Technical Publication

EMA # 402

Water Budget Analysis for Stormwater Treatment Area 5

(October 1, 1999 to April 30, 2001)

February 2002

by

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EXECUTIVE SUMMARY

This report presents a water budget for Stormwater Treatment Area (STA) 5. It covers the period of operation from October 1, 1999 through April 30, 2001. During this timeframe, South Florida experienced the beginning of a severe drought that extended from November 1999 through September 2001. Hurricane Irene impacted the area from October 14 to 17, 1999.

STA-5 is located along the western boundary of the Everglades Agricultural Area (EAA) adjacent to the L-3 canal, west of the northwestern corner of the Rotenberger Wildlife Management Area. It is comprised of four treatment cells with a total effective treatment area of 4118 acres. Construction of STA-5 was completed in December 1998 at a cost of $10.6 million. The STA was in a startup phase of operations from initial flooding in January 1999 through October 1999. On October 15, 1999, due to conditions caused by Hurricane Irene, the Florida Department of Environmental Protection (FDEP) issued an emergency order to the South Florida Water Management District (SFWMD) authorizing discharges from STA-5 for a 14-day period until October 29, 1999. STA-5 began routine flow-through operations in June 2000.

A total of 62,872 ac-ft of water entered STA-5 from the gated culverts at G342A-D from October 1, 1999 through April 30, 2001. This constituted 43 percent of the total inflow to the STA's treatment cells. During this nineteen-month period, STA-5 received 50 percent of the expected annual inflow volume at G342A-D. Rainfall accounted for 19,869 ac-ft or 14 percent of the total inflow. The area surrounding STA-5 received about 75 percent of its expected annual rainfall in calendar year 2000. Flow from seepage canal pumps at G349A and G350A contributed 31,209 and 29,477 ac-ft of flow, which was 21 and 20 percent, respectively, of the total inflow to the cells during the period of the study. Of these amounts, 2,194 ac-ft came from the Miami Canal due to pumping at G349B and 2,308 ac-ft due to pumping at G350B. A temporary pump was located at the northeast corner of STA-5 in February 2001. It supplied 1,772 ac-ft of water to Cell 1B from the Miami canal through April 30, 2001.

During this same 19-month period (from October 1, 1999 through April 30, 2001), 74,393 ac-ft of water were discharged from the STA at G344A–D (49 percent of the total outflow). Evapotranspiration accounted for an additional 28,812 ac-ft of water leaving the STA (19 percent of the total outflow). Estimated seepage out of STA-5 accounted for 31 percent of the total outflow from the STA or 46,447 ac-ft. Water budget error was less than 2 percent.

This was the first water budget for STA-5. The first water budgets for the ENR and STA-6 were prepared after two years of operation. Because it covers a shorter period of time, results and conclusions from this work should be considered preliminary. This report provides a first look at the hydraulic performance of the STA and the cells in its two treatment flow ways. Improvements to the water budget and a better understanding of the hydrologic components at STA-5 will come with additional years of data.

ACKNOWLEDGMENTS

The following people helped in preparing and reviewing the drafts of this document: Richard Meeker provided the vegetation maps and descriptions for each of the STA-5 treatment cells; Ron Bearzotti drafted the permit history of the STA-5; Wossenu Abtew, Ashie Akpoji, Nagendra Khanal, John Raymond, Felicia Berger, Ron Bearzotti and Garth Redfield reviewed the drafts of the report and made valuable suggestions on how to improve it.

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INTRODUCTION

"Water mass balances form the basis for all reliable data analysis and design calculations. Data sets that do not include this vital information must be viewed with some suspicion because rainfall, evapotranspiration and leakage can all have large effects on performance of treatment wetlands" (Kadlec and Knight, 1996).

This report presents a water budget for Stormwater Treatment Area (STA) 5. It covers the period of operation from October 1, 1999, through April 30, 2001. STA-5 is located along the western boundary of the Everglades Agricultural Area (EAA) adjacent to the L-3 canal, west of the northwestern corner of the Rotenberger Wildlife Management Area. STA-5 and its location relative to major canals and roadways are shown in Figure 1. It is comprised of four treatment cells with a total effective treatment area of 4118 acres.

Construction of STA-5 was completed in December 1998 at a cost of $10.6 million. The STA was in a startup phase of operations from initial flooding in January 1999 through October 1999. On October 15, 1999, due to conditions caused by Hurricane Irene, the Florida Department of Environmental Protection issued an emergency order to the South Florida Water Management District authorizing discharges from STA-5 for a 14-day period until October 29, 1999. STA-5 began routine flow-through operations in June 2000.

During the period of this study, South Florida experienced the beginning of a severe drought that extended from the November 1999 through September 2001. Hurricane Irene impacted the area from October 14 to 17, 1999 (Abtew and Huebner, 2000). The report is based upon daily water budgets for hydrologic units in STA-5. Daily results were aggregated to develop monthly and period of analysis (nineteen months, from October 1999 through April 2001) water budgets. The daily water budget accounted for inflow, outflow, rainfall, evapotranspiration, seepage and error.

This section of the report presents background information about STA-5, water budget analyses and hydro-meteorological monitoring at STA-5. Sections describing the operation of STA-5 and the sources of data used for the report follow. The actual water budget analysis is then presented, followed by a summary, recommendations and conclusions.

Background

STA-5 is one of six STAs to be built and operated following the success of the prototype Everglades Nutrient Removal (ENR) project that started in August 1994. Construction of STA-5 was substantially completed by December 30, 1998. It was funded as part of the Everglades Construction Project (ECP), an element of the Everglades Program established by the Everglades Forever Act (§373.4592, Fla. Stat.). Its principal purpose is to reduce phosphorous concentrations in runoff from the C-139 basin to the north and west of STA-5. Prior to construction, the stormwater treatment area was used for agricultural purposes.

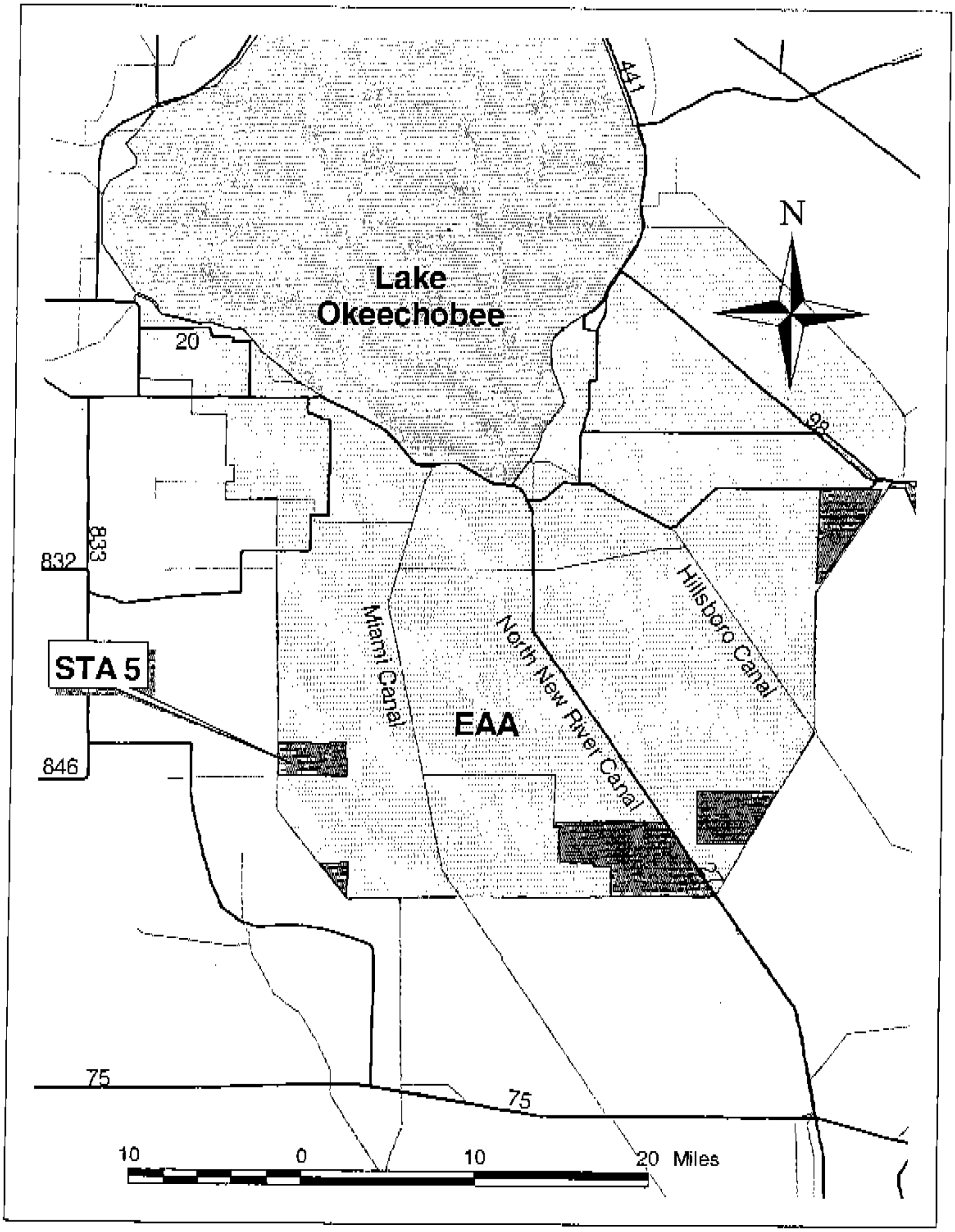

Figure 1. STA-5 Location Map

The Everglades Forever Act (EFA) permit for STA-5 was issued by the Florida Department of Environmental Protection (FDEP) on February 29, 2000. The issuance of the NPDES permit was delayed due to objections by the Friends of the Everglades, a public environmental interest group. However, authorization for interim operations of STA-5 under the terms and conditions of the NPDES permit was recommended by the Division of Administrative Hearings and granted by FDEP on March 20, 2000. After satisfying the Friends of the Everglades' concerns, the NPDES permit was issued on May 24, 2001.

STA-5 was in a start-up phase of operations from initial flooding in January 1999 through October 1999. On October 15, 1999, due to conditions caused by Hurricane Irene, the FDEP issued an emergency order to the South Florida Water Management District authorizing discharges from STA-5. Based on start-up water quality data submitted by the District, FDEP indicated that the operating permit's start-up compliance test had been satisfied and a demonstration of net reduction in phosphorus, mercury and methyl mercury (as identified in specific condition 13 of the EFA permit) was achieved. Emergency discharges from STA-5 associated with Hurricane Irene were authorized for a 14-day period until October 29, 1999. These operations were initiated on October 15, 1999, and ended October 28, 1999. The southern flow-way of STA-5 (Cells 2A and 2B) began routine flow-through operations in June 2000. The northern flow-way of STA-5 (Cells 1A and 1B) began routine flow-through operations in August 2000.

The water budgets completed for the ENR and STA-1W (SFWMD, 1996; Abtew and Mullen, 1997; Abtew and Downey, 1998; Guardo, 1999; Abtew et al., 2000; Abtew and Bechtel, 2001; Abtew et al., 2001) and presentation of the results influenced the methods used in this study. A water budget for the first two years of operation at STA-6 was published in February 2001 (Huebner). Techniques used in this analysis closely parallel those in the STA-6 study. Results from the ENR and STA-6 water budget studies were also used to evaluate and compare water budget errors in the analysis for STA-5.

The water budget at STA-5 involves the following hydrologic/hydraulic components:

- Inflow through pumps and gated structures
- Outflow through gated structures
- Rainfall
- Evapotranspiration
- Seepage
- Change in storage
- Water budget error.

Each component makes up an important part of the water budget for STA-5. The budget is developed for varying time periods ranging from 1 day to 19 months using the following equation:

$$\frac{\Delta S}{\Delta t} = I - O + R - ET \pm G + \varepsilon \qquad (1)$$

where	ΔS	=	change in storage over the time period
	Δt	=	time period
	I	=	average inflow over the time period
	O	=	average outflow over the time period
	R	=	rainfall over the time period
	ET	=	evapotranspiration over the time period
	G	=	levee and deep seepage over the time period
	ε	=	water budget error over the time period

In Equation 1, all terms had the same units, acre-feet per unit time (day, month, year). To do this for rainfall and evapotranspiration, the values (in inches or millimeters) were converted to feet and multiplied by the effective surface area in acres, (e.g., 839 acres for Cell 1A) to get a volume of rainfall or evapotranspiration for a selected time period.

Nineteen months of daily average stage, flow, rainfall and evapotranspiration data were used in this report. The data were analyzed using Equation 1 on a daily, monthly and period of analysis basis. Each of the terms in Equation 1 was quantified for each time period.

Site Description

STA-5 is located along the western boundary of the Everglades Agricultural Area (EAA) adjacent to the L-3 canal, west of the northwestern corner of the Rotenberger Wildlife Management Area. It is comprised of four treatment cells that have a total effective treatment area of 4118 acres. The cells are divided into two flow ways running from west to east. The northern flow way consists of Cells 1A and 1B; the southern flow way, Cells 2A and 2B. The cells are bermed wetlands with gated culverts and weir structures that control inflow, outflow and stage (water level) within the cells. Figure 2 shows a schematic of the cells and control structures. Table A-1 in Appendix A contains a summary of site properties used in the water budget calculations for STA-5.

The treatment cells receive water via the L-3 canal north of the Deer Fence canal at structures G342A, B, C and D. Water then flows into distribution ditches just east of the structures that feed the treatment areas in Cells 1A and 2A. Eight intermediate combination weir/culverts, structures G343A through H, pass flow from cells 1A and 2A to Cells 1B and 2B. Water is discharged to the east through structures G344A, B, C and D. Water from the STA flows east to the Miami Canal via an approximately five mile long canal constructed in conjunction with the STA. Water discharged from STA-5 will also be used to restore hydropatterns in the Rotenberger Wildlife Management Area using pumps located at structure G410 near the southeastern corner of STA-5.

