Performance Evaluation of the Palm Bay Boundary Canal Baffle Box Structure

Final Report

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City of Palm Bay

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SECTION 1

INTRODUCTION

The Palm Bay Boundary Canal is a tributary to lower Turkey Creek which forms the border between the City of Palm Bay and the town of Malabar. The Boundary Canal receives runoff inputs from a 282-acre residential area within the City of Palm Bay and several hundred acres of undisturbed coastal scrub habitat. Based on evaluations performed by the City of Palm Bay, the Boundary Canal is the single, largest source of sediment loadings to lower Turkey Creek.

The Boundary Canal has a history of erosion problems and complaints due to the fine sandy soils from which the canal was formed. During 2000, the City of Palm Bay entered into an Agreement with the St. Johns River Water Management District (SJRWMD) to implement sediment and erosion control practices within the Boundary Canal. The baffle box project is one of a series of efforts by the City of Palm Bay, in conjunction with SJRWMD, to reduce and control the amount of sediment and other pollutants entering Turkey Creek, an outstanding Florida Water, which feeds directly into the Indian River Lagoon, an Estuary of National Significance. The baffle box project includes installation of a sediment trap/baffle box, south of Port Malabar Road combined with canal bank restoration and stabilization with stone rubble to reduce erosion from the canal bank. The baffle box is designed to remove suspended materials reducing the velocity of stormwater runoff discharging through the structure, allowing discrete particles to settle and be retained. A location map for the Boundary Canal and baffle box site is given in Figure 1-1.

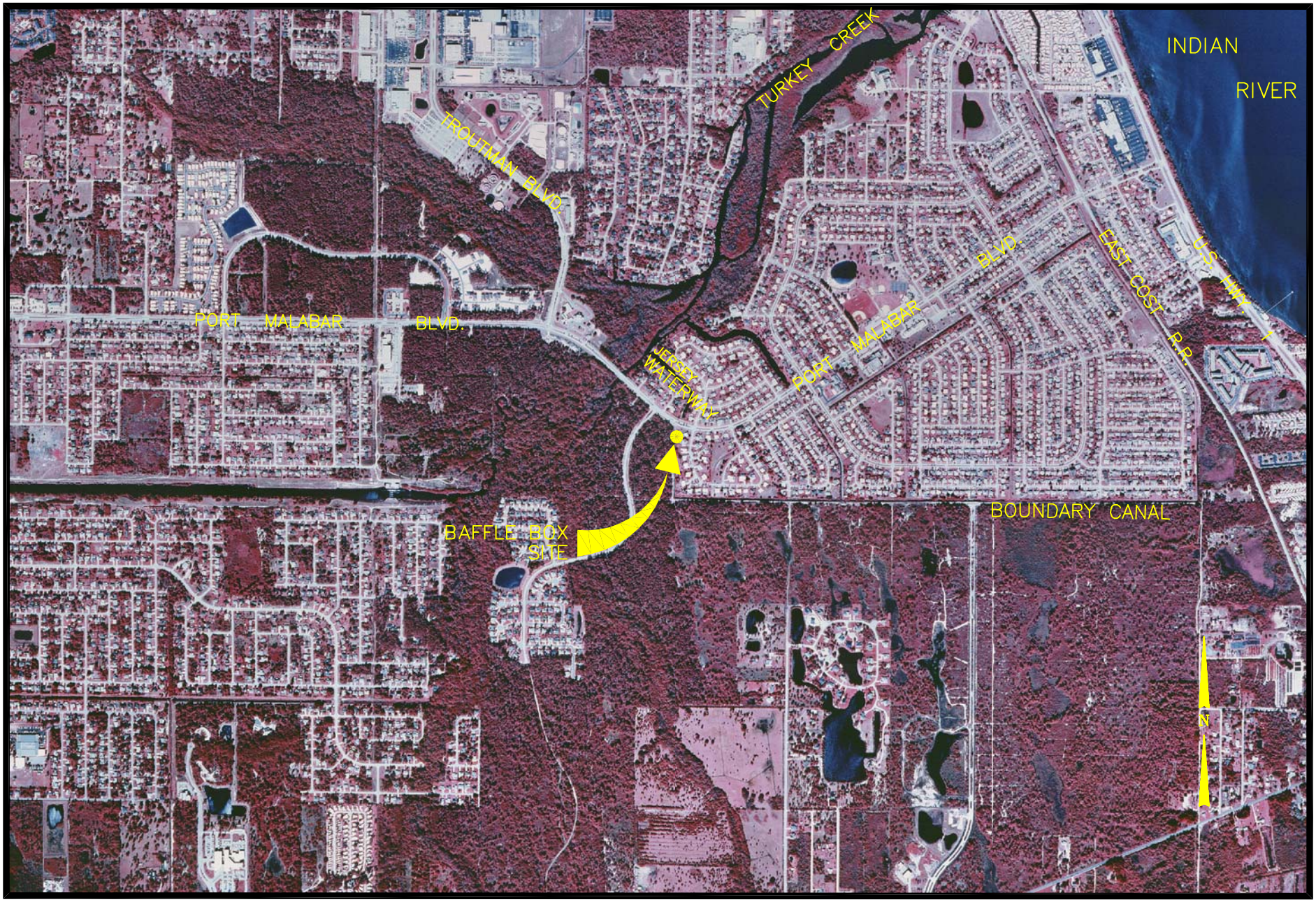


Figure 1-1. Location Map for the Palm Bay Boundary Canal Site.

The contract between the City of Palm Bay and SJRWMD requires that the performance efficiency of the baffle box be monitored to document mass removal efficiencies and to estimate annual load reductions to the Jersey Waterway and Turkey Creek. During August 2001, the City of Palm Bay entered into a contract with Environmental Research & Design, Inc. (ERD) to conduct performance efficiency monitoring of the recently constructed baffle box structure. Site instrumentation was installed by ERD during May 2002. Field monitoring was initiated during June 2002, and data were collected to estimate the percent reductions in loadings of total nitrogen, total phosphorus and suspended solids achieved within the baffle box structure. The contract between ERD and the City of Palm Bay specified a four-month monitoring period, although field monitoring activities were performed by ERD over a period of six months.

The analyses and conclusions expressed in this report are based upon field monitoring and laboratory analyses performed by ERD from June-November 2002. Continuous monitoring of inputs and outputs from the baffle box were performed to allow estimation of the overall performance efficiency of the structure.

This report has been divided into three separate sections for presentation and analysis of the field and laboratory activities. Section 1 contains an introduction to the report and provides a summary of the work efforts performed by ERD. Section 2 contains a description of the field monitoring and laboratory analyses conducted by ERD. A discussion of the results of the field and laboratory activities is given in Section 3.

SECTION 2

FIELD AND LABORATORY ACTIVITIES

Field and laboratory investigations were conducted from June-November 2002 to evaluate the performance efficiency of the recently constructed baffle box for the City of Palm Bay Boundary Canal. The Boundary Canal begins on the east side of the Florida East Coast Railroad, west of US 1. The Canal flows south to a small wetland and then turns due west for 6700 feet, bordering the town of Malabar, before turning north to Port Malabar Boulevard. The Canal ends at a 48-inch x 76-inch reinforced concrete pipe under Port Malabar Boulevard and discharges into the Jersey Waterway which flows directly into Turkey Creek. As indicated in Figure 1-1, the baffle box is located immediately south of Port Malabar Boulevard, approximately 1100 feet east of Troutman Boulevard.

The Boundary Canal baffle box was constructed during 2001 by the City of Palm Bay to provide sedimentation for discharges through the Boundary Canal prior to entering the Jersey Waterway. The primary basin area discharging to the baffle box contains approximately 282 acres, consisting of 90% residential and 10% commercial land uses. The Canal also receives runoff from several hundred acres of undisturbed coastal scrub habitat south of Port Malabar Boulevard.

A schematic of the baffle box structure is given in Figure 2-1. The baffle box is a reinforced, concrete structure, which is approximately 15 ft.-7 in. in length, 10 ft. wide, and 11 ft.-10 in. tall. Two round cast-iron access manholes are provided for cleanout purposes, along with a 42-inch x 42-inch aluminum access hatch. The structure contains two baffles, approximately 3 feet tall, which extend across the entire width of the box. These baffles are

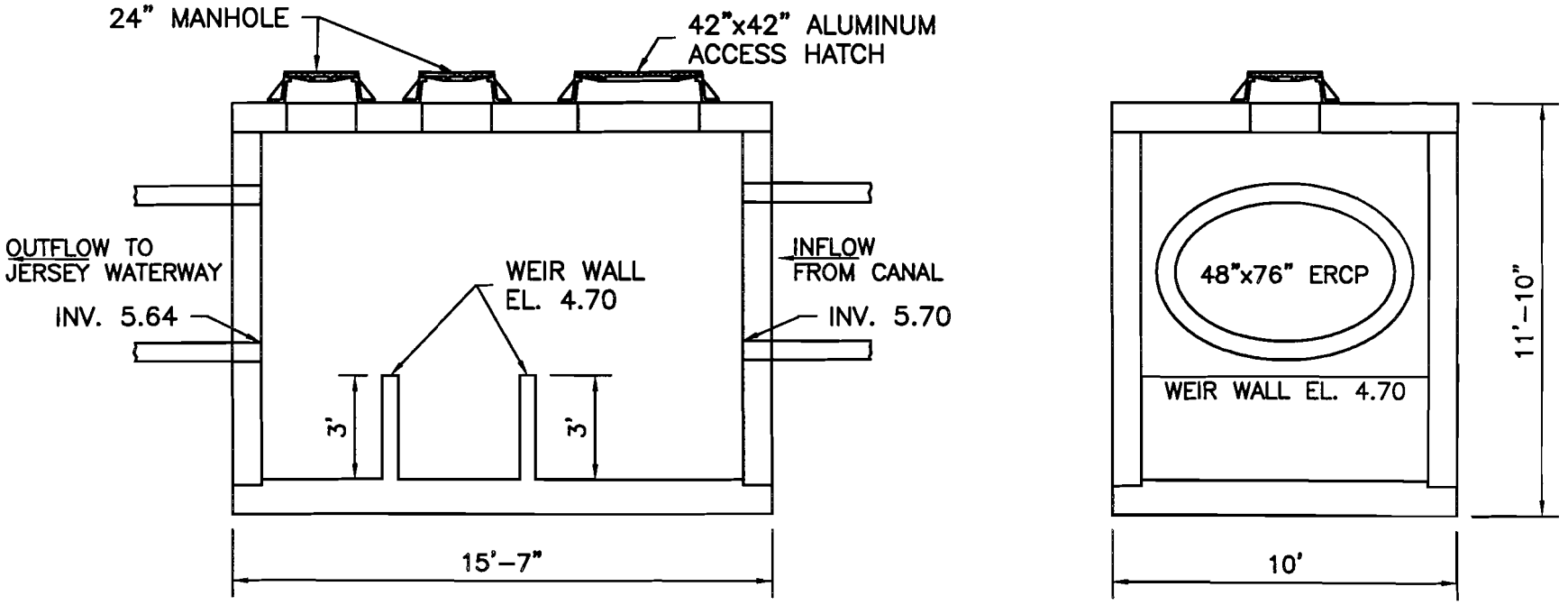


Figure 2-1. Schematic of the Baffle Box Structure.

designed to slow the velocity of water moving through the structure, providing opportunities for settling of discrete particles within the box. Both the inflow and the outflow for the structure consist of 48-inch x 78-inch elliptical reinforced concrete pipes (ERCP). The baffle box structure provides approximately 324 cubic feet of storage within the three containment cells up to the top of the weir walls (Source: City of Palm Bay). The baffle box was delivered to the site as a precast structure which was set into place and connected to the inflow and outflow storm sewer lines. Inflow from the Boundary Canal enters on the south side of the baffle box with discharges from the system occurring beneath Port Malabar Boulevard and into the adjacent Jersey Waterway.

2.1 Field Instrumentation and Monitoring

2.1.1 Site Instrumentation

A schematic of field instrumentation and monitoring locations used at the Boundary Canal baffle box site is given in Figure 2-2. Instrumentation was installed to allow estimation of hydrologic inputs into the baffle box structure, under both storm event and baseflow conditions, as well as to collect flow-weighted samples of inflow and outflow from the system under a wide range of flow conditions.

