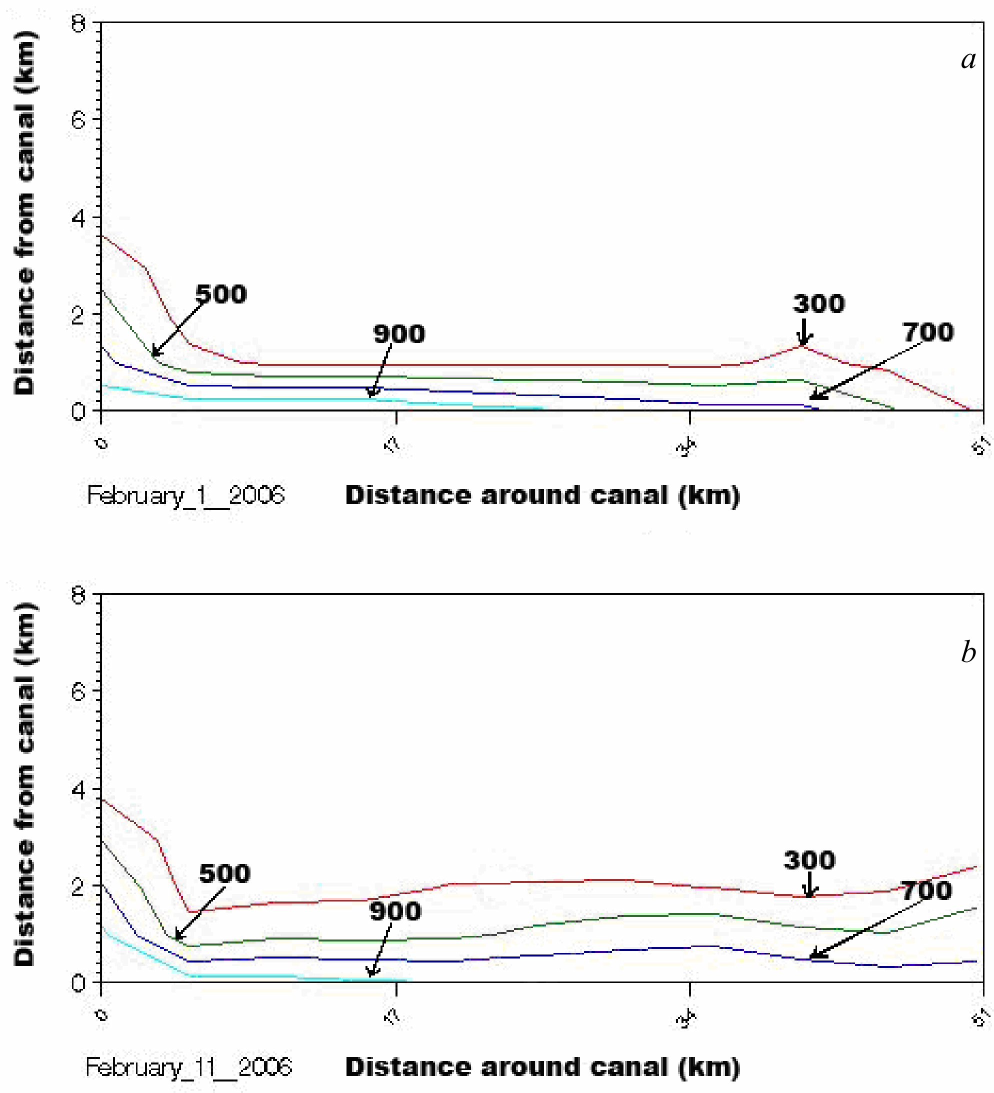

Figure 3-7. a) Pre and b) post -February 2006 rain event conductivity contours for the canal and interior of the Refuge. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals).

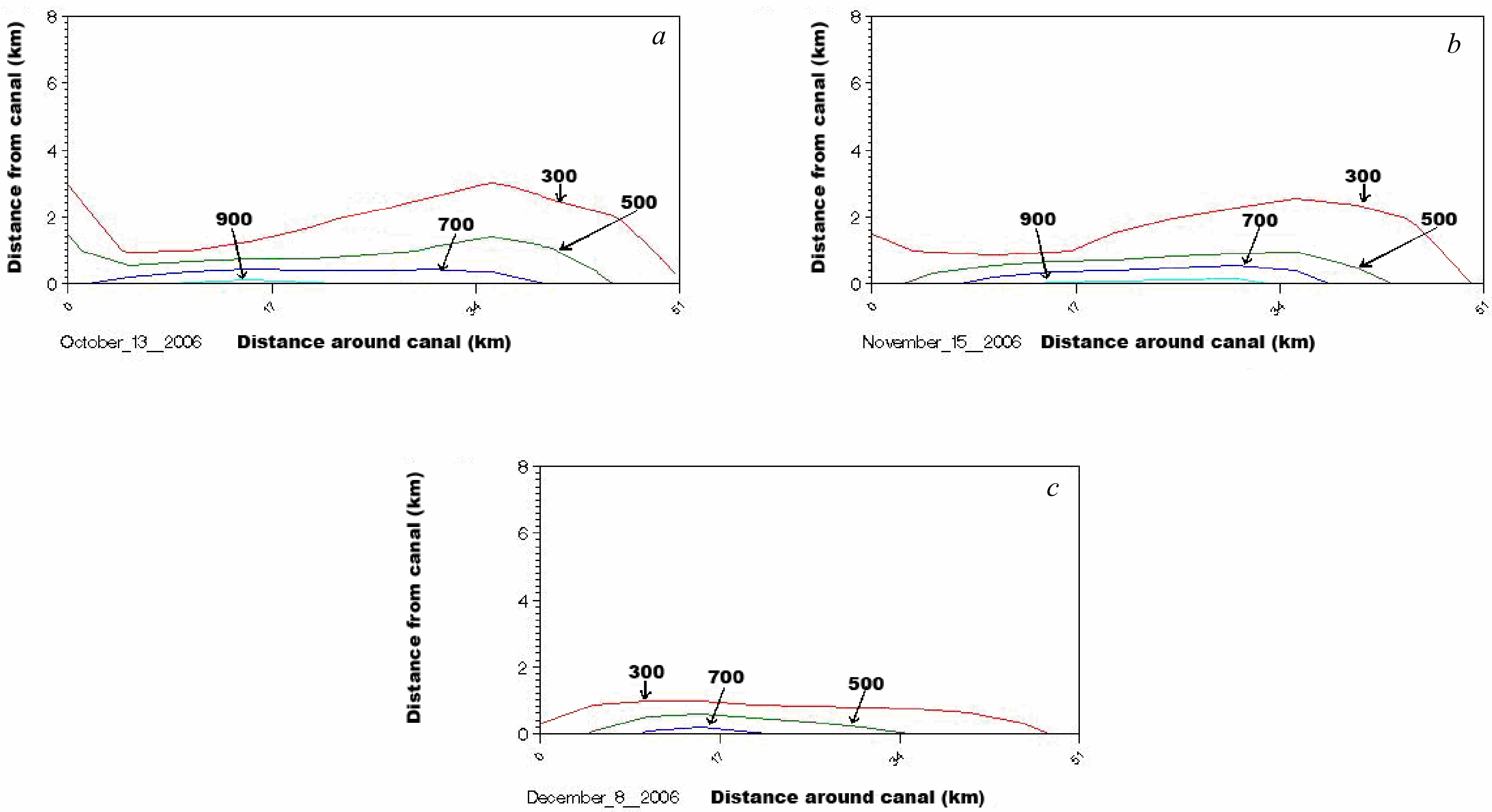

Figure 3-8. a) Intrusion following heavy rainfall from mid-August through September 2006 under high inflow and high outflow conditions (I_H-O_H). b) Intrusion resulting from I_{L-M}-O_{L-M} during the period from mid-October through mid-November 2006. c) Intrusion resulting from I_L-O_{L-M} during the period from mid-October through mid-December 2006. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals).

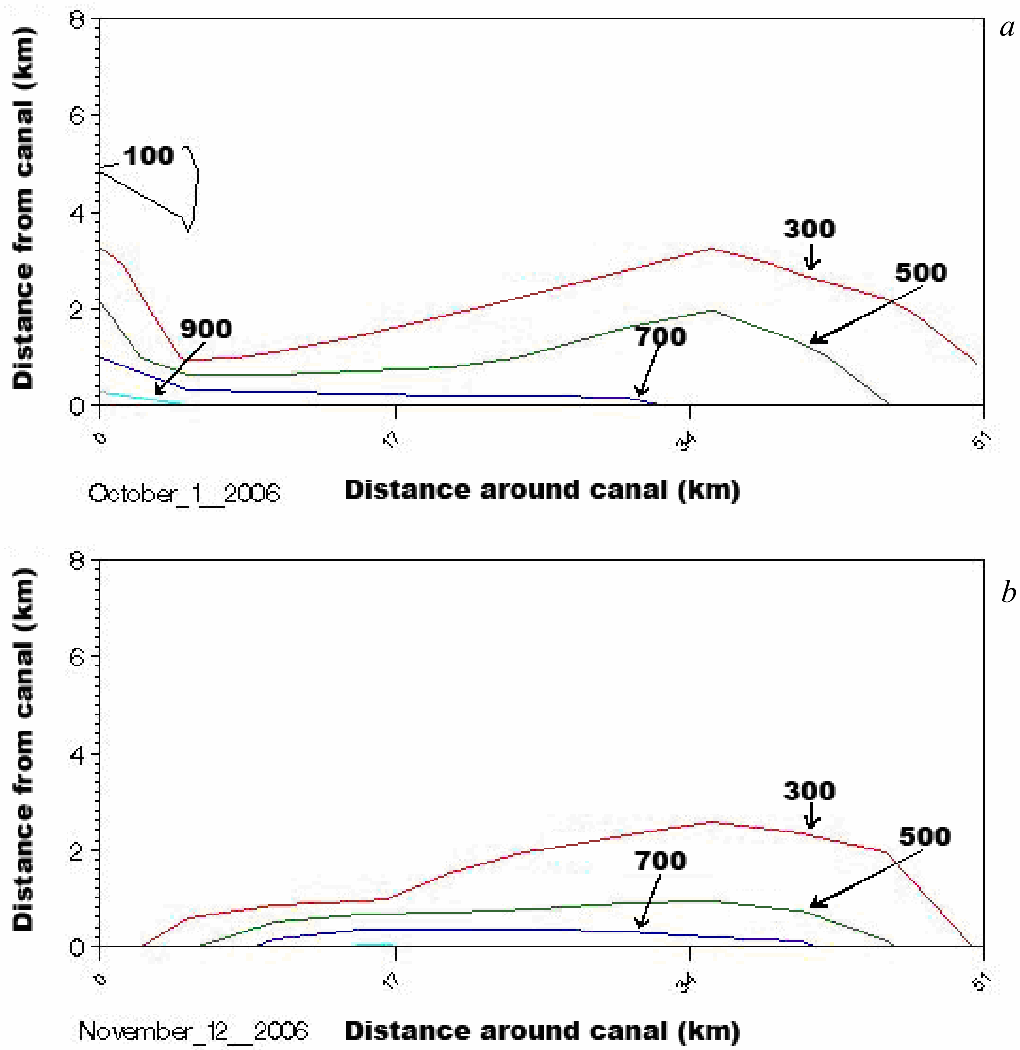

Figure 3-9. a) Intrusion following heavy rainfall from mid-August through September 2006 and prior to the initiation of outflows through the G-301 structure. b) Intrusion after one month of outflows through the G-301 structure. Data were plotted from the mid-west perimeter of the Refuge (0 km on the x-axis) to the mid-east perimeter of the Refuge (46 km on the x-axis). The y-axis represents the distance into the marsh from the canal for each conductivity sonde site established in the Refuge (marsh and canals).

Chapter 4. Hydrodynamic and Water Quality Modeling[5]

Abstract

Hydrodynamic, hydrologic and water budget models coupled with water quality and mass balance models are valuable tools that provide predictions of movement of water and constituents. Models can provide a basis for answering questions about the hydrologic, hydrodynamic and water quality conditions occurring under present conditions and management rules, and project how these processes would be altered by different structural changes and management scenarios. Predictions of hydrologic and water quality conditions can, in turn, support predictions of ecologic processes and conditions if the relationship of ecologic indicators to hydrology and water quality are known. The needed complexity and spatial resolution of a model are dependent on the specific hydrological and ecological system under study, and the nature of the questions being addressed.

This chapter is a status report on an ongoing project to model water and water quality in the Arthur R. Marshall Loxahatchee National Wildlife Refuge. It provides a snapshot of modeling approaches and results presently available. We document the development of water budget, hydrodynamic and constituent models that will be used to provide a quantitative framework for management decisions related to inflow and outflow quantities, timing, and water quality. More detailed modeling results are published or will be published in other reports.

A simple water budget model was developed as a 2-compartment (double-box) completely-mixed flow (CMF) model that predicts canal compartment and marsh compartment volumes and stages. This model, implemented in an Excel workbook, was calibrated for the 5-year period of record between January 1995 and December 1999, and validated with data for a 5-year period from January 2000 to December 2004. Data for the 2-year period from January 2005 to December 2006 are now available and provided a second validation period. Statistical analyses demonstrate the applicability of this model to predict temporal variation of water levels in both the marsh and the Refuge perimeter canal.

A 4-compartment (4-box) model for simple water quality constituents has also been developed. This model is implemented using the USEPA WASP model and is driven by flows imported from the CMF water budget model. The model compartments are in a 1-dimensional configuration representing the canal, and three marsh cells. The model has been configured to simulate chloride (Cl), sulfate (SO_4), and total phosphorus (TP).

MIKE-FLOOD is a coupled one and two-dimensional computer model used for complex hydrodynamic modeling in order to predict spatial and temporal distribution of water. It

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has been configured to simulate water flow and stage inside the Refuge. Results thus far show agreement between observed and predicted stages at specific locations. MIKE-FLOOD includes a constituent mass transport module that simulates advection and dispersion, as well as transport between the canal and marsh. Additionally, a module named ECO Lab provides the capability simulate reactive transport for the complex model. As with the WASP model, the ECO Lab module is being used to simulate Cl, SO_4, and TP.

Future applications of the completed model will examine the impacts, both positive and negative, of management and structural alternatives. The complex hydrological and water quality models could, for example, examine operational strategies that would minimize intrusion of canal water into the Refuge interior. An understanding of any ecological tradeoff between an optimal hydrologic regimen and avoidance of intrusion of the currently high-nutrient canal water is a priority need for management in the short-term until the water quality of Stormwater Treatment Area effluent is good enough to cause no imbalance of Refuge flora and fauna.

Background

Although previous efforts directed at modeling hydrology and water quality of the A.R. M. Loxahatchee National Wildlife Refuge (Refuge) have been of value (Lin 1979; MacVicar et al. 1984; Lin and Gregg 1988; Richardson et al. 1990; Fitz and Sklar 1999; MacVicar and Lindahl 2000; Raghunathan et al. 2001; Munson et al. 2002; Welter 2002), none of these modeling efforts adequately address some of the current Refuge needs. The Refuge is impacted by changes in water flow and stage (Brandt et al. 2000; USFWS 2000; Brandt 2006), excessive nutrient loading (Newman et al. 1997; USFWS 2000) and altered dissolved mineral concentrations including chloride (Swift 1981; Swift 1984; Swift and Nicholas 1987; Browder et al. 1991; Browder et al. 1994; McCormick and Crawford 2006). Hydrodynamic and water quality models have the potential to provide needed management and scientific support related to these concerns.

The goal of the modeling program (Brandt et al. 2004) is to provide best available technical support for management decisions related to Refuge inflow and outflow water quantity, timing, and quality. A water budget model and a two-dimensional hydrodynamic and water quality model for the Refuge were developed to provide a quantitative framework for these management decisions. These models also predict water movement and water quality resulting from alternative operation scenarios, Stormwater Treatment Area (STA) performance, climatic variation and structural changes within the Refuge.

Models can assist managers in decision-making, but alone are not sufficient. Objectives and alternatives must first be defined before alternatives can be compared. When fully calibrated and validated, the models described here should assist in answering questions and provide information such as the questions listed below (Brandt et al. 2004):

- What is the impact of different management scenarios on the water distribution inside the Refuge?
- What is the impact of the management scenarios on the hydroperiod?
- Does the water depth (duration and frequency) satisfy the needs of plant communities and associated wildlife?
- What are the spatial and temporal distributions of phosphorus concentrations within the Refuge?
- What are the impacts of management decisions and strategies on the water quality?
- What are the impacts of alternative regulation schedules on the water quantity (stage) and quality (total phosphorus [TP], chloride [Cl], and possibly other constituents [e.g., sulfate; SO_4]) in the Refuge?
- How does (and what are the effects of) surface and ground water interactions in the Refuge?
- What was the impact of moving the location of inflows?
- How do new inflow volume and concentration boundary conditions representing STA design alternatives impact the Refuge hydrology and water quality?

These models will provide a necessary tool supporting investigation of these questions, but, for most questions, these Refuge models are not sufficient alone to answer these questions. Questions related to ecological change require a definition of how water quality and quantity impact Refuge communities. For example, the models may predict water depths and flows, and nutrient concentrations, but prediction of changes in distribution of species such as cattail or sawgrass may require further research, assumptions or modeling. Similarly, the Refuge models can only predict the effects on the Refuge of changes outside of the model's domain, Water Conservation Area (WCA) 1, if the changed boundary flows and concentrations that result from these changes are defined by other models or assumptions. The Refuge model can predict these effects of external changes if appropriate altered boundaries are input to the Refuge model. Project analyses using the Refuge models will necessarily require predictions from other models of project-related impacts to the Refuge model boundaries. For example, analyses of impacts to the Refuge from the EAA Feasibility Study alternatives (A.D.A. Engineering and SFWMD 2005) require specification of quantity and quality of inflow to the Refuge under each alternative scenario.

It is a priority for the Refuge to ensure an appropriate Water Regulation Schedule and structure operations that will produce maximum benefits for fish and wildlife, flood control and water supply. It is also a priority to better understand and to minimize the impact of excessive nutrient loading. The main goal of this modeling effort is to provide a quantitative framework for management decisions related to water quality, quantity and timing. This goal is being accomplished through the development of two models: (a) a water budget-mass balance model; and (b) a complex hydrodynamic-water quality model. This chapter provides a status update from the 2nd Annual Report (USFWS 2007) on the lumped compartmental and the more complex spatially explicit modeling approaches. This chapter provides a brief overview of the status of the modeling program. The reader is directed to the reports cited herein for detailed information about specific modeling aspects.

The modeling studies are assisted and reviewed by an independent panel. The modeling Technical Advisory Panel met last on October 27, 2006 in Lafayette, Louisiana. This panel had previously met in a public session in West Palm Beach in late 2005. This expert panel is chaired by Dr. Vincent S. Neary (Tennessee Tech Univ.). Members of the panel, Drs. Malcolm L. Spaulding (Univ. of Rhode Island) and J. Alex McCorquodale (Univ. of New Orleans) were selected by Dr. Neary. At the October 2006 meeting, presentations were made to the panel on all aspects of modeling completed to-date and other aspects planned. The panel provided valuable questions and comments following the presentations and submitted a written report in early 2007.

The first of two planned modeling workshops to present modeling status and results was held on June 18, 2007. This workshop was attended by state and federal agency representatives, university researchers and others. A second workshop is planned for August 2007. Workshop presentations are currently available at http://loxmodel.mwaldon.com.

Compartmental Modeling

Water budget modeling

A completely-mixed flow (CMF) water budget model was developed for the Refuge (Arceneaux et al. 2006; Arceneaux 2007; Arceneaux et al. 2007; Meselhe et al. 2007) and is now available for use (model and documentation can currently be downloaded at: http://loxmodel.mwaldon.com/). This model predicts canal and marsh stages from observed inflow, outflow, precipitation, and evapotranspiration (Figure 4-1). The simplified water budget model was developed to predict temporal variations of water levels in the canal and in the marsh based on user-specified inflow and outflow conditions of the boundary hydraulic structures.

Canal and marsh stages are calculated in this model from the differential equations:

$$\frac{dE_C}{dt} = P - ET - G_C + \frac{(Q_{in} - Q_{MC} - Q_{out})}{A_C} \qquad (1)$$

and,

$$\frac{dE_M}{dt} = P - ET - G_M + \frac{Q_{MC}}{A_M} \qquad (2)$$

where P and ET are respectively precipitation and evapotranspiration, G_C and G_M are loss to groundwater, A_C and A_M are surface areas of canal and marsh, and Q_{in} Q_{out} and Q_{MC} are the volumetric flows into the canal, out of the canal, and between the canal and marsh. This box-model is computationally efficient and can perform decadal simulations in minutes. This feature allows the Refuge managers to assess various management strategies quickly and efficiently, at least on a preliminary basis. This model allows rapid testing of model sensitivity to parameters, and support quick tests of a broader suite of management scenarios than can feasibly be examined and verified using the more complex spatially explicit model.

The water budget model was calibrated using the period from 1995 to 1999, and validated with data from 2000 to 2004. Recently, the period 2005 to 2006 have also been applied in model validation. Total annual flow volumes over this period have included a range of meteorological conditions (Figure 4-2). Model results fit well with observed stage (Figure 4-3). Bias, root mean square error (RMSE), correlation coefficient (R), variance reduction, and the Nash Sutcliffe efficiency (Nash and Sutcliffe 1970) were performed for the calibration and validation periods (Arceneaux et al. 2007).

Observed and predicted stages for the marsh are in better agreement than the observed and predicted values for the canal. Some reasons for this variation include: (1) the area for the perimeter canal was assumed constant; (2) the variability of the water level is greater in the canal than in the marsh; (3) the emphasis during the calibration was to match the observed marsh stages with the model prediction; and (4) water supply delivery flows through G-94A, G-94B and G-94C (see Figure 2-1), prior to 2000, were unavailable, and set to zero.

<u>Annual constituent loads as basis for compartmental chloride and phosphorus modeling</u>

Annual mass loads for Cl and TP were calculated to gain improved understanding of the processes affecting Refuge water quality. Chloride mass loads provide a useful insight into water movement because chloride uptake or release by biological or chemical processes in surface water is insignificant in relation to surface water concentrations. Thus, chloride acts as a natural conservative tracer of water flow. Unlike water inflow and outflow volumes, chloride annual inflow load was found to consistently exceed outflow load over the period 1995-2004 (Figure 4-4). This, we conclude, demonstrates that measurable quantities of chloride, and presumably other constituents, are discharged from the Refuge through groundwater flow.

Total phosphorus annual load has a pattern similar to that exhibited by Cl (Figure 4-5), but typically exhibits a more reduced outflow load relative to inflow loads (Figure 4-6). We interpret this as showing that while some TP is lost through groundwater flow, a significant portion of the TP load is also sequestered within the Refuge. Calendar year 2004 is exceptional, having more TP discharged through outflow than entering through inflow (Figures 4-6 and 4-7). It is conjectured that this net TP export in 2004 resulted from the multiple hurricanes that affected the Refuge through direct impact and runoff in September 2004 (Waldon 2006). The observed average canal concentration greatly exceeded modeled concentration that month (Arceneaux et al. 2007) suggesting a mechanism was active at that time that was not represented in the model structure. It is conjectured here that this mechanism was entrainment of canal sediments from water velocity and wind-induced turbulence.

<u>Compartmental chloride and phosphorus modeling</u>

The 4-compartment model has been applied to Cl, SO_4, and TP in the Refuge (Arceneaux 2007; Arceneaux et al. 2007). The spatial conceptualization of the model is mapped in Figure 4-8, and the model structure is diagrammed in Figure 4-9. Flows driving the constituent model are imported from the water budget model. Flows between marsh compartments are calculated assuming a flat-pool. Despite data limitations for Cl, current modeling results for Cl (Figure 4-10) are encouraging. Total phosphorus was modeled using a simple k-c* formulation that was unlikely to match transient TP concentrations observed in the marsh. Modeling for TP is less reliable (Figure 4-11), and in its current formulation is unsuitable for use as a management tool, but could be useful for research purposes. Efforts are underway to improve the TP model by using a more complex model structure analogous to that used in the DMSTA model (Walker and Kadlec 2002). Sulfate modeling is currently under development, and preliminary results are quite encouraging.

Model improvements are currently under investigation. One improvement suggested by the modeling Technical Advisory Panel is to provide a more quantitative basis for compartment mapping, as well as for the number of compartments utilized. Cluster analysis of observed data is being applied to suggest a new compartmental model structure.

The WASP model has proven to be a convenient and user friendly platform for initial constituent model implementation. A need is now recognized for added flexibility in testing new model structure. In particular, we plan to increase the number of compartments in both the water budget and constituent models, and add new constituent dynamics for SO_4 and TP. The STELLA™ simulation platform (isee systems, inc., Lebanon, NH, www.iseesystems.com) will be considered for implementation of these new model structures.

Fully-Dynamic Spatially-Explicit Modeling

Many management needs require a higher spatial resolution than is available through compartmental modeling. Although relatively flat, spatial topographic detail can affect water constituent patterns (Figure 4-12). Model prediction of higher resolution spatial variations of stage, flow, and constituent concentrations can be only obtained using a spatially explicit (two-dimensional) numerical model and it is necessary to use a dynamic spatially-variable numerical model. These spatially complex models, however, are far less computationally efficient, more difficult to operate, and their results are less easily presented and interpreted. We are therefore pursuing a mixed modeling strategy, implementing complex dynamic spatially explicit models to complement development and application of compartmental models. These spatially explicit models simulate the same period as the compartmental models, calendar years 1995 through 2006.

<u>Hydrodynamic and constituent modeling</u>

The MIKE FLOOD model is a widely-used, user-friendly, proprietary suite of linked modeling modules. The MIKE 21 model uses a structured Cartesian grid within a suite of modeling programs that include hydrodynamic (DHI Water & Environment 2005c), advection/dispersion (DHI Water & Environment 2005b), and ecological modeling (DHI Water & Environment 2005a) modules. The MIKE FLOOD model for the Refuge has been calibrated for the five-year period of record from January 2000 to December 2004. The model was validated for the five-year period from 1995-1999, and two-year period 2004-2006. Bias, root mean square error (RMSE), correlation coefficient (R), variance reduction and the Nash Sutcliffe efficiency (Nash and Sutcliffe 1970) were performed for the calibration and validation periods. Full calibration and validation statistics will be reported in future reports. Calibration of the advection-dispersion module used Cl as conservative tracer. A current simulation of central Refuge stage at the 1-7 gage is presented in Figure 4-13 as an example of model results.

The ECO Lab module (DHI Water & Environment 2005a) is now being used to model Cl dynamics, and the ECO Lab module will soon be extended to implement sulfate and total phosphorus concentration models. This water quality model will aid in the understanding of how different structure operations and management scenarios (structural alterations, management decisions, strategies and regulations) affect the water quality in the Refuge. The model will help to identify how water quality may be altered and how the spatial and temporal distribution of TP inside the Refuge may be altered given a particular management scenario.

Chloride is being modeled as a conservative constituent and TP will be modeled using the DMSTA differential equations using the DHI ECO Lab software to link the MIKE FLOOD advection dispersion module results to the constituent dynamics. Example results for Cl are presented in Figure 4-14.

Future modeling extensions and refinements currently being considered include:

- Improved modeling Refuge hydrodynamics at low marsh stages through improved modeling of surface water – groundwater interactions;
- Enhanced post-processing tools for models automating selected performance metrics and Habitat Suitability Indices (HSIs);
- Comparison with other model results including (but not limited to), if feasible, SFWMM, ATLSS, ELM, and EDEN; and
- Documentation of additional monitoring needs for model performance improvement including rainfall, water velocity, and wind speed and direction.

Model Application

A goal of the modeling is to define and simulate alternative management strategies. Performance measures, HSIs, and descriptive statistics, as well as spatial mapping, will be used in comparison of alternatives. Examples of scenarios that may be simulated include:

- Given a projected inflow condition, project the temporal and spatial pattern of water depths. Determine the area of the Refuge that will have suitable conditions for wading bird foraging and estimate duration. The complex model will be used for this purpose.
- Analyze benefits and impacts of revisions to the Refuge's Water Regulation Schedule. This analysis may include changing zone boundary stages or the sequence in which water supply make-up water is delivered. The simplified and the complex models will be used for this purpose.
- Analyze changing the temporal and spatial distribution of outflow for water delivery to WCA-2 and the urban areas to the east. It is conjectured that water quality benefits are maximized by gate openings that minimize the east-west canal stage difference across the Refuge. The simplified and the complex models will be used for this purpose.

