City of Naples

Beach Outfall Management Evaluation

FINAL Technical Memorandum
on
Beach Stormwater Outfalls Hydrologic and Hydraulic
Modeling for Existing Conditions

Prepared For
City of Naples

Prepared by:

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November 2012

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1 INTRODUCTION

1.0 Background

The Naples Beach Stormwater Outfalls Hydrologic and Hydraulic Modeling study area is located in the southern portion of the City of Naples Basin II. Drainage Basin II is one of the main basins serving the City of Naples with a contributing area of approximately 920 acres. The drainage system consists of a series of catch basins and pipes that convey stormwater to the beach outfalls. There are ten (10) stormwater outfalls within Basin II discharging to the Gulf of Mexico along Naples Beach. Outfall #1 only serves private property and is privately owned and operated; therefore, it is not included in this study. The model study area for the remaining nine (9) outfalls has an approximate drainage area of 395 acres. Under current conditions the City experiences flooding in the low areas close to the beach. According to the Florida Department of Environmental Protection (FDEP), there is an ongoing concern that stormwater runoff discharged to the Gulf of Mexico via the beach outfalls likely affects beach erosion, impacts turtle nesting habitat, interferes with lateral beach access, and degrades water quality. The City is also concerned about these issues and aesthetics. However, in 2009 there was minimal to no impact on turtle nesting, water quality and beach erosion.

This Existing Conditions Technical Memorandum documents the work related to Task 4 – Development of Stormwater System Model of the City of Naples – Beach Stormwater Outfall Project. This activity is the first part of a study to identify a series of alternatives that will consider measures within the drainage basin to reduce the impacts of the outfalls on the beach while maintaining the same or greater level of service as compared to the existing conditions.

1.1 Objectives

The objective of this task is to prepare a stormwater model using XP-SWMM to be used in the analysis of alternatives for the City of Naples Beach Stormwater Outfalls. The hydrologic (RUNOFF) and hydraulic (EXTRAN) modules of XP-SWMM were applied to simulate flows and stages across the study area. More specifically, the objectives of this task are as follows:

- Develop a stormwater model of the nine (9) beach outfalls within Basin II operated by the City of Naples using XP-SWMM.
- Model Verification and Validation.
- Prepare production runs for existing conditions without alternatives for design storm events (5-year 1-hour storm, 5-year 1-day, and 25 and 100-year, 3-day storms).

2 MODEL CONSTRUCTION

A stormwater model was prepared covering the drainage area of the nine (9) Beach Outfalls within Basin II. This model does not cover the entire area of Basin II. Only the areas draining towards the outfalls owned by the City are represented in the model. The nine (9) outfalls are included in a single model.

2.1 Data Compilation and Evaluation

The data provided by the City of Naples for the limit of the study area were reviewed as part of the initial activities in this task. A reconnaissance visit of the basin was also performed to identify the major drainage structures required for the model construction. Based on this visit, a list of additional data needs (invert elevation and control structure dimensions) was prepared. This list was used to obtain additional survey data needed to complete the model. A copy of the survey is provided with this Technical Memorandum (**Appendix A**), as well as the electronic files (**Appendix E**).

The City of Naples provided a copy of the City's GIS geodatabase. This information included topographical information (LiDAR) and aerial photographs.

The following is a list of information that was used to develop the model in addition to the information related to the storm sewer network provided by the City:

- Meteorological information obtained from the SFWMD's Basis of Design for Environmental Resources Permit, August 2000.
- Tidal information from NOAA web site: http://www.noaa.gov/
- Conceptual Stormwater Management Analysis Naples Beach Outfalls, prepared by Gulfshore Engineering Inc., November 2009.

2.2 Model Development

2.2.1 Software Description

The Stormwater Management Hydrologic and Hydraulic Model, XP-SWMM version 10.0 was utilized for this study. The XP-SWMM model is based on the original EPA SWMM, which is a comprehensive urban hydrology model that is widely used and accepted all over the world and meets all of City of Naples' modeling requirements. The main advantage of this model is that it includes the effect of storage within the basin and the interaction of this storage with the storm sewer network. The hydrologic calculations performed in the previous study cannot be directly translated to outfall flows because the assumption that the existing network has the required conveyance capacity to transport the peak flows generated during large storm events is not valid. XP-SWMM simulates the flow through the main elements of the network allowing ponding in the sub-basins. Ponded water is slowly drained by the network when tailwater stages recede.

XP-SWMM applies links and nodes that execute hydrology, hydraulics, and quality analysis of stormwater systems, water quality control devices and best management practices (BMPs). Nodes symbolize the junction of hydraulic links and also function as a location for input of flow and pollutants into the drainage system. A node can also represent a storage device such as a pond or lake, a point junction representing a point of change in a channel or conduit geometry, a boundary condition in the model, and a watershed in RUNOFF. Links represent hydraulic elements for flow and element transport through the system. Examples of elements stored in links include pipes, channels, pumps and weirs.

XP-SWMM has three layers. The first layer, called the RUNOFF layer, is a stormwater layer for hydrology and water quality. The runoff block (or layer) creates surface runoff and subsurface flow based on design or measured rainfall hyetographs, antecedent conditions, land use, soils, hydraulic properties and topography. This layer includes several different runoff generating methods including kinematic wave, Laurenson, SCS, and unit hydrograph method.

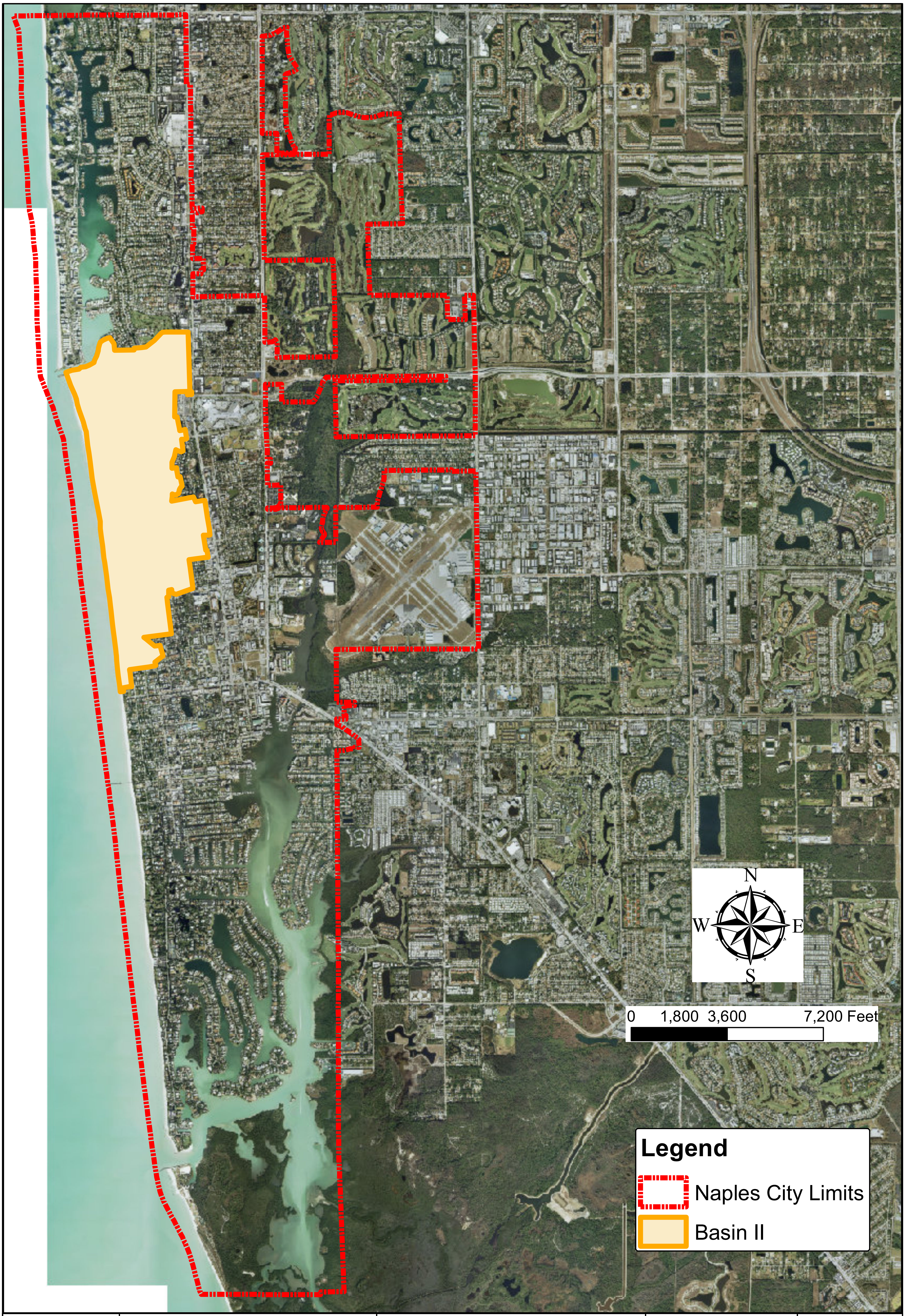
The second layer is the TRANSPORT layer, which is a sanitary layer that produces wastewater flows including storage/treatment for BMPs and water quality routing. This layer was not used in the present study but it represents a potential use for the model in case water quality calculations are required.

The final layer is the EXTRAN layer. This layer is the hydraulics layer for the hydraulic simulation of open and closed conduit stormwater systems, including canals and culverts.

2.2.2 Study Area

The study area comprises the southern portion of Basin II, an area of approximately 395.3 acres, located in the northwest part of the City of Naples. **Figure 1** shows the study area.

Figure 2 shows the location of the nine beach outfalls modeled, and **Table 1** presents the area breakdown of the outfalls.



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Study Area

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Figure 1

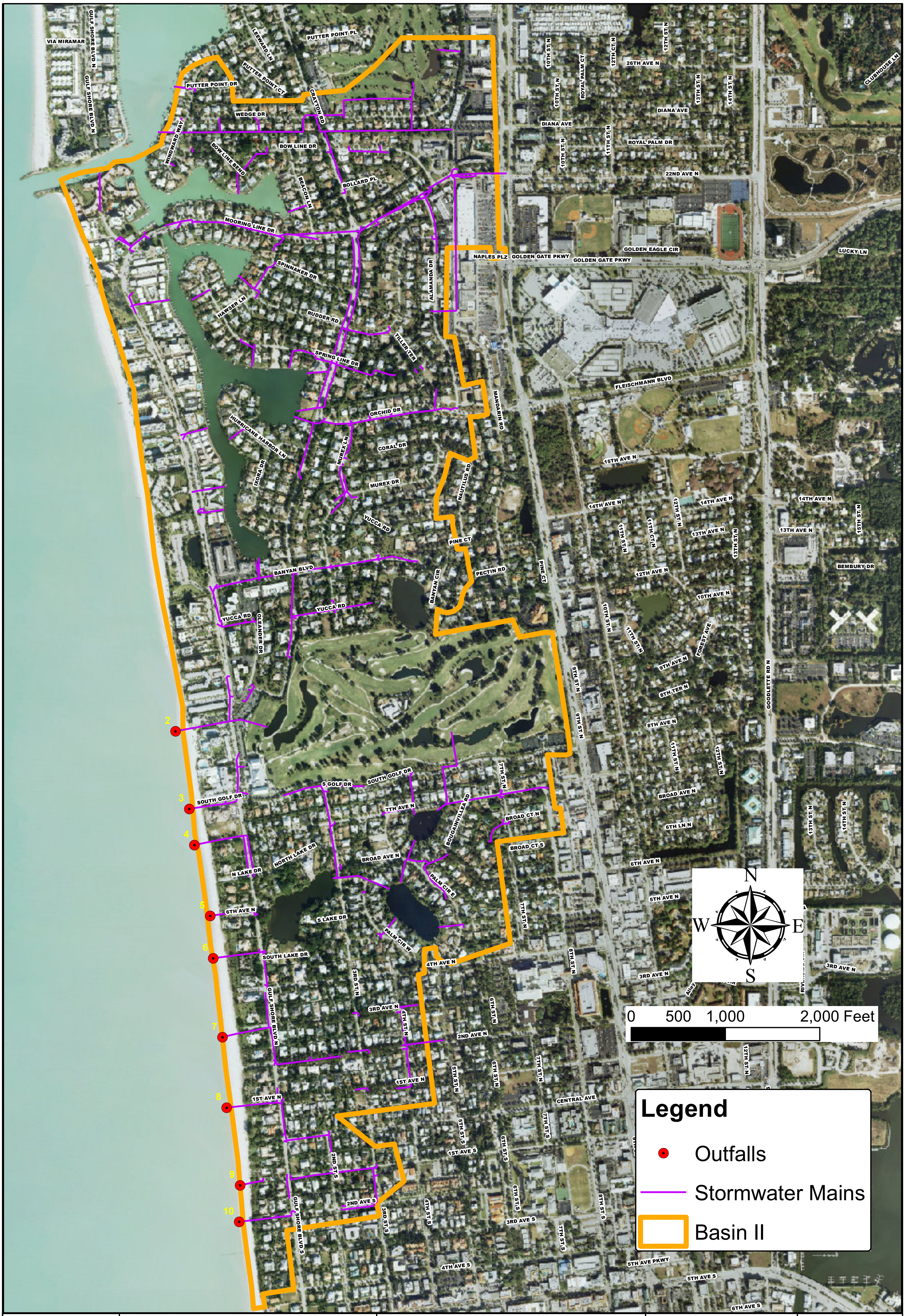

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Figure 2

Table 1: Model Sub-basin Area Breakdown

Outfall Name	Contributing Area (Acres)
2_0	71.10
3_0	9.24
4_0	21.93
5_0	3.23
6_0	199.20
7_0	23.60
8_0	32.58
9_0	10.84
10_0	5.66
***11_1**	17.95
TOTAL	**395.33**

*Basin 11_1 may contribute with overland flow to outfalls 7 and 8, but it outfalls toward the east side of Basin II.

2.2.3 Drainage Sub-Basins, Nodes and Links.

The study area was divided in basins and sub-basins during the model conceptualization. The sub-basin delineation was created using the following information provided by The City of Naples:

- City of Naples GIS geo-database
- LIDAR information and aerial photographs
- Information obtained during the site visit and meeting with City officials.

Figure 3 shows the sub-basin delineation for each outfall and **Figure 4** shows the model node-link network constructed during the conceptualization phase.

The nomenclature used to name the nodes and sub-basins consisted of the outfall number followed by the sub-basin number, i.e., the node representing sub-basin 3 of outfall 2 was named is “2_3”. The link’s name contains the “from” and “to” nodes, i.e. a link connecting node 2_2 to node 2_1 was named: “2_2-2_1”.

2.2.3.1 Hydrologic Description

Table 2 includes a summary of the hydrologic characteristics of the sub-basins. The Runoff module includes separate calculations for pervious and impervious areas. The percent impervious presented in the table were obtained from the available GIS layers.

The hydrologic methodology selected within RUNOFF was the Soil Conservation Service procedure to estimate excess rainfall. This methodology is based on a Curve Number (CN) that depends on the soil type and land use. The CN used for pervious areas in the model was 80. The model assumes 100% of excess rainfall from impervious areas. A peak factor of 256 was used to describe the shape of the unit hydrograph based on the SCS methodology. Due to the size of the sub-basins a time of concentration of 10 minutes was used for all sub-basins in the model. Width and slope calculations were obtained from GIS information.

2.2.3.2 Hydraulic Description

Links in the model represent the main storm sewer pipes, control structures and overland weirs. The overland weirs were added to simulate sheet flow through the streets that occurs during major storm events.

Elevation-area tables were developed for each model sub-basin, based on surface contour maps provided by the City of Naples. These tables are provided in **Appendix B**. Elevation-area tables are essential in the model, to properly capture the effect of storage during peak discharges at the outfalls.

Table 2: Model Sub-basin Hydrological Parameters

Name	Area (Acres)	% Lakes	% Pervious	% Impervious	Width (ft)	Slope ft/ft
2_1	11.85	0.0	48.0	52.0	1475	0.004
2_2	30.60	9.2	91.5	8.5	1320	0.008
2_3	8.32	0.0	84.9	15.1	1208	0.013
2_4	20.33	20.2	73.2	26.8	1452	0.014
3_1	9.24	0.0	43.3	56.7	894	0.006
4_1	21.93	0.0	59.9	40.1	1061	0.004
5_1	3.23	0.0	67.8	32.2	521	0.013
6_1	7.61	0.0	72.4	27.6	799	0.011
6_2	22.62	25.3	86.3	13.7	1408	0.009
6_3	15.36	0.0	49.7	50.3	1228	0.003
6_4	10.27	43.5	76.6	23.4	2982	0.027
6_5	8.07	0.0	56.8	43.2	717	0.004
6_6	12.43	0.0	53.8	46.2	967	0.006
6_7	9.86	20.2	68.2	31.8	1023	0.012
6_8	18.61	0.0	57.7	42.3	811	0.002
6_9	14.19	0.0	43.5	56.5	651	0.002
6_10	15.37	0.0	45.5	54.5	1395	0.002
6_11	60.27	8.1	95.0	5.0	3500	0.011
6_12	4.54	0.0	87.4	12.6	659	0.015
7_1	15.17	0.0	60.2	39.8	730	0.005
7_2	8.43	0.0	60.2	39.8	406	0.005
8_1	12.60	0.0	56.8	43.2	603	0.004
8_2	6.69	0.0	56.8	43.2	640	0.005
8_3	8.59	0.0	56.8	43.2	815	0.004
8_4	3.48	0.0	56.8	43.2	551	0.004
8_5	1.22	0.0	56.8	43.2	180	0.003
9_1	10.84	0.0	60.8	39.2	1027	0.003
10_1	4.68	0.0	57.2	42.8	340	0.008
10_2	0.98	0.0	57.2	42.8	288	0.007
11_1	17.95	0.0	58.8	41.2	1533	0.002

*Basin 11_1 may contribute with overland flow to outfalls 7 and 8, but it outfalls toward the east side of Basin II.

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Model Sub-Basin Delineation

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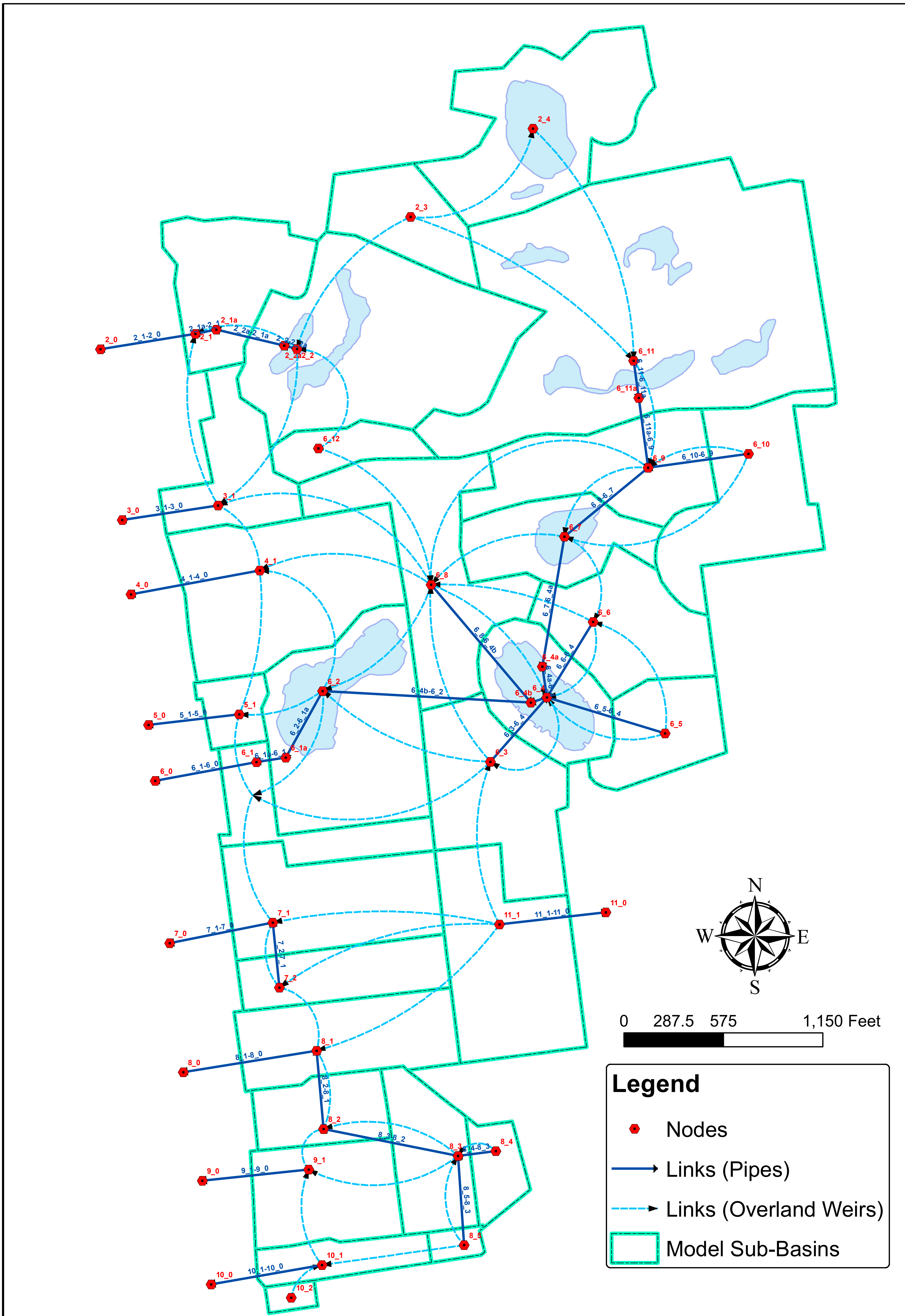
Figure 3



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Model Node-Link Network

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Figure 4

2.2.4 Rainfall

Four design storm events were modeled: the 5-year, 1-hour; 5-year, 1-day; the 25-year, and 100-year, 3-day storm events. Rainfall totals for these storms are shown in **Table 3**. Regional storm event rainfall distributions developed by the South Florida Management District (SFWMD) were used to construct rainfall hyetographs for the design storm events.