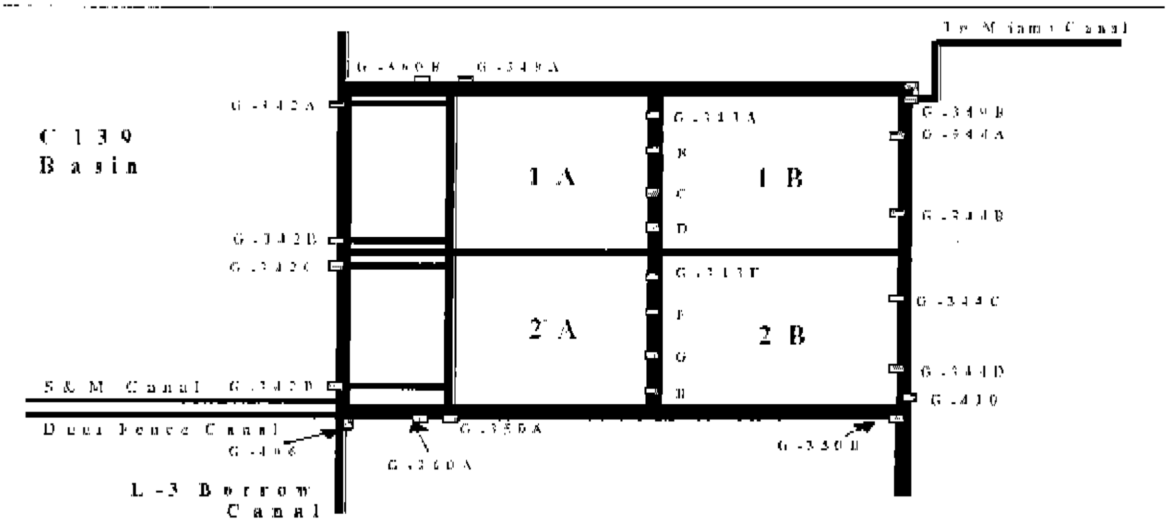

Figure 2. Schematic Diagram of STA-5 (not to scale)

Vegetation coverage varies among the cells as follows: Cell 1A is dominated by emergent vegetation including primrose willow (*Ludwigia spp.*), Cattail (*Typha spp.*), smartweed (*Polygonum spp.*), and mixed grasses; Cell 1B is submerged aquatic vegetation (SAV)/ periphyton dominated. Species include southern naiad (Najas guadalupensis), coontail (*Ceratophyllum demersum*), and hydrilla (*Hydrilla verticillata*). Some water hyacinth (*Eichhorina crassipes*) also present; Cell 2A is dominated by emergent vegetation including primrose willow (*Ludwigia spp.*), Cattail (*Typha spp.*), smartweed (*Polygonum spp.*), and mixed grasses; and Cell 2B is Cattail dominated. Other important plants in Cell 2B include primrose willow and mixed grasses. Figure 3 shows the result of the vegetation survey conducted in 2000 by Environmental Research Institute of Michigan.

Monitoring

Three hydro-meteorological parameters were monitored at STA-5, flow, stage (water surface elevation) and rainfall. The station locations are shown in Figure 2. A fourth parameter, evapotranspiration, was estimated for STA-5 based on values monitored at nearby locations. Tables A-2 through A-5 in Appendix A list the stations where daily average stage, flow, rainfall and evapotranspiration data were recorded together with database (DB) key numbers and station descriptions.

The depth of rainfall in inches was recorded at G343B_R, located near the center of the STA. The rainfall data were compared to rainfall amounts at nearby rainfall recording locations to check for potential data errors.

Evapotranspiration (ET) is the loss of water to the atmosphere by vaporization (evaporation) at the surface of a water body and/or by respiration of living organisms including vegetation (transpiration). The evapotranspiration data used in this water budget analysis were derived from two sources: (1) ET data for the ENR and STA-1W; and (2) ET values computed using recorded air temperature and total radiation.

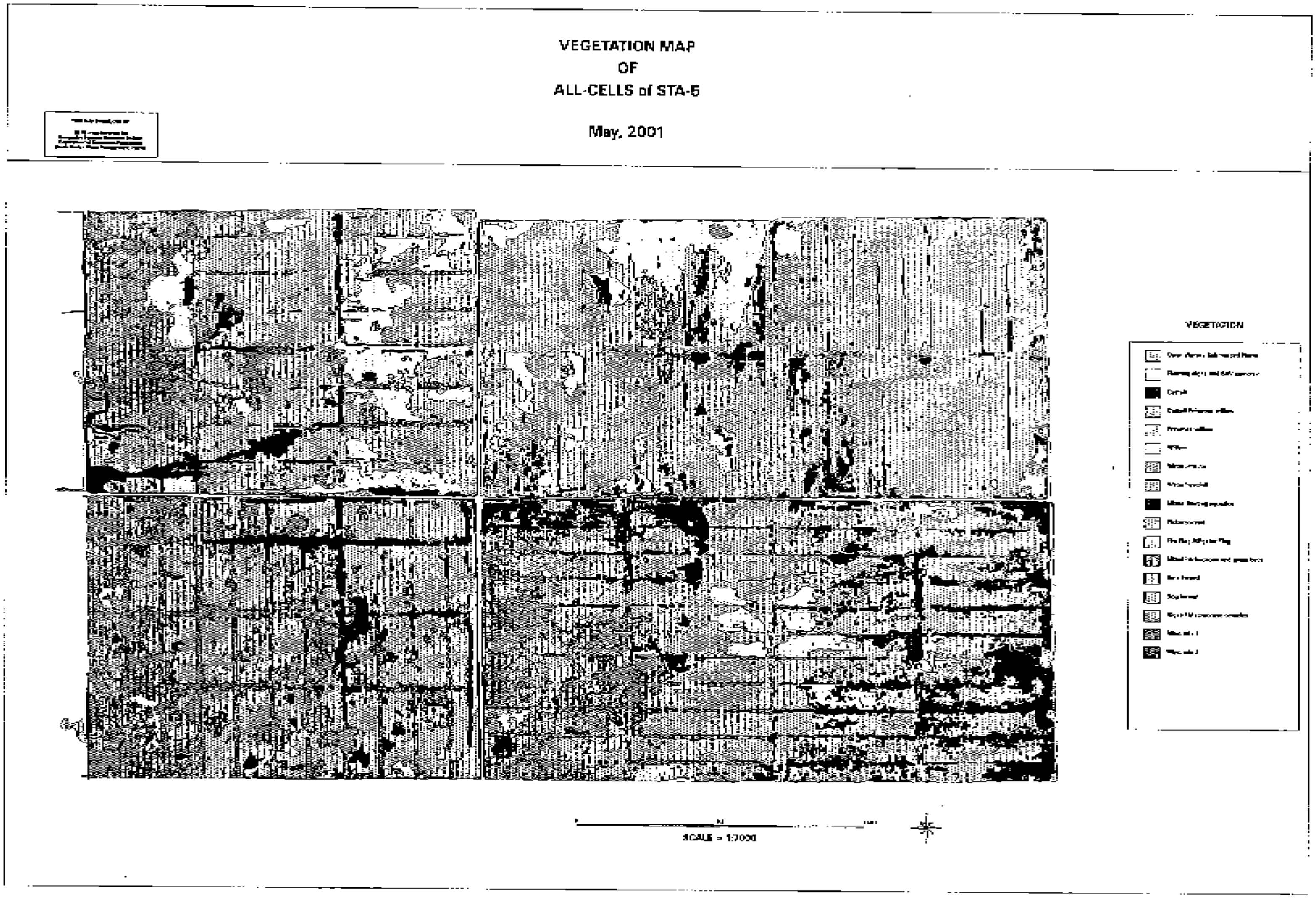

Figure 3. Vegetation Map of STA-5

STA OPERATION

Runoff from the C-139 basin is conveyed southward to the L-3 canal. Under normal operating conditions, the G406 structure is closed blocking flow to the south in the L-3 canal and forcing water through the gated box-culverts at G342 and into STA-5. The gates at G406 are opened when the water level in the L-3 canal exceeds 16.0 ft NGVD. When open, G406 allows water from the C-139 basin to bypass STA-5 and flow south to the northern boundary of Water Conservation Area (WCA) 3.

STA-5 was designed for gravity flow from the inlet structures, G342A through D, at the western end of the STA to outlet structures, G344A through D, at the eastern end of the STA. The STA is divided into four treatment cells, two along a northern flow way (Cells 1A and 1B) and two along a southern flow way (Cells 2A and 2B). The division into various treatment cells was to accommodate different vegetation types and to account for a significant drop in the terrain going from west to east. The drop in terrain reflects the transition from ridge to slough found in the remnant Everglades further to the south. The G343A through H structures in a north-south levee separate the A and B cells. Weir boxes with a crest set at 14.0 ft NGVD at G343 control the water level in Cells 1A and 2A.

Seepage canals are located along most of the northern and southern boundaries of the STA. Two pumps at G349A and two at G350A re-circulate water from the seepage canals into Cells 1A and 2A. The maximum capacity of each pump is 26.9 cfs. Two more pumps, one at G349B and another at G350B, are used during dry periods to pump water from the discharge canal along the eastern side of the STA and discharge it into the seepage canals. This provides additional water to the pumps at G349A and G350A to help prevent cell dryout in the STA. Water for this purpose in the discharge canal ultimately comes from the Miami canal to the east. Each of the pumps has a maximum capacity of 39 cfs.

STA-5 is currently operated under an interim Operations Plan (SFWMD, 2000). The interim plan accommodates additional flow to STA-5 that will be directed to STA-6, Section 2 once that STA is constructed. Until that time, STA-5 will treat most of the runoff from the C-139 basin except during periods of extreme flooding, in which case flow will bypass the STA via the gated structure at G406.

Six operational scenarios were presented in the interim Operations Plan for STA-5: (1) *startup* phase operations began after substantial project completion in December 1998; (2) *normal*, flow-through operations began in the summer of 2000. Under normal conditions, the STA accommodates a flow of up to 770 cfs. Depths in Cells 1A, 2A and 2B are maintained between 0.5 and 4.5 ft above average ground elevation in each cell. The depth in Cell 1B is maintained between 0.5 and 3.5 ft. Wind and wave effects are more pronounced in Cell 1B because it is primarily an open body of water containing submerged aquatic vegetation (SAV). Therefore, the maximum depth of water that the cell can accommodate is limited in comparison to the other cells. Water levels in the seepage canals are maintained at approximately 9.0 ft NGVD by pumps at G349A and G350A. The gates at G406 are closed unless the stage in the L-3 north of G406 exceeds 16.0 ft NGVD; (3) under *extreme* hydrologic conditions (flooding), the gates at G342 and G344 are fully opened, the gates at G406 are operated to allow flow to bypass the STA and the seepage pumps are off; (4) during *drought* conditions, gates at G344 are closed, the gates at G342 are closed if the level in the L-3 canal falls below the stage in Cells 1A and 2A, the pumps at G349B and G350B pump water from the discharge canal into the seepage canals, the pumps at G349A and G350A discharge into Cells 1A and 2A and the low level outlets at G343 are fully opened; (5) treatment Cells 1A and 1B or 2A and 2B may be removed from service for *maintenance* purposes and releases may be made at G406 to accommodate flows above the capacity of a single flow way; and (6) structures and pumps may be operated to investigate different operating schemes to *optimize* the efficiency of the STA with respect to phosphorous removal consistent with provisions of the Everglades Forever Act.

A full description of STA-5, its design and operation are provided in the STA-5 Operation Plan (Revised, SFWMD, 2000).

HYDROLOGIC AND HYDRAULIC DATA

The following sections describe the data that were used for the water budget computations and any special considerations concerning the data. The data came from the South Florida Water Management District's corporate database, DBHYDRO. The corresponding database (DB) keys and station names are presented in Appendix A.

Rainfall

Daily rainfall data for STA-5 was collected at G343B_R. The data, stored in the DB key for this station, were compared to rainfall values at seven nearby rain gage locations to check for data errors. Missing values were filled based upon the best available information usually from nearby rain gages. The data were loaded into a preferred DB key every month. A final QA/QC check of the data was completed on a quarterly basis. The preferred DB key provided a high-quality, continuous record of daily rainfall amounts. Table B-1 in Appendix B lists the daily rainfall amounts recorded at G343B_R.

Evapotranspiration

Evapotranspiration (ET) data was taken from a preferred DB key for STA-1W that contained daily values of ET. This data for ET were considered to be of the highest quality available. ET was also estimated using Equation 2 and air temperature and total solar radiation data from meteorological stations at the Rotenberger Wildlife Management Area - ROTNWX, located near the outlet of STA-6, Lake Okeechobee Tower South - L006, the Big Cypress Seminole Indian Reservation – BIG CY SIR and at the IFAS Everglades Research and Education Center in Belle Glade – BELLE GLADE. The ET values computed from data at these stations corroborated the ET values at STA-1W used in this study. Table C-1 in Appendix C lists the daily ET values used. The value of the empirical constant, K_l, was taken as 0.53, an average for South Florida wetlands with a range of vegetative cover (Abtew, 1996).

$$ET = K_l \frac{R_s}{\lambda} \qquad (2)$$

where ET = evapotranspiration (mm/d)
K_l = empirical constant
R_s = total solar radiation ($MJ/m^2/d$)
λ = latent heat of vaporization (varies with air temperature) (MJ/kg)

Stage

Stage data were collected on an instantaneous basis, averaged and recorded as daily average stage in DBHYDRO. The instantaneous stage data were also used to compute flows at the inlet and the outlet structures at STA-5. A headwater stage and a tailwater stage are needed to compute flow at each of the structures. As a result, more than one stage value was available to report average daily stage within each of the treatment cells. The daily stage at each of the recording gages within a cell was averaged to generate a daily mean stage for the entire cell.

Stage data, as well as gate opening data, were recorded using two methods. Data were stored on-site in solid state data loggers called CR10's. Data stored in CR10's were transmitted periodically to a District database. Stage and gate opening data were also telemetered to a District database. Daily mean stage values used in this study were based on data that was telemetered.

When the recorded stage in a treatment cell fell below the average ground elevation, a function was used to estimate the volume of water that was available for release or necessary to fill voids in the soils beneath the cells. Equations were developed for a falling and a rising water table and are presented in Figure D-1 in Appendix D. They are the same equations used for this purpose in the water budget analysis for STA-6 (Huebner, 2001) based on work done by Abtew, et al., (1998).

Flow

Daily average flow rates were determined using two methods, culvert equations and pump performance curves. At G349A, G350A, G349B and G350B, average daily flow was computed instantaneously using motor speed, headwater and tailwater elevation data. The daily average flow at these stations was recorded in DBHYDRO and reviewed on a monthly basis for accuracy and missing data. A complete record of daily average flow was loaded to a preferred DB key in DBHYDRO monthly. A final QA/QC check of the flow data in the preferred DB keys was done on a quarterly basis.

Daily average flows at G342A through D, G344A through D and were computed using combination culvert/orifice equations for each structure based on headwater and tailwater stages and gate opening data. Daily mean flow at each structure was recorded in DBHYDRO. This information was loaded into preferred DB key in DBHYDRO monthly. A final QA/QC check of the flow data in the preferred DB key was done on a quarterly basis.

Seepage

No direct measurement of seepage was made at STA-5 during the period of this study. A number of attempts to quantify seepage at STA sites have been made. The most recent, detailed studies have been associated with the ENR project (Choi and Harvey, 2000) and those discussed in the 1998-99 water budget analysis for STA-6 (Huebner, 2001).

In this analysis, seepage was computed as:

$$G = 1.983 * K_{sp} * L * \Delta H \qquad (3)$$

where G = seepage, levee and deep (ac-ft/d)

K_{sp} = coefficient of seepage (cfs/mi/ft)

L = length along the seepage boundary (mi)

ΔH = hydraulic head difference between the unit and the boundary (ft)

1.938 = constant to convert from cfs to ac-ft/d

The value of K_{sp} was adjusted to minimize the net water budget error in the 19-month period of study. The results from previous studies were used to compare values of the seepage coefficient. The values compared favorably with the range of values presented in previous studies (Huebner, 2001).

Figures 4 and 5 were developed from surface water and groundwater data in the region surrounding STA-5 to depict near surface groundwater flow domains. Figure 4 depicts mean monthly surface and groundwater table levels during a dry season month (February 2000) and Figure 5 shows mean monthly groundwater table conditions during a wet season month (October 2000). Water level contours in the STA in the wet season are slightly higher than during the dry season. The water levels maintained in the STA are higher than those areas surrounding the STA. The seepage canals have had an effect along the northern and southern boundaries of STA-5. The contours to the west of STA-5 are dominated by the L-3 water levels and pumping activity of a well operated by US Sugar, USSS, that lies west of the L-3 canal. Contours to the east of STA-5 reflect levels in the Miami canal and the lower groundwater table in the Rotenberger Wildlife Management Area.

