Technical Publication
ERA # 447

Water-budget Analysis for Stormwater Treatment Area 5

(Water Year 2006; May 1, 2005 to April 30, 2006)

May 2007

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EXECUTIVE SUMMARY

This report presents a water budget for Stormwater Treatment Area 5 (STA-5) from May 1, 2005 to April 30, 2006 (Water Year 2006, or WY06). The report augments the previous water-budget reports for STA-5. This report uses the May – April water year to coincide with periods used in the *South Florida Environmental Report* published annually at the South Florida Water Management District (SFWMD or District).

STA-5 is located along the western boundary of the Everglades Agricultural Area (EAA) adjacent to the L-2 canal, west of the northwestern corner of the Rotenberger Wildlife Management Area. It has a total effective treatment area of 4,118 acres. After initial flooding in 1999, culminating in October flood flows caused by Hurricane Irene, the Florida Department of Environmental Protection (FDEP) issued an emergency order to the SFWMD authorizing discharges from STA-5 for a 14-day period in October 1999. STA-5 began routine flow-through operations in June 2000.

Four hurricanes affected the District in WY06; Hurricanes Dennis, Katrina, Rita and Wilma. Hurricane Wilma, who made landfall on October 24, 2005, was the most severe with respect to damage to the STAs. The impacts included re-suspension of settled sediment, vegetation damage and levee and pump station damages.

In WY06, a total of 214,621 acre-feet (ac-ft) of water entered STA-5 through the gated culverts at G342A through D. It constituted 90 percent of the total inflow to the STA's treatment cells and 274 percent of the expected annual inflow volume at G342A through D (78,340 ac-ft). During the same water year, rainfall accounted for 13,785 ac-ft or 5 percent of the total inflow. Flow from seepage canal pumps at G349A and G350A contributed 22,037 ac-ft of flow, which was 8 percent of the total inflow that year. In addition, Pump G507 provided 2,354 ac-ft from the Miami Canal to Cell 1B, for submerged aquatic vegetation used to uptake phosphorus. The pumps at G349B and G350B that also provide water to the STA from the Miami Canal did not operate in WY06.

During WY06, 200,872 ac-ft of water were discharged from STA-5 at G344A through D (68 percent of the total outflow). Evapotranspiration accounted for an additional 17,749 ac-ft of water leaving the STA (7 percent of the total outflow). Estimated seepage out of the STA accounted for 12 percent of the total outflow or 29,030 ac-ft. Water-budget errors other than those inherent in the above estimates were less than 5 percent for WY06.

Significant errors in the water budgets for the northern and southern flow-ways during WY06 were mainly due to the volume of water pumped from Cell 2B to Cell 1B during reconstruction of the G343 structures between Cells 2A and 2B. The volume of water transferred between cells during construction was not recorded. Errors in the cell-by-cell water budgets ranged from 11 to 13 percent.

ACKNOWLEDGMENTS

The author would like to thank the following for reviewing the drafts of this document and thereby contributing to this final version: Charlie Balmaseda, Pam Lehr, Guy Germain, Violeta Ciuca, Wossenu Abtew and John Raymond.

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INTRODUCTION

This report presents a water budget for Stormwater Treatment Area 5 (STA-5) covering Water Year 2006 (WY06). In this report, WY06 spans May 1, 2005 through April 30, 2006 to coincide with the period used in the South Florida Environmental Report and previous Everglades Consolidated Reports (SFWMD, 2004). The report is based upon daily water budgets for Treatment Cells (or Flow-ways) 1 and 2 in STA-5. Daily results were aggregated to develop monthly and annual water budgets for WY06. The daily water budget accounted for inflow, outflow, rainfall, evapotranspiration, seepage and error.

During WY06, four hurricanes affected South Florida:

- Hurricane Dennis in July 2005
- Hurricane Katrina in August 2005
- Hurricane Rita in September 2005
- Hurricane Wilma in October 2005

Wilma, who made landfall on October 24, 2005, was the most severe with respect to damage to the STAs. The impacts included re-suspension of settled sediment, vegetation damage and levee and pump station damages (SFWMD, 2007). Moreover, reconfiguration of the interior control structures at G343 in the STA's treatment cells was begun in February 2005 and continued through WY06.

This section of the report presents background and describes hydrometeorological monitoring at STA-5. Subsequent sections describe the operation of STA-5 and the sources of data used for the report. The actual water-budget analyses for each treatment cell (flow-way) and the entire STA are presented, followed by a summary and recommendations.

Background

STA-5 is located along the western boundary of the Everglades Agricultural Area (EAA), adjacent to the L-2 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**. STA-5's principal purpose is to reduce the phosphorous load in runoff from the C-139 basin to the north and west of STA-5. The land now occupied by the STA was used for agricultural purposes prior to construction.

STA-5 was completed in December 1998. Initial flooding occurred 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 authorizing discharges from STA-5 for a 14-day period until October 29, 1999.

FDEP issued an Everglades Forever Act (EFA) permit for STA-5 on February 29, 2000. The issuance of the National Pollution Discharge Elimination System (NPDES) permit was delayed due to objections by the Friends of the Everglades, an 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. The project received an NPDES permit on May 24, 2001.

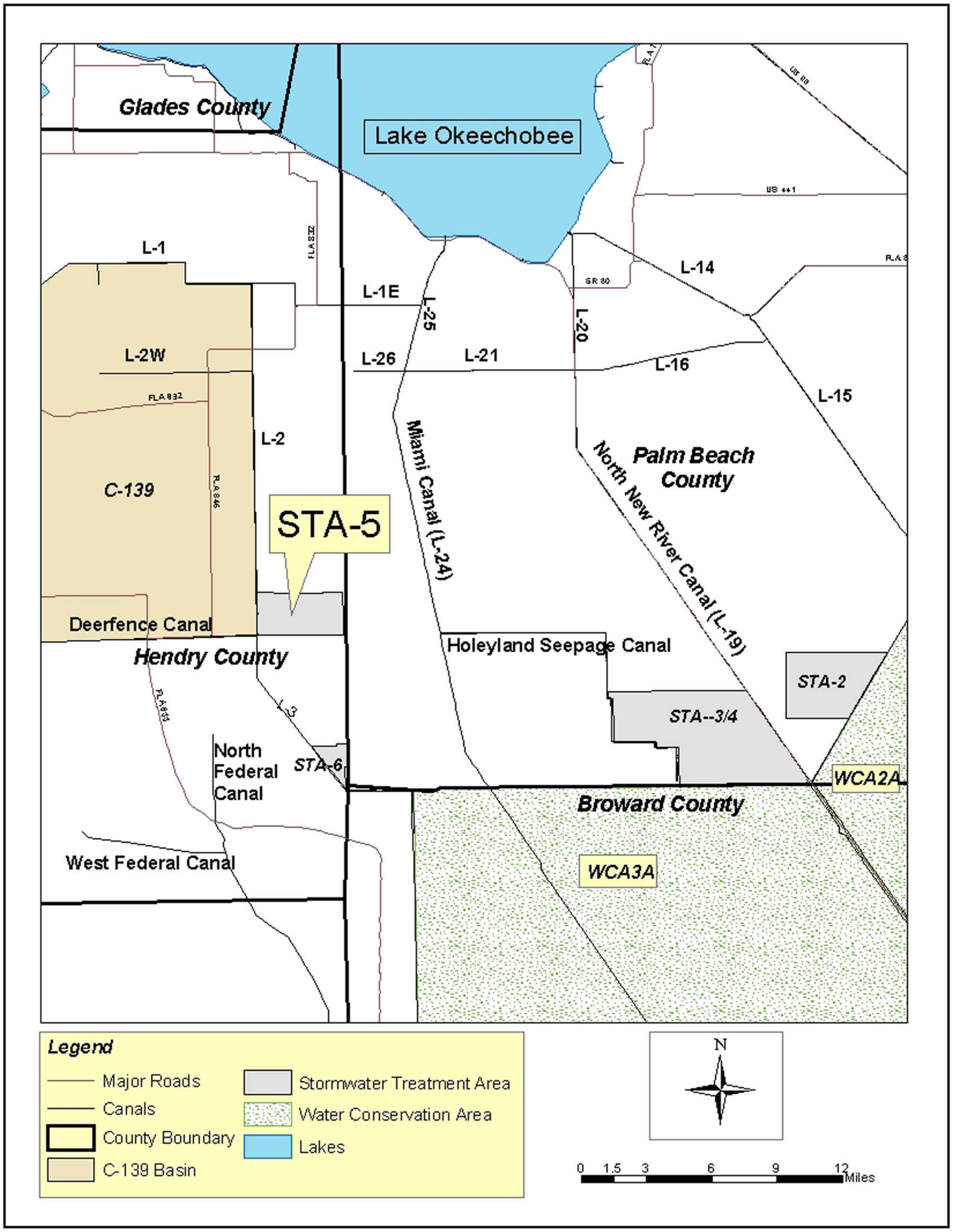

Figure 1. STA-5 location map.

The southern flow-way of STA-5 (Cells 2A and 2B) began routine flow-through operations in June 2000; water entered the flow-way at G342C and D and was discharged from the STA at G344C and D (see **Figure 2**). The northern flow-way of STA-5 (Cells 1A and 1B) began routine flow-through operations in August 2000.

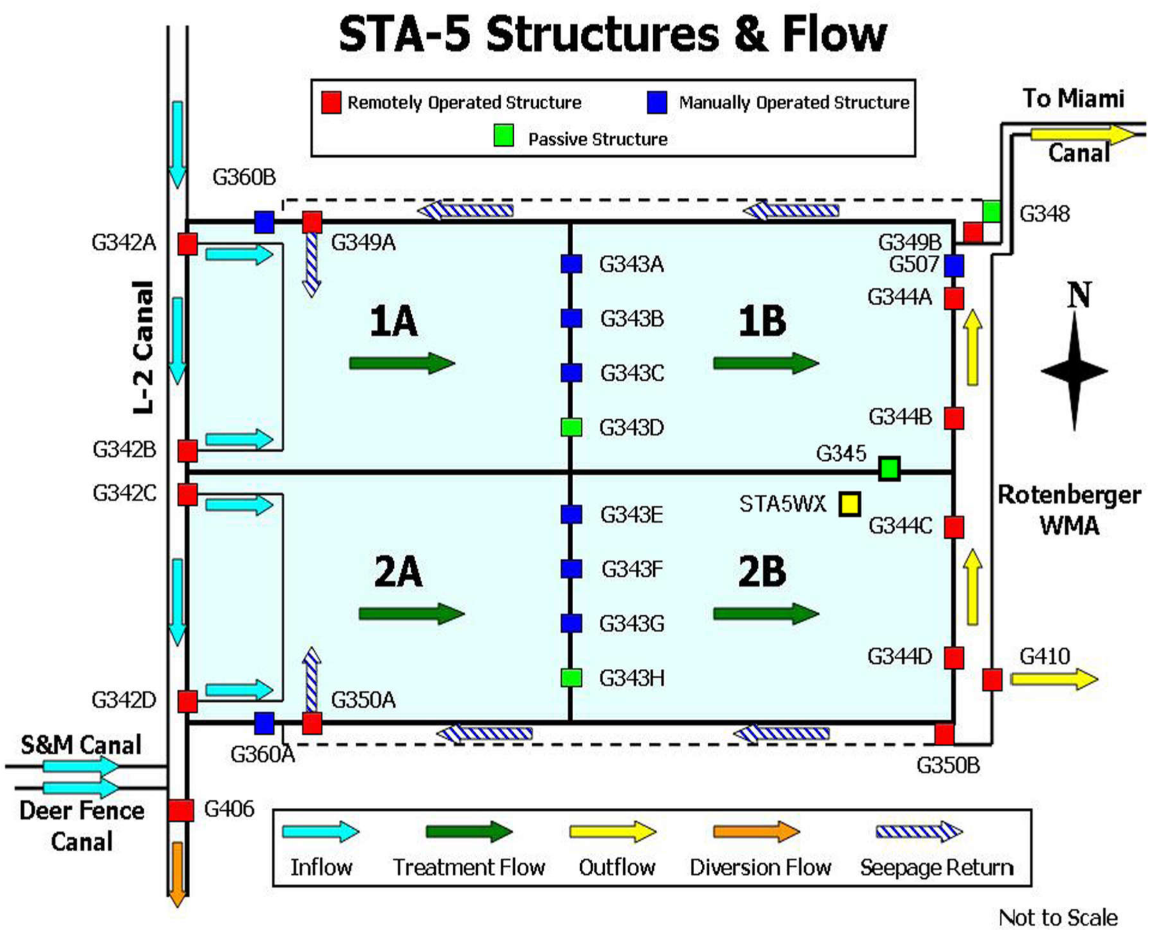

Figure 2. Schematic diagram of STA-5.