- Test operational alternatives for pumps and outflow structures to find ways to reduce effluent intrusion. The simplified and the complex models will be used for this purpose.
- Estimate the long-term impact on interior Cl concentration resulting from discharge by the STAs. The simplified and the complex models will be used for this purpose.
- Test changes in hydroperiod and water quality resulting from possible alternative designs for CERP project KK, the "Loxahatchee National Wildlife Refuge Internal Canal Structures." (USACE and SFWMD 1999) The complex model will be used for this purpose.
- Estimate water quality improvement at interior stations that would result from meeting 10 ppb TP concentration at all inflows. The simplified and the complex models will be used for this purpose.
- Estimate the long-term impact (spatial extent) on interior TP concentration resulting from discharges by the STAs that exceed 10 ppb (e.g., STA-1W outflow of 100 ppb). The complex hydrodynamic and water quality models will be used for this purpose.
- Estimate the spatial impact of STA bypass (untreated water) on the Refuge.
- Analyze the benefit of diverting part or all urban water supply flows around the Refuge.
- Explore other operational changes that reduce the impact of external loads on interior stations. The simplified and the complex models will be used for this purpose.

Summary

Initial modeling efforts of the Refuge have been completed. Two modeling workshops demonstrating the results of modeling research were planned and one has been completed at the time of this writing. The models developed here will provide insight into the spatial and temporal variation of flow conditions (stage and velocity), and constituent transport and transformation within the marsh and in the perimeter canal. These models will provide a valuable tool supporting Refuge management.

The modeling effort began with an in-depth review of important hydrodynamic and water quality processes occurring in the Refuge, historic publications on Refuge and Everglades modeling and data availability. Significant effort was directed at model selection, with a final strategy, supported by the modeling Technical Advisory Panel, to utilize a dual modeling approach. This approach combines efforts to develop a CMF water budget and constituent mass balance model (otherwise termed a box or compartmental model), with development of an implementation of a MIKE-FLOOD/ECO Lab spatially explicit model. The CMF model is efficient, providing excellent spatially-averaged marsh and rim-canal projections for water stage and Cl. At this time the CMF model for TP is not reliable for predicting concentrations in the Refuge interior. This research has applied sound scientific principles and approaches to the setup of both the CMF and MIKE FLOOD models. Initial CMF simulations helped identify model data needs and knowledge gaps. The dual modeling approach increases overall confidence in numerical predictions.

It should be recognized that data availability constraints limit rigorous model calibration and validation. Despite specific data deficiencies, potential success of the hydrodynamic model and the phosphorous fate and transport model is good. It is imperative to identify additional monitoring data needs to support future modeling efforts

These tools are not regional models and can not project the response of the natural system outside the Refuge's boundaries to any management alterations. Influences such as stages and flows outside the model boundary may influence conditions inside the Refuge. The model can provide detailed information about the response of the Refuge to regional management changes and alterations. However, the impact of regional changes on the Refuge model boundary conditions must be assumed or obtained from regional modeling efforts (e.g., the SFWMM). The hydrodynamic model is not designed to accurately project stage and flow near flowing structures. The limit of this restriction is difficult to quantify, but needs to be considered in application of modeling results. The user must therefore also be cognizant of this model limitation.

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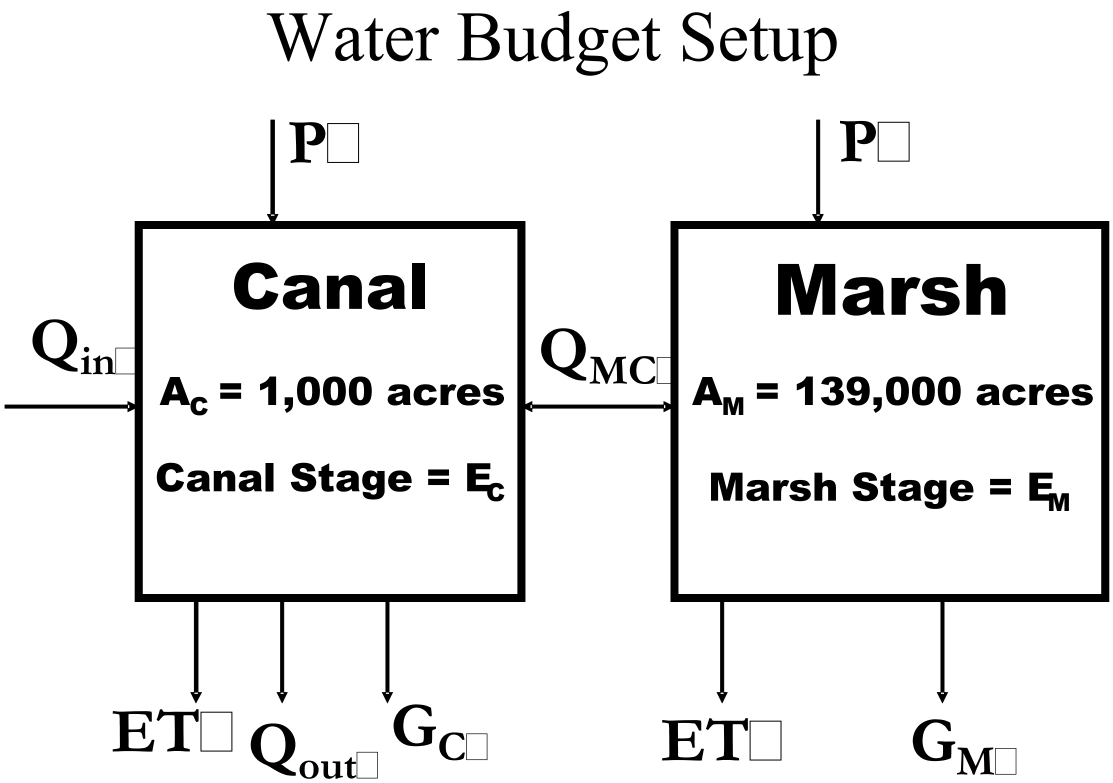

Figure 4-1. Refuge 2-box CMF water budget model structure (Arceneaux et al. 2007).

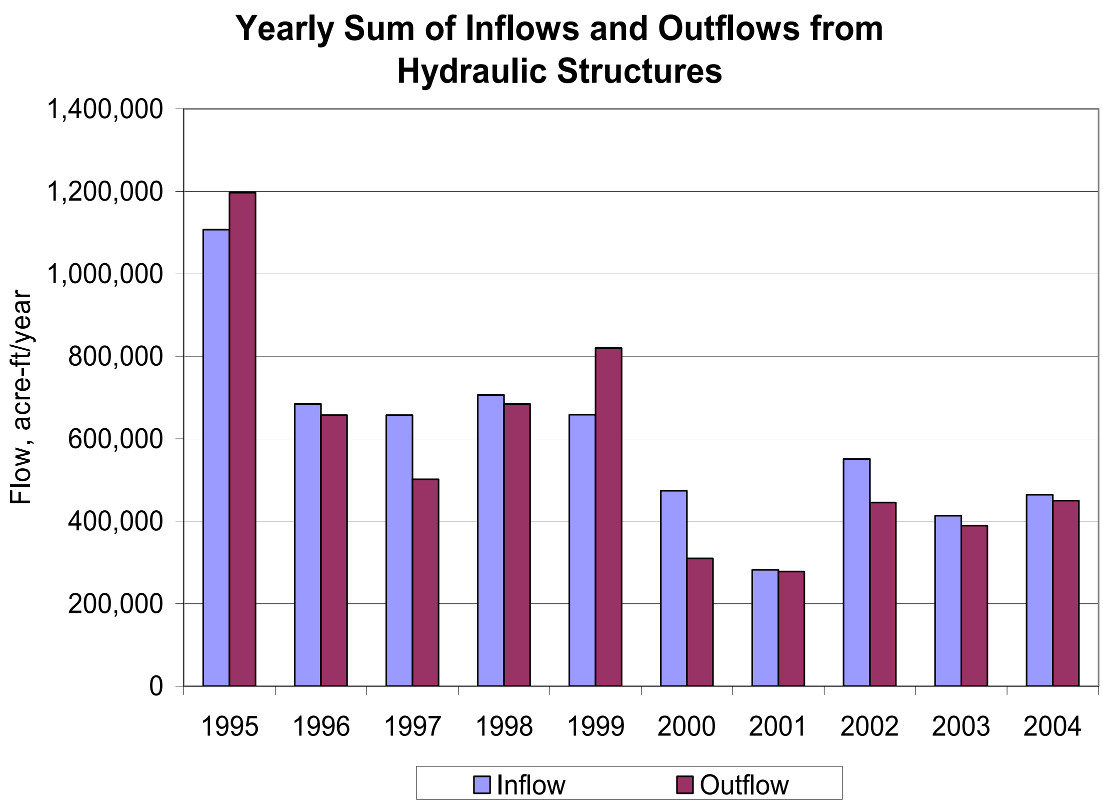

Figure 4-2. Refuge total annual (calendar year) inflow and outflow over the period of simulation.

(a)

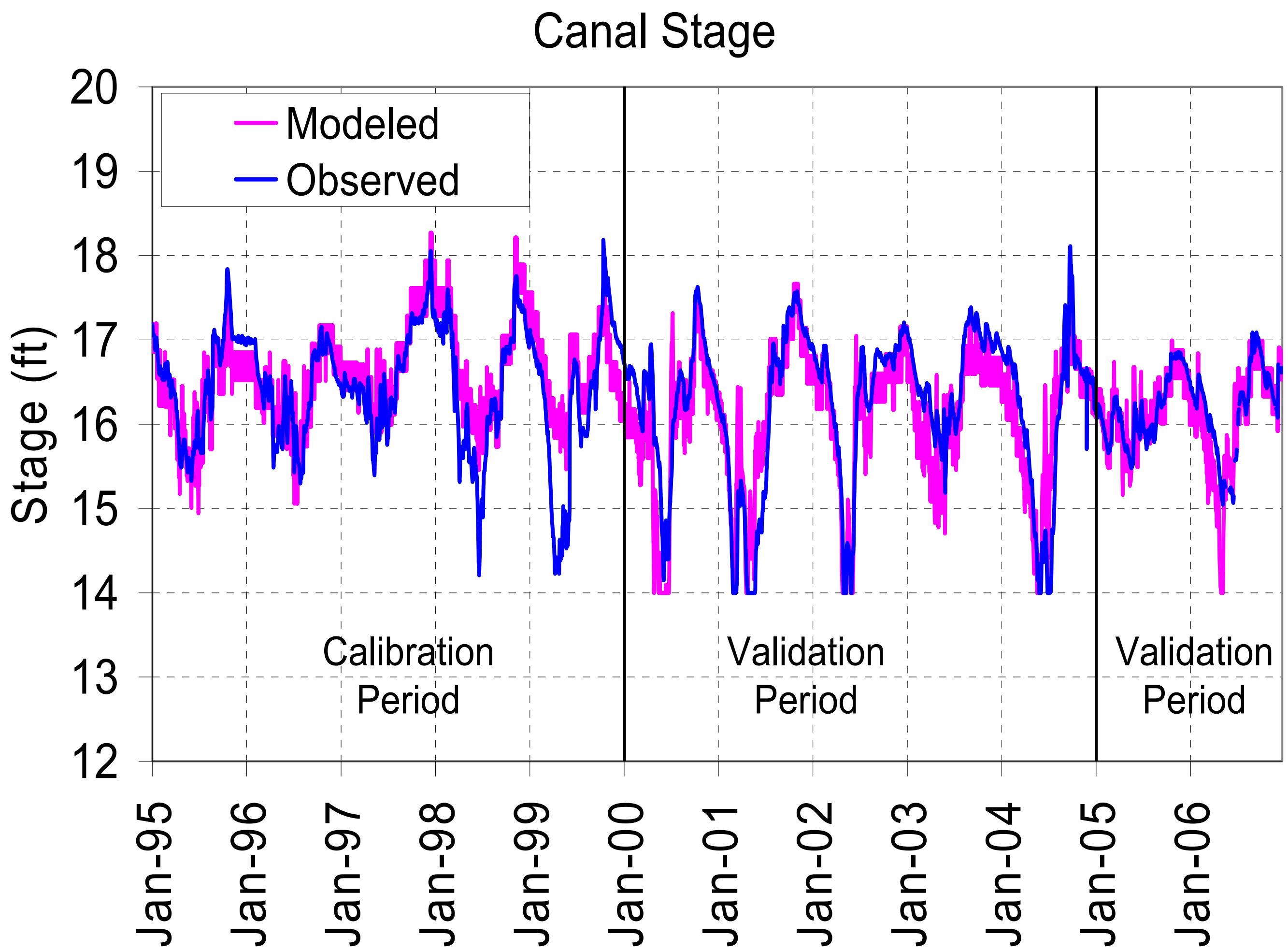

Figure 4-3a. Modeled and observed stage in the Refuge canal (a).

(b)

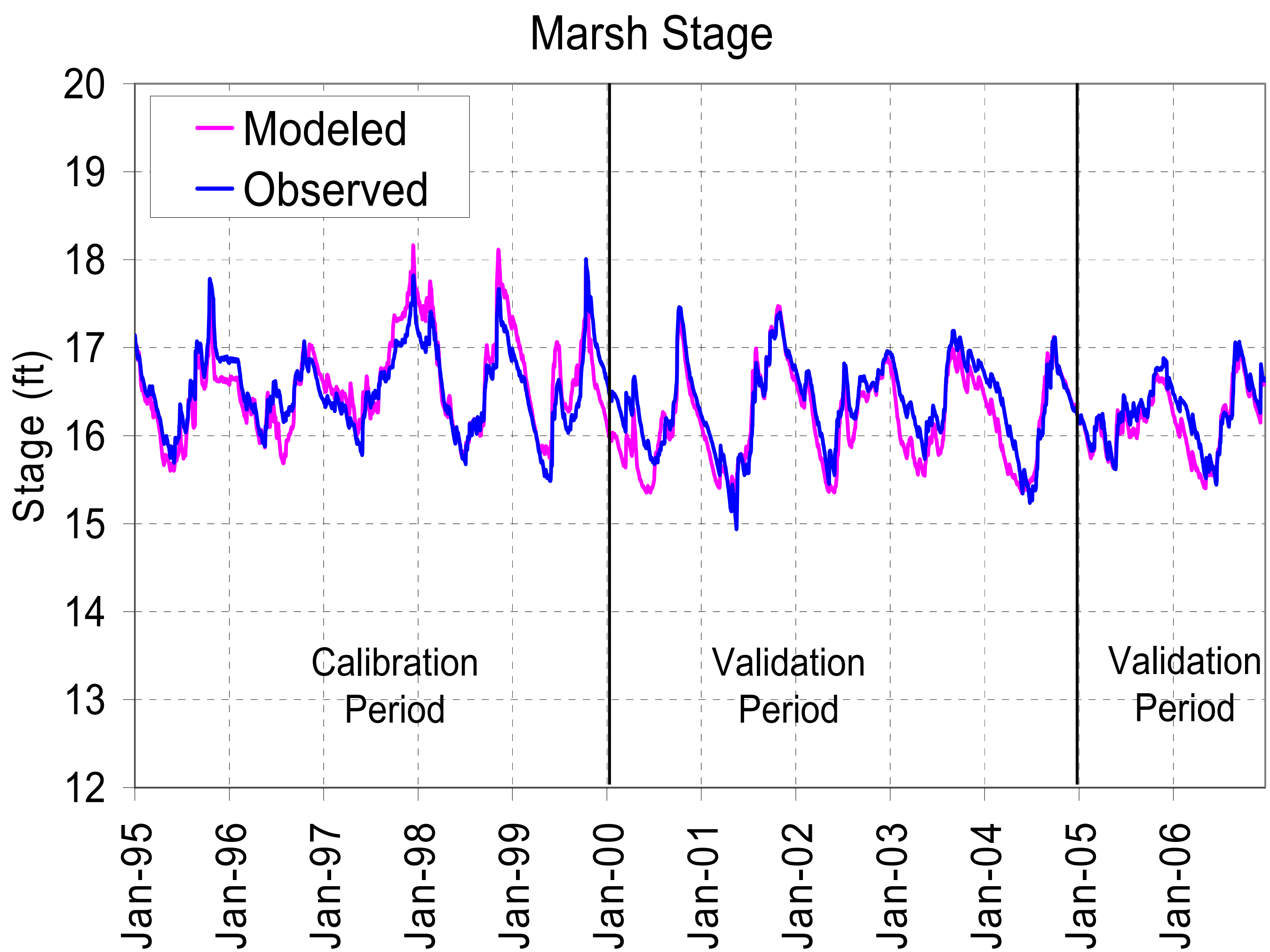

Figure 4-3b. Modeled and observed stage in the Refuge marsh (b).

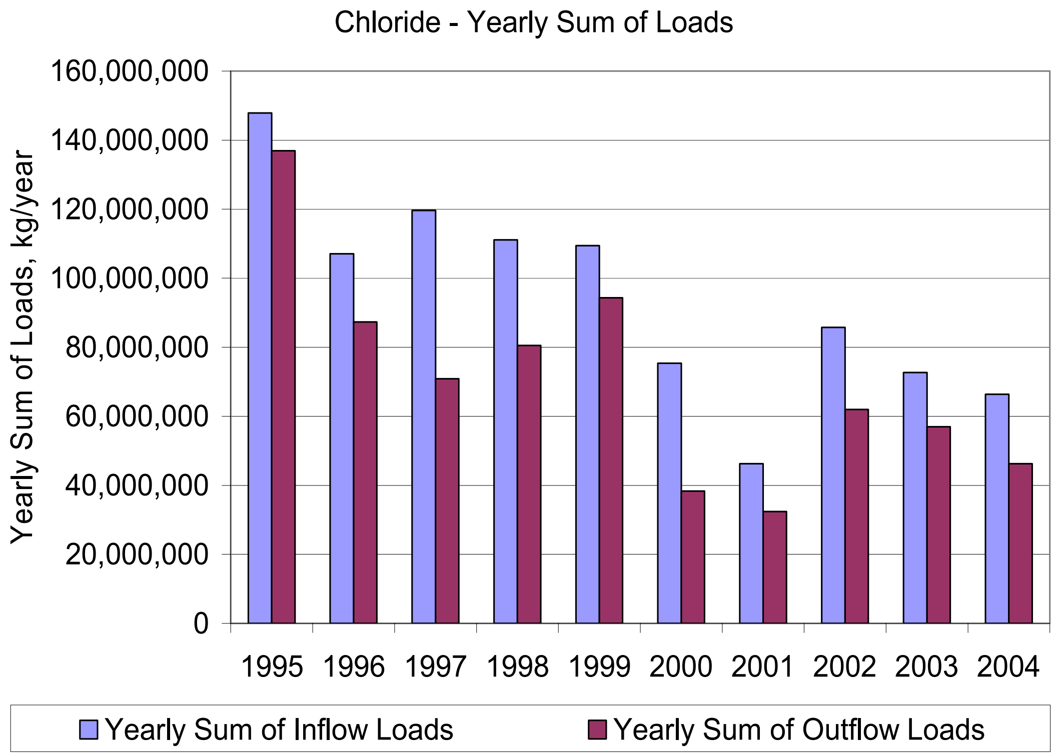

Figure 4-4. Annual (calendar year) Refuge chloride inflow and outflow loads.

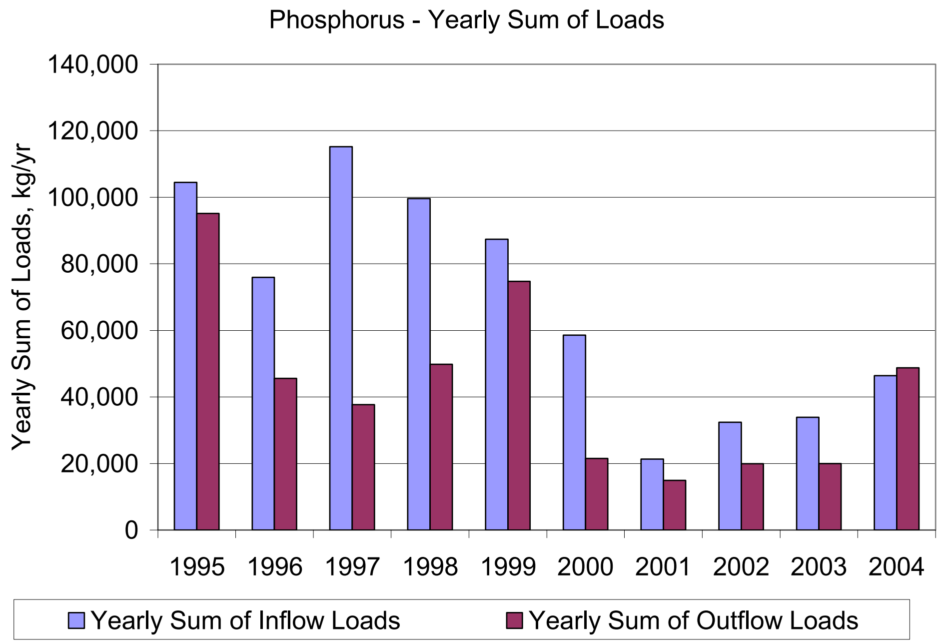

Figure 4-5. Annual (calendar year) Refuge total phosphorus inflow and outflow loads.

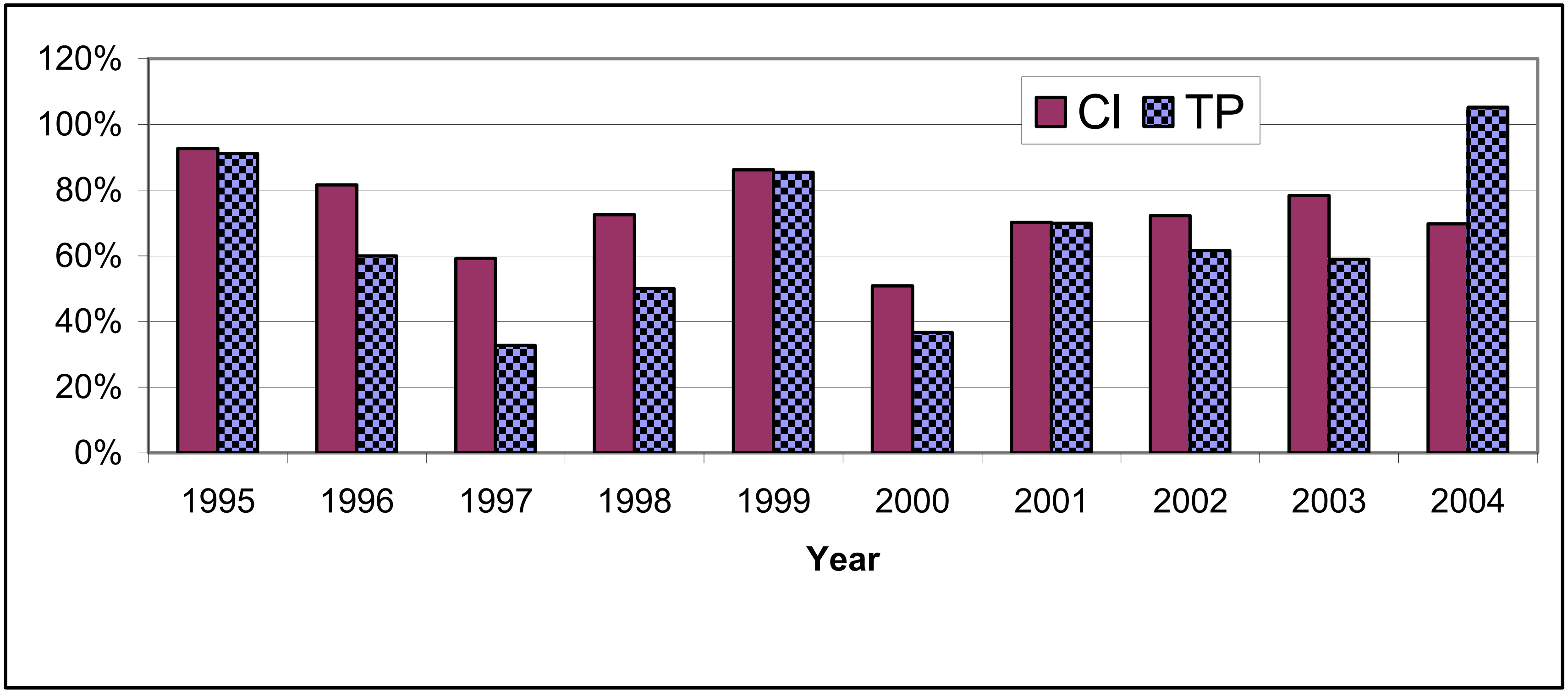

Figure 4-6. Total annual (calendar year) observed outflow load as a percent of inflow load for chloride and total phosphorus.

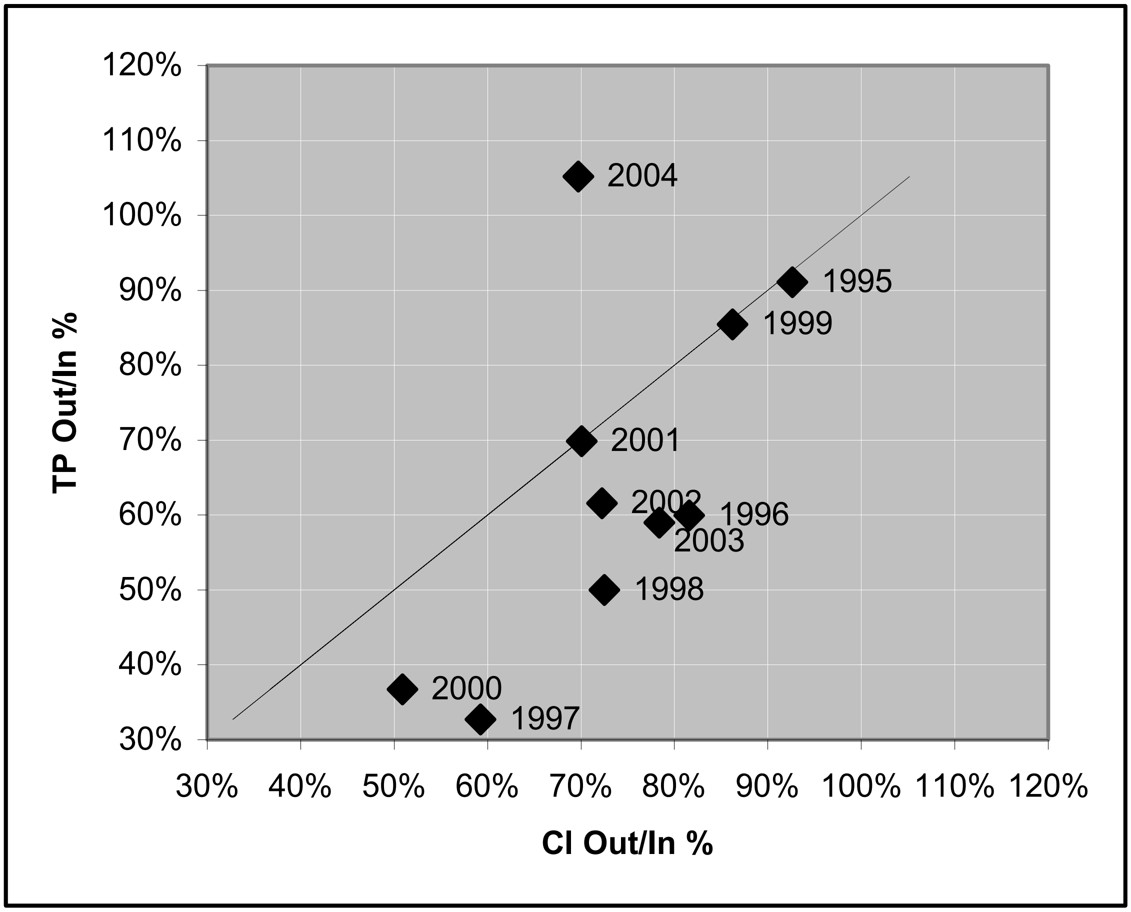

Figure 4-7. Total annual outflow loads as a percentage of inflow loads for total phosphorus are plotted against chloride for the calendar years of study 1995-2004. The line traces a 1:1 ratio between the percentages.