Table 3: Design Storms

Design Storm	Rainfall Amount (inches)
5-year; 1-hour	1.17
5-year; 1-day	5.50
25-year; 3-day	11.14
100-year; 3-day	14.95

2.2.5 Head Losses

Minor losses in the pipe were accounted for in the model. Entrance and exit loss coefficients for pipes were set at 0.5 and 0.9, respectively.

2.2.6 Roughness

The following roughness coefficients were used for each pipe in the model:

- For reinforced concrete pipes (R.C.P.) a Manning's roughness value of 0.012 was used
- For reinforced polyvinyl chloride pipes (P.V.C.) a Manning's roughness value of 0.011 was used
- For corrugated metal pipes, a Manning's roughness of 0.021 was used
- For overland flow, a constant roughness value of 0.034 was used

Note: All pipes were assumed free of sediment deposit and debris.

2.2.7 Tidal Information

The tidal information used in the model was obtained from the NOAA web site (http://www.noaa.gov/). Values corresponding to August 2012 were used. **Appendix C** shows the historical tide elevations used in the model as a tailwater or downstream boundary condition in all beach outfalls.

3 MODEL VALIDATION

No historical information was available to prepare formal model validation statistics or plots. However, a series of comparisons were performed with previous studies to verify that the results obtained with the model are reasonable. The storm event used to perform these comparisons was the 25-year 3-day storm. Raw hydrologic calculations obtained (prior to hydraulic routing) with the XP-SWMM model were compared with the total runoff volume obtained in the previous study (Gulfshore Engineering Study, 2009). **Table 4** includes this comparison. The comparison was done based on total runoff volume and not based on peak flows because the number and size of the sub-basins used in the current study is different than those used in the previous study.

Table 4: Total Runoff Volume Comparison

Outfall	Previous Study Runoff Volume Ac-ft	Model Runoff Volume Ac-ft
2	79.5	53.7
3	8.3	7.6
4	13.8	17.3
5	3.8	2.5
6	102.6	137.2
7	25.6	18.6
8	36.5	20.3
9	7.1	8.6
10	10.1	2.4
*11	NA	14.2
Total =	287.3	282.4

*Basin 11 may contribute overland flow to outfalls 7 and 8, but it outfalls toward the east side of Basin II.

Table 5 compares the total volume produced by the RUNOFF module with the total volume output in the EXTRAN module for each outfall.

Table 5: RUNOFF and EXTRAN Total Volume Comparison

Outfall	RUNOFF Volume Ac-ft	EXTRAN Volume Ac-ft	Difference Volume Ac-ft
2	53.71	45.86	7.84
3	7.60	9.80	-2.20
4	17.34	17.00	0.35
5	2.51	4.79	-2.28
6	137.16	142.23	-5.07
7	18.64	26.22	-7.58
8	20.25	26.48	-6.22
9	8.55	9.53	-0.98
10	2.38	6.20	-3.83
11	14.23	6.54	7.69
TOTAL	282.37	294.65	-12.28

Results shown in **Table 4** indicate a good match in the hydrological calculations despite the differences in the approach used to compute runoff. The volume comparison shown in **Table 5** validates the assumption made in the model for the starting conditions in the basin. The starting or initial water levels used in each sub-basin indicate the amount of storage being used before the start of the storm.

4 MODEL RESULTS

Production runs were prepared for the following storm events:

- 1-hour 5-year
- 24-hour 5-year
- 72-hour 25-year
- 72-hour 100-year

Appendix D presents flow and stage hydrographs for the nine (9) outfalls obtained with each one of the production runs. **Appendix E** contains electronic copies of the model input files and model output text files. **Table 6** presents a summary of the peak stages at each model node for all production runs, and **Table 7** shows a summary of the peak flow at each outfall for the different storm events modeled.

Table 6: Model Peak Stages for all Storm Events

Node Name	** Main Road Elevation (ft NGVD)	1 hour 5-yr Max Water Elevation (ft NGVD)	24-hour 5-yr Max Water Elevation (ft NGVD)	72-hour 25-yr Max Water Elevation (ft NGVD)	72-hour 100-yr Max Water Elevation (ft NGVD)
10_1	Golf Shore Blvd varies 4.5 – 5.0	4.93	5.00	5.66	6.27
10_0	Outfall	3.62	3.62	3.62	3.62
9_1	Golf Shore Blvd varies 4.5 – 5.0	4.96	5.00	5.66	6.27
9_0	Outfall	3.62	3.62	3.62	3.62
8_2	Golf Shore Blvd varies 4.5 – 5.0	4.87	4.96	5.61	6.27
8_1	Golf Shore Blvd varies 4.5 – 5.0	4.76	4.93	5.61	6.27
8_0	Outfall	3.62	3.62	3.62	3.62
7_2	Golf Shore Blvd varies 4.5 – 5.0	4.87	4.94	5.60	6.27
7_1	Golf Shore Blvd varies 4.0 – 4.5	4.36	4.48	5.42	6.27
7_0	Outfall	3.62	3.62	3.62	3.62
11_1	3rd street N varies 8.5 – 9.0	8.32	8.64	8.83	8.88
11_0	Outfall	3.50	3.50	3.50	3.50
6_10	7th Ave N varies 8.5 – 10.5	7.40	8.55	9.29	9.35
6_8	3rd Street N varies 7.5 – 8.5	6.31	6.90	7.73	7.97
6_6	Palm Circle E varies 7.5 – 9.0	5.80	7.04	8.12	8.19
6_7	7th Ave N varies 7.0 – 8.5	4.84	6.12	8.02	8.42
6_4	NA Lake	4.08	5.01	7.03	7.68
6_3	Palm Circle W varies 7.0 – 8.5	7.87	7.88	8.06	8.22
6_2	South Lake Dr varies 4.5 – 8.0	3.50	3.66	5.42	6.27
6_5	5th Avenue N varies 8.5 – 9.0	8.39	8.48	8.65	8.73
6_1	Golf Shore Blvd varies 4.0 – 4.5	3.50	3.50	5.42	6.27
6_0	Outfall	3.62	3.62	3.62	3.62

Table 6 (Continued)
Model Peak Stages for all Storm Events

Node Name	** Main Road Elevation (ft NGVD)	1 hour 5-yr Max Water Elevation (ft NGVD)	24-hour 5-yr Max Water Elevation (ft NGVD)	72-hour 25-yr Max Water Elevation (ft NGVD)	72-hour 100-yr Max Water Elevation (ft NGVD)
4_1	Golf Shore Blvd varies 4.5 – 5.0	4.50	4.54	5.43	6.27
4_0	Outfall	3.62	3.62	3.62	3.62
3_1	Golf Shore Blvd varies 4.5 – 5.5	4.47	4.60	5.63	6.28
3_0	Outfall	3.62	3.62	3.62	3.62
2_3	NA Golf Course	9.10	9.40	9.74	9.84
2_1	Golf Shore Blvd varies 4.5 – 5.0	3.56	3.56	5.63	6.27
2_0	Outfall	3.62	3.62	3.62	3.62
6_9	South Golf Dr. varies 7.5 – 12.0	5.00	6.13	8.04	8.44
5_1	Golf Shore Blvd varies 4.0 – 4.5	4.25	4.27	5.42	6.27
5_0	Outfall	3.62	3.62	3.62	3.62
10_2	NA residential, no roads within basin	5.60	5.60	5.66	6.27
2_2	NA Golf Course	4.57	5.63	6.45	6.56
8_3	1st Avenue S varies 6.5 – 8.5	4.47	5.96	6.97	7.11
8_4	1st Avenue S varies 9.0 – 9.5	4.47	5.96	6.97	7.11
8_5	2nd Avenue S varies 8.0 – 9.5	8.53	8.56	8.60	8.62
2_4	NA Golf Course	4.05	4.83	6.73	7.97
6_1a	Golf Shore Blvd varies 4.5 – 5.0	3.50	3.56	5.42	6.27
6-4a	NA Lake	3.50	5.79	7.47	7.90
6_11a	NA Golf Course	3.50	3.50	8.06	8.45
6_4b	NA Lake	3.70	4.15	5.83	6.62
2_2a	NA Golf Course	3.56	3.68	6.35	6.37
2_1a	Golf Shore Blvd varies 4.5 – 5.5	3.56	3.56	5.65	6.29
6_11	NA Golf Course	4.64	6.47	8.63	8.91
6_12	NA Golf Course	4.77	6.81	7.73	7.97
11_1a	3rd street N varies 8.5 – 9.0	8.26	8.55	8.74	8.79

** The range of elevations in the main road does not necessarily represent the lowest elevation of the sub-basin.

Table 7: Model Peak Flows for all Storm Events

Outfall	1 hour 5-year Max Flow (cfs)	24-hour 5-year Max Flow (cfs)	72-hour 25-year Max Flow (cfs)	72-hour 100-year Max Flow (cfs)
2	16.13	18.26	64.71	70.94
3	8.88	9.31	10.56	11.39
4	9.62	9.24	10.94	11.94
5	5.33	5.33	6.42	7.15
6	21.96	27.20	61.57	68.97
7	18.54	17.95	21.14	23.06
8	29.94	31.15	33.91	36.60
9	7.62	7.68	8.53	9.31
10	9.29	9.22	10.36	10.96
Total	**127.3**	**135.3**	**228.1**	**250.3**

5 SENSITIVITY ANALYSIS

A sensitivity analysis was performed to evaluate the effect of the percent impervious in model results. For this analysis, the percent impervious was re-calculated under a less conservative assumption, thus resulting in smaller values. **Table 8** compares the original and the modified percent impervious for each sub-basin. The 24-hour 5-year and the 72-hour 25-year models were re-run using the modified percent impervious. Results from these runs are presented in **Table 9**. As seen in **Table 9**, changes in percent impervious do not have a significant effect on the peak flows for each outfall. This is due to the fact that the size of the peak flows are a stronger function of the outfall pipe sizes than of the total runoff in the basin.

Table 8: Alternate Percent Impervious used in the Sensitivity Analysis

Name	% Impervious original	% Impervious used in the Sensitivity Analysis
2_1	52.0	49.4
2_2	8.5	5.9
2_3	15.1	12.5
2_4	26.8	24.2
3_1	56.7	38.9
4_1	40.1	17.9
5_1	32.2	15.3
6_1	27.6	14.7
6_2	13.7	1.9
6_3	50.3	20.3
6_4	23.4	0.0
6_5	43.2	13.8
6_6	46.2	16.4
6_7	31.8	11.0
6_8	42.3	23.1
6_9	56.5	23.8
6_10	54.5	22.2
6_11	5.0	5.0
6_12	12.6	12.6
7_1	39.8	15.9
7_2	39.8	15.9
8_1	43.2	18.1

Table 8: Alternate Percent Impervious used in the Sensitivity Analysis (cont')

Name	% Impervious original	% Impervious used in the Sensitivity Analysis
8_2	43.2	18.1
8_3	43.2	18.1
8_4	43.2	18.1
8_5	43.2	18.1
9_1	39.2	13.0
10_1	42.8	20.3
10_2	42.8	20.3
11_1	41.2	16.7

Table 9: Sensitivity Analysis Results

Outfall	24-hour 5-year Max Flow (cfs)	72-hour 25-year Max Flow (cfs)	24-hour 5-year Sensitivity Analysis Max Flow (cfs)	72-hour 25-year Sensitivity Analysis. Max Flow (cfs)	24-hour 5-year Difference. Max Flow (cfs)	72-hour 25-year Difference Max Flow (cfs)
2	18.26	64.71	17.98	64.47	0.28	0.24
3	9.31	10.56	9.10	10.53	0.21	0.03
4	9.24	10.94	9.21	10.83	0.03	0.11
5	5.33	6.42	5.33	6.33	0.00	0.09
6	27.20	61.57	23.43	60.62	3.77	0.95
7	17.95	21.14	17.71	20.92	0.24	0.22
8	31.15	33.91	30.30	33.78	0.85	0.13
9	7.68	8.53	7.60	8.45	0.08	0.08
10	9.22	10.36	9.13	10.31	0.09	0.05
Total	**135.3**	**228.1**	**129.8**	**226.2**	**5.55**	**1.90**

6 REFERENCES

Gulfshore Engineering Inc., Conceptual Stormwater Management Analysis, Naples Beach Outfall, November 2009

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XP-Software, XP-SWMM Users manual, 2009

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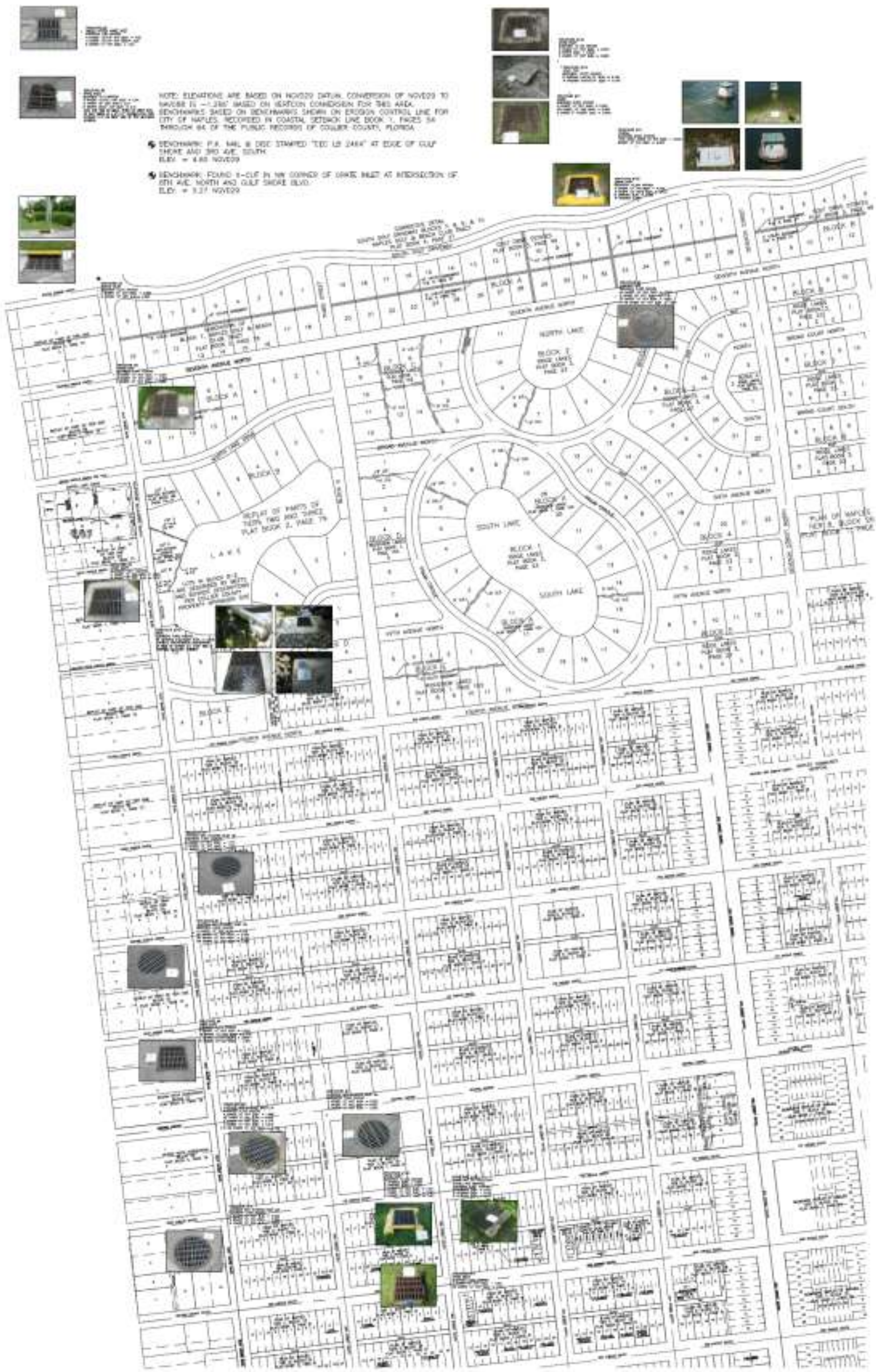
APPENDIX A
Additional Survey provided by Stantec


NOTE: ELEVATIONS ARE BASED ON NGVD29 DATUM. CONVERSION OF NGVD29 TO
BENCHMARKS BASED ON BENCHMARKS SHOWN ON EROSION CONTROL LINE FOR CITY OF NAPLES RECORDED IN COASTAL SETBACK LINE BOOK 1, PAGES 54 THROUGH 64 OF THE PUBLIC RECORDS OF COLLIER COUNTY, FLORIDA.
BENCHMARK: FOUND X-CUT IN NW CORNER OF GRATE INLET AT INTERSECTION OF 8TH AVE. NORTH AND GULF SHORE BLVD.
NORTH LAKE
SOUTH LAKE
LAKE

APPENDIX B

Elevation-Area Tables

Basin	Stage (ft)	Area (Acres)
2_1	0.0	0.00
	5.0	1.53
	6.0	7.91
	7.0	10.50
	9.5	11.85

Basin	Stage (ft)	Area (Acres)
2_2	0.0	0.00
	4.5	2.82
	6.0	6.53
	7.0	10.29
	10.0	21.60
	15	30.6

Basin	Stage (ft)	Area (Acres)
2_3	0.0	0.00
	8.5	0.10
	10.0	2.41
	12.0	7.28
	15.0	8.32

Basin	Stage (ft)	Area (Acres)
2_4	0.0	0.00
	7.0	4.10
	10.0	5.75
	12.0	14.75
	15.0	20.33

Basin	Stage (ft)	Area (Acres)
3_1	0.0	0.00
	5.0	0.65
	6.0	2.85
	8.0	6.82
	10.0	9.24

Basin	Stage (ft)	Area (Acres)
4_1	0.0	0.00
	4.0	0.24
	5.0	2.89
	6.0	8.48
	8.0	16.80
	12	21.93

Basin	Stage (ft)	Area (Acres)
5_1	0.0	0.00
	4.0	0.013
	5.0	1.97
	7.0	2.52
	10.5	3.23

Basin	Stage (ft)	Area (Acres)
6_1	0.0	0.00
	3.0	0.23
	5.0	1.25
	6.0	2.16
	8.0	5.08
	10	7.61

Basin	Stage (ft)	Area (Acres)
6_2	0.0	0.00
	3.0	5.73
	5.0	7.88
	7.0	15.17
	9.0	18.10
	12	22.62

Basin	Stage (ft)	Area (Acres)
6_3	0.0	0.00
	7.0	0.05
	7.5	0.59
	9.0	7.09
	11.5	15.36

Basin	Stage (ft)	Area (Acres)
6_4	0.0	0.00
	4.0	4.47
	6.0	5.18
	8.0	7.40
	10.0	10.27

Basin	Stage (ft)	Area (Acres)
6_5	0.0	0.00
	8.0	0.10
	10.0	2.61
	12.0	4.90
	13.5	8.08

Basin	Stage (ft)	Area (Acres)
6_6	0.0	0.00
	8.0	0.70
	10.0	5.45
	12.0	10.20
	15.0	12.43

Basin	Stage (ft)	Area (Acres)
6_7	0.0	0.00
	3.5	1.99
	6.0	2.30
	8.0	5.18
	11.0	9.86

Basin	Stage (ft)	Area (Acres)
6_8	0.0	0.00
	7.0	0.95
	8.0	8.40
	9.0	16.50
	10.0	18.61

Basin	Stage (ft)	Area (Acres)
6_9	0.0	0.00
	7.5	0.60
	9.0	7.77
	11.0	12.33
	13.0	14.19

Basin	Stage (ft)	Area (Acres)
6_10	0.0	0.00
	9.0	0.53
	11.0	6.20
	13.0	12.68
	15.0	15.36

Basin	Stage (ft)	Area (Acres)
6_11	0.0	0.00
	6.5	4.88
	10.0	18.00
	11.0	31.73
	13.0	49.00
	16	60.27

Basin	Stage (ft)	Area (Acres)
6_12	0.0	0.00
	6.5	0.35
	8.0	2.30
	10.0	3.74
	12.0	4.54

Basin	Stage (ft)	Area (Acres)
7_1	0.0	0.00
	4.0	0.42
	5.0	2.41
	7.0	9.65
	10.5	15.17

Basin	Stage (ft)	Area (Acres)
7_2	0.0	0.00
	4.0	0.04
	5.0	1.20
	7.0	4.06
	10.0	8.43

Basin	Stage (ft)	Area (Acres)
8_1	0.0	0.00
	4.5	0.23
	6.0	3.11
	8.0	8.75
	10.0	12.60

Basin	Stage (ft)	Area (Acres)
8_2	0.0	0.00
	4.5	0.37
	6.0	1.50
	8.0	5.40
	10.0	6.14
	14	6.69

Basin	Stage (ft)	Area (Acres)
8_3	0.0	0.00
	6.5	0.04
	8.0	1.66
	10.0	6.50
	12.0	8.59

Basin	Stage (ft)	Area (Acres)
8_4	0.0	0.00
	9.0	0.80
	10.0	2.68
	11.0	3.48

Basin	Stage (ft)	Area (Acres)
8_5	0.0	0.00
	8.0	0.01
	9.0	0.52
	10.0	0.96
	10.5	1.22

Basin	Stage (ft)	Area (Acres)
9_1	0.0	0.00
	4.5	0.15
	6.0	4.71
	8.0	8.53
	10.0	10.84