The water budget at STA-5 was comprised of the following hydrologic/hydraulic components:

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

Each component made up an important part of the water budget for STA-5. The budget was developed for periods ranging from one day to one year using the following equation:

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

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 have the same units (ac-ft per day, month or year). Rainfall and evapotranspiration values (in inches or millimeters) have been converted to feet and multiplied by the effective surface area in acres (e.g., 839 acres for Cell 1A), to determine a volume of rainfall or evapotranspiration for a selected period.

A full year of daily average stage (water surface elevation), flow, rainfall and evapotranspiration data was used in this report. The daily data were analyzed using Equation 1 and aggregated monthly and annually.

Site Description

STA-5 consists of four treatment cells with a total effective treatment area of 4,118 acres. **Figure 2** shows a schematic of the cells and control structures. 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 clverts and weir structures that control inflow, outflow and stage within the cells.

Vegetation in the STA-5 cells varies. It includes primrose willow, cattail, smartweed, mixed grasses and submerged aquatic vegetation (Environmental Research Institute, 2001). The results of a recent vegetation study are shwn in **Figure 3 and Table 1** (Scheda Ecological Associates, 2006). Appendix A, **Table A-1** contains a summary of site properties used in the water-budget calculations for STA-5.

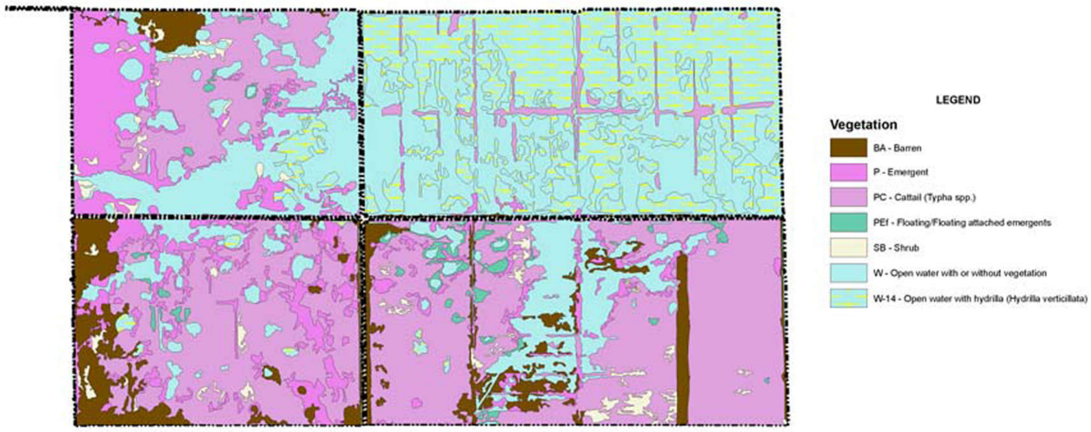

Figure 3. STA-5 vegetation map.

Table 1. Summary of STA-5 vegetation coverage.

Habitat	Percent Area
Emergent	11%
Cattail (Typha spp.)	36%
Floating/Floating attached emergents	1%
Shrub	2%
Open water with or without vegetation	26%
Open water with hydrilla (Hydrilla verticillata)	17%
Barren/Other	7%

STA Operation

The STA's treatment cells receive runoff from the C-139 basin via the L-2 canal north of the Deer Fence Canal (see **Figure 2**). Under normal operating conditions, the by-pass structure in the L-2 canal south of the STA, G-406, is closed. The gates at G-406 are opened when the water level in the L-2 canal exceeds 16.0 ft NGVD.

In the STA, water flows west to east by gravity, into distribution ditches located east of the gated culverts at G342A through D in Cells 1A and 2A (see **Figure 2**). Two pump units at G349A and two at G350A recirculate water from the seepage canals located along the northern and southern borders of the STA into Cells 1A and 2A, respectively. Eight intermediate combination weir/box culvert structures, G343A through H, pass flow from Cells 1A and 2A to Cells 1B and 2B. When the G343A through D structures were reconstructed starting in WY05, water was pumped from Cell 1B to Cell 2B to facilitate the construction. Upon completion of work on the G343 structures in Flow-way 1 between Cells 1A and 1B in WY06, water from Cell 2B was pumped into Cell 1B to facilitate reconstruction of the G343 structures in Flow-way 2 between Cells 2A and 2B. Culverts at G345 located near G344B and G344C between Cells 1B and 2B, provide the ability to transfer water between the northern and southern flow-ways in the eastern treatment cells.

Water is discharged to the east through structures G344A through D. Water from the STA flows in a canal leading to the Miami Canal, five miles to the east. Water discharged from STA-5 is also used for hydropattern restoration in the Rotenberger Wildlife Management Area using pumps located at structure G-410 near the southeastern corner of STA-5.

STA-5 operates under a revised operation plan (SFWMD, 2000a) which is an interim plan. The plan accommodates additional flow to STA-5 which will be directed to STA-6 after Section 2 of STA-6 is constructed. A full description of STA-5, its design and operation are provided in the plan.

Cell 1B was taken out of service in February 2005 (WY05) for installation of new gated structures at G343A, B, C and D. By July 2005 (WY06), water levels in Cells 1A and 1B had recovered. Starting January 2006, the water levels in Cells 2A and 2B were drawndown to allow reconstruction of the G343 structures in Flow-way 2. The quantity of water pumped from Cell 2B to Cell 1B was not recorded.

Monitoring

During WY06, rainfall, stage, gate openings and pump operations were monitored at STA-5. Flow was computed for pumps and gated culverts using calibrated rating equations. The calibration was based on in-channel flow measurements using acoustic Doppler devices. Evapotranspiration was estimated for STA-5 based on data from a monitoring station located approximately 30 mi to the east at STA-1W. Seepage in each cell was estimated using an equation that relates differences in water surface elevations along a length of levee to the amount of water gained or lost due to seepage and is also discussed below. Estimated seepage is not recorded in DBHYDRO, the South Florida Water Management District's corporate database.

Appendix A, **Table A-2** through **Table A-5**, list the stations where daily average stage, flow, rainfall and evapotranspiration data were recorded together with database (DB) key numbers and station descriptions. Station locations are shown in **Figure 2**.

Rainfall

Daily rainfall data for STA-5 were collected at weather station, STA5WX. Missing values were filled based upon the best available information, usually from nearby rain gauges. The data were loaded into a preferred DB key every month. The preferred DB key provided a high-quality, continuous record of daily rainfall amounts. Appendix B, **Table B-1** lists the daily rainfall amounts recorded at STA5WX and used in this analysis.

Stage and Gate Openings

Stage and gate opening data were monitored on an instantaneous basis. Both parameters were recorded using two methods. The first method sampled the state of the stage and gate openings every 15 minutes, stored data on-site in solid-state, CR10 data loggers and transmitted the data periodically to a District database. The second method transmitted stage and gate opening data immediately to a District database via telemetry whenever there was a change in state. Daily mean stage values and gate openings used in this study were based on telemetered data.

Flow

The instantaneous stage data and gate openings were used to compute instantaneous flows at the inlet and outlet structures at STA-5. Instantaneous stage data were also averaged and recorded as daily average stage in DBHYDRO. Each treatment cell has several structures associated with it. As a result, more than one stage value was available to compute average daily stage within each of the treatment cells. The daily stage at each of the recording gauges within a cell was arithmetically averaged to generate a daily mean stage for the entire cell.

Daily average flow rates were determined using two methods, culvert equations and pump performance equations. At pump stations G349A, G350A, G349B, G350B and G507, average daily flow was computed instantaneously using motor speed and 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.

Daily average flow at the gated culverts in STA-5 (G342A through D, G344A through D, and G406) were based on flow values that were calculated using instantaneous headwater stage, tailwater stage and gate openings. A complete record of daily average flow was loaded monthly to a preferred DB key in DBHYDRO. A final QA/QC check of the flow data in the preferred DB keys was performed on a quarterly basis.

Evapotranspiration

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 potential evapotranspiration data used in this report were derived from ET data for STA-1W that is based on a predictive equation (Abtew, 1996). These data for ET were considered to be of the highest quality available. **Table C-1** in Appendix C list the daily ET values used.

Estimated Seepage

No direct measurement of seepage was made at STA-5 during the period of this study. In this analysis, seepage was computed as (Bouwer, 1978):

$$G = 1.983 K_{sp} L \Delta H \quad \text{(Equation 2)}$$

where

- G = levee (horizontal) and deep (vertical) seepage (ac-ft/d)
- K_{sp} = coefficient of seepage (cfs/mi/ft)
- L = length along the seepage boundary (mi)
- ΔH = hydraulic head difference between the cell stage and the water level along the cell's boundary (ft)
- 1.983 = constant to convert from cfs to ac-ft/d

The value of K_{sp} was adjusted to minimize the sum of the squared daily water-budget error for the entire STA for the period of record starting in WY01 through WY06. Unique seepage coefficient values were used for each treatment cell in this report (Huebner, 2001) and are shown in Appendix A, **Table A-6**.

In general, there is a net loss of water from the STA due to higher water surface elevations maintained in the treatment cells as compared to the discharge canal and the seepage canals located along the northern and southern boundaries of the STA.

WATER BUDGET

Methodology

In this analysis, STA-5 was divided into two hydrologic units: the northern flow-way, consisting of Cells 1A and 1B; and 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 annual basis using Equation 1. A daily, monthly and annual 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 year, 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 annual water budgets.

Results

Rainfall and Evapotranspiration

Rainfall data for STA-5 are presented in Appendix B. Evapotranspiration (ET) data are presented in Appendix C. **Table 2** presents the annual rainfall summary for WY06. The amount of rainfall for WY06 was 40.17 inches (75 percent of expected rainfall based on the historic record for the Everglades Agricultural Area). **Figure 4** shows the monthly rainfall surplus or deficit based on the sum of rainfall less estimated ET at STA-5. In 9 of 12 months, ET exceeded rainfall. During WY06, ET exceeded rainfall by a total of 11.5 in.

Table 2. Rainfall amounts for WY06.

Water Year	Rainfall Amount (inches)	Percent of Expected Rainfall
WY06	40.17	75

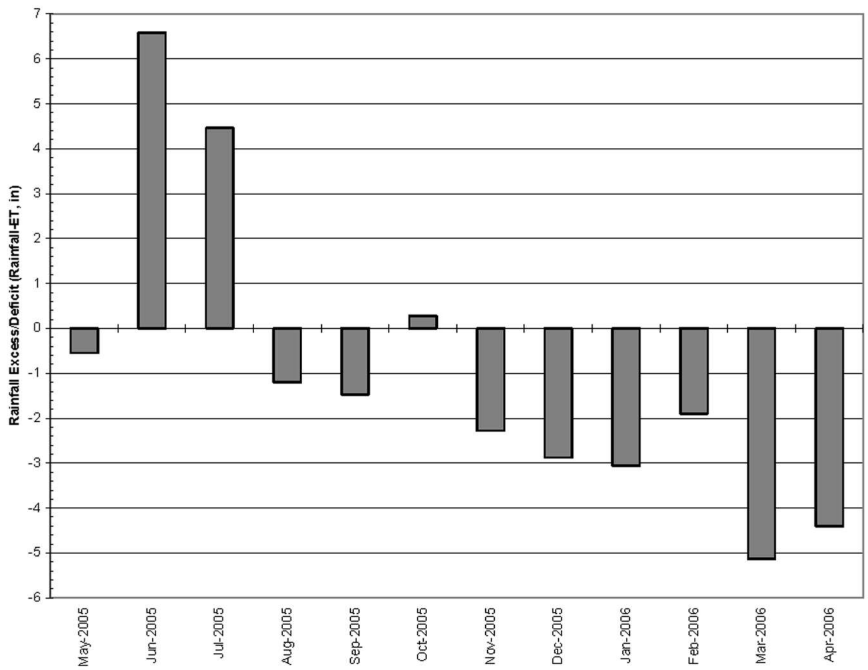

Figure 4. Monthly rainfall less estimated evapotranspiration at STA-5.