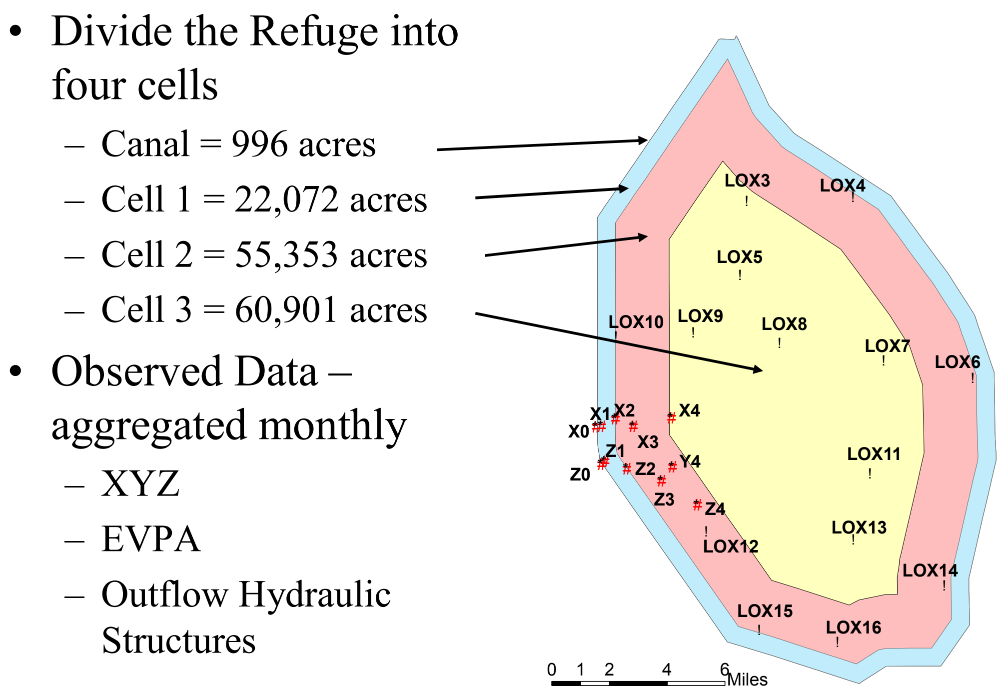

Figure 4-8. Compartment structure of the Refuge 4-compartment water quality model. The locations of water quality monitoring sites used in calibration are shown. Additional stations were used for the 2004-2006 validation period.

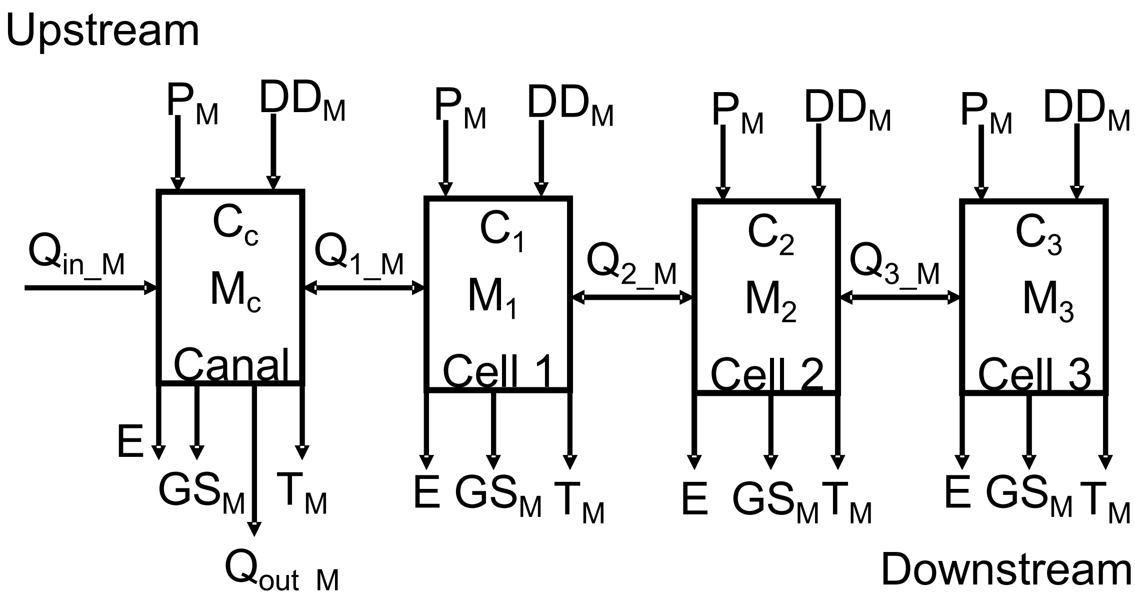

Figure 4-9. Constituent model structure is a one-dimensional series of compartments including a canal (left-most box) and marsh cells (three right boxes). Precipitation (P) and dry deposition (DD) contribute mass while groundwater recharge (G) and transpiration driven flow (T) remove mass. Mass is assumed to not be transported with evaporation (E) flow. Flow between cells, Inflow, and outflow (Q) are imported from the water budget model.

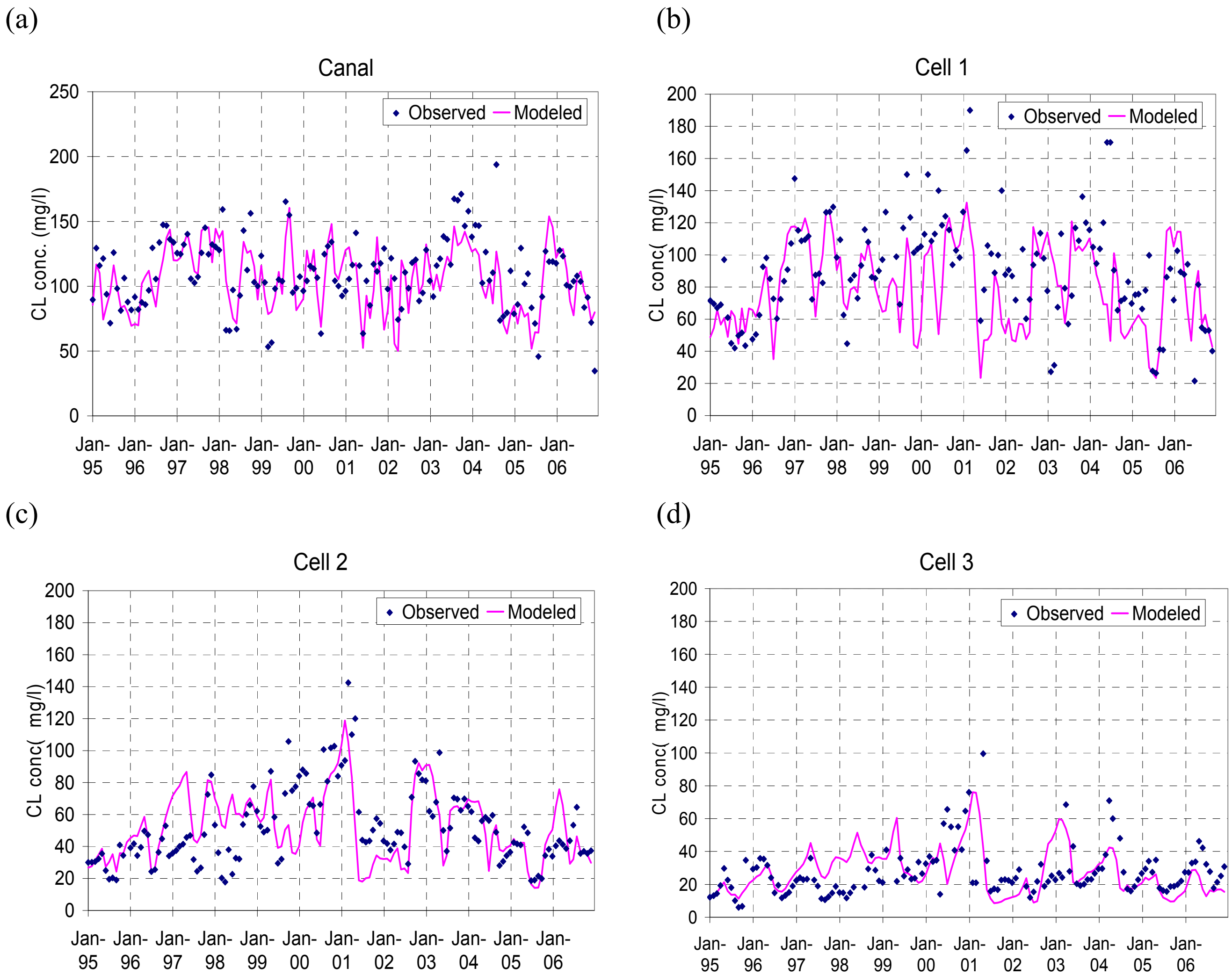

Figure 4-10. Chloride model results are compared with observed average values in each cell.

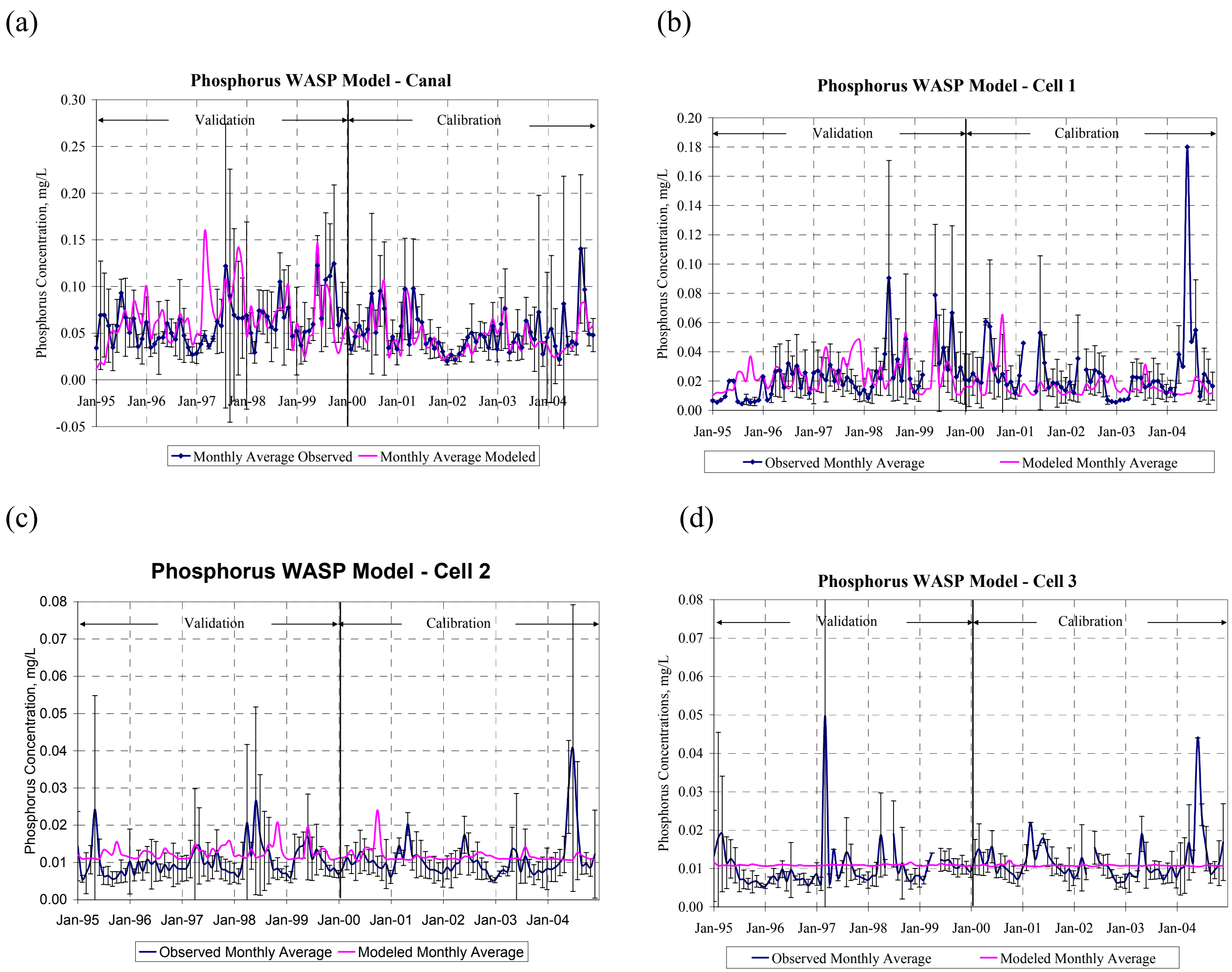

Figure 4-11. Total phosphorus model results are compared with observed average values and standard deviation in each cell.

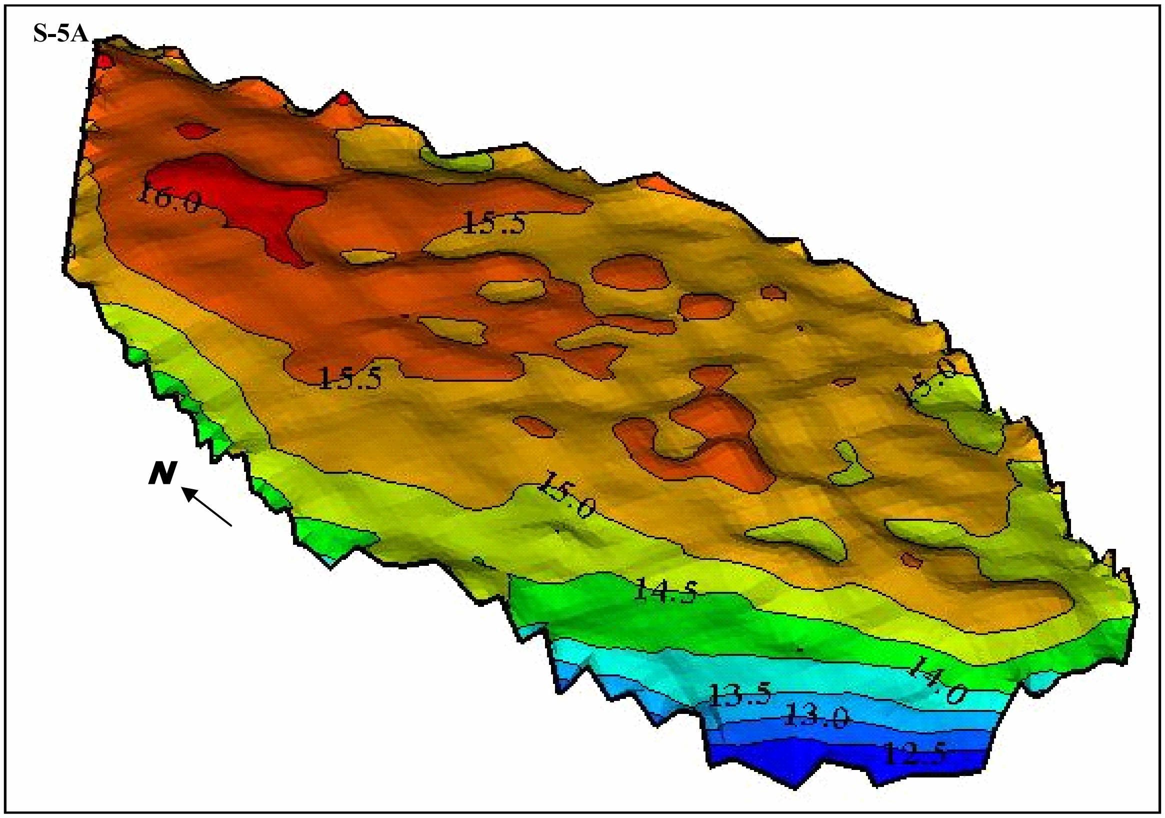

Figure 4-12. Topography of the Refuge (in feet NGVD 1929) based on USGS published (Desmond 2003) elevations are illustrated. For reference, a north arrow and the S-5A inflow pump at the northern boundary of the Refuge are shown.

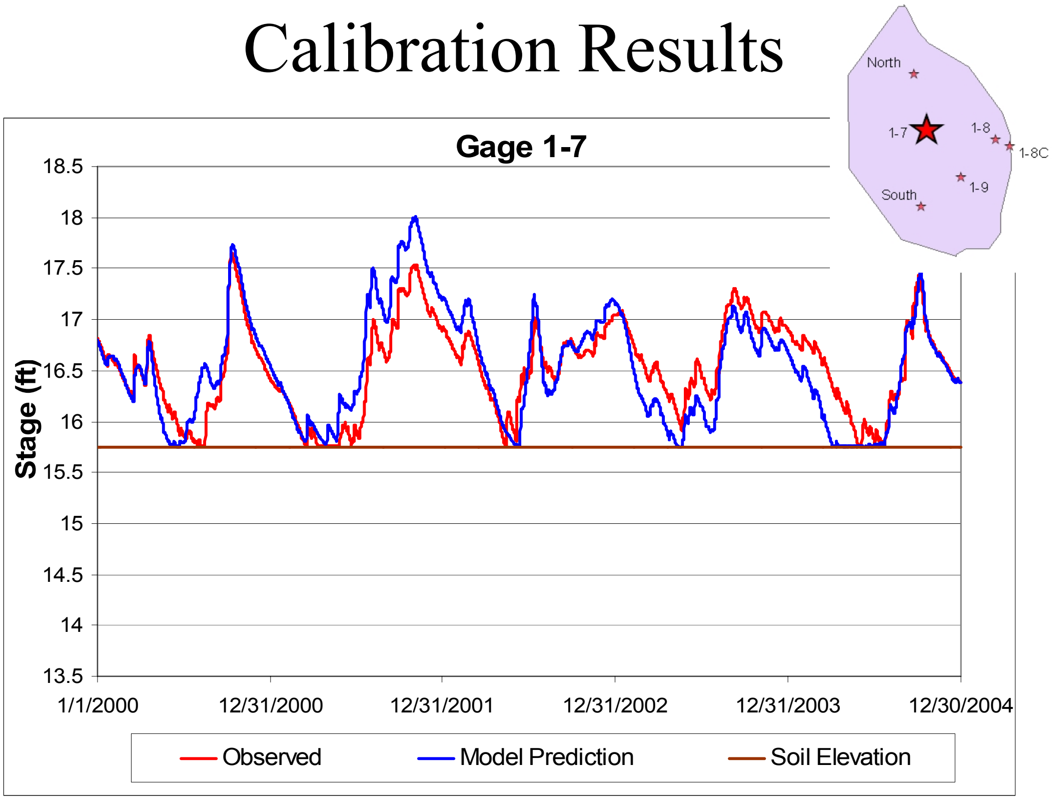

Figure 4-13. Observed and simulated stage at the 1-7 gage (shown by a ★ in the inset map). The MIKE-FLOOD model continues to be under development.

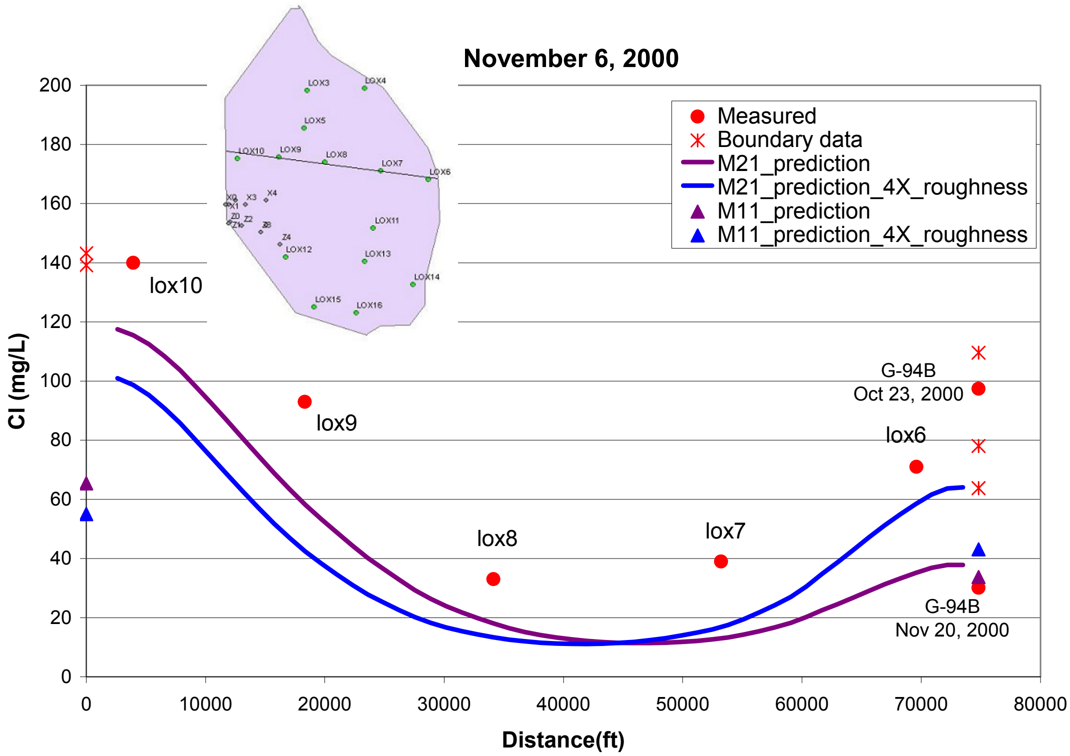

Figure 4-14. Simulation of chloride across a Refuge MIKE-21 (M21) marsh transect (shown by the line in the inset map) is compared here to observed values. Simulations with two levels of marsh roughness are compared. The MIKE-11 (M11) canal simulation results and observed values are plotted at each end of the transect.

Chapter 5. Synthesis of Findings[6]

Background

The general purposes of the Refuge's water quality monitoring and modeling program are to improve the scientific understanding of Refuge water quality and to provide an improved scientific foundation for water management decisions to protect Refuge resources. In this program, we: (1) improved the spatial coverage and extent of water quality monitoring to better characterize the entire marsh; (2) documented changes in marsh conductivity along transects from the canals to the interior in response to water management; and (3) applied modeling tools for support of Refuge management decisions and planning related to water management operations, water supply, and water quality.

Water Quality Characteristics of the Fringe Marsh

The Refuge marsh was classified for analyses based upon conductivity data variability and changes in overall conductivity with perpendicular distance from the perimeter canal into the marsh interior (USFWS 2007). In general, water quality data for 2006 continued to indicate that the Perimeter Zone (extending from the canal up to 2.5 km (1.6 miles) into the Refuge marsh) is subject to canal water intrusion. In addition, canal water occasionally was observed in the Transition Zone (extending from 2.5 to 4.5 km (1.6 to 2.8 miles) into the marsh). These findings are of concern because this area may be exposed to poor water quality and resulting ecological impacts. Although canal waters were clearly impacting the Perimeter and Transition Zone in 2006, the variability in water quality parameters in these zones and the Interior Zone was lower than observed in 2004 and 2005. Perimeter Zone conductivity is driven partly by differences between canal and marsh stages. Conductivity in the Perimeter Zone consistently is greater than conductivity in the Interior Zone (defined as the marsh area farther than 4.5 km (2.8 miles) from the perimeter canals). Average total phosphorus (TP) concentrations in 2006 in the Perimeter Zone (11 $\mu g\ L^{-1}$, or ppb) were lower than canal concentrations (69 $\mu g\ L^{-1}$), but higher than the Transition (8 $\mu g\ L^{-1}$) and Interior zones (9 $\mu g\ L^{-1}$). Reduced TP concentrations in the Refuge in 2006 appears to be at the cost of reduced water quantity as 2006 was characterized by a decrease in inputs to the Refuge with a large decrease in inflows relative to 2004 and 2005. Drought and management decisions in 2006 have decreased marsh stages for more extensive periods of time relative to 2004, with conditions drying areas of the northern Refuge in 2006. Average values of other water quality parameters in 2006 continue to show a decreasing gradient from the canal into the interior marsh.

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[6] Prepared by Matthew C. Harwell, Nicholas G. Aumen

Improved Understanding of Phosphorus Dynamics

This study focused on canal water intrusion by addressing two water management questions related to intrusion:

- Under what operational or environmental conditions does canal water intrude into the marsh and how far does it intrude?

- How does relative flow through different structures affect water flow and water quality within the interior marsh?

Canal water intrusion continued to be documented near the STA outflows, and along the S-6 transect, despite limited discharges during the period of record. Analysis of intrusion dynamics focused on a number of events and associated hydrological conditions that were not easy to analyze statistically. Despite these limitations, important insights were gained. Intrusion varies by location and was influenced by canal and marsh stage differences, inflow and outflow rates and rainfall conditions. There was frequent and persistent intrusion of canal water from 0.5 to 3 km (0.3 to 1.9 miles) into the Refuge interior. Three major differences in canal water intrusion between 2006 and 2005 were observed. One major change observed in 2006 was that the extent canal water intrusion on the east side of the Refuge was greater than in 2005. Another key difference observed in 2006 was that intrusion on the west side of the Refuge was less than in 2005. A third major difference observed in 2006 was that across the Refuge, the duration of intrusion was extensive (three to five weeks) following high inflow events, and was greater than in 2005.

The relative difference between marsh and canal stages remains an important driver of water movement and intrusion. When canal stage was higher than marsh stage, intrusion occurred under all conditions of inflow and outflow. We observed increased intrusion across the Refuge when inflows occurred (low, moderate and high rates) and canal-marsh stage difference was small. Also, we found that when rainfall is high and extended, canal water intrusion can be buffered or reduced.

The hydrodynamic and water quality models under development will be used to address the influences of water depths, flow, and water quality under different water management scenarios. The first version of the water budget model (period of record from 1995-2006) is available and has already been used. This model predicts canal and marsh stages from observed inflow, outflow, precipitation, and evapotranspiration. Initial Cl, SO_4, and TP mass balance models are completed and future revisions identified. Because the mass balance models can be run very quickly, a wide range of inputs can be looked at for initial screening purposes. The more-complex dynamic model, available for use by fall 2007, then can be used to evaluate a subset of those scenarios.

Linkages to Water Management Recommendations

Water management operations affect patterns of intrusion, suggesting ways to minimize negative impacts by adjusting inflow and outflow rates and locations when possible, depending on relative marsh and canal stages. Data analyses presented in this, and previous reports (e.g., USFWS 2007), coupled with future scenario analyses using the models, will allow us to more fully develop water management recommendations. In addition to recommending operational strategies, these data and scenario analyses will provide information to identify potential linkages between canal water intrusion and any future high phosphorus events:

- If there are potential negative impacts of pump, structure, or STA operations, how can they be minimized or eliminated?
- When water supply releases from the eastern Refuge boundary are made up by increased Refuge inflows, what is the optimal pattern of structure operations? Should we continue to require that all make-up water be provided prior to water supply releases?
- When canal stages are below the interior marsh elevation, what are the impacts of water supply releases on interior surface water and groundwater conditions?

In last year's report (USFWS 2007), we made a number of specific management recommendations. The most recent data presented in this report continues to support those recommendations.

Literature Cited

USFWS, 2007. A.R.M. Loxahatchee National Wildlife Refuge - Enhanced Monitoring and Modeling Program – 2nd Annual Report – February 2007. LOX06-008, U.S. Fish and Wildlife Service, Boynton Beach, FL. 183 pp. available at: http://sofia.usgs.gov/lox_monitor_model/reports/.

Appendices

App. 2-1. Summary statistics of water quality data for 2005 (January – December) and 2006 (January – December) for individual EVPA and LOXA stations.

App. 2-2. Summary statistics of monthly water quality data (January 2005 – December 2006) by zone.

Appendix 2-1

Individual EVPA and LOXA station summary statistics of water quality data for 2005 (January – December) and 2006 (January – December). Where values were below the minimum detection limits, a value of one half of the minimum detection limit is reported (sensu Weaver and Payne 2006).

