Flood Protection Level of Service for the Basins C7, C8 and C9: Identification and Mitigation of Sea Level Rise Impacts

Deliverable 3.4.1

Final Report – Flood Protection Level of Service Provided by Existing District Infrastructure for Current (2015) Sea Level Conditions and Three Future (2065) Sea Level Rise Scenarios for the C7 Basin

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FLOOD PROTECTION LEVEL OF SERVICE PROVIDED BY EXISTING DISTRICT INFRASTRUCTURE FOR CURRENT (2015) SEA LEVEL CONDITIONS AND THREE FUTURE (2065) SEA LEVEL RISE SCENARIOS FOR THE C7 BASIN

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Appendices

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1.0 INTRODUCTION

The South Florida Water Management District (SFWMD, or District) is conducting a system-wide review of the regional water management infrastructure within each of the primary basins to determine the level of service (LOS) currently being provided for flood protection. The LOS to be evaluated as part of this project include the amount of protection provided by the water management facilities within a basin considering current conditions, sea level rise (SLR), future development, and known water management issues in each watershed. This information can then be used by local governments, the District, and other state and federal agencies to identify:

(1) Areas where improvements to the design, maintenance, construction and operation or upgrade of water management facilities are required;
(2) The appropriate entity or entities responsible for making improvements and funding; and
(3) Technical resources available to support these efforts.

In April 2015, the District was awarded a Pre-Disaster Mitigation Competitive Grant from the Federal Emergency Management Agency (FEMA) through the Florida Division of Emergency Management (FEMA Grant Application Number PDMC-PL-04-FL-2014-004 -Attachment A; SFWMD /Florida Div. of Emergency Management Grant Agreement DEM No. I5DM-Kl-10-60-16-452). The study objective is to reduce the potential for loss of life and property by updating the Miami-Dade County Local Mitigation Strategy (LMS) to assess alternative mitigation strategies. The project has two elements: 1) a technical assessment of the flood protection level of service (FPLOS) for the existing infrastructure under current and future SLR scenarios; and 2) a strategic assessment of alternative mitigation strategies intended for incorporation into the Miami-Dade LMS.

The study associated with this project will include the C7 Basin located in north Miami-Dade County. **Figure 1-1** shows the extent of the Basin and the limits of Miami-Dade County. The C7 Basin watershed has an area of approximately 32 square (sq) miles.

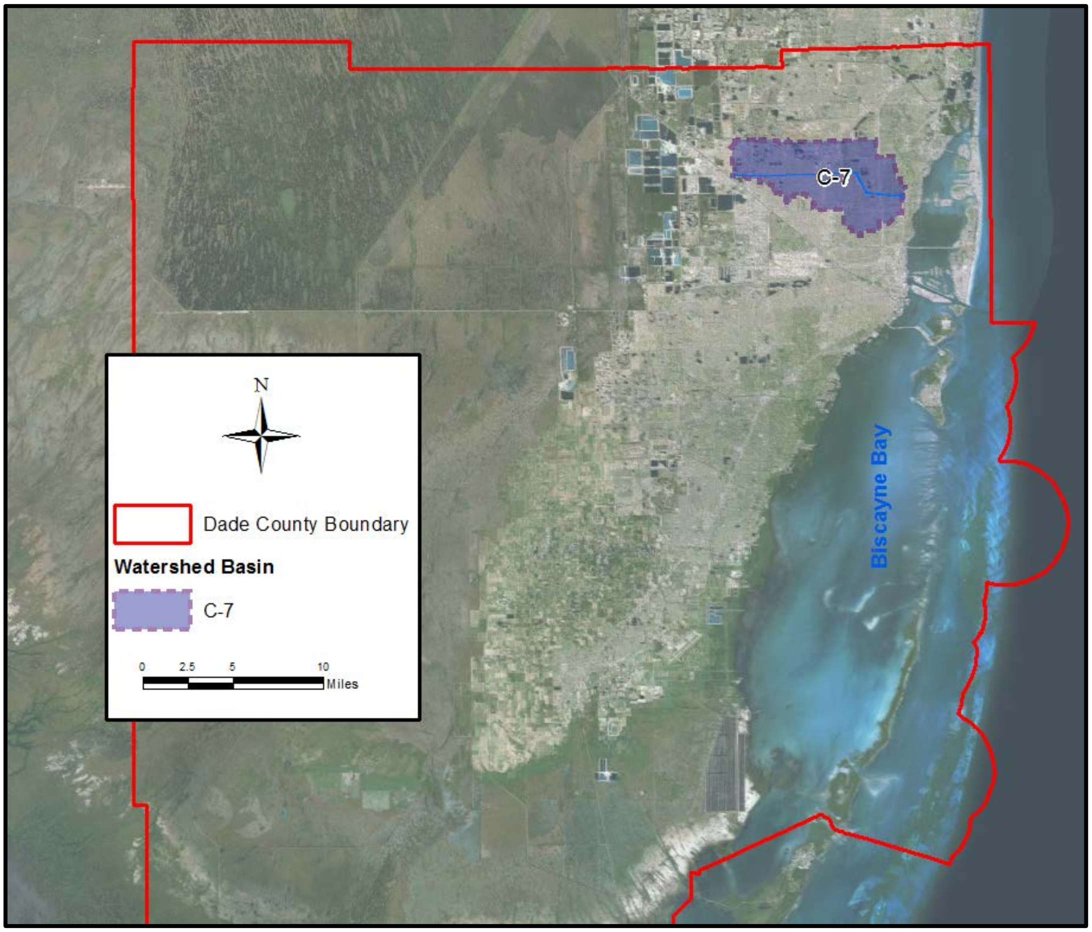


Figure 1-1 – District C7, C8, and C9 Basins within Miami-Dade County

1.1 Project Objectives

The objectives of this project are to perform hydrologic and hydraulic modeling, flood damage assessments, and evaluations of flood protection LOS for existing and future conditions for the District C7 Basin, including:

- Assessing the existing flood protection LOS in the C7 Basin provided by the existing District infrastructure under the current sea level conditions;
- Assessing the 2065 flood protection LOS assuming no infrastructure changes for three (3) future sea level rise scenarios;
- Identify up to three (3) alternative flood mitigation strategies for the C7 District basins, working in collaboration with Miami-Dade County and other stakeholders (this effort will be performed under a separate Work Order);
- Perform hydrologic/hydraulic modeling using the Miami Dade County XP-SWMM modeling tool to assess the 2065 LOS of the alternative flood mitigation strategies for three future sea level rise scenarios; and
- Perform economic impacts analysis to determine the impacts for alternative implementation of the selected District basin (this effort will be performed under a separate Work Order).

The results of this project must produce work products that can be integrated into Miami-Dade's FEMA Local Mitigation Strategy.

1.2 Scope of Work

The District contracted ADA under Work Order No: 4600003093-W005 under Contract No.4600003093 to support the District with several key objectives of this project. The scope of work for Contract No: 4600003093-W005 is comprised of five (5) tasks and 19 deliverables as follows:

Task 1: Evaluation of Modeling Tools Memorandum

- Deliverable 1.1 Evaluation of Modeling Tools Memorandum

Task 2: Model Development and Verification Memorandum

- Deliverable 2.1 Data Memorandum for C7, C8, and C9 Basin LOS Study
- Deliverable 2.2.1 Model Verification Memorandum for C7 Basin LOS Study
- Deliverable 2.2.2 Model Verification Memorandum for C8 Basin LOS Study
- Deliverable 2.2.3 Model Verification Memorandum for C9 Basin LOS Study
- Deliverable 2.3 Verification Model and Associated Data for C7, C8, and C9 Basin LOS Study

Task 3: Assessment of Flood Protection Level of Service provided by existing District infrastructure for Current (2015) Sea Level conditions and three (3) future (2065) Sea Level Scenarios Memorandum

- Deliverable 3.1.1 Existing Conditions - Model Set-Up for C7 Basin
- Deliverable 3.2.1 Draft Report: Flood Protection LOS for Existing Infrastructure and Future SLR in the C7 Basin
- Deliverable 3.2.2 Draft Report: Model Verification Memorandum for C8 Basin LOS Study
- Deliverable 3.2.3 Draft Report: Model Verification Memorandum for C9 Basin LOS Study
- Deliverable 3.3 Existing Infrastructure Hydraulic Model, Post-Processing Tool and Associated Data
- Deliverable 3.4 Final Report: Flood Protection LOS for Existing Infrastructure for C7

Task 4: Assessment of Flood Protection LOS for Alternative Flood Protection Scenarios for Three (3) Future (2065) Sea Level Rise Scenarios Memorandum

- Deliverable 4.1 Draft Report: Flood Protection LOS for C7 Basin Alternative Scenarios Memorandum

Deliverable 4.2 Alternative Flood Protection Hydraulic Models and Associated Data for C7 Basin
Deliverable 4.3 Final Report: Flood Protection LOS for Alternative Scenarios for C7 Basin Memorandum

Task 5: Forms and Reports to FEMA in support of FEMA Grant Agreement

Deliverable 5.1 Monthly Charge Reports
Deliverable 5.2 Quarterly Progress Reports

The purpose of Task 3, Deliverable 3.2.1 – *Draft Report – Flood Protection Level of Service Provided by Existing District Infrastructure for Current (2015) Sea Level Conditions and Three Future (2065) Sea Level Rise Conditions for the C7 Basin* - is to develop an Existing Scenario XP-SWMM model for the C7 Basin using the verified XP-SWMM Baseline Scenario models developed in Task 2.

The Baseline scenario model tidal boundary condition and canal cross-sections at S-27 were updated using data provided by the District and significant flood control projects were implemented based on as-builts provided by Florida Department of Transportation (FDOT). The existing conditions model was used to assess the FPLOS of the District infrastructure under the current sea level condition. For the Future SLR Scenario models, the boundary condition at S-27 was updated based on three (3) projections of future sea levels. In addition to implementation of higher sea levels, the Future SLR Scenario models also implemented projections of increased groundwater levels based on scaling factors provided by the District and the findings reported in the 2014 USGS Scientific Investigations Report 2014-5162, Hydrologic Conditions in Urban Miami-Dade County, Florida, and the Effect of Groundwater Pumpage and Increased Sea Level on Canal Leakage and Regional Groundwater Flow.

The C7 Existing Scenario and Future SLR Scenario models were executed for the following four (4) design storm events:

5-year, 24-hour
10-year, 24-hour
25-year, 72-hour
100-year, 72-hour

The model results were post-processed for each sea level scenario to simulate the maximum water surface profile in the C-7 Canal., determine structure S-27 outflow hydrographs, establish FPLOS performance metric graphics, and assess FPLOS impacts of future SLR scenarios.

The C7 Existing Scenario and Future SLR Scenario model results will be submitted to the District to assist with the development of three alternative strategies to mitigate flooding impacts caused by sea level rise. The development of the alternative strategies is to be completed under a separate work order. Once the alternatives have been developed, the FPLOS for the alternative flood protection scenarios will be assessed for the three (3) future sea level rise scenarios using -the upgraded model to be developed by the District using the No Name storm rainfall conditions. This level of effort will be performed under Task 4 of the Scope of Work.

2.0 DATA COLLECTION

Establishment of the C7 Existing Scenario and Future Scenario models required collecting data from the following entities:

- Miami-Dade County Department of Regulatory and Economic Resources (RER)
- South Florida Water Management District (the District)
- United States Geological Survey (USGS)
- Florida Department of Transportation (FDOT)

2.1 RER

The following information was requested from Miami-Dade County Department of Regulatory and Economic Resources (RER), which has the most pertinent and applicable data within the C7 Basin:

1. RER Watershed Planning Stormwater Modeling Component, Phase II, Stormwater Management Master Plan for the C7 Basin
    a. Technical Memorandum: Model Setup
    b. Volume No. 1: Hydrologic and Hydraulic Modeling for Existing Conditions Without Control Measures
    c. Volume No. 3: Problem Identification and Ranking of Existing Conditions
    d. Volume No. 4: Control Measures Evaluation
    e. Executive Summary and Final Report
2. RER Stormwater Management Master Plan XP-SWMM models for the C7 Basin (See Section 2.3 for detailed description of model names and XP-SWMM engine used by RER):
    a. 5-year, 24-hour Model
    b. 10-year, 24-hour model
    c. 25-year, 72-hour model
    d. 100-year, 72-hour model
3. 2015 Aerial images within the drainage basin
4. GIS shapefiles downloaded from the County's GIS site include:
    a. RER sub-basin delineations
    b. Water bodies/canals
    c. Roadway Network by classification (local, arterial, and evacuation routes)
    d. LUMA Landuse (July 2016) and Future Landuse (2020 and 2030)
    e. Lot/Right-of-Way lines and parcels
    f. Building footprints
5. DERM Part I, Planning Criteria and Procedures, Volumes 1 through 7, dated March 1995
6. DERM Part II, Planning Criteria and Procedures, Volumes 1 through 5, dated March 1995

A catalog of the data files associated with the RER models that was provided by RER is included in **Appendix A**.

On July 26, 2016, ADA met with RER and the District at the RER office to identify available data, including the most recent model files, to clarify data received from the District, to discuss the revisions made by the County since the models were developed, and to define additional data needs.

2.2 The District

The District provided rating curve equations and structure specific flow equation coefficients for the S-27 control structure. The rating curve equations represent the following flow conditions: submerged orifice flow-controlled submerged (CS) and submerged weir flow-uncontrolled submerged (US). In addition, the District provided recent survey results for updating the canal cross-sections upstream of S-27. Spreadsheets were provided as examples of the output for the FPLOS evaluation of PM #2 and PM #5.