Basin	Stage (ft)	Area (Acres)
10_1	0.0	0.00
	4.0	0.05
	5.0	0.74
	7.0	2.62
	10.0	4.68

Basin	Stage (ft)	Area (Acres)
10_2	0.0	0.00
	5.5	0.004
	6.0	0.20
	8.0	0.63
	9.0	0.98

Basin	Stage (ft)	Area (Acres)
11_1	0.0	0.00
	8.0	0.40
	9.0	5.33
	10.0	13.10
	11.0	17.95

APPENDIX C
Tidal Curve Used in the Model

Time (hours)	Tide Elevation (msl, ft NGVD)
1	0.346
2	1.096
3	1.436
4	2.016
5	2.356
6	2.876
7	2.596
8	2.296
9	1.926
10	1.646
11	1.496
12	1.556
13	2.056
14	2.536
15	3.016
16	3.426
17	3.616
18	3.436
19	2.956
20	2.406
21	1.626
22	0.896
23	0.196
24	-0.234
25	-0.074
26	0.636
27	1.326
28	1.876
29	2.346
30	2.746
31	2.706
32	2.326
33	1.996
34	1.616
35	1.346
36	1.186
37	1.336
38	1.956
39	2.586
40	3.126

Time (hours)	Tide Elevation (msl, ft NGVD)
41	3.296
42	3.436
43	3.236
44	2.796
45	2.196
46	1.536
47	0.766
48	0.076
49	-0.044
50	0.496
51	0.976
52	1.706
53	2.116
54	2.516
55	2.616
56	2.586
57	2.166
58	1.846
59	1.496
60	1.146
61	1.096
62	1.406
63	1.946
64	2.536
65	2.976
66	3.286
67	3.286
68	3.006
69	2.586
70	2.066
71	1.256
72	0.746
73	0.236
74	0.106
75	0.686
76	1.116
77	1.916
78	2.486
79	2.556
80	2.696

Time (hours)	Tide Elevation (msl, ft NGVD)
81	2.486
82	2.026
83	1.606
84	1.286
85	1.056
86	1.016
87	1.466
88	1.956
89	2.556
90	2.866
91	3.146
92	3.176
93	2.906
94	2.436
95	1.856
96	1.376
97	0.936
98	0.376
99	0.616
100	1.126
101	1.816
102	2.236
103	2.576
104	2.686
105	2.616
106	2.346
107	2.026
108	1.506
109	0.996
110	0.716
111	0.816
112	1.376
113	1.896
114	2.316
115	2.776
116	2.846
117	2.756
118	2.506
119	2.046
120	1.496

Time (hours)	Tide Elevation (msl, ft NGVD)
121	1.046
122	0.676
123	0.526
124	0.796
125	1.406
126	1.896
127	2.346
128	2.516
129	2.546
130	2.256
131	1.976
132	1.676
133	1.256
134	0.836
135	0.626
136	0.856
137	1.376
138	1.926
139	2.286
140	2.546
141	2.956
142	2.526
143	2.156
144	1.786
145	1.576
146	1.326
147	1.176
148	1.096
149	1.496
150	1.946
151	2.186
152	2.566
153	2.956
154	2.756
155	2.526
156	1.916
157	1.526
158	1.186
159	0.926
160	0.776

Time (hours)	Tide Elevation (msl, ft NGVD)
161	0.996
162	1.396
163	1.776
164	2.116
165	2.316
166	2.326
167	2.306
168	2.166
169	2.086
170	1.746
171	1.536
172	1.306
173	1.526
174	1.916
175	2.316
176	2.586
177	2.766
178	2.866
179	2.706
180	2.426
181	2.206
182	1.696
183	1.286
184	0.966
185	0.876
186	1.076
187	1.446
188	1.796
189	2.126
190	2.146
191	2.206
192	2.206
193	1.956
194	1.806
195	1.606
196	1.596
197	1.386
198	1.436
199	1.786
200	2.056

Time (hours)	Tide Elevation (msl, ft NGVD)
201	2.446
202	2.676
203	2.666
204	2.506
205	2.216
206	1.776
207	1.346
208	1.146
209	0.976
210	0.856
211	0.916
212	1.126
213	1.506
214	1.766
215	2.026
216	2.196
217	2.136
218	2.176
219	2.206
220	1.646
221	1.836
222	1.556
223	1.886
224	2.066
225	2.356
226	2.616
227	2.816
228	2.876
229	2.636
230	2.476
231	2.056
232	1.716
233	1.226
234	0.966
235	0.866
236	0.866
237	1.096
238	1.476
239	1.716
240	1.906

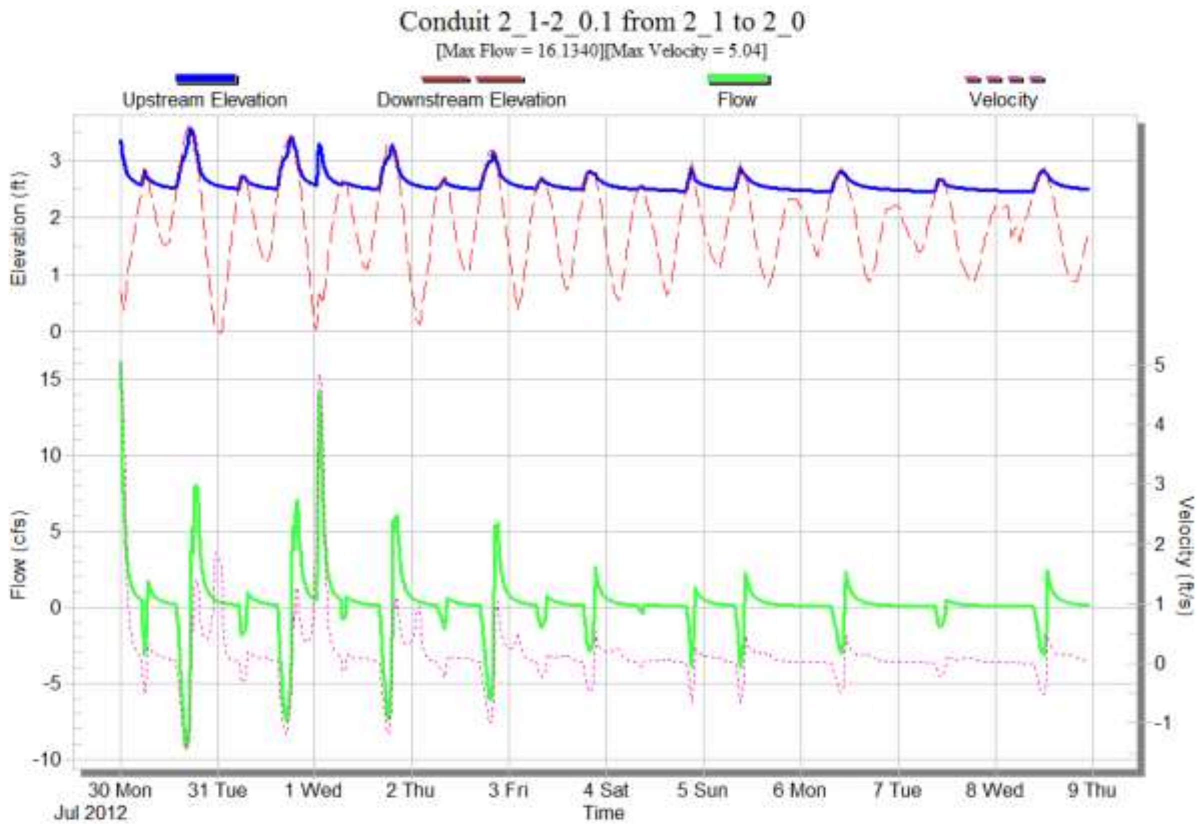
Time (hours)	Tide Elevation (msl, ft NGVD)
241	2.006
242	1.926
243	1.866
244	1.996
245	1.966
246	1.716
247	1.736
248	2.196
249	2.226
250	2.456
251	2.516
252	2.616
253	2.836
254	2.776
255	2.436
256	2.056
257	1.566
258	1.286
259	0.896
260	0.516
261	0.736
262	0.916
263	1.326
264	1.586
265	1.746
266	1.906
267	2.146
268	2.186
269	2.076
270	1.986
271	2.016
272	2.006
273	1.976
274	2.216
275	2.406
276	2.656
277	2.866
278	2.876
279	2.556
280	2.376

Time (hours)	Tide Elevation (msl, ft NGVD)
281	1.926
282	1.256
283	0.956
284	0.576
285	0.376
286	0.446
287	0.836
288	1.176
289	1.416
290	1.786
291	2.046
292	2.156
293	2.326
294	2.226
295	2.136
296	1.746
297	1.616
298	1.666
299	1.986
300	2.246
301	2.616
302	2.736
303	2.796
304	2.656
305	2.296
306	1.876
307	1.346
308	0.746
309	0.416
310	0.256
311	0.426
312	0.746
313	1.236
314	1.566
315	1.886
316	2.136
317	2.186
318	2.136
319	2.036
320	1.786

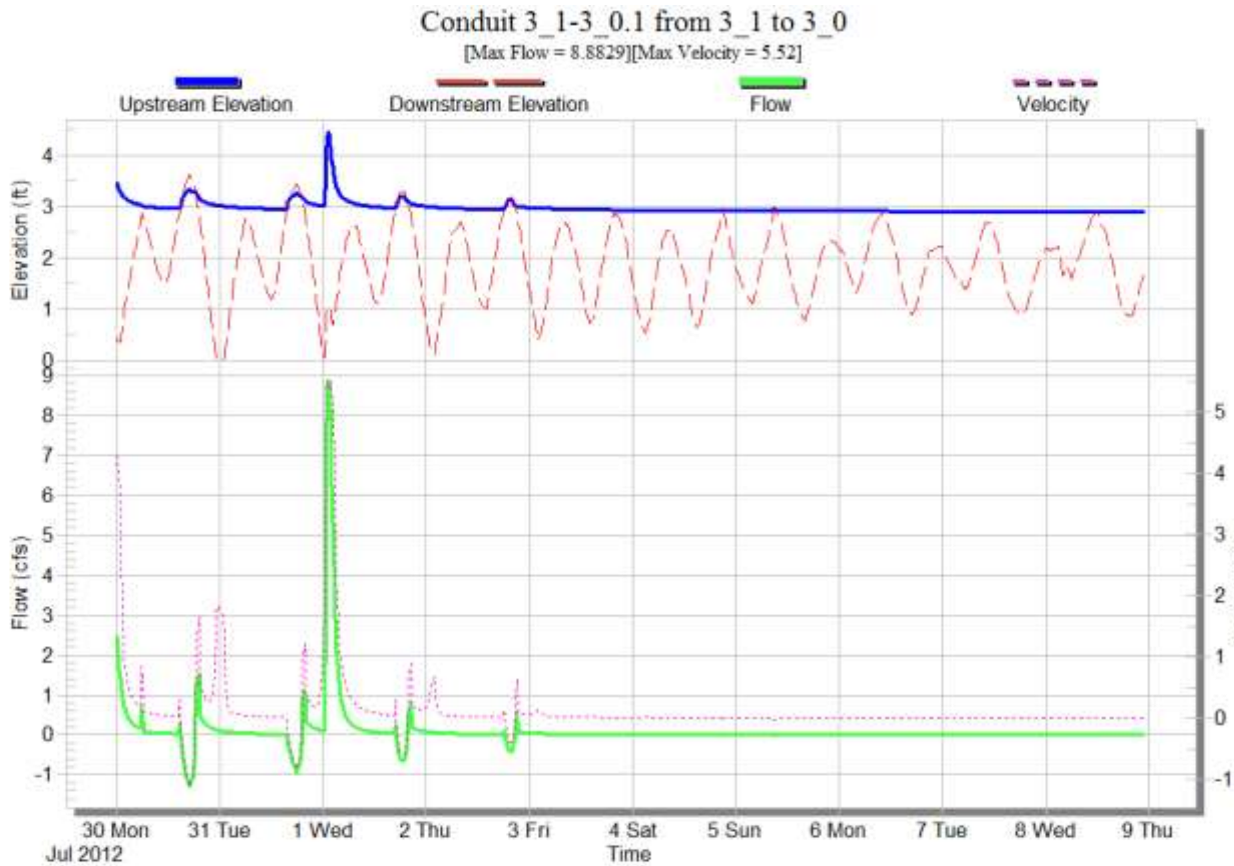
Time (hours)	Tide Elevation (msl, ft NGVD)
321	1.656
322	1.546
323	1.696
324	2.006
325	2.376
326	2.666
327	2.766
328	2.836
329	2.566
330	2.246
331	1.776
332	1.136
333	0.536
334	0.086
335	0.046
336	0.286

APPENDIX D

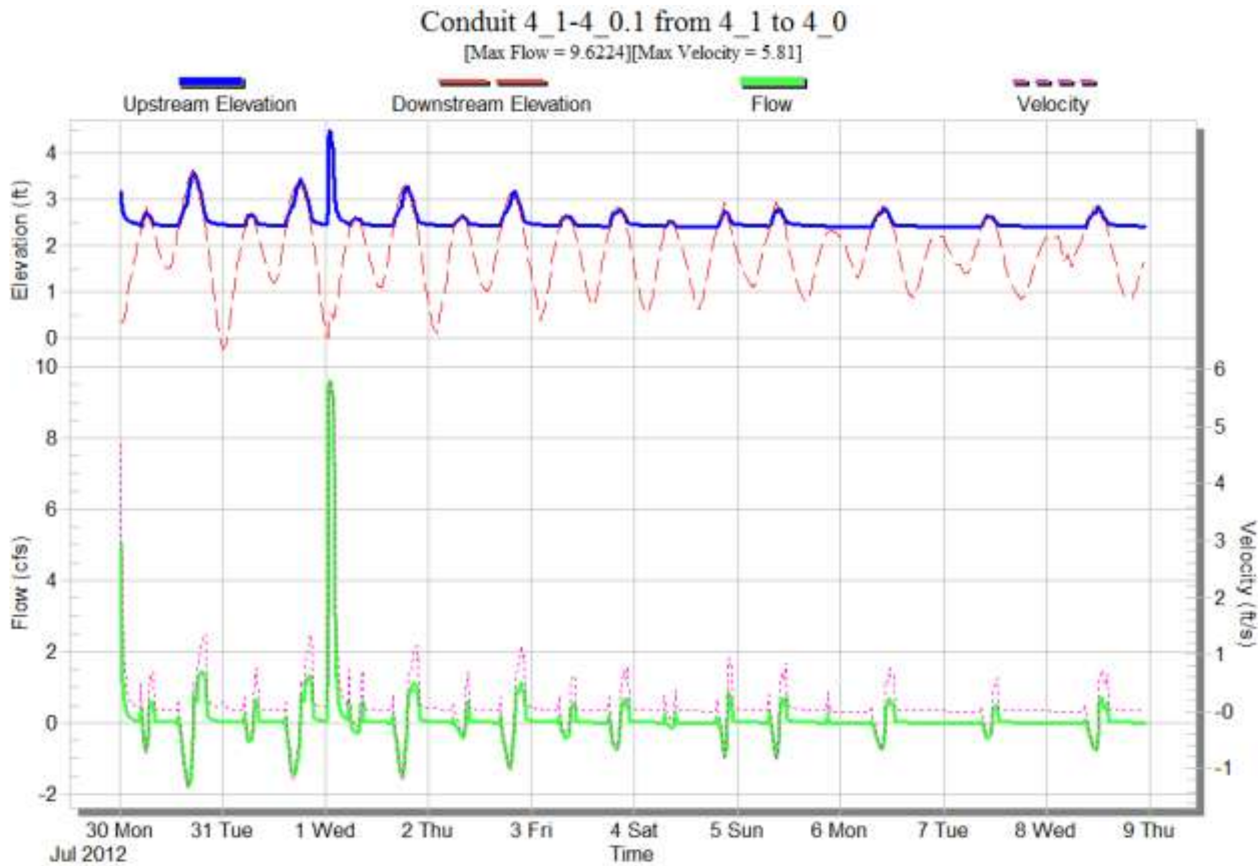
Models Results: Outfalls Stage and Flow Hydrographs