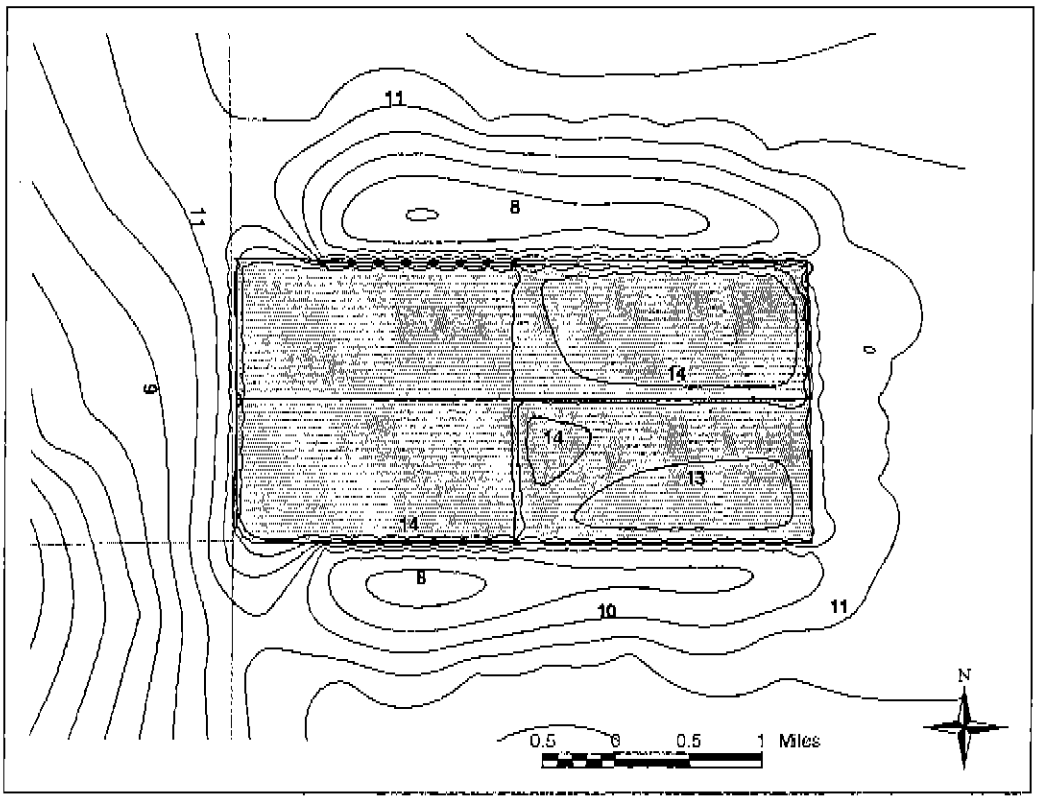

Figure 4. Mean Monthly Surface and Groundwater Table Elevation (Dry Season) – February 2000

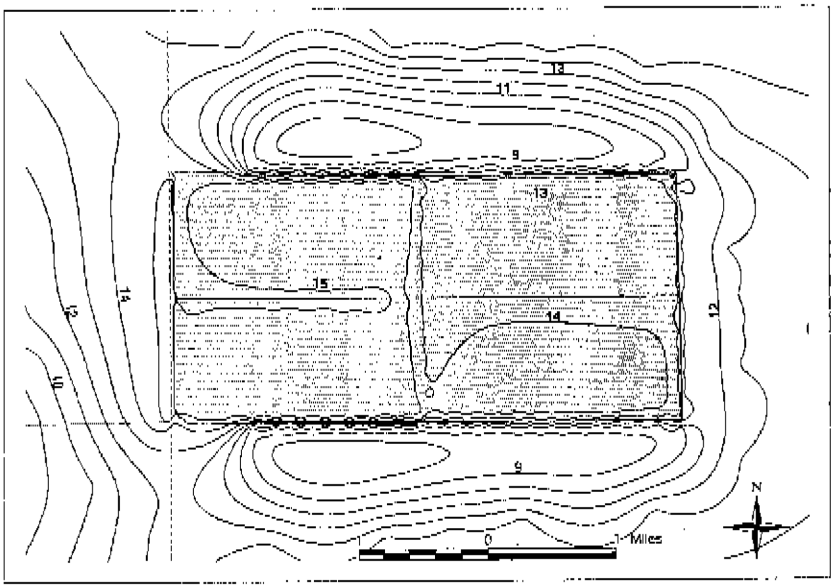

Figure 5. Mean Monthly Surface and Groundwater Table Elevation (Wet Season) – October 2000

WATER BUDGET

Methodology

For the purposes of this analysis, STA-5 was divided into two hydrologic units: 1) the northern flow way consisting of Cells 1A and 1B and 2) the southern flow way consisting of Cells 2A and 2B. A water budget analysis was performed on each of the units on a daily, monthly and period of study (19-month) basis using Equation 1. A daily, monthly and period of study water budget was also completed for the entire STA using data from both flow ways. Terms in equation 1 were converted to acre-feet (ac-ft) per unit time (day, month or for 19 months depending upon the period being used for the water budget calculations). The discussion of the results in the following section of the report focuses on the period of study water budget.

Results

Rainfall and Evapotranspiration

Rainfall data for STA-5 is presented in Appendix B. Evapotranspiration (ET) data can be found in Appendix C. Figure 6 shows the monthly rainfall surplus or deficit based on the sum of rainfall less estimated ET at STA-5. In 14 of 19 months, ET exceeded rainfall. The October 1999 rainfall surplus reflected the effect of Hurricane Irene. Starting in November 1999, traditionally the month when the dry season starts, ET was greater than rainfall except in June, September and October 2000. The rainfall surplus in October 2000 was due to an unnamed tropical wave. November 1999 was the beginning of an extended drought in South Florida. During the nineteen-month period ET exceeded rainfall by a total of 26.06 in. The 40.26 in. of rainfall received at STA-5 during calendar year 2000 represented 75 percent of the expected rainfall for the East EAA rain area for that period, 53.46 in.

Northern Flow Way – Cells 1A and 1B

Table 1 presents the water budget for the northern flow way at STA-5. The properties (width, length, and surface area) of the elements that make up the northern flow way, i.e. Cells 1A and 1B, are listed in Table A-1 in Appendix A. Table 1 also shows summary information for the daily water budget analysis in the section titled Residuals Analysis. A similar table is shown in the corresponding section for the other hydrologic units at STA-5. Inflow was measured at G342A and B and G349A; outflow was recorded at G344A and B.

In Table 1, error in the water budget was less than 5 percent. The low error was due inpart to the coefficient of seepage, which was adjusted to minimize the sum of the squared daily error (SSE) for the period of study. Daily and monthly water budget residuals were used as a check on using this parameter to minimize SSE. The percentage of days where the daily water budget did not balance within a 0.25 ft (3 in.) depth was less than 3 percent. This implies that daily values in the budget were adequately quantified. For the northern flow way, daily residuals were less than 1.0 inch 92 percent of the time. Daily water budget residuals are shown in Figure 7. Three periods of high flow were observed during this study, one in October 1999 (Hurricane Irene) and one in September and October 2000 (caused by an unnamed tropical wave) and one in March 2001.

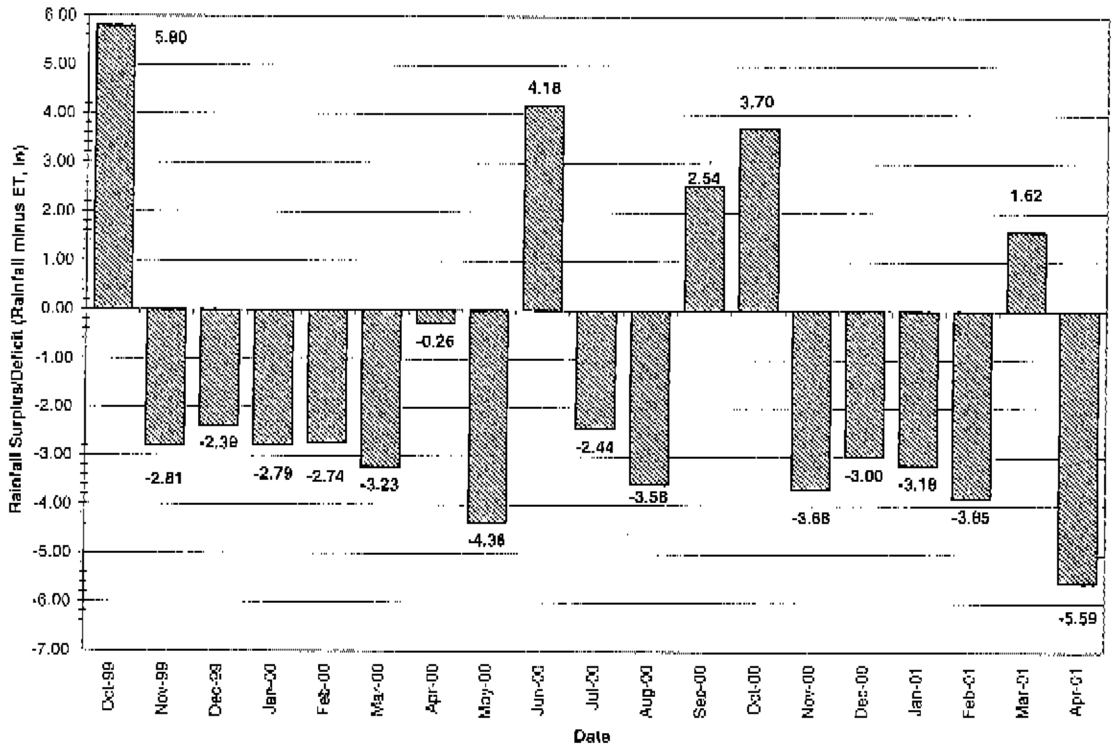

Figure 6. Monthly Rainfall less Estimated Evapotranspiration at STA-5

Table 1. Water Budget Summary for Cells 1A and 1B

1999-2001			STA 5 Water Budget - Cell 1				
	INFLOW	**ac-ft**	**Percent**	**OUTFLOW**	**ac-ft**	**Percent**	
	G342A & B	24,951	36.77	**G344A & B**	37,742	52.13	
	+ G349A	31,209	45.99	**ET**	14,406	19.90	
	+ STA5TP_P	1,772	2.61	**Seepage**	16,831	23.25	
	Rain	9,935	14.64	**Error**	3,427	4.73	
	Total	67,867	100.00	**Total**	72,405	100.00	
	Storage Chg.	-4,538					
	Residuals Analysis			**Count**	**1" error**	**2" error**	**3" error**
Sum=	3,426.52	**Avg Err**	5.93	**# >**	19	6	3
Max=	1,308.13	**St Dev**	148.35	**# <**	29	16	12
Min=	-837.08	**Avg Abs Err**	76.23	**Total**	48	22	15
		St Dev	127.36	**Percent**	8.30	3.81	2.60
SSE =	12,718,504	**Sum Abs Err**	44,059.33				

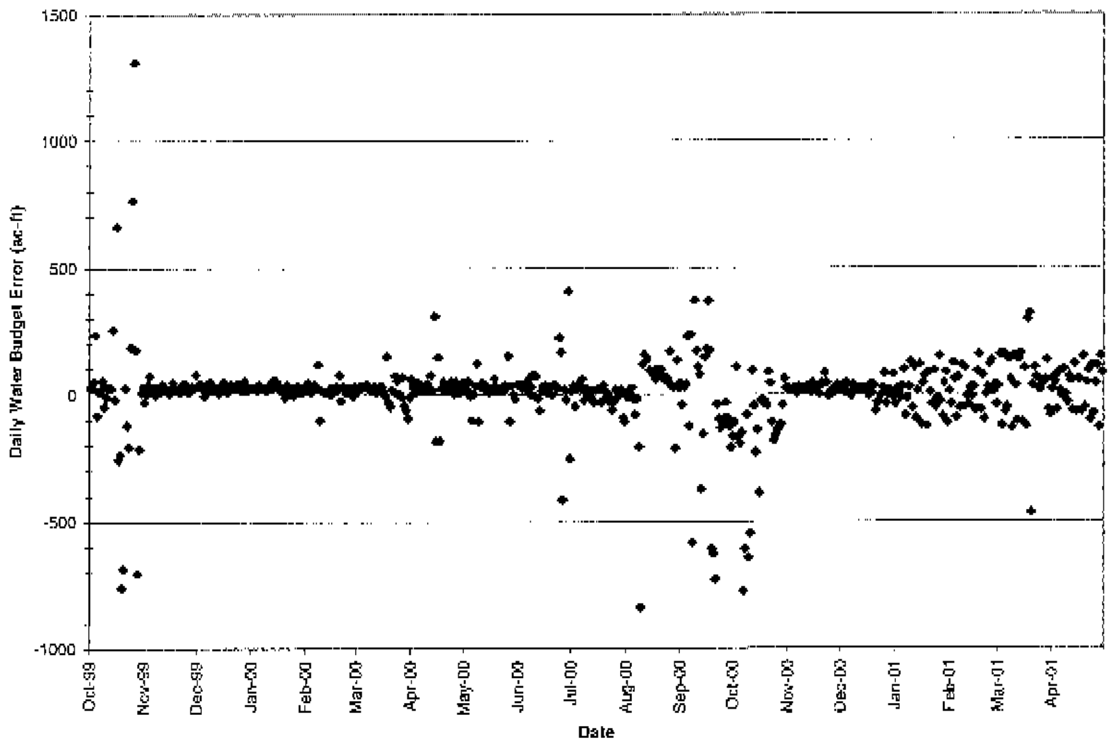

Figure 7. Daily Water Budget Residuals for Cells 1A and 1B

The seepage coefficient was 1.00 cfs/mi/ft, well within the values reported in other studies (Brown and Caldwell, 1996; Guardo and Rohrer, 2000). Seepage constituted 23 percent of the water budget. **Figure 8** shows the estimated seepage for Cells 1A and 1B over the period of the study and **Figure 9** displays the water levels versus surrounding canals and cells. For the nineteen month period examined, seepage out of the northern flow way was greater than seepage into Cells 1A and 1B. In general, seepage was into the treatment cells from the L-3 canal and Cells 2A and 2B and out of the treatment cells in toward the seepage canal along the STA's northern boundary and the discharge canal along the eastern boundary. Inflow, outflow and stage for Cells 1A and 1B are shown in **Figure 10**. Approximately 66 percent of the flow leaving the northern flow way at G344A and B entered the STA at G342A and B. **Table 2** presents the results of the monthly water budget analysis for Cells1A and 1B.