The District Sea Level Rise Team provided DSS files for the tidal boundary hydrographs at Structure S-27. Tidal conditions were provided for the Existing and Future sea level rise conditions for each design storm event scenario.

In addition to the datasets provided, the following reports were obtained from the District:

1. South Florida Water Management District Surface Water Management Basin Atlas Maps. October 1987.
2. South Florida Water Management District, Operations Control Center. Structure Books.
3. G-72 Structure Basin Planning Study, Final Planning Study Report. September 2010.
4. Structural Repairs and Improvements, Corrected Final Design Submittal, Miami Field Station, Structure S-27. September 2012.
5. Atlas of Flow Computations at Hydraulic Structures in the South Florida Water Management District. Technical Publication HHB Report #2015-001. October 2015.
6. Ansar, Matahel, and Zhiming Chen. “Generalized Flow Rating Equations at Prototype Gated Spillways.” *Journal of Hydraulic Engineering*, Vol. 135, No. 7, July 1, 2009.
7. South Florida Water Management District Repair Scheduling and Tracking report
8. Appendix A, Flood Protection Level of Service (LOS) Analysis for the C-4 Watershed. South Florida Water Management District Hydrology and Hydraulics Bureau. December 29, 2015.
9. Level of Service, Derivation of Performance Measure 4 (PM4). South Florida Water Management District Hydrology and Hydraulics Bureau. August 2016.

2.3 USGS

For the implementation of increased groundwater for the future sea level rise scenarios, the following report was obtained from USGS:

Hughes, J.D., and White, J.T., 2014, Hydrologic conditions in urban Miami-Dade County, Florida, and the effect of groundwater pumpage and increased sea level on canal leakage and regional groundwater flow: U.S. Geological Survey Scientific Investigations Report 2014–5162, 175 p., http://dx.doi.org/10.3133/sir20145162.

2.4 FDOT

FDOT provided ADA with a GIS file containing all projects within FDOT District 6, which encompasses the C7 Basin. Financial Project Identification Numbers (FPID) were obtained from the GIS file for projects in the C7 Basin that impacted the primary and secondary drainage system since 2005. The FPIDs were used to obtain the as-built plans from FDOT for the following two (2) projects:

1. FPID 432687-1-52-01, currently under construction. Managed Lanes Improvement Project for SR 826/I-75. FDOT provided the Class III Drainage Construction Permit issued on May 22, 2013 and the associated as-built plans.
2. FPID 249941-6-52-01, currently under construction. Improvement and Widening of SR823/NW 57 Avenue. The project includes six (6) phases. As-built plans were obtained for all phases.

2.5 Calibrated XP-SWMM C7 Basin Models

RER provided a total of approximately 30GB of data and model files to the District for completion of the FPLOS study. The C7 Basin data folder was organized into the following sub-folders:

- **Calibration models** with event simulations for specific rainfall events
- **Mapping** data with .xls, .csv, AutoCAD, and GIS coverage files
- **Production Models** with continuous simulations (average, wet, dry) and event simulations
- **Reports** and technical memorandums (TM) providing the background, assumptions, and approach on how each of the basin models were developed. The date of the reports provided are included in the **Appendix A** data catalog.

RER provided the calibration models and the production models for the C7 Basin. The calibration models were used as reference for the models being developed for the purpose of this study. The production models that will be used for this study are provided in **Table 2-1**, along with the native XP-SWMM engine version the models were developed in.

Table 2-1 – RER C7 Basin XP-SWMM Calibrated Model Version

Basin	Model Files	XP-SWMM Version
C7 Basin	5-year, 24-hour: C7_2005_5 10-year, 24-hour: C7_2005_10 25-year, 72-hour: C7_2005_25 100-year, 72-hour: C7_2005_100	2005, v9.10

3.0 C7 (LITTLE RIVER CANAL) BASIN OVERVIEW

The C7 Basin is located in northeastern Miami-Dade County. The extent of the C7 Basin is the southernmost basin of the FPLOS study area and encompasses approximately 32 sq. miles. The watershed is bordered by the C8 basin to the north and the C6 basin on the south and west sides. There are two major canals, and five tributary canals in the C7 Basin. The major canals are the C7 (Little River Canal) and the Red Road Canals. The tributary canals are the Gratigny Canal, Peters Pike Canal, C7 Spur Canal, Palm Springs Canal, and 127th Street Canal.

The C7 Basin connects with the C8 Basin through culverts at NW 22nd Avenue and NW 135th Street (the Spur Canal #1), Red Road Canal's intersection with the Gratigny Expressway (State Road 924), and the northwest corner of the basin where the Palmetto Expressway (State Road 826) merges with I-75 (Palmetto Canal). The C7 Basin connects with the C6 Basin at NW 87th Avenue and the Gratigny Canal, and where the Red Road Canal intersects with the southern boundary of the basin (approximately NW 81st Street or NW 26th Street in Hialeah). The basin discharges to Biscayne Bay through the District control structure S-27. **Figure 3-1** shows the extent of the C7 Basin along with areas of interconnectivity with Basins C6 and C8, major roads, network of canals, and major control structures.

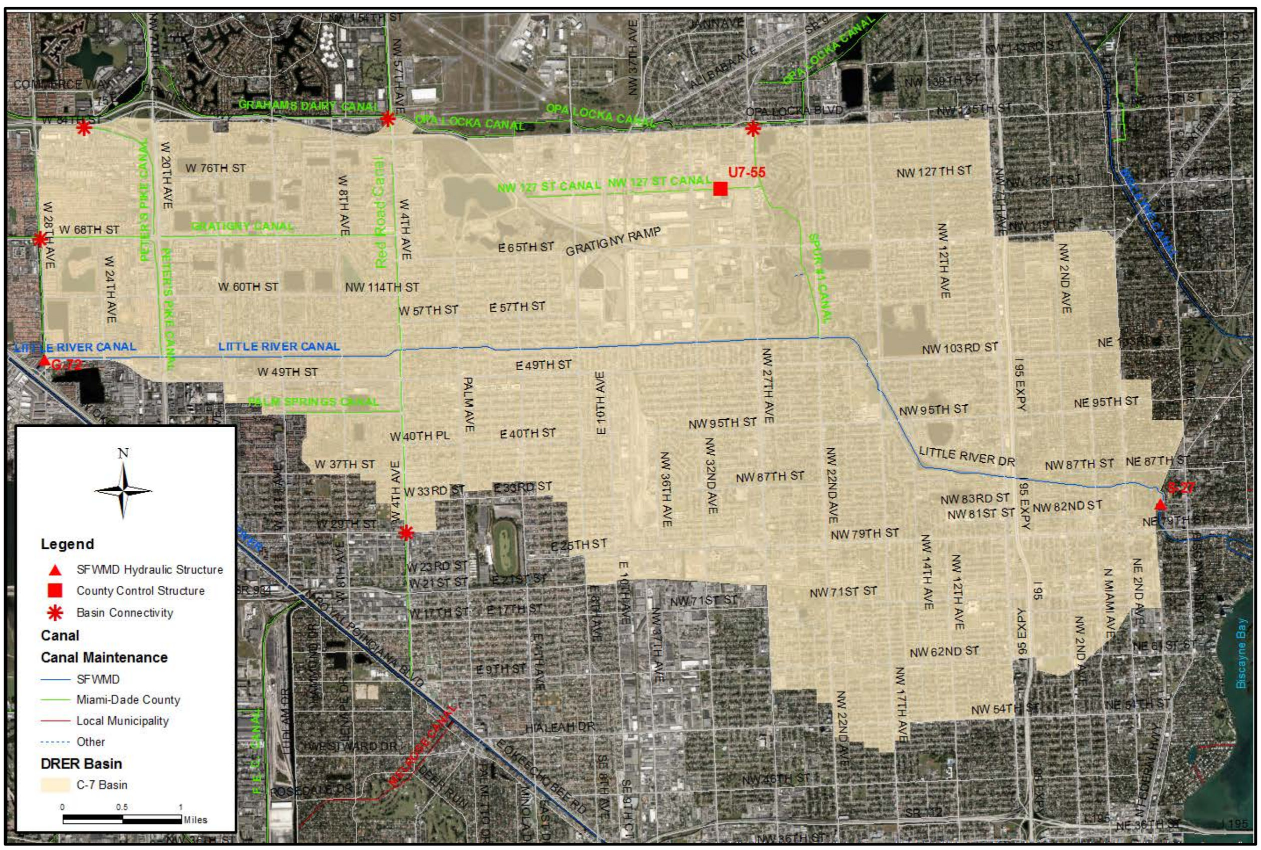


Figure 3-1 - C7 Basin

A considerable amount of the urban developments within the Basin are at or below the high tide elevation making them prone to flooding. Based on the findings of the 2005

Miami-Dade County SWMP for the C7 Basin, the top 20 subbasins prone to flooding are the areas shaded in **Figure 3-2**.The top 20 subbasins are primarily located in the eastern portion of the basin, south of the C-7 Canal.

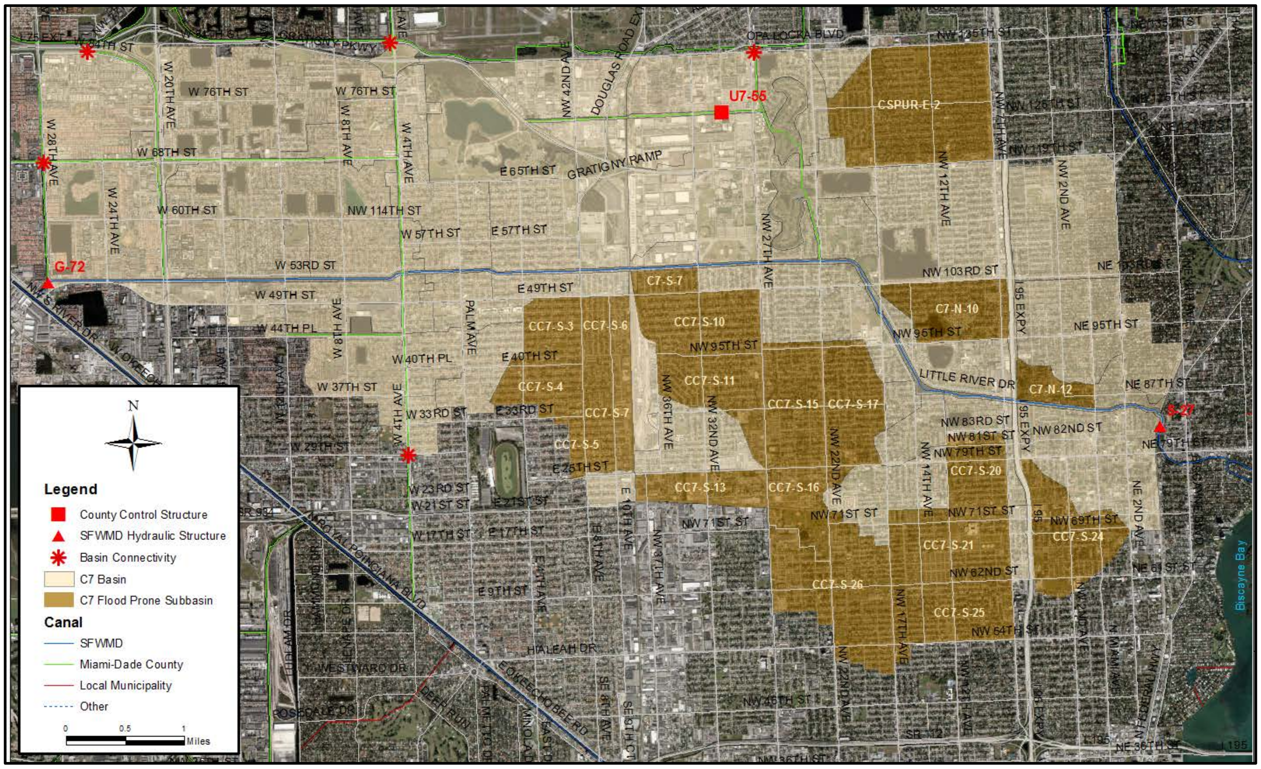


Figure 3-2 - 2005 C7 Basin SWMP Areas Prone to Flooding

From the District Environmental Resource Permit (ERP) Applicant's Handbook Volume II, May 2016, the C-7 Canal has essentially unlimited gravity inflow and was designed for 100-year+ storm frequency. There are three control structures within C7 Basin designed to control inflow to or from the C-7 Canal. All three structures are described below, however, the only structure that currently follows an operational schedule is S-27.

- **Structure S-27**: This District structure is a double-gated spillway located in the C-7 Canal approximately 700 ft west Biscayne Bay, near the intersection of the C-7 Canal and NE 81st Street. The spillway controls the stage in the lower reaches of the C-7 Canal, regulates discharge to the downstream areas, and prevents saltwater intrusion during high tidal conditions. The operational parameters of the structure are provided in **Table 3-1**.