Northern Flow-way – Cells 1A and 1B

Table 3 presents the annual water-budget summary 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 are listed in Appendix A, **Table A-1**. **Table 3** also summarizes errors for the analysis based on WY06 daily water budgets. This document includes similar summaries in discussion of other hydrologic units at STA-5 (see **Table 6** and **Table 10**). Inflow was measured at G342A and B, G349A and G507_P; outflow at G344A and B.

Error in the water budget was less than 11 percent. However, the water-budget results for WY06 for each cell are misleading because, from February 2005 through the remainder of the water year, Cells 1B, 2A and 2B were drawn down at some time for reconstruction of the intermediate culverts at G343. The water from Cell 1B was pumped to Cell 2B and later in WY06, water from Cell 2B was subsequently pumped into Cell 1B.

A coefficient of seepage that was unique for each flow-way was used for this report. The seepage coefficient used for Cells 1A and 1B was 0.9 cfs/mi/ft. The previous report used a seepage coefficient of 0.5 cfs/mi/ft for these cells. Daily water-budget residuals are shown in **Figure 5**.

Table 3. Annual water-budget summary for Cells 1A and 1B.

Cells 1A & 1B	WY06	% Inflow
INFLOW	139,263	95.0
SEEPAGE IN	403	0.3
RAIN	6,893	4.7
TOTAL INFLOW	146,559	% Outflow
OUTFLOW	112,529	85.4
SEEPAGE OUT	10,300	7.8
ET	8,875	6.7
TOTAL OUTFLOW	131,704	
CHANGE IN STORAGE	-20	% Error
REMAINDER	-14,875	-10.6

Notes:

1. All values in ac-ft.
2. INFLOW measured at G342A , G342B, G349A and G507.
3. RAIN measured at STA5WX.
4. OUTFLOW measured at G344A and G344B.
5. ET measured at STA1W.
6. SEEPAGE IN and SEEPAGE OUT estimated based on head differences between cell water levels and surrounding water levels using a seepage coefficient of: Cell 1A=0.9 cfs/mi/ft, Cell 1B=0.9 cfs/mi/ft, Cell 2A=4.0 cfs/mi/ft, Cell 2B=4.0 cfs/mi/ft.
7. ΔS for water levels below average ground level estimated using an equation (Appendix E) based on data available in Abtew, et al. (1998).

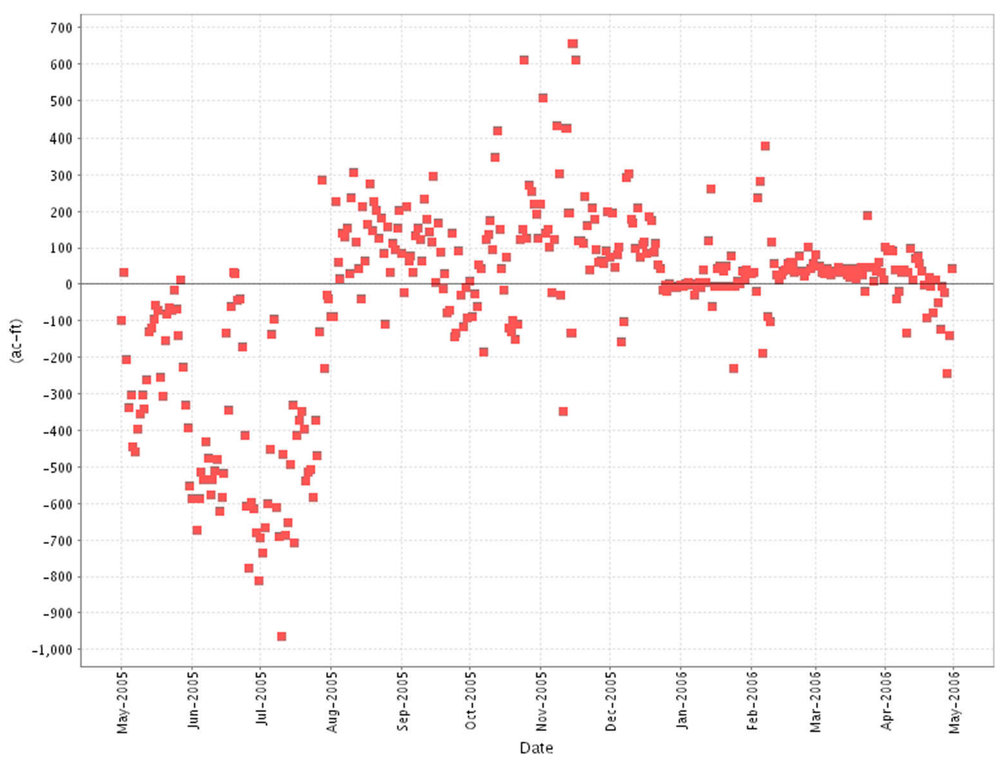

Figure 5. Daily water-budget residuals for Cells 1A and 1B.

Estimated net seepage in the northern flow-way constituted 7.5 percent of the water budget for WY06. **Figure 6** shows the estimated seepage for Cells 1A and 1B for WY 2005. **Table 4** summarizes inflow and outflow at culverts and pumps in the northern flow-way for WY06. **Figure 7** displays the water levels in the treatment cells versus surrounding canals and cells. For the year examined, seepage out of the northern flow-way was greater than seepage in. In general, seepage flowed into the treatment cells from the L-2 Canal and Cells 2A and 2B and out of the treatment cells 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 8**. Approximately 88 percent of the flow leaving the northern flow-way at G344A and B entered the STA at G342A and B for WY06. **Table 5** presents the results of the monthly water-budget analysis for Cells 1A and 1B. Average daily error is less than 1.0 in., except in May through July 2005, when the water level in Cell 1B was lowered for G343 construction by pumping water into Cell 2B.

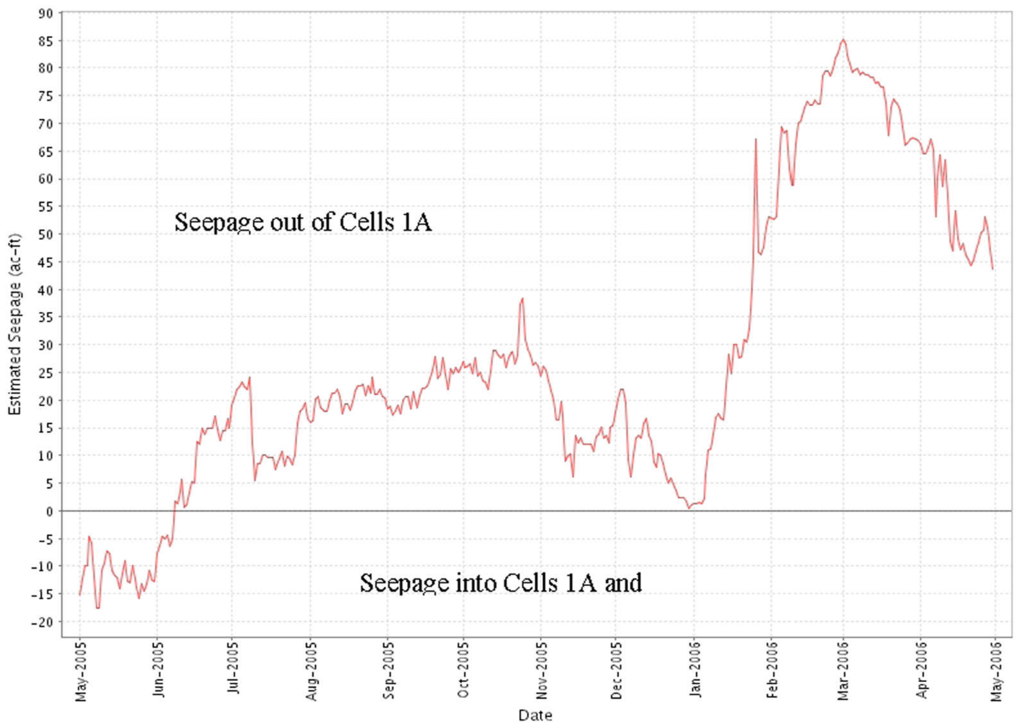

Figure 6. Estimated daily seepage for Cells 1A and 1B.

Table 4. Inflow and outflow at structures – Northern Flow-way.

Water Year	Inflow (ac-ft)	Outflow (ac-ft)	Outflow as Percentage of Inflow
WY06	139,263	112,529	81

Note: Inflow calculated at G342A, G342B, G349A, and G507_P. Outflow calculated at G344A and B.

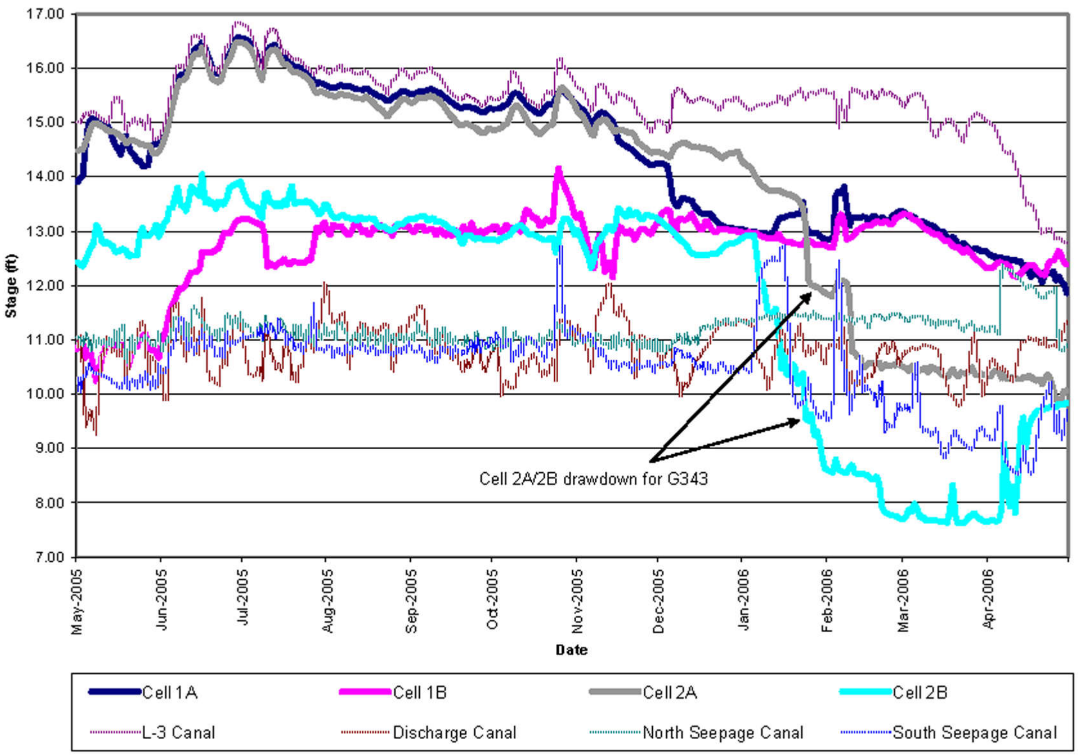

Figure 7. Cells 1A, 1B, 2A and 2B stage versus surrounding areas.