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
	Count	0	0	0	3	0	4	0	0	0	0	0	0	0	0	0	0	4	0	3	4	4	0	0	5	0	0	0	0
	Average				22.77		5.09											6.32		0.30	102.03	0.01			24.24				
LOX3-2005	StdDev				1.46		0.99											0.27		0.10	15.92	0.00			4.64				
	Min				21.60		3.81											6.07		0.20	78.60	0.01			16.60				
	Max				24.40		6.19											6.69		0.40	114.00	0.01			28.00				
	Count	1	1	1	2	1	2	1	1	1	1	0	0	1	1	1	1	2	1	2	2	2	1	1	2	1	1	1	1
	Average	8.00	135.00	5.40	18.60	157.00	3.59	26.00	20.80	0.80	1.80			10.40	0.02	0.00	2.00	6.54	4.72	0.09	99.00	9.00	1.42	101.00	25.85	1.47	27.00	1.50	1.00
LOX3-2006	StdDev		0		3.676955		0.169706											0.516188		0.010607	18.38478	0			3.040559				
	Min	8.00	135.00	5.40	18.60	157.00	3.59	26.00	20.80	0.80	1.80			10.40	0.02	0.00	2.00	6.54	4.72	0.09	99.00	9.00	1.42	101.00	25.85	1.47	27.00	1.50	1.00
	Max		135.00		18.60		3.59											6.54		0.09	99.00	9.00			25.85				
	Count	6	5	6	10	6	10	6	6	6	6	6	5	6	6	6	6	10	6	10	9	10	6	6	12	6	6	6	6
	Average	92.00	14.40	28.23	54.02	133.17	4.86	27.83	103.63	4.17	8.05	0.00	0.00	38.37	0.01	0.01	0.00	6.91	7.19	1.74	332.54	0.01	1.34	273.67	24.24	1.43	28.50	3.25	0.97
LOX4-2005	StdDev	25.65	3.78	8.23	27.33	18.94	2.21	4.62	30.55	1.97	2.42	0.00	0.00	15.14	0.01	0.00	0.00	0.36	2.52	0.85	132.38	0.01	0.28	87.25	5.75	0.42	4.97	4.29	0.27
	Min	56.00	9.00	16.70	22.10	113.00	2.19	23.00	60.30	1.40	4.50	0.00	0.00	17.40	0.00	0.00	0.00	6.52	3.81	0.80	194.30	0.01	1.03	115.00	17.30	1.02	24.00	1.50	0.60
	Max	120.00	18.00	37.80	94.50	167.00	9.00	33.00	138.00	6.60	10.70	0.01	0.01	55.20	0.03	0.01	0.01	7.80	10.20	3.20	533.00	0.03	1.62	362.00	34.40	2.01	34.00	12.00	1.40
	Count	4	4	4	8	4	8	4	4	4	4	0	4	4	4	4	4	8	4	8	7	8	4	4	8	4	4	4	4
	Average	95.50	12.50	28.10	65.26	131.00	4.32	27.00	103.00	3.63	7.95		0.00	35.00	0.01	0.01	2.00	6.78	9.52	3.56	445.09	9.38	1.22	270.00	22.21	1.24	26.25	1.50	0.58
LOX4-2006	StdDev	35.68847	5.91608	10.9903	18.38718	6.218253	1.735894	1.632993	38.74119	1.452297	2.735568		0.001414	9.929418	0.005485	0.003775	0	0.131882	6.283595	5.622134	103.9737	1.59799	0.164798	86.97509	5.24852	0.175689	2.061553	0	0.170783
	Min	69.00	7.00	20.00	39.20	124.00	2.58	25.00	73.80	2.80	5.80	0.00	0.00	26.80	0.00	0.00	2.00	6.56	3.50	0.50	263.00	7.00	1.07	186.00	14.80	1.03	24.00	1.50	0.40
	Max	148.00	19.00	44.00	90.70	138.00	7.51	29.00	159.00	5.80	11.90	0.00	0.01	48.00	0.02	0.01	2.00	6.98	18.20	16.90	555.00	11.00	1.37	379.00	28.90	1.39	29.00	1.50	0.80
	Count	0	0	0	5	0	5	0	0	0	0	0	0	0	0	0	0	5	0	5	5	5	0	0	6	0	0	0	0
	Average				23.98		5.06											6.18		0.06	114.36	0.01			25.52				
LOX5-2005	StdDev				2.35		0.43											0.06		0.02	9.85	0.00			4.70				
	Min				20.20		4.39											6.10		0.05	98.50	0.01			17.00				
	Max				26.50		5.57											6.25		0.10	124.00	0.01			29.90				
	Count	2	1	2	4	2	4	2	1	2	2	0	2	2	2	2	2	4	2	4	3	4	2	2	4	2	2	2	2
	Average	8.50	128.00	4.90	24.48	107.50	5.11	24.00	16.80	0.65	1.60		0.01	11.45	0.01	0.01	2.00	6.51	5.22	0.34	105.43	8.75	1.45	106.00	20.83	1.47	23.50	1.50	0.75
LOX5-2006	StdDev	0.707107	0	0.707107	9.353564	21.92031	1.382712	2.828427		0.070711	0.282843		0.008485	2.899138	0.009546	0.010607	0	0.508027	2.665793	0.441673	31.55413	1.707825	0.353553	4.242641	6.751975	0.19799	3.535534	0	0.070711
	Min	8.00	128.00	4.40	13.60	92.00	3.77	22.00	16.80	0.60	1.40	0.00	0.00	9.40	0.00	0.00	2.00	6.06	3.33	0.09	75.00	7.00	1.20	103.00	15.00	1.33	21.00	1.50	0.70
	Max	9.00	128.00	5.40	33.60	123.00	6.55	26.00	16.80	0.70	1.80	0.00	0.02	13.50	0.02	0.02	2.00	7.22	7.10	1.00	138.00	11.00	1.70	109.00	28.70	1.61	26.00	1.50	0.80
	Count	9	9	9	10	9	10	9	9	9	9	9	1	9	9	8	9	10	8	10	9	10	9	9	12	9	9	9	9
	Average	51.89	50.56	17.06	36.29	72.89	4.66	17.22	61.02	1.77	4.48	0.00	0.00	22.11	0.01	0.01	0.00	6.94	5.82	1.72	243.14	0.01	1.09	159.56	23.34	1.15	17.33	1.50	0.63
LOX6-2005	StdDev	19.04	19.59	6.17	18.16	11.13	1.66	3.60	22.72	0.79	1.79	0.00		10.87	0.01	0.01	0.00	0.27	4.95	0.97	93.29	0.00	0.14	67.97	4.57	0.14	3.57	0.00	0.21
	Min	30.00	21.00	9.60	13.50	54.00	1.12	13.00	33.60	0.80	2.40	0.00	0.00	9.70	0.00	0.00	0.00	6.54	0.17	0.70	114.00	0.01	0.89	84.00	16.60	0.95	13.00	1.50	0.40
	Max	81.00	87.00	25.80	56.90	89.00	7.39	22.00	92.20	3.20	7.20	0.00	0.00	36.20	0.02	0.04	0.00	7.46	13.60	3.90	344.70	0.01	1.28	250.00	28.90	1.32	22.00	1.50	1.10
	Count	9	8	9	11	8	12	9	6	9	9	1	1	9	8	9	9	12	9	11	12	11	9	9	11	9	7	9	9
	Average	60.11	78.13	18.89	38.39	70.13	4.09	17.67	71.12	1.82	4.90	0.00	0.00	25.32	0.01	0.02	2.00	6.98	7.33	1.64	252.56	7.27	1.16	193.11	22.77	1.18	18.00	1.50	0.60
LOX6-2006	StdDev	18.99634	45.83647	6.085525	12.82322	17.83606	1.799254	2.783882	25.32449	0.734469	1.414214			8.042042	0.004013	0.029736	0	0.284504	6.476106	1.788448	80.28957	3.717282	0.237475	62.02307	4.522409	0.242819	3.366502	0	0.15
	Min	46.00	25.00	14.70	21.50	53.00	2.31	14.00	53.20	1.30	4.00	0.00	0.00	18.70	0.00	0.00	2.00	6.50	0.58	0.40	161.00	4.00	0.89	126.00	16.40	0.91	14.00	1.50	0.40
	Max	108.00	182.00	34.60	72.30	101.00	7.10	22.00	121.00	3.60	8.50	0.00	0.00	45.80	0.01	0.08	2.00	7.60	20.80	6.70	480.50	17.00	1.56	347.00	29.10	1.61	23.00	1.50	0.80
	Count	8	7	8	10	8	10	8	8	8	8	8	2	8	8	7	8	10	7	10	9	10	8	8	12	8	8	8	8
	Average	11.25	38.86	6.28	26.16	90.63	3.69	19.88	23.04	0.89	1.81	0.00	0.01	13.23	0.01	0.01	0.00	6.14	4.14	0.35	127.22	0.01	1.15	114.00	24.20	1.29	20.38	1.50	0.90
LOX7-2005	StdDev	3.28	9.99	1.65	10.76	8.67	1.70	3.76	5.96	0.33	0.46	0.00	0.01	4.05	0.00	0.01	0.00	0.17	0.65	0.12	49.72	0.01	0.18	37.34	4.64	0.30	3.62	0.00	0.24
	Min	7.00	31.00	4.40	12.50	82.00	0.97	15.00	15.80	0.50	1.20	0.00	0.00	7.80	0.00	0.00	0.00	5.98	2.97	0.20	71.00	0.01	0.86	57.00	17.50	0.90	16.00	1.50	0.60
	Max	17.00	60.00	9.00	44.10	106.00	6.77	27.00	32.70	1.50	2.50	0.00	0.02	19.20	0.02	0.02	0.00	6.52	4.82	0.60	217.00	0.02	1.44	164.00	30.40	1.76	27.00	1.50	1.20
	Count	9	6	9	10	8	10	9	7	9	9	1	3	9	9	9	9	10	9	10	8	10	8	9	9	8	8	9	9
	Average	17.67	61.83	8.43	32.09	92.88	5.80	25.00	31.03	1.02	2.36	0.00	0.00	18.27	0.01	0.01	3.11	6.66	6.14	0.19	156.60	9.00	1.45	133.22	23.41	1.51	25.25	1.50	0.80
LOX7-2006	StdDev	6.403124	40.58284	1.926136	5.774551	15.71567	1.709205	2.54951	6.569808	0.396162	0.278887		0.001732	2.186321	0.009119	0.004531	3.333333	0.528965	3.485913	0.091141	23.28599	6.895039	0.232194	29.68492	5.048377	0.23409	3.19598	0	0.173205
	Min	11.00	30.00	6.10	25.00	69.00	3.34	21.00	23.00	0.60	1.90	0.00	0.00	15.50	0.00	0.00	2.00	6.22	2.16	0.09	124.00	0.01	1.20	92.00	15.10	1.21	20.00	1.50	0.60
	Max	29.00	130.00	12.40	42.50	117.00	8.33	30.00	42.00	1.90	2.70	0.00	0.01	21.20	0.03	0.02	12.00	7.80	11.40	0.40	184.40	27.00	1.72	172.00	29.00	1.74	30.00	1.50	1.10
	Count	10	9	10	10	10	10	10	10	10	10	10	1	10	10	10	10	10	9	10	8	10	10	10	12	10	10	10	10
	Average	9.30	46.11	5.55	23.87	75.10	4.98	22.40	21.71	0.82	1.91	0.00	0.09	14.14	0.01	0.01	0.00	6.19	3.91	0.13	105.53	0.01	1.33	113.80	24.07	1.46	22.50	2.35	1.25
LOX8-2005	StdDev	2.36	10.89	1.00	7.49	12.43	1.35	4.27	3.97	0.27	0.37	0.00		3.85	0.00	0.03	0.00	0.19	1.77	0.12	24.81	0.00	0.21	32.91	4.81	0.33	4.17	2.69	0.75
	Min	7.00	21.00	3.90	14.40	67.00	3.04	16.00	15.40	0.60	1.40	0.00	0.09	8.90	0.00	0.00	0.00	5.90	1.70	0.05	75.00	0.01	1.01	46.00	17.60	1.11	16.00	1.50	0.50
	Max	13.00	58.00	6.80	35.90	108.00	6.93	28.00	27.20	1.40	2.50	0.01	0.09	20.00	0.01	0.09	0.01	6.47	5.94	0.40	145.50	0.02	1.64	160.00	31.10	2.09	28.00	10.00	3.10
	Count	10	7	10	11	9	11	10	8	10	10	1	3	10	10	10	10	11	10	11	9	11	10	10	10	10	9	10	10
	Average	12.50	49.71	7.33	31.31	76.33	5.57	27.10	28.91	0.91	2.35	0.00	0.01	17.65	0.01	0.01	2.00	6.48	4.25	0.10	149.72	10.09	1.54	132.50	23.98	1.59	27.11	1.50	0.80
LOX8-2006	StdDev	5.060742	24.06044	1.79756	8.762015	17.35655	1.670138	3.813718	6.751177	0.381372	0.552268		0.004041	4.297868	0.005609	0.005007	0	0.481286	1.543945	0.06625	40.58678	2.879394	0.25309	36.52777	5.143453	0.252375	3.789606	0	0.253859
	Min	6.00	31.00	5.40	18.60	60.00	3.18	22.00	20.20	0.50	1.60	0.00	0.00	11.40	0.00	0.00	2.00	6.06	2.87	0.05	94.00	7.00	1.27	104.00	16.00	1.29	24.00	1.50	0.50
	Max	22.00	103.00	10.40	48.90	113.00	8.91	36.00	40.80	1.60	3.60	0.00	0.01	27.50	0.02	0.02	2.00	7.80	7.01	0.30	215.50	15.00	2.07	226.00	29.50	2.15	36.00	1.50	1.30

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
	Count	2	2	2	7	2	7	2	2	2	2	2	0	2	2	2	2	7	2	7	6	7	2	2	8	2	2	2	2
	Average	18.00	44.50	6.70	24.07	54.00	4.49	18.50	27.00	1.10	2.50	0.00		15.35	0.01	0.01	0.00	6.34	5.12	0.08	123.87	0.01	1.21	139.00	25.55	1.28	19.00	1.50	0.80
LOX9-2005	StdDev	2.83	3.54	0.00	5.05	5.66	1.08	0.71	0.00	0.14	0.00	0.00		0.92	0.01	0.00	0.00	0.09	0.91	0.06	21.74	0.00	0.05	46.67	4.71	0.10	0.00	0.00	0.28
	Min	16.00	42.00	6.70	15.30	50.00	2.92	18.00	27.00	1.00	2.50	0.00		14.70	0.00	0.00	0.00	6.19	4.47	0.05	85.40	0.01	1.17	106.00	18.30	1.21	19.00	1.50	0.60
	Max	20.00	47.00	6.70	30.70	58.00	5.75	19.00	27.00	1.20	2.50	0.00		16.00	0.02	0.01	0.00	6.42	5.76	0.20	149.00	0.01	1.24	172.00	30.10	1.35	19.00	1.50	1.00
	Count	3	2	3	8	3	8	3	2	3	3	0	1	3	3	3	3	8	3	8	6	8	2	3	7	2	3	3	3
	Average	15.67	78.50	5.97	29.48	55.67	5.06	19.67	24.75	0.73	2.27		0.01	13.93	0.01	0.01	2.00	6.59	4.43	0.10	130.27	8.75	1.17	95.00	22.77	1.29	19.00	1.50	0.73
LOX9-2006	StdDev	4.725816	45.96194	0.929157	9.861867	15.82193	1.193559	1.154701	6.151829	0.152753	0.503322			4.346646	0.004907	0.004041	0	0.531998	0.899852	0.040245	65.3522	5.470701	0.240416	5.567764	5.672658	0.169706	1	0	0.152753
	Min	12.00	46.00	5.20	15.30	42.00	3.79	19.00	20.40	0.60	1.80	0.00	0.01	10.00	0.00	0.00	2.00	6.21	3.46	0.09	49.00	5.00	1.00	90.00	15.80	1.17	18.00	1.50	0.60
	Max	21.00	111.00	7.00	42.30	73.00	7.03	21.00	29.10	0.90	2.80	0.00	0.01	18.60	0.01	0.01	2.00	7.80	5.24	0.20	209.00	22.00	1.34	101.00	29.70	1.41	20.00	1.50	0.90
	Count	2	2	2	9	2	9	2	2	2	2	0	0	2	2	2	2	9	2	9	7	9	2	2	8	2	2	2	2
	Average	35.50	59.50	9.95	23.09	73.00	4.68	16.50	39.20	1.25	3.50			13.15	0.00	0.00	2.00	6.85	10.58	1.50	157.67	7.78	0.83	148.50	21.99	0.92	16.00	2.25	0.75
LOX10-2006	StdDev	14.84924	38.89087	3.606245	7.382825	9.899495	1.746399	2.12132	14.99066	0.353553	1.414214			6.151829	0	0.002121	0	0.434313	2.432447	0.653835	49.63489	0.971825	0.127279	38.89087	5.683922	0.176777	2.828427	1.06066	0.070711
	Min	25.00	32.00	7.40	12.10	66.00	1.48	15.00	28.60	1.00	2.50	0.00	0.00	8.80	0.00	0.00	2.00	6.52	8.86	0.80	95.00	7.00	0.74	121.00	14.00	0.79	14.00	1.50	0.70
	Max	46.00	87.00	12.50	34.40	80.00	7.26	18.00	49.80	1.50	4.50	0.00	0.00	17.50	0.00	0.01	2.00	7.90	12.30	2.80	232.00	10.00	0.92	176.00	28.80	1.04	18.00	3.00	0.80
	Count	3	3	3	9	3	9	3	3	3	3	3	0	3	3	3	3	9	3	9	8	9	3	3	10	3	3	3	3
	Average	41.67	32.33	11.97	25.47	79.67	3.78	17.00	46.50	1.33	4.03	0.00		14.13	0.01	0.01	0.00	6.70	9.60	1.91	180.95	0.01	0.91	152.00	21.97	0.93	17.00	1.50	0.77
LOX10-2005	StdDev	3.21	13.58	1.01	10.60	9.87	1.12	1.73	4.33	0.29	0.47	0.00		2.18	0.00	0.01	0.00	0.20	2.43	0.44	63.41	0.00	0.06	32.05	5.04	0.03	1.73	0.00	0.15
	Min	38.00	24.00	10.80	13.60	73.00	2.33	15.00	41.50	1.00	3.50	0.00		11.70	0.00	0.00	0.00	6.52	6.79	1.40	104.00	0.01	0.84	115.00	15.60	0.90	15.00	1.50	0.60
	Max	44.00	48.00	12.60	42.10	91.00	5.31	18.00	49.20	1.50	4.40	0.00		15.90	0.01	0.02	0.00	7.13	11.10	2.70	276.00	0.02	0.96	171.00	28.10	0.95	18.00	1.50	0.90
	Count	9	9	9	10	9	10	9	9	9	9	9	0	9	9	8	9	10	8	10	6	10	9	9	12	9	9	9	9
	Average	10.89	52.00	6.54	21.12	66.67	3.50	19.56	22.68	0.38	1.52	0.00		12.33	0.01	0.01	0.00	6.08	2.28	0.10	98.63	0.01	1.07	97.78	23.72	1.35	20.00	3.06	1.11
LOX11-2005	StdDev	4.17	15.93	2.03	4.66	10.90	1.72	3.21	6.25	0.12	0.26	0.00		2.53	0.01	0.01	0.00	0.27	1.52	0.06	20.57	0.01	0.18	39.37	4.46	0.52	3.24	3.33	0.90
	Min	5.00	27.00	3.60	14.30	54.00	1.40	14.00	13.40	0.20	1.10	0.00		8.30	0.00	0.00	0.00	5.72	0.34	0.05	70.00	0.01	0.83	55.00	16.80	0.92	15.00	1.50	0.50
	Max	16.00	81.00	8.70	28.50	91.00	6.24	23.00	29.40	0.60	1.80	0.00		15.90	0.03	0.02	0.01	6.48	4.39	0.20	123.20	0.03	1.36	190.00	30.00	2.64	24.00	11.00	3.40
	Count	8	7	8	10	7	10	8	5	8	8	1	2	8	7	8	8	10	8	10	10	10	7	8	9	8	5	8	8
	Average	14.13	74.57	8.09	28.46	66.14	5.13	22.18	28.48	0.36	1.75	0.00	0.01	14.56	0.01	0.01	2.00	6.50	2.20	0.09	137.43	7.20	1.20	121.50	22.72	1.26	22.60	1.50	0.68
LOX11-2006	StdDev	3.97986	28.99918	1.387122	8.337492	16.06682	1.728932	2.654242	4.937307	0.159799	0.316228		0.003536	2.735971	0.005926	0.005398	0	0.552056	0.968489	0.039119	36.21037	2.347576	0.157041	29.91416	3.932486	0.183959	4.09878	0	0.128174
	Min	10.00	45.00	6.40	18.60	54.00	2.92	20.00	21.40	0.20	1.40	0.00	0.00	10.90	0.00	0.00	2.00	5.70	1.16	0.05	94.00	4.00	1.06	82.00	17.40	1.06	19.00	1.50	0.50
	Max	22.00	118.00	10.10	45.60	99.00	7.75	27.00	34.60	0.60	2.30	0.00	0.01	19.40	0.02	0.02	2.00	7.80	3.94	0.20	203.40	13.00	1.54	164.00	28.20	1.64	28.00	1.50	0.80
	Count	10	10	10	10	10	10	10	10	10	10	10	1	10	10	9	10	10	9	10	9	10	10	10	12	10	10	10	10
	Average	48.90	17.40	13.81	25.84	58.00	5.26	15.80	53.22	1.32	4.57	0.00	0.01	18.04	0.01	0.01	0.00	6.87	6.28	1.15	197.09	0.01	0.91	119.70	24.50	1.02	15.90	2.75	0.59
LOX12-2005	StdDev	14.27	6.70	3.66	7.18	9.89	1.78	2.20	14.16	0.33	1.21	0.00		5.07	0.00	0.00	0.00	0.33	3.16	0.53	44.03	0.00	0.07	47.63	4.44	0.20	2.02	3.95	0.15
	Min	27.00	10.00	8.10	15.80	45.00	2.73	12.00	31.10	0.80	2.70	0.00	0.01	11.00	0.00	0.00	0.00	6.38	3.21	0.40	118.00	0.01	0.76	39.00	18.10	0.80	12.00	1.50	0.30
	Max	68.00	31.00	18.60	35.20	76.00	7.49	18.00	72.40	1.80	6.30	0.00	0.01	25.00	0.02	0.01	0.00	7.22	11.40	2.20	254.20	0.02	0.99	182.00	30.50	1.57	18.00	14.00	0.80
	Count	12	11	12	12	11	12	11	9	12	12	1	1	12	11	12	12	12	12	12	12	12	12	12	11	12	11	12	12
	Average	64.58	28.91	17.36	36.22	63.64	5.01	19.36	70.79	1.54	5.87	0.00	0.00	24.54	0.01	0.01	2.00	7.01	7.32	1.30	247.20	7.58	1.13	176.08	24.27	1.16	20.18	1.50	0.63
LOX12-2006	StdDev	14.96941	10.53997	4.030894	7.845188	15.6925	1.118815	3.107176	16.72135	0.496274	1.306163			5.413864	0.003823	0.00442	0	0.195934	2.418719	1.340963	57.38201	2.234373	0.212066	41.28495	4.35387	0.229637	3.682884	0	0.200567
	Min	52.00	11.00	14.50	28.00	47.00	2.84	16.00	55.90	1.10	4.80	0.00	0.00	19.60	0.00	0.00	2.00	6.70	4.02	0.50	204.00	4.00	0.88	123.00	16.80	0.90	16.00	1.50	0.50
	Max	106.00	46.00	28.30	54.30	92.00	6.94	26.00	109.00	2.60	9.30	0.00	0.00	37.50	0.01	0.02	2.00	7.30	11.30	5.30	398.30	13.00	1.50	284.00	29.50	1.54	26.00	1.50	1.20
	Count	8	8	8	8	8	8	8	8	8	8	8	0	8	8	7	8	8	8	8	4	8	8	8	10	8	8	8	8
	Average	12.75	53.50	7.08	19.69	63.00	4.54	18.13	23.68	0.40	1.46	0.00		11.38	0.01	0.01	0.00	6.21	2.23	0.13	101.03	0.01	1.08	97.00	23.57	1.29	18.63	2.69	1.30
LOX13-2005	StdDev	3.96	20.41	1.76	3.09	10.80	1.93	2.47	5.14	0.12	0.20	0.00		1.75	0.01	0.00	0.00	0.28	1.80	0.14	18.22	0.00	0.12	22.60	4.54	0.33	2.67	3.36	1.04
	Min	6.00	32.00	4.00	15.10	48.00	1.77	14.00	14.80	0.20	1.10	0.00	0.00	8.80	0.00	0.00	0.00	5.78	0.20	0.05	75.00	0.01	0.94	57.00	17.60	1.00	14.00	1.50	0.70
	Max	16.00	89.00	8.30	23.00	76.00	7.13	21.00	27.20	0.60	1.60	0.00	0.00	13.20	0.02	0.01	0.01	6.54	4.78	0.40	116.00	0.01	1.23	128.00	29.70	1.89	22.00	11.00	3.80
	Count	7	6	7	10	6	10	7	5	7	7	1	0	7	6	7	7	10	7	10	10	10	7	7	9	7	5	7	7
	Average	19.00	83.83	8.59	24.04	56.17	4.99	18.71	27.36	0.40	1.60	0.00		12.90	0.02	0.01	2.00	6.55	1.95	0.08	122.39	7.50	1.13	102.86	23.26	1.19	18.80	1.50	0.76
LOX13-2006	StdDev	4.966555	31.23086	1.16823	5.318563	7.082843	1.659845	1.976047	3.480374	0.057735	0.208167			1.896488	0.032611	0.006451	0	0.522217	1.37812	0.012517	21.43914	1.178511	0.127466	34.55155	3.926229	0.146287	3.114482	0	0.198806
	Min	10.00	6	6.60	17.10	44.00	2.25	16.00	21.60	0.30	1.20	0.00	0.00	9.90	0.00	0.00	2.00	5.90	0.38	0.05	90.00	6.00	0.95	65.00	17.80	1.03	15.00	1.50	0.40
	Max	24.00	35.00	10.40	36.30	64.00	7.31	21.00	30.70	0.50	1.80	0.00	0.00	15.20	0.09	0.02	2.00	7.90	3.94	0.10	167.00	9.00	1.33	169.00	28.60	1.44	22.00	1.50	1.00
	Count	10	10	10	10	10	10	10	10	10	10	10	4	10	10	9	10	10	9	10	8	10	10	10	11	10	10	10	10
	Average	47.70	16.10	16.21	30.91	84.20	4.31	17.60	57.26	1.37	4.08	0.00	0.01	20.24	0.01	0.01	0.00	6.71	4.92	1.94	217.53	0.01	0.87	133.30	23.81	0.98	17.70	1.95	0.50
LOX14-2005	StdDev	12.07	4.41	3.37	5.38	14.70	1.32	1.26	12.03	0.44	0.90	0.00	0.01	3.51	0.00	0.00	0.00	0.14	3.26	0.60	28.91	0.00	0.06	33.10	4.71	0.17	1.49	1.42	0.11
	Min	30.00	11.00	11.10	20.40	67.00	2.36	16.00	38.10	0.80	2.50	0.00	0.00	12.80	0.00	0.00	0.00	6.44	1.10	1.10	180.00	0.01	0.77	73.00	17.50	0.81	16.00	1.50	0.30
	Max	66.00	25.00	21.50	39.30	107.00	6.49	20.00	75.10	1.90	5.20	0.01	0.02	25.40	0.02	0.01	0.00	6.94	9.38	3.00	249.00	0.01	0.96	187.00	30.20	1.40	20.00	6.00	0.60
	Count	12	11	12	12	11	12	11	9	12	12	1	1	12	11	12	12	12	12	12	12	12	12	12	11	12	9	12	12
	Average	54.92	31.27	18.16	37.73	73.00	4.64	18.55	64.67	1.45	4.33	0.00	0.00	23.78	0.01	0.01	2.67	6.84	4.90	2.18	239.78	7.75	0.94	168.25	24.02	0.99	19.44	1.50	0.58
LOX14-2006	StdDev	20.62857	9.317627	6.374874	13.34414	11.57584	1.270655	3.012097	25.24663	0.909045	1.408631			8.226325	0.003477	0.003777	2.309401	0.209364	3.372162	2.346419	87.3975	2.261335	0.195128	61.1691	4.103369	0.226046	3.468109	0	0.128806
	Min	39.00	11	13.90	28.60	60.00	2.29	15.00	49.40	0.70	3.60	0.00	0.00	18.80	0.00	0.00	2.00	6.60	0.34	0.80	181.00	5.00	0.75	128.00	17.40	0.70	14.00	1.50	0.30
	Max	116.00	9.00	37.10	77.80	92.00	6.88	23.00	128.00	4.00	8.50	0.00	0.00	48.80	0.02	0.02	10.00	7.40	12.50	8.90	502.10	11.00	1.38	348.00	28.90	1.40	24.00	1.50	0.80