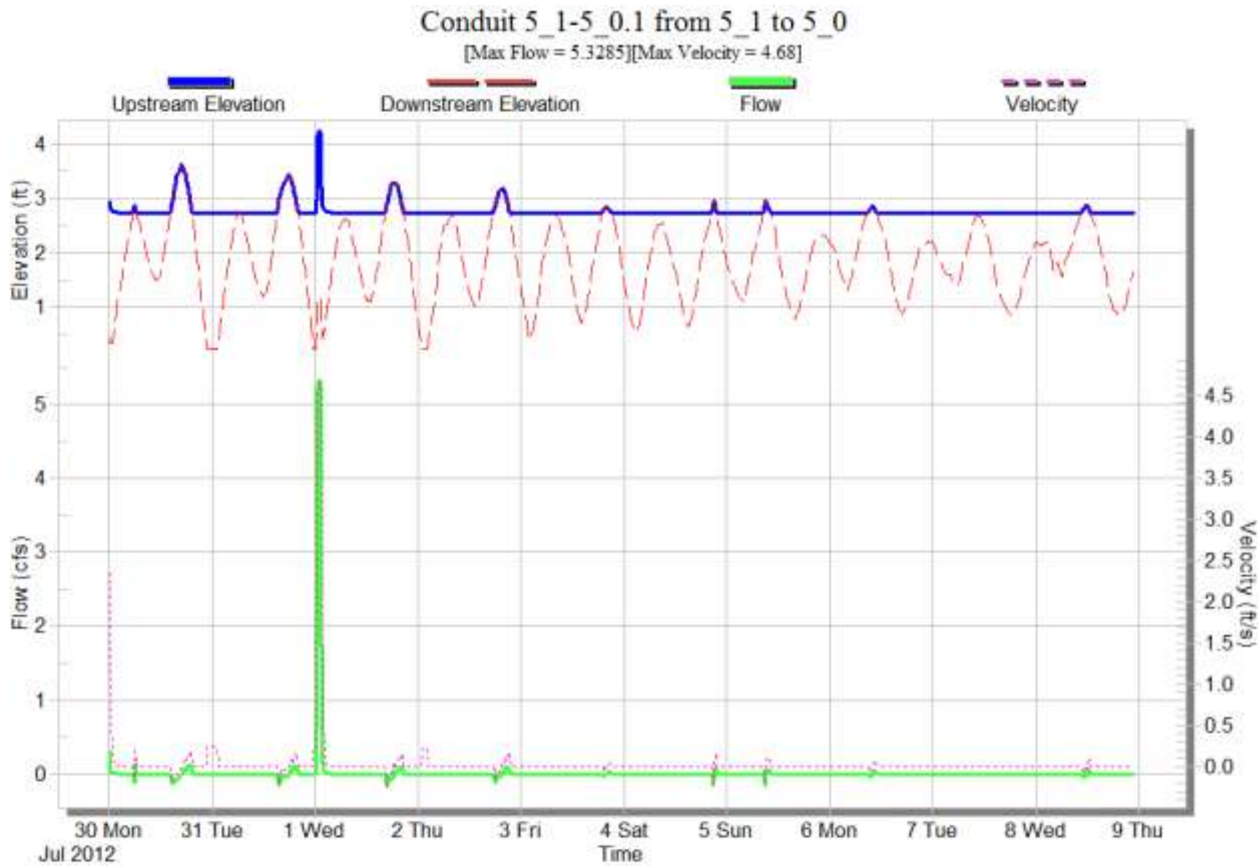
5- year, 1-hour Storm – Outfall # 2



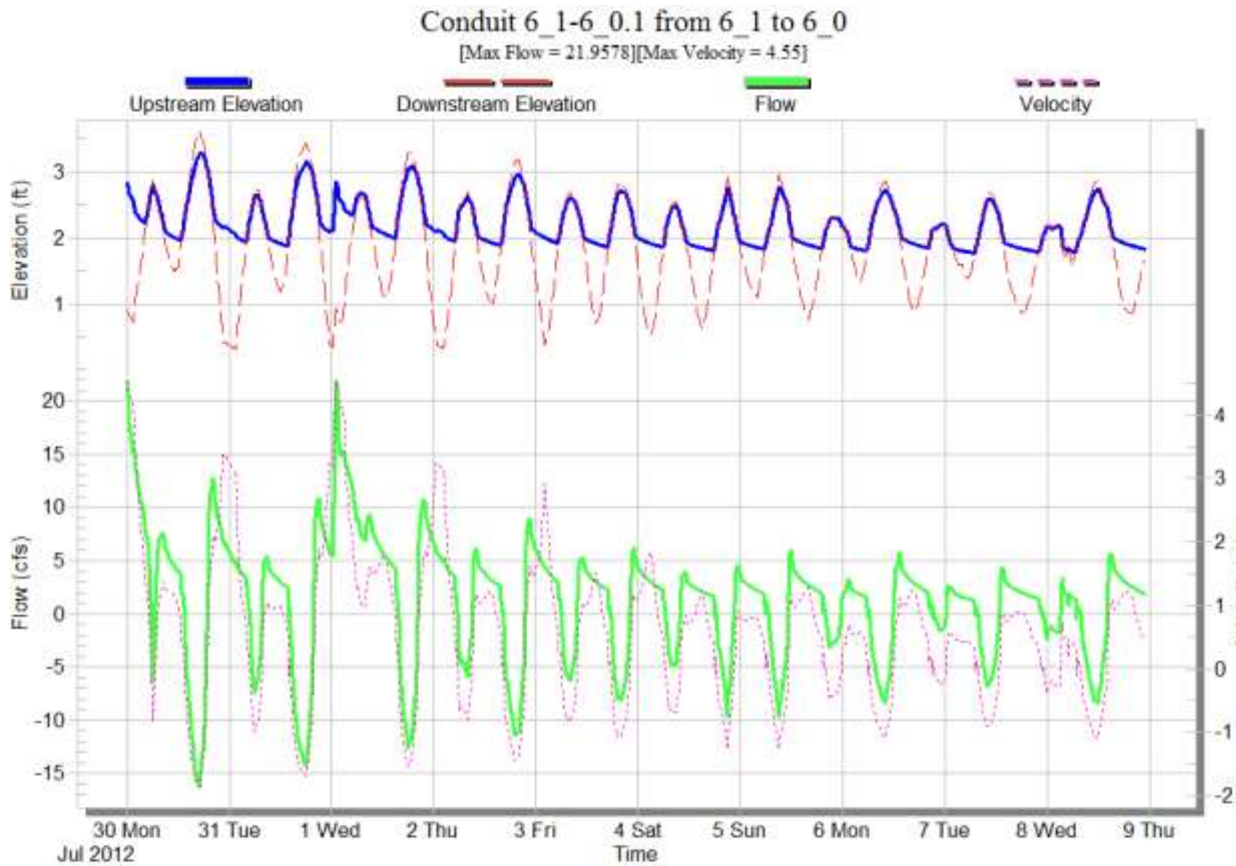
5- year, 1-hour Storm – Outfall # 3



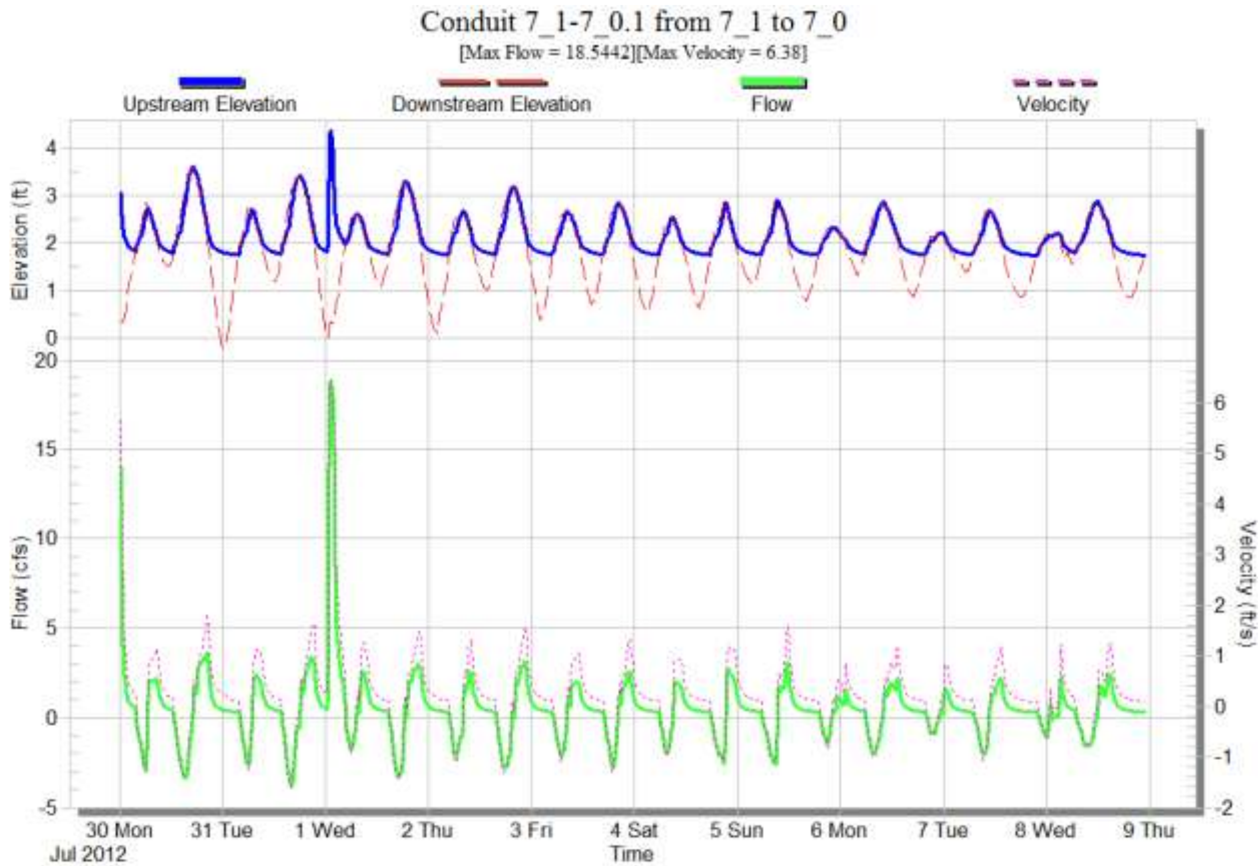
5- year, 1-hour Storm – Outfall # 4



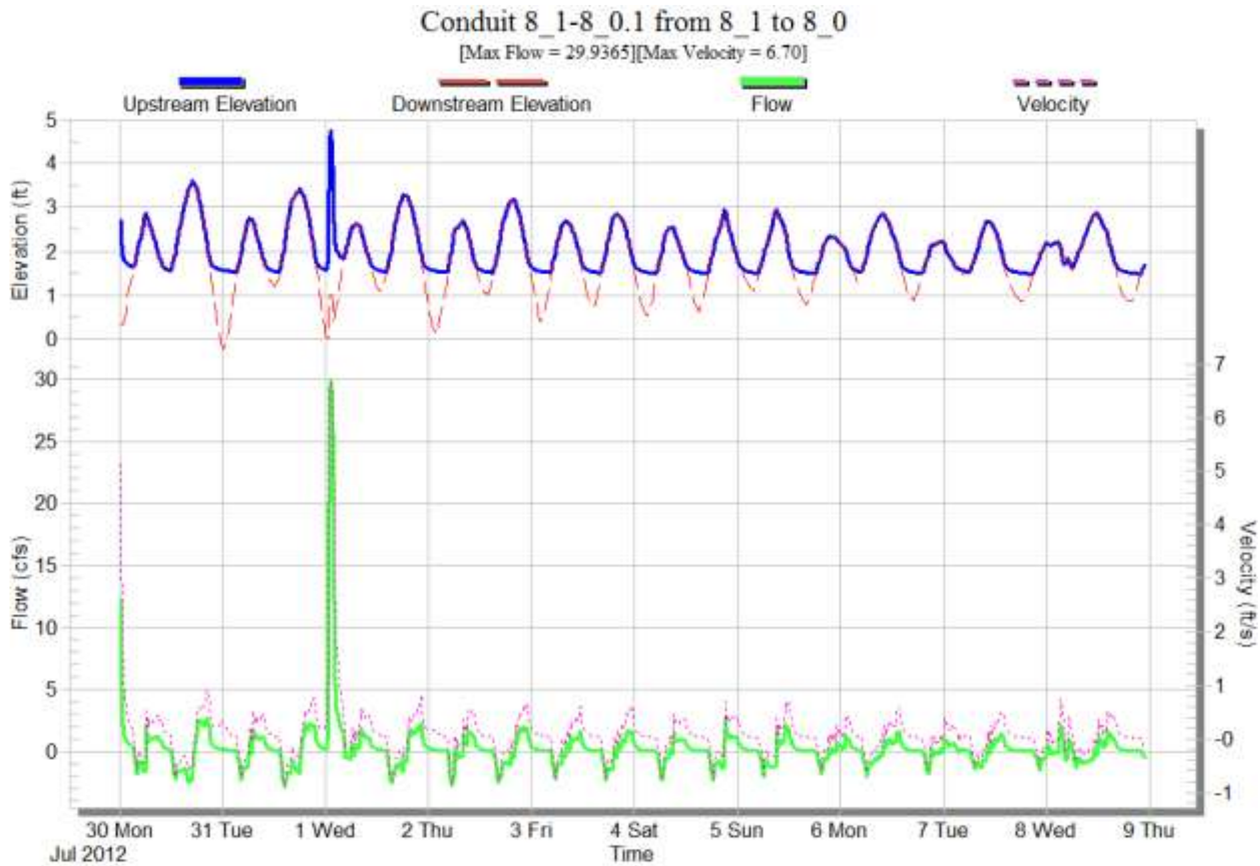
5- year, 1-hour Storm – Outfall # 5



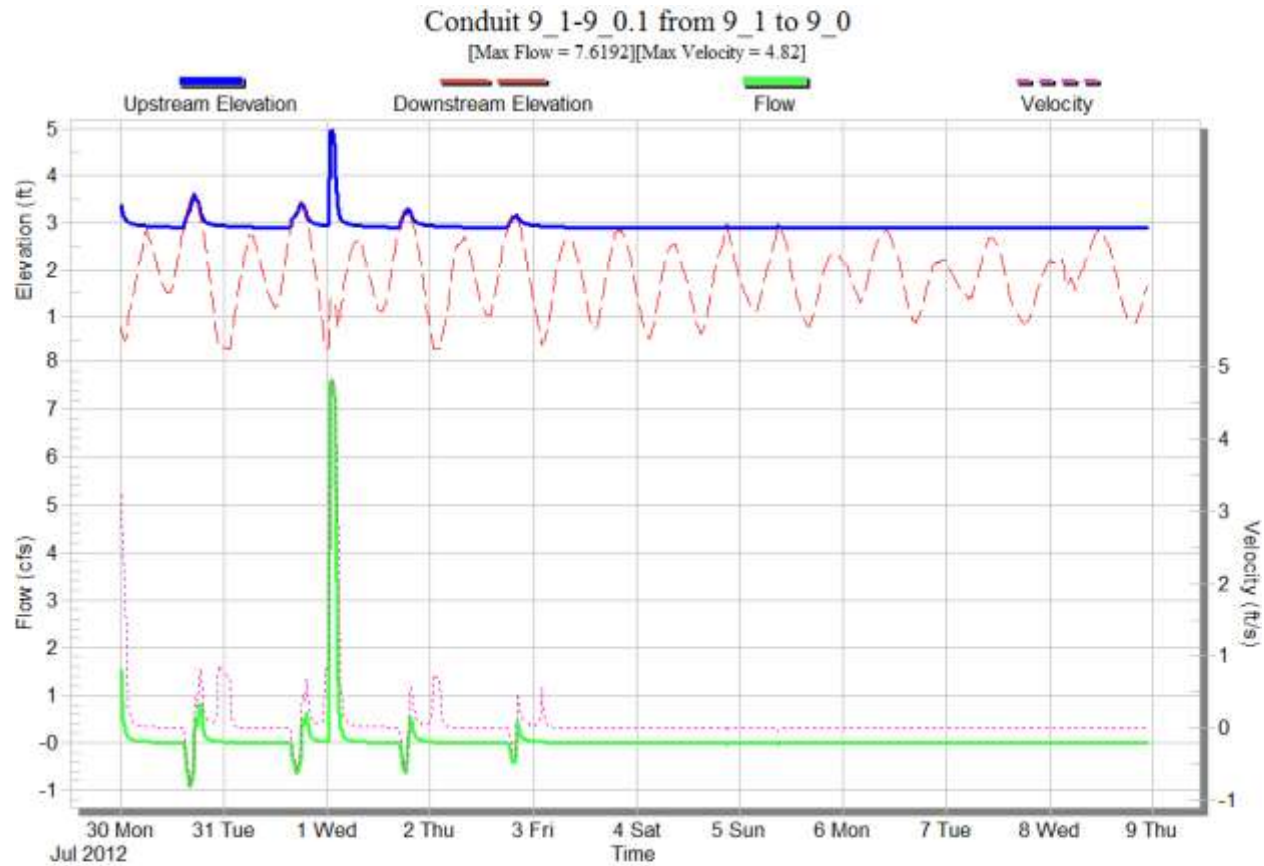
5- year, 1-hour Storm – Outfall # 6



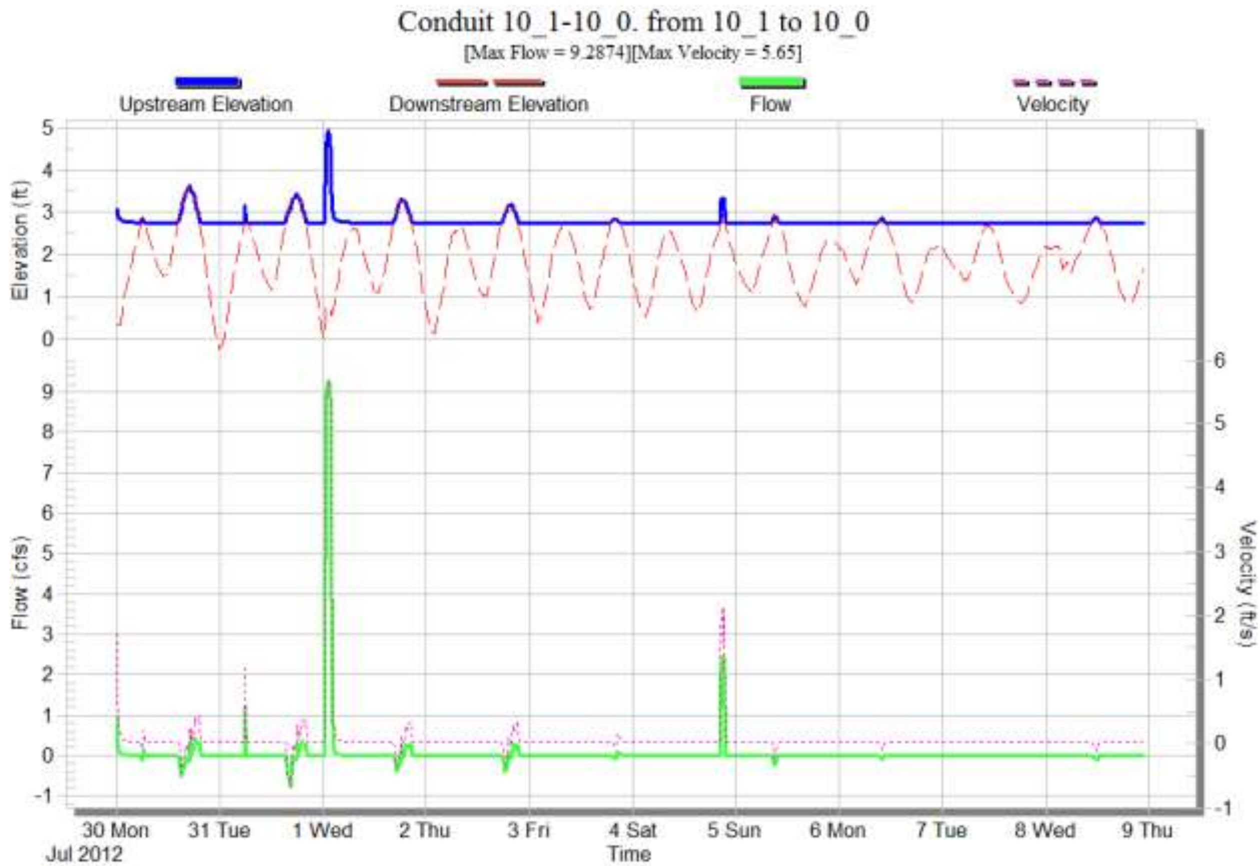
5- year, 1-hour Storm – Outfall # 7



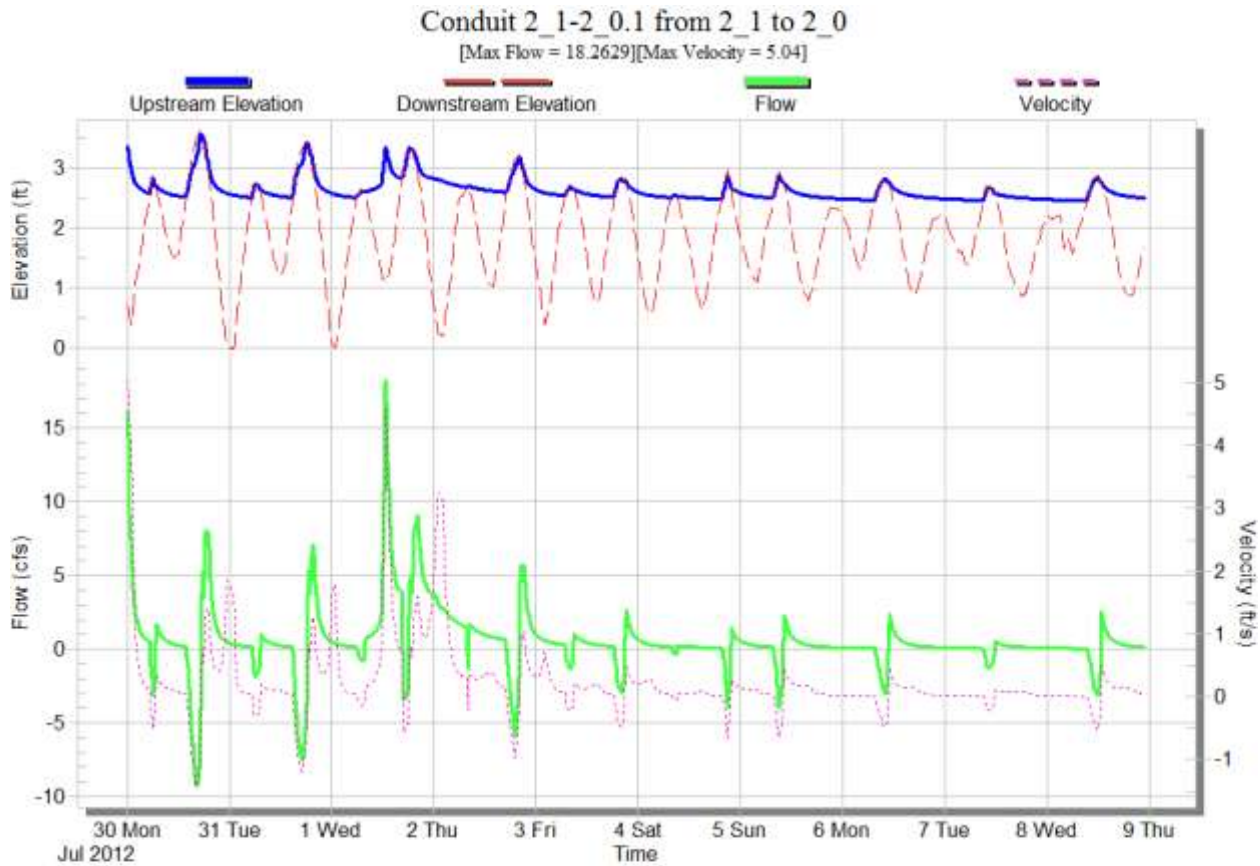
5- year, 1-hour Storm – Outfall # 8



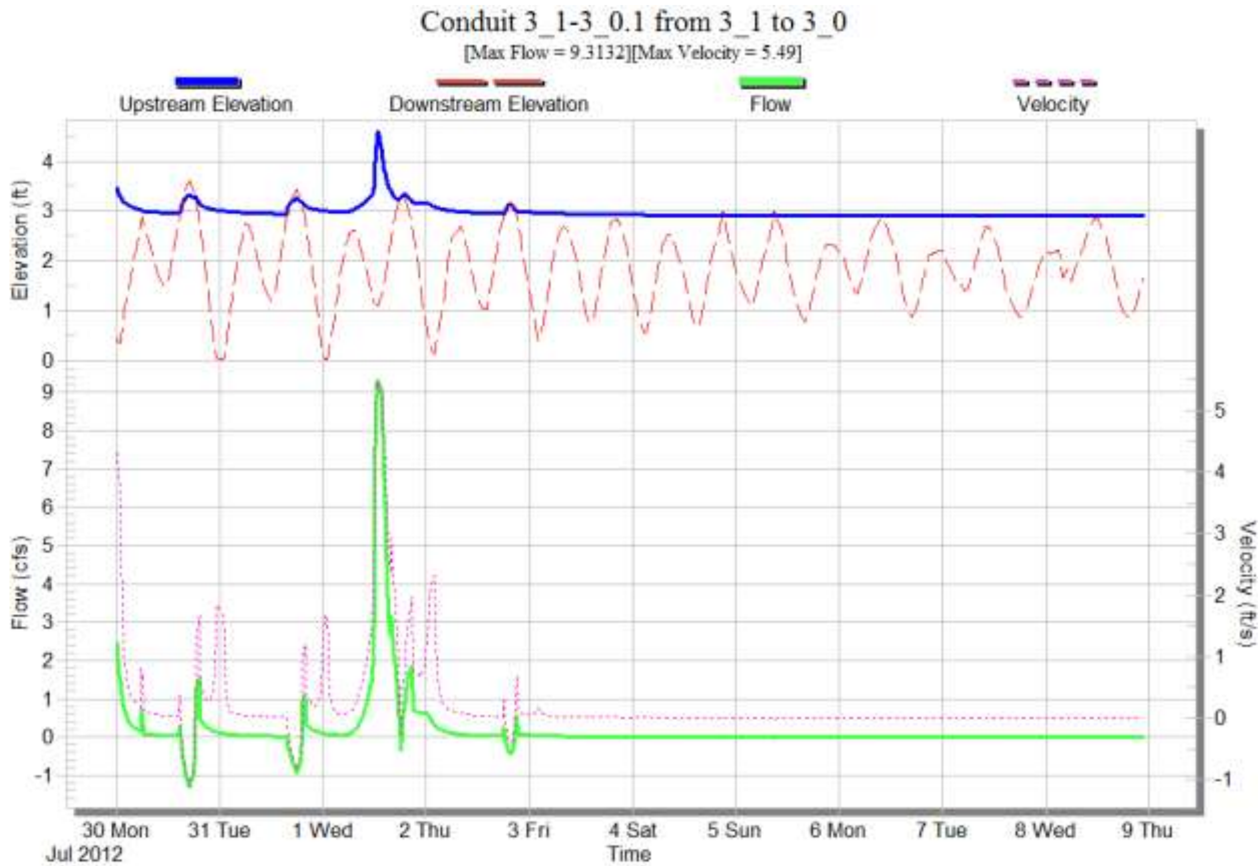