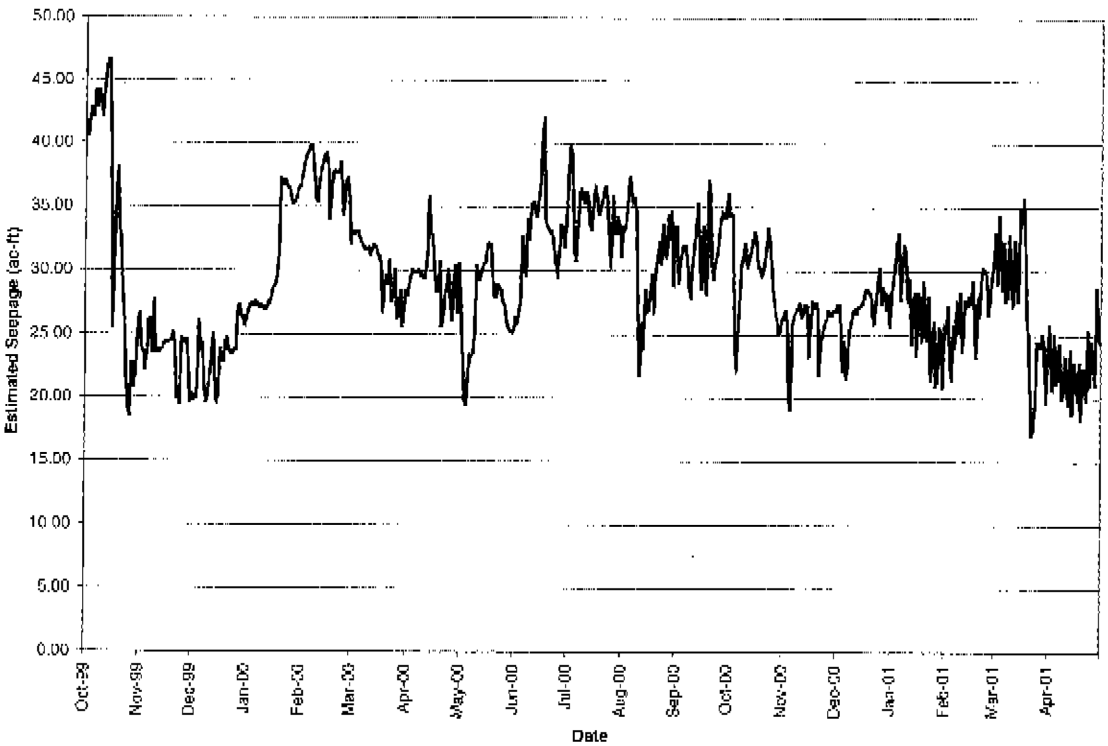

Figure 8. Estimated Seepage for Cells 1A and 1B

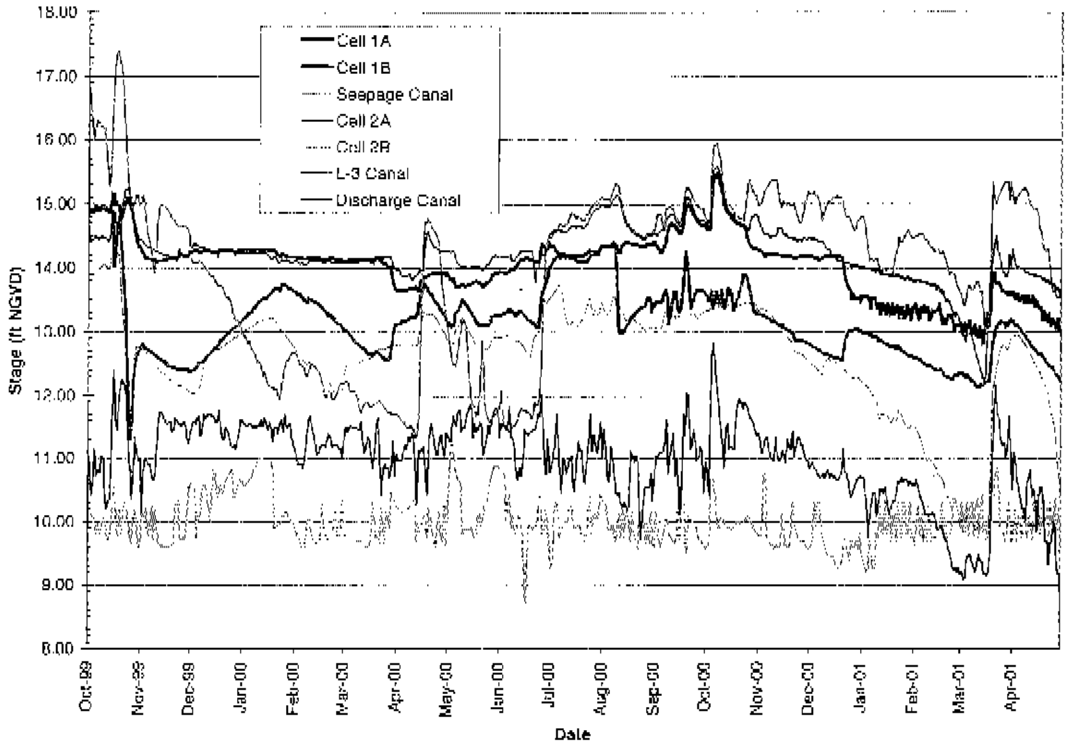

Figure 9. Cell 1A and 1B Stage versus Surrounding Areas

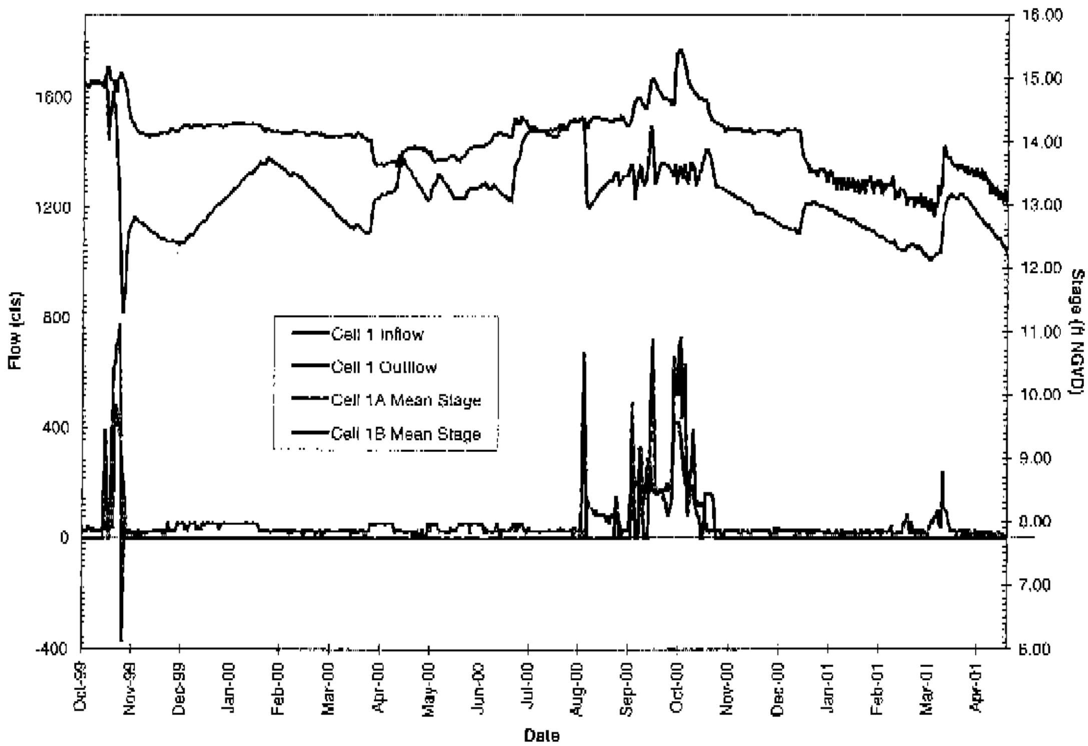

Figure 10. Inflow, Outflow and Stage for Cells 1A and 1B

Table 2. Monthly Water Budget for Cells 1A and 1B.

Month	Inflow (ac-ft)	Outflow (ac-ft)	Storage (ac-ft)	Rain (ac-ft)	ET (ac-ft)	Seepage (ac-ft)	Error (ac-ft)	Check Error (ac-ft)	Daily Avg. Error (in)
Oct-99	6,636	8,804	-2,846	1,651	655	1,075	599	599	0.11
Nov-99	1,460	10	-484	84	567	714	737	737	0.14
Dec-99	3,001	0	1,015	60	470	716	859	859	0.16
Jan-00	2,679	0	497	137	616	962	742	742	0.14
Feb-00	1,360	0	-777	206	677	1,083	592	592	0.12
Mar-00	1,710	0	-292	290	844	936	512	512	0.10
Apr-00	2,167	0	301	918	963	884	936	936	0.18
May-00	2,278	0	111	372	1,120	839	581	581	0.11
Jun-00	2,193	0	1,244	1,661	944	982	684	684	0.13
Jul-00	1,781	3	410	472	890	1,077	-127	-127	0.02
Aug-00	4,212	3,242	-1,120	257	871	962	514	514	0.10
Sep-00	8,906	9,889	503	1,196	760	958	-2,005	-2,005	0.39
Oct-00	10,500	15,740	-714	1,368	733	923	-4,814	-4,814	0.91
Nov-00	1,425	7	-661	2	634	775	671	671	0.13
Dec-00	1,437	23	-366	29	544	831	434	434	0.08
Jan-01	1,057	18	-566	98	643	835	225	225	0.04
Feb-01	1,476	5	-530	0	661	756	584	584	0.12
Mar-01	2,945	0	1,447	1,119	841	850	926	926	0.17
Apr-01	699	0	-1,709	15	975	672	778	778	0.15

Note: Negative storage values indicate decreasing stage over the month. No signs are shown for other values, except error. To compute the water budget error, flow into the cell was taken as positive and flow out of a cell was taken as negative.

Southern Flow Way – Cells 2A and 2B

Table 3 shows the period of study water budget for the southern flow way comprised of Cells 2A and 2B. Inflow was measured at G342C and D and G350A; outflow was recorded at G344C and D.

Table 3. Water Budget Summary Cells 2A and 2B

1999-2001		STA 5 Water Budget - Cell 2					
	INFLOW	ac-ft	Percent	OUTFLOW	ac-ft	Percent	
	G342C & D	37,920	49.04	G344C & D	36,651	46.16	
	+ G350A	29,477	38.12	ET	14,406	18.14	
	Rain	9,935	12.85	Seepage	28,448	35.83	
				Error	-106	-0.13	
	Total	77,332	100.00	Total	79,399	100.00	
	Storage Chg.	-2,067					
	Residuals Analysis			Count	1" error	2" error	3" error
Sum=	-106.11	Avg. Err.	-0.18	# >	30	6	0
Max=	502.67	St. Dev.	145.17	# <	38	17	5
Min=	-1,678.38	Avg Ab Err	75.66	Total	68	23	5
		St. Dev.	123.85	Percent	11.76	3.98	0.87
SSE =	12,160,306	Sum Abs Err	43,734.30				

As a percentage of the budget, error is less than 1 percent. Less than 1 percent of the days have errors that are greater than 0.25 ft (3 in.) in depth. Eighty-eight percent of the days have a budget error less than 1.0 in. in depth. Figure 11 shows the daily residual error plot for the nineteen-month water budget. The seepage coefficient for the Cells 2A and 2B was 2.15 cfs/mi/ft, which agrees well with values from the literature. Seepage constitutes 36 percent of the water budget. Seepage out of the southern flow way is depicted in Figure 12. In general, seepage from the southern flow way is into the northern flow way, the L-3 canal, the seepage canal along the southern boundary of the cells and the discharge canal along the eastern boundary of the STA. Based on water elevation differences, some water seeped into the southern flow way from the L-3 canal and the northern flow way at times during the year. Stage in the cells and in surrounding areas is presented in Figure 13. Ninety-seven percent of the water flowing into Cell

2A at G342C and D flowed out of the STA at G344C and D. Figure 14 shows the inflow, outflow and stage in Cells 2A and 2B for study period.

The monthly water budget is shown in Table 4. The monthly error in ac-ft/month and the daily average error in inches are given in the right two columns in the table. All average daily errors based on the monthly water budget are less than 1.0 in.