Inflow monitoring for the baffle box structure was performed in the 48-inch x 76-inch ERCP which enters along the southeast side of the baffle box structure. An automatic sequential stormwater sampler with integral flow meter, manufactured by Sigma (Model No. 900 MAX-AV) was installed to provide a continuous hydrograph record of inputs into the baffle box. The automatic sampler was mounted approximately 30 inches below the top of the structure beneath the aluminum hatch cover. Sensor cables and sample tubing were extended from the sampler

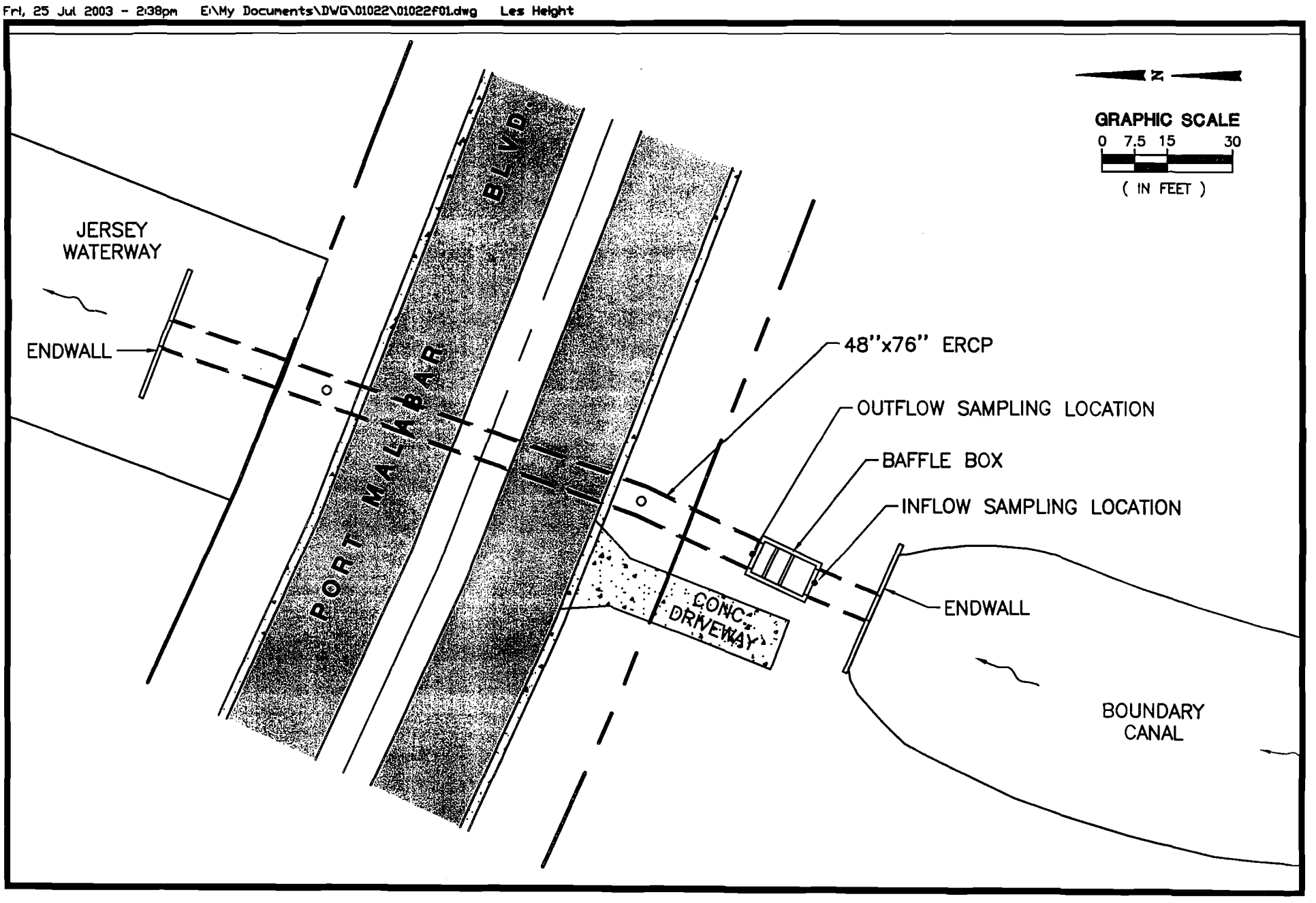


Figure 2-2. Sampling Locations for the Palm Bay Baffle Box Project.

into the 48-inch x 76-inch ERCP to the point of sample collection. The integral flow meter was programmed to provide a continuous record of hydraulic inputs into the baffle box, with measurements stored into internal memory at 10-minute intervals.

The automatic stormwater sampler contained 24 one-liter polyethylene bottles and was programmed to collect stormwater and baseflow samples in a flow-weighted mode. A single flow-weighted composite sample was generated from each monitored storm or baseflow event by combining the individual flow-weighted samples for a given event to form a single composite sample. Since 120 VAC power was not available at the site, the automatic collector was operated on gel cell batteries which were replaced on a weekly basis. A total of 8 separate flow-weighted composite samples of stormwater runoff, 11 composite baseflow samples, and 13 samples of mixed runoff and baseflow were collected at the inflow site during the 6-month monitoring program.

Flow measurements were performed at the inflow monitoring site using the velocity/cross-sectional area method. A velocity-depth probe was inserted into the 48-inch x 76-inch ERCP immediately upstream from the baffle box which performed simultaneous measurements of water velocity and depth. The depth measurements were converted into a cross-sectional area based upon the geometry of the pipe and multiplied by the measured velocity of flow to obtain a measurement of the discharge rate through the pipe in cubic feet per second (cfs).

A second automatic sequential sampler (Sigma Model 800 SL) was installed at the outflow from the baffle box to collect flow-weighted samples of discharges from the system. The automatic outfall sampler contained 24 one-liter polyethylene bottles and was connected electronically to the inflow sampler so that outflow samples were collected simultaneously with

the inflow samples. Since 120 VAC power was not available at the site, the stormwater collector was operated on a gel cell battery which was replaced on a weekly basis. The automatic sampler was placed on the same wooden platform used for the inflow sampler with sensor cables and sample tubing extending into the outfall structure to the point of sample collection. A total of 8 separate flow-weighted composite outflow samples was collected during storm event conditions, with 11 samples collected during baseflow conditions, and 14 samples collected with mixed characteristics at the outfall monitoring site during the 6-month monitoring program.

Rainfall at the baffle box site is assumed to be similar to rainfall measured at the Basin 7 monitoring site approximately 6845 feet (1.3 miles) north of the baffle box site. The rainfall recorder (Texas Electronics Model 1014-C) at the Basin 7 site produced a continuous record of all rainfall which occurred at the site from May-December 2002. This record is used to provide information on general rainfall characteristics in the vicinity of the baffle box during the monitoring program, and to assist in evaluation of hydrologic inputs to the system.

2.1.2 Evaluation of Collected Solids

The City of Palm Bay performed inspection activities on the baffle box structure on approximately a monthly basis during the 6-month monitoring program. Measurements of sediment depth were performed in each of the 3 chambers during each inspection visit. When necessary, removal of accumulated solid material was conducted using a vactor type vehicle. Estimates of the depth of accumulated solids within the chambers was performed by City personnel prior to each maintenance event.

Samples of collected solids from the baffle box were provided to ERD by the City of Palm Bay on two separate occasions for chemical and physical characterization. Each of the

collected samples was thoroughly mixed, and a sub sample was collected for laboratory analysis. The collected samples were analyzed for grain size distribution, organic content, moisture content, total phosphorus, total nitrogen, and total solids.

2.2 Laboratory Analyses

A summary of laboratory methods and MDLs for analyses conducted on inflow and outflow samples collected during this project is given in Table 2-1. All laboratory analyses were conducted in the ERD Laboratory. Details on field operations, laboratory procedures, and quality assurance methodologies are provided in the FDEP-approved Comprehensive Quality Assurance Plan No. 870322G for Environmental Research & Design, Inc. In addition, a Quality Assurance Project Plan (QAPP), outlining the specific field and laboratory procedures to be conducted for this project, was submitted and approved by SJRWMD prior to initiation of any field and laboratory activities. A summary of laboratory methods for analyses conducted on sediment samples is given in Table 2-2.

TABLE 2-1

ANALYTICAL METHODS AND DETECTION LIMITS FOR LABORATORY ANALYSES

MEASUREMENT PARAMETER	METHOD	METHOD DETECTION LIMITS (MDLs)[1]
pH	EPA-83, Sec. 150.1[2]	NA
Conductivity	EPA-83, Sec. 120.1	0.3 µmho/cm
Ammonia-N (NH_3-N)	EPA-83, Sec. 350.1[2]	0.01 mg/l
Nitrate + Nitrate (NO_x-N)	EPA-83, Sec. 353.3	0.004 mg/l
Total Nitrogen	Alkaline Persulfate Digestion[3]	0.001 mg/l
Orthophosphorus	SM-19, Sec. 4500-P E.[4]	0.001 mg/l
Total Phosphorus	Alkaline Persulfate Digestion[3]	0.001 mg/l
TSS	EPA-83, Sec. 160.2	0.7 mg/l
Turbidity	EPA-83, Sec. 180.1	0.1 NTU

1. MDLs are calculated based on the EPA method of determining detection limits.
2. Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, Revised March 1983.
3. FDEP-approved alternate method.
4. Standard Methods for the Examination of Water and Wastewater, 19th Ed., 1995.

TABLE 2-2

SUMMARY OF LABORATORY ANALYSES FOR SEDIMENT SAMPLES

PARAMETER	METHOD OF ANALYSIS
Moisture Content	EPA/CE-81-1[1]; p. 3-54, p. 3-58
Organic Content	EPA/CE-81-1; pp. 3-59 and 3-60
Total P	EPA-83[2], Sec. 365.4
Total N	EPA/CE-81-1; p. 3-205
Particle Size	EPA/CE-81-1; pp. 3-33 to 3-47

1. Procedures for Handling and Chemical Analysis of Sediments and Water Samples, EPA/Corps of Engineers, EPA/CE-81-1, 1981.
2. Methods for Chemical Analysis of Water and Wastes, EPA/4-78-020, Revised March 1983.

SECTION 3

RESULTS

Field monitoring, sample collection, and laboratory analyses for inflow and outflow were conducted at the Boundary Canal baffle box site over a 6-month period from June-November 2002. A discussion of the results of these efforts is given in the following sections.

3.1 Site Hydrology

3.1.1 Rainfall Characteristics

Rainfall characteristics at the baffle box site are assumed to be similar to rainfall measured at the Palm Bay Basin 7 detention pond site, which is located approximately 1.3 miles north of the baffle box. As part of another research project performed by ERD for the City of Palm Bay, a continuous record of rainfall characteristics was collected at the Basin 7 wet detention pond site from May 1-December 31, 2002 using a tipping-bucket rainfall collector with a resolution of 0.01 inch and a digital data logging recorder. The characteristics of individual rain events measured at the Basin 7 project site during the baffle box monitoring program from June-November 2002 are given in Table 3-1. For each individual rain event, information on total rainfall, event start time, event end time, event duration, average rainfall intensity, and antecedent dry period are included in Table 3-1. Average rainfall intensity is calculated as the total rainfall divided by the total event duration.

TABLE 3-1

SUMMARY OF RAINFALL MEASURED AT THE BASIN 7 WET DETENTION POND DURING THE BAFFLE BOX MONITORING PROGRAM FROM JUNE-NOVEMBER 2002

EVENT START		EVENT END		TOTAL RAINFALL (in)	DURATION (hrs)	ANTECEDENT DRY PERIOD (days)	AVERAGE INTENSITY (in/hr)
DATE	TIME	DATE	TIME				
6/7/02	12:17	6/7/02	12:17	0.01	---	6.6	---
6/7/02	20:55	6/7/02	21:28	0.17	0.55	0.4	0.31
6/8/02	11:34	6/8/02	13:12	0.61	1.64	0.6	0.37
6/10/02	19:47	6/10/02	20:02	0.12	0.25	2.3	0.49
6/14/02	14:28	6/14/02	15:08	0.12	0.66	3.8	0.18
6/14/02	23:05	6/14/02	23:05	0.01	---	0.3	---
6/16/02	15:48	6/16/02	23:11	0.40	7.39	1.7	0.05
6/17/02	13:35	6/17/02	16:59	0.62	3.40	0.6	0.18
6/18/02	18:27	6/18/02	21:32	0.72	3.07	1.1	0.23
6/19/02	13:36	6/19/02	23:36	1.52	10.00	0.7	0.15
6/20/02	17:34	6/21/02	1:26	0.81	7.87	0.7	0.10
6/21/02	12:32	6/21/02	21:32	1.49	9.00	0.5	0.17
6/25/02	12:08	6/25/02	12:41	0.18	0.55	3.6	0.33
6/26/02	14:25	6/26/02	15:37	0.48	1.20	1.1	0.40
6/27/02	12:14	6/27/02	12:14	0.01	---	0.9	---
6/30/02	16:02	6/30/02	18:42	0.43	2.67	3.2	0.16
7/1/02	13:05	7/1/02	13:34	0.26	0.48	0.8	0.55
7/4/02	16:33	7/4/02	19:12	0.84	2.65	3.1	0.32
7/5/02	13:15	7/5/02	18:16	1.07	5.02	0.8	0.21
7/8/02	0:39	7/8/02	1:43	0.11	1.07	2.3	0.10
7/8/02	10:29	7/8/02	12:20	0.24	1.85	0.4	0.13
7/9/02	10:26	7/9/02	10:57	0.09	0.52	0.9	0.17
7/10/02	8:09	7/10/02	9:27	0.41	1.30	0.9	0.32
7/12/02	13:31	7/12/02	16:51	0.19	3.33	2.2	0.06
7/13/02	13:28	7/13/02	13:39	0.25	0.17	0.9	1.48
7/17/02	6:41	7/17/02	6:54	0.06	0.22	3.7	0.27
7/20/02	13:37	7/20/02	19:21	0.45	5.75	3.3	0.08
7/21/02	13:09	7/21/02	17:10	0.15	4.01	0.7	0.04