5- year, 1-hour Storm – Outfall # 9



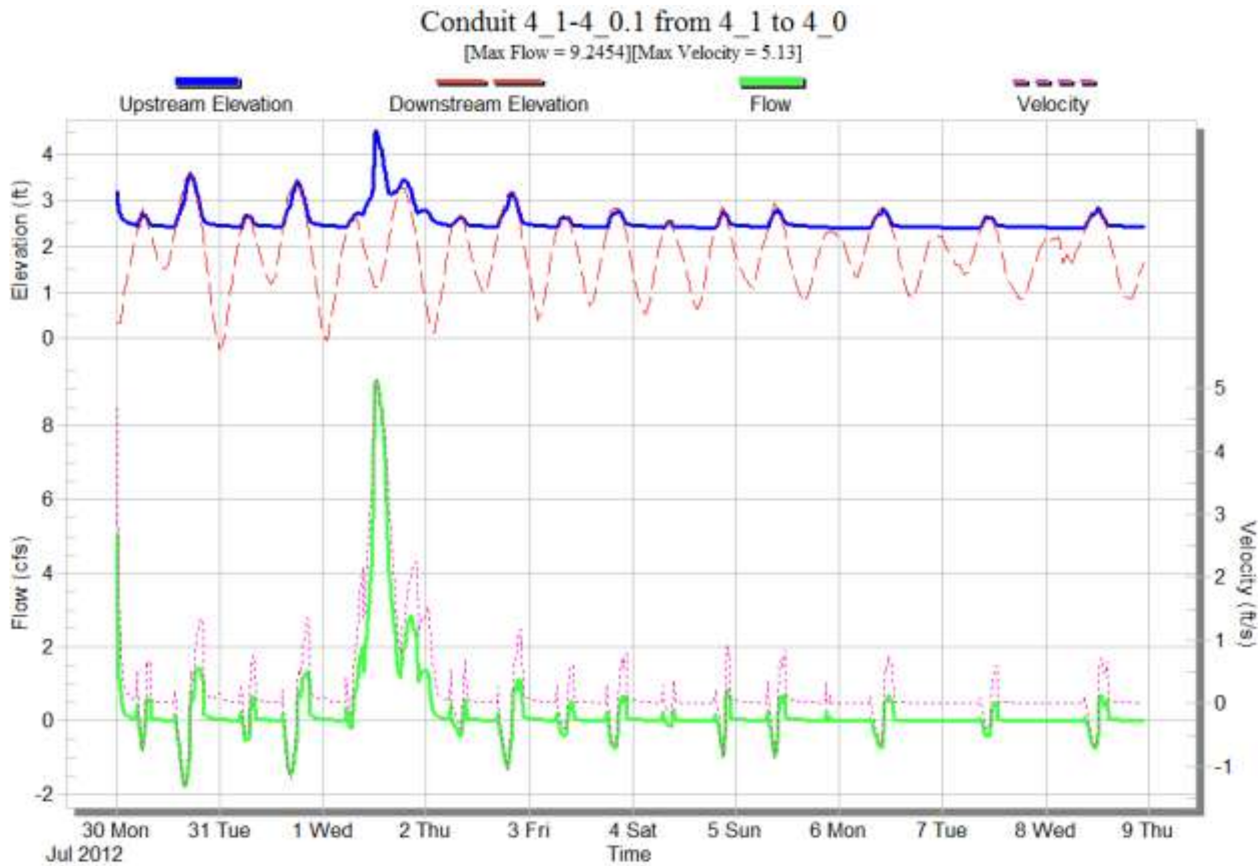
5- year, 1-hour Storm – Outfall # 10



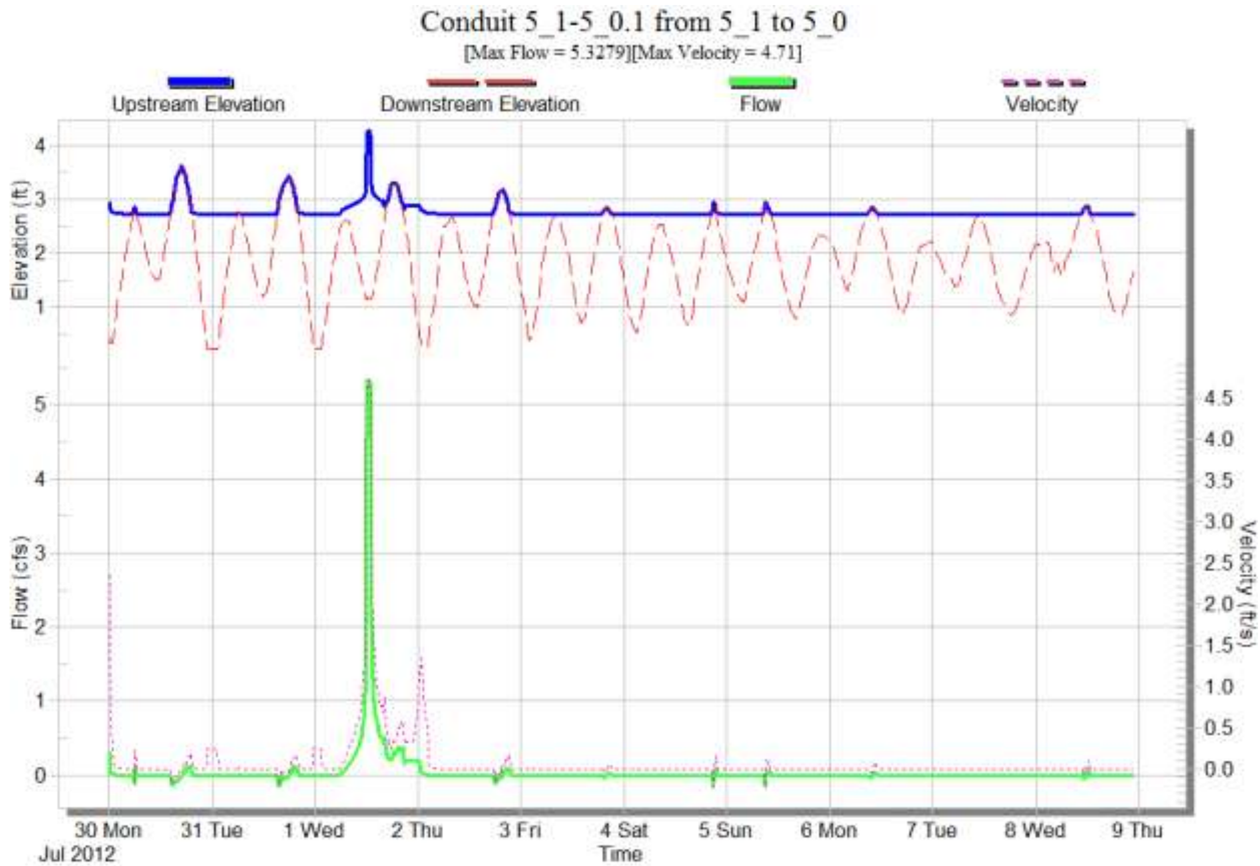
5- year, 24-hour Storm – Outfall # 2



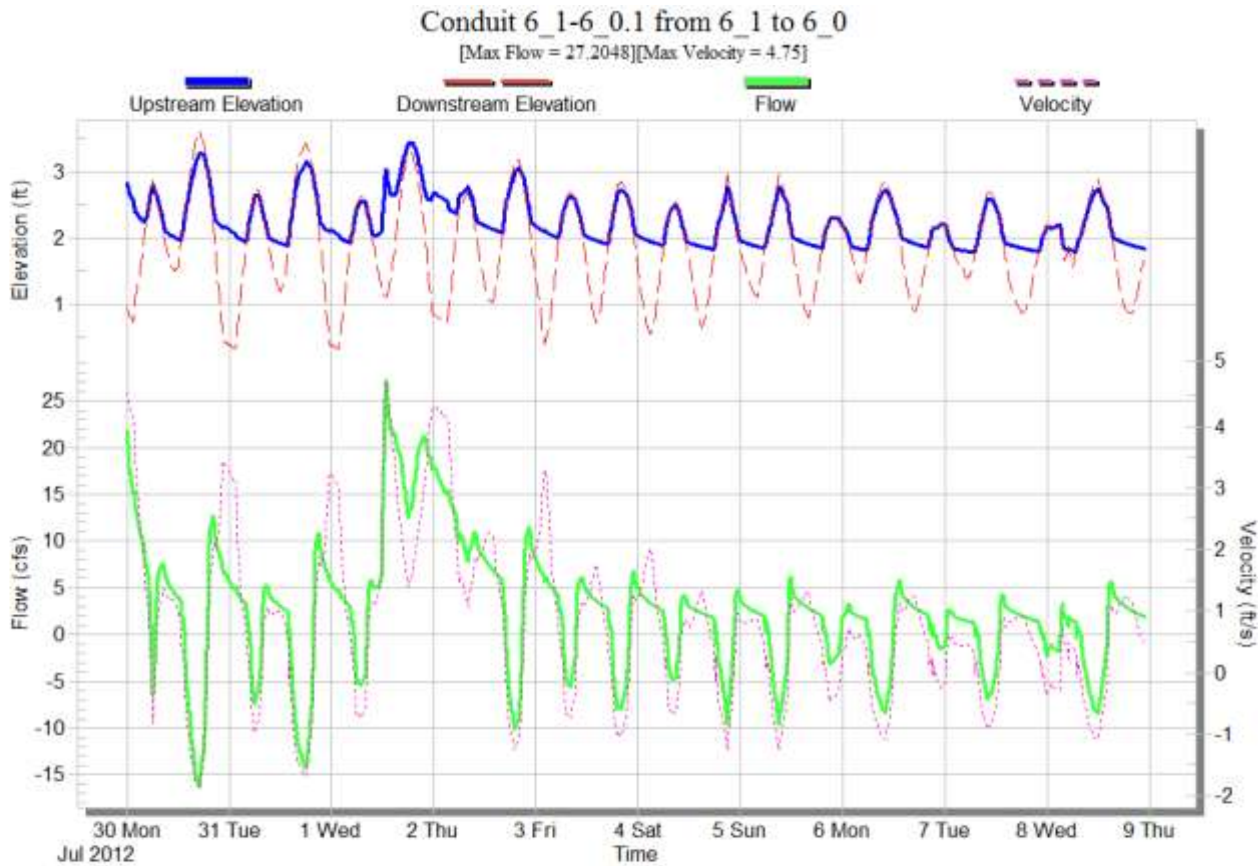
5- year, 24-hour Storm – Outfall # 3



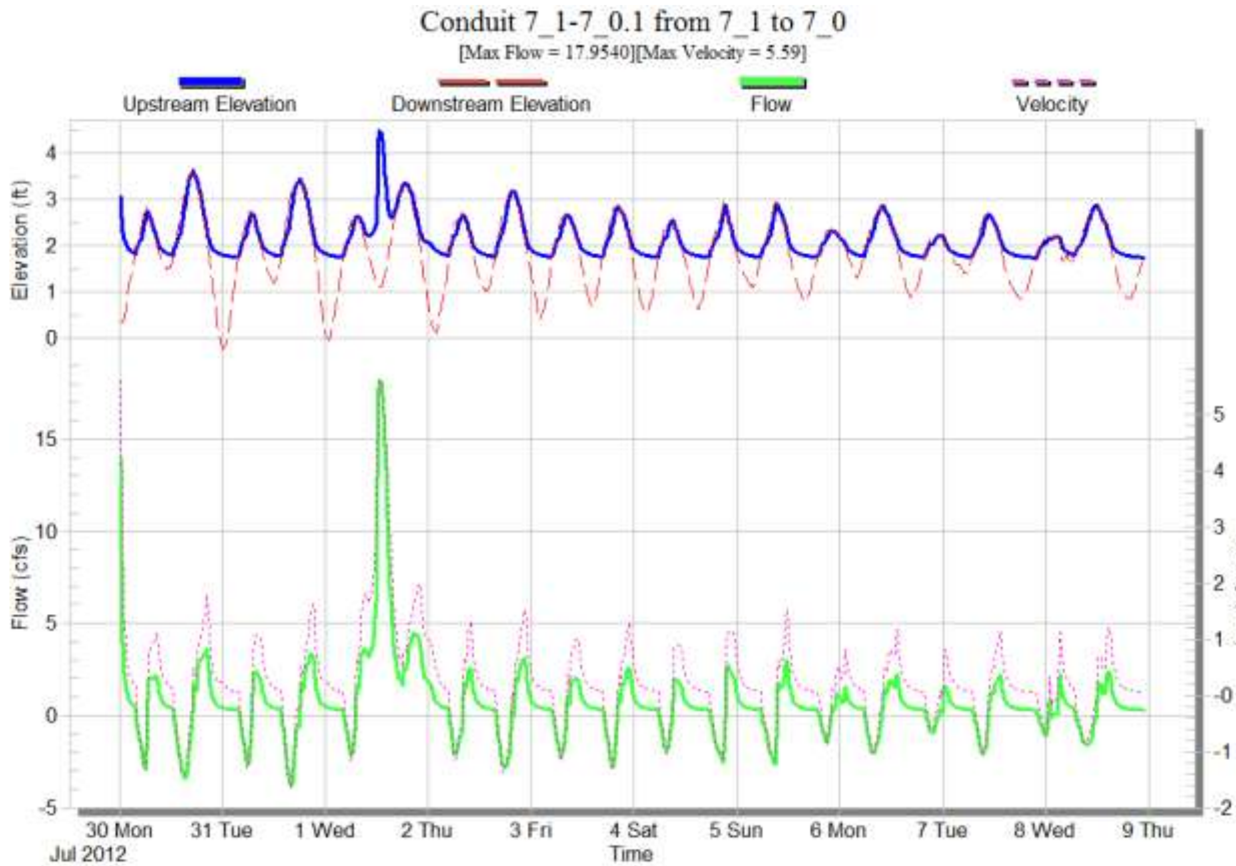
5- year, 24-hour Storm – Outfall # 4



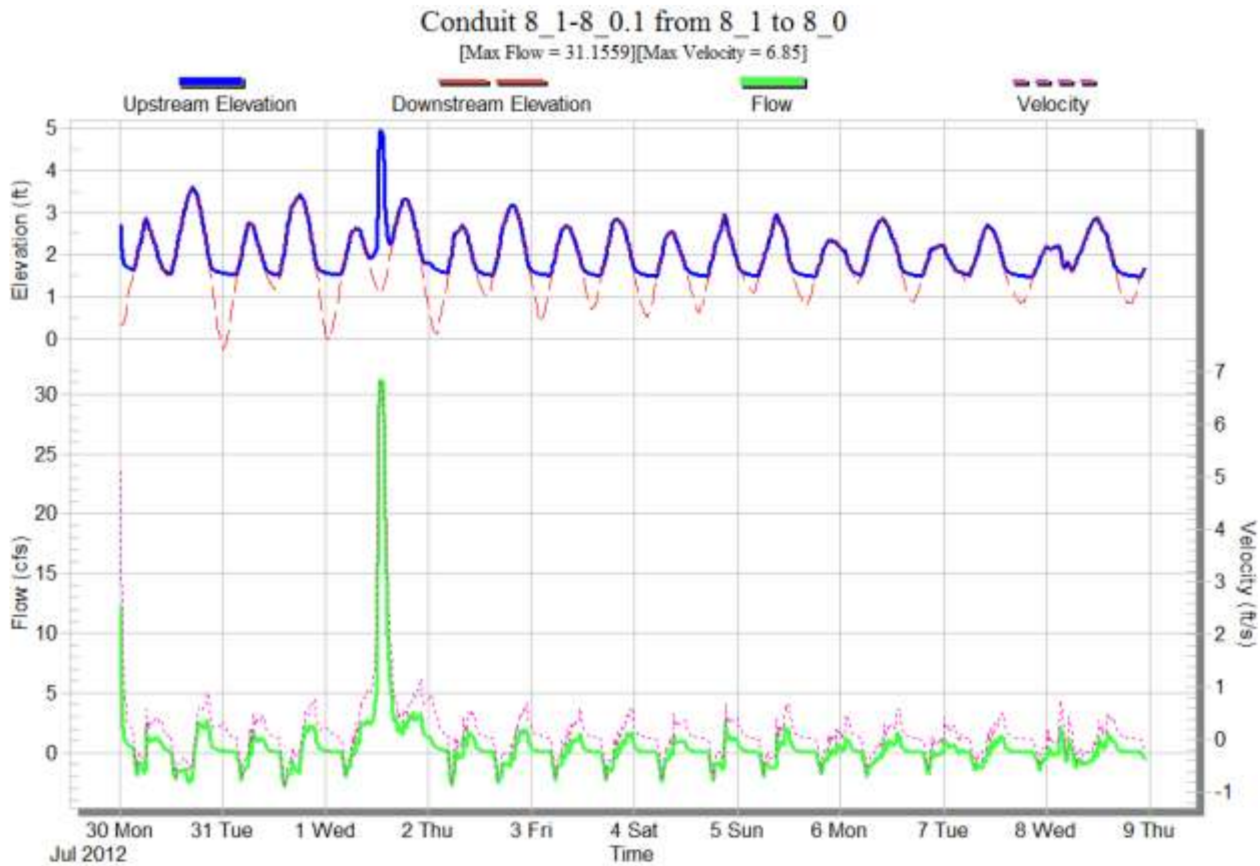
5- year, 24-hour Storm – Outfall # 5



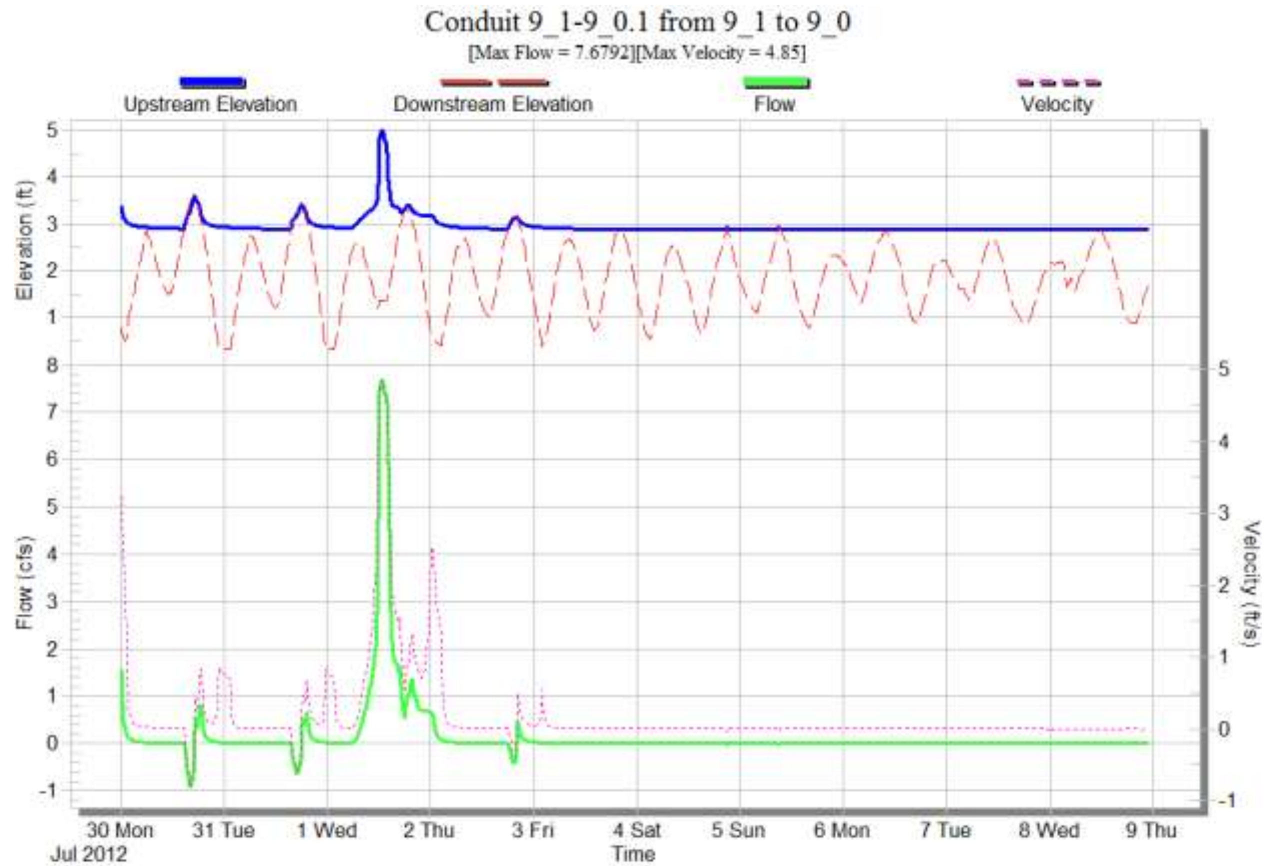
5- year, 24-hour Storm – Outfall # 6



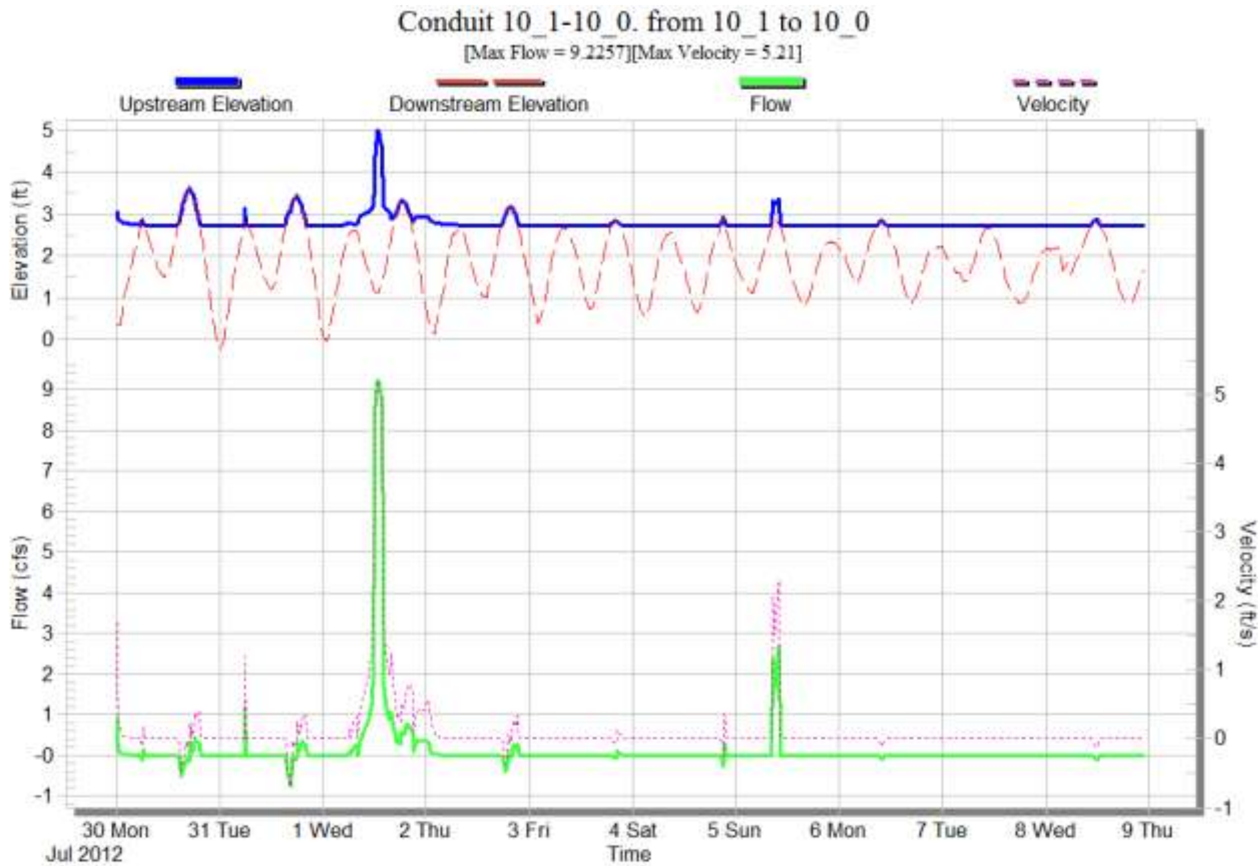