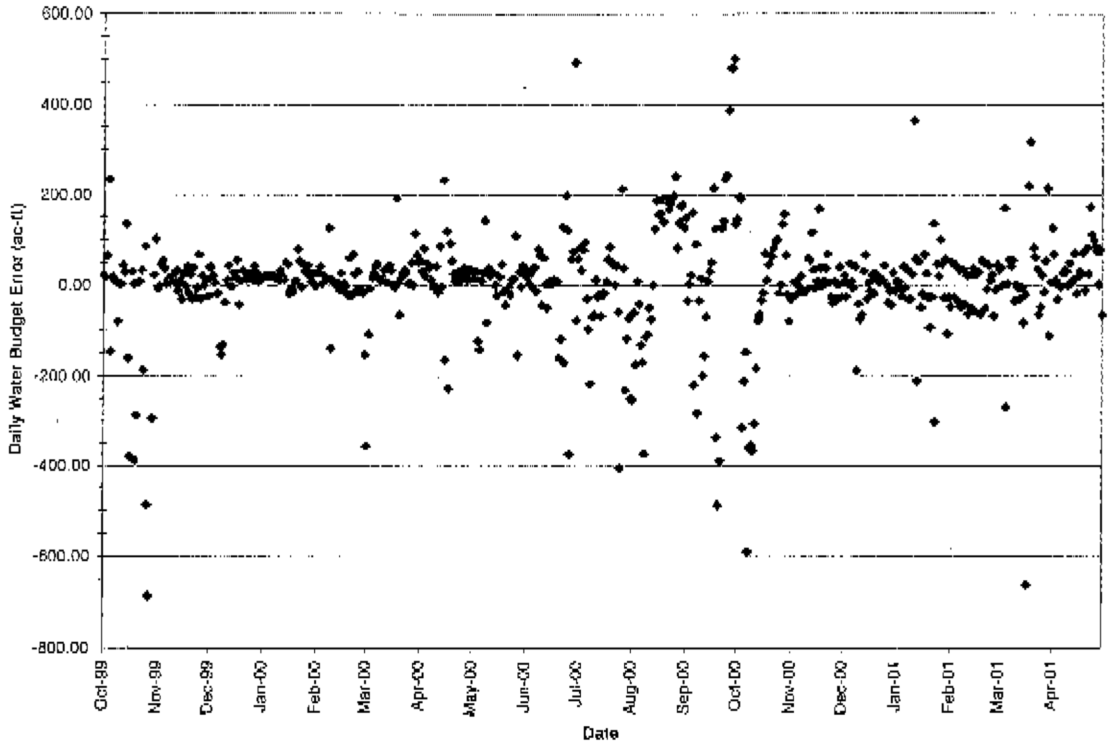

Figure 11. Water Budget Residuals for Cells 2A and **2B**

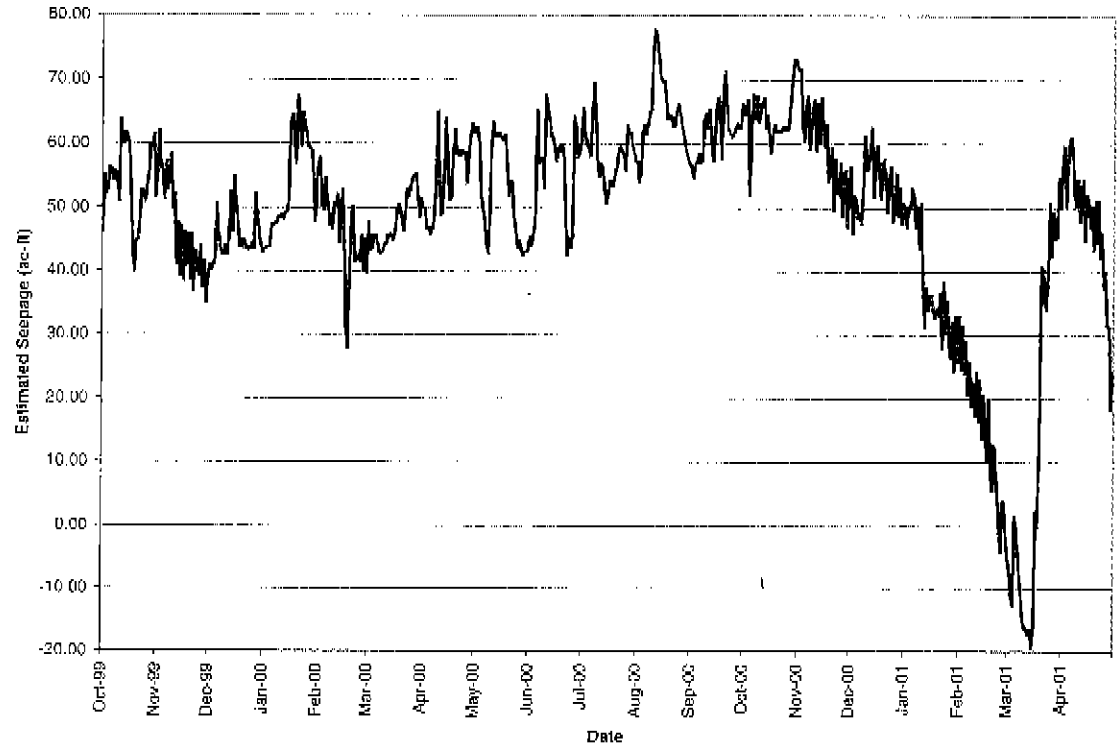

Figure 12. Estimated Seepage Cells 2A and 2B

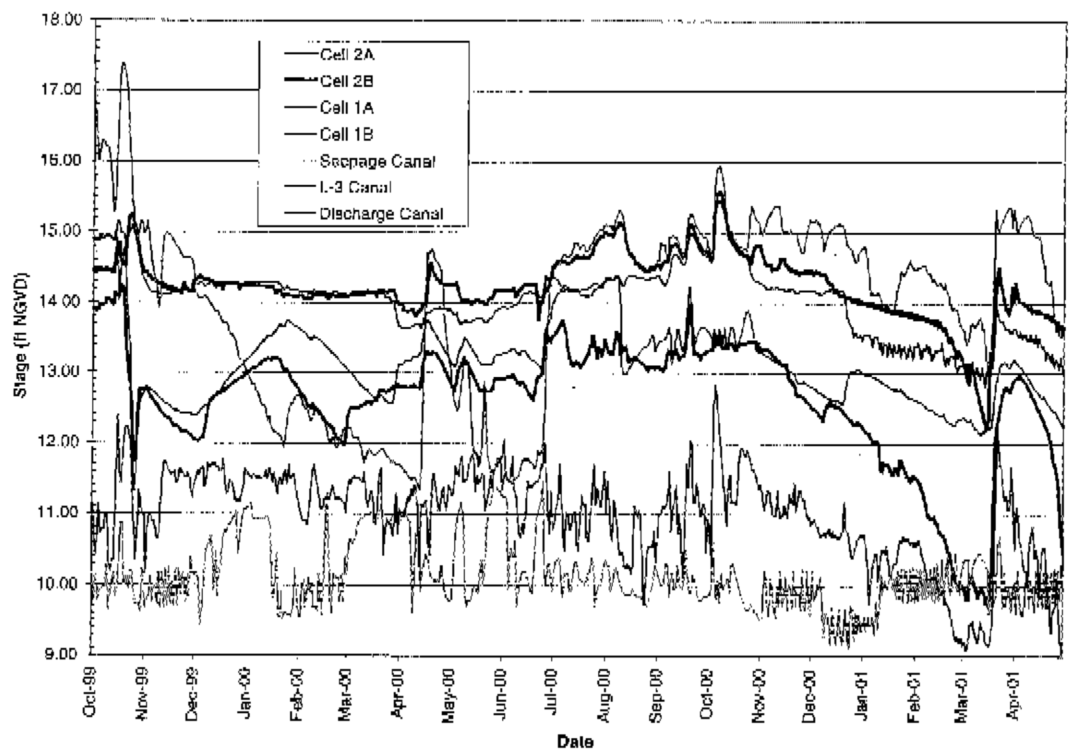

Figure 13. Stage in Cells 2A and 2B and Surrounding Areas

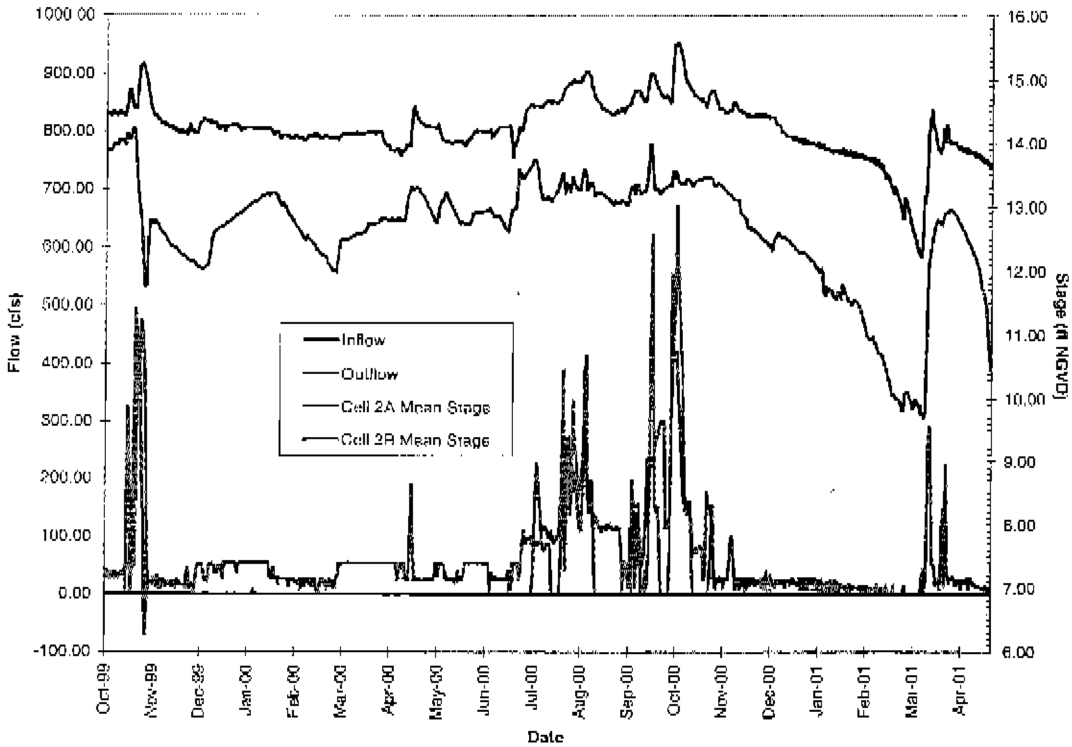

Figure 14. Inflow, Outflow and Stage Cells 2A and 2B

Table 4. Monthly Water Budget for Cells 2A and 2B

Month	Inflow (ac-ft)	Outflow (ac-ft)	Storage (ac-ft)	Rain (ac-ft)	ET (ac-ft)	Seepage (ac-ft)	Error (ac-ft)	Check Error (ac-ft)	Daily Avg. Error (in)
Oct-99	4.547	8,464	-1,463	1,651	655	1,673	-3,131	-3,131	0.59
Nov-99	1,210	5	-963	84	567	1,395	292	292	0.06
Dec-99	2,891	0	1,066	60	470	1,407	8	8	0.00
Jan-00	2,466	15	-368	137	616	1,672	668	668	0.13
Feb-00	1,091	0	-845	206	677	1,343	122	122	0.02
Mar-00	3,253	0	808	290	844	1,485	406	406	0.08
Apr-00	2,777	0	320	918	963	1,657	755	755	0.15
May-00	2,436	0	-26	372	1,120	1,636	79	79	0.01
Jun-00	2,422	0	1.005	1,661	944	1,676	459	458	0.09
Jul-00	7,515	5.781	353	472	890	1,809	-847	-847	0.16
Aug-00	9,234	5,970	-842	257	871	1,999	1,491	1,491	0.28
Sep-00	8,754	5,517	408	1.196	760	1,857	1,407	1.407	0.27
Oct-00	10,545	10,763	119	1,368	733	1,994	-1,696	-1,696	0.32
Nov-00	1,722	118	-1.262	2	634	1,791	444	444	0.09
Dec-00	1.270	12	-742	29	544	1,655	-170	-170	0.03
Jan-01	796	6	-1,040	98	643	1,179	107	107	0.02
Feb-01	385	-2	-651	0	661	434	-57	-57	0.01
Mar-01	2.623	0	4,153	1,119	641	367	-1,619	-1,619	0.30
Apr-01	1,461	0	-2,096	15	975	1,419	1,179	1,179	0.23

Note: Negative storage values indicate decreasing stage over the month. No signs are shown for other values, except error. To compute the water budget error, flow into the cell was taken as positive and flow out of a cell was taken as negative.

STA-5

Table 5 contains the summary of the water budget for the entire STA, which includes both flow ways, discussed above. Using a seepage coefficient of 1.61 cfs/mi/ft, error for the nineteen months was less than 2 percent of the budget. Seepage was 31 percent of the water budget. Slightly more than 1 percent of the days during the study period had errors that were greater than 0.25 ft (3.0 in).

Table 5. Water Budget Summary for STA-5

1999-2001			STA-5 Water Budget				
	INFLOW	ac-ft	Percent	OUTFLOW	ac-ft	Percent	
	G342A-D	62,872	43.30	G344A-D	74,393	49.01	
	+ G349A_P	31,209	21.49	ET	28,812	18.98	
	+ G350A_P	29,477	20.30	Seepage	46,477	30.62	
	+ STA5TP_P	1,772	1.22	Error	2,123	1.40	
	Rain	19,869	13.68				
	Total	145,199	100.00	Total	151,804	100.00	
	Storage Chg.	-6,605					
	Residuals Analysis			Count	1" error	2" error	3" error
Sum=	2,122.75	Avg. Err.	3.67	# >	17	3	0
Max=	900.09	St. Dev.	244.24	# <	30	15	6
Min=	-2,146.89	Avg Ab Err	128.26	Total	47	18	6
		St. Dev.	207.81	Percent	8.13	3.11	1.04
SSE =	34,426,645	Sum Abs Err	74,135.76				

Figure 15 shows the residual in the daily water budgets. The peaks in the residual plot occur during periods of high inflow, indicating that the daily water budget under these conditions does not accurately quantify the hydrologic processes occurring in the STA. Figure 16 presents the estimated seepage out of STA-5. It shows that there is a constant, net loss of water from the treatment cells. However, the pumps at G349A and G350A return a volume of water to Cells 1A and 2A greater than the seepage loss shown in Table 5. Inflow, outflow and stage are shown in Figure 17.