TABLE 3-1 -- CONTINUED

SUMMARY OF RAINFALL MEASURED AT THE BASIN 7 WET DETENTION POND DURING THE BAFFLE BOX MONITORING PROGRAM FROM JUNE-NOVEMBER 2002

EVENT START		EVENT END		TOTAL RAINFALL (in)	DURATION (hrs)	ANTECEDENT DRY PERIOD (days)	AVERAGE INTENSITY (in/hr)
DATE	TIME	DATE	TIME				
8/1/02	19:36	8/1/02	21:57	0.27	2.35	11.1	0.11
8/2/02	14:26	8/2/02	16:13	0.76	1.78	0.7	0.43
8/3/02	15:03	8/3/02	16:04	0.21	1.02	1.0	0.21
8/4/02	21:54	8/4/02	23:37	0.28	1.72	1.2	0.16
8/5/02	21:36	8/5/02	21:55	0.24	0.32	0.9	0.76
8/8/02	17:20	8/8/02	19:26	0.52	2.10	2.8	0.25
8/9/02	8:12	8/9/02	9:38	0.09	1.43	0.5	0.06
8/11/02	6:53	8/11/02	19:41	2.89	12.80	1.9	0.23
8/12/02	21:17	8/12/02	23:43	0.53	2.43	1.1	0.22
8/17/02	4:06	8/17/02	6:32	0.72	2.43	4.2	0.30
8/17/02	14:29	8/17/02	15:08	0.31	0.65	0.3	0.48
8/18/02	6:01	8/18/02	18:43	0.19	12.70	0.6	0.01
8/19/02	5:23	8/19/02	17:56	0.30	12.55	0.4	0.02
8/19/02	22:13	8/19/02	22:31	0.04	0.30	0.2	0.13
8/30/02	2:07	8/30/02	3:37	0.06	1.50	10.2	0.04
8/30/02	22:46	8/31/02	1:19	0.17	2.54	0.8	0.07
9/2/02	14:00	9/2/02	21:54	0.76	7.90	2.5	0.10
9/23/02	16:10	9/23/02	19:26	0.18	3.27	20.8	0.06
9/24/02	6:24	9/24/02	7:03	0.13	0.66	0.5	0.20
9/24/02	19:16	9/24/02	20:10	0.10	0.90	0.5	0.11
9/26/02	14:48	9/26/02	15:03	0.08	0.25	1.8	0.32
9/27/02	13:54	9/27/02	14:19	0.14	0.43	1.0	0.33
9/30/02	6:48	9/30/02	6:48	0.01	---	2.7	---
9/30/02	14:44	9/30/02	14:46	0.04	0.04	0.3	1.02

TABLE 3-1 -- CONTINUED

SUMMARY OF RAINFALL MEASURED AT THE BASIN 7 WET DETENTION POND DURING THE BAFFLE BOX MONITORING PROGRAM FROM JUNE-NOVEMBER 2002

EVENT START		EVENT END		TOTAL RAINFALL (in)	DURATION (hr)	ANTECEDENT DRY PERIOD (days)	AVERAGE INTENSITY (in/hr)
DATE	TIME	DATE	TIME				
10/1/02	15:01	10/1/02	15:11	0.04	0.17	1.0	0.24
10/14/02	3:19	10/14/02	6:15	0.42	2.94	12.5	0.14
10/14/02	13:10	10/14/02	14:23	0.10	1.22	0.3	0.08
10/15/02	17:19	10/15/02	17:38	0.03	0.32	1.1	0.10
10/16/02	8:50	10/16/02	8:50	0.01	---	0.6	---
10/21/02	16:56	10/21/02	17:56	0.06	1.00	5.3	0.06
10/23/02	2:21	10/23/02	5:09	0.62	2.79	1.4	0.22
10/24/02	1:02	10/24/02	1:33	0.03	0.52	0.8	0.06
10/24/02	16:30	10/24/02	22:35	1.41	6.07	0.6	0.23
11/13/02	11:52	11/13/02	11:52	0.01	---	19.6	---
11/16/02	7:50	11/16/02	19:49	0.75	11.99	2.8	0.06
11/16/02	23:18	11/16/02	23:18	0.01	---	0.1	---
11/17/02	7:11	11/17/02	11:02	0.16	3.86	0.3	0.04
11/21/02	2:30	11/21/02	3:04	0.05	0.58	3.6	0.09
			Total:	**24.54**			

A total of 24.54 inches of rainfall fell in the vicinity of the baffle box site over the 6-month monitoring period from a total of 66 separate storm events. A summary of rainfall characteristics measured at the Basin 7 wet detention pond from June-November 2002 is given in Table 3-2. Individual rainfall amounts measured at the site range from 0.01-2.89 inches, with an average of 0.37 inches/event. Durations for events measured at the site range from 0.04-12.8 hours, with antecedent dry periods ranging from 0.1-20.8 days.

TABLE 3-2

SUMMARY OF RAINFALL CHARACTERISTICS IN THE VICINITY OF THE BOUNDARY CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

PARAMETER	UNITS	MINIMUM VALUE	MAXIMUM VALUE	MEAN VALUE
Event Rainfall	in	0.01	2.89	0.37
Event Duration	hr	0.04	12.8	3.02
Average Intensity	in/hr	0.01	1.48	0.23
Antecedent Dry Period	days	0.1	20.8	2.52

A comparison of measured and typical "average" rainfall in the vicinity of the Boundary Canal baffle box site is given in Figure 3-1. Measured rainfall presented in this figure is based upon the field-measured rain events presented in Table 3-1, summarized on a monthly basis. "Average" rainfall conditions are based upon historical monthly rainfall averages recorded at the Melbourne Meteorological Station over the 53-year period from 1948-2000. This site appears to be the closest long-term meteorological station for the baffle box monitoring site.

As seen in Figure 3-1, measured rainfall in the vicinity of the baffle box site was less than "normal" during four of the six months included in the monitoring program. Rainfall measured during June and August appears to be somewhat greater than average rainfall conditions. Overall, the measured rainfall of 24.54 inches from May-December 2002 is approximately 25% less than the "average" rainfall of 32.66 inches which typically occurs during the period from June-November in the Palm Bay area.

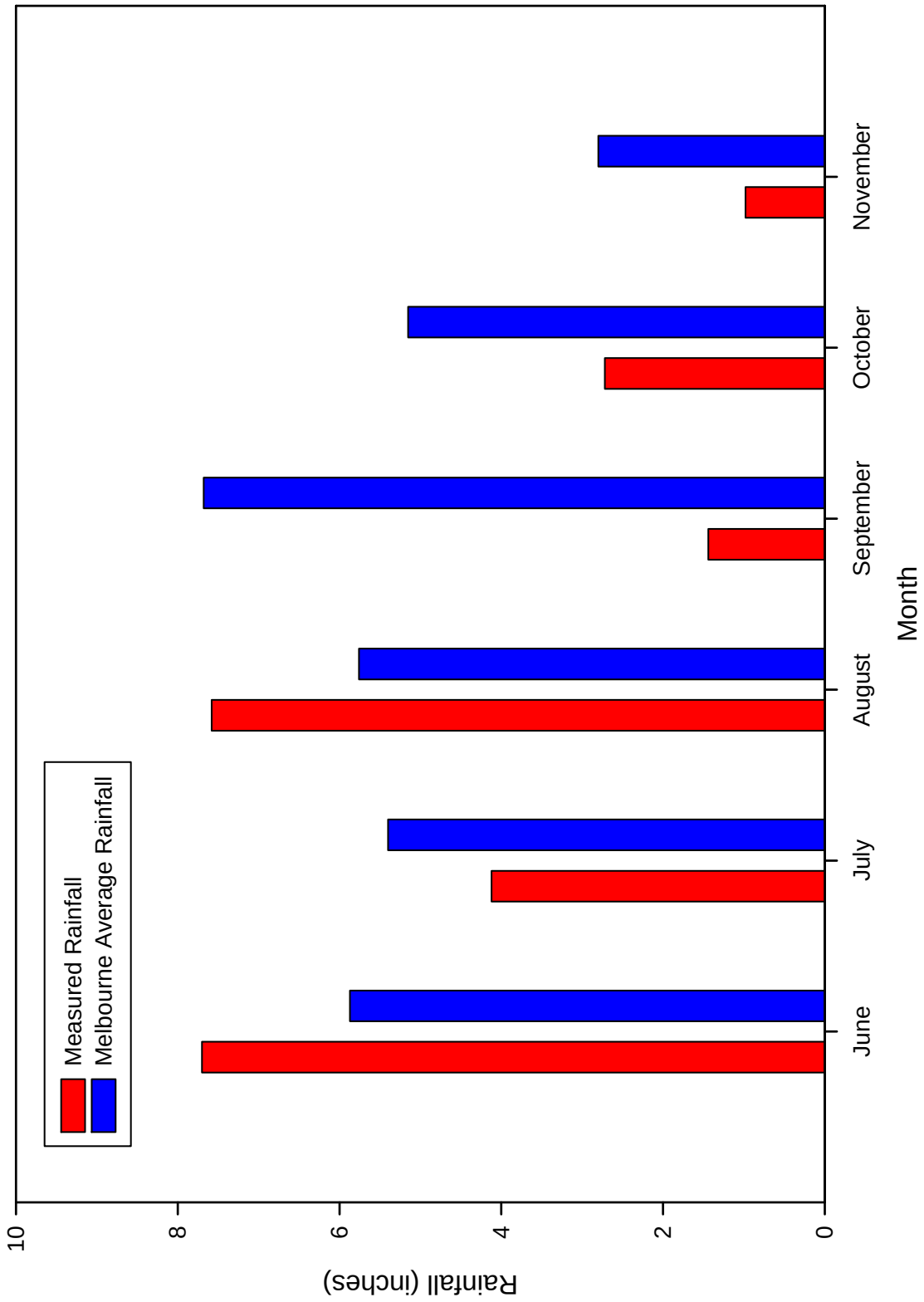


Figure 3-1. Comparison of Average and Measured Rainfall in the Vicinity of the Palm Bay Baffle Box.

3.1.2 Hydrologic Inputs

Continuous inflow hydrographs were recorded at the inflow to the baffle box structure at 10-minute intervals from June-November 2002. The inflow hydrographs provided information on baseflow and runoff conditions as well as total daily volume and cumulative total volume for the period of record.

Inflow hydrographs measured at the Palm Bay baffle box site are summarized in Figures 3-2, 3-3 and 3-4 for the periods of June-July, August-September and October-November, respectively. In general, inflow into the baffle box responded rapidly to significant rain events in the adjacent watershed. Storm events typically increased flow into the baffle box to values ranging from 1-5 cfs. A constant baseflow of approximately 0.1 cfs is present between storm events, which was continuous throughout the monitoring period. This baseflow presumably represents drawdown of groundwater within the basin between rain events.

Estimated daily inputs from the Boundary Canal into the baffle box structure are summarized in Appendix A. In general, daily inflows appear to be highly correlated with the daily rainfall. Inflows during each monthly monitoring period are summed to provide estimates of total inputs for each month, representing the sum of baseflow and runoff inputs. This information is utilized in subsequent sections to estimate mass loadings entering and leaving the baffle box structure.