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
	Count	10	10	10	10	10	10	10	10	10	10	10	2	10	10	9	10	10	9	10	9	10	10	10	12	10	10	10	10
	Average	90.60	15.60	26.95	47.04	56.70	5.30	18.80	103.00	2.72	8.68	0.00	0.02	33.22	0.02	0.01	0.00	7.20	6.83	10.95	386.48	0.01	1.15	230.60	24.94	1.23	19.20	1.50	0.59
LOX15-2005	StdDev	38.43	5.38	11.43	19.30	2.71	1.23	2.53	43.56	1.34	3.68	0.00	0.03	13.50	0.02	0.01	0.00	0.22	2.66	7.71	140.47	0.00	0.15	88.43	4.60	0.14	2.66	0.00	0.18
	Min	31.00	8.00	9.90	20.30	54.00	4.20	14.00	37.60	1.00	3.10	0.00	0.00	13.10	0.00	0.00	0.00	6.80	3.56	1.50	171.00	0.01	0.88	98.00	18.20	0.93	14.00	1.50	0.40
	Max	153.00	23.00	46.50	79.50	61.00	7.76	23.00	179.00	5.40	15.40	0.00	0.04	55.80	0.06	0.05	0.01	7.46	10.60	25.80	605.20	0.01	1.41	363.00	32.00	1.45	24.00	1.50	1.00
	Count	12	11	11	12	11	12	10	8	11	11	1	1	11	10	11	12	12	12	12	12	12	11	12	11	11	8	12	12
	Average	118.58	25.64	34.09	68.20	56.73	4.99	20.71	138.00	3.49	11.24	0.00	0.00	45.58	0.02	0.01	2.00	7.30	9.03	15.96	491.23	7.50	1.38	314.50	24.64	1.42	23.38	1.50	0.55
LOX15-2006	StdDev	24.97074	7.579878	6.454526	14.77596	8.088151	1.264706	7.468692	26.10419	1.043508	2.310962			9.594876	0.021902	0.005591	0	0.247734	4.142492	9.142056	103.8821	1.243163	0.118498	64.41132	4.153137	0.124367	2.199838	0	0.15667
	Min	68.00	4.41	25.80	50.30	47.00	2.79	0.05	100.00	2.00	8.70	0.00	0.00	34.90	0.00	0.00	2.00	6.60	3.09	5.10	357.90	5.00	1.22	248.00	17.50	1.25	21.00	1.50	0.30
	Max	148.00	31.27	42.80	95.60	70.00	7.24	26.00	170.00	5.20	15.40	0.00	0.00	65.50	0.08	0.02	2.00	7.57	15.60	30.50	656.00	10.00	1.58	432.00	29.70	1.64	27.00	1.50	0.90
	Count	10	10	10	10	10	10	10	10	10	10	10	2	10	10	9	10	10	9	10	8	10	10	10	12	10	10	10	10
	Average	41.40	17.30	13.67	29.13	81.40	3.41	16.90	48.88	1.04	3.57	0.00	0.00	19.04	0.01	0.01	0.00	6.54	4.27	1.09	194.91	0.01	0.84	110.80	23.98	0.92	17.20	1.65	0.59
LOX16-2005	StdDev	9.71	4.74	2.31	5.13	12.95	1.47	1.79	8.73	0.29	0.73	0.00	0.00	3.26	0.01	0.00	0.00	0.13	2.34	0.40	25.45	0.00	0.08	27.54	4.68	0.12	2.04	0.47	0.17
	Min	30.00	9.00	10.90	20.10	66.00	1.73	15.00	36.70	0.70	2.30	0.00	0.00	12.60	0.00	0.00	0.00	6.32	0.97	0.60	165.00	0.01	0.72	67.00	17.30	0.77	14.00	1.50	0.30
	Max	60.00	25.00	18.00	35.80	105.00	6.72	20.00	65.00	1.50	4.80	0.00	0.01	23.10	0.02	0.01	0.00	6.74	7.04	2.00	229.50	0.01	0.93	160.00	30.80	1.09	20.00	3.00	0.80
	Count	11	11	10	12	10	12	11	7	10	10	1	1	10	10	11	11	12	11	12	12	12	11	11	11	11	9	11	10
	Average	65.27	65.27	19.60	40.23	74.70	3.45	17.58	68.86	1.52	5.03	0.00	0.00	26.64	0.01	0.01	2.00	6.69	6.59	3.47	260.37	7.00	0.89	185.64	23.78	0.93	17.70	1.50	0.56
LOX16-2006	StdDev	31.85935	31.85935	9.720882	16.13406	18.52956	2.005689	2.040499	41.86263	1.269996	2.534671			11.82194	0.002993	0.003742	0	0.206522	3.785689	4.836853	119.7948	1.595448	0.176625	80.10777	4.22654	0.17363	2.717536	0	0.157762
	Min	36.00	36.00	12.10	27.90	52.00	0.23	15.00	43.00	0.40	3.10	0.00	0.00	17.00	0.00	0.00	2.00	6.40	1.66	0.20	172.00	5.00	0.71	102.00	16.70	0.75	15.00	1.50	0.40
	Max	130.00	130.00	40.80	79.60	113.00	7.78	22.00	145.00	4.40	10.50	0.00	0.00	52.20	0.01	0.01	2.00	7.20	14.00	15.50	558.60	10.00	1.31	357.00	28.60	1.29	23.00	1.50	0.80
	Count	4	4	4	8	4	7	4	4	4	4	4	4	4	4	4	4	8	4	8	8	8	4	4	8	4	4	4	4
	Average	150.00	5.75	42.70	80.96	174.50	3.03	31.50	158.98	6.55	12.75	0.01	0.02	49.13	0.01	0.02	0.00	6.98	21.68	8.69	588.75	0.02	1.55	381.50	21.84	1.63	31.75	1.50	0.80
LOXA101-2005	StdDev	45.84	0.96	14.81	28.59	17.64	1.40	3.11	54.63	1.87	4.33	0.00	0.02	18.81	0.00	0.02	0.00	0.22	8.81	9.14	174.44	0.02	0.30	127.18	4.61	0.38	2.63	0.00	0.29
	Min	94.00	5.00	26.80	38.90	159.00	1.65	27.00	99.90	3.80	8.00	0.01	0.00	27.10	0.01	0.01	0.00	6.63	10.20	0.90	318.00	0.01	1.23	236.00	15.80	1.31	28.00	1.50	0.50
	Max	206.00	7.00	62.60	125.00	197.00	4.93	34.00	232.00	7.90	18.50	0.01	0.05	72.80	0.02	0.06	0.01	7.24	31.00	29.20	802.00	0.06	1.96	544.00	28.40	2.18	34.00	1.50	1.10
	Count	4	0	4	9	0	9	4	0	0	0	0	0	0	0	2	2	9	4	9	9	8	0	4	9	4	4	3	4
	Average	168.25		74.05	109.60		2.77	32.25								0.01	4.15	7.21	17.90	23.04	759.36	14.96		552.25	22.82	1.73	32.50	2.67	0.82
LOXA101-2006	StdDev	81.84691		11.59353	17.25514		2.218544	2.061553								0.002051	0.212132	0.224914	3.450604	19.74665	154.0771	10.99402		42.97577	5.628842	0.225592	2.380476	1.607275	0.264449
	Min	48.00		57.20	79.40	0.00	0.16	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	4.00	7.01	15.60	3.10	531.90	4.70	0.00	519.00	10.30	1.40	29.00	1.50	0.63
	Max	220.00		83.00	130.00		7.16	35.00								0.01	4.30	7.74	23.00	61.00	943.70	36.00		610.00	27.23	1.90	34.00	4.50	1.20
	Count	3	3	3	7	3	6	3	3	3	3	3	3	3	3	3	3	7	3	7	7	7	3	3	7	3	3	3	3
	Average	84.33	19.00	25.97	43.64	139.00	3.64	23.00	100.03	4.00	8.53	0.01	0.01	33.23	0.01	0.01	0.00	6.77	13.57	7.17	316.83	0.01	1.06	233.67	22.59	1.05	23.33	1.50	0.83
LOXA102-2005	StdDev	48.23	17.58	14.43	22.28	26.51	1.29	1.73	57.25	1.59	5.10	0.00	0.00	23.77	0.00	0.00	0.00	0.18	2.15	9.59	145.97	0.00	0.34	120.44	4.77	0.35	1.53	0.00	0.21
	Min	55.00	6.00	16.80	25.50	116.00	1.66	22.00	63.40	2.80	5.20	0.00	0.00	17.70	0.00	0.01	0.00	6.55	11.90	2.30	200.20	0.01	0.86	146.00	15.60	0.84	22.00	1.50	0.60
	Max	140.00	39.00	42.60	89.90	168.00	4.84	25.00	166.00	5.80	14.40	0.01	0.01	60.60	0.01	0.02	0.01	7.04	16.00	28.80	624.00	0.02	1.46	371.00	29.30	1.45	25.00	1.50	1.00
	Count	3	0.00	3	7	0	7	3	0	0	0	0	0	0	0	3	0	7	3	7	7	6	0	3	7	3	3	3	3
	Average	79.33	0	16.50	37.49		2.82	22.33								0.01		6.84	15.54	6.59	262.24	9.08		171.67	21.27	0.71	21.67	2.50	0.52
LOXA102-2006	StdDev	35.23256		1.5	16.38815		2.492204	1.527525								0.007638		0.489353	8.292408	10.36716	102.3014	4.268216		12.58306	6.214098	0.185562	1.527525	1.322876	0.182483
	Min	58.00		15.00	25.00	0.00	0.91	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.37	6.61	1.50	188.50	6.20	0.00	160.00	9.37	0.52	20.00	1.50	0.40
	Max	120.00		18.00	73.00	0.00	8.19	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	7.74	23.00	30.00	488.20	17.00	0.00	185.00	27.01	0.89	23.00	4.00	0.73
	Count	3	3	3	8	3	7	3	3	3	3	3	3	3	3	3	3	8	3	8	8	8	3	3	8	3	3	3	3
	Average	106.33	4.67	31.10	50.64	176.67	3.02	31.67	120.97	4.93	10.57	0.01	0.01	43.67	0.01	0.01	0.00	6.86	16.43	6.66	346.99	0.02	1.39	324.33	21.14	1.44	32.33	1.50	0.83
LOXA103-2005	StdDev	41.31	2.08	14.46	23.48	56.54	1.54	5.13	54.60	1.29	4.53	0.00	0.00	17.15	0.00	0.00	0.00	0.29	2.38	10.45	155.46	0.01	0.14	106.40	5.02	0.18	5.03	0.00	0.25
	Min	81.00	3.00	22.50	21.10	119.00	1.36	26.00	88.30	4.00	7.80	0.01	0.00	32.40	0.00	0.01	0.00	6.42	14.30	1.00	166.20	0.01	1.26	257.00	14.20	1.27	27.00	1.50	0.60
	Max	154.00	7.00	47.80	93.90	232.00	5.72	36.00	184.00	6.40	15.80	0.01	0.01	63.40	0.01	0.02	0.01	7.28	19.00	32.20	676.00	0.04	1.54	447.00	28.60	1.63	37.00	1.50	1.10
	Count	3	0	3	7	0	7	3	0	0	0	0	0	0	0	3	1	7	3	7	7	7	0	3	7	3	3	2	3
	Average	83.33		15.07	42.11		3.51	26.00								0.01	4.20	6.87	14.66	5.94	285.10	8.57		162.67	21.45	0.95	26.00	2.25	0.52
LOXA103-2006	StdDev	41.19871		2.759227	20.80508		2.217437	4								0.001323		0.424578	6.041824	9.778012	127.8514	4.969814		48.18022	5.905423	0.240069	4	1.06066	0.258134
	Min	52.00		13.00	19.00	0.00	0.86	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	4.20	6.41	8.97	1.20	161.10	1.80	0.00	130.00	9.78	0.77	22.00	1.50	0.35
	Max	130.00		18.20	81.00	0.00	7.17	30.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	4.20	7.56	21.00	28.00	548.60	17.00	0.00	218.00	26.95	1.22	30.00	3.00	0.82
	Count	11	11	11	11	11	9	11	11	11	11	10	10	11	10	10	10	11	10	10	11	11	11	11	11	11	11	11	11
	Average	244.18	1.95	83.15	132.66	124.73	3.99	33.91	308.09	8.75	24.42	0.03	0.32	93.28	0.12	0.35	0.06	7.61	20.25	65.24	1008.33	0.10	2.15	651.18	25.43	2.35	33.64	3.00	6.15
LOXA104-2005	StdDev	42.79	1.31	17.74	25.65	38.39	1.77	7.38	65.21	1.47	5.23	0.04	0.38	20.04	0.21	0.41	0.05	0.20	7.03	22.76	190.29	0.05	0.59	156.41	5.09	0.55	7.78	2.16	4.22
	Min	178.00	0.50	59.90	91.70	73.00	0.89	22.00	218.00	7.30	16.60	0.00	0.00	64.10	0.01	0.00	0.01	7.16	8.53	39.10	722.00	0.06	1.32	386.00	17.70	1.55	21.00	1.50	2.20
	Max	315.00	5.00	112.00	182.00	188.00	7.19	43.00	419.00	11.50	34.00	0.11	1.26	135.00	0.70	1.32	0.16	7.89	27.80	100.00	1354.00	0.20	3.33	920.00	32.70	3.41	44.00	8.00	14.70
	Count	12	0	12	12	0	12	11	0	0	0	0	0	0	0	12	6	12	12	12	12	12	0	12	12	12	12	12	12
	Average	250.83		83.40	135.08		4.32	33.36								0.12	47.67	7.62	18.57	61.37	1010.72	74.33		658.67	25.28	2.09	33.33	4.60	5.77
LOXA104-2006	StdDev	27.59721		11.54682	15.09641		2.248839	3.384456								0.174588	38.8673	0.195006	5.39062	13.24746	104.8953	35.19384		81.55236	4.371855	0.269043	4.030189	2.045394	4.955675
	Min	3.00		2.76	7.00	0.00	0.86	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	2.38	1.00	7.00	0.01	0.00	3.00	5.02	0.18	3.00	0.00	0.25
	Max	315.00		112.00	182.00	188.00	12.00	43.00	419.00	11.50	34.00	10.00	10.00	135.00	10.00	12.00	47.67	12.00	27.80	100.00	1354.00	74.33	11.00	920.00	32.70	12.00	44.00	12.00	14.70

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
	Count	5	5	5	7	5	7	5	5	5	5	5	5	5	5	4	5	8	5	7	8	7	5	5	8	5	5	5	5
	Average	186.60	3.20	57.66	90.57	132.00	2.81	32.20	216.20	7.06	17.54	0.00	0.00	72.42	0.01	0.00	0.01	6.89	21.89	22.26	628.20	0.02	1.65	484.40	23.80	1.74	32.20	2.20	0.86
LOXA105-2005	StdDev	57.16	1.64	19.68	39.23	3.54	1.55	6.22	73.75	1.35	5.93	0.00	0.00	23.55	0.02	0.00	0.00	0.16	9.04	19.45	250.79	0.01	0.41	163.96	6.87	0.34	6.50	1.57	0.15
	Min	122.00	2.00	35.30	44.80	129.00	1.32	25.00	132.00	5.50	10.70	0.00	0.00	46.60	0.00	0.00	0.00	6.62	9.85	4.90	332.80	0.01	1.17	298.00	14.70	1.31	25.00	1.50	0.70
	Max	238.00	6.00	73.60	141.00	138.00	5.30	38.00	273.00	8.30	22.10	0.01	0.00	95.80	0.04	0.01	0.01	7.15	30.60	58.90	942.10	0.04	1.98	631.00	36.40	2.03	40.00	5.00	1.10
	Count	1	0	1	6	0	6	1	0	0	0	0	0	0	0	2	0	6	1	6	6	6	0	1	6	1	1	1	1
	Average	130.00		39.00	71.27		3.50	20.00								0.01		6.84	22.00	16.98	511.20	17.83		320.00	22.24	0.99	22.00	2.00	0.59
LOXA105-2006	StdDev				21.87763		2.038686									0.000707		0.112205		12.92492	173.468	15.34166			4.209489				
	Min	130.00		39.00	52.00	0.00	0.99	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	6.72	22.00	6.80	363.90	10.00	0.00	320.00	15.00	0.99	22.00	2.00	0.59
	Max	130.00		39.00	99.90	0.00	6.12	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	7.02	22.00	40.00	793.10	49.00	0.00	320.00	26.40	0.99	22.00	2.00	0.59
	Count	3	3	3	7	3	6	3	3	3	3	3	3	3	3	2	3	7	3	7	7	7	3	3	7	3	3	3	3
	Average	112.67	5.33	34.67	53.27	138.00	3.35	26.00	131.67	5.57	11.00	0.01	0.00	45.03	0.01	0.01	0.00	6.70	19.70	9.07	376.06	0.01	1.18	323.00	21.64	1.25	26.33	1.50	1.03
LOXA106-2005	StdDev	27.59	3.21	9.83	21.80	18.03	1.35	1.00	37.23	0.60	3.16	0.00	0.00	11.82	0.00	0.00	0.00	0.14	5.41	10.56	141.11	0.00	0.13	160.59	5.21	0.20	0.58	0.00	0.06
	Min	92.00	3.00	27.20	24.20	118.00	1.91	25.00	104.00	5.00	8.70	0.00	0.00	35.10	0.00	0.00	0.00	6.53	14.80	2.60	196.70	0.01	1.08	189.00	13.80	1.09	26.00	1.50	1.00
	Max	144.00	9.00	45.80	89.50	153.00	5.70	27.00	174.00	6.20	14.60	0.01	0.01	58.10	0.01	0.01	0.01	6.91	25.50	32.30	641.00	0.02	1.33	501.00	27.50	1.47	27.00	1.50	1.10
	Count	3	0	3	7	0	7	3	0	0	0	0	0	0	0	4	1	7	3	7	7	7	0	3	7	3	3	3	3
	Average	105.67		21.13	43.09		2.45	22.00								0.01	3.10	6.60	24.09	8.50	316.70	8.17		216.00	22.72	0.69	21.67	2.00	0.48
LOXA106-2006	StdDev	65.39368		3.233162	16.63795		2.049534	2								0.002525		0.077121	16.58682	8.713973	118.4216	4.253906		21.16601	4.912372	0.112398	1.154701	0.5	0.15695
	Min	57.00		17.40	31.00	0.00	0.93	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.10	6.47	9.26	3.70	233.50	3.20	0.00	200.00	13.00	0.59	21.00	1.50	0.30
	Max	180.00		23.00	80.00	0.00	6.70	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.10	6.67	42.00	28.00	576.10	17.00	0.00	240.00	26.63	0.81	23.00	2.50	0.60
	Count	1	1	1	4	1	4	1	1	1	1	1	1	1	1	0	1	4	1	4	4	4	1	1	4	1	1	1	1
	Average	50.00	8.00	15.40	25.83	156.00	3.03	22.00	60.50	2.50	5.40	0.00	0.01	21.10	0.00		0.01	6.64	2.47	3.95	197.18	0.01	0.91	28.00	24.30	1.29	22.00	20.00	1.40
LOXA107-2005	StdDev				3.64		1.26											0.26		4.66	30.37	0.01			2.53				
	Min	50.00	8.00	15.40	21.00	156.00	1.81	22.00	60.50	2.50	5.40	0.00	0.01	21.10	0.00		0.01	6.42	2.47	1.00	152.70	0.01	0.91	28.00	22.00	1.29	22.00	20.00	1.40
	Max	50.00	8.00	15.40	29.30	156.00	4.35	22.00	60.50	2.50	5.40	0.00	0.01	21.10	0.00		0.01	7.01	2.47	10.90	219.50	0.02	0.91	28.00	27.70	1.29	22.00	20.00	1.40
	Count	1	0	1	4	0	4	1	0	0	0	0	0	0	0	0	1	4	1	4	4	4	0	1	4	1	1	2	1
	Average	100.00		13.00	23.23		3.30	23.00									4.60	6.50	18.00	1.70	169.75	6.25		160.00	22.30	0.63	23.00	2.25	0.37
LOXA107-2006	StdDev				8.617956		2.57105											0.094163		1.298756	28.60099	0.896289			6.057819			0.353553	
	Min	100.00	0.00	13.00	15.00	0.00	1.04	23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.60	6.41	18.00	0.68	134.90	5.10	0.00	160.00	13.60	0.63	23.00	2.00	0.37
	Max	100.00	0.00	13.00	32.90	0.00	6.82	23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.60	6.63	18.00	3.60	196.80	7.10	0.00	160.00	26.78	0.63	23.00	2.50	0.37
	Count	1	1	1	4	1	4	1	1	1	1	1	1	1	1	1	1	4	1	4	4	4	1	1	4	1	1	1	1
	Average	31.00	4.00	9.00	31.25	175.00	3.98	29.00	36.00	1.40	3.30	0.01	0.01	23.50	0.01	0.02	0.01	6.57	0.98	0.25	191.15	0.01	1.68	87.00	23.77	2.19	28.00	9.00	3.20
LOXA108-2005	StdDev				3.76		1.58											0.24		0.13	38.93	0.01			2.09				
	Min	31.00	4.00	9.00	27.70	175.00	2.74	29.00	36.00	1.40	3.30	0.01	0.01	23.50	0.01	0.02	0.01	6.30	0.98	0.10	146.20	0.01	1.68	87.00	21.38	2.19	28.00	9.00	3.20
	Max	31.00	4.00	9.00	34.70	175.00	6.29	29.00	36.00	1.40	3.30	0.01	0.01	23.50	0.01	0.02	0.01	6.82	0.98	0.40	240.60	0.03	1.68	87.00	26.20	2.19	28.00	9.00	3.20
	Count	3	0	3	5	0	5	3	0	0	0	0	0	0	0	2	1	5	3	2	5	5	0	3	5	3	3	2	3
	Average	124.67		7.50	34.56		3.13	30.67								0.01	2.00	6.31	7.07	0.34	170.34	6.84		133.33	22.98	1.13	31.33	4.00	0.54
LOXA108-2006	StdDev	177.8239		0.519615	8.704482		2.432776	2.309401								0		0.423178	0.46188	0.36416	25.06308	3.069691		11.54701	6.739932	0.057735	2.886751	0	0.034641
	Min	22.00		7.20	27.00	0.00	1.80	28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.00	6.06	6.80	0.09	149.00	3.10	0.00	120.00	11.30	1.10	28.00	4.00	0.52
	Max	330.00		8.10	44.80	0.00	7.44	32.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.00	7.06	7.60	0.60	199.20	10.00	0.00	140.00	27.00	1.20	33.00	4.00	0.58
	Count	9	9	9	11	9	9	9	9	9	9	9	6	9	8	7	9	11	9	10	11	11	9	9	11	9	9	9	9
	Average	70.56	12.67	21.67	44.48	99.67	2.48	21.78	84.09	3.28	7.32	0.00	0.01	32.23	0.01	0.01	0.00	6.66	9.90	7.99	294.96	0.01	1.07	224.11	23.58	1.17	21.78	2.67	0.63
LOXA109-2005	StdDev	36.24	4.42	12.67	29.05	14.92	0.91	3.63	47.82	1.78	3.98	0.00	0.00	18.08	0.01	0.00	0.00	0.14	7.12	10.26	177.54	0.01	0.20	112.50	5.13	0.25	3.49	3.50	0.14
	Min	37.00	7.00	10.80	18.00	79.00	1.07	16.00	42.10	1.60	3.70	0.00	0.00	12.20	0.00	0.00	0.00	6.43	3.02	1.60	140.60	0.01	0.84	122.00	15.80	0.86	17.00	1.50	0.50
	Max	148.00	18.00	46.30	98.40	123.00	3.65	27.00	177.00	6.50	15.00	0.01	0.01	64.40	0.02	0.01	0.01	6.86	21.60	33.40	670.00	0.03	1.35	421.00	29.20	1.63	26.00	12.00	0.90
	Count	8	0	8	9	0	9	8	0	0	0	0	0	0	0	6	1	9	8	9	9	8	0	8	9	8	8	6	8
	Average	60.75		17.48	35.80		2.40	20.88								0.01	5.90	6.56	9.64	5.11	238.12	6.26		185.75	23.33	0.85	21.50	2.30	0.66
LOXA109-2006	StdDev	17.02729		4.954291	15.95611		1.53983	2.900123								0.002483		0.137659	2.149756	5.106967	92.34924	1.585594		63.2224	4.868313	0.305588	2.976095	0.938083	0.26038
	Min	40.00		11.00	17.00	0.00	0.84	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.90	6.32	5.75	1.20	140.40	3.60	0.00	100.00	14.20	0.49	18.00	1.50	0.40
	Max	80.00		23.00	60.10	0.00	5.78	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	5.90	6.75	12.30	16.00	358.70	8.00	0.00	268.00	28.14	1.30	27.00	3.50	1.10
	Count	1	1	1	6	1	6	1	1	1	1	1	1	1	1	0	1	7	1	6	6	6	1	1	7	1	1	1	1
	Average	46.00	22.00	12.90	24.92	114.00	4.98	20.00	51.50	3.00	4.70	0.00	0.00	21.20	0.00		0.00	6.62	5.03	1.27	155.30	0.01	1.01	113.00	23.61	1.16	20.00	1.50	0.90
LOXA110-2005	StdDev				5.09		1.82											0.23		1.27	31.39	0.01			4.69				
	Min	46.00	22.00	12.90	16.80	114.00	2.79	20.00	51.50	3.00	4.70	0.00	0.00	21.20	0.00		0.00	6.26	5.03	0.50	109.70	0.01	1.01	113.00	17.00	1.16	20.00	1.50	0.90
	Max	46.00	22.00	12.90	31.20	114.00	7.49	20.00	51.50	3.00	4.70	0.00	0.00	21.20	0.00		0.00	6.89	5.03	3.80	204.00	0.02	1.01	113.00	28.90	1.16	20.00	1.50	0.90
	Count	2	0	2	6	0	6	2	0	0	0	0	0	0	0	2	1	6	2	6	6	6	0	2	6	2	2	2	2
	Average	22.00		7.20	22.98		5.02	20.50								0.01	6.30	6.53	10.50	0.77	134.35	6.82		101.00	23.80	0.65	21.00	2.00	0.75
LOXA110-2006	StdDev	2.828427		0.424264	7.181202		1.695854	0.707107								0.003253		0.157184	2.12132	0.62098	27.64994	3.220197		12.72792	5.042288	0.056569	1.414214	0	0.205061
	Min	20.00		6.90	16.00	0.00	3.21	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	6.30	6.28	9.00	0.23	103.30	2.80	0.00	92.00	14.80	0.61	20.00	2.00	0.60
	Max	24.00		7.50	31.60	0.00	7.20	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	6.30	6.75	12.00	1.70	173.20	11.00	0.00	110.00	27.82	0.69	22.00	2.00	0.89