Table 3-1 - Summary of S-27 Operational Parameters

Structure	Trigger (Headwater Elevation)	Open (ft-NGVD29)	Hold (ft-NGVD29)	Close (ft-NGVD29)
S27	S27_H	≥ 1.9	1.5	< 1.0 or ΔH ≤ 0.2 ft in high flood tide

*Note: ΔH is the head differential across the structure

- **Structure G-72**: This District structure is located at the western head of the C-7 Canal at NW 87th Avenue and NW 103rd Street (**See Figure 3-1**). The four-barreled corrugated metal pipe culvert is not designed for flood control operations, instead, it is designed for water supply during dry season and controls the flow between the C6 Basin, Miami Canal, and the C7 Basin. Based on data from the District DBHydro, the structure is operated infrequently for water supply and the last documented water supply delivery was made in 1995 and 1996.

  It is expected that very little, if any, flow passes from the C6 Basin to the C7 basin at this structure. The structure at this boundary is modeled as permanently closed.

- **Structure U7-55**: This RER structure is a culvert located on the NW 127th Street Canal at NW 127th Street just west of NW 27th Avenue (**See Figure 3-1**). The structure consists of a manual gate that is lowered to block flow though the 127th Street Canal at U7-55. There is no operational data available for this structure and according to the description in CDM's "Volume No. 1, Hydrologic and Hydraulic Modeling for Existing Conditions Without Control Measures Stormwater Master Plan, C7 Basin, Phase II" March 2005, it is in state of disrepair. The structure is simulated as always open in the RER scenario XP-SWMM C7 Basin models.

4.0 MIAMI-DADE COUNTY C7 BASIN XP-SWMM MODEL OVERVIEW AND VERIFICATION

The XP-SWMM computer program was developed by XP Software Inc. using the Storm Water Management Model (SWMM) previously developed by the United States Environmental Protection Agency (EPA). The XP-SWMM modeling software is a one-dimensional, node-link, hydrodynamic model that was originally derived from the EPA SWMM models. XP-SWMM offers substantial enhancements over the EPA SWMM model, including a more refined and robust mathematical engine with a graphical user interface with import/export capabilities with GIS and AutoCAD. XP-SWMM also has the capability of performing two-dimensional analysis. The County did not previously use the two-dimensional analyses; therefore, two-dimensional analyses will not be performed as part of the FPLOS assessment.

Miami-Dade County used the XP-SWMM model to develop Storm Water Management Master Plans for all the District basins within the County in 2008. These models are comprehensive and were approved by FEMA in updating the Flood Insurance Rate Maps (FIRM) for the County in 2009.

RER developed the Stormwater Management Master Plans for the main basins and watersheds within Miami-Dade County. To standardize these master plans, RER established detailed procedures for developing and applying hydrologic/hydraulic computer models, establishing basin flood protection levels of service, ranking and prioritizing problem areas, and ranking and prioritizing flood protection projects. The procedures were documented in Part I, Volumes 2 and 3, of the “Stormwater Planning Procedures” document, dated March 1995, which was obtained from RER. These procedures were approved by FEMA. RER used these procedures to develop the XP-SWMM models for the County Basins including the C7 Basin.

The XP-SWMM model representation of the C7 Basin was constructed of storage nodes representing major hydrologic subbasins, hydraulic junctions where changes in the stormwater management systems occur, and links representing major hydraulic components such as drainage conduits and canals; and overland flow weirs that represent overflows between sub-basins and canals. The C7 Basin model encompasses approximately 20,500 acres subdivided into 154 subbasins with and average subbasin area of 132 acres. The subbasin delineation for the C7 Basin is shown in **Figure 4-1**.

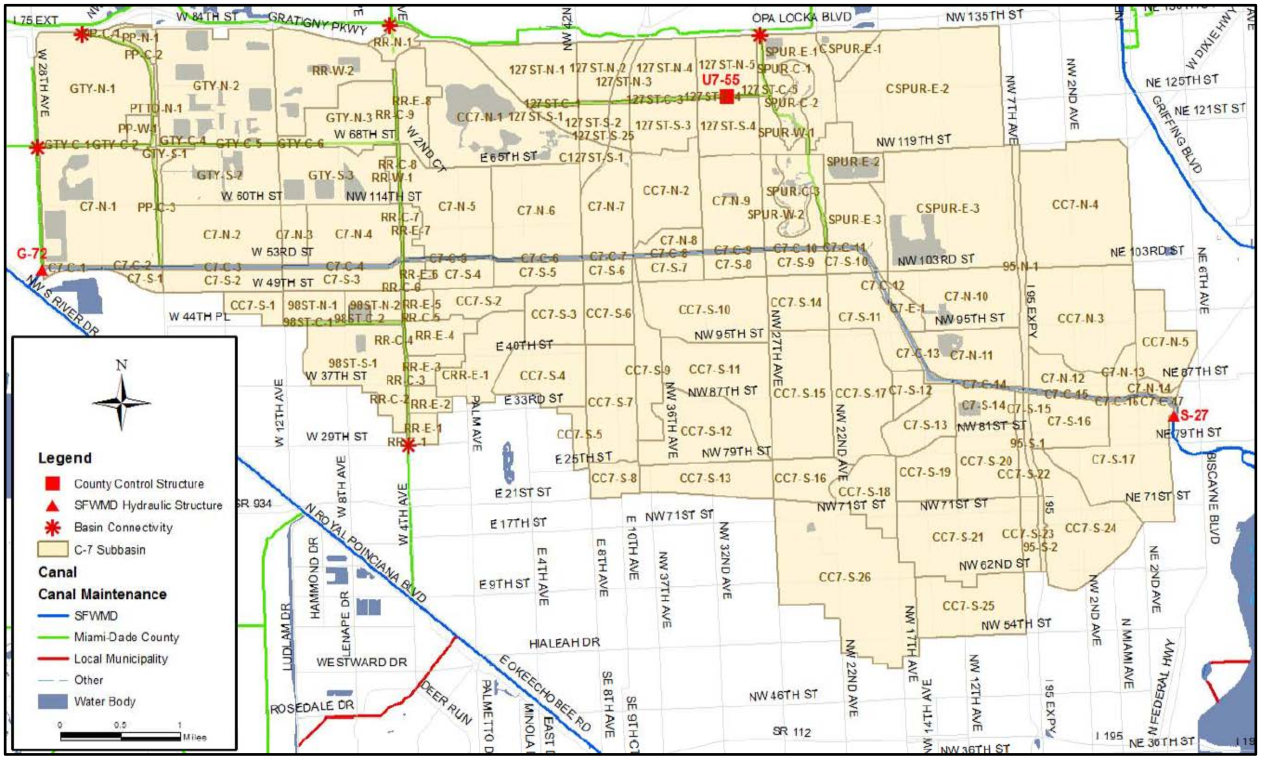


Figure 4-1- C7 Subbasin Location

For subbasin nomenclature, RER used a uniform naming system which was implemented in all the Stormwater Management Plans for the County. The naming convention applicable to all basins can be summarized as follows, using the C7 Basin as an example:

- Each subbasin is given a name based on the location within the basin, proximity to one of the major canals or tributaries, or proximity to a major road. Subbasins are assigned a direction from the adjacent canal and numbered upstream to downstream in that area, thus, the first upstream subbasin east of the C-7 Canal is labeled C7C-E-1, the next is C7C-E-2, and so forth.
- Subbasins that contain portions of the canals are assigned the canal name, a ‘C’ label, and are numbered upstream to downstream such as C7-C-14.
- Subbasins along major roads are assigned names based on the roadway such as 127ST-N-1.
- Closed subbasins, meaning there is no positive connection to the canal network, are assigned a leading ‘C’ label in the name such as CC7-N-1.

The model scenarios developed for completion of the setup and verification of the C7 Basin County models to meet the objectives of this task are provided in **Table 4-1**.

Table 4-1 - Model Scenarios for Completion of Project Work Scope

Task	Model Scenario	Scenario Description
Task 2	**RER**	Original models developed and used for the 2008 Miami-Dade County Stormwater Management Master Plans. The C7 Basin Model was developed using XP-SWMM 9.10
Task 2	**Verification (VER)**	RER scenario models ran locally using the XP-SWMM engine version 9.10 to verify similar results with the results presented in the Stormwater Management Master Plan report.
Task 2	**Baseline (BASE)**	Conversion of Verification scenario models to XP-SWMM 2012 and modification of the S-27 control structure to incorporate operational protocols with multiple rating curves developed by the District for representation of different flow regimes.
Task 3	**Existing (EXIST)**	Representation of current conditions. Implements updates to canal cross-sections, land use data, tidal boundary conditions, groundwater, and recent improvement projects to the primary and secondary conveyance systems. Used for establishing the current FPLOS.
Task 3	**Future (FUT)** SLR1 SLR2 SLR3	Representation of future conditions taking into account SLR projections and associated groundwater rise. Three (3) future SLR projections include: SLR1 – Low SLR estimate SLR2 – Medium SLR estimate SLR3 – High SLR estimate Used to establish the future FPLOS based on three (3) SLR predictions.

XP-SWMM uses two different modules, or Blocks, to calculate stormwater stages and flows: 1) Runoff (hydrologic) Block, and 2) Extran (hydraulic) Block.

4.1 C7 Basin Runoff Block

The hydrologic model components are developed in the Runoff Block. The Runoff Block is used to generate runoff hydrographs for each subbasin and incorporates the processes of rainfall, infiltration, evaporation, and depressional storage for each sub-catchment, and calculates runoff to collection nodes. The Runoff Block imports the rainfall hydrograph and exports surface runoff and groundwater hydrographs for each subbasin in the model. Groundwater hydrographs are directed to user-specified nodes throughout the canal network that correspond to outfall locations or points of discharge into the canal system.

Nodes can collect runoff from more than one subbasin and/or groundwater base flow. For the case of runoff, the model uses different sub-catchment to account for multiple subbasins directed to one node. A second sub-catchment may also be used to account for the BMP land use area. XP-SWMM allows up to five (5) sub-catchments for each subbasin, each sub-catchment must have the following input parameters:

- The Area in acres for each subbasin (and corresponding node/sub-catchment).

- The Directly Connected Impervious Area (DCIA). DCIA is a percentage calculated based on the procedure developed by RER to correlate DCIAs to land use. The Miami Dade County Land Use map was used as the base map. The DCIA for each subbasin (and corresponding node/sub-catchment) was adjusted to account for BMPs.
- The Slopes (ft/ft) of the subbasins (and corresponding node sub-catchments). The average slope of DEM grids is typically computed and the average slope of the grids within each subbasin estimated and used as the subbasin slopes.
- The width of the subbasin. The subbasin width is an estimate of the overland flow path width across the subbasin, with the flow path going from higher elevations to lower elevations. The width of the basin, like the slope, affects the shape of the runoff hydrograph. Large widths relative to the area produce high peak flows, whereas small widths attenuate the overland flow. For most subbasins, widths were initially calculated by dividing the area by the average of three representative flow path lengths. For long narrow basins, it was calculated as twice the measured length of the basin. To account for the smaller areas after dividing the subbasins based upon BMP treatment type, the widths were found by dividing the new areas by the original flowpath lengths. The widths were then reduced to 50% of the calculated value during the calibration process.

XP-SWMM generates discharges from subbasin collection nodes to specified canal locations using vertical flow in the unsaturated and saturated portions of the subsurface storage and a one-directional discharge flow from subbasins to canals.

The C7 Basin models use the EPA non-linear reservoir method to generate the groundwater inflow and surface runoff hydrographs. The rainfall depths used for the development of the C7 Basin production models are based on maps from the District Permit Information Manual, Volume 4, and are provided in **Table 4-2**.

Table 4-2 - C7 Basin Rainfall Depth (inches)

Storm Event	Main Basin	South Basin	Coastal	Inland
5-year, 24-hour	7.0	7.0	6.5	7.0
10-year, 24-hour	8.0	8.0	8.0	8.5
25-year, 72-hour	14.0	14.0	12.5	13.0
100-year, 72-hour	17.0	17.5	16.0	16.0

Variation of rainfall throughout the Basin is represented through the use of four (4) different spatially distributed rainfall depths. A map of the rainfall distribution (from CDM's "Volume No. 1, Hydrologic and Hydraulic Modeling for Existing Conditions Without Control Measures Stormwater Master Plan, C7 Basin, Phase II" March 2005) is shown in **Figure 4-2**.