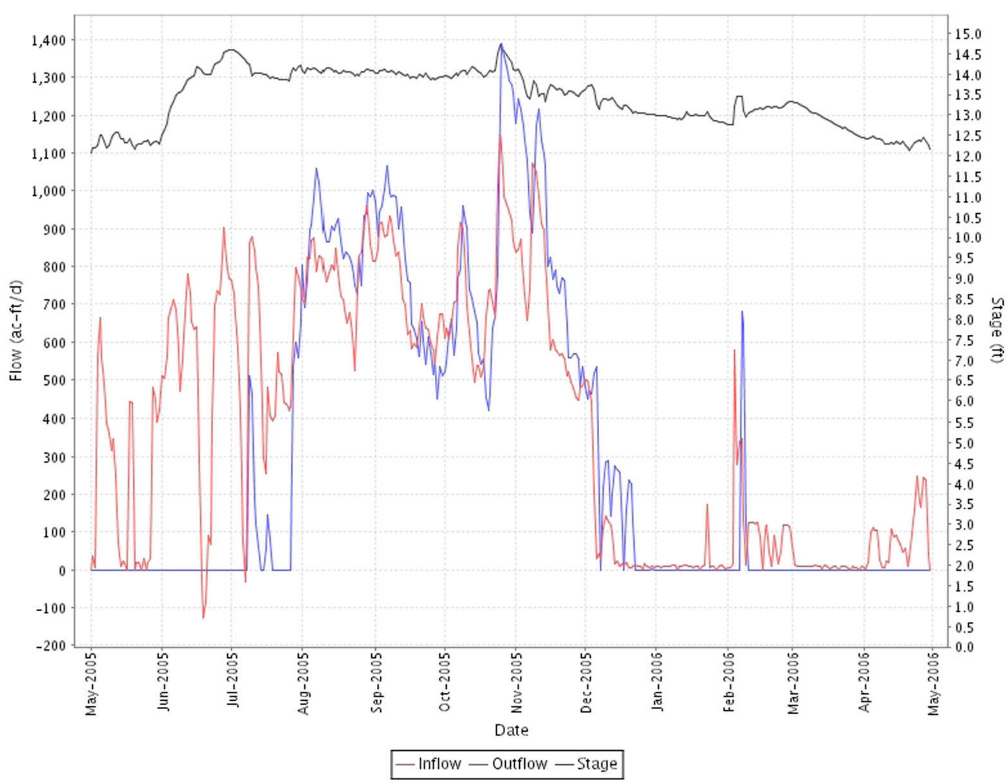

Figure 8. Inflow, outflow and stage for Cells 1A and 1B.

Table 5. Monthly water budget for Cells 1A and 1B.

Month-Year	INFLOW	OUTFLOW	CHANGE IN STORAGE	ET	RAIN	SEEPAGE	REMAINDER
May-05	6,837	0	515	920	827	-364	-6,593
Jun-05	16,109	0	3,604	677	1,805	191	-13,442
Jul-05	16,511	3,981	-775	907	1,673	429	-13,641
Aug-05	24,256	27,239	-248	838	633	629	3,569
Sep-05	21,777	22,879	-292	714	462	663	1,724
Oct-05	23,322	24,895	385	636	683	852	2,763
Nov-05	20,826	26,169	-1,119	545	153	456	5,072
Dec-05	3,041	5,916	-1,202	513	19	307	2,473
Jan-06	433	0	-435	551	26	801	459
Feb-06	3,365	1,451	1,098	646	319	1,985	1,496
Mar-06	308	0	-1,660	934	53	2,330	1,243
Apr-06	2,479	0	108	996	240	1,617	2

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 considered positive and flow out of the cell was considered negative.

Southern Flow-way – Cells 2A and 2B

Table 6 shows the WY06 water budget for the southern flow-way, comprised of Cells 2A and 2B. Inflow was measured at G342C and D and G350A; outflow at G344C and D. The seepage coefficient for the Cells 2A and 2B was 4.0 cfs/mi/ft. As a percentage of the budget, error was 13 percent for WY06.

Table 6. Annual water-budget summary for Cells 2A and 2B.

Cells 2A & 2B	WY06	% Inflow
INFLOW	99,749	81.1
SEEPAGE IN	16,356	13.3
RAIN	6,893	5.6
TOTAL INFLOW	122,998	% Outflow
OUTFLOW	88,343	80
SEEPAGE OUT	13,328	12.0
ET	8,875	8.0
TOTAL OUTFLOW	110,546	
CHANGE IN STORAGE	-2,631	% Error
REMAINDER	-15,082	-12.9

Notes:

1. All values in ac-ft.
2. INFLOW measured at G342C, G342D and G350A.
3. RAIN measured at STA5WX.
4. OUTFLOW measured at G344C and G344D.
5. ET measured at STA1W.
6. SEEPAGE IN and SEEPAGE OUT estimated based on head differences between cell water levels and surrounding water levels using a seepage coefficient of: Cell 1A=0.9 cfs/mi/ft, Cell 1B=0.9 cfs/mi/ft, Cell 2A=4.0 cfs/mi/ft, Cell 2B=4.0 cfs/mi/ft.
7. ΔS for water levels below average ground level estimated using an equation (Appendix E) based on data available in Abtew, et al. (1998).

Figure 9 shows the daily residual error plot for the WY06 water budget. **Table** 7 shows the annual inflow and outflow at culverts and pumps for the southern flow-way for WY06.

Net estimated seepage was into the flow-way in WY06 (3,028 ac-ft). Seepage into and out of the southern flow-way is depicted in **Figure 10**. In general, seepage into the southern flow-way occurred during the latter part of the water year when Cells 2A and 2B were drawn down for G343 reconstruction. Stage in the cells and in surrounding areas is shown in **Figure** 7. **Figure 11** shows the inflow, outflow and stage in Cells 2A and 2B for study period. Approximately 88,343 ac-ft of water was discharged at G344C and D. This was 102 percent of the inflow to the southern flow at G342C and D for WY06.

In the monthly water budget shown in **Table 8**, the right column shows the monthly error in ac-ft/month. All average daily errors based on the monthly water budget are less than 1.0 in., except for June, July and December 2005 when inflow and outflow to the Flow-way 2 cells were affected by construction activities.

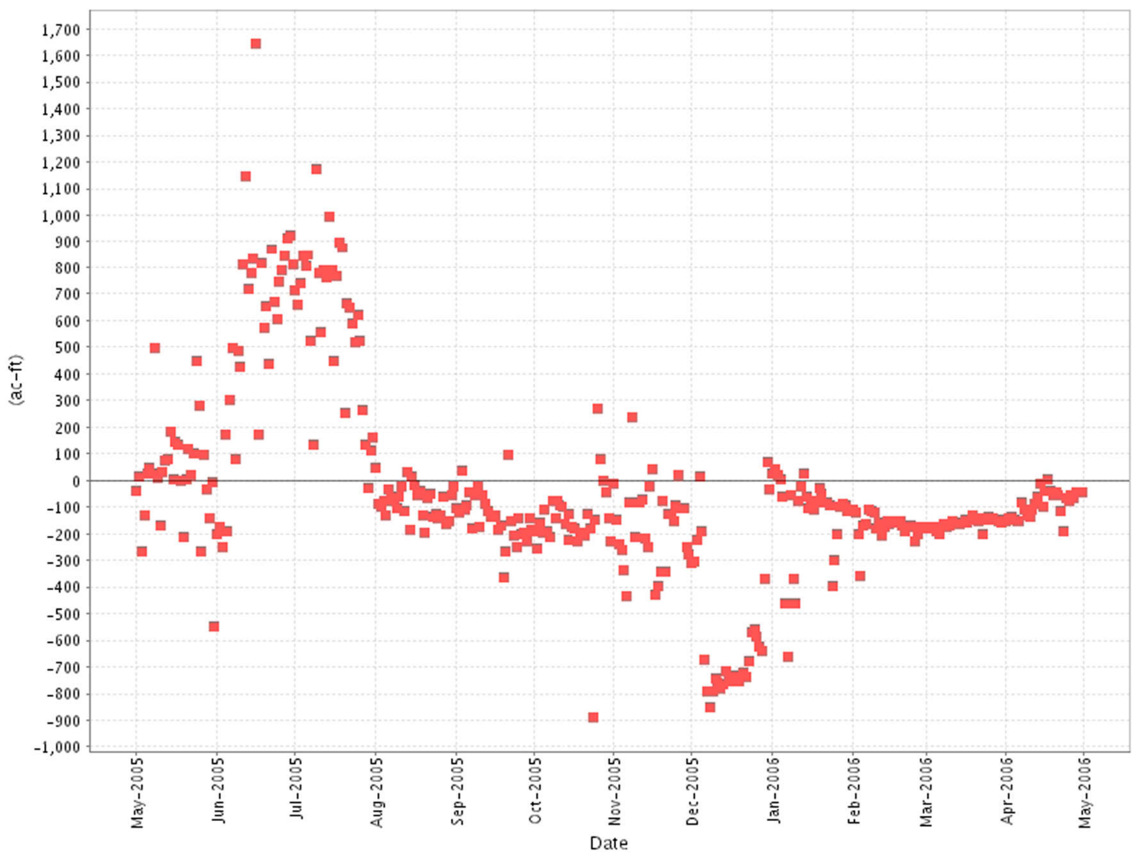

Figure 9. Water-budget residuals for Cells 2A and 2B.

Table 7. Inflow and outflow at structures – Southern Flow-way.

Water Year	Inflow (ac-ft)	Outflow (ac-ft)	Outflow As Percentage of Inflow
WY06	99,749	88,343	88

Note: Inflow calculated at G342C, G342D and G350A.
Outflow calculated at G344C and G344D.

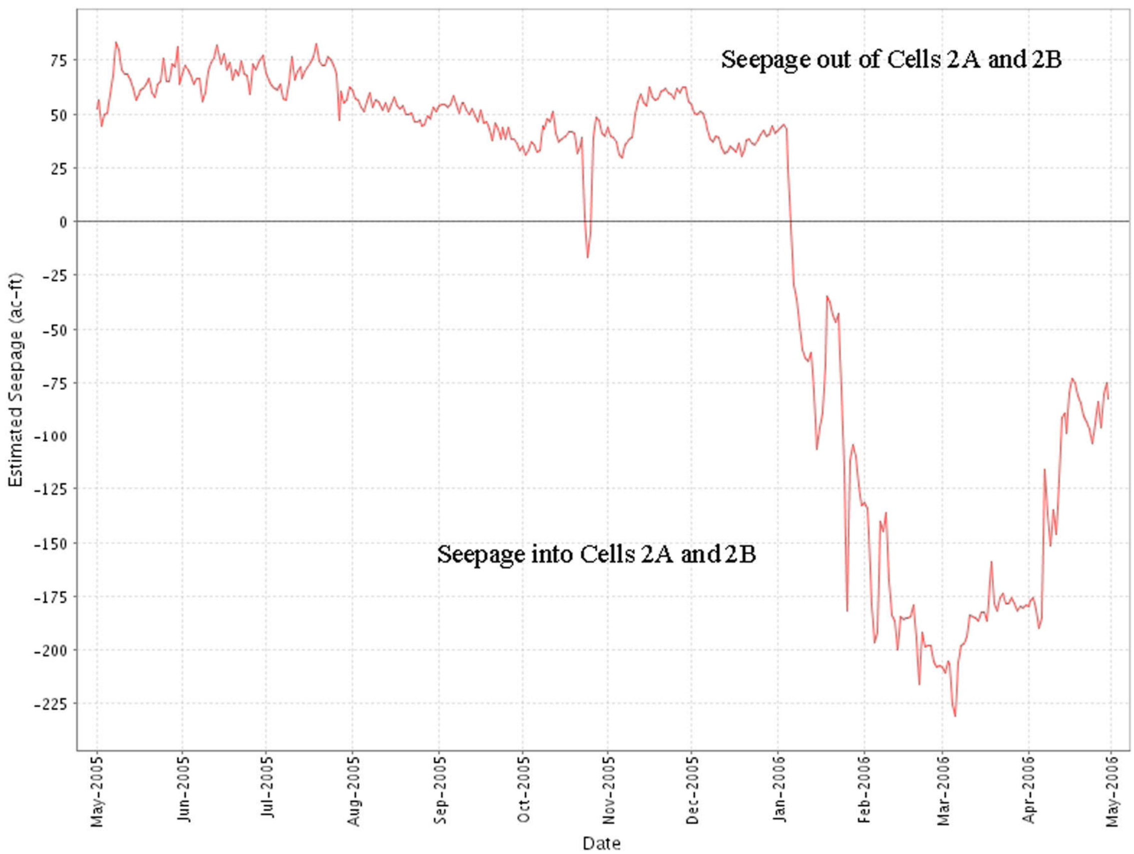

Figure 10. Estimated daily seepage at Cells 2A and 2B.