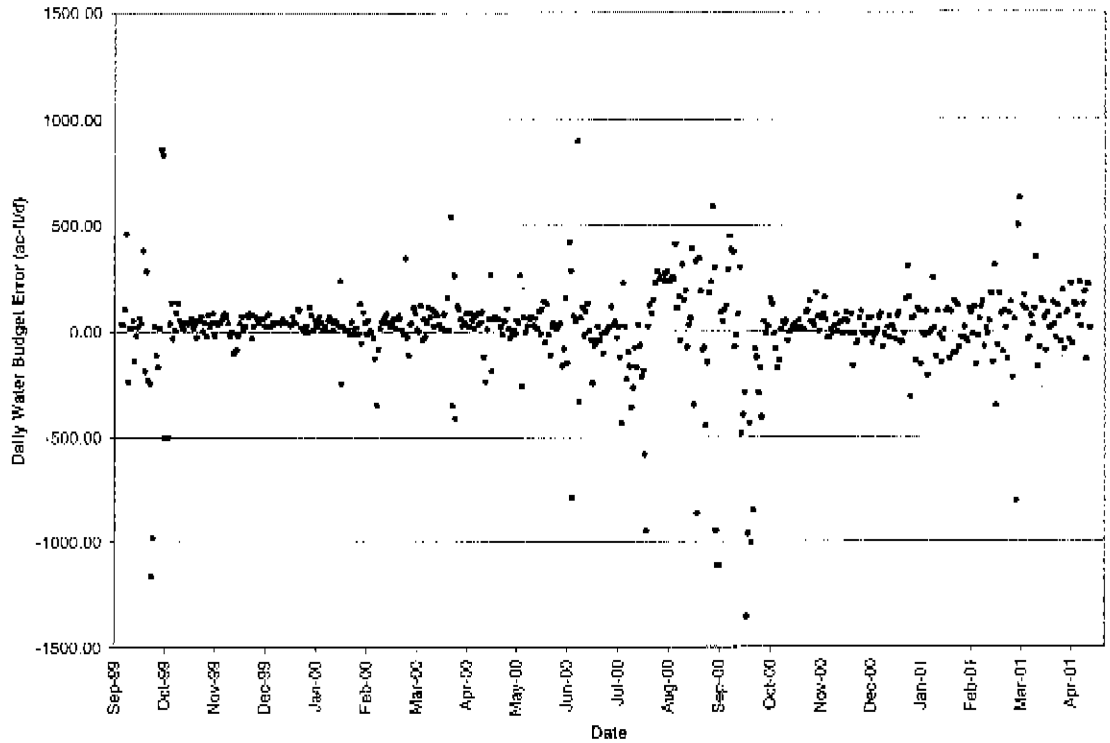

Figure 15. Water Budget Residuals for STA-5

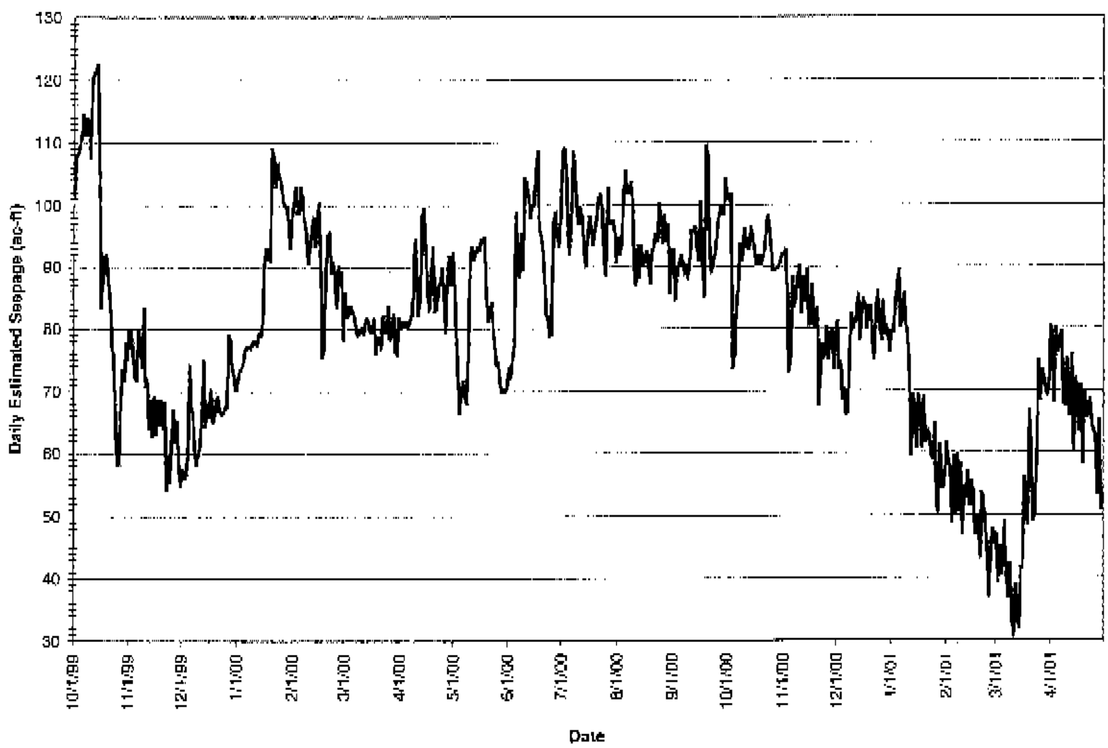

Figure 16. STA-5 Estimated Seepage

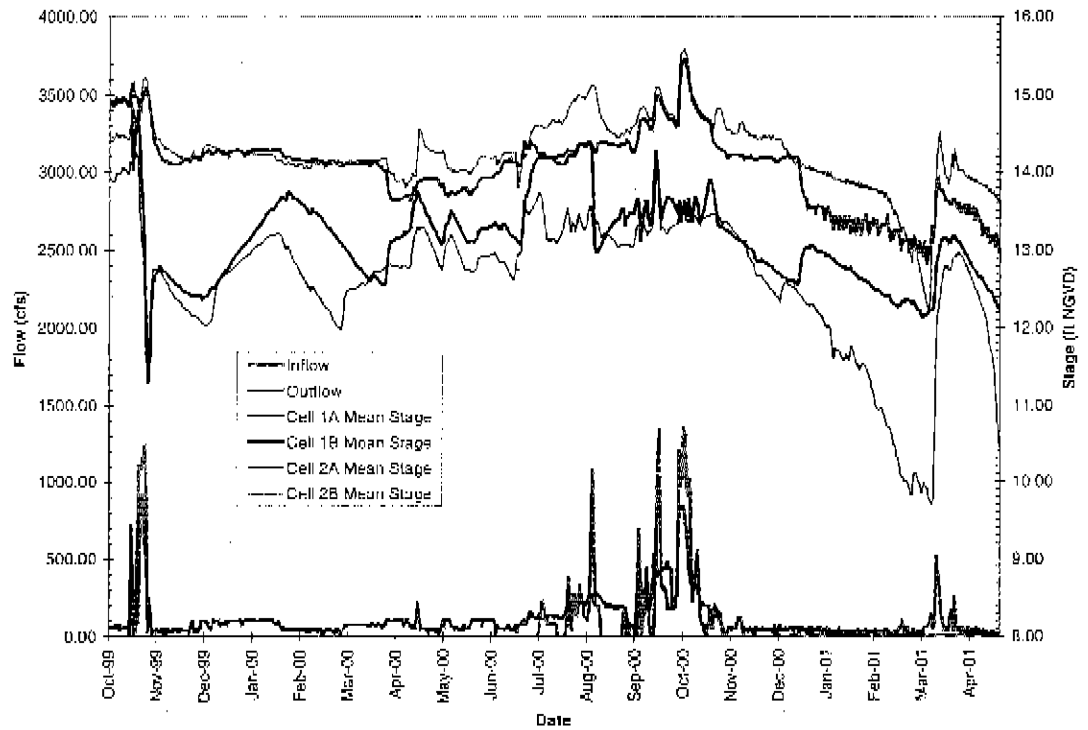

Figure 17. Inflow, Outflow and Stage STA-5

Table 6 shows the monthly water budget summary. The daily average errors are less than 1.0 in. The two highest values are for October 1999 and October 2000 when rainfall and runoff from Hurricane Irene and an unnamed tropical wave affected the STA. Figure 18 summarizes the inflows and outflows to STA-5 for the period October 1999 through April 2001. The inflow volume at G342A through D was 84 percent of the volume discharged at G344A thought D.

Table 6. Monthly Water Budget for STA-5

Month	Inflow (ac-ft)	Outflow (ac-ft)	Storage (ac-ft)	Rain (ac-ft)	ET (ac-ft)	Seepage (ac-ft)	Error (ac-ft)	Check Error (ac-ft)	Daily Avg. Error (in)
Oct-99	11,183	17,267	-4,309	3,301	1,310	2,920	-2,704	-2,704	0.25
Nov-99	2,670	15	-1,446	168	1,134	2,037	1,100	1,100	0.11
Dec-99	5,891	0	2,081	120	940	2,061	929	929	0.09
Jan-00	5,145	15	128	275	1,193	2.739	1,305	1,344	0.12
Feb-00	2,460	0	-1,622	412	1,353	2,686	455	455	0.05
Mar-00	4.963	0	516	580	1.687	2,487	852	852	0.08
Apr-00	4.944	0	621	1,836	1,927	2,595	1,638	1,638	0.16
May-00	4.714	0	85	745	2,240	2.493	641	641	0.06
Jun-00	4,616	0	2.249	3,322	1.889	2.756	1,044	1,044	0.10
Jul-00	9.296	5.784	763	944	1,780	3,038	-1,126	-1,126	0.11
Aug-00	13,446	9.213	-1,962	515	1,743	2,933	2,033	2,033	0.19
Sep-00	17,662	15,406	911	2,392	1,520	2,821	-604	-604	0.06
Oct-00	21,045	26,503	-595	2.735	1,465	2,847	-6,440	-6,440	0.61
Nov-00	3,147	125	-1,923	3	1,268	2,454	1,227	1,227	0.12
Dec-00	2,707	35	-1.108	58	1,088	2,439	311	311	0.03
Jan-01	1,853	24	-1,607	196	1,285	2,123	223	223	0.02
Feb-01	1,861	4	-1,181	0	1,321	1,439	278	278	0.03
Mar-01	5,568	0	5,599	2,237	1,682	1,573	-1.049	-1,049	0.10
Apr-01	2,160	0	-3,805	31	1,949	2,036	2,011	2,011	0.20

Note: Negative storage values indicate decreasing stage over the month. No signs are shown for other values, except error. To compute the water budget error, flow into the cell was taken as positive and flow out of a cell was taken as negative.

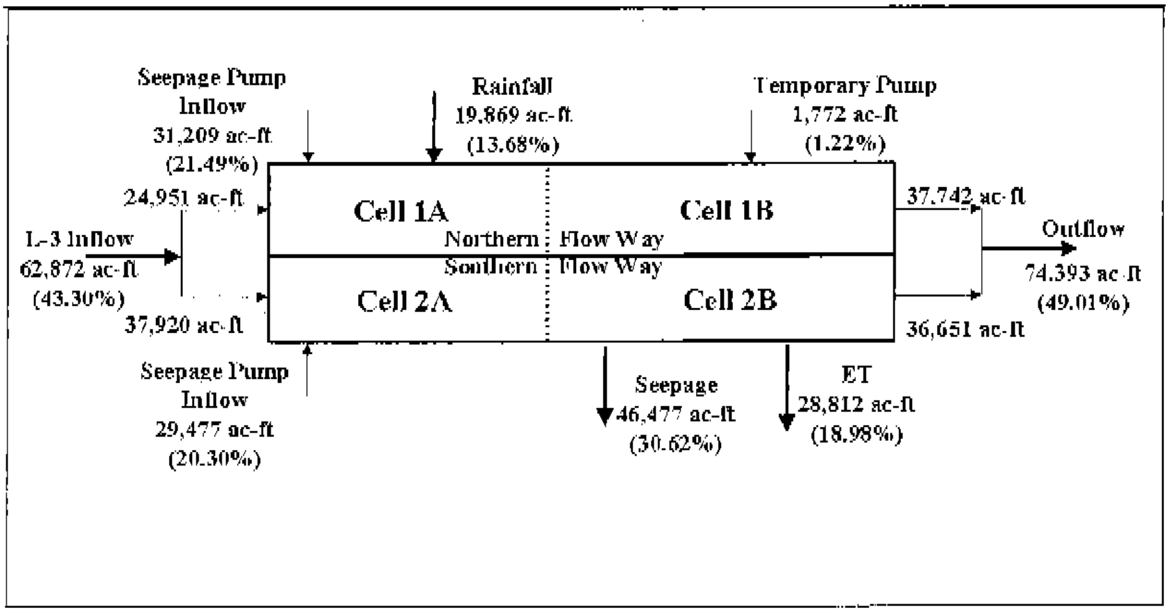

Figure 16. STA-5 Water Budget Volumes

Mean Hydraulic Retention Time

Mean hydraulic retention time (MHRT) is a measure of how long water remains in each cell and estimates the treatment time. Over this period, physical, chemical and biological processes remove particulate and soluble phosphorous and other contaminants. The mean hydraulic retention time (also referred to as mean cell residence time) was determined using equation 4:

$$t = \frac{V}{Q} \tag{4}$$

where t = mean hydraulic retention time (d)
V = cell volume (ac-ft)
Q = flow rate (ac-ft/d)

Table 7 shows the mean hydraulic retention time in days for the northern flow way (Cells 1A and 1B) and the southern flow way (Cells 2A and 2B). Since rainfall, evapotranspiration and seepage are large percentages of the water budget, the MHRT was based upon the average stage during the study period and the average volume of total inflow and total outflow including these parameters. In traditional calculations of MHRT, rainfall, evapotranspiration and seepage are taken as negligible and not included in the calculation of MHRT. The retention times for each flow way (25.8 days for the northern flow way and 19.5 days for the southern flow way) are comparable with those reported for the ENR (17 days in 1994-96, 24.5 days in 1996-97 and 25.4 days in 1997-98).

Table 7. Mean Hydraulic Retention Time (MHRT)

	Mean Stage (ft NGVD)	Mean Depth (ft)	Volume (ac-ft)	Average Flow (ac-ft/d)	MHRT (days)
Cell 1A	14.06	1.31	1098	121	9.0
Cell 1B	13.17	1.67	2042	121	16.8
Cell 2A	14.25	1.50	1254	136	9.3
Cell 2B	12.64	1.14	1386	136	10.2

SUMMARY AND DISCUSSION

A total of 62,872 ac-ft of water entered STA-5 from the gated culverts at G342A – D from October 1, 1999 to April 30, 2001. This flow constituted 43 percent of the total inflow to the STA. Rainfall accounted for 19,869 ac-ft or 14 percent of the total inflow. Flow from seepage canal pumps at G349A and G350A contributed 31,209 ac-ft and 29,477 ac-ft of flow which was 21 and 20 percent, respectively, of the total inflow to the treatment area during the period of the study. Of these amounts, 2,194 ac-ft came from the Miami canal due to pumping at G349B and 2,308 ac-ft due to pumping at G350B. Due to the drought, a temporary pump was located at the northeast corner of STA-5 in February 2001. It supplied 1,772 ac-ft of water to Cell 1B from the Miami canal. The area around STA-5 received about 75 percent of its expected annual rainfall in calendar year 2000. The Pollution Prevention Plan (SFWMD, 2000) cites expected flows into the STA through the G342A – D culverts of 78,340 ac-ft per year or 215 ac-ft per day. During the study period, STA-5 received flow through these structures equaling a mean value of 109 ac-ft per day or 50 percent of the expected annual volume.

During the same period, 74,393 ac-ft of water were discharged from the STA at G344A – D (49 percent of the total outflow). Evapotranspiration accounted for an additional 28,812 ac-ft of water leaving the STA (19 percent of the total outflow). Estimated seepage out of STA-5 accounted for 31 percent of the total outflow from the STA or 46,477 ac-ft. The volume of seepage was based upon head differences between the treatment cells and the water levels in the areas surrounding the STA and a seepage coefficient of 1.61 cfs/ft/mi. This coefficient was well within the values found in literature concerning the design of STAs and other analyses of seepage potential. Water budget error was less than 2 percent as discussed previously.

The greatest monthly errors in the water budget for the STA occurred in October 1999 and October 2000 when flows into STA-5 were affected by rainfall and runoff caused by Hurricane Irene and an unnamed tropical wave. Nevertheless, the daily average error in the monthly water budgets for STA-5 were less than 1.0 inch.

Cells 1A and 1B, constituting the northern flow way, received 24,951 ac-ft of water from October 1999 to April 2001 through structures G342A and B. The pumps at G349A provided an additional 31,209 ac-ft of water during the same period. Rain into these cells accounted for 9,935 ac-ft of inflow. The volume of water stored in the cells decreased by 4,538 ac-ft over this period. G344A and B discharged 37,742 ac-ft of water. ET accounted for another 14,406 ac-ft. Seepage out of Cells 1A and 1B was estimated at 16,831 ac-ft using a seepage coefficient of 1.00 cfs/ft/mi. Water budget error was less than 5 percent.

The southern flow way, Cells 2A and 2B, received 37,920 ac-ft of water during the study period through culverts G342C and D. This was 52 percent more inflow from the L3 canal than the northern flow way received and is the main reason that the budget for the two southern cells differs markedly from that for the northern cells. The pumps at G350A discharged 29,477 ac-ft of water into Cell 2A. Rainfall contributed 9,935 ac-ft of water to these cells. Storage in Cells 2A and 2B decreased by 2,067 ac-ft. G344C and D released 36,651 ac-ft or water during the study period. ET accounted for a loss of 14,406 ac-ft and seepage losses were estimated at 28,448 ac-ft using a seepage coefficient of 2.15 cfs/ft/mi. Seepage was out of the southern flow way and into the cells of the northern flow way, the seepage canal, and discharge canal. Water budget error was less than 1 percent.

Mean hydraulic residence times during this period were 25.8 days for the northern flow way, Cells 1A and 1B, and 19.5 days for the southern flow way. Cells 2A and 2B. This difference reflects the higher volume of flow that passed through the southern flow way during the period (approximately 15 percent more flow) and a lower average depth over the nineteen-month period. These values compare favorably with the MHRT's observed for STA-1W and the ENR project.
There were a number of problems associated with calculating the water budget for STA-5 similar to those encountered for STA-6. The largest source of error may be the values computed for seepage. The seepage and budget residual combined constitute 32 percent of the water budget. The seepage coefficients used in this study were calibrated based on minimizing the sum of the squared daily net water budget error. Other errors, such as those associated with flow calculations, may also be incorporated in the seepage estimates. The daily average budget error computed for the monthly water budget indicates that if this was the case, it is not practically significant.

The daily water budget residuals or error for STA-5 shown in Figures 7, 11 and 15 (residuals for Cells 1A and 1B, Cells 2A and 2B and STA-5 as a whole) are not random. The residuals increase when flow increases. This situation occurred in October 1999, September and October 2000 and March 2001. Figure 19 shows the residuals for STA-5 plotted with inflow data and seepage data. The largest residuals are observed during the three periods of significantly higher inflow. Although seepage also increases during these periods (in response to increased stages), the volume of outflow from STA-5 plus the increased seepage and the increase in storage do not equal the volume of water entering STA-5 on a daily basis. This is expected since the mean residence time or time to flow through the treatment cells is greater than a day. Flow measurement error may also affect the results, but to a lesser extent. The same type of response has been observed at STA-6 (Huebner, 2001) and STA-1W (Abtew et al., 2001). This response to large flows and rapidly changing water levels is not adequately represented in the daily water budget equation by the traditional equations for storage and levee seepage used in this and other studies.