5- year, 24-hour Storm – Outfall # 7



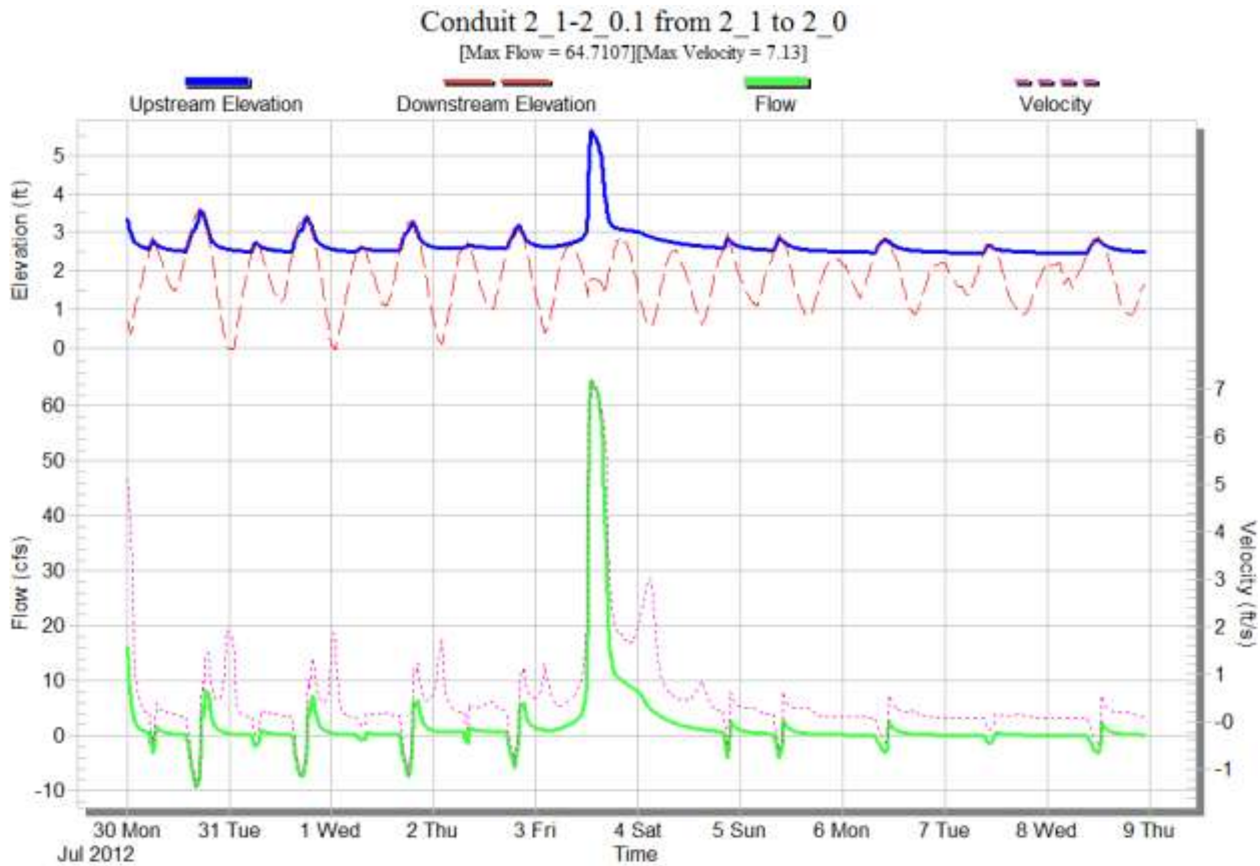
5- year, 24-hour Storm – Outfall # 8



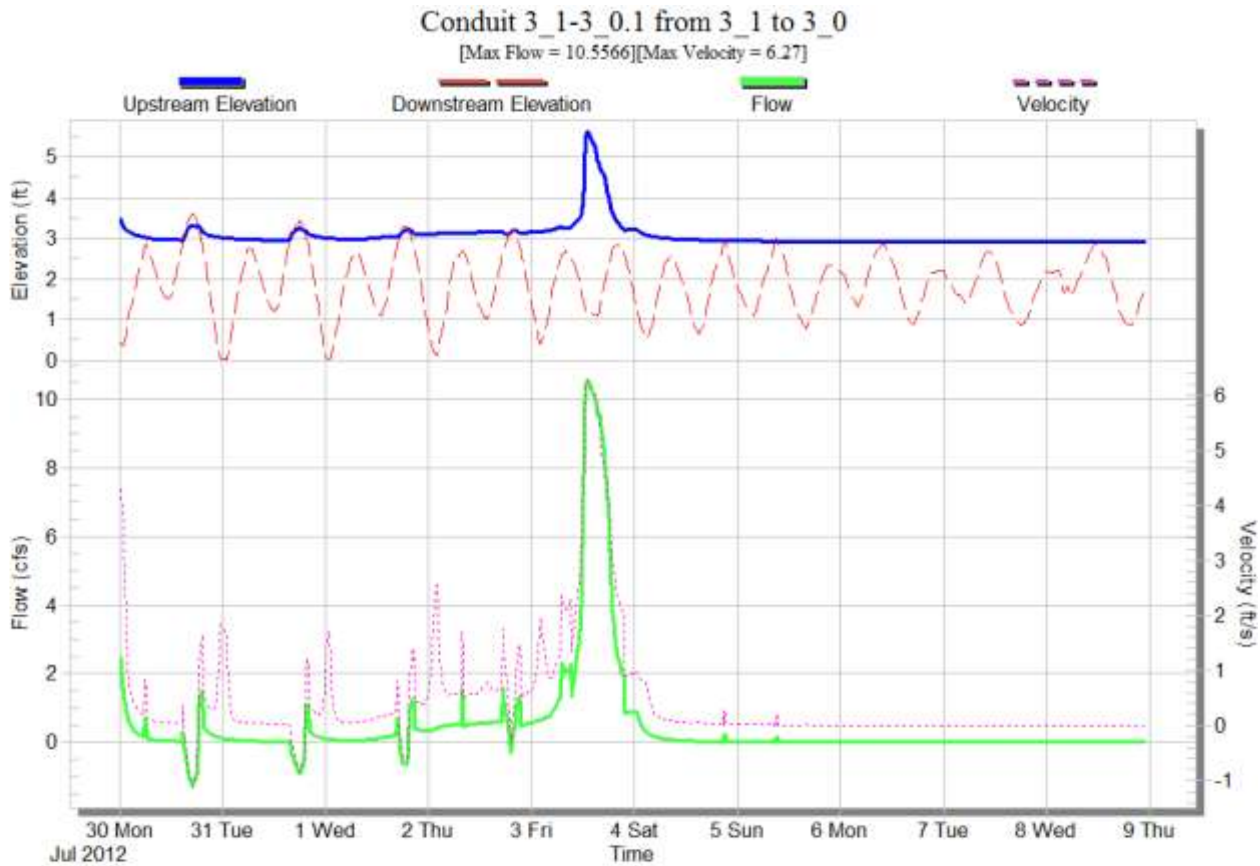
5- year, 24-hour Storm – Outfall # 9



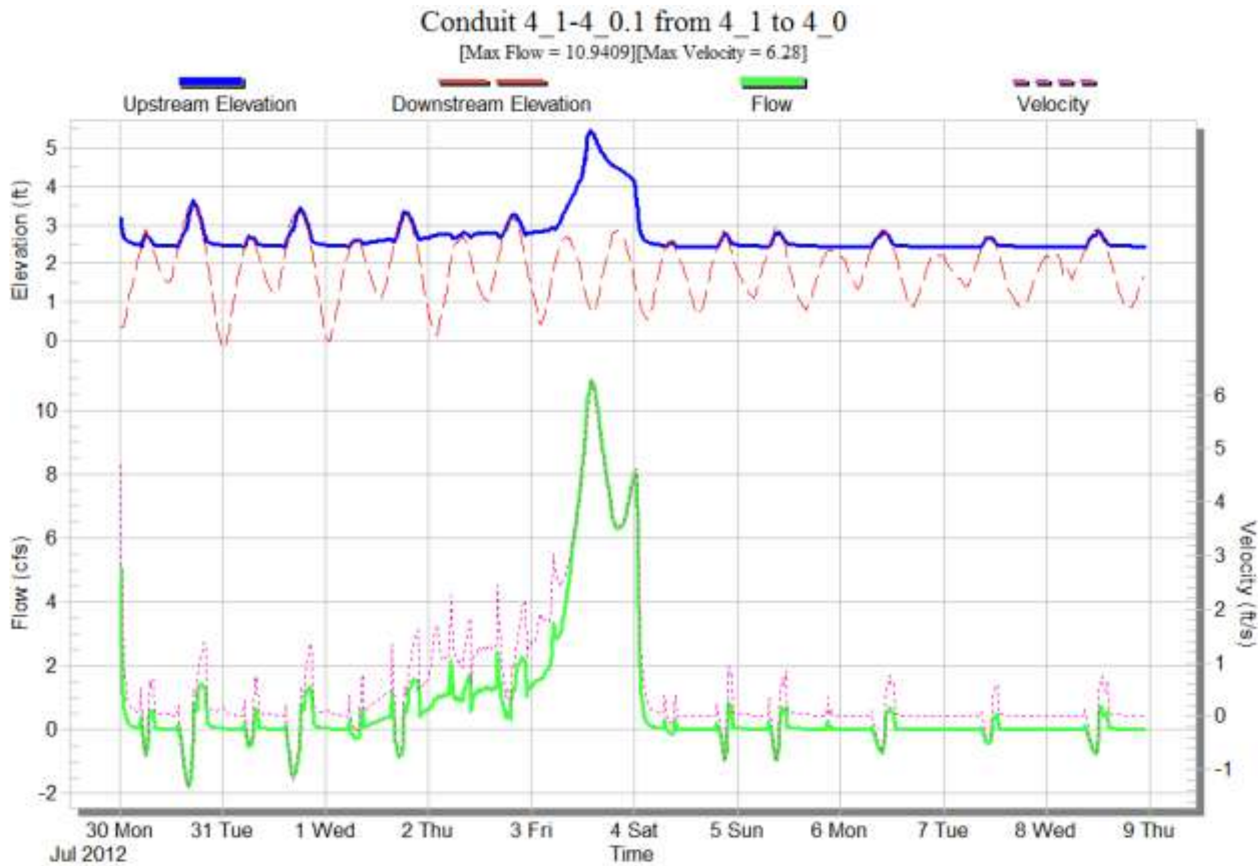
5- year, 24-hour Storm – Outfall # 10



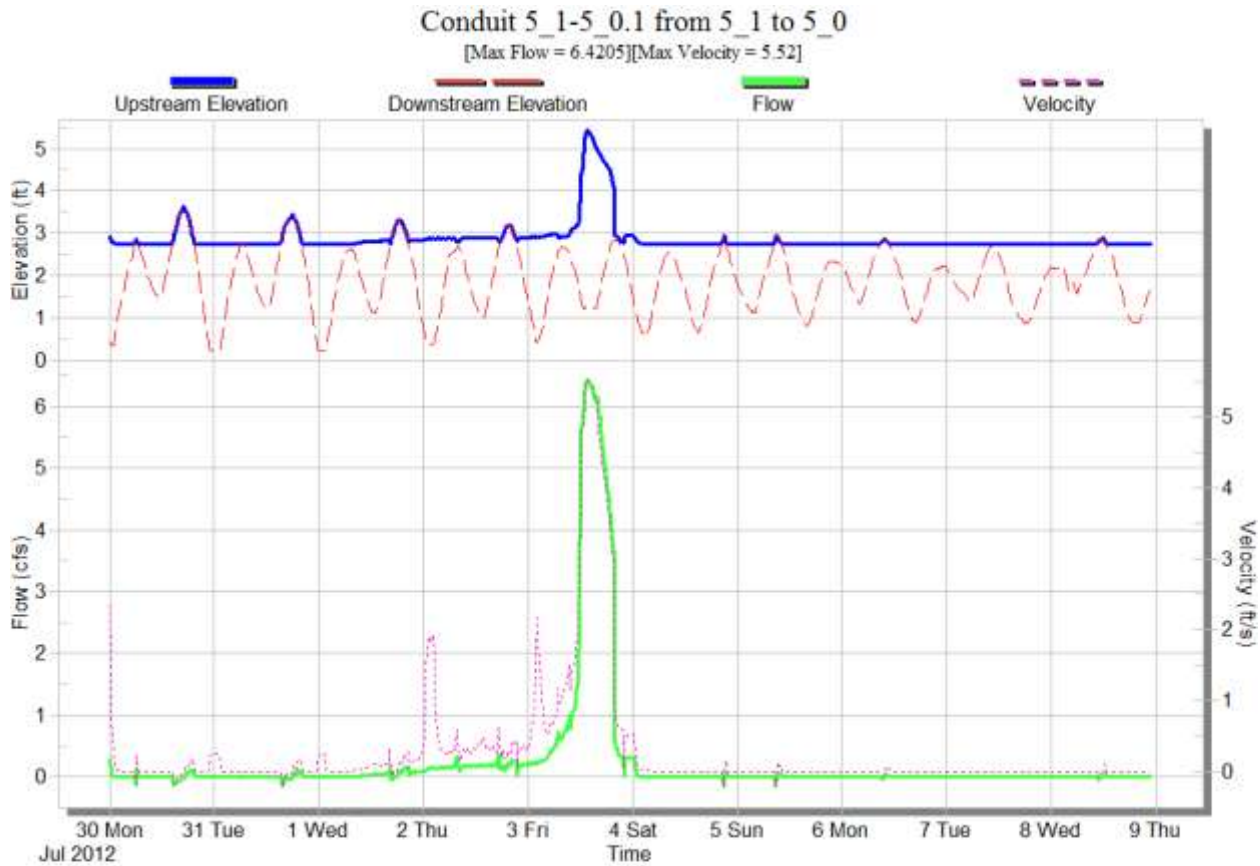
25- year, 72-hour Storm – Outfall # 2



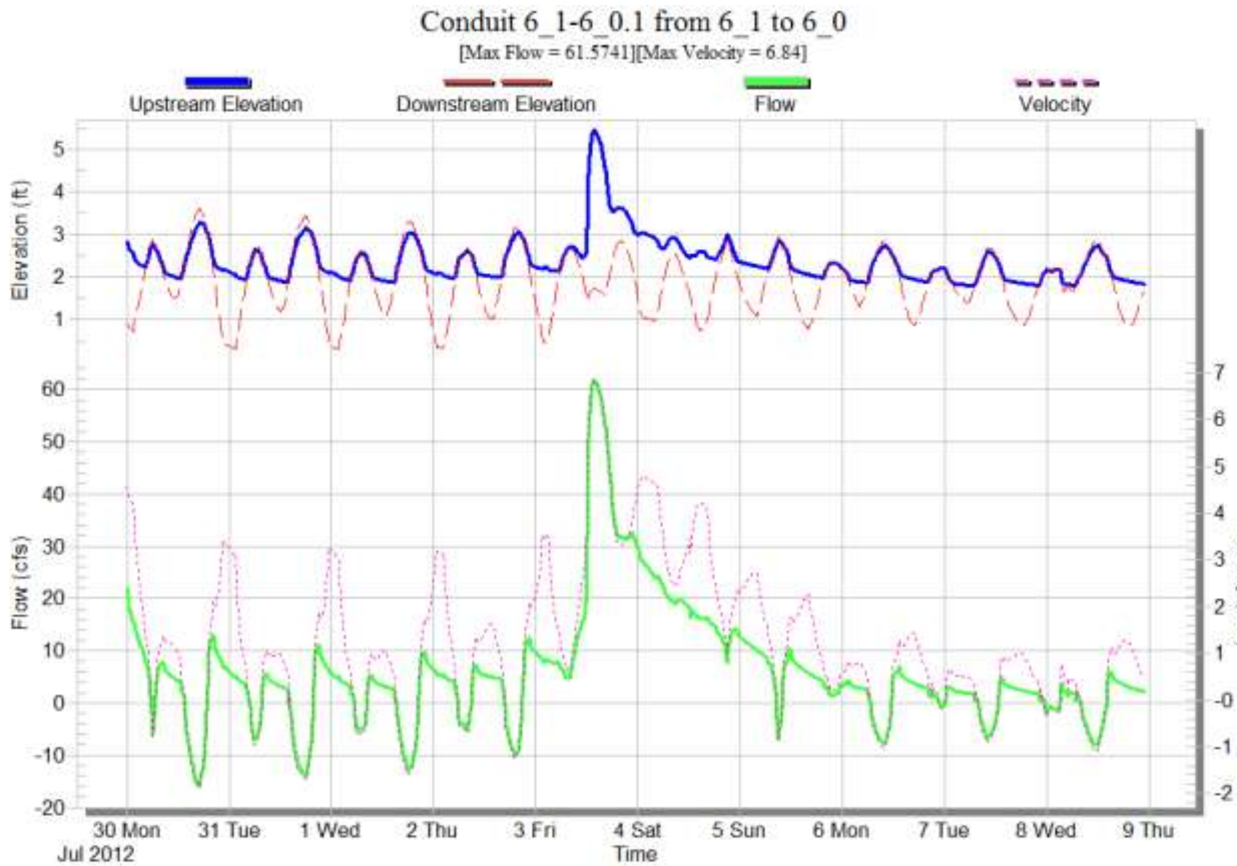
25- year, 72-hour Storm – Outfall # 3



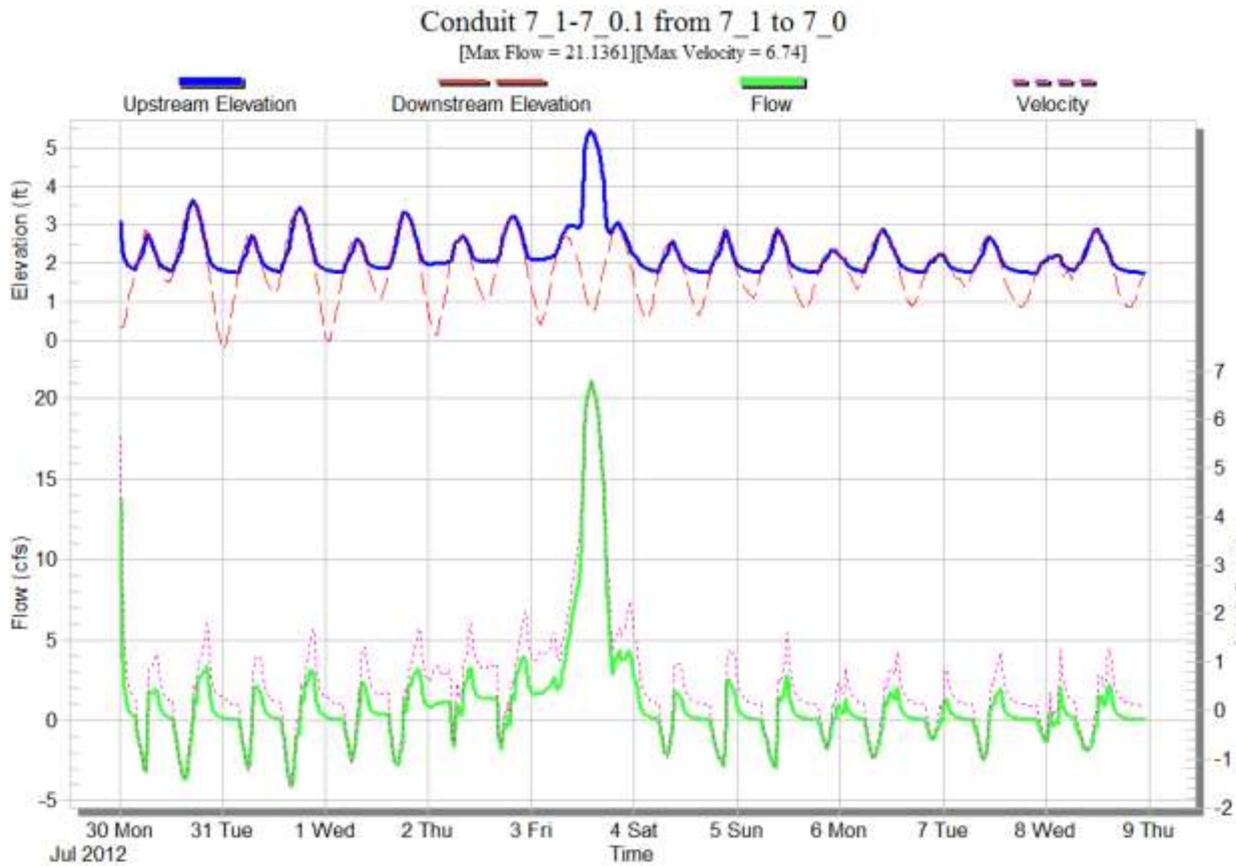
25- year, 72-hour Storm – Outfall # 4



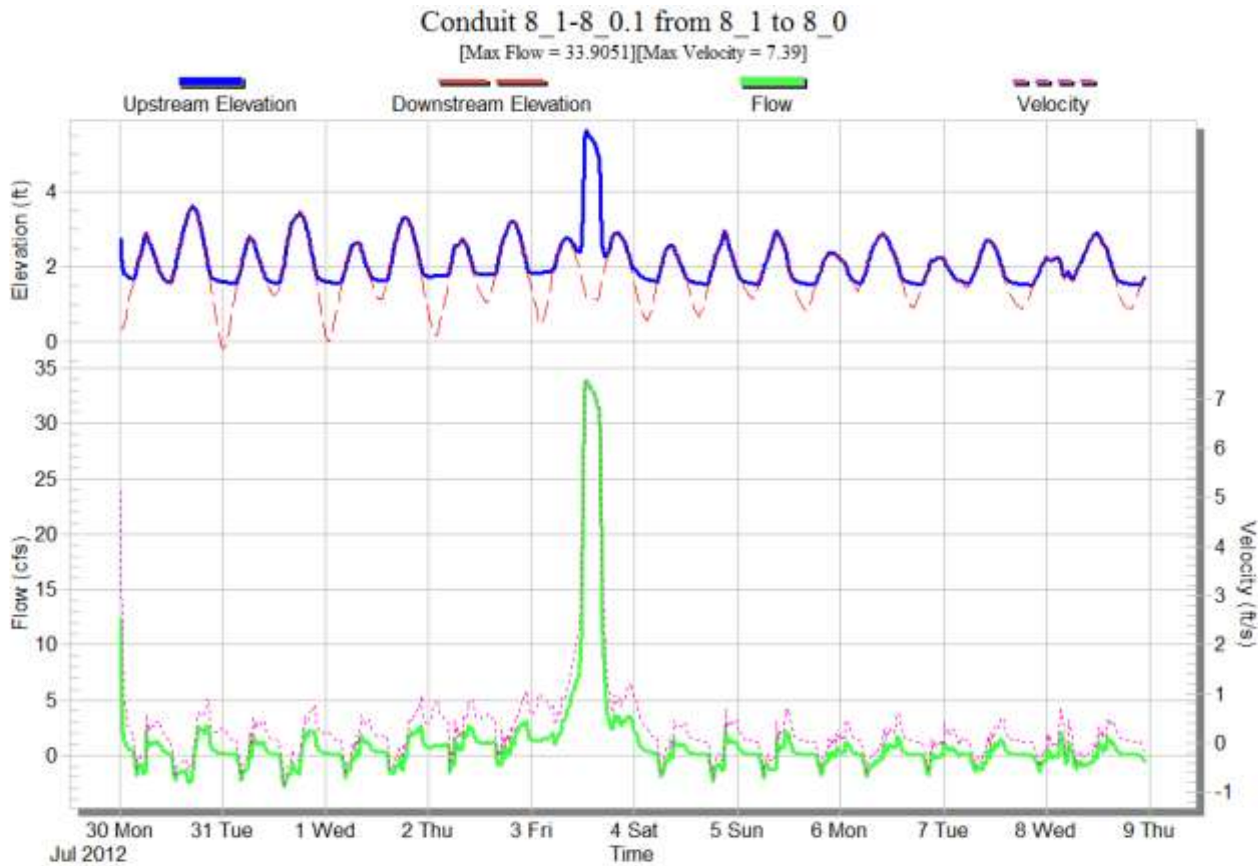