A summary of rainfall-runoff relationships at the baffle box site from June-November 2002 is given in Table 3-3. Calculated monthly runoff coefficients for the basin area discharging to the baffle box are summarized in the final column of Table 3-3 based on an assumed basin area of 282 acres. These calculated coefficients (C values) represent the fraction of rainfall within the basin which entered the baffle box structure during storm events. For purposes of

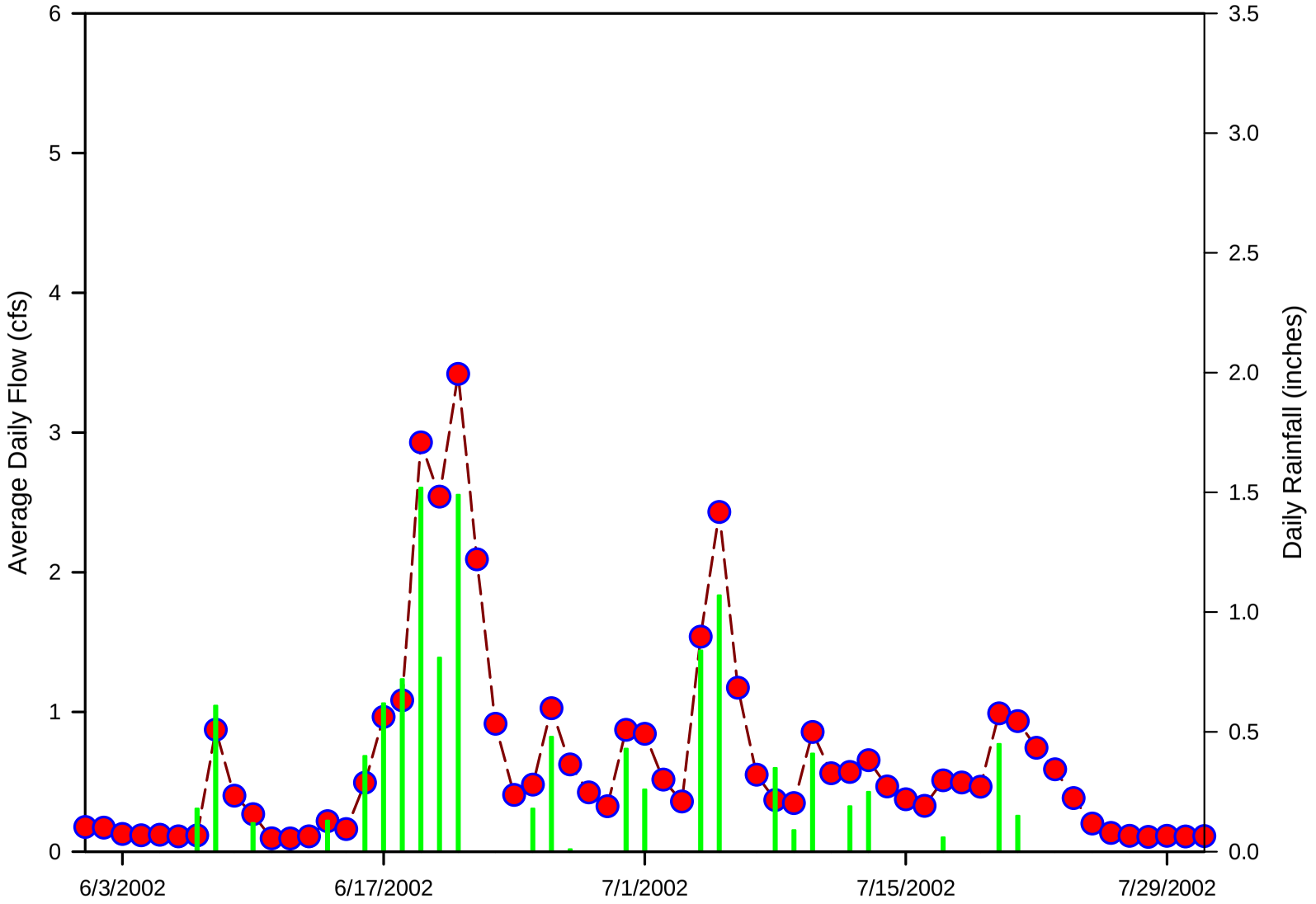


Figure 3-2. Inflow Hydrographs Measured at the Palm Bay Baffle Box Site during June - July 2002.

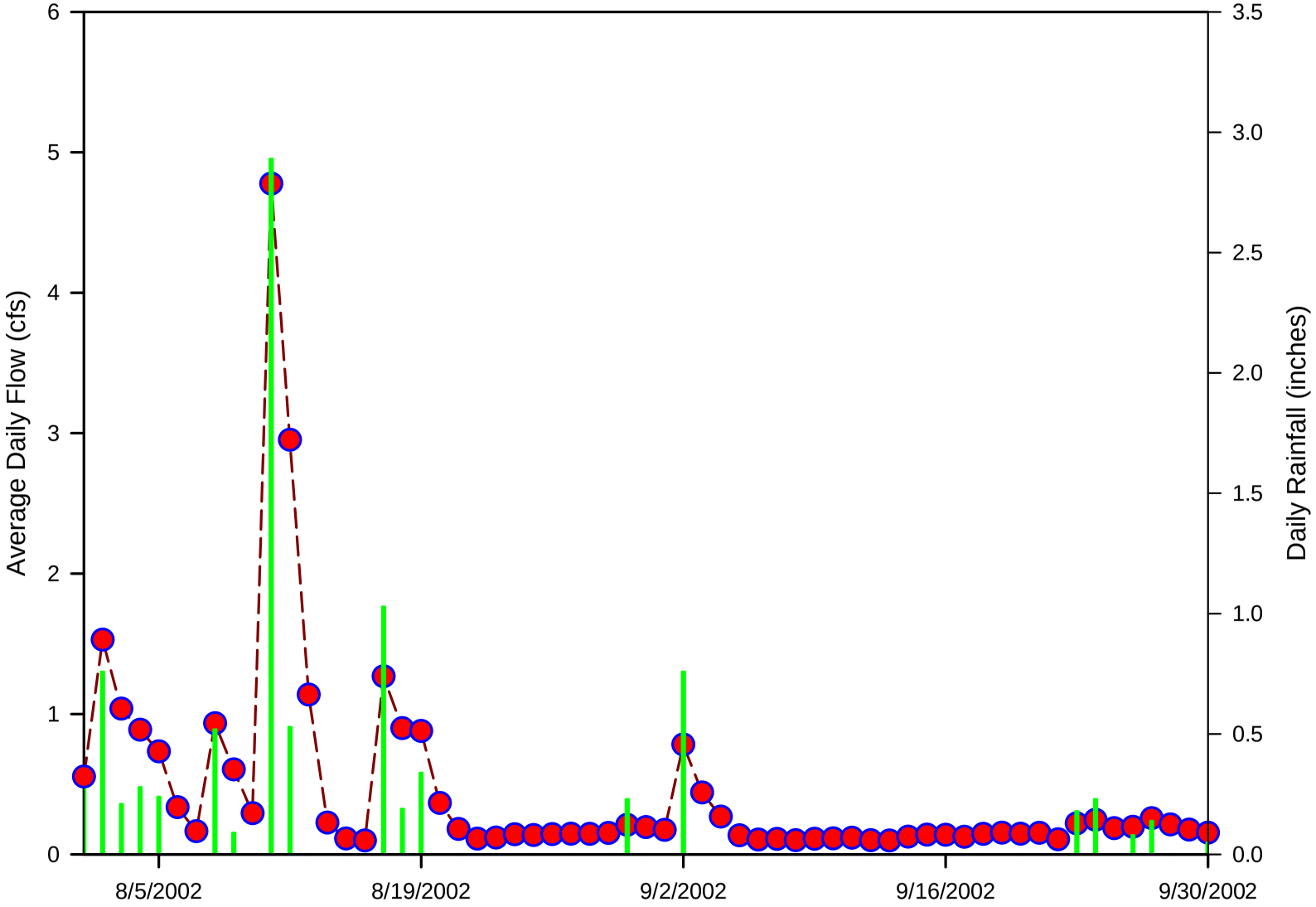


Figure 3-3. Inflow Hydrographs Measured at the Palm Bay Baffle Box Site during August - September 2002.

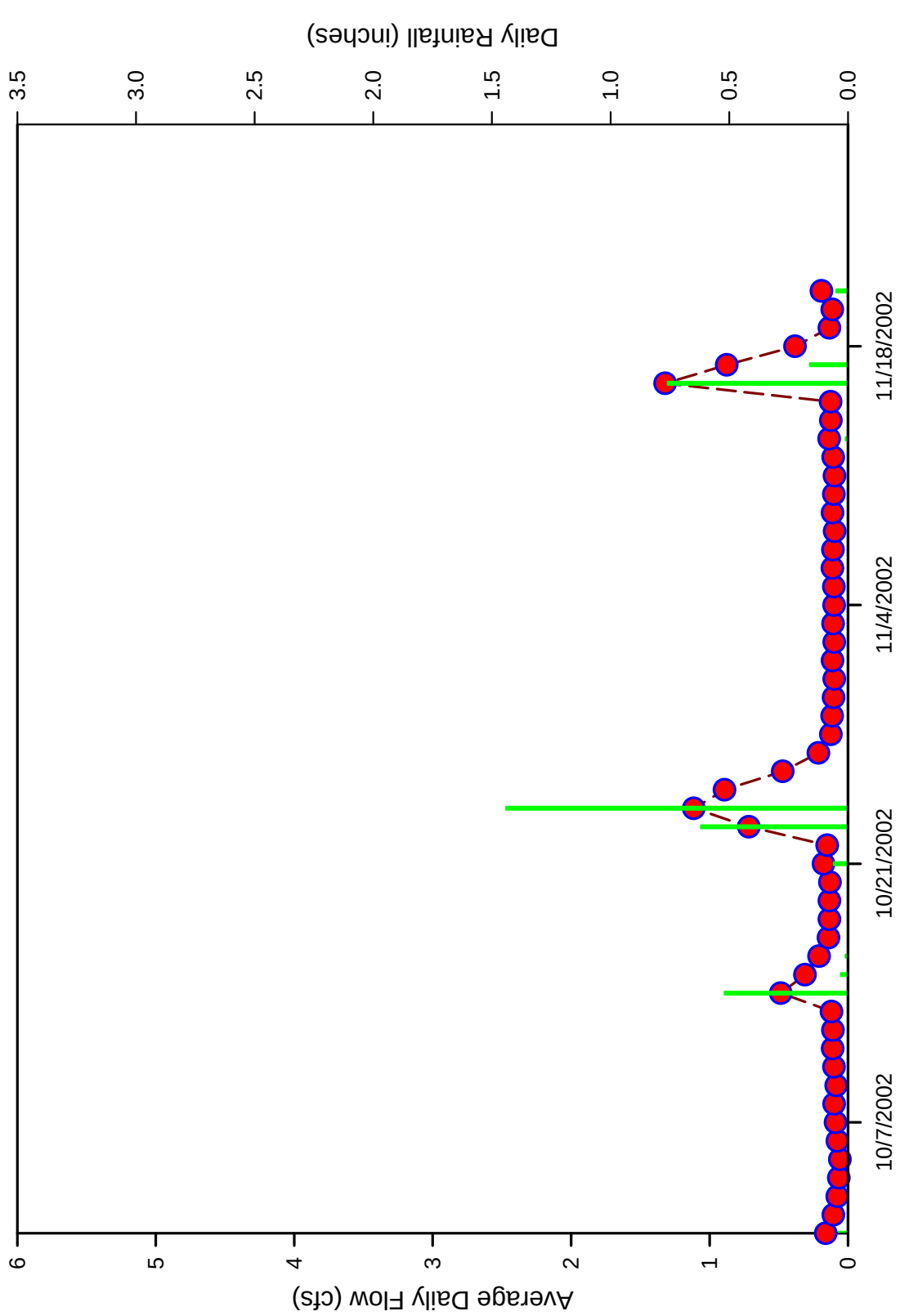


Figure 3-4. Inflow Hydrographs Measured at the Palm Bay Baffle Box Site during October - November 2002.

these calculations, the estimated baseflow volume is subtracted from the total daily volume to yield an estimate of inflow resulting from stormwater runoff. Calculated runoff coefficients range from a low of 0.200 in November, indicating that 20.0% of the rainfall within the basin actually reached the baffle box as stormwater runoff, to a high of 0.361 in August, indicating that 36.1% of the rainfall reached the baffle box in the form of stormwater runoff. The overall runoff coefficient for the basin during the 6-month monitoring program is 0.296. Runoff coefficients for the Boundary Canal basin are somewhat higher than coefficients measured by ERD in Basin 7 during the same period. Differences in the runoff coefficients are likely related to the drainage systems in the two basins, with shallow swales used predominately in Basin 7 and curb and gutter systems in the Boundary Canal basin.

TABLE 3-3

SUMMARY OF RAINFALL-RUNOFF RELATIONSHIPS AT THE BAFFLE BOX SITE FROM JUNE-NOVEMBER 2002

MONTH	RAINFALL (inches)	RUNOFF (ft^3)	RUNOFF COEFFICIENT (C VALUE)[1]
June	7.70	2,186,646	0.277
July	4.12	1,016,423	0.241
August	7.58	2,804,246	0.361
September	1.44	285,313	0.194
October	2.72	924,556	0.332
November	0.98	200,488	0.200
TOTAL	**24.54**	**7,417,672**	**0.296**

1. Based on an assumed drainage basin area of 282 acres.

3.2 Characteristics of Monitored Inflows and Outflows

Inflows and outflows from the Boundary Canal baffle box structure were monitored on a continuous basis from June-November 2002. Samples were collected from the inflow and

outflow automatic samplers, on approximately a weekly basis. Stored hydrograph information was used to divide the samples into samples representative of both storm event and baseflow conditions within the Boundary Canal. However, a portion of the collected samples appeared to be reflective of a combination of runoff and baseflow conditions. These samples were also collected and analyzed in the ERD laboratory for the same parameters used for stormwater and baseflow. For evaluation purposes, these samples are referred to as "mixed." A summary of sample collection activities performed at the Boundary Canal baffle box site is given in Table 3-4.

TABLE 3-4

SUMMARY OF SAMPLE COLLECTION PERFORMED AT THE BOUNDARY CANAL BAFFLE BOX SITE

SAMPLE TYPE	NUMBER OF SAMPLES COLLECTED	
	INFLOW	OUTFLOW
Stormwater Runoff	8	8
Baseflow	11	11
Mixed Runoff Baseflow	13	14

A complete listing of the chemical characteristics of individual samples collected during stormwater, baseflow, and mixed conditions at the Boundary Canal baffle box site from June-November 2002 is given in Appendix B. A discussion of the chemical characteristics of collected samples is given in the following sections.