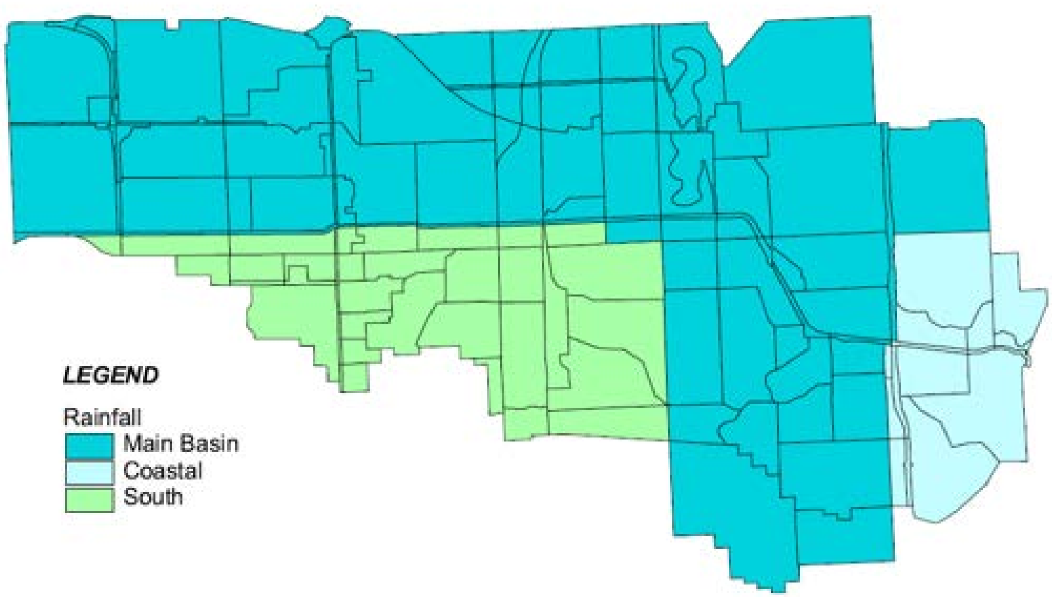
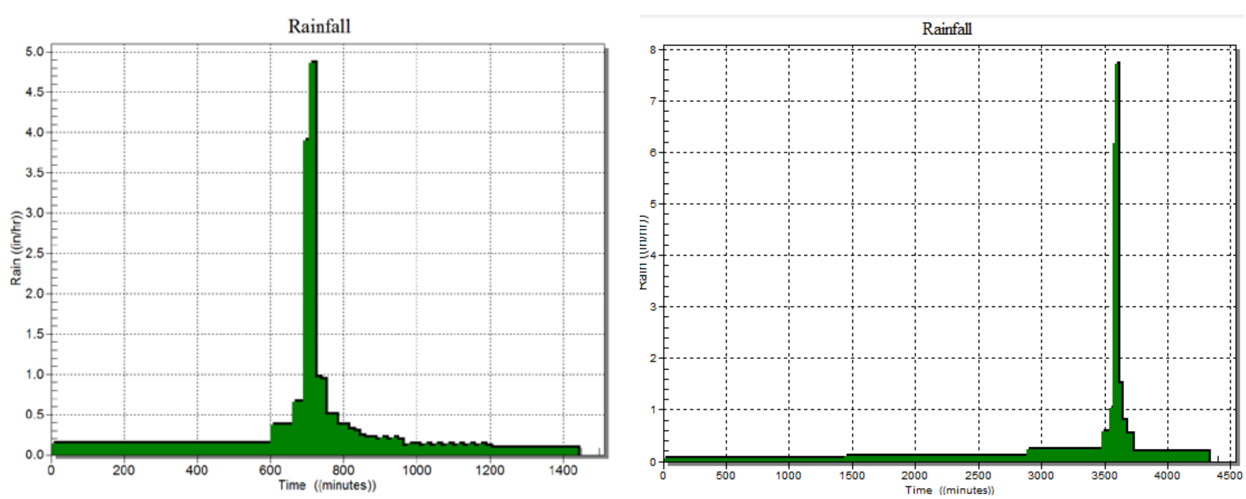


Figure 4-2 - C7 Basin Distribution of Rainfall

The standard District design rainfall distribution was used for the 24-hour and 72-hour storms. The distributions from the C7 Basin for each storm distribution for the main basin storm events are shown in **Figure 4-3**. Each 24-hour and 72-hour event rainfall event follows the respective distribution with varying depth of rainfall.



24-hour Rainfall Distribution 72-hour Rainfall Distribution

Figure 4-3 - Rainfall Intensity Curves

DCIA is a percentage calculated as described in the DERM Stormwater Master Plan C7 Basin Report, Volume 2, “Hydrologic and Hydraulic Modeling of Existing and Future Conditions without Control Measures”, September 1997.The Miami Dade County 2002 Land Use map was used as the base map. The DCIA for each subbasin (and corresponding node/sub-catchment) was adjusted to account for BMPs.

4.1.1 Representation of BMPs

The C7 Basin models use French drain base flow (FDBASE) and Green-Ampt base flow (GABASE) for global infiltration to the subbasins divided for representation of BMPs. The subdivision of the C7 subbasins to represent BMPs resulted in a total of 280 sub-catchments. Sub-catchments with BMPs are assigned to sub-catchment one (1) and implemented using the Horton infiltration parameters shown in **Figure 4-4.** Areas that do not contain BMPs are assigned to sub-catchment two (2) and implemented using the Green-Ampt parameters shown in **Figure 4-8**.

Treatment systems with up to 7.0 inches of storage, or equivalent to the 5-year event rainfall depth, are considered systems with large capacities. During calibration, the maximum amount of infiltration was reduced to 5.0 inches to account for the age and decreased efficiency of BMPs present in the C7 Basin.

For the separation of treatment system types and calculation of DCIA, GIS processing of the RER 2002 land use and treatment system AutoCAD files were completed to create a table with the subbasin areas and the associated land use and treatment system type. Table A-4, in Appendix A of CDM's "Volume 1, Hydrologic and Hydraulic Modeling for Existing Conditions Without Control Measures, Stormwater Master Plan, C-7 Basin, Phase II" March 2005, provides the area, the land use percent breakdown, and the calculated theoretical DCIA of each of the subbasins in the C7 Basin. The polygon representing each subbasin was exported to a table with a defined area, land use type, and type of treatment system for each sub-catchment.

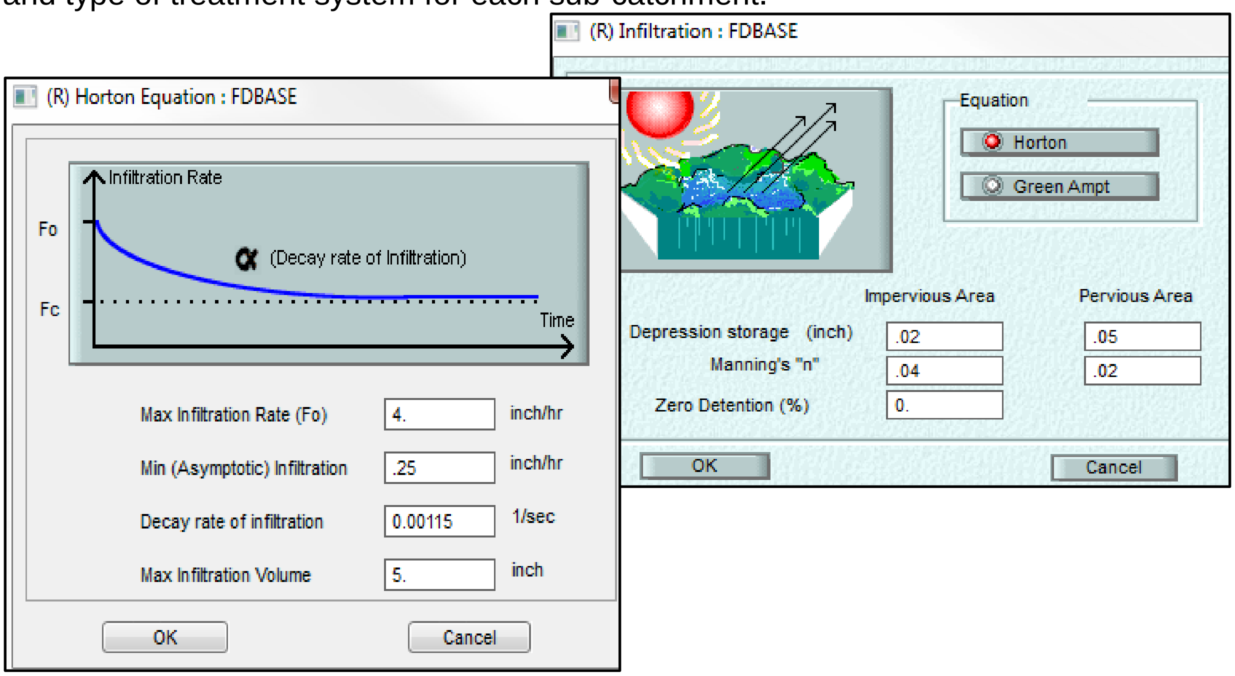


Figure 4-4 - Horton Infiltration Parameters for BMPs

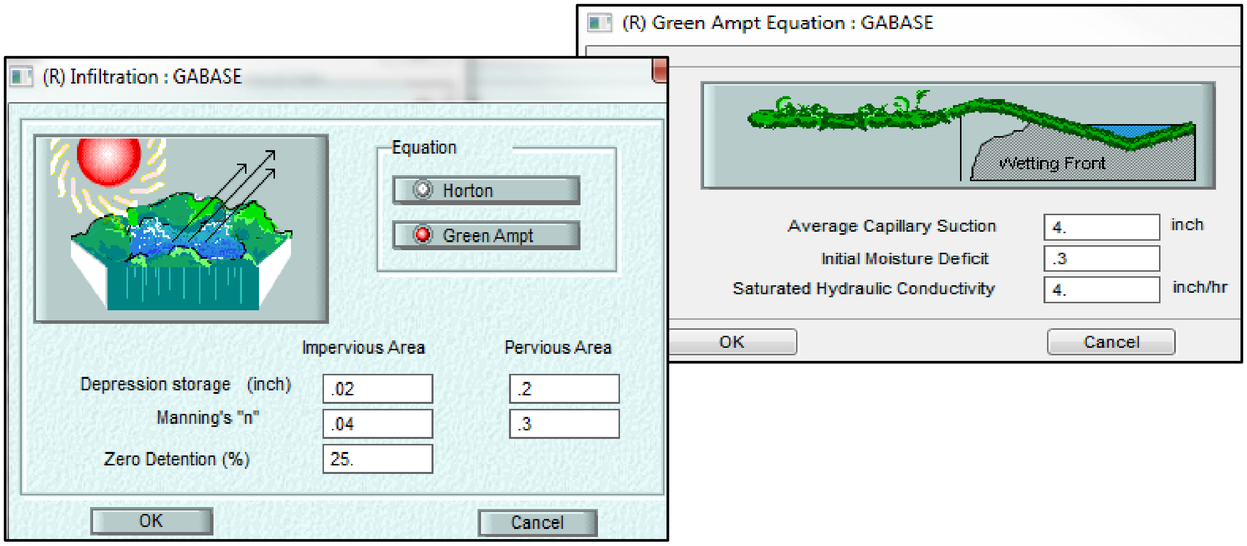


Figure 4-5 – Green-Ampt Infiltration Parameters for Non-BMPs

4.1.2 Infiltration Approach

In XP-SWMM there are two options available for modeling infiltration from pervious areas: Green-Ampt and Horton infiltration methods. The Horton parameters are empirical values that are best estimated from calibration to monitored data. Conversely, the Green-Ampt parameters are physical parameters that can be measured in the field and estimated using estimated soil composition. The subbasins in the C7 RER scenario models represent exfiltration trench systems and BMPs by splitting the physically delineated subbasins into two (2) sub-catchments at the drainage node. The second sub-catchment is assigned a directly connected impervious area (DCIA) value of 0.0 (100% pervious area). The divided sub-catchments have different infiltration parameters and DCIA values. All other runoff parameters remain the same in both areas.

In the RER scenario models, the Horton method is used over areas serviced by exfiltration trenches and other BMPs. The Horton method was selected because the XP-SWMM program allows for a maximum infiltration volume to be assigned to the sub-catchment within the Horton input dialogue.

The equation employed by XP-SWMM for Horton's Equation is:

$$\text{CUMINF (TT)} = \text{WLN*TT} + (\text{WLX-WLN})/\text{DCY*}(1.0\text{-EXP }(\text{-DCY*TT}))$$

Where:

CUMINF (TT) = cumulative infiltration over time step TT, inches
WLN = Equilibrium infiltration capacity, inches/hour
WLX = Initial or infiltration capacity at start of time step, inches/hour
DCY = Time constant, 1/hour
EXP = natural log exponent.

The sub-catchment parameters for Horton infiltration are set to allow full infiltration of a user-defined maximum infiltration value and conversion to full runoff once the maximum amount has been reached. The Horton infiltration values were set using the analysis performed by CDM for the C-100 Basin SWMP (Stormwater Master Plan C-100 Basin Report, Volume 1, "Hydrologic and Hydraulic Modeling of Existing and Future Conditions without Control Measures", CDM, May 2003).

Non-BMP areas are assigned Green-Ampt infiltration parameters. For the swale areas in the non-BMP sub-catchments, the depression storage parameters are adjusted to account for the swale percentage area. For areas with 100% swale land use, the depression storage was increased by 0.5 inches.

The Green-Ampt Equation employed by XP-SWMM is:

F22 (X) = X- (X-F-C1*ALOG (X+C1)+C2)/(1.0-C1/(X+C1))

Where:

X = Time elapsed
F22 (X) = F22 is a FORTRAN function to determine X, given infiltration and rainfall rates
C1 = Average capillary suction times soil moisture deficit, inches*fraction
F = Cumulative infiltration, inches
C2 = Initial moisture deficit
ALOG = FORTRAN function that returns the log value

4.1.3 Groundwater

The groundwater interflow database assigns hydrographs to each node/subbasin. The following parameters, depicted in **Figure 4-6**, are defined in the database for each subbasin:

- Depth of Upper Zone (DWT1) – The depth of the upper zone represents the vertical distance from ground surface to the top of the water table.
- Depth of the Lower Zone (D1) – The depth of the lower zone is estimated from the base of the Biscayne aquifer. The aquifer depth is interpolated at every groundwater node to calculate the depth of the lower zone at the node.
- Channel Depth (BC) – The channel bottom elevation is found for each node from the nearest channel surveyed cross section. The channel depth is the vertical distance from the groundwater elevation to the channel bottom elevation.
- Depth from Channel Bottom to Aquifer Base (BO) – This distance is depth of the lower zone minus the channel depth.