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
	Count	5	5	5	7	5	6	5	5	5	5	5	1	5	5	4	5	7	5	7	6	7	5	5	7	5	5	5	5
	Average	36.20	40.40	10.54	21.60	76.60	3.37	16.80	41.34	1.34	3.64	0.00	0.01	13.98	0.01	0.00	0.00	6.52	6.88	1.27	141.63	0.01	0.88	122.20	22.57	1.11	17.00	7.50	2.06
LOXA111-2005	StdDev	4.44	3.51	1.17	7.10	13.28	0.73	1.92	4.67	0.32	0.44	0.00		3.51	0.01	0.00	0.00	0.16	4.19	0.44	23.16	0.01	0.09	20.95	4.60	0.42	2.00	11.07	3.10
	Min	30.00	37.00	8.80	13.20	63.00	1.91	14.00	34.50	1.10	3.00	0.00	0.01	8.90	0.00	0.00	0.00	6.32	2.19	0.70	109.20	0.01	0.74	108.00	15.90	0.79	14.00	1.50	0.50
	Max	40.00	46.00	11.60	33.40	97.00	3.78	19.00	45.80	1.90	4.10	0.00	0.01	17.50	0.03	0.01	0.01	6.82	12.50	2.10	169.10	0.02	0.96	159.00	27.80	1.79	19.00	27.00	7.60
	Count	3		3	6	0	6	3	0	0	0	0	0	0	0	2	1	6	3	6	6	6	0	3	6	3	3	0	3
	Average	28.00		8.00	18.00		4.00	16.67								0.01	3.90	6.43	8.10	1.29	123.93	8.45		91.67	22.95	0.58	16.00		0.85
LOXA111-2006	StdDev	2		0.754983	6.809112		2.001387	0.57735								0.000495		0.199366	2.338803	1.092514	34.18612	6.333325		7.571878	5.039332	0.185831	1		0.565892
	Min	26.00		7.30	12.00	0.00	2.07	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.90	6.24	5.40	0.50	94.10	3.60	0.00	83.00	13.90	0.37	15.00	0.00	0.51
	Max	30.00		8.80	26.90	0.00	7.58	17.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.90	6.78	9.50	3.30	171.60	21.00	0.00	97.00	27.24	0.73	17.00	0.00	1.50
	Count	7	7	7	10	7	8	7	7	7	7	7	3	7	7	6	7	10	7	9	10	10	7	7	10	7	7	7	7
	Average	53.86	21.14	16.40	34.68	89.43	3.74	20.00	62.69	2.53	5.29	0.00	0.00	20.99	0.01	0.01	0.00	6.75	7.12	3.20	240.66	0.01	1.02	161.43	23.33	1.07	19.86	2.79	0.80
LOXA112-2005	StdDev	6.82	7.10	2.58	13.35	19.01	1.50	1.91	9.88	1.03	0.88	0.00	0.00	5.26	0.00	0.00	0.00	0.18	2.95	2.10	69.24	0.01	0.04	28.80	5.46	0.09	1.86	2.20	0.22
	Min	40.00	12.00	11.80	16.50	66.00	1.64	17.00	45.00	1.10	3.70	0.00	0.00	11.70	0.00	0.00	0.00	6.46	2.65	1.30	139.50	0.01	0.98	125.00	14.50	0.96	17.00	1.50	0.60
	Max	61.00	33.00	20.20	58.80	120.00	5.91	23.00	77.00	4.20	6.50	0.01	0.01	27.00	0.01	0.01	0.01	7.05	11.60	8.50	376.40	0.02	1.07	196.00	29.40	1.23	23.00	6.00	1.20
	Count	6	0	6	8	0	8	6	0	0	0	0	0	0	0	4	3	8	6	8	8	7	0	6	8	6	6	6	6
	Average	50.00		13.47	26.45		3.14	18.00								0.01	4.77	6.60	8.32	2.26	188.75	6.80		141.33	23.80	0.81	18.00	2.33	0.86
LOXA112-2006	StdDev	9.033272		3.050683	8.41699		1.850123	3.34664								0.004397	2.411086	0.211643	2.185787	1.282035	58.13855	1.891208		43.6104	4.860332	0.320479	3.098387	0.816497	0.397123
	Min	40.00		10.00	17.00	0.00	1.61	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	6.24	4.00	0.47	118.50	4.00	0.00	100.00	14.10	0.47	14.00	1.50	0.30
	Max	62.00		18.00	38.60	0.00	6.90	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	7.30	6.94	10.00	4.80	266.90	9.00	0.00	206.00	28.59	1.20	21.00	3.50	1.30
	Count	3	3	3	9	3	7	3	3	3	3	3	1	3	3	2	3	9	3	8	8	9	3	3	9	3	3	3	3
	Average	33.00	47.33	9.30	20.09	74.00	3.79	16.00	36.67	1.27	3.23	0.00	0.03	13.03	0.01	0.01	0.00	6.61	6.16	0.78	129.39	0.01	0.92	106.67	23.32	1.05	16.00	4.00	0.87
LOXA113-2005	StdDev	2.00	19.86	0.17	6.67	14.00	1.52	0.00	0.40	0.29	0.06	0.00		1.10	0.01	0.00	0.00	0.22	2.22	0.32	15.90	0.00	0.07	29.02	4.14	0.16	1.00	4.33	0.31
	Min	31.00	33.00	9.20	14.00	60.00	2.10	16.00	36.30	1.10	3.20	0.00	0.03	11.80	0.00	0.00	0.00	6.25	3.60	0.40	109.00	0.00	0.86	77.00	17.60	0.88	15.00	1.50	0.60
	Max	35.00	70.00	9.50	35.20	88.00	6.49	16.00	37.10	1.60	3.30	0.00	0.03	13.90	0.02	0.01	0.00	6.86	7.46	1.20	160.10	0.02	1.00	135.00	29.10	1.20	17.00	9.00	1.20
	Count	3	0	3	8	0	8	3	0	0	0	0	0	0	0	0	1	8	3	7	8	8	0	3	8	3	3	0	3
	Average	22.00		7.17	23.75		4.01	15.67									5.10	6.51	5.53	0.55	142.61	7.23		80.33	22.48	0.63	15.33		0.87
LOXA113-2006	StdDev	3.464102		0.981495	10.62114		2.268105	0.57735										0.328623	1.059874	0.341293	51.41821	3.157191		10.78579	4.258846	0.182483	0.57735		0.456545
	Min	20.00		6.60	12.00	0.00	2.01	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.10	6.13	4.40	0.30	87.30	4.10	0.00	68.00	14.80	0.51	15.00	0.00	0.59
	Max	26.00		8.30	39.40	0.00	9.16	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.10	7.15	6.50	1.30	221.20	14.00	0.00	88.00	27.49	0.84	16.00	0.00	1.40
	Count	4	4	4	8	4	7	4	4	4	4	4	1	4	4	3	4	9	4	7	8	8	4	4	9	4	4	4	4
	Average	27.25	30.75	7.90	18.50	73.00	3.30	15.75	31.60	1.23	2.90	0.00	0.03	12.10	0.01	0.00	0.00	6.55	5.56	0.44	122.65	0.01	0.84	106.50	23.68	1.08	16.25	3.63	0.75
LOXA114-2005	StdDev	1.26	6.80	0.36	3.40	6.22	1.97	0.96	1.26	0.21	0.12	0.00		1.40	0.00	0.00	0.00	0.30	2.74	0.29	13.08	0.01	0.07	26.65	4.06	0.45	1.26	4.25	0.57
	Min	26.00	24.00	7.60	15.90	66.00	2.15	15.00	30.50	1.00	2.80	0.00	0.03	10.30	0.00	0.00	0.00	6.26	2.94	0.20	110.50	0.01	0.76	80.00	17.04	0.81	15.00	1.50	0.40
	Max	29.00	40.00	8.40	26.20	80.00	7.63	17.00	33.40	1.50	3.00	0.00	0.03	13.40	0.01	0.00	0.00	7.18	8.39	1.00	153.00	0.03	0.90	142.00	28.10	1.75	18.00	10.00	1.60
	Count	3	0	3	7	0	7	3	0	0	0	0	0	0	0	1	0	7	3	3	7	6	0	3	7	3	3	2	3
	Average	21.00		6.33	20.11		3.01	16.67								0.00		6.34	5.27	0.32	122.80	5.18		83.00	23.32	0.64	16.33	2.50	0.54
LOXA114-2006	StdDev	5		0.70946	6.403236		2.209583	1.527525										0.236432	3.082748	0.335522	28.66589	1.128568		7.937254	4.896379	0.159478	0.57735	0	0.092916
	Min	16.00		5.70	13.00		1.63	15.00								0.00		6.07	1.80	0.09	87.10	3.70		74.00	13.70	0.46	16.00	2.50	0.48
	Max	26.00		7.10	29.10		7.94	18.00										6.71	7.70	0.70	160.70	6.20		89.00	27.07	0.75	17.00	2.50	0.65
	Count	11	11	11	11	11	9	11	11	11	11	11	11	11	11	11	11	10	10	11	11	11	11	11	11	11	11	11	11
	Average	218.18	1.68	74.66	116.13	113.73	4.26	30.27	277.00	7.90	22.02	0.02	0.27	82.59	0.05	0.29	0.05	7.65	18.12	59.32	907.55	0.09	1.87	580.18	25.25	2.12	30.27	3.59	5.69
LOXA115-2005	StdDev	49.97	1.06	19.85	38.02	32.02	2.32	7.90	75.07	2.05	6.32	0.02	0.52	26.55	0.06	0.53	0.04	0.19	6.84	26.45	249.07	0.04	0.54	184.67	4.57	0.56	8.11	2.40	5.01
	Min	140.00	0.50	46.00	46.70	74.00	0.83	20.00	161.00	3.30	11.20	0.00	0.01	35.90	0.00	0.01	0.00	7.35	11.10	19.00	481.50	0.05	1.18	256.00	19.60	1.13	19.00	1.50	2.40
	Max	312.00	4.00	110.00	184.00	158.00	9.14	42.00	409.00	11.00	32.90	0.07	1.82	128.00	0.23	1.87	0.14	7.92	29.00	107.00	1338.00	0.19	2.66	878.00	31.20	2.84	43.00	8.00	18.60
	Count	12	0	12	12	0	12	11	0	0	0	0	0	0	0	11	5	12	12	12	11	12	0	12	12	12	11	12	12
	Average	241.58		79.54	124.00		4.60	35.18								0.19	38.96	7.58	18.95	60.16	948.83	64.50		598.75	25.18	1.89	31.73	4.00	4.56
LOXA115-2006	StdDev	35.77825		12.44438	22.16877		1.978428	10.666								0.467013	38.07273	0.253178	6.172741	16.42196	156.8682	40.41939		125.803	4.18519	0.429288	4.314879	1.637626	1.721624
	Min	170.00		56.00	78.00	0.00	1.30	26.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.30	7.10	11.20	29.00	659.90	25.00	0.00	410.00	17.30	1.10	23.00	1.50	2.20
	Max	280.00		94.80	148.00	0.00	8.20	66.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.58	95.50	7.98	33.00	85.90	1096.00	143.00	0.00	760.00	29.95	2.50	37.00	7.00	7.50
	Count	10	10	10	10	10	8	10	10	10	10	10	9	10	10	9	10	9	9	10	10	10	10	10	10	10	10	10	10
	Average	169.10	2.40	56.46	84.99	113.10	1.79	27.40	204.58	5.55	15.45	0.00	0.00	59.68	0.05	0.01	0.00	7.16	13.09	33.65	668.40	0.04	1.51	447.50	22.84	1.80	27.40	5.25	1.67
LOXA116-2005	StdDev	68.27	1.56	25.29	47.50	12.36	0.45	6.90	93.94	2.75	7.53	0.00	0.00	32.67	0.02	0.00	0.00	0.16	8.37	29.81	321.30	0.02	0.46	239.84	5.10	0.49	7.49	5.04	0.93
	Min	66.00	0.50	21.30	17.30	96.00	1.10	17.00	74.30	1.20	5.10	0.00	0.00	14.70	0.03	0.00	0.00	6.74	3.24	4.90	209.00	0.02	0.88	130.00	15.30	1.01	16.00	1.50	0.70
	Max	273.00	5.00	96.20	157.00	138.00	2.29	38.00	349.00	9.70	27.30	0.01	0.01	112.00	0.07	0.01	0.01	7.31	26.00	89.00	1160.00	0.06	2.35	843.00	29.00	2.42	39.00	16.00	3.20
	Count	9	0	9	9	0	9	8	0	0	0	0	0	0	0	7	3	9	9	9	9	9	0	9	9	8	8	8	9
	Average	196.78		66.63	107.67		1.60	30.75								0.01	6.67	7.16	19.11	42.97	805.66	32.90		514.44	22.40	1.69	31.00	3.00	2.13
LOXA116-2006	StdDev	56.59235		19.67333	38.24265		0.928809	5.063878								0.003097	3.05505	0.142955	4.994858	21.47731	249.6344	31.68975		179.7666	4.354127	0.610919	5.631544	3.262339	3.003239
	Min	80.00		26.00	38.00	0.00	0.49	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.00	6.96	11.00	12.00	311.60	8.10	0.00	210.00	15.00	0.74	19.00	1.50	0.70
	Max	253.00		84.80	156.00	0.00	3.42	37.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	10.00	7.41	25.00	78.20	1085.00	90.00	0.00	718.00	27.48	2.70	38.00	11.00	10.00

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
	Count	3	3	3	10	3	9	3	3	3	3	3	3	3	3	2	3	10	3	10	10	10	3	3	10	3	3	3	3
	Average	151.33	6.67	48.60	65.29	118.00	2.47	27.33	180.67	5.97	14.43	0.00	0.01	59.40	0.02	0.01	0.00	6.78	16.07	15.65	475.84	0.02	1.36	430.67	22.14	1.46	27.00	1.50	1.63
LOXA117-2005	StdDev	51.54	2.52	18.06	37.06	20.07	1.20	6.11	65.01	2.05	4.85	0.00	0.00	24.05	0.01	0.00	0.00	0.22	7.66	11.52	241.01	0.01	0.40	195.77	5.74	0.41	5.57	0.00	0.99
	Min	101.00	4.00	30.30	16.70	104.00	0.99	22.00	115.00	3.90	9.60	0.00	0.00	35.60	0.00	0.01	0.00	6.42	9.80	3.90	153.50	0.01	0.98	249.00	14.00	1.01	22.00	1.50	0.50
	Max	204.00	9.00	66.40	126.00	141.00	4.63	34.00	245.00	8.00	19.30	0.00	0.01	83.70	0.03	0.01	0.01	7.21	24.60	34.20	850.50	0.04	1.78	638.00	31.40	1.81	33.00	1.50	2.30
	Count	6	0	6	9	0	9	5	0	0	0	0	0	0	0	4	2	9	6	9	9	9	0	6	9	6	5	3	6
	Average	123.00		39.80	77.11		1.68	25.40								0.01	3.90	6.89	16.87	19.11	527.78	12.12		337.17	21.93	1.00	25.60	2.17	1.22
LOXA117-2006	StdDev	45.55436		15.3727	37.51814		1.188449	5.549775								0.001447	0.424264	0.166208	9.149135	12.39278	233.0256	4.423171		162.9606	4.375883	0.392479	5.029911	0.57735	0.80574
	Min	70.00	0.00	22.00	36.00	0.00	0.41	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.60	6.63	5.00	6.70	188.80	7.90	0.00	160.00	15.10	0.69	21.00	1.50	0.50
	Max	196.00	0.00	62.80	135.00	0.00	4.67	35.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	4.20	7.07	26.00	42.10	865.80	20.00	0.00	613.00	27.42	1.69	34.00	2.50	2.70
	Count	7	7	7	11	7	10	7	7	7	7	7	5	7	7	6	7	10	6	11	10	11	7	7	11	7	7	7	7
	Average	68.29	10.57	21.74	34.48	99.29	3.15	19.71	81.27	2.79	6.51	0.00	0.01	25.76	0.01	0.01	0.00	6.70	9.85	5.85	265.51	0.01	0.95	180.86	23.96	1.08	19.71	8.07	0.89
LOXA118-2005	StdDev	28.20	3.64	9.01	21.91	15.41	1.50	3.59	33.35	1.49	2.64	0.00	0.00	14.24	0.01	0.00	0.00	0.25	9.45	2.64	122.18	0.00	0.19	108.21	6.26	0.29	3.86	15.10	0.99
	Min	34.00	5.00	11.40	11.20	81.00	1.79	14.00	42.20	1.00	3.30	0.00	0.00	9.20	0.00	0.00	0.00	6.28	3.10	2.80	111.70	0.01	0.71	33.00	14.20	0.76	14.00	1.50	0.40
	Max	104.00	16.00	34.10	74.00	127.00	6.98	24.00	126.00	5.10	9.90	0.00	0.01	45.00	0.03	0.01	0.01	7.11	23.10	11.20	457.50	0.02	1.17	325.00	33.50	1.65	25.00	42.00	3.10
	Count	9	0	9	10	0	10	8	0	0	0	0	0	0	0	3	3	10	9	10	10	9	0	9	10	8	8	6	9
	Average	60.78		19.22	34.07		3.36	18.50								0.01	3.73	6.76	10.12	5.23	244.08	6.18		186.44	23.46	0.75	18.63	2.07	0.65
LOXA118-2006	StdDev	14.52393		5.744949	14.38302		1.449927	2.828427								0.003055	0.23094	0.231084	4.733069	2.578996	81.53253	1.289164		65.02713	4.142436	0.233957	2.326094	0.625033	0.313299
	Min	45.00		12.00	17.00	0.00	1.14	13.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.60	6.38	3.40	2.80	147.40	3.60	0.00	97.00	17.10	0.41	15.00	1.50	0.40
	Max	84.00		27.00	63.20	0.00	6.33	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	4.00	7.01	17.00	10.80	390.70	7.60	0.00	296.00	29.13	1.05	22.00	2.70	1.29
	Count	6	6	6	11	6	10	6	6	6	6	6	1	6	6	5	6	10	6	11	9	11	6	6	11	6	6	6	6
	Average	37.50	22.50	10.85	19.81	73.17	5.37	15.83	42.28	1.30	3.72	0.00	0.01	13.92	0.01	0.01	0.00	6.57	5.64	1.11	144.03	0.02	0.77	112.17	24.67	2.12	16.83	16.17	1.40
LOXA119-2005	StdDev	7.23	10.35	1.78	8.21	6.68	1.39	2.48	7.13	0.41	0.64	0.00		4.43	0.01	0.00	0.00	0.20	2.86	0.30	44.84	0.02	0.15	27.03	6.95	3.22	3.19	34.24	2.02
	Min	28.00	13.00	8.70	11.10	63.00	2.63	13.00	33.90	0.90	3.00	0.00	0.01	8.60	0.00	0.00	0.00	6.30	3.19	0.70	92.10	0.01	0.59	76.00	13.60	0.66	13.00	1.50	0.40
	Max	49.00	42.00	13.90	35.20	81.00	7.90	20.00	54.40	1.80	4.80	0.00	0.01	21.50	0.02	0.02	0.01	6.96	10.70	1.70	225.00	0.07	1.04	156.00	35.00	8.68	22.00	86.00	5.50
	Count	7	0	7	10	0	10	6	0	0	0	0	0	0	0	4	0	10	7	10	10	7	0	7	10	7	6	5	7
	Average	30.14		9.10	19.27		4.77	15.67								0.01		6.58	7.23	0.90	130.57	7.09		103.00	23.98	0.58	15.50	2.94	0.72
LOXA119-2006	StdDev	7.289915		1.715615	6.029935		1.568899	2.65832								0.006856		0.259583	2.638825	0.368697	31.61382	5.83536		34.18089	4.319479	0.163139	1.974842	1.546932	0.309662
	Min	20.00		7.40	13.00	0.00	3.17	12.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	6.22	2.80	0.57	95.60	2.60	0.00	73.00	17.30	0.34	13.00	1.50	0.40
	Max	41.00		11.90	28.80	0.00	8.63	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	7.00	11.00	1.80	175.30	20.00	0.00	174.00	30.62	0.85	19.00	5.00	1.30
	Count	8	8	8	11	8	10	8	8	8	8	8	0	8	8	8	8	10	7	11	9	10	8	8	11	8	8	8	8
	Average	22.75	57.13	7.18	23.00	52.38	5.57	16.50	29.28	1.08	2.76	0.00		13.59	0.02	0.01	0.00	6.55	6.15	0.19	133.60	0.02	1.12	106.50	25.85	2.32	16.75	33.19	3.78
LOXA120-2005	StdDev	6.16	34.88	1.70	8.62	5.48	1.70	3.74	7.01	0.27	0.67	0.00		3.97	0.02	0.00	0.00	0.26	2.75	0.13	47.48	0.03	0.29	43.26	5.82	2.56	3.73	55.68	6.79
	Min	16.00	33.00	5.50	13.80	43.00	2.43	13.00	22.50	0.80	2.10	0.00		10.60	0.00	0.00	0.00	6.09	1.32	0.05	86.00	0.00	0.96	61.00	16.70	1.00	13.00	1.50	0.40
	Max	33.00	138.00	10.60	38.00	61.00	8.47	24.00	43.40	1.50	4.10	0.00		22.30	0.06	0.01	0.01	6.94	9.32	0.40	223.00	0.10	1.84	160.00	34.70	8.39	24.00	130.00	20.00
	Count	10	0	10	10	3	10	10	3	3	3	3	3	3	3	10	3	10	10	10	10	10	3	10	10	10	10	10	10
	Average	25.60		8.27	31.14		5.85	20.11								0.00		6.87	5.00	0.12	157.36	7.92		123.90	25.52	1.08	19.78	1.70	0.76
LOXA120-2006	StdDev	6.058969		1.512944	13.45541		1.422304	4.044887								0.002		0.340303	1.341192	0.050933	57.67485	4.572487		47.84106	3.929671	0.465479	3.562926	0.447214	0.226087
	Min	16.00		6.10	17.00	0.00	3.59	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.46	2.68	0.09	106.70	2.60	0.00	69.00	19.40	0.41	17.00	1.50	0.56
	Max	37.00		11.10	57.80	0.00	8.24	27.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	7.47	6.58	0.20	308.00	20.00	0.00	226.00	31.62	1.84	26.00	2.50	1.10
		1	1	5	1	5	1	1	1	1	1	1	1	1	1	1	5	1	5	6	5	1	1	6	1	1	1	1	1
	Average	216.00	3.00	73.10	107.32	100.00	0.75	31.00	268.00	7.50	20.90	0.00	0.01	71.10	0.03	0.01	0.01	7.01	15.10	47.92	757.98	0.07	1.73	503.00	21.76	2.69	31.00	22.00	3.60
LOXA121-2005	StdDev				51.87		0.40											0.09		30.62	358.94	0.03			5.53				
	Min	216.00	3.00	73.10	30.60	100.00	0.23	31.00	268.00	7.50	20.90	0.00	0.01	71.10	0.03	0.01	0.01	6.86	15.10	9.90	322.70	0.05	1.73	503.00	15.50	2.69	31.00	22.00	3.60
	Max	216.00	3.00	73.10	172.00	100.00	1.24	31.00	268.00	7.50	20.90	0.00	0.01	71.10	0.03	0.01	0.01	7.11	15.10	95.10	1252.00	0.12	1.73	503.00	27.57	2.69	31.00	22.00	3.60
	Count	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Average																												
LOXA121-2006	StdDev																												
	Min																												
	Max																												
	Count	5	5	5	9	5	9	5	5	5	5	5	2	5	5	4	5	10	5	9	11	10	5	5	11	5	5	5	5
	Average	185.60	7.80	57.96	72.70	104.40	2.25	26.80	206.00	5.78	14.90	0.00	0.01	55.74	0.02	0.01	0.00	7.08	15.83	12.50	567.37	0.01	1.36	421.00	23.26	1.42	27.00	1.50	0.90
LOXA122-2005	StdDev	55.32	3.42	17.72	34.27	9.04	1.28	4.32	59.76	1.17	4.03	0.00	0.00	17.20	0.01	0.01	0.00	0.18	3.83	6.92	235.03	0.01	0.23	133.41	5.44	0.25	4.53	0.00	0.29
	Min	109.00	5.00	35.10	22.70	93.00	0.54	20.00	122.00	3.90	8.40	0.00	0.01	28.30	0.00	0.00	0.00	6.78	9.43	3.50	240.00	0.01	1.00	218.00	14.20	1.04	20.00	1.50	0.50
	Max	244.00	12.00	76.30	102.00	118.00	4.87	30.00	264.00	6.80	18.00	0.00	0.01	70.00	0.04	0.02	0.01	7.32	18.90	23.40	810.10	0.03	1.54	544.00	30.40	1.66	31.00	1.50	1.20
	Count	7	0	7	9	0	9	6	0	0	0	0	0	0	0	3	3	9	7	9	9	8	0	7	9	7	6	4	7
	Average	168.29		54.21	81.51		1.74	26.33								0.01	4.13	7.03	14.21	19.19	648.13	9.51		395.00	23.03	1.16	26.67	2.63	0.88
LOXA122-2006	StdDev	46.69659		13.85598	26.56598		1.181889	3.932768								0.002501	1.514376	0.183492	4.238879	10.12293	167.5544	3.355779		109.4303	4.523986	0.335942	3.614784	1.314978	0.407787
	Min	130.00		42.00	54.00	0.00	0.42	23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.40	6.81	9.20	8.10	470.40	5.00	0.00	310.00	16.50	0.62	23.00	1.50	0.40
	Max	268.00		83.50	127.00	0.00	4.60	34.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	5.20	7.39	20.00	35.00	936.20	16.00	0.00	625.00	28.90	1.72	33.00	4.50	1.60

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
LOXA123-2005	Count	6	6	6	9	6	7	6	6	6	6	6	2	6	6	5	6	8	5	9	9	9	6	6	9	6	6	6	6
	Average	142.33	13.00	44.33	65.74	82.83	1.51	25.67	167.27	4.82	13.72	0.00	0.01	55.53	0.04	0.01	0.00	7.10	14.92	17.62	493.70	0.01	1.44	359.17	23.48	1.65	26.00	5.25	1.53
	StdDev	52.56	4.56	19.49	35.75	7.49	1.40	4.18	69.80	2.20	5.13	0.00	0.00	23.59	0.02	0.01	0.00	0.21	4.66	17.55	237.21	0.01	0.24	184.80	5.22	0.40	4.29	9.19	1.82
	Min	77.00	5.00	22.60	23.10	72.00	0.20	21.00	89.60	2.60	8.10	0.00	0.01	29.70	0.01	0.00	0.00	6.86	11.40	3.30	213.80	0.01	1.19	182.00	16.30	1.23	21.00	1.50	0.50
	Max	232.00	18.00	78.70	140.00	90.00	4.28	33.00	290.00	8.60	22.70	0.00	0.01	97.80	0.07	0.03	0.01	7.36	22.70	58.20	988.50	0.04	1.83	692.00	29.40	2.30	33.00	24.00	5.20
LOXA123-2006	Count	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Average																												
	StdDev																												
	Min																												
	Max																												
LOXA124-2005	Count	8	7	8	12	8	11	8	8	8	8	8	2	8	8	6	8	12	8	12	11	11	8	8	12	8	8	8	8
	Average	34.00	10.57	12.76	26.38	83.00	2.08	17.75	44.14	1.04	3.00	0.00	0.00	16.95	0.01	0.01	0.00	6.48	4.89	1.17	171.94	0.02	0.89	117.38	21.80	1.20	17.88	4.50	0.71
	StdDev	12.87	2.82	3.96	9.05	13.40	1.11	1.67	14.68	0.58	1.18	0.00	0.00	5.82	0.00	0.01	0.00	0.43	3.71	1.65	56.91	0.03	0.10	30.33	5.48	0.68	1.81	7.18	0.20
	Min	21.00	6.00	8.70	14.20	67.00	0.61	15.00	29.20	0.50	1.80	0.00	0.00	9.50	0.00	0.00	0.00	5.93	0.86	0.05	99.30	0.01	0.75	72.00	10.40	0.77	15.00	1.50	0.40
	Max	55.00	14.00	19.70	43.20	111.00	3.83	20.00	70.00	2.00	5.10	0.01	0.01	27.20	0.02	0.02	0.01	7.30	10.40	6.20	268.00	0.11	1.01	159.00	27.10	2.82	20.00	22.00	1.00
LOXA124-2006	Count	9	0	9	10	0	9	9	0	0	0	0	0	0	0	7	4	10	9	9	10	9	0	9	10	9	9	6	9
	Average	45.11		15.88	37.49		1.49	17.33								0.01	7.73	6.51	4.55	1.34	228.47	14.01		142.22	22.94	0.87	17.78	1.83	0.62
	StdDev	15.89374		4.374008	17.30603		0.999126	2.12132								0.011909	8.248384	0.192342	1.986706	1.58343	99.76077	13.28631		48.36005	4.616315	0.17496	2.538591	0.60553	0.219602
	Min	34.00		12.90	26.00	0.00	0.57	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50	6.25	1.22	0.30	161.50	2.60	0.00	100.00	12.60	0.51	15.00	1.50	0.39
	Max	85.00		27.00	76.00	0.00	3.54	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	20.00	6.74	7.30	4.80	444.50	47.00	0.00	260.00	27.70	1.06	21.00	3.00	1.00
LOXA126-2005	Count	9	8	9	12	9	11	9	9	9	9	9	1	9	9	7	9	12	9	12	11	11	9	9	12	9	9	9	9
	Average	103.44	28.00	35.74	55.37	89.11	2.66	22.11	123.33	3.54	8.28	0.00	0.02	41.08	0.01	0.01	0.00	6.80	6.62	8.28	384.21	0.01	1.36	261.00	24.01	1.48	22.33	2.50	0.76
	StdDev	51.72	15.88	19.69	29.56	16.61	1.32	4.62	64.56	1.60	3.83	0.00		17.59	0.01	0.01	0.00	0.26	6.21	12.60	222.69	0.01	0.26	116.99	4.28	0.37	4.47	2.22	0.25
	Min	30.00	17.00	10.30	10.80	71.00	0.92	12.00	35.60	1.00	2.40	0.00	0.02	8.00	0.00	0.00	0.00	6.30	0.48	0.50	105.00	0.01	0.95	64.00	16.50	0.86	13.00	1.50	0.40
	Max	191.00	54.00	68.30	99.40	116.00	4.64	27.00	236.00	6.20	15.80	0.01	0.02	66.30	0.05	0.02	0.01	7.08	15.60	40.50	770.00	0.03	1.70	488.00	29.60	2.04	28.00	8.00	1.10
LOXA126-2006	Count	8	0	8	10	0	9	8	0	0	0	0	0	0	0	5	2	10	8	10	10	8	0	8	10	8	8	5	8
	Average	98.38		30.79	58.43		2.44	19.88								0.01	3.20	6.91	7.20	8.33	411.15	9.63		266.75	23.71	1.11	20.38	1.80	1.08
	StdDev	46.18577		17.02582	28.34353		1.683902	3.943802								0.003351	0.707107	0.188116	3.219907	11.26638	183.5504	4.619756		112.1361	4.795142	0.335463	4.206712	0.447214	0.805233
	Min	63.00		9.50	30.00	0.00	0.50	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.70	6.62	0.56	0.28	265.10	4.60	0.00	180.00	12.50	0.69	16.00	1.50	0.50
	Max	180.00		58.00	118.00	0.00	5.63	27.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.70	7.26	10.00	30.00	735.10	20.00	0.00	451.00	28.93	1.54	27.00	2.50	2.90
LOXA127-2005	Count	6	3	6	12	6	11	6	6	5	6	7	1	6	6	5	6	12	6	11	11	11	6	6	12	6	6	6	6
	Average	24.17	49.00	9.42	28.17	75.00	4.56	21.50	34.10	1.56	2.57	0.00	0.01	18.10	0.01	0.01	0.00	6.60	3.75	0.23	140.25	0.01	1.31	132.17	24.98	1.46	21.67	2.67	0.73
	StdDev	4.26	5.00	2.15	13.95	12.84	1.11	3.62	7.40	0.58	0.48	0.00		5.04	0.00	0.00	0.00	0.27	1.82	0.19	52.58	0.00	0.18	21.02	4.62	0.30	4.18	1.91	0.19
	Min	20.00	44.00	6.80	11.60	55.00	2.30	17.00	25.20	1.10	2.00	0.00	0.01	11.40	0.00	0.00	0.00	6.23	1.47	0.05	82.00	0.01	1.07	104.00	16.60	1.08	16.00	1.50	0.50
	Max	32.00	54.00	12.20	50.60	88.00	6.08	25.00	43.80	2.50	3.20	0.00	0.01	23.80	0.01	0.01	0.01	7.13	5.92	0.70	238.20	0.01	1.51	161.00	29.90	1.87	25.00	6.00	1.00
LOXA127-2006	Count	6	0	6	9	0	9	6	0	0	0	0	0	0	0	5	0	10	6	5	10	7	0	6	10	6	6	5	6
	Average	27.00		11.53	30.91		3.35	20.50								0.01		6.48	4.50	1.29	152.19	8.56		125.83	24.27	1.14	20.67	1.80	0.68
	StdDev	11.83216		6.709297	5.601661		1.723928	4.037326								0.003678		0.261755	3.05154	2.465374	20.78399	2.2523		17.81479	5.345289	0.469027	3.932768	0.447214	0.201296
	Min	17.00		7.30	24.00	0.00	1.59	15.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.12	0.23	0.09	121.40	6.00	0.00	110.00	11.50	0.67	15.00	1.50	0.41
	Max	49.00		25.00	43.00	0.00	7.20	27.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	6.90	8.40	5.70	192.70	13.00	0.00	161.00	29.45	1.95	27.00	2.50	1.00
LOXA128-2005	Count	3	3	3	7	3	7	3	3	3	3	3	0	3	3	2	3	8	3	7	7	6	3	3	8	3	3	3	3
	Average	23.67	62.33	7.00	21.33	65.33	5.06	17.00	28.37	1.30	2.67	0.00		13.60	0.01	0.00	0.00	6.47	4.56	0.16	121.26	0.01	1.04	90.67	25.62	1.57	17.33	10.33	2.07
	StdDev	1.53	55.14	0.44	3.64	6.66	2.03	1.00	0.92	0.26	0.06	0.00		1.15	0.00	0.00	0.00	0.11	2.01	0.12	13.05	0.01	0.07	32.15	6.26	0.90	1.53	15.30	2.37
	Min	22.00	30.00	6.50	16.80	58.00	2.34	16.00	27.30	1.10	2.60	0.00		12.70	0.00	0.00	0.00	6.39	2.65	0.05	107.00	0.01	0.98	54.00	17.20	1.04	16.00	1.50	0.60
	Max	25.00	126.00	7.30	28.20	71.00	7.49	18.00	28.90	1.60	2.70	0.00		14.90	0.01	0.00	0.00	6.74	6.66	0.40	148.30	0.03	1.12	114.00	34.20	2.61	19.00	28.00	4.80
LOXA128-2006	Count	3	0	3	8	0	8	3	0	0	0	0	0	0	0	2	1	8	3	3	8	7	0	3	3	3	3	8	3
	Average	15.00		5.80	22.16		6.51	18.00								0.00	3.20	6.71	4.63	0.19	121.58	4.39		87.00	0.76	18.00	3.67	27.00	1.08
	StdDev	1.732051		0.69282	6.345738		2.242682	0								0.001273		0.292709	0.51316	0.108282	27.4477	1.864071		5.196152	0.063509	0	1.607275	5.193614	0.975004
	Min	13.00		5.40	14.00	0.00	3.89	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.20	6.34	4.20	0.09	86.20	1.60	0.00	84.00	0.72	18.00	2.50	20.70	0.45
	Max	16.00		6.60	30.50	0.00	11.01	18.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.20	7.25	5.20	0.30	164.20	7.00	0.00	93.00	0.83	18.00	5.50	34.22	2.20
LOXA129-2005	Count	12	10	12	12	12	11	12	12	12	12	12	12	12	11	7	11	12	12	12	12	11	12	12	12	12	12	12	12
	Average	191.75	2.30	68.23	91.70	125.83	3.19	27.92	230.92	6.04	14.74	0.05	0.20	62.85	0.12	0.42	0.03	7.41	11.68	32.57	737.81	0.10	1.81	475.67	24.78	2.25	28.42	9.79	7.59
	StdDev	47.09	1.06	19.35	25.85	34.65	2.04	4.23	68.83	2.16	5.73	0.10	0.45	17.28	0.21	0.64	0.05	0.27	4.19	24.15	200.89	0.06	0.54	127.87	4.16	0.62	4.25	8.38	4.80
	Min	99.00	1.00	33.50	32.30	87.00	1.10	23.00	108.00	1.70	5.90	0.01	0.00	24.50	0.00	0.03	0.01	6.97	7.40	3.50	321.00	0.06	1.24	211.00	18.30	1.59	23.00	1.50	1.90
	Max	251.00	4.00	96.60	119.00	185.00	6.65	36.00	332.00	8.80	22.90	0.33	1.60	82.70	0.70	1.77	0.18	7.89	20.60	76.60	1002.00	0.26	3.04	652.00	30.20	3.52	38.00	32.00	19.40
LOXA129-2006	Count	12	0	12	12	0	11	11	0	0	0	0	0	0	0	9	7	12	12	12	12	12	0	12	12	12	12	12	12
	Average	204.75		69.93	111.00		3.14	27.00								0.08	19.11	6.94	9.35	35.68	814.98	66.58		507.25	25.27	1.74	27.00	8.06	6.88
	StdDev	32.67505		9.59177	33.03167		1.636773	6.049793								0.119415	16.4689	1.526571	4.187799	15.46898	178.1403	26.64398		119.2348	4.497366	0.587034	6.045284	3.630041	3.943262
	Min	150.00		54.00	62.00	0.00	0.15	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	4.20	2.13	2.69	13.00	582.10	19.00	0.00	350.00	15.30	0.94	17.00	3.50	2.40
	Max	275.00		89.60	165.00	0.00	6.04	36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	48.00	7.68	15.00	57.80	1116.00	110.00	0.00	723.00	30.69	2.63	36.00	15.00	14.10