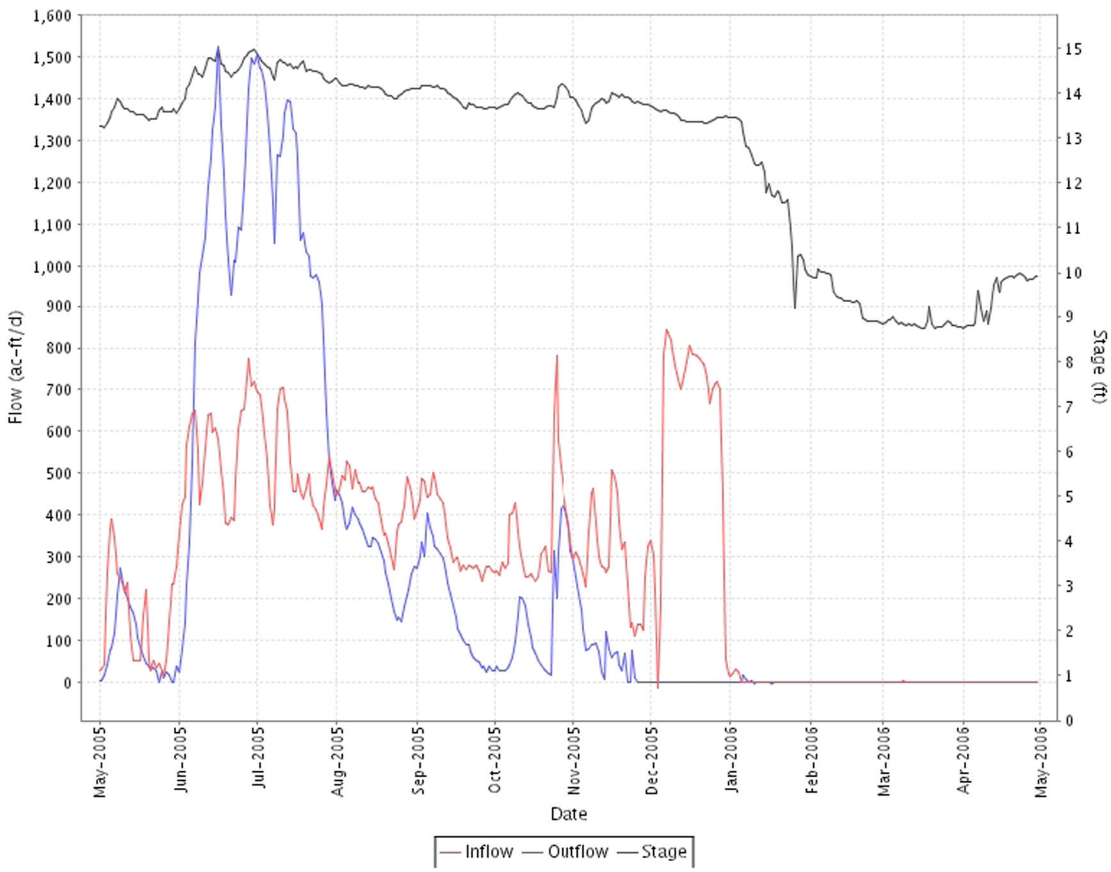

Figure 11. Inflow, outflow and stage at Cells 2A and 2B.

Table 8. Monthly water budget for Cells 2A and 2B.

Month-Year	INFLOW	OUTFLOW	CHANGE IN STORAGE	ET	RAIN	SEEPAGE	REMAINDER
May-05	4,549	2,506	468	920	827	1,995	514
Jun-05	16,600	29,575	2,924	677	1,805	2,112	16,884
Jul-05	16,009	34,524	-1,292	907	1,673	2,087	18,544
Aug-05	13,387	9,494	-460	838	633	1,625	-2,522
Sep-05	10,453	5,539	-896	714	462	1,419	-4,139
Oct-05	10,909	4,466	475	636	683	1,092	-4,923
Nov-05	8,794	2,216	-336	545	153	1,540	-4,982
Dec-05	18,953	2	-584	513	19	1,236	-17,806
Jan-06	90	21	-2,915	551	26	-1,766	-4,225
Feb-06	0	0	-69	646	319	-5,058	-4,801
Mar-06	5	-1	0	934	53	-5,849	-4,975
Apr-06	0	0	55	996	240	-3,462	-2,651

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 considered positive and flow out of the cell was considered negative.

STA-5

Table 9 summarizes the annual inflow and outflow volumes at culverts and pumps at STA-5 for WY06. **Table 10** shows the summary of the water budget for the entire STA, which includes both flow-ways, discussed above. Using a seepage coefficient of 0.9 cfs/mi/ft for Cell 1A & 1B and 4.0 cfs/mi/ft for Cell 2A & 2B, error for the WY06 budget became slightly less than 5 percent. Net estimated seepage was about 10 percent of the water budget for WY06.

Table 9. Annual inflow and outflow at culverts and pumps - STA-5.

Water Year	Inflow (ac-ft)	Outflow (ac-ft)	Outflow as Percentage of Inflow
WY06	239,013	200,872	84

Note: Inflow calculated at G342A through D, G349A, G350A and G507_P. Outflow calculated at G344A through D.

Table 10. Annual water-budget summary for STA-5.

STA-5	WY06	% Inflow
INFLOW	239,013	92.9
SEEPAGE IN	4,562	1.8
RAIN	13,785	5.3
TOTAL INFLOW	257,360	% Outflow
OUTFLOW	200,872	81.1
SEEPAGE OUT	29,030	11.7
ET	17,749	7.2
TOTAL OUTFLOW	247,652	
CHANGE IN STORAGE	-2,650	% Error
REMAINDER	-12,359	-4.8

Notes:

1. All values in ac-ft.
2. INFLOW measured at G342C, G342D and G350A.
3. RAIN measured at STA5WX.
4. OUTFLOW measured at G344C and G344D.
5. ET measured at STA1W.
6. SEEPAGE IN and SEEPAGE OUT estimated based on head differences between cell water levels and surrounding water levels using a seepage coefficient of: Cell 1A=0.9 cfs/mi/ft, Cell 1B=0.9 cfs/mi/ft, Cell 2A=4.0 cfs/mi/ft, Cell 2B=4.0 cfs/mi/ft.
7. ΔS for water levels below average ground level estimated using an equation (Appendix E) based on data available in Abtew, et al. (1998).

Figure 12 shows the residual in the daily water budgets. The peaks in the residual plot occur during periods of high inflow, June through December 2005. **Figure 13** presents the estimated seepage out of STA-5. Inflow, outflow and stage are shown in **Figure 14**.

Table 11 shows the monthly water-budget summary. The daily average errors are less than 1.0 in throughout the year, except for December 2005. **Figure 15** summarizes the inflows and outflows to STA-5. The outflow volume during this one-year period at G344A through D was 94 percent of the inflow volume at G342A through D.

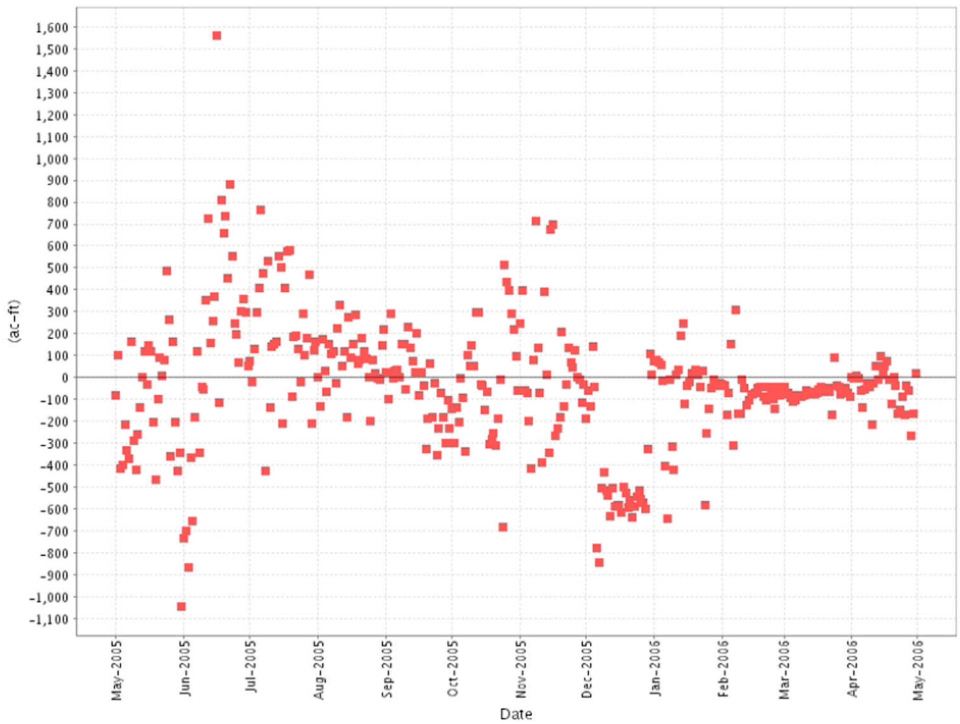

Figure 12. Water-budget residuals for STA-5.

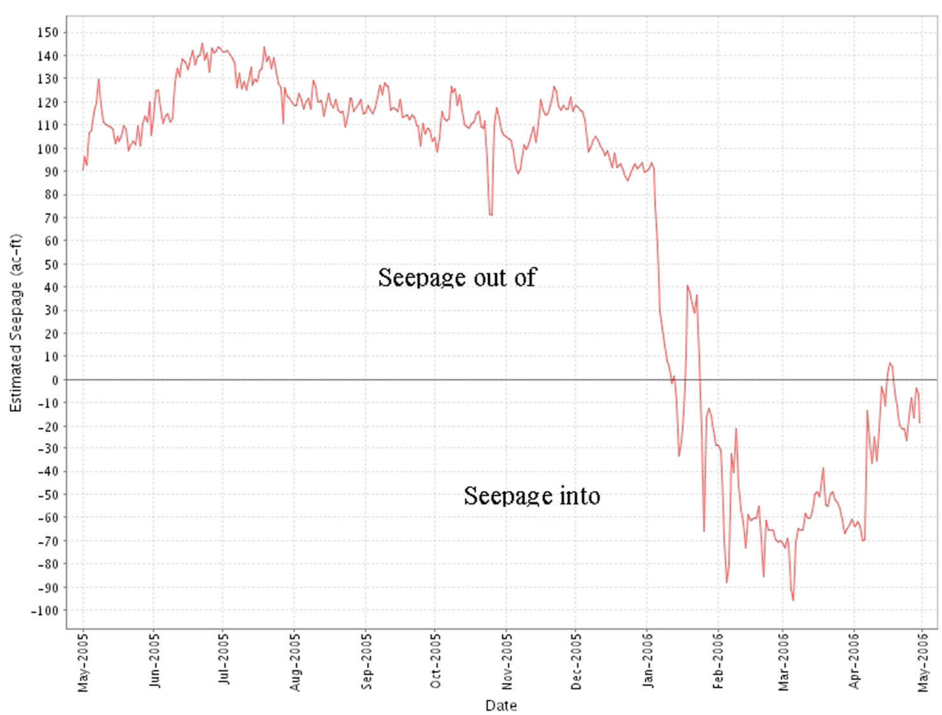

Figure 13. Estimated daily seepage at STA-5.