25- year, 72-hour Storm – Outfall # 5



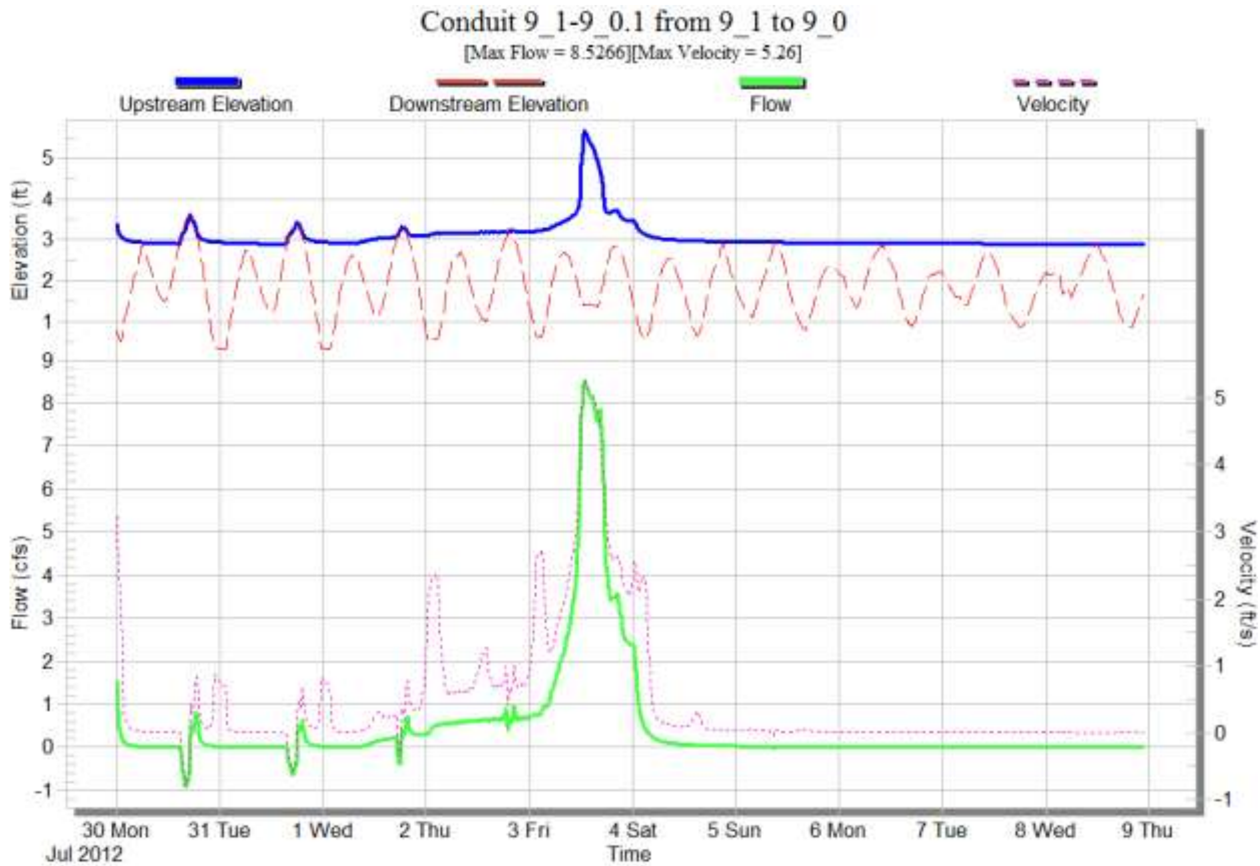
25- year, 72-hour Storm – Outfall # 6



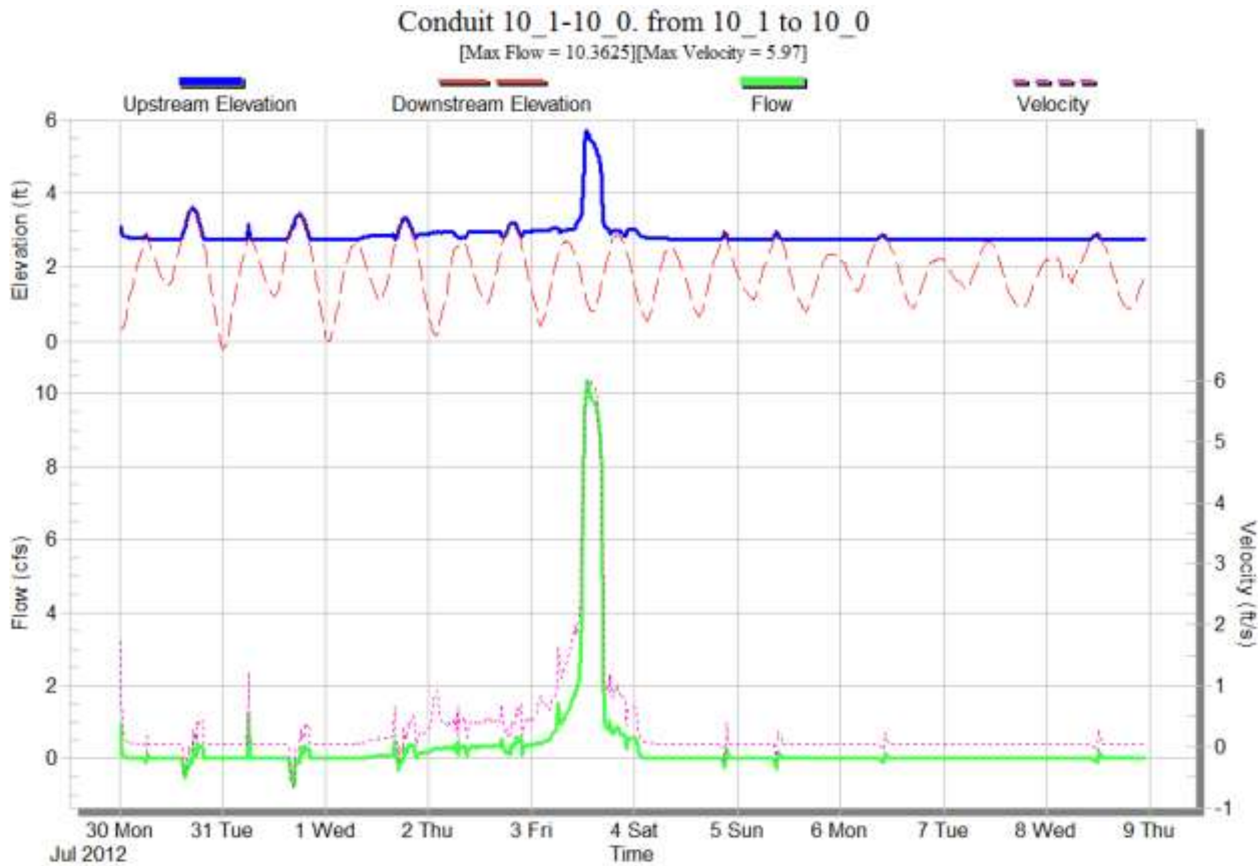
25- year, 72-hour Storm – Outfall # 7



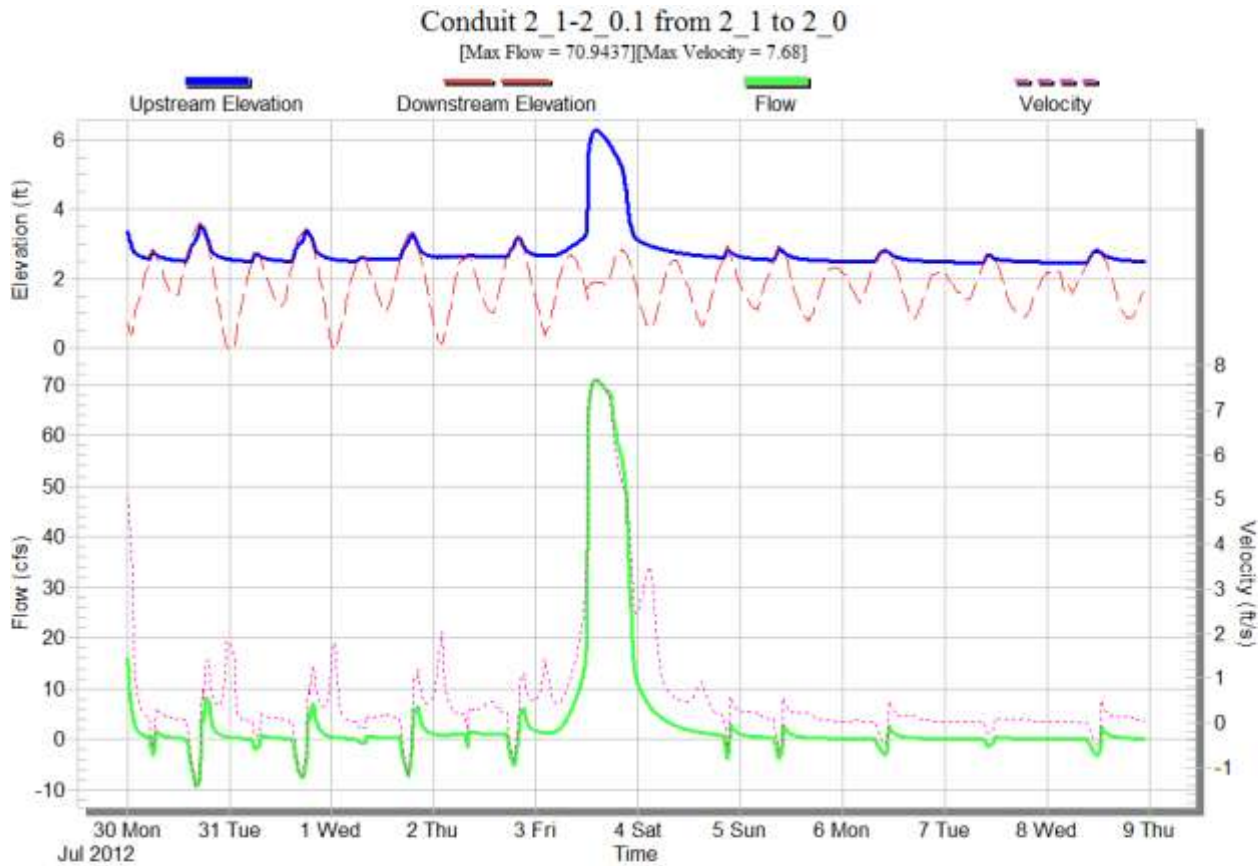
25- year, 72-hour Storm – Outfall # 8



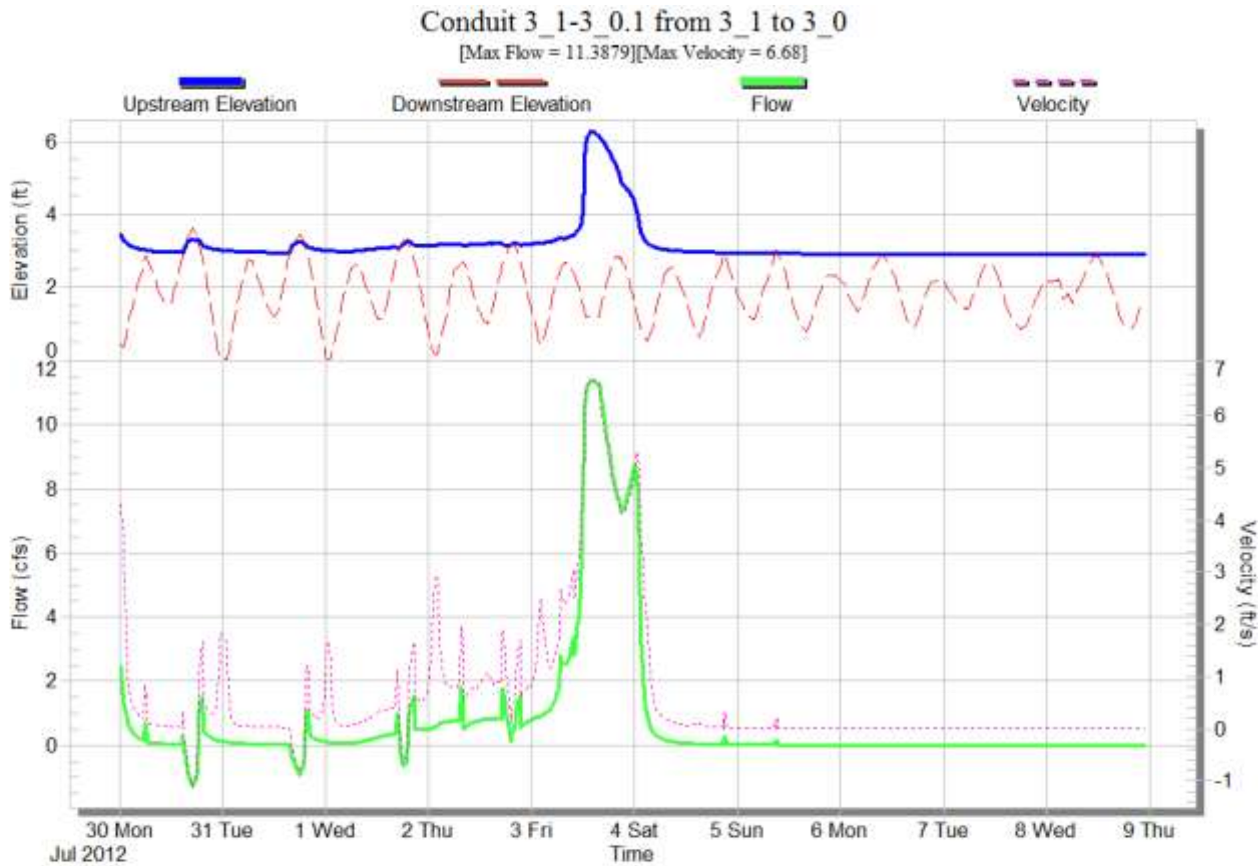
25- year, 72-hour Storm – Outfall # 9



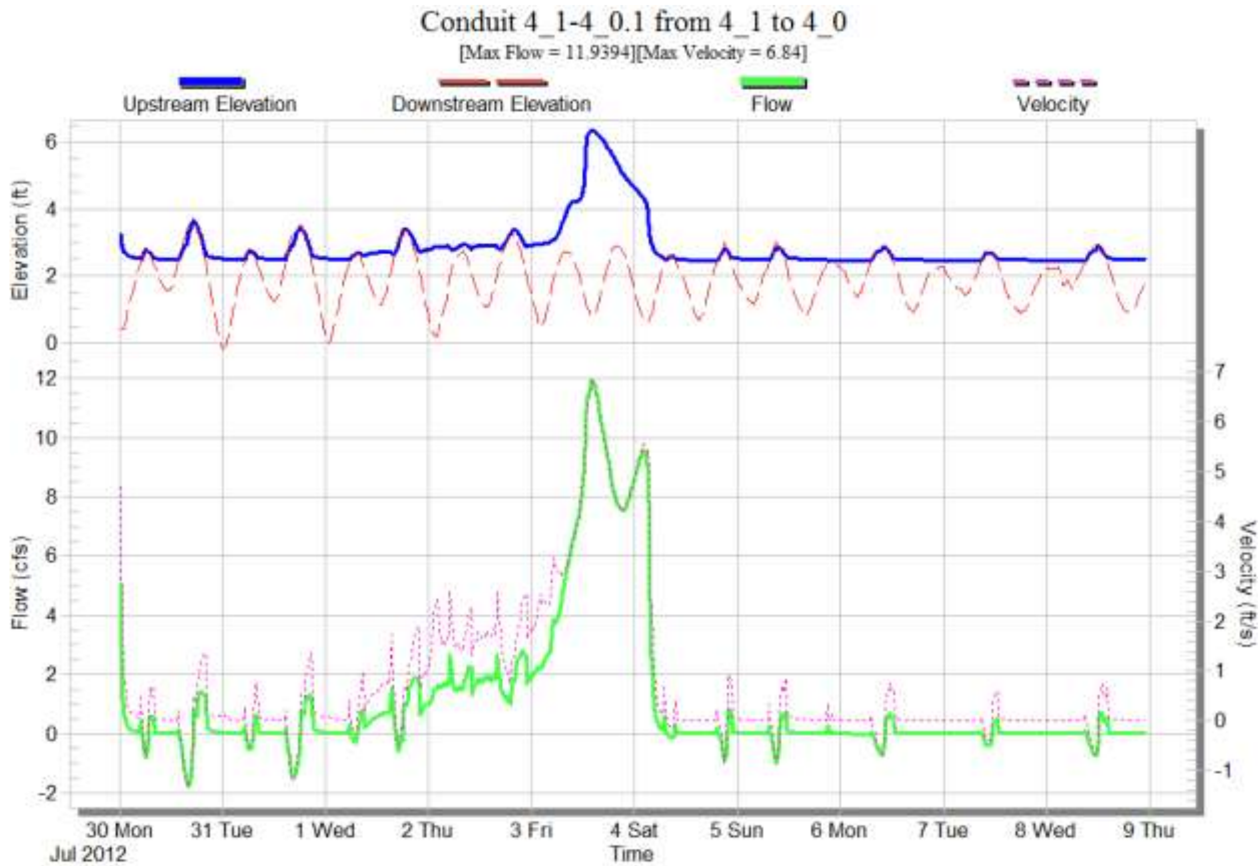
25- year, 72-hour Storm – Outfall # 10



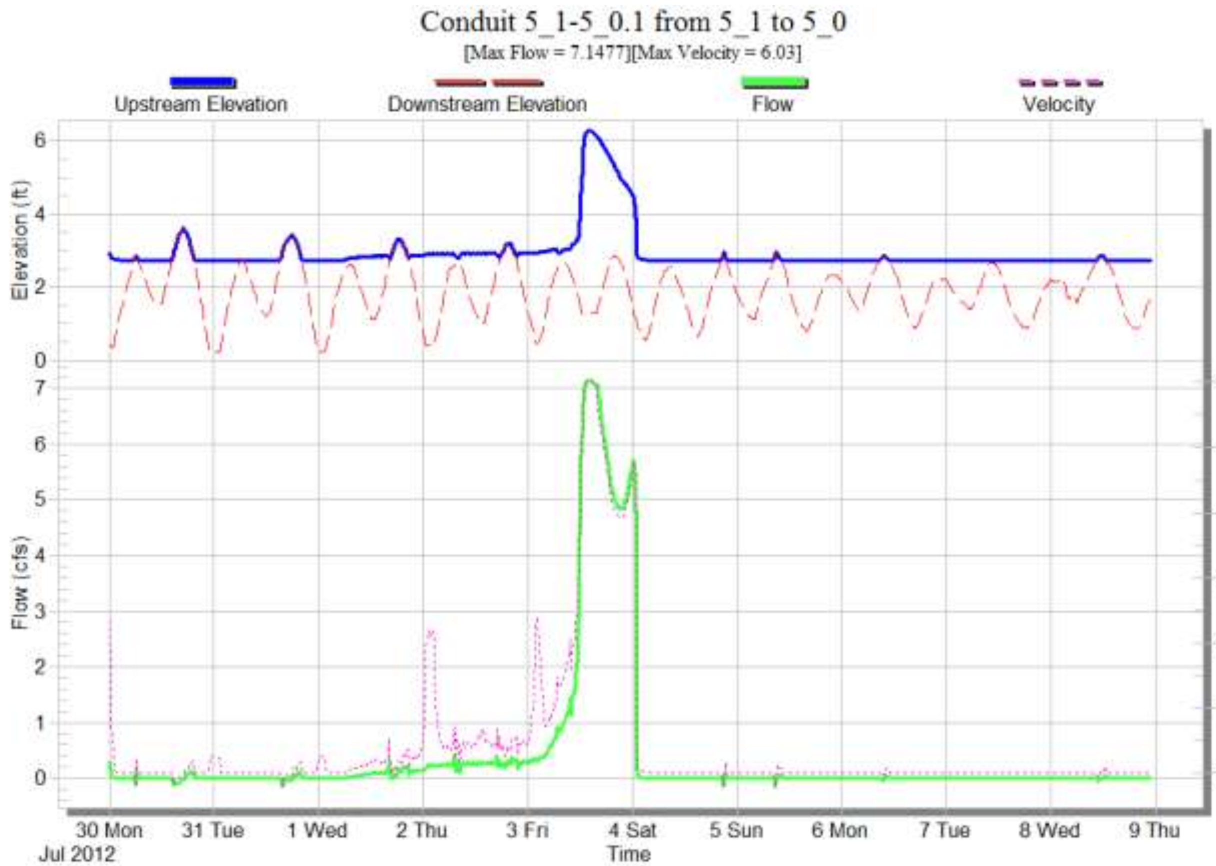
100- year, 72-hour Storm – Outfall # 2



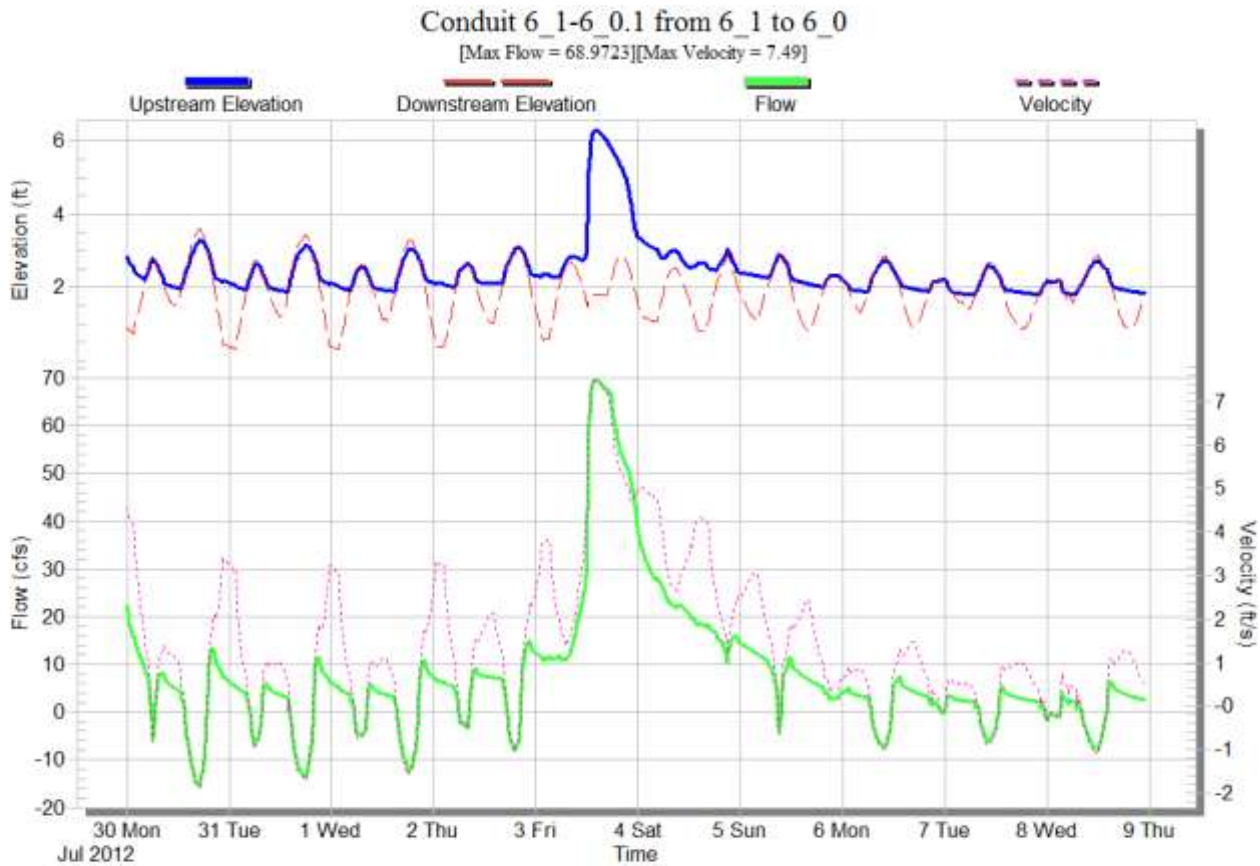
100- year, 72-hour Storm – Outfall # 3