Other possible sources of error in the budget include use of ET values from the ENR located approximately 33 miles to the northeast of STA-5. using average ground elevations for the bottom of the treatment cells and assuming a constant surface area independent of water depth in the cells. These weaknesses had a minor impact on the water budget.

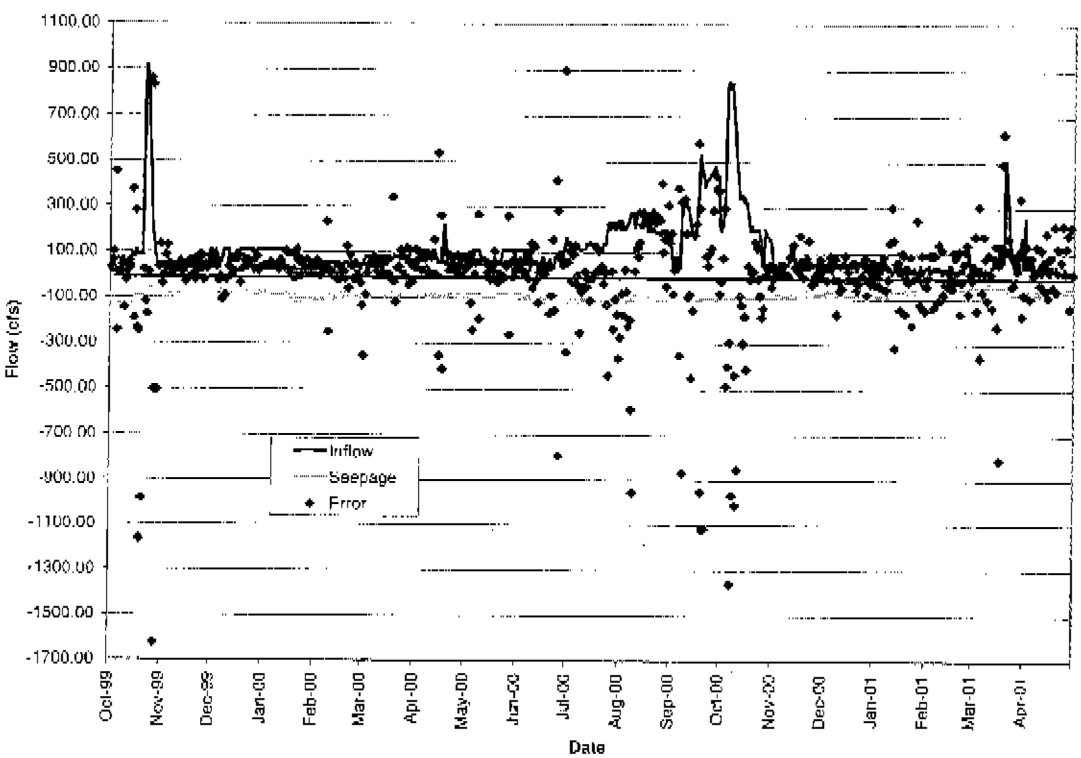

Figure 19. STA-5 Inflow, Seepage and Water Budget Residuals

RECOMMENDATIONS

Seepage was the largest single quantifiable unknown at the site. Although the percentage of the water budget attributed to seepage fell within literature values, it is greater than values reported for the ENR and STA-1W. Additional study of the groundwater flow regime and the impact of seepage on treatment performance is warranted at this site. Piezometers with water level recorders located outside the boundary of STA-5 would have aided the analysis of seepage for this study especially along the northern and southern boundaries. The ability to calculate seepage into and out of an STA should be a design criterion. Location and installation of observation wells for this purpose should be a design/construction requirement for all STAs.

The design of the gated culverts at STA-5 is susceptible to backflow or reverse flow under certain operating conditions. Although the magnitude of these flows is small relative to flow during major runoff events, backflow into or out off the STA is contrary to the design principles of STAs in general. Back-flow at the G344A through D structures introduces untreated water from the Miami canal into the finishing Cells 1B and 2B. Likewise backflow from Cells 1A and 2A at structures G342A through D mixes treated water with untreated water in the L-3 canal. Automating the operation of the gates under conditions of adverse head would minimize the volume of backflow.

CONCLUSIONS

This water budget was the first for STA-5. The first water budgets for the ENR and STA-6 were prepared after two years of operation. Results and conclusions from this work should be considered preliminary. This report provides a first look at the hydraulic performance of the STA and its two treatment flow ways. Improvements to the water budget and a better understanding of the hydrologic components at STA-5 will come with additional years of data.

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APPENDICES

Appendix A – Site Properties and Monitoring Stations

Table A-1. STA-5 Site Properties

Surface Area

Cell 1A (Northwest)	**839 ac**
Cell 1B (Northeast)	**1220 ac**
Cell 2A (Southwest)	**839 ac**
Cell 2B (Southeast)	**1220 ac**
Total	**4118 ac**

Cells 1A and 2A Bottom Elevation **~12.75 ft NGVD**
(Cells 1A and 2A vary in elevation from G342 to G360 from 14.5 to 13.0 ft.; Cells 1A and 2A slope west to east from 13.50 to 11.25 ft. – 12.75 ft. average ground elevation)

Cells 1B and 2B Bottom Elevation **~11.50 ft NGVD**
(Cells 1B and 2B slope west to east from 12.25 to 10.75 ft. – 11.50 ft. average ground elevation)

Inflow

Flow at G342A-D, G349A_P, G350A_P and STA5TP_P

Outflow

Flow at G344A-D

Levee Length		Aspect Ratio
Along Northern Boundary		
Cell 1A	**~ 7,140 ft**	**1.39**
Cell 1B	**~10,380 ft**	**2.03**
Along Southern Boundary		
Cell 2A	**~ 7,140 ft**	**1.39**
Cell 2B	**~10,380 ft**	**2.03**
Along Eastern Boundary		
Cell 1A	**~ 5,120 ft**	
Cell 2A	**~ 5,120 ft**	
Along Western Boundary		
Cell 1B	**~ 5,120 ft**	
Cell 2B	**~ 5,120 ft**	

Table A-2. Stage Monitoring Stations

STATION	STATION DESCRIPTION	DBKEY
G342A_H	G342A STA5 INFLOW STRUCTURE CELL 1A (HEADWATER)	JJ109
G342A_T	G342A STA5 INFLOW STRUCTURE CELL 1A (TAILWATER)	JJ110
G342B_H	G342B STA5 INFLOW STRUCTURE CELL 1A (HEADWATER)	JJ114
G342B_T	G342B STA5 INFLOW STRUCTURE CELL 1A (TAILWATER)	JJ115
G342C_H	G342C STA5 INFLOW STRUCTURE CELL 2A (HEADWATER)	JJ121
G342C_T	G342C STA5 INFLOW STRUCTURE CELL 2A (TAILWATER)	JJ123
G342D_H	G342D STA5 INFLOW STRUCTURE CELL 2A (HEADWATER)	JJ127
G342D_T	G342D STA5 INFLOW STRUCTURE CELL 2A (TAILWATER)	JJ128
G344A_H	G344A STA5 CELL 1B OUTFLOW STRUCTURE (HEADWATER)	JJ133
G344A_T	G344A STA5 CELL 1B OUTFLOW STRUCTURE (TAILWATER)	JJ135
G344B_H	G344B STA5 CELL 1B OUTFLOW (HEADWATER)	JJ138
G344B_T	G344B STA5 CELL 1B OUTFLOW (TAILWATER)	JJ140
G344C_H	G344C STA5 CELL 2B OUTFLOW (HEADWATER)	JJ143
G344C_T	G344C STA5 CELL 2B OUTFLOW (TAILWATER)	JJ145
G344D_H	G344D STA5 CELL 2B OUTFLOW (HEADWATER)	JJ148
G344D_T	G344D STA5 CELL 2B OUTFLOW (TAILWATER)	JJ150
G349A_H	G349A PUMP AT STA5 INFLOW (HEADWATER)	JJ156
G349A_T	G349A PUMP AT STA5 INFLOW (TAILWATER)	JJ157
G350A_H	G350 PUMPS AT STA5 INFLOW (HEADWATER)	JJ160
G350A_T	G350 PUMPS AT STA5 INFLOW (TAILWATER)	JJ161
G349B_H	STORMWATER TREATMENT AREA 5, G349B (HEADWATER)	JJ802
G349B_T	STORMWATER TREATMENT AREA 5, G349B (TAILWATER)	JJ803
G350B_H	G350B STA5 SOUTH SEEPAGE CANAL PUMP STATION (HEADWATER)	JJ810
G350B_T	G350B STA5 SOUTH SEEPAGE CANAL PUMP STATION (TAILWATER)	JJ811
G406_T	G406 STA5 INFLOW STRUCTURE (TAILWATER)	JJ155

Table A-3. Flow Monitoring Stations

STATION	STATION DESCRIPTION	DBKEY
G342A_C	G342A STA5 INFLOW STRUCTURE CELL 1A	J6406
G342B_C	G342B STA5 INFLOW STRUCTURE CELL 1A	J6398
G342C_C	G342C STA5 INFLOW STRUCTURE CELL 2A	J6407
G342D_C	G342D STA5 INFLOW STRUCTURE CELL 2A	J6405
G344A_C	STORMWATER TREATMENT AREA 5 CELL 1B	J0719
G344B_C	STORMWATER TREATMENT AREA 5 CELL 1B	J0720
G344C_C	STORMWATER TREATMENT AREA 5 CELL 2B	J0721
G344D_C	STORMWATER TREATMENT AREA 5 CELL 2B	J0722
G349A_P	STORMWATER TREATMENT AREA 5, G349A INFLOW PUMP	JJ838
G349B_P	STORMWATER TREATMENT AREA 5, G349B INFLOW PUMP	JA353
G350A_P	STORMWATER TREATMENT AREA 5, G350A INFLOW PUMP	JJ839
G350B_P	G350B STA5 SOUTH SEEPAGE CANAL PUMP STATION	JA352
G406_C	G406 STA5 INFLOW STRUCTURE	JU789
STA5TP_P	TEMP PUMP AT STA5 (BETWEEN G349B AND G344A) FOR CELL 1B	N2481

Table A-4. Rainfall Monitoring Sites

STATION	STATION DESCRIPTION	DBKEY
G343B_R	G343B STA5 INTERIOR STRUCTURE BETWEEN CELL 1A AND 1B	JJ837

Table A-5. Weather Stations

STATION	STATION DESCRIPTION	DBKEY	DATA TYPE
STA1W	AREAL COMPUTED PARAMETER FOR STA1W PROJECT	KN810	ET
L006	LAKE OKEECHOBEE TOWER SOUTH (#6)	12911	AIRT
L006	LAKE OKEECHOBEE TOWER SOUTH (#6)	12522	RADT
BIG CY SIR	BIG CYPRESS @ SEMINOLE INDIAN RESERVATION	15682	AIRT
BIG CY SIR	BIG CYPRESS @ SEMINOLE INDIAN RESERVATION	15688	RADT
BELLE GL	IFAS - EVERGLADES RESEARCH AND EDUCATION CENTER	DO530	AIRT
BELLE GL	IFAS - EVERGLADES RESEARCH AND EDUCATION CENTER	DO527	RADT
ROTNWX	ROTENBERGER TRACT WEATHER STATION, LOCATED BY G606 AT STA6	GE352	AIRT
ROTNWX	ROTENBERGER TRACT WEATHER STATION, LOCATED BY G606 AT STA6	GE348	RADT

☐ - Preferred DB Key / Data used for budget calculations

Appendix B – Rainfall Data

Table B-1. Rainfall at G343B_R (in.)

DAY	Oct-99	Nov-99	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01
1	0	0.02	0	0	0	0	0	0	0	0.05	0.09	0.48	0	0	0	0	0	0	0.09
2	0.01	0.38	0	0	0.01	0	0	0	0	0.32	0	0	0	0	0	0	0	0	0
3	0.16	0	0	0	0.02	0	0	0.05	0	0	0	0	1.07	0	0	0	0	0	0
4	1.57	0	0	0	0	0	0	0	0	0.09	0	0.13	5.1	0	0	0.01	0	0.68	0
5	0	0	0.01	0	0	0.01	0	0	0.04	0.38	0.02	1.4	0	0	0	0	0	0	0
6	0.02	0	0	0	0	0	0	0	0.35	0.06	0.02	0.27	1.5	0	0.03	0	0	0	0
7	0	0	0	0	0	0	0.01	0	0.01	0.46	0	0.71	0	0	0.01	0	0	0	0
8	0.33	0	0	0	0.75	0	0.19	0.88	0	0	0	0.15	0	0	0	0	0	0	0
9	0.19	0	0	0	0.03	0	0	0	0.25	0	0	0	0	0	0	0.18	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0.19	0	0.01	0.02	0	0	0	0
11	0	0	0	0	0	0.06	0	0	0.63	0.17	0	0	0	0	0	0	0	0	0
12	0	0	0.01	0	0	0.1	0.32	0	0.63	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0.04	0	0	0.11	0	0	0	0	0	0	0	0	0
14	2.71	0	0.05	0	0	0	3.2	0.01	0	0	0	0	0	0	0	0	0	0	0
15	3.54	0	0.01	0	0	0	0.27	0	0	0	0	0.01	0	0	0	0	0	0	0
16	0.09	0	0	0	0	0	1.32	0	0	0	0	0.03	0	0	0	0	0	0	0
17	0	0	0.15	0	0	0	0	0	0.02	0.1	0	1.94	0	0	0	0	0	0.01	0
18	0	0	0	0	0	0.79	0	0	0.05	0	0	1.34	0	0	0	0	0	0.93	0
19	0	0	0	0	0	0.2	0	0	0.12	0.16	0	0.26	0	0	0	0	0	4.07	0
20	0.66	0.07	0	0	0.39	0	0	0	0	0	0	0.02	0	0	0	0.12	0	0.01	0
21	0.01	0.01	0	0	0	0	0	0	0	0.18	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0.01	0.03	0	0	0	0	0.25	0	0	0
23	0	0	0	0	0	0	0	0	0	0.07	0	0	0.12	0	0	0.01	0	0	0
24	0	0	0	0.8	0	0	0	0.04	1.4	0.18	0	0	0.18	0	0	0	0	0	0
25	0	0.01	0	0	0	0	0	0	3.33	0	0	0	0	0	0.01	0	0	0	0
26	0	0	0	0	0	0	0	1.01	0	0	0.51	0.01	0	0	0	0	0	0.03	0
27	0	0	0	0	0	0.25	0	0	0.05	0	0.28	0.03	0	0	0	0	0	0	0
28	0	0	0.12	0	0	0.17	0	0.18	0.03	0.01	0	0	0	0	0.1	0	0	0	0
29	0	0	0	0	0	0.11	0	0	2.77	0.23	0.01	0	0	0	0	0		0.78	0
30	0	0	0	0		0	0	0	0	0.16	0.32	0	0	0	0	0		0.01	0
31	0.33		0	0		0		0		0.01	0.22		0		0	0		0	
MAX	3.54	0.38	0.15	0.80	0.75	0.79	3.20	1.01	3.33	0.46	0.51	1.94	5.10	0.01	0.10	0.25	0.00	4.07	0.09
MEAN	0.31	0.02	0.01	0.03	0.04	0.06	0.18	0.07	0.32	0.09	0.05	0.23	0.26	0	0.01	0.02	0.00	0.21	0.00
MIN	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SUM	9.62	0.49	0.35	0.80	1.20	1.69	5.35	2.17	9.68	2.75	1.50	6.97	7.97	0.01	0.17	0.57	0.00	6.52	0.09