3.2.1 Inflow Characteristics

3.2.1.1 Stormwater Runoff

A statistical summary of the characteristics of stormwater runoff entering the Boundary Canal baffle box from June-November 2002 is given in Table 3-5. Runoff discharging through the Boundary Canal was found to be highly variable for many of the measured parameters. The range of measured values for ammonia, dissolved orthophosphorus, dissolved organic phosphorus, particulate phosphorus, turbidity and TSS cover one order of magnitude or more between minimum and maximum measured values. This type of variability is common in stormwater runoff generated in urban watersheds.

TABLE 3-5

CHARACTERISTICS OF STORMWATER RUNOFF ENTERING THE BOUNDARY CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

PARAMETER	UNITS	RANGE OF VALUES		MEAN
		MINIMUM	MAXIMUM	
pH	s.u.	6.67	7.15	6.89
Spec. Conductivity	µmho/cm	223	680	450
NH_3	µg/l	12	116	34
NO_X	µg/l	60	338	184
Diss. Organic N	µg/l	197	1,097	593
Particulate N	µg/l	74	971	374
Total N	µg/l	698	1,739	1,185
Diss. Ortho-P	µg/l	<1	12	4
Diss. Organic P	µg/l	1	16	7
Particulate P	µg/l	11	196	86
Total P	µg/l	14	214	96
Turbidity	NTU	3.1	40.5	15.7
TSS	mg/l	2.4	83.7	34.8

In general, stormwater runoff measured in the Boundary Canal is approximately neutral in pH, with measured pH values ranging from 6.67 to 7.15, and an overall mean pH of 6.89. Specific conductivity measurements in runoff within the Boundary Canal appear to be typical of values commonly observed in urban runoff, with an overall mean of 450 μmho/cm. Measured concentrations of turbidity and TSS in the Boundary Canal appear to be somewhat lower than values commonly observed in urban runoff, presumably due to the treatment provided for these constituents during migration through the canal.

In general, runoff discharging through the Boundary Canal seems to be relatively dilute in chemical characteristics compared with runoff concentrations commonly observed in mixed residential and commercial watersheds. The dominant nitrogen species in runoff discharging through the Boundary Canal is dissolved organic nitrogen which comprises approximately 50% of the total nitrogen present. Particulate nitrogen is the second most dominant nitrogen species, comprising approximately 32% of the total nitrogen inputs.

Mean concentrations of ammonia and NO_x are relatively low in value in the runoff inflow, together comprising only 18% of the total nitrogen measured. The overall total nitrogen mean concentration of 1,185 μg/l is approximately 50% less than concentrations typically observed in residential and commercial areas.

Similar to the trends observed for total nitrogen species, measured concentrations of phosphorus species in stormwater runoff discharging through the Boundary Canal appear to be relatively dilute compared with values commonly observed in urban runoff. The mean total phosphorus concentration of 96 μg/l is approximately one-half to one-third of values commonly observed in urban areas. Dissolved orthophosphorus, which typically comprises approximately 50% of the total phosphorus in urban watersheds, comprises only 4% of the total phosphorus

measured in the Boundary Canal. The dominant phosphorus species in the Boundary Canal is particulate phosphorus, which comprises approximately 90% of the total phosphorus measured.

The relatively dilute characteristics of stormwater constituents measured in the Boundary Canal are probably related to the pre-treatment effects of the Boundary Canal. The Boundary Canal acts as a long, linear treatment basin which reduces input concentrations of chemical constituents in stormwater during migration through the canal.

3.2.1.2 Baseflow

A statistical summary of the characteristics of baseflow discharging through the Boundary Canal from June-November 2002 is given in Table 3-6. In general, baseflow inputs through the Boundary Canal exhibit substantially less variability in chemical characteristics than observed for stormwater runoff. Only a few of the measured parameters, including ammonia, NO_x, and dissolved orthophosphorus, exhibit ranges of values between minimum and maximum measured concentrations which cover one order of magnitude or more.

In general, baseflow measured at the Boundary Canal site is approximately neutral in pH, with measured pH values ranging from 6.70 to 7.13 and an overall mean pH of 6.93. Specific conductivity in baseflow within the Boundary Canal appears to be somewhat elevated, with an overall mean of 693 µmho/cm. This value is approximately 50% higher than the mean conductivity of 450 µmho/cm measured in stormwater runoff. Measured concentrations of turbidity and TSS in baseflow appear to be low in value, with a mean turbidity of only 3.4 NTU and a mean TSS of only 4.1 mg/l.

In general, baseflow discharges through the Boundary Canal appear to be dilute with respect to concentrations of nutrients. Measured concentrations for all nitrogen species in

baseflow are lower than mean characteristics for the same parameters measured in stormwater runoff. The dominant nitrogen species in baseflow is dissolved organic nitrogen, which comprises approximately 71% of the total nitrogen present in baseflow. Mean concentrations of ammonia and NO_x are low in value, comprising only 16% of the total nitrogen measured. The overall mean total nitrogen concentration of 645 µg/l in baseflow is approximately 35% lower than the total nitrogen measured in stormwater runoff.

TABLE 3-6

MEAN CHARACTERISTICS OF BASEFLOW ENTERING THE BOUNDARY CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

PARAMETER	UNITS	RANGE OF VALUES		MEAN
		MINIMUM	MAXIMUM	
pH	s.u.	6.70	7.13	6.93
Spec. Conductivity	µmho/cm	517	859	693
NH_3	µg/l	<5	64	31
NO_x	µg/l	5	139	75
Diss. Organic N	µg/l	294	608	460
Particulate N	µg/l	37	204	79
Total N	µg/l	436	749	645
Diss. Ortho-P	µg/l	1	12	3
Diss. Organic P	µg/l	<1	12	3
Particulate P	µg/l	3	20	10
Total P	µg/l	6	25	16
Turbidity	NTU	2.0	5.9	3.4
TSS	mg/l	2.2	7.0	4.1

Similar to the trends observed for total nitrogen species, measured concentrations of phosphorus species in baseflow appear to be extremely dilute compared with values measured in stormwater runoff. The mean total phosphorus concentration of 16 µg/l is only 17% of the mean total phosphorus concentration measured in stormwater runoff. The dominant phosphorous species in baseflow is particulate phosphorus which comprises approximately 63% of the total

phosphorus measured. Dissolved orthophosphorus, with a mean concentration of only 3 µg/l, comprises only 19% of the total phosphorus measured.

3.2.1.3 Mixed Runoff/Baseflow

A statistical summary of the characteristics of mixed runoff/baseflow entering the Boundary Canal baffle box from June-November 2002 is given in Table 3-7. In general, mixed runoff/baseflow discharging through the Boundary Canal appears to be approximately midway in variability between that exhibited by stormwater runoff and baseflow. Several of the measured parameters, including ammonia, NO_x, dissolved orthophosphorus, total phosphorus, dissolved organic phosphorus and particulate phosphorus exhibit approximately one order of magnitude or more between minimum and maximum values measured during the monitoring program.

Mixed runoff/baseflow discharging through the Boundary Canal was found to be approximately neutral in pH, with measured pH values ranging from 6.66-7.29, and overall mean pH of 6.98. Specific conductivity in mixed runoff/baseflow was highly variable, ranging from 123-751 µmho/cm, with an overall mean of 531 µmho/cm. Measured concentrations of turbidity and TSS appear to be approximately midway between those measured for runoff and baseflow.

In general, nitrogen concentrations in mixed runoff/baseflow discharging through the Boundary Canal appear to be approximately midway between characteristics measured in baseflow and stormwater runoff. The dominant nitrogen species in the mixed flow is dissolved organic nitrogen which contributes approximately 52% of the total nitrogen measured. Particulate nitrogen is the second most common nitrogen species contributing 22% of the total nitrogen measured. Concentrations of ammonia and NO_x contribute approximately 22% on an average basis.

TABLE 3-7

MEAN CHARACTERISTICS OF MIXED STORMWATER AND BASEFLOW ENTERING THE BOUNDARY CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

PARAMETER	UNITS	RANGE OF VALUES		MEAN
		MINIMUM	MAXIMUM	
pH	s.u.	6.66	7.29	6.98
Spec. Conductivity	µmho/cm	123	751	531
NH_3	µg/l	5	1,075	107
NO_x	µg/l	21	490	106
Diss. Organic N	µg/l	163	994	506
Particulate N	µg/l	49	802	209
Total N	µg/l	411	1,653	967
Diss. Ortho-P	µg/l	<1	18	10
Diss. Organic P	µg/l	1	18	6
Particulate P	µg/l	2	231	34
Total P	µg/l	7	242	53
Turbidity	NTU	1.7	25.9	5.5
TSS	mg/l	1.8	31.0	9.2

Measured concentrations of phosphorus species appear to be relatively dilute in the mixed flow. The dominant phosphorus species is particulate phosphorus which comprises approximately 64% of the total phosphorus measured. Dissolved orthophosphorus is relatively low in value, comprising only 19% of the phosphorus measured.

3.2.2 Outflow Characteristics

3.2.2.1 Stormwater Runoff

A statistical summary of the characteristics of stormwater discharging from the Boundary Canal baffle box from June-November 2002 is given in Table 3-8. In general, stormwater runoff discharging from the Boundary Canal baffle box is similar to chemical characteristics of stormwater entering the baffle box structure. Slight reductions in mean concentrations are

observed in the discharge from the baffle box, compared with concentrations measured in the inflow, for specific conductivity, ammonia, NO_x, dissolved organic nitrogen, particulate nitrogen, total nitrogen, dissolved organic phosphorus, particulate phosphorus, total phosphorus, turbidity and TSS. Although the reductions in measured concentrations for most of these parameters are relatively small, virtually all measured parameters were found to exhibit concentration reductions in the discharge compared with concentrations measured in the inflow.

TABLE 3-8

MEAN CHARACTERISTICS OF STORMWATER DISCHARGING FROM THE BOUNDARY CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

PARAMETER	UNITS	RANGE OF VALUES		MEAN
		MINIMUM	MAXIMUM	
pH	s.u.	6.85	6.97	6.91
Spec. Conductivity	µmho/cm	283	701	444
NH_3	µg/l	14	77	28
NO_x	µg/l	60	332	177
Diss. Organic N	µg/l	184	1,109	571
Particulate N	µg/l	76	939	274
Total N	µg/l	621	1,719	1,051
Diss. Ortho-P	µg/l	<1	12	4
Diss. Organic P	µg/l	1	13	6
Particulate P	µg/l	5	190	70
Total P	µg/l	8	204	80
Turbidity	NTU	2.0	37.2	14.2
TSS	mg/l	2.8	73.5	25.5

3.2.2.2 Baseflow

A statistical summary of the characteristics of baseflow discharging from the Boundary Canal baffle box from June-November 2002 is given in Table 3-9. In general, the chemical characteristics of discharges of baseflow from the Boundary Canal baffle box are similar to

baseflow inputs into the baffle box structure. Slight reductions in measured concentrations were observed in discharges from the baffle box for ammonia, dissolved organic nitrogen, total nitrogen, dissolved orthophosphorus, dissolved organic phosphorus, particulate phosphorus, total phosphorus, turbidity and TSS. Slight increases in measured concentrations were observed in baseflow discharges for specific conductivity and NO_x. Similar to the trends observed for stormwater, reductions in concentrations of baseflow constituents during migration through the baffle box appear to be relatively low in value.

TABLE 3-9

CHARACTERISTICS OF BASEFLOW DISCHARGING FROM THE BOUNDARY CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

PARAMETER	UNITS	RANGE OF VALUES		MEAN
		MINIMUM	MAXIMUM	
pH	s.u.	6.78	7.17	6.94
Spec. Conductivity	µmho/cm	524	850	699
NH_3	µg/l	<5	65	25
NO_x	µg/l	10	146	80
Diss. Organic N	µg/l	299	629	436
Particulate N	µg/l	46	174	86
Total N	µg/l	531	780	627
Diss. Ortho-P	µg/l	<1	5	2
Diss. Organic P	µg/l	1	12	2
Particulate P	µg/l	5	26	9
Total P	µg/l	5	27	13
Turbidity	NTU	1.7	6.8	3.1
TSS	mg/l	<0.7	5.2	3.6

3.2.2.3 Stormwater Runoff/Baseflow

A statistical summary of mean characterization of mixed runoff/baseflow discharging from the Boundary Canal baffle box structure from June-November 2002 is given in Table 3-10. Mixed runoff/baseflow appears to exhibit a wider range of variability in inflow and outflow characteristics, when compared with variability observed for baseflow and stormwater. Substantial reductions in mean concentrations are apparent for ammonia, NO_x, particulate N, Total N, ortho-P, dissolved organic P, particulate P, total P, turbidity, and TSS in discharges from the baffle box compared with inflow characteristics. In contrast, increases in measured concentrations are apparent in mixed samples for specific conductivity and dissolved organic nitrogen during migration through the baffle box structure.