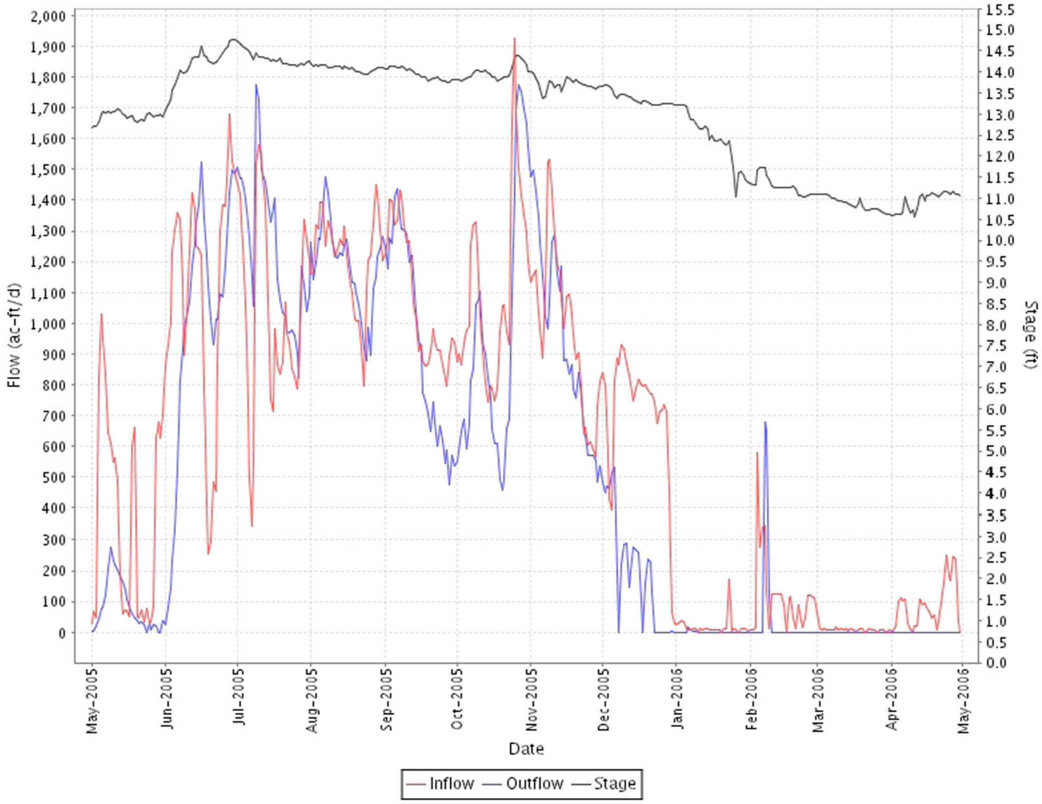

Figure 14. Inflow, outflow and stage at STA-5.

Table 11. Monthly Water Budget for STA-5.

Month-Year	INFLOW	OUTFLOW	CHANGE IN STORAGE	ET	RAIN	SEEPAGE	REMAINDER
May-05	11,386	2,506	983	1,841	1,654	3,333	-4,378
Jun-05	32,709	29,575	6,528	1,354	3,610	3,948	5,086
Jul-05	32,520	38,505	-2,067	1,814	3,346	4,077	6,463
Aug-05	37,642	36,733	-708	1,677	1,266	3,686	2,479
Sep-05	32,230	28,418	-1,188	1,428	923	3,459	-1,037
Oct-05	34,231	29,361	860	1,272	1,366	3,392	-711
Nov-05	29,621	28,385	-1,455	1,089	305	3,288	1,381
Dec-05	21,995	5,917	-1,786	1,025	38	3,055	-13,822
Jan-06	522	21	-3,350	1,101	51	509	-2,293
Feb-06	3,365	1,451	1,029	1,291	638	-1,649	-1,881
Mar-06	313	-1	-1,660	1,867	106	-1,898	-2,111
Apr-06	2,479	0	163	1,991	480	-731	-1,536

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 considered positive and flow out of a cell was considered negative.

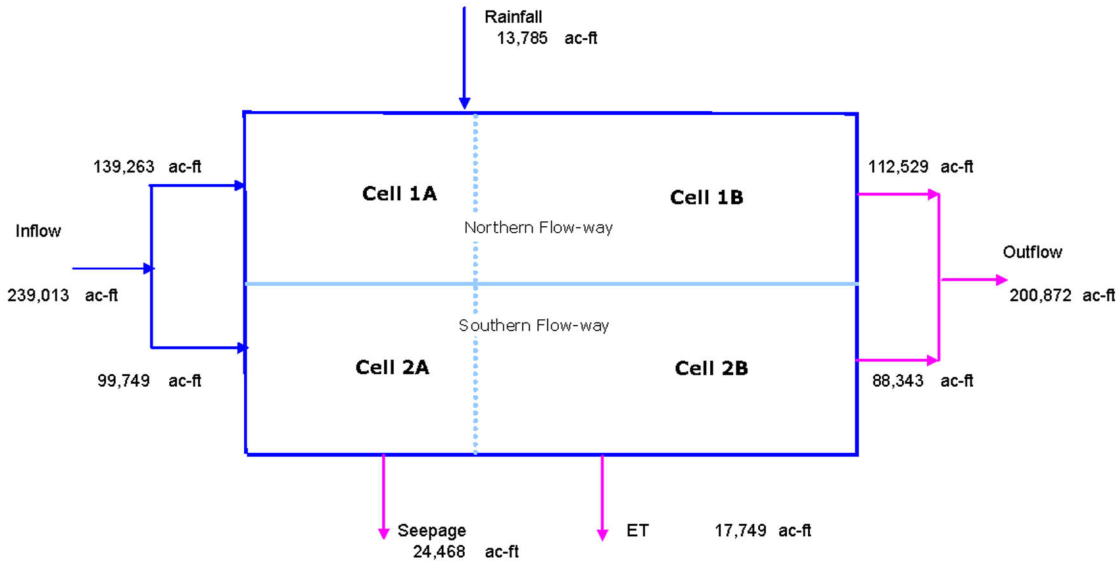

Figure 15. Water-budget volumes for STA-5 (WY06).

Mean Hydraulic Retention Time

Mean hydraulic retention time (MHRT) is a nominal estimate of how long water remains in each cell and estimates the average treatment time. Over this period, physical, chemical and biological processes remove particulate and soluble phosphorous, other nutrients and contaminants. The mean hydraulic retention time (also referred to as *mean cell residence time*) was determined using Equation 3:

$$t = \frac{V}{Q} \qquad \text{(Equation 3)}$$

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

MHRT was based upon the average stage during the study period and the average volume of total inflow and total outflow including rainfall, evapotranspiration and estimated seepage which are large percentages of the water budget. **Table 12** shows the MHRT in days for the northern flow-way (Cells 1A and 1B) and the southern flow-way (Cells 2A and 2B) and the entire STA for wet and dry seasons. MHRT was 7 days for the northern flow-way and 8 days for the southern flow-way during the wet season in WY06 (June to October). During the dry season (May and November to April) MHRT was 10 days for the northern flow-way. Since Flow-way 2 (Cells 2A and 2B were drawn down during the dry season, their average depth was negative and a average MHRT could not be calculated. This also affected the calulation of MHRT for the entire STA during the dry season. The best estimate of MHRT for the entire STA would be to use the MHRT for Cells 1A and 1B. The annual average MHRT for the entire STA was 6 days.

Table 12. Mean hydraulic retention time at STA-5.

WY06	ANNUAL AVG DEPTH	ANNUAL MHRT	WET AVG DEPTH	WET MHRT	DRY AVG DEPTH	DRY MHRT
STA	1.00	6.0	2.09	7.2	0.22	---
Cells 1A & 1B	1.38	7.5	2.02	6.6	0.93	9.5
Cells 2A & 2B	0.62	4.3	2.17	8.1	-0.49	---

Notes:

1. All depths in ft.
2. MHRT in days.

SUMMARY AND DISCUSSION

A total of 214,621 ac-ft of water entered STA-5 from the gated culverts at G342A through D in WY06. This flow constituted about 90 percent of the total inflow to the STA. Rainfall accounted for 13,785 ac-ft or 5 percent of the total inflow. Flow from seepage canal pumps at G349A and G350A contributed 22,037 ac-ft of water which was 8 percent of the total inflow to the treatment area during the water year.

During WY06, 2,354 ac-ft of water came from the Miami Canal via pumping at G507; the pumps at G349B and G350B did not operate. The area around STA-5 received 40.17 inches of rainfall, about 75 percent of what is expected annually. The Pollution Prevention Plan (SFWMD, 2000b) cites expected flows into the STA through the G342A through D culverts of 78,340 ac-ft per year or 215 ac-ft per day. During the study period, STA-5 received 588 ac-ft per day or 173 percent more than the expected annual volume of flow through these structures.

During the same period, 200,872 ac-ft of water was discharged from the STA at G344A through D (81 percent of the total outflow). Evapotranspiration accounted for an additional 17,749 ac-ft of water leaving the STA (7 percent of the total outflow). Estimated seepage out of STA-5 accounted for 12 percent of the total outflow from the STA or 29,030 ac-ft. Estimated seepage into STA-5 accounted for 2 percent (4,562 ac-ft) of the total inflow to the STA. The volume of seepage was based upon head differences between the treatment cells and the water levels in the areas surrounding the STA and an estimated seepage coefficient of 0.9 cfs/ft/mi for Cell 1 and 4.0 cfs/ft/mi for Cell 2. These coefficients were well within the values found in literature concerning the design of STAs and other analyses of seepage potential. Water-budget error was 5 percent for WY06. The daily average error in the monthly water budgets for STA-5 was less than 1.0 in. throughout the period of study except for December 2005.

Cells 1A and 1B, constituting the northern flow-way, received 127,756 ac-ft of water during WY06 through structures G342A and B. The pumps at G349A provided an additional 9,153 ac-ft of water during the same period. At G507, 2.345 ac-ft of water was pumped into Cell 1B. Rain into these cells accounted for 6,893 ac-ft of inflow. The volume of water stored in the cells decreased by 20 ac-ft over this period. G344A and B discharged 112,529 ac-ft of water. ET accounted for another 8,875 ac-ft. Net seepage out of Cells 1A and 1B was estimated at 8,472 ac-ft using seepage coefficients of 0.9 cfs/ft/mi for the northern flow-way and 4.0 cfs/ft/mi for the southern flow-way. Water-budget error was 11 percent.

The southern flow-way, Cells 2A and 2B, received 86,865 ac-ft of water during the study period through culverts G342C and D. The pumps at G350A discharged 12,884 ac-ft of water into Cell 2A. Rainfall contributed 6,893 ac-ft of water to these cells. Storage in Cells 2A and 2B decreased by 2,631 ac-ft. G344C and D released 88,343 ac-ft of water during the study period. ET accounted for a loss of 8,875 ac-ft. There was an estimated net seepage gain of 3,028 ac-ft. Water-budget error was 13 percent.

For the northern flow-way, Cells 1A and 1B, mean hydraulic retention time was 6.6 days for the wet season and 9.5 days during the dry season. Wet season MHRT for the southern flow-way, Cells 2A and 2B was 8.1 days. Overall in WY06, MHRT for the STA was 6.0 days.

There were a number of problems associated with calculating the WY06 water budget for STA-5. The lack of measured and recorded data for the water volume pumped from Cell 1B to Cell 2B and from Cell 2B to 1B during the G343 reconstruction was a major source of errors in water-budget calculations for the northern and southern flow-ways. The problem is expected to affect STA-5 water-budget calculations for WY07 as well. However, when the new structures at G343 in WY 2007 are completed and instrumented, cell-by-cell water budgets can be developed for each STA-5 treatment cell, (1A, 1B, 2A and 2B). This should reduce error in water budget for WY08 and beyond.

Estimated seepage values are considered another significant source of error. The seepage and budget residual combined constitute up to 8 percent of the water budget (see **Table 10**). The seepage coefficients used in this study were calibrated based on minimizing the sum of the squared daily water-budget error for the entire STA from WY01 to WY06. The seepage coefficients were 0.9 cfs/mi/ft for Cell 1A and 1B and 4.0 cfs/mi/ft for Cell 2A and 2B. The previous report used seepage coefficients of 0.5 and 2.2 cfs/mi/ft, respectively. While the seepage estimates may also incorporate other errors, such as those associated with flow calculations, the July 2003 implementation of new rating curves for the inflow and outflow structures should have reduced much of this error.

The daily water-budget residuals or error for STA-5 were shown in **Figure 5**, **Figure 9** and **Figure 12** (residuals for Cells 1A and 1B, for Cells 2A and 2B, and for STA-5 as a whole). **Figure 16** shows the residuals for STA-5 plotted with flow data and estimated seepage data. All follow the same pattern; the residuals tend to increase when flow increases.

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. However, these weaknesses should have had a minor impact on the water budget.