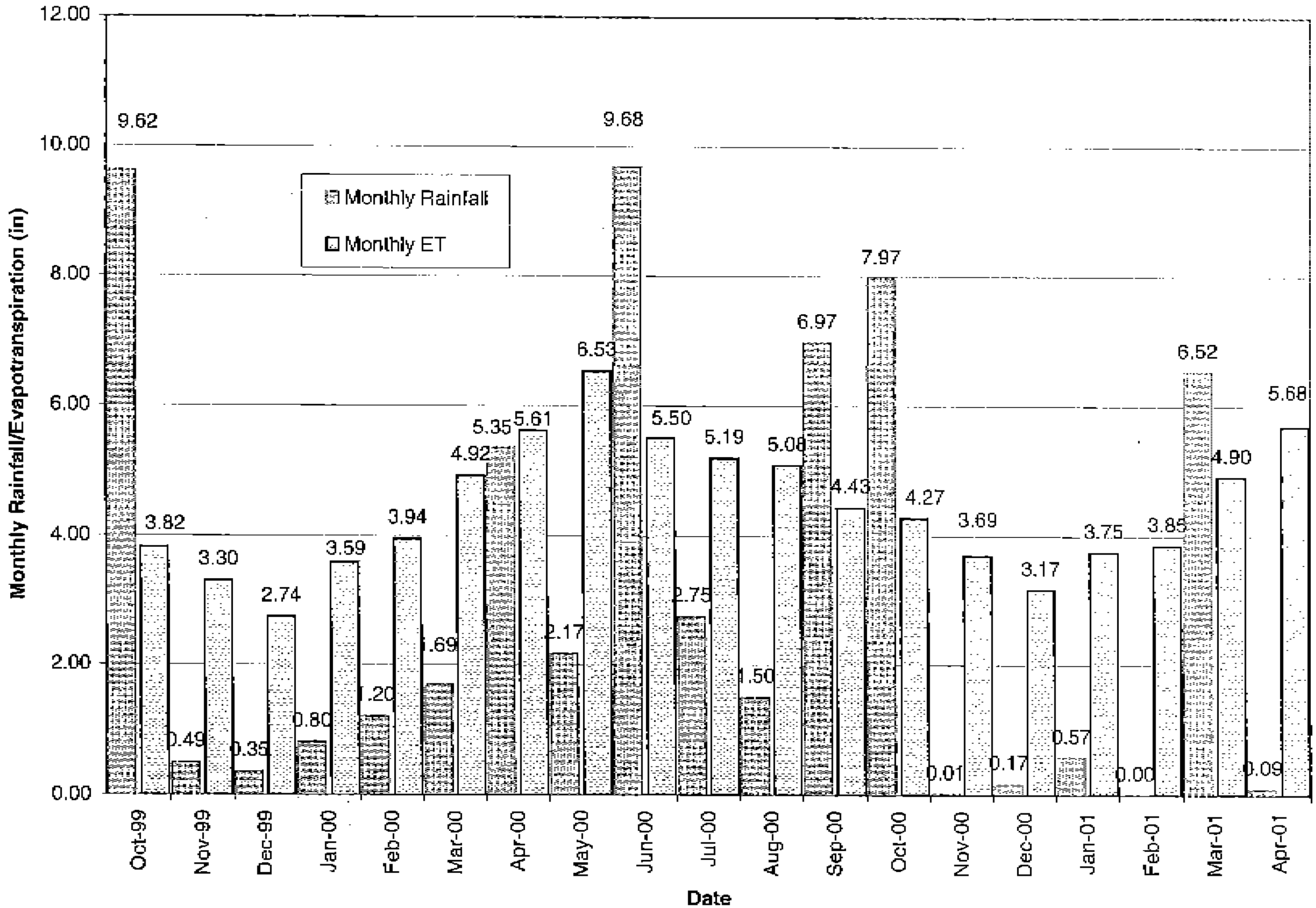

Figure B-1. STA-5 Monthly Rainfall and Evapotranspiration (in.)

Appendix C – Evapotranspiration Data

Table C-1. Evapotranspiration at STA-5 (in.)

DAY	Oct-99	Nov-99	Dec-99	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00	Jan-01	Feb-01	Mar-01	Apr-01
1	0.13	0.14	0.11	0.11	0.10	0.17	0.18	0.23	0.22	0.10	0.18	0.21	0.15	0.16	0.12	0.14	0.15	0.16	0.23
2	0.18	0.10	0.12	0.11	0.05	0.14	0.18	0.21	0.24	0.18	0.08	0.21	0.07	0.14	0.09	0.13	0.13	0.14	0.24
3	0.08	0.17	0.08	0.11	0.08	0.12	0.21	0.11	0.23	0.13	0.13	0.15	0.03	0.15	0.11	0.13	0.10	0.15	0.24
4	0.07	0.13	0.06	0.11	0.12	0.14	0.18	0.22	0.18	0.10	0.21	0.17	0.06	0.13	0.11	0.15	0.12	0.14	0.20
5	0.10	0.13	0.05	0.12	0.16	0.18	0.24	0.24	0.24	0.21	0.13	0.12	0.15	0.15	0.09	0.13	0.09	0.18	0.18
6	0.08	0.11	0.08	0.13	0.13	0.14	0.19	0.21	0.21	0.24	0.13	0.11	0.13	0.14	0.10	0.14	0.15	0.21	0.17
7	0.10	0.13	0.09	0.09	0.11	0.14	0.21	0.21	0.19	0.21	0.18	0.10	0.17	0.15	0.12	0.14	0.15	0.21	0.16
8	0.11	0.13	0.10	0.12	0.03	0.15	0.19	0.13	0.08	0.13	0.21	0.14	0.15	0.15	0.13	0.13	0.15	0.20	0.21
9	0.13	0.14	0.10	0.11	0.16	0.19	0.24	0.23	0.18	0.19	0.18	0.12	0.07	0.14	0.11	0.14	0.13	0.20	0.21
10	0.18	0.13	0.05	0.12	0.17	0.17	0.21	0.24	0.21	0.17	0.22	0.16	0.15	0.10	0.06	0.14	0.14	0.08	0.21
11	0.16	0.10	0.08	0.08	0.16	0.11	0.20	0.23	0.12	0.17	0.20	0.18	0.15	0.15	0.09	0.12	0.10	0.15	0.18
12	0.12	0.15	0.05	0.14	0.14	0.15	0.10	0.24	0.23	0.15	0.15	0.19	0.16	0.14	0.10	0.10	0.15	0.17	0.19
13	0.16	0.13	0.10	0.14	0.13	0.19	0.07	0.20	0.18	0.18	0.15	0.19	0.18	0.14	0.10	0.13	0.14	0.18	0.18
14	0.04	0.14	0.04	0.13	0.15	0.17	0.02	0.24	0.20	0.22	0.18	0.20	0.14	0.10	0.11	0.10	0.15	0.14	0.23
15	0.01	0.15	0.05	0.07	0.17	0.15	0.13	0.21	0.21	0.21	0.19	0.14	0.16	0.15	0.10	0.11	0.15	0.13	0.18
16	0.10	0.14	0.05	0.09	0.17	0.17	0.20	0.23	0.25	0.23	0.21	0.07	0.17	0.15	0.09	0.14	0.14	0.13	0.21
17	0.13	0.09	0.09	0.14	0.17	0.18	0.18	0.15	0.23	0.17	0.18	0.05	0.18	0.14	0.10	0.12	0.13	0.11	0.23
18	0.16	0.10	0.08	0.14	0.14	0.08	0.21	0.22	0.21	0.18	0.15	0.14	0.16	0.12	0.11	0.11	0.13	0.09	0.23
19	0.16	0.10	0.12	0.09	0.13	0.03	0.24	0.21	0.15	0.19	0.17	0.16	0.16	0.13	0.11	0.14	0.14	0.02	0.19
20	0.13	0.10	0.07	0.12	0.15	0.18	0.18	0.25	0.23	0.23	0.15	0.16	0.14	0.04	0.14	0.04	0.12	0.21	0.19
21	0.13	0.09	0.05	0.15	0.18	0.21	0.21	0.25	0.15	0.20	0.14	0.15	0.10	0.14	0.11	0.15	0.15	0.15	0.18
22	0.11	0.07	0.10	0.14	0.14	0.20	0.22	0.21	0.19	0.16	0.15	0.14	0.15	0.15	0.13	0.01	0.15	0.21	0.20
23	0.18	0.05	0.07	0.13	0.13	0.19	0.23	0.19	0.22	0.10	0.16	0.16	0.12	0.12	0.09	0.13	0.13	0.22	0.18
24	0.18	0.04	0.11	0.06	0.15	0.15	0.21	0.20	0.16	0.13	0.18	0.18	0.12	0.10	0.04	0.15	0.16	0.21	0.21
25	0.15	0.05	0.14	0.10	0.13	0.20	0.17	0.23	0.07	0.13	0.18	0.20	0.18	0.04	0.08	0.15	0.14	0.21	0.20
26	0.07	0.07	0.12	0.15	0.13	0.15	0.24	0.23	0.18	0.10	0.15	0.16	0.16	0.07	0.09	0.13	0.15	0.19	0.17
27	0.15	0.11	0.13	0.15	0.13	0.11	0.22	0.17	0.09	0.15	0.16	0.15	0.15	0.10	0.10	0.10	0.16	0.16	0.21
28	0.14	0.10	0.04	0.11	0.14	0.21	0.24	0.22	0.15	0.16	0.16	0.09	0.15	0.13	0.09	0.13	0.15	0.16	0.16
29	0.13	0.10	0.13	0.11	0.17	0.18	0.15	0.24	0.12	0.17	0.16	0.10	0.14	0.07	0.08	0.14		0.15	0.05
30	0.13	0.10	0.13	0.13		0.19	0.21	0.19	0.18	0.10	0.13	0.14	0.13	0.14	0.13	0.07		0.07	0.07
31	0.12		0.13	0.10		0.17		0.21		0.22	0.10		0.13		0.14	0.15		0.18	
MAX	0.18	0.17	0.14	0.15	0.18	0.21	0.24	0.25	0.25	0.24	0.22	0.21	0.18	0.16	0.14	0.15	0.16	0.22	0.24
MEAN	0.12	0.11	0.09	0.12	0.14	0.16	0.19	0.21	0.18	0.17	0.16	0.15	0.14	0.12	0.10	0.12	0.14	0.16	0.19
MIN	0.01	0.04	0.04	0.06	0.03	0.03	0.02	0.11	0.07	0.10	0.08	0.05	0.03	0.04	0.04	0.01	0.09	0.02	0.05
SUM	3.82	3.30	2.74	3.59	3.94	4.92	5.61	6.53	5.50	5.19	5.08	4.43	4.27	3.69	3.17	3.75	3.85	4.90	5.68

Appendix D – Soil Moisture Equations

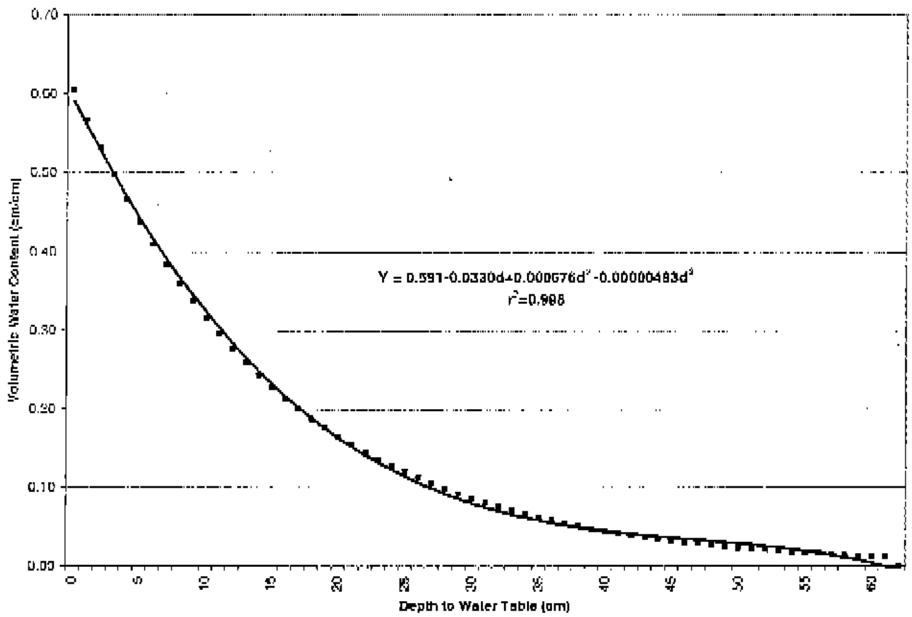

Figure D-1. Falling Water Table (Drying Front) Equation

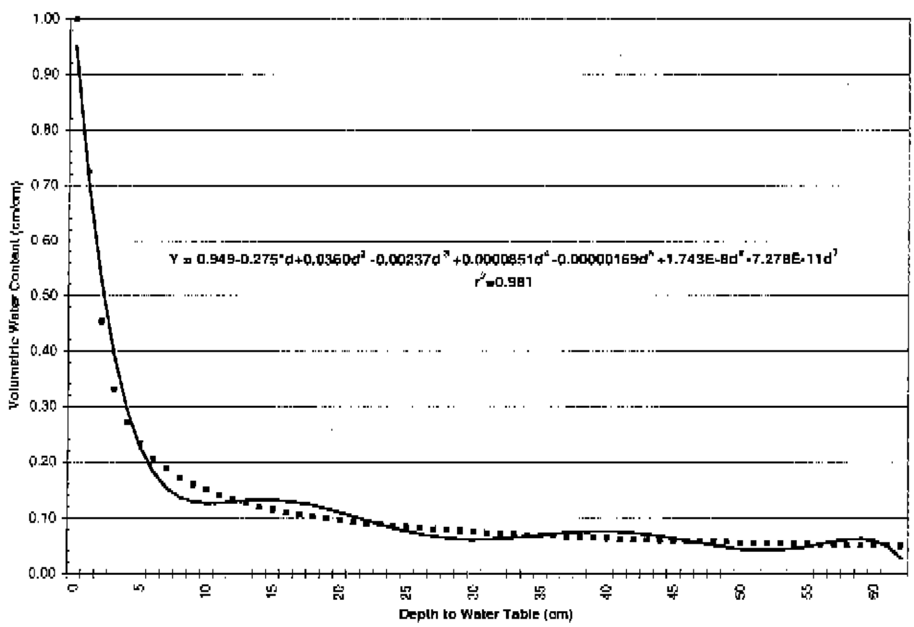

Figure D-2. Rising Water Table (Wetting Front) Equation