TABLE 3-10

CHARACTERISTICS OF MIXED RUNOFF/BASEFLOW DISCHARGING FROM THE BOUNDARY CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

PARAMETER	UNITS	RANGE OF VALUES		MEAN
		MINIMUM	MAXIMUM	
pH	s.u.	6.74	7.15	6.95
Spec. Conductivity	µmho/cm	276	903	549
NH_3	µg/l	<5	46	17
NO_x	µg/l	11	260	75
Diss. Organic N	µg/l	214	901	552
Particulate N	µg/l	36	258	104
Total N	µg/l	387	1,150	747
Diss. Ortho-P	µg/l	<1	7	2
Diss. Organic P	µg/l	1	14	4
Particulate P	µg/l	1	59	17
Total P	µg/l	6	72	24
Turbidity	NTU	1.1	31.1	5.3
TSS	mg/l	<0.7	34.1	6.8

3.2.3 Comparison of Inflow and Outflow Characteristics

A statistical comparison of the characteristics of inflow and outflow concentrations of total N, total P, TSS, and turbidity at the Boundary Canal baffle box site is given in Figure 3-5. A graphical summary of data for each sample type is presented in the form of Tukey box plots, also called "box and whisker plots." The bottom of the box portion of each plot represents the lower quartile, with 25% of the data points lying below this value. The upper line of the box represents the 75% upper quartile, with 25% of the data lying above this value. The horizontal line within the box represents the median value, with 50% of the data lying both above and below this value. The thin, vertical lines, also known as "whiskers," represent the 5 and 95 percentiles for the data sets. Individual values, which lie outside of the 5-95 percentile range, are indicated as red dots.

As seen in Figure 3-5, discharges from the baffle box structure appear to be both lower in concentration and lower in variability than samples collected at the inflow for the majority of the measured parameters. Differences in concentration and variability between the inflow and the outflow are particularly apparent for total N, total P, TSS and turbidity in the stormwater and mixed samples, with a lower degree of differences between inflow and outflow observed for the baseflow constituents.

Differences between the inflow and outflow characteristics are primarily a function of the chemical characteristics of the inflow and the detention time afforded by the baffle box structure. Inputs of stormwater runoff and mixed flows contain relatively high particulate fractions in the form of particulate nitrogen, particulate phosphorus, turbidity and TSS. These parameters are more likely to be removed in a baffle box structure as opposed to dissolved constituents such as ammonia, NO_x, or dissolved ortho-P. In contrast, baseflow entering the baffle box structure

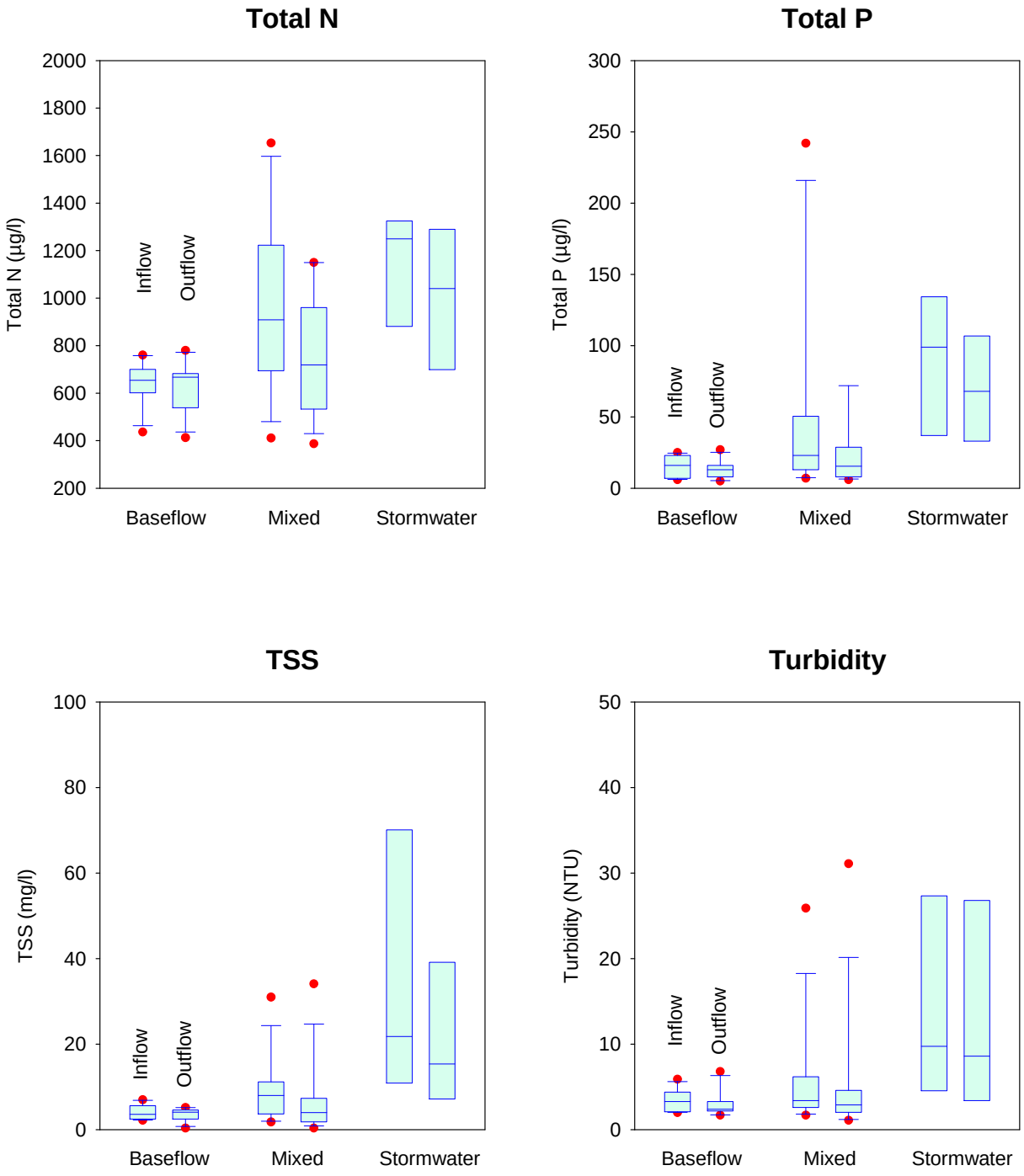


Figure 3-5. Statistical Comparison of Inflow and Outflow Characteristics for the Runoff, Baseflow, and Mixed Samples.

appears to have relatively low levels of particulate nitrogen, particulate phosphorus, turbidity and TSS, which results in a lowered opportunity for removal of particulate matter within the structure. In addition, since the baseflow is characterized by low flow velocities, the particulate matter which is carried by the flow is primarily small diameter solids, since larger diameter material would tend to settle within the canal.

The second factor affecting the performance efficiency of the baffle box structure is the detention time for inputs into the system. A summary of estimated detention times for baseflow and runoff inputs to the Boundary Canal baffle box structure is given in Table 3-11. Based on an average inflow rate of 0.1 cfs and a baffle box volume of 324 ft^3, baseflow inputs into the system have an average detention time of approximately 57 minutes within the baffle box structure. However, since the particulate fractions in the baseflow entering the baffle box are relatively low in value, and are probably comprised of small diameter particles which are resistant to settling, a low removal efficiency is achieved in spite of the relatively long detention time within the system.

TABLE 3-11

ESTIMATED DETENTION TIMES FOR BASEFLOW AND RUNOFF INPUTS TO THE BOUNDARY CANAL BAFFLE BOX

INPUT	AVERAGE DAILY INFLOW (cfs)	AVERAGE DETENTION TIME (minutes)[1]
Baseflow	0.1	54
Runoff	1 – 5	1.1 – 5.4

1. Based on a baffle box volume of 324 ft^3.

Average inflow rates for runoff inputs into the baffle box range from approximately 1-5 cfs. Based upon the mean daily inflow rates, average detention time within the baffle box ranges from approximately 1.1-5.4 minutes. Under peak flow conditions during a storm event, detention times in the baffle box may be substantially shorter than the average daily inflow values given in Table 3-11. Although these average detention times are substantially shorter than the detention time which occurs under baseflow conditions, the larger percentage of particulate matter contained within the runoff inflow, combined with larger diameter particles transported by the runoff flow, allows for a higher degree of accumulation within the baffle box, in spite of the substantially lower average detention time.

3.3 Characteristics of Collected Solids

After completion of the baffle box construction in July 2001, the City of Palm Bay began a program of routine monitoring and inspection activities to evaluate the depth and accumulation rate of sediment material within the baffle box and to indicate when sediment removal may be required. Inspection of the baffle box and monitoring of accumulated sediment depth was performed on approximately a monthly basis beginning in October 2001.

Removal of accumulated solid material from the baffle box is performed whenever the routine inspection and monitoring activities indicate that sediment removal may be required. A summary of maintenance activities performed by the City of Palm Bay on the Boundary Canal baffle box structure through December 2002 is given in Table 3-12. Sediment removal has been performed on five separate occasions since completion of the baffle box in July 2001. On each occasion, approximately 5.5-10.4 yd^3 of sediment were removed from the structure using a vactor type vehicle. During the period from July 2001 through December 2002, a total of

37.92 yd^3 (1,024 ft^3) of sediment material was removed from the baffle box by City of Palm Bay personnel.

TABLE 3-12

SUMMARY OF MAINTENANCE ACTIVITIES PERFORMED BY THE CITY OF PALM BAY IN THE BOUNDARY CANAL BAFFLE BOX STRUCTURE THROUGH DECEMBER 2002

DATE	ACTIVITY
July 2001	Baffle Box Construction Completed
10-09-01	Sediment Removed (5.62 yd^3)
12-14-01	Sediment Removed (7.67 yd^3)
1-31-02	Sediment Removed (8.76 yd^3)
3-26-02	Sediment Removed (10.37yd^3)
11-5-02	Sediment Removed (5.50 yd^3)

Samples of collected baffle box sediments were provided to ERD by the City of Palm Bay based upon sediment removal activities conducted on March 26 and November 5, 2002. The sediment samples provided to ERD were thoroughly mixed and evaluated in the ERD laboratory for a wide array of physical and chemical characteristics, along with standard sieve analyses. A complete listing of the results of sieve analysis on the sediment samples provided to ERD is given in Appendix C.

A summary of the physical and chemical characteristics of solids collected from the Boundary Canal baffle box is given in Table 3-13. Solids collected from the baffle box are characterized by a relatively low moisture content and organic content, suggesting that the solids consist primarily of discrete sand particles with little additional organic matter. Based on the sieve analyses summarized in Appendix C, approximately 90% of the collected solids (by

weight) have particle diameters greater than 0.14-0.21 mm or 140-210 microns. The collected solids also have extremely low levels of total N and total P which is consistent with the large size particles collected within the unit. Previous research by ERD has indicated that the majority of nitrogen and phosphorus associated with solids in stormwater runoff are attached to particles which are less than 10 microns in size. Particles with this diameter exhibit very slow settling velocities and are not effectively removed by the baffle box structure. Based upon the sieve analysis performed by ERD, the soils collected by the baffle box consist primarily of medium and fine sands. Based on the relatively low uniformity coefficients, the solids collected by the baffle box are considered to be relatively uniform in size and are not well-graded.

TABLE 3-13

CHARACTERISTICS OF SOLIDS COLLECTED FROM THE BOUNDARY CANAL BAFFLE BOX

PARAMETER	UNITS	COLLECTION DATE	
		03/26/02	11/15/02
Moisture Content	%	18.2	17.3
Organic Content	%	5.3	5.6
Uniformity Coefficient	--	1.67	1.79
Coefficiency of Gradation	--	0.99	1.03
D_{10}	mm	0.21	0.14
Total N	µg/g wet	54	32
Total P	µg/g wet	6	8

3.4 Performance Efficiency of the Baffle Box Structure

The performance efficiency of the Boundary Canal baffle box is calculated on a mass basis by estimating the input and output mass for each measured constituent during the 6-month monitoring program. Separate estimates of performance efficiencies were calculated for

baseflow, stormwater, and mixed runoff/baseflow to assist in evaluating the performance efficiency of the system under a variety of operating conditions.

Mass loadings of baseflow, stormwater, and mixed runoff/baseflow entering and leaving the baffle box structure were calculated on a monthly basis for each of the 6 months included in the monitoring program. Monthly mass loadings were calculated for each evaluated parameter by multiplying the mean monthly concentrations for baseflow, stormwater, and mixed runoff/baseflow times the estimated monthly volume entering the baffle box structure from each of these sources. The estimated monthly inflows and outflows were added together to perform an estimate of overall mass inputs and outputs from the baffle box structure during the monitoring program from June-November 2002. The estimated inflow and outflow masses were then compared to provide an estimate of removal efficiencies over the range of operating conditions.

A summary of the calculated performance efficiencies of the Boundary Canal baffle box from June-November 2002 is given in Table 3-14. Separate estimated removal efficiencies are calculated for each measured parameter and the three flow modes of baseflow, stormwater, and mixed runoff/baseflow.