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
	Count	11	10	10	12	11	11	11	10	10	10	11	5	10	11	7	11	12	11	12	11	11	11	11	12	11	11	11	11
	Average	117.64	7.60	39.66	65.34	114.82	2.25	25.18	138.03	4.70	9.46	0.00	0.01	44.15	0.01	0.00	0.00	6.76	6.36	5.87	456.01	0.02	1.39	287.27	24.30	1.55	25.45	2.41	0.96
LOXA130-2005	StdDev	47.95	2.17	16.30	32.05	14.65	1.46	5.47	56.03	2.15	3.78	0.00	0.01	19.64	0.00	0.00	0.00	0.23	5.03	8.80	205.84	0.01	0.32	117.69	4.83	0.45	5.48	2.03	0.47
	Min	49.00	3.00	16.50	17.70	98.00	0.55	17.00	56.40	1.40	3.70	0.00	0.00	13.30	0.00	0.00	0.00	6.42	1.23	1.20	171.00	0.01	0.89	115.00	16.40	0.87	17.00	1.50	0.50
	Max	185.00	11.00	63.30	102.00	148.00	4.99	31.00	221.00	7.10	15.20	0.01	0.02	69.40	0.02	0.01	0.01	7.08	16.30	30.20	757.00	0.06	1.78	479.00	30.80	2.45	32.00	7.00	2.20
	Count	7	0	7	11	0	10	7	0	0	0	0	0	0	0	4	1	11	7	11	11	9	0	7	11	7	7	5	7
	Average	152.43		49.77	87.65		1.47	26.00								0.01	3.00	6.88	11.32	9.06	603.91	12.89		399.00	23.56	1.29	26.57	2.00	1.08
LOXA130-2006	StdDev	30.72381		9.52378	31.99489		0.946245	3.511885								0.003317		0.119354	5.919577	9.671326	140.3706	7.325204		82.39539	4.539238	0.3094	3.909695	0.866025	0.976212
	Min	110.00		33.70	30.00	0.00	0.25	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.00	6.68	4.40	1.50	447.80	6.30	0.00	280.00	11.60	0.85	21.00	1.50	0.50
	Max	190.00		59.00	141.00	0.00	2.81	31.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	3.00	7.04	22.00	26.00	851.70	30.00	0.00	518.00	28.18	1.68	31.00	3.50	3.20
	Count	9	8	9	11	9	9	9	9	9	9	9	4	9	9	6	9	10	9	11	9	10	9	9	10	9	9	9	9
	Average	58.22	33.63	17.96	45.22	109.56	4.05	23.00	66.41	2.77	5.22	0.00	0.00	24.87	0.01	0.01	0.00	6.82	4.52	1.43	248.76	0.01	1.34	186.44	23.80	1.46	23.22	2.89	0.72
LOXA131-2005	StdDev	15.94	13.57	4.83	24.28	12.83	0.88	5.57	18.52	1.06	1.57	0.00	0.00	11.63	0.00	0.00	0.00	0.17	3.24	0.66	93.22	0.00	0.35	54.58	4.27	0.43	5.54	4.17	0.41
	Min	33.00	19.00	11.10	15.90	93.00	2.76	17.00	40.20	1.40	3.00	0.00	0.00	11.20	0.00	0.00	0.00	6.54	0.46	0.50	137.00	0.01	0.90	104.00	16.30	0.94	18.00	1.50	0.50
	Max	76.00	58.00	24.10	81.10	128.00	5.71	32.00	90.40	4.40	7.30	0.01	0.01	42.60	0.02	0.02	0.01	7.05	8.38	2.60	383.00	0.01	1.78	271.00	29.00	2.10	32.00	14.00	1.80
	Count	7	0	7	11	0	9	7	0	0	0	0	0	0	0	6	0	11	7	11	11	9	0	7	11	8	7	7	7
	Average	90.29		22.97	47.77		4.17	22.14								0.01		6.99	7.53	2.49	294.15	7.86		208.00	24.08	1.46	22.86	1.86	0.90
LOXA131-2006	StdDev	58.60237		5.935687	9.735614		2.084563	3.716117								0.004844		0.286058	7.651642	3.658919	105.1118	2.768172		45.20693	5.031578	0.921388	3.760699	0.377964	0.514194
	Min	54.00		16.00	31.30	0.00	1.95	16.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.48	0.12	0.09	35.50	3.30	0.00	142.00	11.10	0.74	16.00	1.50	0.50
	Max	220.00		33.00	63.00	0.00	7.68	28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	7.60	20.00	12.00	439.30	13.00	0.00	280.00	28.93	3.57	28.00	2.50	2.00
	Count	12	10	11	12	12	11	11	11	11	11	12	11	11	10	8	11	12	12	12	12	10	11	12	12	11	11	12	12
	Average	201.00	3.90	73.25	97.03	119.83	3.71	28.18	249.55	6.68	16.15	0.05	0.26	68.38	0.16	0.43	0.04	7.48	12.25	36.00	777.48	0.10	1.90	479.17	25.04	2.28	28.91	9.63	7.84
LOXA132-2005	StdDev	41.11	2.60	18.68	22.09	36.23	2.13	5.44	67.31	1.99	6.31	0.10	0.55	15.20	0.25	0.70	0.06	0.26	4.93	25.87	173.14	0.07	0.66	128.49	4.32	0.74	5.50	7.81	4.59
	Min	135.00	1.00	42.00	59.60	86.00	1.12	23.00	140.00	3.20	7.30	0.01	0.01	41.50	0.00	0.04	0.00	7.16	6.93	5.50	474.00	0.05	1.38	286.00	18.10	1.74	24.00	1.50	3.00
	Max	264.00	9.00	104.00	124.00	190.00	7.32	39.00	360.00	9.80	27.40	0.34	1.88	89.50	0.83	2.08	0.21	8.01	24.30	90.00	1054.00	0.29	3.50	714.00	30.20	3.90	40.00	28.00	15.40
	Count	12	0	11	12	0	11	11	0	0	0	0	0	0	0	9	7	12	12	12	12	12	0	12	12	12	12	12	12
	Average	200.50		69.63	115.08		3.36	27.55								0.07	14.26	7.40	9.91	37.47	845.46	67.58		526.25	25.35	1.92	28.25	7.75	6.63
LOXA132-2006	StdDev	35.76565		11.47729	34.21445		1.791086	4.761589								0.095594	14.48653	0.253551	4.597828	17.75338	150.0908	21.59317		99.77349	4.453028	0.444376	4.57513	3.962896	4.68311
	Min	160.00		55.00	35.00	0.00	0.17	19.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.30	7.08	2.13	15.00	657.80	41.00	0.00	420.00	15.30	1.20	20.00	3.00	2.20
	Max	278.00		89.80	161.00	0.00	5.92	36.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	43.00	7.81	16.00	63.00	1136.00	99.00	0.00	709.00	30.79	2.54	36.00	16.00	15.70
	Count	1	1	1	5	1	5	1	1	1	1	1	0	1	1	1	1	6	1	5	6	5	1	1	6	1	1	1	1
	Average	190.00	3.00	65.90	71.20	126.00	1.80	31.00	238.00	6.60	17.80	0.01		74.30	0.12	0.00	0.06	6.85	18.00	10.26	501.07	0.10	2.05	538.00	21.35	2.54	32.00	6.00	4.50
LOXA133-2005	StdDev				30.96		0.83											0.33		17.59	196.49	0.11			4.39				
	Min	190.00	3.00	65.90	22.70	126.00	0.75	31.00	238.00	6.60	17.80	0.01		74.30	0.12	0.00	0.06	6.43	18.00	1.10	200.00	0.02	2.05	538.00	16.97	2.54	32.00	6.00	4.50
	Max	190.00	3.00	65.90	109.00	126.00	2.69	31.00	238.00	6.60	17.80	0.01		74.30	0.12	0.00	0.06	7.20	18.00	41.60	814.00	0.27	2.05	538.00	27.30	2.54	32.00	6.00	4.50
	Count	0	0	0	4	0	3	0	0	0	0	0	0	0	0	0	0	4	0	4	4	4	0	0	4	0	0	2	0
	Average				93.60		1.66											6.80		7.05	577.60	19.75			21.14			2.50	
LOXA133-2006	StdDev				16.103		0.753746											0.068981		7.102347	62.85809	5.909033			5.922941			0.707107	
	Min	0.00		0.00	72.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.70	0.00	1.30	508.70	15.00	0.00	0.00	13.10	0.00	0.00	2.00	0.00
	Max	0.00		0.00	110.00	0.00	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.85	0.00	16.60	645.10	28.00	0.00	0.00	27.32	0.00	0.00	3.00	0.00
	Count	6	6	6	12	6	11	6	6	6	6	6	4	6	6	5	6	12	6	12	11	11	6	6	12	6	6	6	6
	Average	97.00	10.42	29.93	47.89	117.83	3.38	28.00	110.18	5.30	8.62	0.00	0.00	40.45	0.01	0.01	0.01	6.82	7.30	3.68	319.37	0.03	1.56	273.17	24.56	1.87	28.00	5.92	1.32
LOXA134-2005	StdDev	22.48	10.48	7.74	21.90	10.96	1.69	1.90	27.48	0.76	2.04	0.00	0.00	8.37	0.01	0.00	0.00	0.26	3.84	5.50	136.67	0.02	0.22	61.43	5.09	0.30	2.28	3.04	0.40
	Min	75.00	0.50	23.80	17.30	105.00	1.20	25.00	88.40	4.40	7.00	0.00	0.00	33.30	0.00	0.00	0.00	6.40	2.78	0.60	141.20	0.01	1.21	228.00	16.30	1.40	24.00	1.50	0.80
	Max	139.00	29.00	45.10	84.30	131.00	5.63	31.00	164.00	6.60	12.60	0.01	0.01	56.20	0.03	0.01	0.01	7.25	12.40	20.70	589.00	0.07	1.86	390.00	30.40	2.26	31.00	10.00	1.90
	Count	2	0	2	10	0	9	2	0	0	0	0	0	0	0	3	0	10	2	10	10	10	0	2	10	2	2	4	2
	Average	133.00		42.10	77.34		3.26	25.50								0.01		7.00	11.84	10.45	525.52	14.27		331.50	24.80	1.51	26.00	1.88	0.85
LOXA134-2006	StdDev	94.75231		32.38549	25.47797		1.583888	2.12132								0.002572		0.143376	8.711556	12.07599	122.423	8.241905		195.8686	4.791845	0.410122	2.828427	0.25	0.212132
	Min	66.00		19.20	28.00	0.00	1.16	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.79	5.68	0.70	267.80	7.00	0.00	193.00	13.40	1.22	24.00	1.50	0.70
	Max	200.00		65.00	110.00	0.00	6.02	27.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	7.27	18.00	39.00	734.70	36.00	0.00	470.00	29.28	1.80	28.00	2.00	1.00
	Count	12	12	12	12	12	10	12	12	12	12	12	11	12	12	11	12	12	12	12	11	12	12	12	12	12	12	12	12
	Average	197.83	4.67	70.41	103.44	121.92	4.27	28.58	242.42	6.34	16.16	0.05	0.19	70.78	0.14	0.24	0.03	7.51	12.17	37.66	815.18	0.09	1.91	506.08	25.39	2.23	29.42	7.58	7.66
LOXA135-2005	StdDev	51.82	3.37	19.66	25.61	38.37	1.96	5.55	74.73	2.15	6.88	0.08	0.31	19.05	0.26	0.37	0.05	0.33	5.79	26.47	208.03	0.05	0.67	137.03	4.38	0.67	5.82	4.21	4.80
	Min	133.00	1.00	49.90	48.10	73.00	1.20	22.00	154.00	2.90	6.50	0.00	0.01	33.20	0.00	0.02	0.00	7.09	6.66	7.90	455.20	0.04	1.31	326.00	18.40	1.63	23.00	4.00	2.30
	Max	298.00	13.00	108.00	152.00	194.00	7.38	42.00	397.00	9.80	30.80	0.24	1.09	111.00	0.94	1.26	0.18	8.11	28.10	99.00	1161.00	0.22	3.73	793.00	30.50	3.96	43.00	19.00	19.00
	Count	12	0	12	12	0	12	11	0	0	0	0	0	0	0	8	5	12	12	12	12	12	0	12	12	12	12	12	12
	Average	204.42		68.76	130.50		5.04	28.27								0.10	26.82	7.53	8.89	38.98	872.98	72.50		544.83	25.19	2.04	29.42	7.68	6.33
LOXA135-2006	StdDev	41.27834		14.92968	22.138		2.852394	4.221159								0.141697	37.8993	0.245943	4.09452	18.46491	131.4182	34.29683		95.03572	4.484328	0.458155	4.481443	4.053758	4.246309
	Min	130.00		43.00	100.00	0.00	1.38	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.10	7.16	3.20	16.00	739.40	34.00	0.00	430.00	15.10	1.20	21.00	2.00	2.20
	Max	282.00		94.10	170.00	0.00	12.00	35.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.44	93.00	7.98	17.00	75.00	1159.00	150.00	0.00	742.00	29.95	2.62	37.00	15.00	13.80

Site - Year	STAT	ALK	APA	Ca	Cl	COLOR	D-O	DOC	HARD	K	Mg	N02	N03	Na	NH4	NOX	OPO4	Ph_F	SiO2	SO4	SpC	T_PO4	TDKN	TDS	TEMP	TKN	TOC	TSS	TURB
		mg/L	nM/minmL	mg/L	mg/L	PCU	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	units	mg/L	mg/L	uS/cm	mg/L	mg/L	mg/L	Deg.C	mg/L	mg/L	mg/L	mg/L
	Count	1	1	1	6	1	5	1	1	1	1	1	0	1	1	1	1	6	1	5	6	6	1	1	6	1	1	1	1
	Average	219.00	3.00	76.30	66.45	147.00	1.51	36.00	282.00	7.40	22.30	0.01		81.30	0.00	0.01	0.01	6.63	23.90	15.08	473.68	0.06	2.14	632.00	21.38	2.44	36.00	8.00	4.20
LOXA136-2005	StdDev				33.04		1.64											0.18		27.44	253.15	0.05			4.64				
	Min	219.00	3.00	76.30	20.70	147.00	0.45	36.00	282.00	7.40	22.30	0.01		81.30	0.00	0.01	0.01	6.35	23.90	1.40	183.00	0.02	2.14	632.00	16.00	2.44	36.00	8.00	4.20
	Max	219.00	3.00	76.30	120.00	147.00	4.42	36.00	282.00	7.40	22.30	0.01		81.30	0.00	0.01	0.01	6.86	23.90	64.10	934.00	0.15	2.14	632.00	27.40	2.44	36.00	8.00	4.20
	Count	3	0	3	7	0	7	3	0	0	0	0	0	0	0	1	2	7	3	7	7	7	0	3	7	3	3	3	3
	Average	193.33		61.67	87.53		1.85	28.33								0.01	3.40	6.92	20.00	15.57	617.36	20.14		436.67	22.75	1.40	28.67	2.17	1.27
LOXA136-2006	StdDev	30.5505		8.621678	19.28702		1.736027	1.154701									1.272792	0.173754	3.605551	15.9713	147.2351	7.289915		76.37626	4.947238	0.360555	2.081666	0.288675	0.152753
	Min	160.00		54.00	53.70	0.00	0.75	27.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	2.50	6.56	17.00	1.00	342.50	12.00	0.00	370.00	13.60	1.10	27.00	2.00	1.10
	Max	220.00		71.00	118.00	0.00	5.63	29.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	4.30	7.07	24.00	43.00	804.50	28.00	0.00	520.00	27.94	1.80	31.00	2.50	1.40
	Count	8	8	8	12	8	10	8	8	8	8	8	6	8	8	7	8	12	8	12	11	12	8	8	12	8	8	8	8
	Average	70.00	19.75	22.33	41.72	121.25	3.03	25.38	82.31	2.81	6.48	0.00	0.01	26.29	0.01	0.01	0.00	6.62	8.52	3.39	302.35	0.02	1.47	184.50	24.33	1.58	25.75	2.63	0.95
LOXA137-2005	StdDev	34.17	11.25	11.13	22.34	15.95	1.34	3.78	42.06	1.65	3.49	0.00	0.02	15.61	0.01	0.01	0.00	0.22	5.01	7.33	143.94	0.02	0.21	117.26	5.03	0.36	4.03	2.08	0.41
	Min	39.00	10.00	13.30	16.20	96.00	1.04	20.00	47.10	0.80	3.40	0.00	0.00	11.90	0.00	0.00	0.00	6.26	0.96	0.80	120.40	0.01	1.24	24.00	16.70	1.24	20.00	1.50	0.50
	Max	148.00	40.00	48.40	92.00	143.00	5.78	32.00	180.00	5.40	14.40	0.01	0.04	60.80	0.02	0.01	0.01	7.01	17.10	26.60	655.00	0.05	1.84	424.00	30.10	2.31	32.00	6.00	1.80
	Count	7	0	8	11	0	11	8	0	0	0	0	0	0	0	7	2	11	8	11	11	11	0	8	11	8	8	5	8
	Average	121.14		37.38	74.53		2.93	27.63								0.02	4.70	6.87	12.43	8.83	443.35	10.75		328.38	24.38	1.42	27.75	1.90	0.61
LOXA137-2006	StdDev	47.84499		13.42926	19.74619		1.997649	3.814914								0.015523	3.676955	0.170433	9.032362	10.72521	164.9463	5.89701		74.25427	4.975038	0.303456	3.807887	0.547723	0.216861
	Min	60.00		17.10	33.20	0.00	1.18	23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.10	6.61	2.54	0.70	171.60	5.00	0.00	241.00	11.80	1.00	23.00	1.50	0.40
	Max	200.00		62.00	99.00	0.00	7.01	33.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	7.30	7.12	29.00	35.00	724.50	27.00	0.00	480.00	28.52	1.82	33.00	2.50	1.10
	Count	3	3	3	10	3	8	3	3	3	3	3	1	3	3	3	3	10	3	10	9	10	3	3	10	3	3	3	3
	Average	38.00	52.00	12.27	28.22	96.00	5.55	20.33	45.30	1.57	3.57	0.00	0.01	13.93	0.00	0.01	0.00	6.74	4.45	0.99	194.02	0.01	1.22	93.00	25.05	1.34	20.00	3.00	1.00
LOXA138-2005	StdDev	1.73	10.54	0.15	14.57	23.90	2.34	0.58	0.66	0.21	0.06	0.00		0.81	0.00	0.00	0.00	0.24	0.90	0.45	77.00	0.01	0.08	61.73	5.42	0.15	1.00	2.60	0.53
	Min	37.00	41.00	12.10	13.30	75.00	3.03	20.00	44.60	1.40	3.50	0.00	0.01	13.20	0.00	0.00	0.00	6.39	3.41	0.40	96.30	0.01	1.14	24.00	16.60	1.21	19.00	1.50	0.60
	Max	40.00	62.00	12.40	55.00	122.00	8.58	21.00	45.90	1.80	3.60	0.01	0.01	14.80	0.00	0.01	0.01	7.25	5.05	1.70	328.20	0.03	1.30	143.00	33.10	1.50	21.00	6.00	1.60
	Count	3	0	3	8	0	8	3	0	0	0	0	0	0	0	2	0	8	3	8	8	7	0	3	8	3	3	2	3
	Average	96.67		30.40	49.08		6.06	23.33								0.00		7.10	15.83	4.80	311.34	7.11		278.67	25.26	1.05	23.33	2.75	0.61
LOXA138-2006	StdDev	41.63332		13.50111	15.58128		2.851683	2.309401								0.001697		0.468842	11.81454	7.645982	125.3576	2.695941		62.01075	5.943886	0.441852	2.309401	1.767767	0.161658
	Min	50.00		15.20	28.60	0.00	3.61	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.43	2.50	0.09	183.20	3.50	0.00	216.00	11.50	0.63	22.00	1.50	0.52
	Max	130.00		41.00	74.00	0.00	9.94	26.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	7.90	25.00	21.00	539.30	11.00	0.00	340.00	29.60	1.51	26.00	4.00	0.80
	Count	1	1	1	7	1	7	1	1	1	1	1	1	1	1	1	1	8	1	7	7	7	1	1	8	1	1	1	1
	Average	21.00	75.00	6.70	16.84	146.00	5.35	21.00	25.00	0.80	2.00	0.01	0.00	9.10	0.00	0.01	0.01	6.52	1.04	0.31	116.59	0.01	1.23	90.00	26.06	1.47	21.00	6.00	1.50
LOXA139-2005	StdDev				4.87		2.44											0.23		0.17	37.95	0.00			5.36				
	Min	21.00	75.00	6.70	12.90	146.00	3.39	21.00	25.00	0.80	2.00	0.01	0.00	9.10	0.00	0.01	0.01	6.12	1.04	0.10	86.10	0.01	1.23	90.00	16.81	1.47	21.00	6.00	1.50
	Max	21.00	75.00	6.70	27.00	146.00	9.41	21.00	25.00	0.80	2.00	0.01	0.00	9.10	0.00	0.01	0.01	6.87	1.04	0.60	183.00	0.02	1.23	90.00	33.50	1.47	21.00	6.00	1.50
	Count	2	0	2	6	0	6	2	0	0	0	0	0	0	0	2	0	6	2	4	6	6	0	2	6	2	2	2	2
	Average	33.00		11.00	31.32		5.39	22.00								0.01		6.65	14.50	0.45	163.05	5.75		145.00	24.03	0.87	22.50	2.75	0.68
LOXA139-2006	StdDev	7.071068		1.414214	5.481028		3.556547	1.414214								0.000707		0.642041	0.707107	0.307395	26.78333	1.64408		21.2132	6.329897	0.190919	0.707107	1.06066	0.127279
	Min	28.00		10.00	24.00	0.00	1.96	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	6.21	14.00	0.10	137.30	3.80	0.00	130.00	11.70	0.73	22.00	2.00	0.59
	Max	38.00		12.00	38.00	0.00	11.20	23.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	7.87	15.00	0.72	205.80	8.00	0.00	160.00	28.16	1.00	23.00	3.50	0.77
	Count	2	2	2	9	2	7	2	2	2	2	2	1	2	2	2	2	9	2	9	8	9	2	2	9	2	2	2	2
	Average	83.00	18.50	26.50	45.03	166.50	5.70	30.00	99.65	3.45	8.10	0.01	0.00	38.55	0.01	0.01	0.01	6.87	9.96	3.14	295.01	0.02	1.63	265.50	25.33	1.82	30.50	2.25	1.05
LOXA140-2005	StdDev	65.05	6.36	19.80	22.51	4.95	2.56	7.07	75.45	3.18	6.36	0.00		32.46	0.00	0.00	0.00	0.21	7.98	5.81	140.37	0.01	0.62	197.28	5.97	0.71	7.78	1.06	0.35
	Min	37.00	14.00	12.50	22.80	163.00	3.11	25.00	46.30	1.20	3.60	0.01	0.00	15.60	0.01	0.00	0.00	6.69	4.31	0.70	158.20	0.01	1.19	126.00	16.10	1.31	25.00	1.50	0.80
	Max	129.00	23.00	40.50	94.70	170.00	8.70	35.00	153.00	5.70	12.60	0.01	0.00	61.50	0.01	0.01	0.01	7.37	15.60	18.60	604.00	0.04	2.07	405.00	33.20	2.32	36.00	3.00	1.30
	Count	4	0	4	7	0	7	4	0	0	0	0	0	0	0	5	0	7	4	7	7	7	0	4	7	4	4	2	4
	Average	104.25		29.20	60.00		5.97	25.25								0.01		7.00	13.60	4.81	359.00	10.31		266.50	24.82	1.10	25.00	2.00	0.67
LOXA140-2006	StdDev	27.78939		6.910861	11.21145		1.947523	4.573474								0.008204		0.230919	7.341754	5.439427	91.61053	4.986792		47	5.665014	0.278209	4.690416	0.707107	0.304302
	Min	67.00		22.80	38.30	0.00	3.68	22.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	6.66	4.39	0.87	222.30	6.00	0.00	220.00	14.50	0.89	22.00	1.50	0.40
	Max	130.00		37.00	75.00	0.00	10.00	32.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	7.27	20.00	16.00	511.30	20.00	0.00	330.00	31.77	1.51	32.00	2.50	1.10
	Count	2	0	2	2	0	2	2	0	0	0	0	0	0	0	0	1	2	2	2	2	2	0	2	2	2	2	2	2
	Average	93.50		28.50	45.50		2.88	22.50									6.70	6.93	10.80	3.85	346.55	5.45		235.00	20.68	1.01	22.00	2.00	0.65
LOXA141-2006	StdDev	2.12132		2.12132	2.12132		0.53033	2.12132										0.098995	1.697056	0.919239	0.777817	3.747666		7.071068	0.749533	0.410122	1.414214	0	0.070711
	Min	92.00		27.00	44.00	0.00	2.50	21.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.70	6.86	9.60	3.20	346.00	2.80	0.00	230.00	20.15	0.72	21.00	2.00	0.60
	Max	95.00		30.00	47.00	0.00	3.25	24.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	6.70	7.00	12.00	4.50	347.10	8.10	0.00	240.00	21.21	1.30	23.00	2.00	0.70

Appendix 2-2

Summary statistics of monthly water quality data (January 2005 – December 2006) by zone.