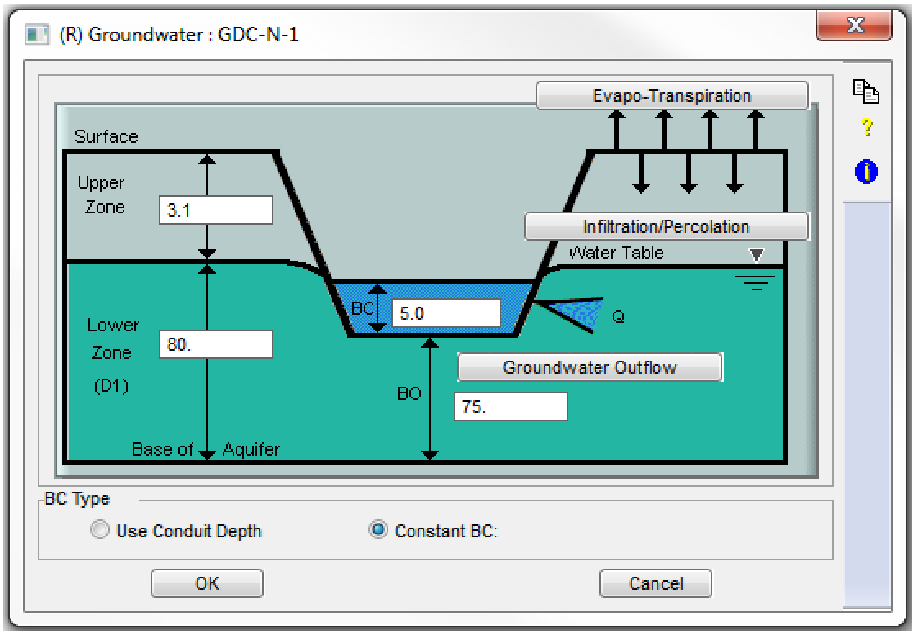


Figure 4-6 - Groundwater Parameters in XP-SWMM

The equation for groundwater outflow is defined using the dialog shown in **Figure 4-7**. The coefficients for groundwater outflow determine the groundwater flow into the drainage network and the rate of change in water-table. Since the flow in channels is not linked to groundwater flow routing, the flow can never be negative. In other words, XP-SWMM is not able to extract water from channels to recharge the groundwater. If the groundwater is below the invert of the channel, the flow becomes zero.

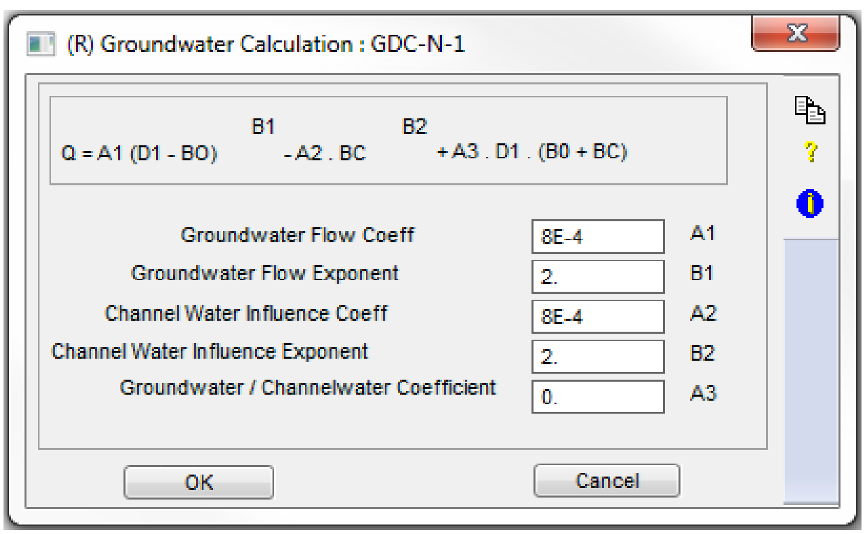


Figure 4-7 - XP-SWMM Groundwater Calculation Dialog

The groundwater table in XP-SWMM is dynamic. If the groundwater table rises to the surface, the infiltration is stopped. If the groundwater table drops below the bottom elevation of the conduit, the groundwater outflow is stopped. Refer to the XP-SWMM Reference Manual for more detailed information about the XP-SWMM solver and flow equation parameters for groundwater flow (http://xpsolutions.com/assets/downloads/xpswmm/xpswmm_Reference_Manual.pdf).

The seepage channels are represented by a multi-link with the second link that has a rating curve that increases seepage flows based on the head differential of the upstream and downstream nodes. The rating curve for the seepage channel regulates flow enough to reduce stages at a rate comparable to variations in the groundwater table level, based on the average October observed groundwater gradients during the period of 1990 to 1999.

4.2 C7 Basin Hydraulic (Extran) Block

The hydraulic model components are developed within the Extran Block. The Extran Block is used to generate stage levels at basin nodes and flows within links using the Saint-Venant dynamic wave equations. This Block simulates the storage and transport of water through a drainage or sanitary sewer network.

The Extran Block uses nodes and links to define the hydraulic network. In XP-SWMM, nodes are referred to as junctions and links as conduits. For each basin, RER coded the Extran Block hydraulic parameters for the primary drainage systems responsible for inter-basin transfers using available as-built plans, permit data, and collected field survey data.

In general, there were several types of conduits used in the C7 Basin Hydraulics models:

- Circular conduits for the cross drains and stormwater pipes
- Rectangular conduits for cross drains, stormwater pipes and bridges
- Bendable weirs for some of the gated control structures
- Irregular shaped conduits for some of the bridges and culverts
- Time varying orifices to simulate control structure gate opening and closing
- Pumps tp move water according to a pump rating curve
- Natural channels for the open channel reaches and overland flow connection between adjacent basins
- Seepage channels to allow for the transfer of water from the canals to the groundwater storage.

The model parameters used to define links include the following:

- Length for channels (LEN) were measured in ft from AutoCAD and aerial images. Overland flow links have a default length of 100 ft.
- NKLASS is the type or link such as circular, rectangular, and natural channel.
- Manning's Roughness (ROUGH) is a standard indicator of the smoothness of the conduit. Roughness values for culverts and equalizer are based on culvert material and condition.
- Depth (DEEP) varies upon the type of NKLASS link specified. The depths of the natural channels are calculated in the model from the cross-section coordinates if zero is entered.
- Width (WIDE) varies upon the type of NKLASS link specified.

- Cross Section Coordinates are entered as an array of x-coordinate positions (STA) and elevations at each coordinate entry (EL) in ft-NGVD29. The minimum elevation should equal the upstream and downstream invert elevations.
- Left and Right Overbank Positions (STCHL and STCHR) are the x-coordinate positions which are assigned as the top of the bank positions.
- Upstream and Downstream Inverts (ZP1 and ZP2) these elevations are measured for culverts and equalizers. For natural channels, the inverts are equal to the minimum elevation of the cross-sectional coordinates. If different, the model will translate the cross-section to the new elevation.

The Nodes/Junction represented on the models includes the following input parameters:

- The node/junction name corresponds to subbasins or link types/direction
- Ground Elevation (GRELEV) also known as spill crest.
- Invert elevation (Z) must be as low as or lower than all links inverts connecting to the node. The node elevation for subbasins without canals or equalizer links is the lowest basin elevation.
- Initial Depth (Y0) is equal to the vertical distance from the groundwater elevation to the node invert at the start of the simulation. If the groundwater is equal to or lower than the node invert, the initial depth is set to 0.0. The average October groundwater levels are used for the design storm events .
- Storage Node Flag (NODST) specify storage areas represented by storage nodes. These nodes have stage-storage area relationships measured from the node invert. The stage-storage relationships were found from elevation data using AutoCAD and/or ArcView. Nodes that represent open and closed subbasins, have the area at the maximum stage (the highest elevation in the basin) equal to the total aerial extent of the subbasin.
- Outfall Flag (FLGOUTF) identifies the outfall nodes. The endpoints junctions of each model network were simulated as outfall junctions and define the boundary conditions of the model. The outfall junctions used by RER for the Basins include Free Outfall, Fixed Backwater, Tidal Series, Stage-Discharge relationship, or Time-Stage relationship.

No secondary stormwater management systems were defined or simulated in the models unless a system served the purpose of conveying runoff from one subbasin to another. Self-contained systems were mostly ignored for this reason. The following items were generally noted regarding development of the Miami-Dade County models:

- Subbasin stage-storage relationships were developed using GIS and the DTMs created for each subbasin.
- Overland connectivity between adjacent subbasins was simulated using natural channel conduits that represent overflow weirs between two sub-basins or a sub-basin and a canal.

- Overland flow channel cross sections were obtained using GIS and the developed DTMs.
- The initial groundwater depth of each junction was established based on the average October groundwater elevations or historical stage. The average October groundwater elevation is used as the initial depth in model nodes.

The C7 Basin model imported the hydraulic data from an XP-SWMM model developed in 1997. The models were updated using cross-section surveys provided by RER. The primary stormwater management system was updated beginning in 2002 to include dredging of the C7-Spur and Gratigny Canals. The culverts and cross-sections for the 2001 Red Road Canal improvements were updated post calibration before the final production runs of the County models. According to the County, improvement projects in RER scenario models were implemented based on the final design. The County also indicated that the cross-sections along the ongoing Palmetto Expressway proposed managed lanes FDOT project corridor are not correctly implemented in the model and will need to be updated based on the RER Class III Permit obtained from FDOT.

4.2.1 SFWMD Control Structure S-27

The operational protocol of the S-27 gated spillway structure is based on the headwater stages of the structures. The Structure has two (2), 15 ft high and 27.7 ft wide gates.

The operational protocols from the District, Operations Control Center, Structure Books, downloaded on 8/4/2016 from the following link provides the most accurate data available for the operational protocol for the structures.

ftp://ftp.sfwmd.gov/pub/hehmke/AsBuilts/Other%20Reports/OCC%20Structure%20Book.pdf

The operational protocol for S-27 from the Structure Books are included in **Appendix B**. It should be noted that as part of the update to the Miami-Dade County Local Mitigation Strategy, these structure books are being updated in the *Water Control Operations Atlas: North and Central Miami-Dade County*.

The gates are automatically operated with a design headwater of 3.0 ft-NGVD29 and a design tailwater of 2.5 ft-NGVD29. The design water elevations provide adequate protection from flooding upstream, limits downstream stage and discharge, and prevents saltwater intrusion into the local groundwater table. A summary of the operational parameters for Structure S-27 are provided in **Table 3-1**. Generally, the gates open and close at a rate of 6 inches per minute.

4.2.1.1 S-27 in the RER Scenario Models

The node-link schematic for the S-27 Structure in the RER models is provided in **Figure 4-8**. For representation of the Structure operations the County model used a multi-link with a canal conduit and bendable weir (BWEIR). The multi-link acts in conjunction with a rating curve-conduit multi-link (S-27), followed by a single-conduit flap gate link (Flap). With the bendable weir option, the weir simulates the instantaneous closing and opening of the structure using flow through the conduit based on the depth of a reference node and two columns of multipliers. The bendable weir dialog box for the operation of S-27 is shown in **Figure 4-9**. The Bend Factor is used when the stage of the reference node is increasing and the Rebound Factor is used when the stage is decreasing. The depth at the node is equal to stage minus invert of the node. The invert at S-27H is (-)13.01 ft-NGVD29.

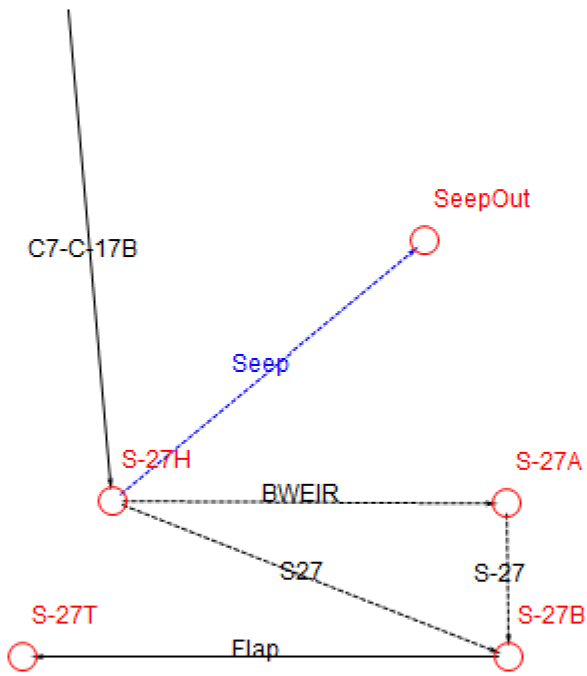
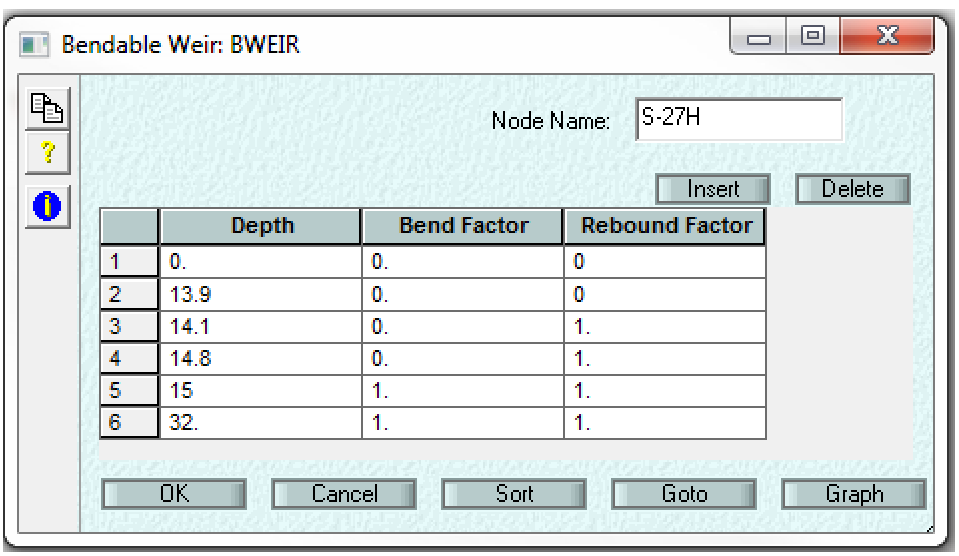


Figure 4-8 - RER Model Node-Link Schematic for S-27


Bendable Weir: BWEIR

Node Name: S-27H

Insert Delete

	Depth	Bend Factor	Rebound Factor
1	0.	0.	0
2	13.9	0.	0
3	14.1	0.	1.
4	14.8	0.	1.
5	15	1.	1.
6	32.	1.	1.