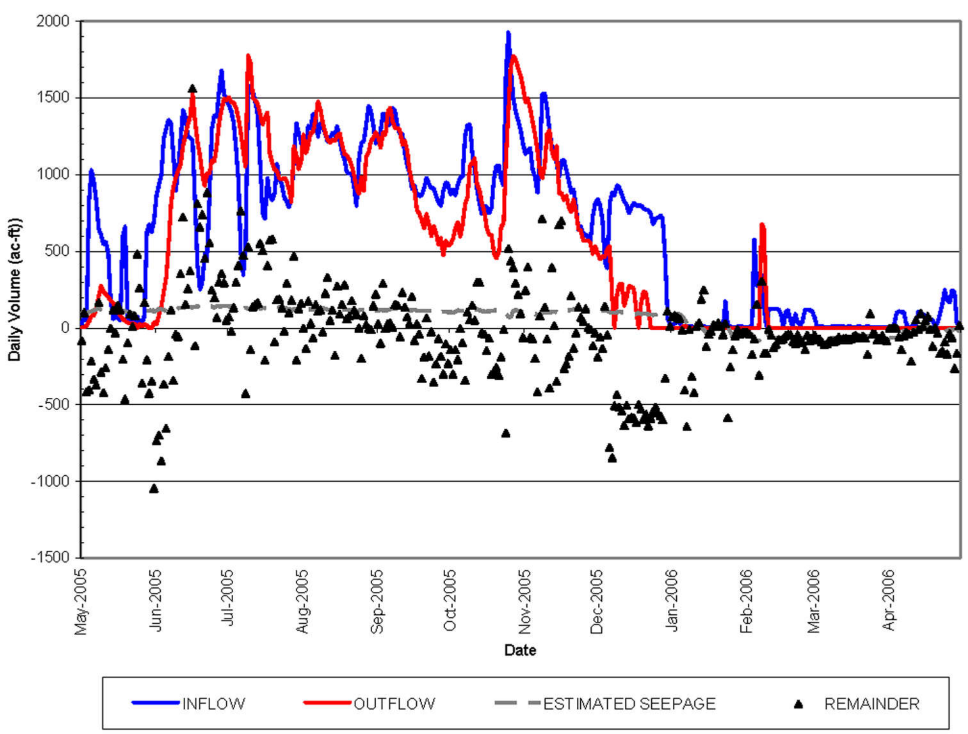

Figure 16. STA-5 Inflow, outflow, seepage and water-budget residuals.

RECOMMENDATIONS

Seepage was the largest single quantifiable unknown at the site. Additional study of the groundwater flow regime and the impact of seepage on treatment performance continues to be warranted. Locating piezometers with water level recorders located outside the boundary of STA-5 could support a more accurate analysis of seepage, especially at the canals along the STA's northern and southern boundaries.

Design criteria should include the ability to calculate seepage into and out of an STA and to sample groundwater quality. Acquisition of data for seepage calcuation and groundwater quality sampling is planned for the three major reserviors currently under construction by the District's accekerated construction program (Acceler8). Data from the reservoirs, specifically during periods when water levels are lower, may provide information useful for STA water-budget analysis. However, levee design for the reservoirs differs significantly from that for the STAs; consequently, differences in site geology could affect usefulness of results at the reservoirs.

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 of the STA is contrary to the design principles of STAs in general. Automating the operation of the gates is underway and should minimize the volume of backflow.

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APPENDICES

Appendix A

Site Properties and Monitoring Stations

Table A-1. STA-5 site properties.

Surface Area	
Cell 1A	839 ac
Cell 1B	1220 ac
Cell 2A	839 ac
Cell 2B	1220 ac
Ground Elevation	
Cell 1A	~ 12.75 ft
Cell 1B	~ 11.50 ft
Cell 2A	~ 12.75 ft
Cell 2B	~ 11.50 ft
Levee Length	
Along Northern Boundary	
Along Cell 1A	7140 ft
Along Cell 1B	10380 ft
Along Southern Boundary	
Along Cell 2A	7140 ft
Along Cell 2B	10380 ft
Along Eastern Boundary	
Along Cell 1A	5120 ft
Along Cell 2A	5120 ft
Along Western Boundary	
Along Cell 1B	5120 ft
Along Cell 2B	5120 ft

Table A-2. Stage monitoring stations.

DBKEY	Structure
JJ109	G342A_H
JJ110	G342A_T
JJ114	G342B_H
JJ115	G342B_T
JJ121	G342C_H
JJ123	G342C_T
JJ127	G342D_H
JJ128	G342D_T
JJ812	G343B_H
JJ813	G343B_T
JJ815	G343F
JJ816	G343F_T
JJ133	G344A_H
JJ135	G344A_T
JJ138	G344B_H
JJ140	G344B_T
JJ143	G344C_H
JJ145	G344C_T
JJ148	G344D_H
JJ150	G344D_T
JJ156	G349A_H
JJ157	G349A_T
JJ802	G349B_H
JJ803	G349B_T
JJ160	G350A_H
JJ161	G350A_T
JJ810	G350B_H
JJ811	G350B_T

Table A-3. Flow monitoring stations.

Inflow Stations

DBKEY	Station	STA
J6406	G342A	STA5
J6398	G342B	STA5
J6407	G342C	STA5
J6405	G342D	STA5
JJ838	G349A	STA5
JJ839	G350A	STA5
SJ382	G507_P	STA5
J6406	G342A	STA5C1
J6398	G342B	STA5C1
JJ838	G349A	STA5C1
SJ382	G507_P	STA5C1
J6407	G342C	STA5C2
J6405	G342D	STA5C2
JJ839	G350A	STA5C2

Outflow stations

DBKEY	Station	STA
J0719	G344A	STA5C
J0720	G344B	STA5
J0721	G344C	STA5
J0722	G344D	STA5
J0719	G344A	STA5C1
J0720	G344B	STA5C1
J0721	G344C	STA5C2
J0722	G344D	STA5C2

Table A-4. Rainfall monitoring stations.

DBKEY	Structure
JJ837	STA5WX (G343B_R)

Table A-5. Evapotranspiration stations.

DBKEY	Structure	STA
KN810	STA1W	STA5

Table A-6. Seepage coefficients.

Cell	Seepage Coefficient
1A	0.9
1B	0.9
2A	4.0
2B	4.0

Appendix B

Rainfall Data

Table B-1. Rainfall at STA5WX (in.) for WY06.

Day	May-2005	Jun-2005	Jul-2005	Aug-2005	Sep-2005	Oct-2005	Nov-2005	Dec-2005	Jan-2006	Feb-2006	Mar-2006	Apr-2006
1	0.00	1.00	0.01	0.08	0.00	0.04	0.35	0.00	0.00	0.00	0.00	0.00
2	0.01	1.07	0.22	0.00	0.47	0.36	0.00	0.00	0.00	0.00	0.00	0.00
3	1.46	1.24	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.41	0.00	0.00
4	1.18	0.30	0.00	0.13	0.05	0.31	0.00	0.00	0.00	1.09	0.00	0.00
5	0.06	1.00	0.00	0.36	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	0.00	0.67	0.00	0.35	0.32	0.13	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.75	0.00	0.54	0.14	0.18	0.00	0.00	0.00	0.00	0.00	0.00
8	0.00	0.12	2.43	0.01	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00
9	0.00	0.77	1.85	0.58	0.00	0.02	0.00	0.00	0.00	0.04	0.00	0.02
10	0.00	0.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19
11	0.00	0.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	0.00	0.01	0.03	0.08	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00
13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.03	0.00	0.00	0.00
14	0.00	0.07	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
16	0.00	0.01	3.34	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.06	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.08	0.05	0.00	0.01	0.00	0.08	0.00	0.00	0.00
19	0.00	0.00	0.08	0.05	0.05	0.02	0.04	0.01	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.30	0.51	0.00	0.02	0.01	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.07	0.01	0.03	0.00	0.01	0.00	0.00	0.00
22	0.21	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.33
23	0.01	0.00	0.00	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.26	0.77
24	0.00	0.46	0.99	0.00	0.00	2.90	0.00	0.00	0.00	0.00	0.00	0.00
25	0.06	0.01	0.00	0.35	0.00	0.00	0.00	0.01	0.00	0.26	0.00	0.09
26	0.76	0.90	0.27	0.14	0.03	0.00	0.00	0.00	0.00	0.04	0.00	0.00
27	0.00	0.00	0.11	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
28	0.00	0.00	0.00	0.00	0.20	0.00	0.01	0.00	0.00	0.00	0.00	0.00
29	0.00	0.00	0.00	0.03	0.11	0.00	0.40	0.03	0.00		0.00	0.00
30	0.15	0.67	0.02	0.00	0.00	0.00	0.02	0.00	0.02		0.05	0.00
31	0.92		0.33	0.00		0.00		0.00	0.00		0.00	
MAX	1.46	1.24	3.34	0.58	0.68	2.90	0.40	0.04	0.08	1.09	0.26	0.77
MEAN	0.16	0.35	0.32	0.12	0.09	0.13	0.03	0.00	0.01	0.07	0.01	0.05
MIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUM	4.82	10.52	9.75	3.69	2.69	3.98	0.89	0.11	0.15	1.86	0.31	1.40

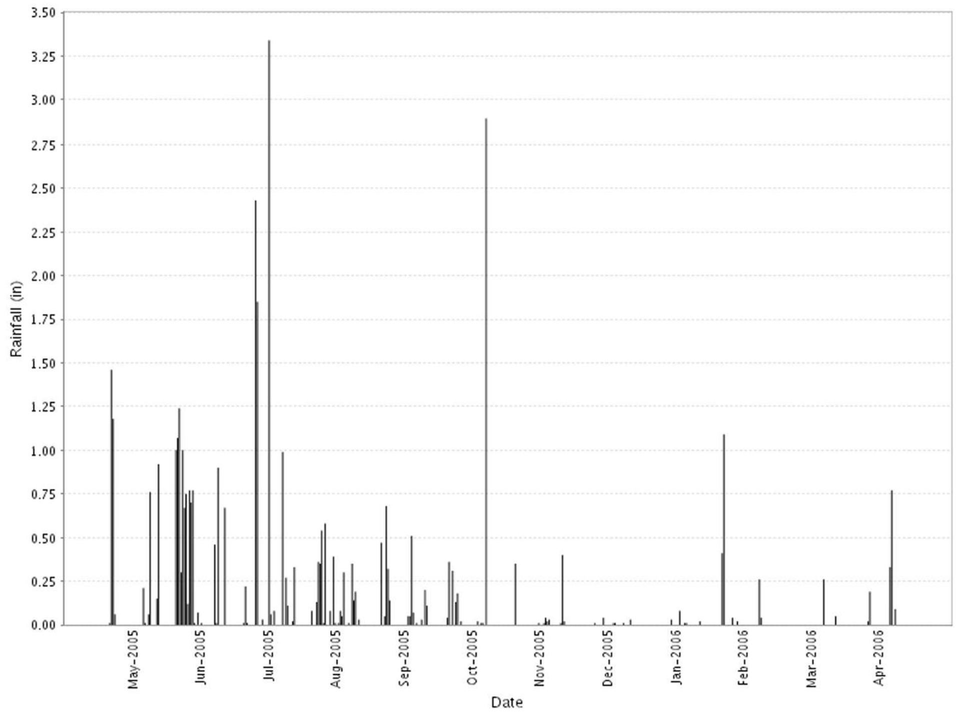

Figure B-1. Rainfall at STA5WX for WY06.

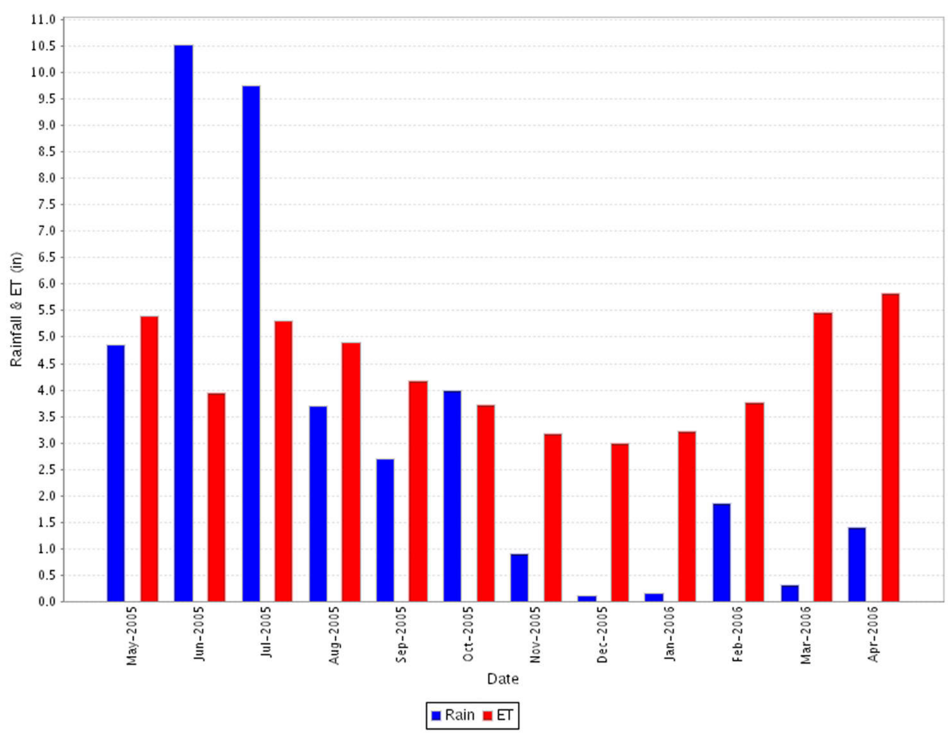

Figure B-2. Monthly rainfall and ET for WY06.