The baffle box appears to exhibit relatively good removal efficiencies for ammonia during all three flow conditions. However, since there does not appear to be any significant uptake mechanisms for ammonia within the baffle box, a portion of the apparent removal efficiencies observed for ammonia, may simply be a result of nitrification processes occurring within the baffle box which convert ammonia into NO_x. This assumption seems to be supported somewhat by the increases in mass loadings of NO_x observed within the baffle box during baseflow and mixed flow conditions.

TABLE 3-14

PERFORMANCE EFFICIENCY OF THE BOUNDARY CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

PARAMETER	BASEFLOW			STORMWATER			MIXED		
	Inflow (kg)	Outflow (kg)	Removal (%)	Inflow (kg)	Outflow (kg)	Removal (%)	Inflow (kg)	Outflow (kg)	Removal (%)
NH_3	0.6	0.5	22	2.7	2.0	2.6	6.5	3.7	43
NO_x	1.5	1.6	-7	5.9	5.3	10	15.3	15.8	-3
Diss. Organic N	8.8	8.3	6	19.3	19.7	-2	148	130	12
Particulate N	1.4	1.7	-17	19.8	14.7	26	44.3	22.8	49
Total N	12.3	12.1	2	47.8	41.7	13	214	173	19
Ortho-P	0.05	0.03	32	0.12	0.09	30	1.08	0.76	30
Diss. Organic P	0.04	0.04	6	0.32	0.24	26	0.68	1.10	-61
Particulate P	0.19	0.17	11	4.12	3.43	17	3.15	4.07	-30
Total P	0.28	0.25	14	4.56	3.75	18	4.91	5.93	-21
TSS	74.1	66.5	10	1,587	1,329	16	1,361	1,335	2

Relatively poor removal efficiencies were observed for dissolved organic nitrogen, ranging from an increase of 2% under stormwater conditions to a removal of 12% under mixed flow conditions. Increases in particulate nitrogen are apparent under baseflow conditions, with relatively substantial reductions in particulate nitrogen observed under stormwater and mixed flow conditions. This somewhat unusual behavior is probably related to the type of particulate matter present within the Boundary Canal during each of the flow regimes. During baseflow conditions, the majority of the larger particles will settle out during migration through the Boundary Canal, leaving only small diameter particles which are unlikely to settle within the baffle box. However, during storm event and mixed flow conditions, larger particles can be expected to be mobilized and transported through the canal, which may actually be removed more easily in the baffle box than the small diameter of particles present in baseflow.

On an overall basis, the baffle box structure removed approximately 2% of the total nitrogen present in the baseflow, with a 13% removal of total nitrogen in stormwater and a 19% removal observed under mixed flow conditions. The vast majority of this removal is a result of settling of particulate nitrogen within the baffle box structure. Although relatively high removal efficiencies are observed for ammonia within the baffle box, the proportion of ammonia is relatively small compared with other nitrogen species.

Relatively good removal efficiencies were achieved for orthophosphorus during each of the three flow conditions with removal ranges from 30-32%. Positive removals were also achieved for dissolved organic phosphorus under baseflow and stormwater conditions, although a relatively significant increase is apparent under mixed flow conditions. A similar pattern is apparent for particulate phosphorus which is reduced, although to a relatively small degree, under baseflow and storm event conditions, with increases occurring under mixed flow conditions. On an overall basis, approximately 14% of the total phosphorus inputs are removed under baseflow conditions, with 18% removed under stormwater conditions, and an increase in phosphorus concentrations observed under mixed flow conditions. The increases in phosphorus concentrations observed under mixed flow conditions may be due to the decomposition of particulate matter and subsequent release of dissolved phosphorus as well as resuspension of small, particulate phosphorus which was previously captured within the baffle box.

Positive removal of suspended solids was observed within the baffle box under each of the three flow conditions. Under base flow conditions, TSS is reduced by approximately 10%, with a 16% reduction under storm event conditions, and a 2% reduction under mixed flow conditions. Although the removal efficiencies for suspended solids are lower than removal efficiencies observed for some of the other parameters, the overall mass of suspended solids removed is substantially greater than any of the other measured parameters.

The estimated inflows and outflows summarized in Table 3-14 for baseflow, stormwater, and mixed conditions were summed together to provide an overall estimate of inflow and outflow from the baffle box during the 6-month monitoring program. As indicated previously, monitoring performed during this period is based upon 24.54 inches of rainfall measured in the vicinity of the Boundary Canal watershed. The estimated overall inflows and outflows were then adjusted to an annual basis by multiplying the total inflows and outflows measured during the monitoring program times the ratio of mean annual rainfall occurring at the Melbourne Monitoring Site from 1948-2000 (48.69 inches) to the rainfall of 24.54 inches measured during the monitoring program.

A summary of estimated inputs and outputs into the Boundary Canal baffle box under combined stormwater and baseflow conditions are summarized in Table 3-15, based upon the 6-month monitoring program performed by ERD. Differences between the estimated annual inflows and outflows are used to calculate the performance efficiency of the baffle box under the entire range of operating conditions.

TABLE 3-15

ESTIMATED ANNUAL PERFORMANCE EFFICIENCY OF THE BOUNDARY CANAL BAFFLE BOX STRUCTURE

PARAMETER	ANNUAL INFLOW (kg/yr)	ANNUAL OUTFLOW (kg/yr)	PERCENT REMOVAL (%)
NH_3	19.5	12.3	37
NO_x	45.6	45.4	0
Diss. Organic N	350	314	10
Particulate N	131	77.9	41
Total N	546	450	18
Ortho-P	2.5	1.7	30
Diss. Organic P	2.1	2.7	-32
Particulate P	15.0	15.3	-2
Total P	19.6	19.8	-1
TSS	6,030	5,455	10

As seen in Table 3-15, the Boundary Canal baffle box is expected to remove significant quantities of both ammonia and particulate nitrogen on an annual basis. No removal of NO_x is anticipated with a relatively small removal of dissolved organic nitrogen. On an annual basis, total nitrogen is expected to be reduced by approximately 18% within the baffle box structure.

A positive removal of approximately 30% is anticipated for orthophosphorus. However, based upon the 6-month monitoring program, increases in dissolved organic P can be anticipated, with relatively little change in particulate phosphorus during migration through the baffle box. On an overall basis, no significant reduction in total phosphorus is anticipated as a result of the baffle box structure. On an annual basis, the baffle box is expected to reduce suspended solids concentrations by approximately 10%. Although this removal efficiency appears to be small, the amount of solids captured corresponds to a reduction of approximately 575 kg of suspended solids each year within the baffle box structure.

3.5 Comparison of Field Measured System Performance with City Maintenance Records

Based on the City of Palm Bay maintenance records, summarized in Table 3-12, a total of 37.92 yd^3 of sand and sediments was removed from the Boundary Canal baffle box structure over the 16-month period from July 2001 through October 2002. (Sample collection was performed on November 5, 2002.) This equates to an accumulated rate of 2.37 yd^3 per month or 28.44 yd^3 (768 ft^3) in a 12-month period. According to the City field notes, the vast majority of this material was removed from the southern (initial) chamber with relatively little material removed from the second and third chambers. As seen in Table 3-15, field monitoring performed by ERD predicts an annual remove of 575 kg/yr in the baffle box structure. Based on an assumed particle density of 2.5 g/cm^3, the annual sediment removal measured in the field monitoring program is equivalent to approximately 8.1 ft^3/year of solid material.

The large discrepancy between the field measured estimates of sediment accumulation and the actual sediment removal performed by the City is probably related to the transport and migration of sediment material in a thin layer along the channel bottom during high flow conditions. This phenomenon, known as bed load, is well documented in channels with exposed beds or where erosion is severe. Under this condition, sediments travel in a thin layer across the channel bottom and are accumulated in the initial chamber of the baffle box. Typical stormwater collection equipment is not capable of adequately monitoring this loading and, as a result, this type of loading is not included in traditional stormwater characterization studies. The presence of this bed load is supported by the fact that the majority of solids in the baffle box accumulate in the initial chamber. Suspended solids commonly present in runoff flow would be expected to settle more uniformly in the three chambers.

Based on an assumed solids density of 2.5 g/cm^3, the actual load of suspended solids removed by the baffle box each year is approximately 54,350 kg/yr, which represents runoff related solids plus the bed load. Since the concentration of nitrogen and phosphorus in the collected solids is extremely low, collection of the additional solids has little impact on collected masses of nutrients in the system.

APPENDICES

APPENDIX A

MEASURED DAILY INFLOW TO THE CANAL BAFFLE BOX FROM JUNE-NOVEMBER 2002

Summary of Daily Inflow to the Baffle Box from June - November 2002

Day	Daily Inflow Volume (ft^3) by Month					
	June	July	August	September	October	November
1	15,160	72,756	47,828	14,997	13,785	9,586
2	14,737	44,480	132,099	67,580	9,043	8,497
3	10,829	30,853	89,617	38,031	6,634	9,213
4	10,063	132,845	76,714	23,193	5,659	8,580
5	10,282	210,003	63,347	11,686	4,958	8,732
6	9,343	101,292	29,008	8,999	6,560	9,605
7	10,008	47,511	14,225	9,426	7,612	9,294
8	75,313	31,877	80,676	8,701	8,572	8,291
9	34,500	29,906	52,256	9,585	7,313	9,554
10	23,069	73,886	25,297	9,802	8,711	8,800
11	8,191	48,466	412,667	10,227	9,493	8,370
12	8,075	49,181	255,119	8,688	9,265	9,093
13	9,409	56,447	98,308	8,553	10,216	11,710
14	18,754	40,210	19,487	10,873	41,842	10,624
15	13,844	32,293	9,679	12,026	26,720	10,765
16	42,522	28,182	8,511	11,989	17,899	114,040
17	83,286	44,018	109,487	10,765	12,061	75,567
18	93,553	42,630	77,661	12,610	11,497	32,981
19	253,063	40,037	75,860	13,370	11,566	11,494
20	219,380	85,428	31,553	12,664	11,225	9,759
21	295,361	80,678	15,581	13,289	15,134	16,421
22	180,668	64,182	9,676	9,175	12,896	
23	79,005	50,863	10,340	19,075	61,792	
24	35,010	33,057	12,278	21,208	96,110	
25	41,377	17,350	11,912	16,072	76,931	
26	88,622	11,547	12,376	16,859	40,612	
27	53,867	9,717	12,686	22,248	18,386	
28	36,578	9,025	12,608	18,384	10,572	
29	27,967	9,696	13,200	15,154	9,832	
30	75,188	9,249	18,093	13,340	8,964	
31		9,588	16,743		8,519	
Total	**1,877,022**	**1,547,254**	**1,854,890**	**478,568**	**600,378**	**400,977**

APPENDIX B

LABORATORY ANALYSES OF INPUTS AND OUTPUTS OF STORMWATER, BASEFLOW, AND MIXED SAMPLES COLLECTED AT THE BOUNDARY CANAL BAFFLE BOX SITE

CHEMICAL CHARACTERISTICS OF BASEFLOW SAMPLES COLLECTED AT THE INFLOW TO THE BOUNDARY CANAL BAFFLE BOX DURING JUNE - NOVEMBER 2002

DATE		pH (s.u.)	Spec. Cond. (µmhos/cm)	NH3 (µg/L)	NO3 (µg/L)	Diss. Organic N (µg/L)	Part. N (µg/L)	Total N (µg/L)	Ortho P (µg/L)	Diss. Organic P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	TSS (mg/L)
Start	End													
7/16/02	7/19/02	6.94	766	47	52	511	58	668	< 1	3	4	7	2.0	2.5
7/22/02	7/24/02	6.74	667	13	70	608	69	760	3	1	3	7	2.9	2.4
7/25/02	7/31/02	6.91	859	29	106	511	54	700	5	1	10	16	2.1	3.6
8/24/02	8/29/02	7.13	738	< 5	5	595	52	654	< 1	1	5	6	2.4	3.4
9/6/02	9/13/02	6.93	632	18	96	482	76	672	3	2	10	15	2.1	4.3
9/14/02	9/20/02	6.91	696	< 5	73	362	204	641	< 1	1	20	21	5.9	6.3
9/28/02	10/4/02	6.92	517	46	46	410	100	602	5	1	17	23	4.3	5.6
10/5/02	10/9/02	6.91	634	36	6	294	100	436	12	1	10	23	4.4	7.0
10/28/02	11/7/02	7.04	799	45	139	512	53	749	3	1	15	19	4.5	5.0
11/8/02	11/15/02	6.70	734	35	129	370	37	571	< 1	3	8	11	3.7	3.0
11/17/02	11/22/02	7.10	581	64	98	408	67	637	1	12	12	25	3.3	2.2

CHEMICAL CHARACTERISTICS OF BASEFLOW SAMPLES COLLECTED AT THE OUTFALL FROM THE BOUNDARY CANAL BAFFLE BOX DURING JUNE - NOVEMBER 2002