OK Cancel Sort Goto Graph

Figure 4-9 – S-27 Bendable Weir Operation Dialog

The reference node is S-27H representing the headwater stage at S-27. There will be no flow in the link when the Bend Factor has a multiplier of zero representing a closed structure, until a depth at the reference node of 14.8 feet (elevation of 1.79 ft-NGVD) is reached. The weir is implemented for flow to begin or stop passing through S-29 linearly a 0.2 feet interval at the given depth for model stability. When the headwater is receding, the gate remains open until the water depth at S-27H reaches a depth of 14.1 feet (elevation of 1.09 ft-NGVD29), as indicated by a multiplier of 1 in the Rebound Factor column. The gate continues closing until it is completely closed at a depth of 13.9 feet (stage equal to 0.89 ft-NGVD29).

The canal rating curve multi-link is in series after the bendable weir to provide a method for calculating head loss over the structure based on the flow. The rating curve was implemented to restrict flow until the difference between stage at S-27H and S-27A reaches 0.2 ft. The rating curve implemented in the County models for S-27 headwater differential criteria is provided in **Figure 4-10**.

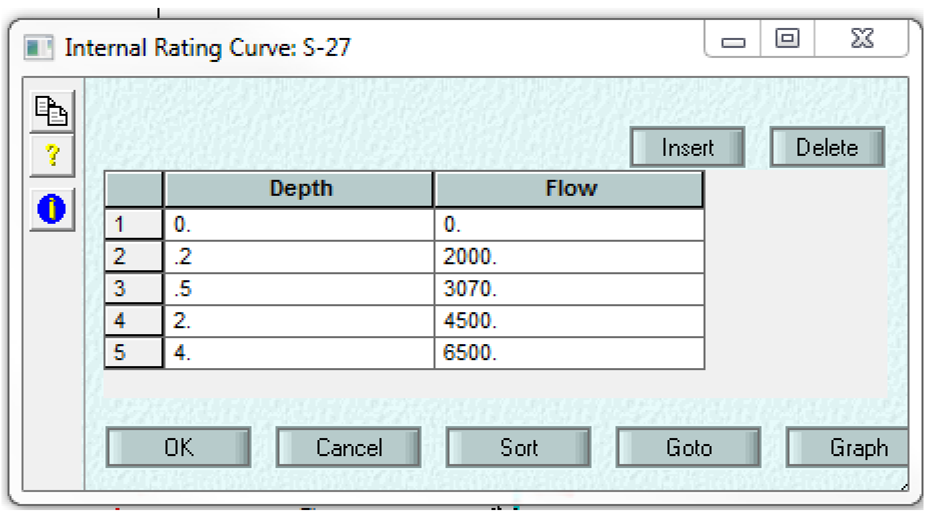


Figure 4-10 - Rating Curve for S-27

The last link before reaching the S-27T outfall is a natural channel conduit with downstream flow only to represent a flap gate at S-27 preventing tidal backflow through the structure.

The “User Stage History Outlet Control” Type was implemented at the S-27T outfall boundary node. The node is implemented using a sinusoidal time-stage relationship with a 3.1 ft-NGVD29 maximum tidal elevation and 12.5-hour lag time to better capture the peak flow at the outfall. One set of boundary conditions were used for calibration based on measured data, and another set was used to simulate design storm event conditions.

Two additional links are located at the S-27H node; however, these links do not represent any operations of S-27. One link is a 200 ft bypass weir with a crest elevation of 4.0 ft-NGVD29 to represent any over-topping of the structure. The other link is a rating curve link to account for the XP-SWMM limitation of simulating the transfer flow from the canal network to the groundwater.

The rating curve used in seepage link at the RER models is shown **Figure 4-11**.

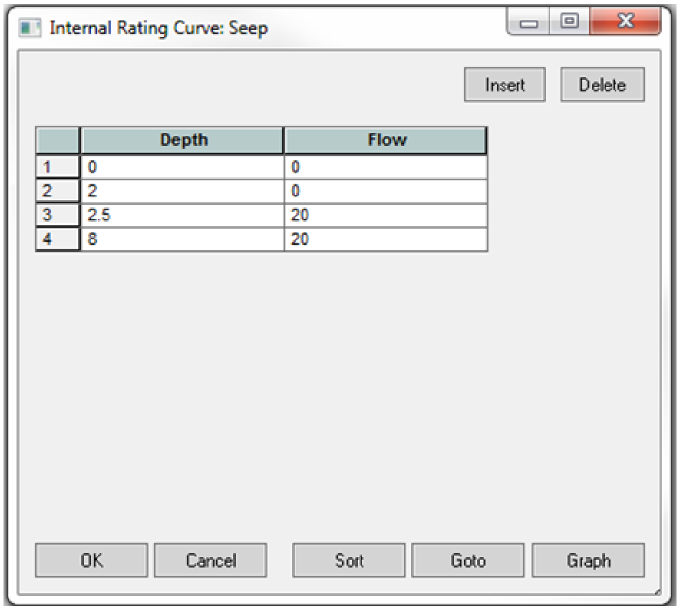


Figure 4-11 – Seepage Rating Curve from C-7 Canal at S-27H

This rating curve indicates that flow is extracted from the C-7 Canal at a rate of 20 cfs when the depth at node S-27H exceeds 2.0 ft.

4.2.2 Weir Diversion

Three categories of weirs are available in XP-SWMM:

1. Internal diversion (transverse or sideflow weir)
2. Outfall weir (transverse or sideflow)
3. Special weir type (Inflatable (regulator) weirs, bendable weirs, and user-defined weirs)

The weir equation, C x L x H, is used,

Where:

H = hydraulic head used to calculate weir discharge.
C = weir discharge coefficient with typical values of 3.0 to 3.3 (imperial units),
L = length of the weir, and k is a power exponent.

The RER scenario models use transverse internal weirs and special bendable weirs (see **Section 4.2.1** for an explanation of the bendable weir functionality). The flow in transverse weirs is determined by:

$$Q = C_w W H^{3/2}$$

Where:

Q	=	Discharge
C_w	=	Weir coefficient
W	=	Weir length
H	=	Hydraulic head over the weir crest

If the water elevation exceeds the surcharge level, the weir will function as an orifice and XP-SWMM uses an equivalent pipe for duration of surcharge. The software calculates the equivalent pipe by equating the following orifice equation to the manning's equation. The equivalent pipe assumes a set diameter and slope, and calculates a Manning's Roughness Coefficient to produce a pipe with the same hydraulic characteristics as the orifice using the following equation:

$$n = \frac{m}{C_0\sqrt{2gL}}(D/4)^{2/3}$$

Where:

n	=	Manning's n for the pipe
m	=	1.486 for units of feet
C_0	=	Orifice discharge coefficient;
D	=	Orifice Diameter;
L	=	Length of equivalent pipe; and
g	=	Gravitational acceleration

4.3 C7 RER Model Calibration

The RER scenario XP-SWMM models were calibrated and verified using available measured rainfall, stage, and flow data recorded for extreme storm events. The models were calibrated by reasonably matching measured peak stage and flow value. Once the models were calibrated and verified, the models were adjusted to perform design event simulations (production runs).

Three storm events were used for the calibration of the C7 Basin. For calibration, model run times were adjusted to include 5 days prior to the beginning of the storm of event to establish antecedent moisture conditions and 5 days after the end of the event to simulate receding stormwater levels. The three high intensity storms used for calibration include:

1. October 2, 2000 Storm ("No Name Storm" which later became Tropical Storm Leslie)
2. October 13, 1999 (Hurricane Irene)
3. November 4, 1998 Storm

The results of the calibration for the C7 Basin models can be found in "Volume 1, Hydrologic and Hydraulic Modeling for Existing Conditions Without Control Measures, Stormwater Master Plan, C-7 Basin, Phase II" March 2005.

Nearly 50% of additional flow volume was observed in the C7 Basin during the 1998 "wet" year calibration event. To account for the additional flow, instead of adding groundwater supply nodes to the model, "User Inflow" hydrographs were implemented at six (6) nodes C-7 Canal nodes (B7-2W, B7-5W, B7-7N, B7-9W, B7-13W, and B7-15W). The hydrographs for the production runs were produced by adding the average rainfall volume from July through September to the 15-minute rainfall depth producing a time series of rainfall depth. The depth from the ground surface to the water table was established for each node by interpolating USGS groundwater contours for the 5 and 10 year records from the 1990s. This parameter was used for calibrating the groundwater supply nodes representing lateral flow of water from outside of the Basin during storm events and when the groundwater table is high.

Other parameters adjusted during calibration of the model include:

- Directly Connected Impervious Area (DCIA) was adjusted to 60% of the values calculated using the 2002 Land Use data.
- Subbasin slopes were calculated by averaging the elevation of three flow paths in each subbasin. These values were then adjusted to 50% of the calculated average.
- Subbasin widths were adjusted to 50% of the calculated values.
- Saturated zone hydraulic conductivity values were set to 4.0 inch/hour.
- The center channel Manning's Roughness factor was adjusted to 0.042.

Peak flow rates were most sensitive to the DCIA values and the center channel Manning's value.

The S-27 structure gate operations were imposed as an internal boundary condition. Recorded gate opening data provided by the District consisted of time series of 15-min gate openings. Once the model was calibrated, the gate operations were changed to rule-based operations for the production runs as described in **Section 4.2.1**. A more detailed description of the calibration structure setup and gate operations is given in Section 1.4.4.3 of the C-7 SWMP (*Volume 1, Hydrologic and Hydraulic Modeling for Existing Conditions Without Control Measures, Stormwater Master Plan, C-7 Basin, Phase II" March 2005*).

4.3.1 Groundwater

For calibration of the groundwater in the RER C7 Basin models, groundwater supply nodes were added to account for lateral baseflow into the Basin using the total flow volumes in the subbasins for Hurricane Irene and the No-Name Storm events. The groundwater parameters were calibrated to simulate the recession rate of the water-table versus time curve from observed well data. The resulting baseflow was augmented with the addition of user hydrographs at six nodes in the C-7 Canal. During the production runs of the RER scenario models, the average October water levels were implemented for the initial depth of each node. The initial depth represents the distance between the node invert and the groundwater table at the beginning of the model run.

A global groundwater database using groundwater inflow hydrographs was developed and assigned to each node/sub-catchment. As documented in Section 3.1.3 in *Technical Memorandum: Model Setup, Stormwater Master Plan C-7 Basin, Phase II*, June 2004, the following groundwater parameters were adjusted during calibration:

- Evapo-transpiration (ET) Parameters
- Infiltration/ Percolation Parameters
- Saturated Hydraulic Conductivity (HKSAT)

Groundwater coefficients establish the volume of base flow and the rate of change in the depth of the groundwater table. Groundwater outflow was calibrated for the following parameters from the dialogue shown in **Figure 4-6**:

- Groundwater Flow Coefficient (A1) and Channel Water Influence Coefficient (A2) – A1 and A2 are calculated using the distance from the subbasin to the “drain to” node. A1 (also A2, as they are kept equal) is proportional to the inverse of this distance squared. The proportionality constant was used as the calibration parameter. There is no “real” distance for the groundwater supply nodes the coefficients were calibration parameters =0.05.
- Groundwater Flow Exponent (B1) = 2.0
- Channel Water Influence Exponent (B2) = 2.0
- Groundwater/ Channel Water Coefficient (A3) = 0.0

These parameters determine the rate that the water table rises and falls in the model.

4.4 C7 Basin RER Model Verification

For verification of the C7 RER models and establishment of the Verification Scenario, the RER scenario models were first executed in XP-SWMM version 9.10 to verify the model files received correspond to the models used for the results reported in Stormwater Master Plan Report. For verification of the models, the time period of the C7 production models were not changed. The 24-hour storm events were executed for 48 hours and the 72-hour storm events were executed for 96 hours.

Once the peak stages of the Verification scenario models were confirmed to match the reported RER scenario results, the peak flows and total flow volume passing through the S-27 Structure were recorded from the Verification Scenario models. The stage time series of S-27 headwater was also recorded from the Verification scenario models. The maximum stage from the Verification scenario models were compared to the reported stage results for the RER scenario models found in Appendix A of the Stormwater Master Plan, C-7 Basin, Phase II, Volume No. 1, Hydrologic and Hydraulic Modelling for Existing Conditions Without Control Measures, March 2005.