Appendix C

Evapotranspiration Data

Table C-1. Evapotranspiration at STA-5 (in.) for WY06.

Day	May-2005	Jun-2005	Jul-2005	Aug-2005	Sep-2005	Oct-2005	Nov-2005	Dec-2005	Jan-2006	Feb-2006	Mar-2006	Apr-2006
1	0.10	0.07	0.18	0.20	0.14	0.16	0.05	0.14	0.09	0.13	0.18	0.17
2	0.15	0.04	0.20	0.17	0.15	0.14	0.14	0.13	0.11	0.08	0.19	0.20
3	0.09	0.07	0.17	0.16	0.11	0.13	0.11	0.11	0.10	0.07	0.17	0.21
4	0.08	0.07	0.19	0.18	0.06	0.06	0.12	0.12	0.12	0.02	0.16	0.20
5	0.08	0.11	0.23	0.11	0.09	0.14	0.13	0.08	0.12	0.16	0.19	0.22
6	0.19	0.17	0.22	0.20	0.08	0.08	0.11	0.07	0.11	0.17	0.17	0.20
7	0.19	0.15	0.19	0.17	0.13	0.09	0.14	0.06	0.13	0.16	0.19	0.21
8	0.23	0.11	0.19	0.21	0.12	0.15	0.11	0.08	0.13	0.16	0.20	0.17
9	0.23	0.07	0.06	0.17	0.19	0.12	0.14	0.11	0.11	0.17	0.17	0.13
10	0.21	0.05	0.08	0.14	0.16	0.12	0.15	0.11	0.07	0.16	0.15	0.19
11	0.20	0.09	0.18	0.18	0.16	0.12	0.11	0.08	0.10	0.14	0.18	0.21
12	0.17	0.22	0.17	0.11	0.19	0.15	0.13	0.13	0.10	0.07	0.15	0.18
13	0.20	0.22	0.14	0.18	0.18	0.15	0.12	0.12	0.08	0.16	0.17	0.18
14	0.15	0.21	0.14	0.17	0.18	0.12	0.09	0.12	0.12	0.17	0.14	0.20
15	0.18	0.22	0.22	0.18	0.19	0.09	0.11	0.06	0.14	0.12	0.15	0.24
16	0.19	0.21	0.14	0.18	0.17	0.15	0.10	0.09	0.13	0.15	0.19	0.23
17	0.19	0.18	0.19	0.16	0.17	0.16	0.10	0.09	0.11	0.16	0.18	0.22
18	0.20	0.16	0.18	0.19	0.16	0.12	0.05	0.08	0.07	0.18	0.19	0.19
19	0.18	0.14	0.22	0.20	0.12	0.10	0.07	0.02	0.08	0.16	0.15	0.11
20	0.18	0.02	0.21	0.17	0.06	0.12	0.10	0.04	0.08	0.14	0.19	0.23
21	0.20	0.09	0.20	0.14	0.14	0.06	0.08	0.07	0.09	0.14	0.18	0.20
22	0.17	0.09	0.20	0.16	0.07	0.07	0.14	0.11	0.08	0.12	0.19	0.20
23	0.20	0.14	0.20	0.18	0.11	0.11	0.14	0.11	0.11	0.16	0.08	0.22
24	0.21	0.19	0.13	0.17	0.18	0.05	0.12	0.09	0.10	0.13	0.17	0.20
25	0.19	0.22	0.15	0.02	0.17	0.16	0.13	0.10	0.14	0.08	0.23	0.20
26	0.14	0.13	0.19	0.11	0.15	0.17	0.13	0.12	0.13	0.07	0.21	0.17
27	0.22	0.10	0.17	0.12	0.12	0.15	0.09	0.13	0.08	0.17	0.23	0.16
28	0.20	0.12	0.17	0.11	0.13	0.14	0.08	0.12	0.09	0.19	0.21	0.20
29	0.21	0.11	0.13	0.15	0.15	0.13	0.02	0.08	0.09		0.15	0.17
30	0.16	0.21	0.16	0.15	0.15	0.13	0.09	0.12	0.07		0.19	0.20
31	0.11		0.11	0.15		0.09		0.12	0.14		0.18	
MAX	0.23	0.22	0.23	0.21	0.19	0.17	0.15	0.14	0.14	0.19	0.23	0.24
MEAN	0.17	0.13	0.17	0.16	0.14	0.12	0.11	0.10	0.10	0.13	0.18	0.19
MIN	0.08	0.02	0.06	0.02	0.06	0.05	0.02	0.02	0.07	0.02	0.08	0.11
SUM	5.37	3.95	5.29	4.88	4.16	3.71	3.17	2.99	3.21	3.76	5.44	5.80

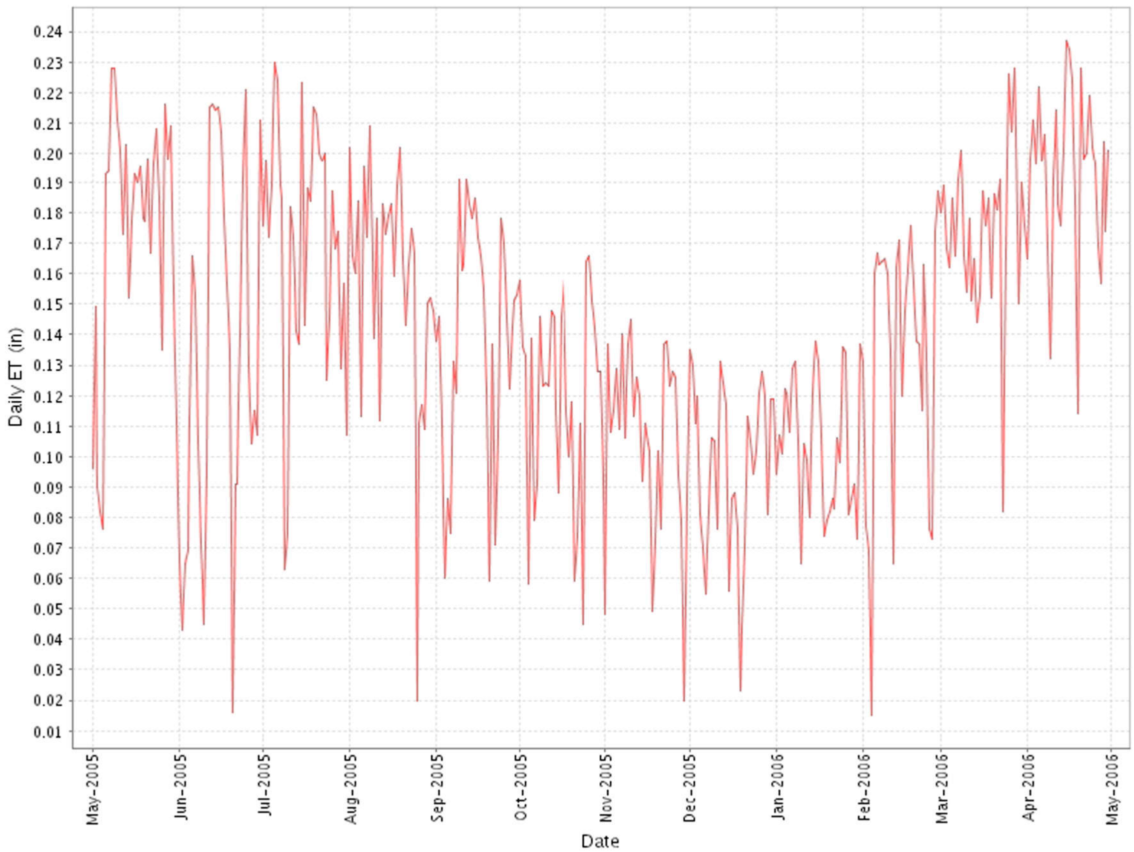

Figure C-1. STA-5 daily evapotranspiration for WY06.

Appendix D
Soil Storage

When the water level in an STA treatment cell falls below the average ground elevation, the change volume of storage becomes a function of the soil porosity as well as the water surface elevation and geometry of the cell. Previous water-budget reports for STAs 5 and 6 relied on a 7th order wetting curve equation and a 3rd order drying curve equation (Huebner, 2001) to account for change of storage when the water level was below ground elevation. Unfortunates, due to a hysteresis effect, following these curves through a wetting and drying cycles occasionally lead to the problem that summing the daily change in storage over a period did not result in a change of storage equal to calculating the change in storage from the beginning of the period to the end of the period. In order to correct this anomaly, the curves were collapsed into the following equation which is shown in **Figure D-1**:

f=a*exp(-b*x)+c*exp(-d*x)		
	a	0.605
r^2 = 0.9990	b	16.8264
	c	0.3786
	d	1.5843

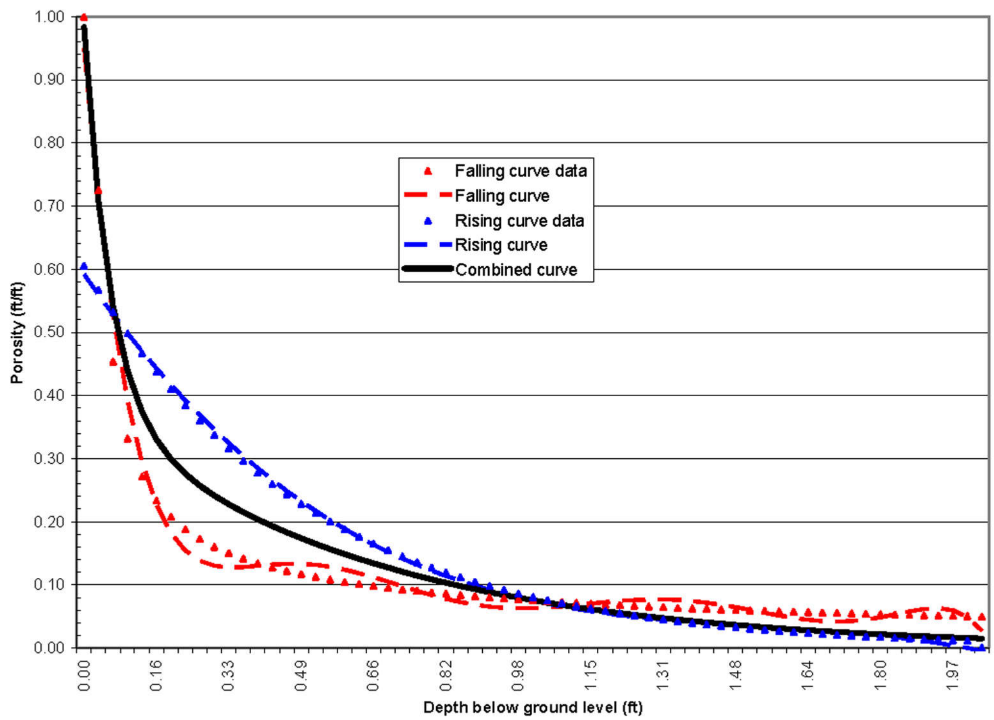

Figure D-1. Wetting and drying curves.

By allowing the wetting and drying curves to follow the same line, daily change in storage can be summed and the sum will equal that calculated based on the beginning water surface elevation and the ending water surface elevation over a period of interest. This introduces minimal error into the change storage calculations over a day and only affects that calculation when the water level is below the ground surface or when the cell is dry.