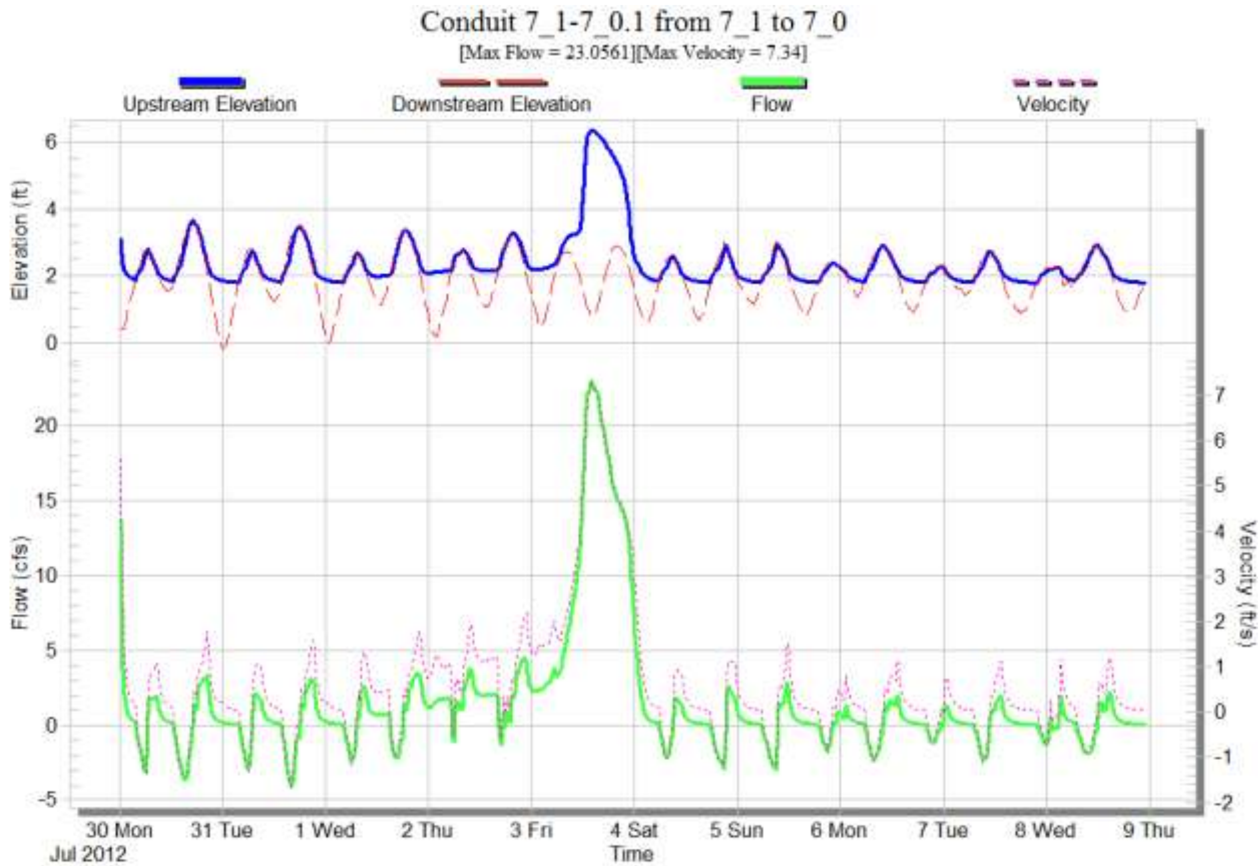
100- year, 72-hour Storm – Outfall # 4



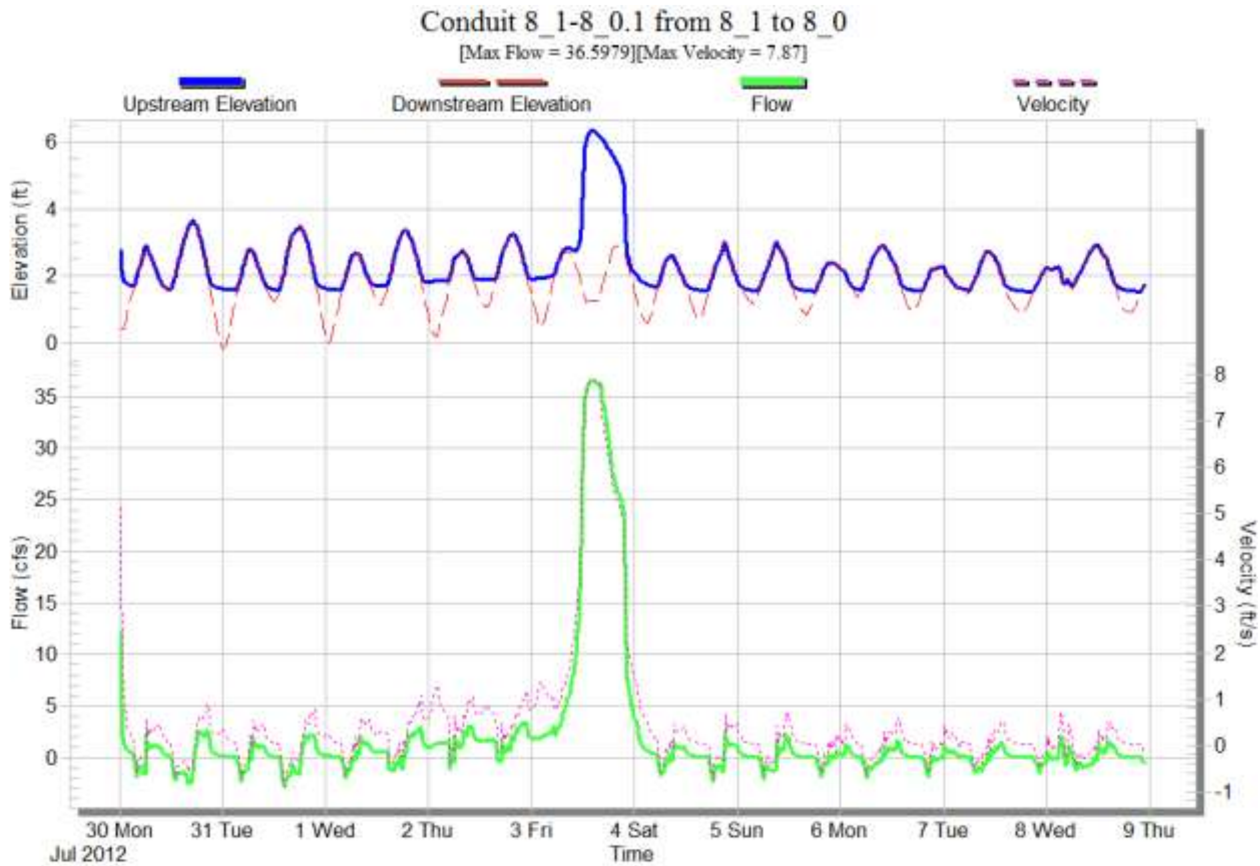
100- year, 72-hour Storm – Outfall # 5



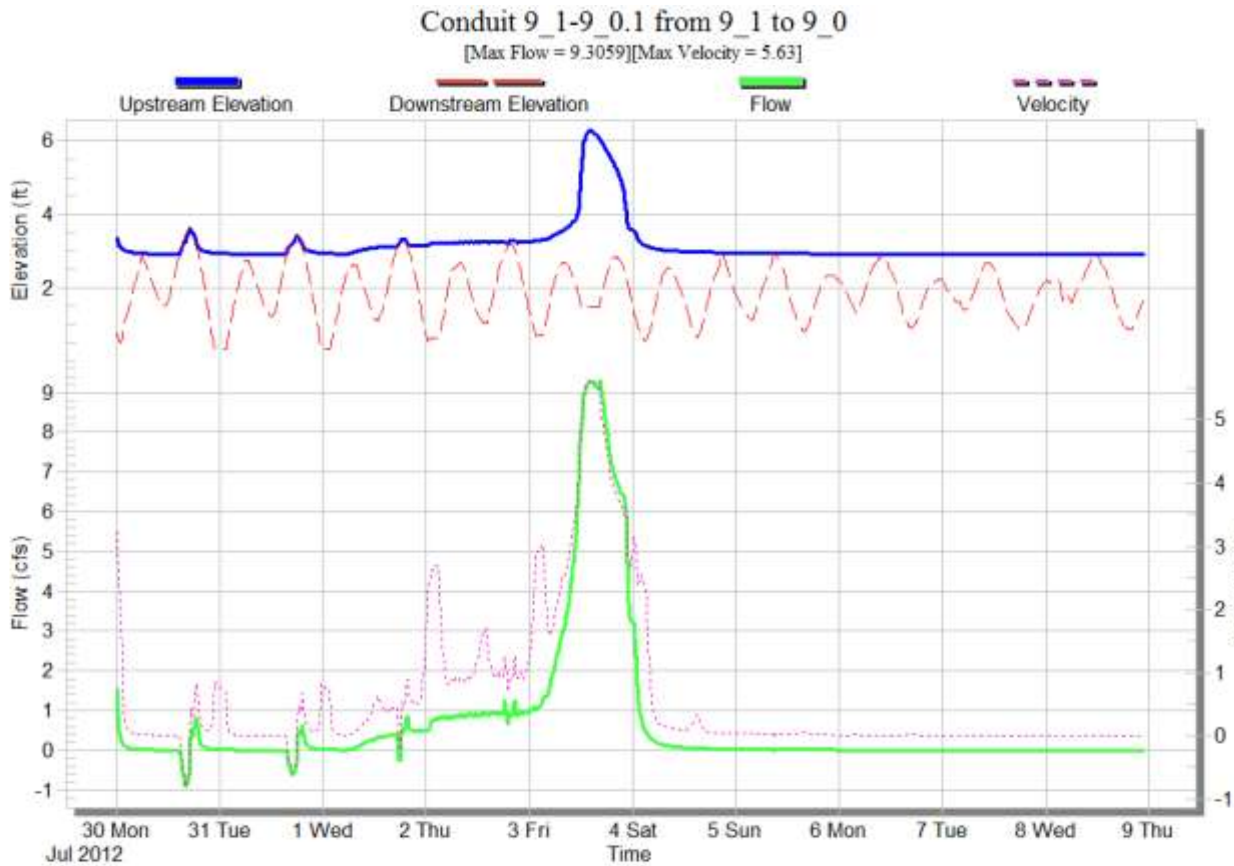
100- year, 72-hour Storm – Outfall # 6



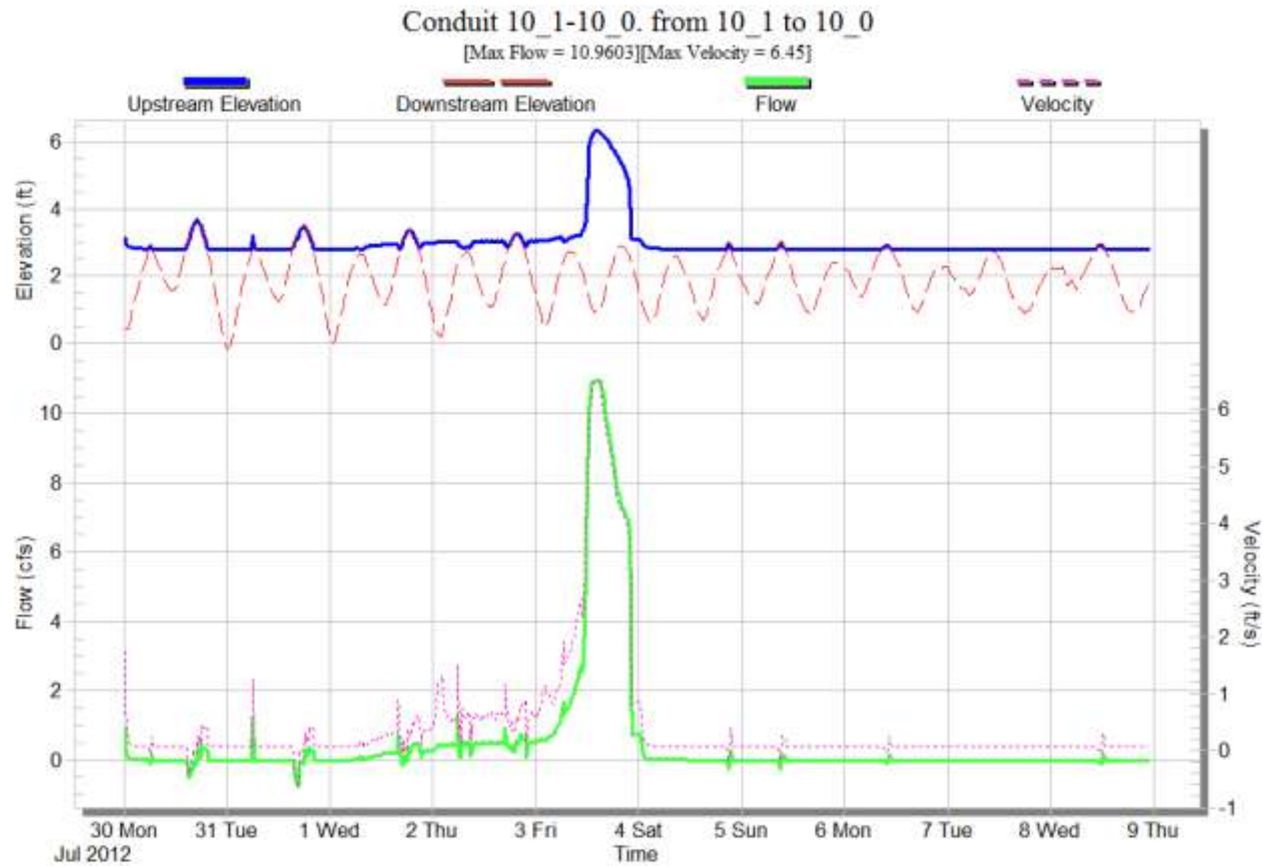
100- year, 72-hour Storm – Outfall # 7



100- year, 72-hour Storm – Outfall # 8



100- year, 72-hour Storm – Outfall # 9



100- year, 72-hour Storm – Outfall # 10

APPENDIX E

Electronic Copy of Model Input and Output files

(To be provided with Final Technical Memorandum)