The peak stage comparison for all of the sub-basins of the RER Scenario models (RER Model) and Verification Scenario models (VER) are provided in **Appendix C**. The values of statistical summary of peak stages are shown in **Table 4-3**.

Table 4-3 - RER and VER Peak Stage Differential Comparison

Storm Event	RER-VER Peak Stage Differential (ft)		
	Max	Min	Average
5-year, 24-hour	0.13	-0.04	0.01
10-year, 24-hour	0.06	-0.04	0.00
25-year, 72-hour	0.05	-0.04	0.00
100-year, 72-hour	0.05	-0.04	0.01

Of the 244 nodes within the C7 Basin, minor stage differences were observed between the RER and VER models. The largest stage difference was 0.13 ft which was deemed acceptable by the District for verification of the RER models.

Flow passing through the S-27 Structure in the RER Scenario were not documented in the Stormwater Master Plan Report. As a result, the peak flows and flow volumes at the S-27 Structure could not be compared for the Verification Scenario models.

Based on the findings of the C7 Basin model verification, there was an adequate amount of data available to develop the Baseline Scenario model (BASE) for the C7 Basin and for implementation of the Scenario Manager Tool in XP-SWMM version 2012. The Verification Scenario models (VER) were used to confirm the model files received from RER (RER Model) corresponded to the results reported in the Stormwater Master Plan. Of the 244 sub-basins (model nodes) in the C7 Basin, minor stage differences ranging from 0.02 ft to 0.67 ft were observed between the RER Scenario and Verification Scenario models excluding the differences at the boundary nodes. The largest stage difference was 0.13 ft which is an acceptable difference for the validation of the RER model files.

5.0 C7 BASIN BASELINE MODEL SETUP AND VALIDATION

Once the Verification Scenario was validated based on the RER Scenario model peak stages, the Verification Scenario model was modified to implement scenario manager within XP-SWMM. Once scenario manager was implemented, the S-27 Structure setup was modified to better represent the different flow conditions through the structure and to allow for modification of the operational protocols for evaluation of alternative mitigation strategies. The Verification scenario models were also converted to XP-SWMM version 2012. The model was converted to XP-SWMM 2012 due to increased functionality of the Real Time Control (RTC) module and compatibility of the Version 9.10 model database with the 2012 XP-SWMM version. By converting to the more recent version of the software, RTC may be implemented for evaluating alternative mitigation strategies if the C7 Basin is selected for the evaluation in Task 4.

The implementation of scenario manager and reconfiguration of the S-27 Structure established the Baseline Scenario model (BASE). The Baseline scenario model was executed for the following four (4) design storm events:

5-year, 1-day
10-year, 1-day
25-year, 3-day
100-year, 3-day

The Baseline scenario model was verified by assessing the peak stage of the Baseline simulation results compared with the RER scenario model results. The peak flow and total volume of the Baseline scenario models through the S-27 Structure was compared to the peak flow and total volume through the S-27 Structure in the Verification scenario model.

5.1 Scenario Manager

As part of the Stormwater Management Master Plan development for the C7 Basin, RER developed separate models for each design storm event (total of 4 models). This is an inefficient approach for making modifications to the models or evaluating alternative scenarios, which requires making the same modification to each of the design storm even models. Within XP-SWMM, the scenario manager tool allows for multiple simulations to be executed with a single command and model. The tool is designed for evaluating alternative model configurations, boundary conditions, and rainfall events. The setup of a scenario requires establishment of a Base Model. Parent scenarios are then developed from the base model and child scenarios are developed from the parent scenario. XP-SWMM allows up to 50 scenarios per model. **Figure 5-1** shows an example of the hierarchical structure of scenarios in the setup dialog for the scenario manger tool.

By default, there is a Base Scenario as the first parent scenario. Any change made to the Base Scenario is also applied to its child Scenarios. For example, if a cross-section in the Base Scenario is changed, the scenario manager updates the cross-section in all the child scenarios as well. New objects added to the model in any of the child scenarios are implemented in the Base Scenario, but as inactive elements. For the C7 Baseline Scenario Model, the child scenarios were established for each storm event. After the model is executed, the results from multiple runs can be compared within the XP-SWMM interface. Child scenarios can also be established within each storm scenario as needed.

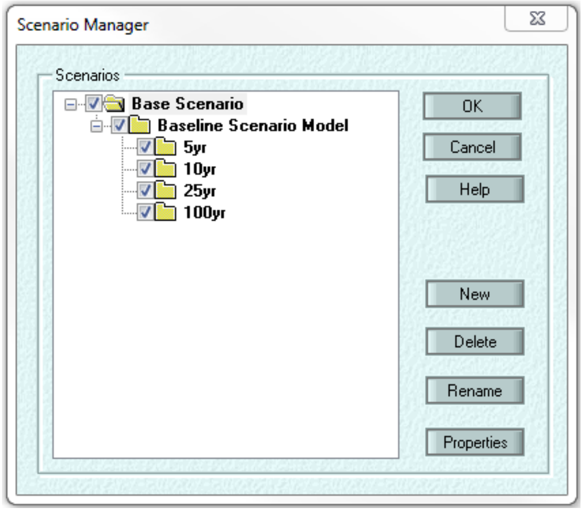


Figure 5-1 - Scenario Manager Tool

5.2 XP-SWMM Real-Time Control Module

The RTC module in XP-SWMM allows for the operation of the hydraulic control structures within the model to respond to simulated hydraulic conditions. As such, the tidal gate for structures or upstream pump stations can be parameterized to operate based on any combination of velocity, flow, and water level at any node, conduit, weir, orifice, or pump within the system. The models previously developed by County models do not currently have RTC implemented. As part of the model verification task for the C7 Basin, the tidal structure operations were initially modified to incorporate RTC capabilities, however, as it is explained in Section 5.3.1.3, the implementation of the RTC for this model application was not successful. Instead of RTC, a multiple rating curve method (Section 5.4) was implemented for all model production runs.

5.3 Modifications to Scope of Work Due to XP-SWMM Software Limitations

The following subsections outline deviations from the SOW due to limitations of the XP-SWMM software discovered during *Task 2, Model Development and Verification Memorandum*. The latest calibrated XP-SWMM models for the C7, C8 and C9 Basins were obtained from RER. The project scope includes conversion of each basin model to the latest 2016 XP-SWMM software version, and implementation of RTC. Based on compatibility errors between different versions of the XP-SWMM software engines, it was determined by RER, the District, and ADA, the best approach for the objectives of this study is to work in the native XP-SWMM software version for each Basin. Conserving the model version will avoid errors that occur when converting the model database files. Known limitations due to the one-dimensional calculation of groundwater flow limited the analysis of the Performance Metrics (PM). In addition, numerous errors in the operation of the RTC module were discovered in XP-SWMM version 9.10 prohibiting the use of RTC for this study.

5.3.1.1 RER Scenario Model Update to Latest Version of XP-SWMM

Significant differences in computed stages and flows were observed when converting model database files to the latest version of the XP-SWMM software. The model database files are not transferred properly in the most recent model engine version (2016.1 at the time of this study). The differences require significant modifications and, consequently, a complete recalibration of the model. When the database is updated, model parameters become significantly more sensitive and the groundwater parameters throughout the model require revision. It was observed that links implemented as a bridge do not get transferred with the converted database. In addition, infiltration parameters become more sensitive and require updated at each model node. Conversion of the C7 Basin model from XP-SWMM version 9.10 to version 2012 yielded reasonable results for peak stages, S-27 peak flows, and S-27 total flow volume.

5.3.1.2 Assessment of PM #6

The assessment of the FPLOS for PM # 6, duration of flooding in the primary canal system estimates the recovery time of the canal stage in response to storm events and sea level rise scenarios. The XP-SWMM software is limited to a one-directional computation of groundwater flow from the sub-basin to the canal. This is a known limitation in the XP-SWMM software. The RER models implement rating curves to represent seepage canals upstream of outfall structure links to simulate flow from the C-7 Canal to the groundwater table. The flow is based on the stage in the canal and the boundary condition of the outfall node. For the assessment of PM #6, each node in the model would have to be modified to include an additional link with a rating curve to account for the infiltration of canal flows to the groundwater. Such a significant modification throughout the model would require recalibration of the models, which is outside of the scope and timeframe of this study.

5.3.1.3 Real Time Control

The original SOW included implementation of RTC in the XP-SWMM baseline model scenario for the operation of the boundary control structures. During the course of this study, it was discovered that the RTC module has numerous malfunctioning controls. These malfunctioning controls were confirmed by XP-SWMM technical support. **Appendix D** includes email correspondence with XP-SWMM confirming the presence of errors in the RTC module. While some RTC parameters may function properly, these parameters would not accurately simulate the different flow conditions at the boundary control structures modified for the Baseline scenario models. There was an improvement made to the RTC functionality in XP-SWMM version 2012. However, there are still noted errors in the RTC module in all versions of the XP-SWMM software. Due to the limitations of the RTC module, RTC was not implemented for Structure S-27 in the C7 Baseline Scenario model.

5.4 Modification of Structure S-27

For establishment of the baseline scenario models, the Verification scenario models were executed in XP-SWMM version 2012 with a number of Regulator Weirs implemented in series with rating curves after the Bendable Weir developed by RER (BWEIR_US link). The rating curves were developed based on different ranges of TW elevations using the following equations from the District *Atlas of Flow Computations for the South Florida Water Management District* to account for the different flow conditions passing through the S-27 gates. The equations were developed using dimensional analysis based on the Case 5 spillway classification.

Table 5-1 - Flow Condition Equations for the District Control Structures

Flow Condition	Equation	Restriction	Remarks
Controlled submerged	$Q = L\sqrt{g y_c^{\,3}}$ $y_c = aG_o\left(\frac{H-h}{G_o}\right)^b$	$\frac{h}{G_o} \geq 1.0$	Also known as submerged orifice
Uncontrolled submerged	$Q = L\sqrt{g y_c^{\,3}}$ $y_c = aH(1-\frac{h}{H})^b$	$\frac{h}{G_o} < 1.0, \frac{H}{G_o} < \frac{1}{K}, \& \frac{h}{H} \geq K$ $K = 2/3$	Also known as submerged weir

Where:

a	=	Case 5 flow computation parameter
b	=	Case 5 flow computation parameter
g	=	Gravitational acceleration (32.2 ft/s^2)
G_0	=	Gate opening (ft)
h	=	Tailwater depth above sill crest (ft)
H	=	Headwater depth above sill crest (ft)
L	=	Gate width (ft)
Q	=	Flow rate (cfs)

The flow equation coefficients for the CS condition were calculated and provided by Mark Wilsnack and Lichun Zhang of the District Hydrology and Hydraulics Group. The coefficients provided are listed in **Table 5-4**. The previously published default values of 1.02 for *a* and 0.3 for *b*, where used for the US flow condition.

Table 5-2 - Coefficient Values for Controlled Submerged Flow at S-27

Control Structure	Controlled Submerged *a*	Controlled Submerged *b*
S-27	1.0784	0.3649

A schematic of the model setup is shown in **Figure 5-2**. The model setup remained unchanged upstream of the S-27H2 node. The BWEIR_US link is a bendable weir that allows outflow from the C-7 Canal when the S-27 headwater rises to 1.9 ft-NGVD29 and stops outflow from the C-7 canal when the headwater drops to 1.0 ft-NGVD29. The flow that passes through the bendable weir then goes through one (1) of the eight (8) regulator weirs per time step.

The Regulator Weir Links, shown in blue, are based on the S-27 headwater (node S-27H) stage for the CS flows and the S-27 tailwater stage for the US flow condition. The XP-

SWMM model is limited to simulate the operation of gates at the control structure as fully open or fully closed. As a result, the CS condition is only valid in the model when the S-27 headwater (node S-27H) is greater than 4.5 ft-NGVD29. When the headwater is less than 4.5 ft-NGVD29, the US flow condition is applied. The rating curve links, shown in orange, are implemented based on the difference of hydraulic head between the headwater and tailwater elevations. The rating equations are applied over 1.0 ft-NGVD29 tailwater elevation increments for the US condition, up to a tailwater stage of 4.49 ft-NGVD29.