Table A2-2-1. EVPA and LOXA sites classified into zones for analyses.

Zones	Sites
Canal Zone	LOXA104, LOXA115, LOXA129, LOXA132, LOXA135
Perimeter Zone (< 2.5 km)	LOX4, LOX6, LOX10, LOX14, LOX15, LOX16 LOXA101, LOXA102, LOXA103, LOXA105, LOXA106, LOXA107, LOXA109, LOXA112, LOXA116, LOXA117, LOXA118, LOXA121, LOXA122, LOXA123, LOXA124, LOXA126, LOXA130, LOXA131, LOXA133, LOXA134, LOXA136, LOXA137, LOXA138, LOXA140
Transition Zone (2.5 – 4.5 km)	LOX12 LOXA108, LOXA110, LOXA111, LOXA113, LOXA114, LOXA119, LOXA127, LOXA139
Interior Zone (> 4.5 km)	LOX3, LOX5, LOX7, LOX8, LOX9, LOX11, LOX13 LOXA120, LOXA128

Table A2-2-2. Summary Statistics of arithmetic mean monthly water quality data by zone presented for: (a) calendar year 2005; and (b) 2006.

Table A2-2-2a : 2005 Summary Arithmetic Mean Data By Zone

(Mean = arithmetic mean, Count = # of sites, 95% CI Up = 95% upper arithmetic mean confidence interval,
95% CI Low = 95% lower arithmetic mean confidence interval)

		Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
TP (µg L^{-1})	Canal - Mean	66.2	124.8	100.3	70.3	69.3	216.8	76.0	57.0	61.0	67.6	148.8	92.2
	Canal - Count	5	5	3	3	3	5	5	4	5	5	5	5
	Canal - 95% CI Up	97.4	213.2	125.3	78.3	121.8	335.5	100.2	72.4	79.5	110.3	223.0	146.2
	Canal - 95% CI Low	35.0	36.4	75.4	62.4	16.9	98.1	51.8	41.6	42.5	24.9	74.6	38.2
	Perimeter - Mean	28.3	24.7	15.7	21.5	31.1	38.5	9.2	12.6	13.5	10.8	12.0	11.1
	Perimeter - Count	29	27	14	19	9	23	17	19	29	25	26	30
	Perimieter - 95%CI Up	136.2	72.9	39.3	66.9	52.9	101.6	18.2	34.0	33.8	18.8	22.9	28.8
	Perimeter - 95% CI Low	-79.5	-23.4	-7.9	-24.0	9.3	-24.7	0.3	-8.9	-6.8	2.8	1.0	-6.5
	Transition - Mean	13.7	11.6	44.5	10.3	52.0	20.4	6.9	6.0	6.9	7.3	8.1	6.8
	Transition - Count	7	5	2	3	1	8	7	6	7	8	9	9
	Transition - 95% CI Up	27.4	23.4	118.0	13.3		35.0	12.1	9.3	10.5	8.2	9.9	9.5
	Transition - 95% CI Low	0.0	-0.2	-29.0	7.3		5.7	1.6	2.7	3.2	6.3	6.3	4.0
	Interior - Mean	9.7	9.4	17.5	9.5	102.0	31.5	8.6	6.7	6.6	6.6	7.3	7.9
	Interior - Count	7	5	4	4	1	2	9	7	5	8	9	9
	Interior - 95% CI Up	13.2	13.0	31.7	10.6		38.4	13.2	9.2	8.8	9.2	9.7	16.5
	Interior - 95% CI Low	6.2	5.8	3.3	8.4		24.6	3.9	4.3	4.4	4.1	4.9	-0.7
TN (mg L^{-1})	Canal - Mean	2.08	2.81	1.96	2.09	2.23	4.70	2.27	1.77	2.16	2.25	4.19	2.52
	Canal - Count	5	5	3	3	3	5	2	3	3	3	5	5
	Canal - 95% CI Up	2.99	5.32	2.26	2.60	2.86	7.03	2.35	3.09	2.54	3.27	4.94	3.51
	Canal - 95% CI Low	1.17	0.31	1.66	1.57	1.59	2.37	2.19	0.44	1.78	1.24	3.44	1.53
	Perimeter - Mean	1.42	1.78	1.43	1.71	1.98	2.06	1.02	1.15	1.10	1.02	1.32	1.27
	Perimeter - Count	20	15	5	11	3	8	1	6	14	12	23	24
	Perimeter - 95%CI Up	2.28	3.66	2.25	2.75	2.64	2.94		1.61	1.60	1.36	2.11	1.99
	Perimeter - 95% CI Low	0.57	-0.10	0.61	0.68	1.33	1.19		0.70	0.60	0.68	0.52	0.54
	Transition - Mean	1.30	1.28	1.57	1.33	8.69	1.84		0.91	0.97	0.81	0.91	0.95
	Transition - Count	4	2	1	2	1	2	0	1	1	4	6	6
	Transition - 95% CI Up	2.10	2.10		2.17		2.85				1.04	1.16	1.25
	Transition - 95% CI Low	0.50	0.46		0.49		0.84				0.57	0.65	0.64
	Interior - Mean	1.64	1.50	2.21	1.60	8.40	3.17	1.10	1.03	1.14	1.21	1.11	1.14
	Interior - Count	5	3	3	4	1	1	2	4	4	4	7	6
	Interior - 95% CI Up	1.94	1.95	2.98	2.12			1.13	1.30	1.42	1.50	1.32	1.37
	Interior - 95% CI Low	1.33	1.06	1.44	1.07			1.08	0.76	0.86	0.92	0.91	0.92
Conductivity (µS cm^{-1})	Canal -Mean	751	1073	722	937	880	1061	709	563	795	832	1064	1063
	Canal - Count	5	5	3	3	5	5	4	5	5	5	5	5
	Canal - 95% CI Up	908	1976	757	1159	964	1232	1257	1029	1320	1254	1274	1587
	Canal - 95% CI Low	593	171	688	715	797	890	160	97	270	410	854	538
	Perimeter - Mean	381	404	416	347	411	593	211	188	253	215	427	480
	Perimeter - Count	27	28	12	19	14	23	11	19	29	25	26	30
	Perimieter - 95%CI Up	704	760	737	594	687	1049	332	314	649	435	955	1064
	Perimeter - 95% CI Low	59	48	95	101	135	138	91	63	-142	-5	-101	-103
	Transition - Mean	168	191	220	204	221	154	118	108	127	110	132	150
	Transition - Count	7	3	2	4	2	8	3	6	7	8	9	9
	Transition - 95% CI Up	198	208	235	303	269	232	135	146	177	157	206	237
	Transition - 95% CI Low	137	173	204	106	172	76	100	70	77	64	59	64
	Interior - Mean	144	140	220	153	201	112	89	90	107	109	110	120
	Interior - Count	2	4	2	2	1	2	6	7	6	8	9	9
	Interior - 95% CI Up	156	199	228	204		134	112	135	154	137	124	133
	Interior - 95% CI Low	131	81	212	102		90	65	44	60	81	95	107
CL (mg L^{-1})	Canal -Mean	97.8	138.2	92.0	127.7	116.4	118.7	88.7	66.9	103.9	121.6	130.2	134.4
	Canal - Count	5.0	5.0	3.0	3.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Canal - 95% CI Up	121.9	261.9	93.8	170.4	134.6	145.4	149.7	150.6	183.9	166.2	158.7	223.2
	Canal - 95% CI Low	73.7	14.5	90.1	85.0	98.2	92.0	27.7	-16.8	23.9	77.0	101.7	45.6
	Perimeter - Mean	55.0	70.4	56.2	52.2	62.7	81.0	20.8	21.4	32.0	27.4	59.7	69.4
	Perimeter - Count	29	26	14	19	14	23	17	19	29	25	26	30
	Perimeter - 95%CI Up	95.9	145.9	99.7	85.4	99.6	139.6	29.7	33.2	86.7	58.2	132.0	150.7
	Perimeter - 95% CI Low	14.0	-5.1	12.7	19.1	25.8	22.4	11.8	9.7	-22.6	-3.5	-12.6	-11.9
	Transition - Mean	27.9	43.3	33.8	31.4	40.2	24.6	17.8	14.0	17.1	15.3	19.8	22.9
	Transition - Count	7	5	2	3	2	8	7	6	7	8	9	9
	Transition - 95% CI Up	35.9	96.0	37.7	39.5	62.7	41.2	27.0	18.3	25.8	19.9	29.7	34.4
	Transition - 95% CI Low	20.0	-9.4	29.9	23.3	17.6	8.1	8.5	9.7	8.4	10.7	9.9	11.4
	Interior - Mean	27.4	30.1	33.9	27.5	37.6	19.0	16.7	16.5	20.0	20.5	21.1	23.1
	Interior - Count	7	5	5	4	1	2	8	7	6	8	9	9
	Interior - 95% CI Up	35.8	43.5	50.1	36.7		20.2	20.6	24.7	28.6	26.8	25.7	27.1
	Interior - 95% CI Low	19.0	16.8	17.7	18.3		17.7	12.8	8.4	11.3	14.1	16.5	19.1
SO_4 (mg L^{-1})	Canal -Mean	34.20	52.60	38.50	31.73	56.20	88.70	25.64	12.05	32.76	33.28	77.60	63.16
	Canal - Count	5	5	3	3	5	5	5	4	5	5	5	5
	Canal - 95% CI Up	54.32	88.90	40.54	46.47	69.27	108.15	77.52	25.33	87.19	87.87	104.99	135.84
	Canal - 95% CI Low	14.08	16.30	36.46	17.00	43.13	69.25	-26.24	-1.23	-21.67	-21.31	50.21	-9.52
	Perimeter - Mean	7.51	7.54	5.44	3.88	4.33	27.57	1.54	2.45	5.34	2.98	11.20	12.87
	Perimeter - Count	28	26	14	19	14	23	17	17	29	25	26	30
	Perimeter - 95%CI Up	26.43	26.15	15.00	14.70	12.58	61.88	3.85	7.20	24.57	8.63	48.85	57.95
	Perimeter - 95% CI Low	-11.42	-11.07	-4.12	-6.93	-3.93	-6.73	-0.76	-2.29	-13.89	-2.68	-26.45	-32.20
	Transition - Mean	0.60	0.86	1.10	0.90	0.45	1.33	0.36	0.39	0.56	0.79	0.97	0.81
	Transition - Count	7	5	2	3	2	8	7	4	7	8	9	9
	Transition - 95% CI Up	1.31	1.72	1.38	3.13	1.14	3.59	0.94	1.00	1.24	1.66	2.08	1.83
	Transition - 95% CI Low	-0.11	0.00	0.82	-1.33	-0.24	-0.94	-0.21	-0.22	-0.12	-0.09	-0.15	-0.20
	Interior - Mean	0.09	0.13	0.23	0.26	0.20	0.40	0.19	0.17	0.11	0.15	0.15	0.14
	Interior - Count	7	5	5	4	1	2	8	7	6	8	9	9
	Interior - 95% CI Up	0.27	0.43	0.65	0.70		0.40	0.43	0.38	0.30	0.42	0.41	0.35
	Interior - 95% CI Low	-0.10	-0.17	-0.19	-0.17		0.40	-0.05	-0.04	-0.08	-0.12	-0.11	-0.07
Tdepth (in.)	Perimeter - Mean	11.6	11.0	5.4	11.6	5.8	16.5	6.5	6.1	10.3	11.4	13.5	14.5
	Perimeter - Count	30	29	25	19	19	24	26	30	30	26	29	29
	Perimeter - 95%CI Up	21.6	24.8	15.6	26.0	18.1	25.7	14.1	14.9	22.0	23.2	28.0	28.3
	Perimeter - 95% CI Low	1.6	-2.8	-4.7	-2.7	-6.5	7.3	-1.2	-2.8	-1.4	-0.5	-1.0	0.7
	Transition - Mean	9.0	5.6	2.2	7.3	3.2	11.6	4.9	4.1	5.6	8.9	11.0	10.7
	Transition - Count	7	9	8	4	8	9	9	9	9	8	9	9
	Transition - 95% CI Up	15.9	16.4	6.4	17.0	10.1	16.8	8.3	7.6	8.5	12.5	17.8	18.7
	Transition - 95% CI Low	2.1	-5.1	-2.1	-2.5	-3.7	6.4	1.6	0.7	2.6	5.4	4.3	2.7
	Interior - Mean	8.2	5.9	4.9	7.4	4.3	13.0	8.9	7.7	7.3	8.5	14.0	12.0
	Interior - Count	9	9	8	7	6	3	9	9	6	9	9	9
	Interior - 95% CI Up	17.8	17.1	11.6	18.2	12.1	21.5	19.4	15.0	14.1	16.6	25.5	22.5
	Interior - 95% CI Low	-1.5	-5.3	-1.9	-3.4	-3.5	4.5	-1.6	0.4	0.5	0.4	2.4	1.6

Table A2-2-2b : 2006 Summary Arithmetic Mean Data By Zone

(Mean = arithmetic mean, Count = # of sites, 95% CI Up = 95% upper arithmetic mean confidence interval,
95% CI Low = 95% lower arithmetic mean confidence interval)

		Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
TP (µg L^{-1})	Canal - Mean	55.8908	103.279	79.37595	63.7569	61.71806	54.4432	93.5911	49.97656	122.532	39.5658	46.38547	33.9543
	Canal - Count	5	5	5	5	5	5	5	5	5	5	5	5
	Canal - 95% CI Up	86.7382	153.606	124.5708	96.5071	103.7417	85.4521	135.482	87.07703	171.758	68.4849	65.25652	45.5166
	Canal - 95% CI Low	25.0433	52.9527	34.18105	31.0067	19.69445	23.4343	51.7003	12.87608	73.3047	10.6467	27.51443	22.3919
	Perimeter - Mean	13.6314	15.34	13.65099	15.422	29.56239	30.0241	8.35707	10.08786	11.2681	10.0877	10.99486	9.79424
	Perimeter - Count	29	32	14	19	9	23	17	19	29	25	26	29
	Perimieter - 95%CI Up	121.447	59.4143	37.22656	60.8669	51.33173	93.1738	17.2726	31.53189	31.6008	18.1293	21.97759	27.6438
	Perimeter - 95% CI Low	-94.184	-28.7344	-9.92459	-30.0228	7.793053	-33.126	-0.5585	-11.3562	-9.0645	2.04617	0.012134	-8.05532
	Transition - Mean	6.44134	6.15623	7.415586	8.27838	7	13	10.2343	8	5.62193	5.51172	5.024411	0.17205
	Transition - Count	8	9	4	5	1	1	7	1	9	7	9	2
	Transition - 95% CI Up	8.25594	8.061	9.945935	11.2509			23.3824		10.4757	10.5113	10.95321	10.4224
	Transition - 95% CI Low	4.62673	4.25145	4.885236	5.30589			-2.9138		0.76821	0.51211	-0.90439	-10.0783
	Interior - Mean	6.70292	6.28975	8.612963	8.25965	10.38791	10.8167	10.9573	10.6099	7.11458	7.08109	5.382794	0.0356
	Interior - Count	5	5	4	6	5	2	5	4	9	9	4	7
	Interior - 95% CI Up	10.2461	8.61771	10.63724	10.6333	20.70355	20.7953	28.1339	24.03507	12.0085	9.55342	9.185059	4.07986
	Interior - 95% CI Low	3.15978	3.96179	6.588684	5.88598	0.07228	0.83796	-6.2193	-2.81527	2.22068	4.60876	1.580529	-4.00867
TN (mg L^{-1})	Canal - Mean	2.46436	2.6905	2.312435	2.35507	2.418735	1.98621	1.8612	1.714413	1.78538	1.27902	1.441107	1.70295
	Canal - Count	5	5	5	5	5	5	5	5	5	5	5	5
	Canal - 95% CI Up	2.95592	4.20215	2.442531	2.6386	2.834862	2.78718	2.49987	2.415452	2.89269	1.98143	2.287614	2.17429
	Canal - 95% CI Low	1.9728	1.17886	2.182339	2.07155	2.002609	1.18524	1.22253	1.013374	0.67808	0.57661	0.5946	1.23161
	Perimeter - Mean	1.11659	1.23284	1.32265	1.21819	1.163719	1.94004		0.997729	0.95016	0.90513	0.852376	1.04884
	Perimeter - Count	16	22	13	6	3	3	22	8	25	23	18	10
	Perimieter - 95%CI Up	1.77009	1.94885	2.01248	1.71373	1.743513	4.37048		1.657671	1.70113	1.81332	1.553122	1.51625
	Perimeter - 95% CI Low	0.4631	0.51683	0.63282	0.72265	0.583926	-0.4904		0.337787	0.19919	-0.00306	0.15163	0.58143
	Transition - Mean	0.99264	0.94769	1.478312	1.14925	1.223	1.547		0.933702	0.7197	0.68792	0.690855	1.023
	Transition - Count	3	3	2	2	1	1	7	2	9	9	6	1
	Transition - 95% CI Up	1.4196	1.54614	2.634177	1.2683				2.1159	1.10281	1.32102	1.078678	
	Transition - 95% CI Low	0.56568	0.34924	0.322447	1.0302				-0.2485	0.3366	0.05481	0.303031	
	Interior - Mean	1.29642	1.26613	1.602492	1.60535	2.153			1.455298	1.12679	1.11095	0.679542	
	Interior - Count	3	3	4	5	1	0	4	3	9	6	3	6
	Interior - 95% CI Up	1.57305	1.48434	2.028838	1.78795				2.378629	1.60032	1.82247	1.319755	
	Interior - 95% CI Low	1.01979	1.04792	1.176147	1.42274				0.531967	0.65325	0.39943	0.03933	
Conductivity (µS/cm)	Canal -Mean	971.279	914.384	982.9362	1044.02	1122.893	732.046	838.119	883.8054	966.523	810.052	745.2466	732.362
	Canal - Count	5	5	5	5	4	5	5	5	5	5	5	5
	Canal - 95% CI Up	1223.81	1119.78	1175.378	1140.3	1186.854	911.667	954.055	1162.043	1196.6	1162.91	1057.431	1002.25
	Canal - 95% CI Low	718.746	708.99	790.4947	947.743	1058.932	552.425	722.182	605.5679	736.447	457.192	433.0617	462.479
	Perimeter - Mean	302.455	369.404	378.933	328.823	275.8313	299.448	382.247	413.3515	357.528	345.546	307.4375	303.183
	Perimeter - Count	24	29	24	14	6	6	24	23	27	26	25	20
	Perimieter - 95%CI Up	748.98	954.03	812.049	728.081	486.7055	542.682	821.84	696.6	851.244	778.987	638.9486	665.788
	Perimeter - 95% CI Low	-144.07	-215.222	-54.1829	-70.4347	64.95712	56.2135	-57.347	130.103	-136.19	-87.8955	-24.0736	-59.4227
	Transition - Mean	164.254	159.022	196.64	182.835	260.4	280.5	134.248	173.9509	124.605	124.551	139.0078	176.502
	Transition - Count	8	9	4	5	1	1	8	4	9	9	9	3
	Transition - 95% CI Up	211	210.462	257.9134	252.849			264.188	435.826	218.26	212.532	217.3488	257.101
	Transition - 95% CI Low	117.509	107.582	135.3666	112.822			4.30826	-87.9242	30.9505	36.5701	60.66687	95.9019
	Interior - Mean	137.957	114.668	160.465	168.164	191.6765	248.256	142.169	138.3505	93.4187	105.877	115.0125	142.169
	Interior - Count	4	5	4	6	4	2	5	6	9	9	4	4
	Interior - 95% CI Up	181.824	176.932	224.3586	216.065	233.464	397.797	210.584	174.644	127.122	131.064	133.7453	162.879
	Interior - 95% CI Low	94.0896	52.4038	96.57134	120.263	149.889	98.7137	73.754	102.057	59.7156	80.69	96.27972	121.458
CL (mg L^{-1})	Canal -Mean	150.729	123.911	137.7994	146.666	152.4359	83.3273	109.818	119.8329	120.762	111.768	100.4563	98.9911
	Canal - Count	5	5	5	5	4	5	5	5	5	5	5	5
	Canal - 95% CI Up	1223.81	1119.78	1175.378	1140.3	1186.854	911.667	954.055	1162.043	1196.6	1162.91	1057.431	1002.25
	Canal - 95% CI Low	718.746	708.99	790.4947	947.743	1058.932	552.425	722.182	605.5679	736.447	457.192	433.0617	462.479
	Perimeter - Mean	44.5547	62.5052	60.59776	51.5433	44.19099	47.1245	58.1822	60.80022	45.7866	44.6862	45.50968	39.8996
	Perimeter - Count	24	29	24	14	6	6	24	23	27	26	25	20
	Perimieter - 95%CI Up	748.98	954.03	812.049	728.081	486.7055	542.682	821.84	696.6	851.244	778.987	638.9486	665.788
	Perimeter - 95% CI Low	-144.07	-215.222	-54.1829	-70.4347	64.95712	56.2135	-57.347	130.103	-136.19	-87.8955	-24.0736	-59.4227
	Transition - Mean	27.8512	29.3101	33.52831	31.2992	40.7	43.1	19.5404	25.31223	20.0391	19.0815	24.44514	28.0949
	Transition - Count	8	9	4	5	1	1	8	4	9	9	9	3
	Transition - 95% CI Up	211	210.462	257.9134	252.849			264.188	435.826	218.26	212.532	217.3488	257.101
	Transition - 95% CI Low	117.509	107.582	135.3666	112.822			4.30826	-87.9242	30.9505	36.5701	60.66687	95.9019
	Interior - Mean	27.4794	27.1895	33.12459	34.7357	45.67719	48.6703	26.6561	25.07701	17.1887	19.7422	22.94992	29.8695
	Interior - Count	4	5	4	6	4	2	5	6	9	9	4	4
	Interior - 95% CI Up	181.824	176.932	224.3586	216.065	233.464	397.797	210.584	174.644	127.122	131.064	133.7453	162.879
	Interior - 95% CI Low	94.0896	52.4038	96.57134	120.263	149.889	98.7137	73.754	102.057	59.7156	80.69	96.27972	121.458
SO_4 (mg L^{-1})	Canal -Mean	34.3821	55.4699	52.64897	54.7549	59.96442	25.6776	51.9326	44.59802	64.2799	42.6591	24.23809	22.1001
	Canal - Count	5	5	5	5	5	5	5	5	5	5	5	5
	Canal - 95% CI Up	85.2187	88.9823	90.33666	76.0263	71.38804	57.1294	67.771	91.51536	87.8977	71.3515	55.76303	41.866
	Canal - 95% CI Low	-16.455	21.9575	14.96127	33.4835	48.5408	-5.7741	36.0941	-2.31932	40.6621	13.9667	-7.28685	2.33422
	Perimeter - Mean	2.02037	7.37661	2.227558	1.39729	0.864849	1.87334	8.4833	4.311396	6.93984	5.53346	3.408654	2.67192
	Perimeter - Count	26	29	24	14	5	6	24	23	27	26	25	20
	Perimieter - 95%CI Up	25.0497	48.9422	20.12296	11.0815	5.257174	10.0863	37.29	19.17537	42.0226	30.9806	14.21893	10.221
	Perimeter - 95% CI Low	-21.009	-34.189	-15.6678	-8.28697	-3.52748	-6.3397	-20.323	-10.5526	-28.143	-19.9136	-7.40162	-4.87715
	Transition - Mean	0.29814	0.91911	0.418245	0.37217	0.6	0.5	0.82099	2.521904	1.66097	0.40084	0.471284	0.54314
	Transition - Count	8	9	4	5	1	1	5	2	6	7	5	2
	Transition - 95% CI Up	1.05392	1.97965	1.261401	0.94325			2.01181	8.204214	5.47083	0.997	0.709164	0.66787
	Transition - 95% CI Low	-0.4576	-0.14142	-0.42491	-0.19891			-0.3698	-3.16041	-2.1489	-0.19531	0.233404	0.41841
	Interior - Mean	0.12873	0.14578	0.098029	0.11616	0.119692	0.3	0.15037	0.107093	0.09605	0.087	0.085	
	Interior - Count	5	5	4	6	5	1	3	6	7	7	2	5
	Interior - 95% CI Up	0.75639	0.29546	0.190048	0.22933	0.392811		0.2805	0.193125	0.18125	0.09811	0.085	
	Interior - 95% CI Low	-0.4989	-0.00389	0.00601	0.00298	-0.15343		0.02023	0.021061	0.01086	0.07588	0.085	
Tdepth (in.)	Perimeter - Mean	9.63595	10.7872	8.615545	5.96475	8.277129	2.56021	9.38344	7.60499	16.6088	14.4866	10.41371	5.25711
	Perimeter - Count	28	29	24	21	6	12	25	29	27	20	21	23
	Perimieter - 95%CI Up	24.4872	24.2378	21.95135	20.5539	21.12753	13.2268	20.9413	20.70532	33.8418	27.2334	19.05379	12.5776
	Perimeter - 95% CI Low	-5.2153	-2.66352	-4.72026	-8.62441	-4.57327	-8.1064	-2.1744	-5.49534	-0.6242	1.73978	1.773637	-2.06333
	Transition - Mean	8.05343	9.0736	9.321989	6.80706	19.2864	1.61657	7.6397	6.670787	14.3323	11.8379	9.104284	2.59281
	Transition - Count	9	9	4	7	1	6	9	9	9	8	8	8
	Transition - 95% CI Up	25.1975	25.4422	30.8215	17.5969		8.5511	21.7286	19.24102	33.5375	19.8225	15.14716	7.60939
	Transition - 95% CI Low	-9.0906	-7.29499	-12.1775	-3.98282		-5.318	-6.4492	-5.89945	-4.873	3.85321	3.061408	-2.42378
	Interior - Mean	11.2509	11.4579	8.86816	7.79864	6.831673	6.24821	7.87839	6.350421	10.6637	10.4499	16.09934	8.04717
	Interior - Count	5	5	5	7	5	2	5	6	9	4	3	2
	Interior - 95% CI Up	23.0009	23.1207	17.06712	18.0691	9.307554	8.43021	15.346	15.85427	23.3328	20.106	25.86774	22.7757
	Interior - 95% CI Low	-0.4991	-0.205	0.669198	-2.47181	4.355792	4.0662	0.41079	-3.15342	-2.0055	0.79389	6.330952	-6.68138