DATE		pH (s.u.)	Spec. Cond. (µmhos/cm)	NH3 (µg/L)	NO3 (µg/L)	Diss. Organic N (µg/L)	Part. N (µg/L)	Total N (µg/L)	Ortho P (µg/L)	Diss. Organic P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	TSS (mg/L)
Start	End													
7/16/02	7/19/02	7.10	581	64	98	408	67	637	1	12	12	25	3.3	2.2
7/22/02	7/24/02	7.13	771	13	56	531	83	683	< 1	3	9	12	1.8	2.3
7/25/02	7/31/02	6.81	684	< 5	68	629	81	780	< 1	3	5	8	2.2	2.5
8/24/02	8/29/02	6.87	850	< 5	100	498	81	681	4	3	11	18	1.7	2.8
9/6/02	9/13/02	7.17	745	13	50	513	91	667	< 1	3	2	5	2.4	5.2
9/14/02	9/20/02	6.93	706	21	146	448	68	683	3	2	3	8	2.3	4.2
9/28/02	10/4/02	6.98	686	< 5	68	379	90	539	< 1	1	26	27	6.8	4.6
10/5/02	10/9/02	6.95	524	12	40	398	102	552	< 1	1	12	13	2.3	4.0
10/28/02	11/7/02	6.82	651	15	10	335	53	413	5	1	7	13	3.2	4.1
11/8/02	11/15/02	6.79	791	17	121	428	174	740	3	1	12	16	3.3	4.5
11/17/02	11/22/02	6.78	752	65	121	299	46	531	< 1	2	5	7	3.3	< 0.7

CHEMICAL CHARACTERISTICS OF MIXED BASEFLOW AND STORMWATER SAMPLES COLLECTED AT THE INFLOW TO THE BOUNDARY CANAL BAFFLE BOX DURING JUNE - NOVEMBER 2002

DATE		pH (s.u.)	Spec. Cond. (µmhos/cm)	NH3 (µg/L)	NO3 (µg/L)	Diss. Organic N (µg/L)	Part. N (µg/L)	Total N (µg/L)	Ortho P (µg/L)	Diss. Organic P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	TSS (mg/L)
Start	End													
5/31/02	6/12/02	6.78	621	14	177	354	164	709	1	1	32	34	3.9	6.9
6/13/02	6/18/02	7.01	674	26	52	284	49	411	1	1	9	11	1.7	3.0
6/28/02	7/12/02	6.66	497	24	55	803	394	1276	4	1	10	15	3.1	4.4
7/13/02	7/16/02	6.72	628	42	45	639	69	795	3	1	4	8	2.2	1.8
8/3/02	8/5/02	7.11	454	24	86	798	173	1081	11	9	10	30	3.0	8.4
8/9/02	8/11/02	7.22	441	14	57	994	104	1169	8	3	10	21	3.2	8.0
8/12/02	8/15/02	7.17	123	5	70	726	175	976	20	18	26	64	5.9	14.4
8/16/02	8/23/02	7.02	422	63	50	654	142	909	3	12	8	23	4.5	10.2
8/30/02	9/5/02	6.82	618	5	141	573	97	816	4	1	2	7	2.0	2.3
9/21/02	9/27/02	6.90	683	20	93	374	96	583	< 1	1	15	16	6.5	7.4
10/10/02	10/16/02	7.07	668	21	21	476	163	681	3	6	28	37	6.8	10.8
10/17/02	10/22/02	7.29	751	1075	38	250	290	1653	73	17	87	177	3.4	11.6
10/25/02	10/26/02	6.97	322	58	490	163	802	1513	4	7	231	242	25.9	31.0

CHEMICAL CHARACTERISTICS OF MIXED BASEFLOW AND STORMWATER SAMPLES COLLECTED AT THE OUTFALL FROM THE BOUNDARY CANAL BAFFLE BOX DURING JUNE - NOVEMBER 2002

DATE		pH (s.u.)	Spec. Cond. (µmhos/cm)	NH3 (µg/L)	NO3 (µg/L)	Diss. Organic N (µg/L)	Part. N (µg/L)	Total N (µg/L)	Ortho P (µg/L)	Diss. Organic P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	TSS (mg/L)
Start	End													
5/31/02	6/12/02	6.92	903	< 5	47	381	42	472	1	1	4	6	2.8	< 0.7
6/13/02	6/18/02	6.83	543	22	46	283	36	387	< 1	1	7	8	1.1	1.9
6/19/02	6/27/02	6.85	648	24	68	410	41	543	2	1	6	9	1.3	1.6
6/28/02	7/12/02	6.74	500	18	51	809	41	919	4	1	9	14	2.1	3.0
7/13/02	7/16/02	6.80	646	15	45	674	36	770	3	1	4	8	1.8	1.9
8/3/02	8/5/02	7.12	455	19	90	820	220	1149	2	4	25	31	3.0	6.2
8/9/02	8/11/02	7.15	287	< 5	98	727	258	1085	7	14	51	72	9.2	15.3
8/12/02	8/15/02	7.00	502	30	49	901	170	1150	< 1	3	19	22	4.0	7.3
8/16/02	8/23/02	7.11	251	46	59	684	36	825	3	11	11	25	4.4	6.2
8/30/02	9/5/02	6.83	619	< 5	130	558	100	790	4	2	1	7	2.3	3.2
9/21/02	9/27/02	6.89	660	< 5	60	391	125	578	1	1	15	17	5.2	7.4
10/10/02	10/16/02	6.96	687	< 5	11	479	126	618	1	8	19	28	2.3	1.4
10/17/02	10/22/02	6.98	710	< 5	29	394	77	502	< 1	1	11	12	3.5	4.8
10/25/02	10/26/02	7.12	276	46	260	214	147	667	4	9	59	72	31.1	34.1

CHEMICAL CHARACTERISTICS OF STORMWATER SAMPLES COLLECTED AT THE INFLOW TO THE BOUNDARY CANAL BAFFLE BOX DURING JUNE - NOVEMBER 2002

DATE		pH (s.u.)	Spec. Cond. (µmhos/cm)	NH3 (µg/L)	NO3 (µg/L)	Diss. Organic N (µg/L)	Part. N (µg/L)	Total N (µg/L)	Ortho P (µg/L)	Diss. Organic P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	TSS (mg/L)
Start	End													
7/20/02	7/21/02	7.15	615	25	113	486	74	698	< 1	3	11	14	3.2	2.4
8/1/02	8/1/02	6.82	680	12	338	696	194	1240	1	1	83	85	8.6	19.4
8/2/02	8/2/02	6.91	320	18	318	432	971	1739	9	9	196	214	40.5	77.7
8/9/02	8/9/02	6.92	358	17	60	1097	158	1332	5	2	26	33	3.1	10.2
8/12/02	8/12/02	6.83	223	13	97	1052	141	1303	12	16	85	113	10.1	24.2
10/23/02	10/24/02	6.93	474	116	94	401	489	1100	1	8	117	126	29.2	47.4
10/27/02	10/27/02	6.67	340	29	306	197	276	808	3	9	125	137	21.8	83.7
11/16/02	11/16/02	6.86	592	42	143	384	690	1259	1	7	41	49	9.4	13.0

CHEMICAL CHARACTERISTICS OF STORMWATER SAMPLES COLLECTED AT THE OUTFALL FROM THE BOUNDARY CANAL BAFFLE BOX DURING JUNE - NOVEMBER 2002

DATE		pH (s.u.)	Spec. Cond. (µmhos/cm)	NH3 (µg/L)	NO3 (µg/L)	Diss. Organic N (µg/L)	Part. N (µg/L)	Total N (µg/L)	Ortho P (µg/L)	Diss. Organic P (µg/L)	Part. P (µg/L)	Total P (µg/L)	Turbidity (NTU)	TSS (mg/L)
Start	End													
7/20/02	7/21/02	6.97	628	14	114	456	76	660	< 1	3	5	8	2.0	2.8
8/1/02	8/1/02	6.97	701	15	298	652	149	1114	1	1	63	65	6.5	15.9
8/2/02	8/2/02	6.86	323	17	310	453	939	1719	9	5	190	204	37.2	73.5
8/9/02	8/9/02	6.88	364	18	60	1109	138	1325	3	1	21	25	2.4	4.8
8/12/02	8/12/02	6.90	219	14	76	874	221	1185	12	10	49	71	6.4	14.4
10/23/02	10/24/02	6.85	432	77	74	452	364	967	1	8	97	106	29.3	39.4
10/27/02	10/27/02	6.95	283	25	332	184	80	621	3	13	91	107	19.3	38.4
11/16/02	11/16/02	6.92	604	46	154	389	227	816	2	5	50	57	10.7	14.8

APPENDIX C

CHARACTERISTICS OF SOLID SAMPLES COLLECTED FROM THE BOUNDARY CANAL BAFFLE BOX

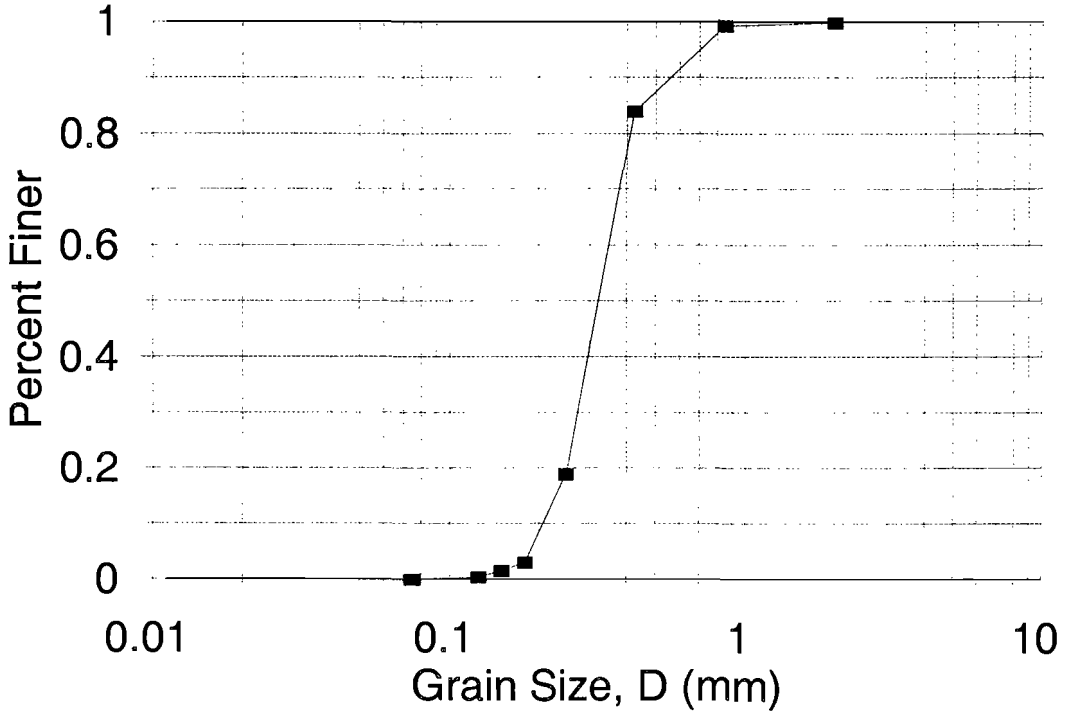
Boundary Canal Baffle Box
03/26/02

Seive Number	Grain Size (mm)	Weight of Sediment (grams)	Percent Retained on Seive	Cummulative Percent Retained	Percent Finer
10	2.000	0.17	0.08%	0.08%	99.92%
20	0.850	1.03	0.50%	0.59%	99.41%
40	0.425	31.51	15.42%	16.01%	83.99%
60	0.250	132.95	65.07%	81.08%	18.92%
80	0.180	32.21	15.76%	96.84%	3.16%
100	0.150	3.09	1.51%	98.36%	1.64%
120	0.125	2.25	1.10%	99.46%	0.54%
200	0.075	1.07	0.52%	99.98%	0.02%
PAN	>0.075	0.04	0.02%	100.00%	0.00%
	Total	204.32	100.00%		

D10= 0.21
D30= 0.27
D60= 0.35

Uniformity Coefficient= 1.67
Coefficient of Gradiation= 0.99

Moisture Content= 18.2 %
Organic Content= 8.8 %



Boundary Canal Baffle Box
11/15/02

Seive Number	Grain Size (mm)	Weight of Sediment (grams)	Percent Retained on Seive	Cummulative Percent Retained	Percent Finer
10	2.000	0.55	0.31%	0.31%	99.69%
20	0.850	0.56	0.31%	0.62%	99.38%
40	0.425	12.32	6.86%	7.48%	92.52%
60	0.250	50.51	28.13%	35.61%	64.39%
80	0.180	71.55	39.85%	75.46%	24.54%
100	0.150	14.53	8.09%	83.55%	16.45%
120	0.125	17.36	9.67%	93.22%	6.78%
200	0.075	11.98	6.67%	99.89%	0.11%
PAN	>0.075	0.19	0.11%	100.00%	0.00%
	Total	179.55	100.00%		

D10= 0.14
D30= 0.19
D60= 0.25

Uniformity Coefficient= 1.79
Coefficient of Gradiation= 1.03

Moisture Content= 17.3
Organic Content= 8.8 %