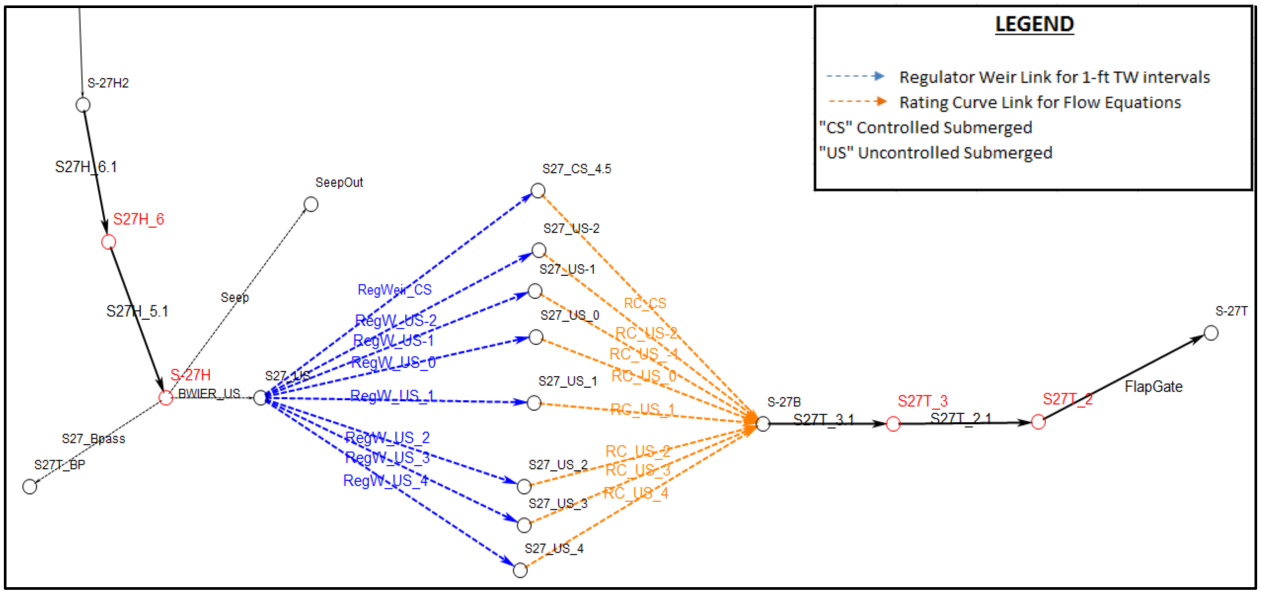


Figure 5-2 - Schematic of S-27 in VER Scenario Models

The CS flow condition is represented with one regulator weir-rating curve pair of links. The regulator weir will only allow flow to the CS rating curve link if the stage of S-27H is greater than or equal to 4.5 ft-NGVD29. The headwater node invert is (-)13.4 ft-NGVD29, resulting in a depth of 17.9 ft-NGVD29 to represent a stage of 4.5 ft-NGVD29 elevation. If the headwater reaches and/or exceeds 4.5 ft-NGVD29, the flow through the rating curve link follows the CS equation from **Table 5-3**. The CS flow is dependent on the headwater and tailwater hydraulic head differential. Since the rating curve setup in the C7 Basin XP-SWMM is also based on the head differential, the rating curve depth allows flow through the structure when the head differential is greater than 0.2 ft, per S-27 operational protocol. The rating curve and bendable weir developed for CS flow through S-27 is provided in **Figure 5-3**.

When the tailwater stage is 4.49 ft-NGVD29 or less, flow follows the US flow equation from **Table 5-3**. The US flow condition is represented by a series of seven (7) regulator weir-rating curve link pairs that are implemented in parallel. Flow passes through one of the US regulator weir links per time step based on the S-27 tailwater stage. For example, if the tailwater is between 2.0 and 3.0 ft-NGVD29, flow will only pass the RegW_US_2 link. Flow then passes through the RC_US_2 based on the flow calculations using the US flow equation. Again, the US rating curves were developed to restrict any flow until the headwater–tailwater differential is greater than 0.2 ft. The input dialog for the RegW_US_2 and RC_US_2 are in **Figure 5-4**. The tailwater node has an invert elevation of (-)13.01 ft-NGVD29, resulting in a depth of 15.01 ft-NGVD29 for a stage 2.0 ft-NGVD29. Once the tailwater reaches 3.0 ft-NGVD29, flow passes through the RegW_US_3 and RC_US_3 until the tailwater reaches 4.0 ft-NGVD29.

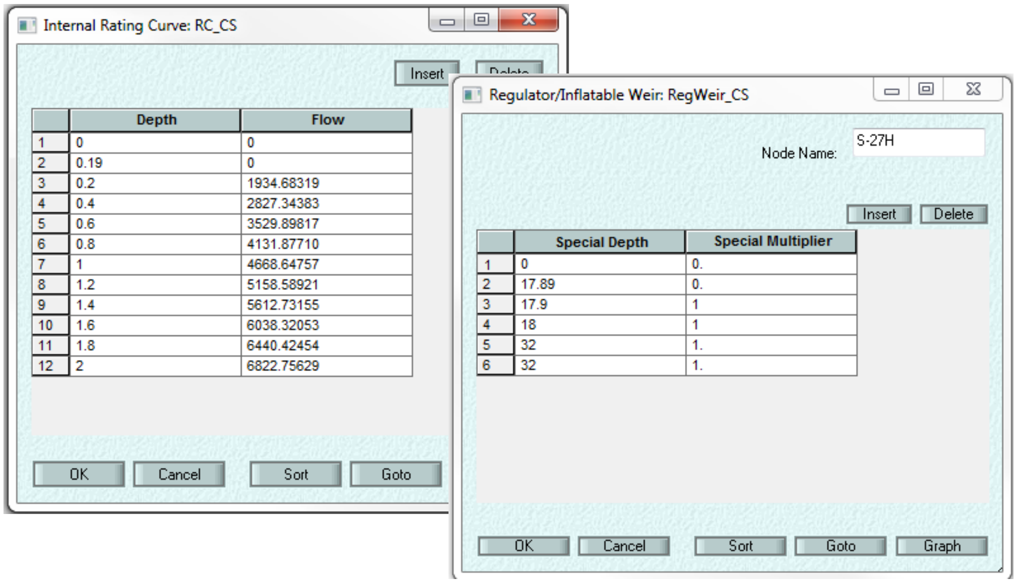


Figure 5-3 - Implementation of Controlled Submerged Flow for S-27

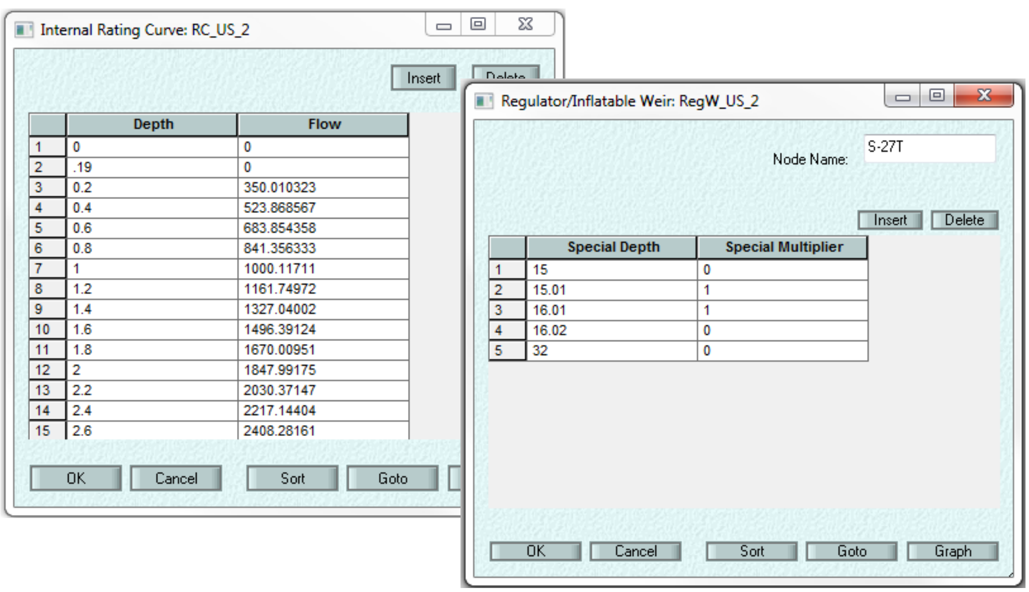


Figure 5-4 - Implementation of Uncontrolled Submerged Flow for S-27

5.4.1 Interconnection with Basins C6 and C8

The C7 Basin interconnects with the C8 Basin at two (2) locations through two (2) culverts in the C7 Spur Canal near NW 27th Avenue and a culvert in the Red Road Canal under Gratigny Expressway, adjacent to NW 57th Avenue. The C7 Basin connects with the C6 Basin at 87th Avenue and the Gratigny Canal, and where the Red Road Canal intersects with the southern boundary of the basin (approximately 81st Street (26th Street in

Hialeah)). The location of the interconnectivity with both the C6 and the C8 Basins are shown in **Figure 3-1**. The points of interconnection are represented with a multi-link rating curve based on the relationship between the C-7 Canal stage and flow through the respective culverts simulated for the 2000 “No Name” storm event and the 1989 dry year simulation. The C7 Basin model is executed using the glass wall approach for the boundary conditions at these points of interconnectivity.

5.5 Baseline Scenario Model Verification Results

For verification of the C7 Baseline model results, computed stages in all the subbasins were compared to the computed stages in the RER Scenario model (RER) described in **Section 4.0**. The comparison of the Baseline scenario and RER scenario peak stages are provided in **Appendix E** and a statistical summary of the stage results are provided in **Table 5-5**. The greatest differential stages between the Baseline and RER nodes occurred at two (3) boundary storage nodes.

Table 5-3 - Statistical Summary of C7 BASE Peak Stage

Storm Event	RER-BASE Peak Stage Differential (ft)		
	Max	Min	Average
5-year, 24-hour	0.15	-0.53	-0.03
10-year, 24-hour	0.67	-0.28	-0.02
25-year, 72-hour	2.73	-0.82	0.05
100-year, 72-hour	4.75	-0.64	0.08

The greatest stage differential is 4.75 ft and 2.73 ft occurring during the 100-year and 25-year events, respectively. The stage differential occurs at two boundary storage nodes in the model after the storm event has passed due to the storage relationship established in the RER model. The average differential is nearly zero for all storm events.

The difference in stages within the C7 Baseline model at the S-27 Structure headwater (Node S-27H), G-72 tailwater (Node C-6BC-1), and two dispersed nodes along the C-7 Canal were also compared with the stage results of the C7 RER. The difference in peak stage between the RER Verified model and Baseline model at these selected nodes is provided in **Table 5-6**. The overall average difference of stage within the selected nodes is 0.08 ft with the maximum difference occurring at the S-27 headwater node with 0.29 ft of difference. The next largest difference occurs at G-72 tailwater, which is located at the upstream end of the C-7 Canal at the western end of the C7 Basin.

Table 5-4 – RER and Baseline Scenario Peak Stage Difference

Node	5yr Stage Difference	10yr Stage Difference	25yr Stage Difference	100yr Stage Difference
S-27H	0.02	0.08	0.29	0.29
C-6BC-1 (G-72 TW)	0.03	0.03	0.09	0.21
C7-S-11	0.02	0.02	0.03	0.05
C7-N-5	0.07	0.03	0.03	0.06

Flow passing through the S-27 Structure in the RER Scenario were not documented in the Stormwater Master Plan Report. As a result, the flow hydrographs and flow volumes of the Baseline Scenario through the S-27 gated spillway were compared to the results from the Verification Scenario Model. The total volume and peak flow through the S-27 structure are provided in **Table 5-7** and **Table 5-8.**

Table 5-5 – Verification and Baseline Total Flow Volume at S-27

Model Scenario	Total Volume (ac-ft)	% Difference
5yr VER	447,522	
5yr BASE	438,626	-1.99%
10yr VER	534,486	
10yr BASE	518,320	-3.02%
25yr VER	2,494,854	
25yr BASE	2,471,934	-0.92%
100yr VER	3,238,641	
100yr BASE	3,206,734	-0.99%

Table 5-6 - Verification and Baseline Peak Flow at S-27

Model Scenario	Max Flow (cfs)	% Difference
5yr VER	1,567.35	
5yr BASE	1,638.83	4.56%
10yr VER	1,759.67	
10yr BASE	1,827.57	3.86%
25yr VER	2,711.62	
25yr BASE	2,821.79	4.06%
100yr VER	3,205.22	
100yr BASE	3,517.68	9.75%

The time series data for the S-27 headwater were also not documented in the SWMP. Hydrographs at the S-27 Structure outfall flow and S-27 headwater stage for the Baseline scenario and Verification scenario models are provided in **Appendix F**. During the development of the Baseline Scenario model, it was discovered that the tidal boundary at the S-27 Structure was inversed for the 72-hour storm events in the RER model compared to the 24-hour events. For the purpose of validating the Baseline Scenario results, the tidal boundary remained unchanged. As part of the adjustments that will be made to the Baseline Scenario model for the Existing Scenario model, the tidal boundary will be modified for all storm events.

For verification of the C7 Baseline model, peak stages were compared to the RER Master Plan results, and the peak flows and total flow volumes at S-27 headwater were compared to the output of the Verification Scenario models. The greatest stage differential between the RER Scenario stage results and the Baseline Scenario stage is 4.76 ft and 2.73 ft occurring during the 100-year and 25-year events, respectively. The stage differential occurs at boundary storage nodes in the model after the storm event. The average differential is nearly zero for all storm events. The average difference of the stage within the selected nodes along the C-7 Canal was 0.0826 ft. The maximum difference occurred at the G-72 tailwater node with a 0.221 ft stage difference. The total flow volume through the S-27 Structure was within 23% of the total flow volume passing through the S-27 structure in the Verification Scenario. The peak flows were within 10% of the Verification Scenario peak flows with a maximum difference in the peak flow occurring for the 100yr, 72hr storm event in which the Baseline Scenario had 9.75% higher peak flow.

The overall conclusion of the C7 Basin model verification, is that the Baseline Scenario model results for peak stage, peak S-27 flow, and total S-27 flow volumes are reasonable compared to the calibrated RER Scenario models. The C7 Baseline model is acceptable to establish an existing conditions model with the implementation of key improvements that have been made since development of the model in 2005. The validated C7 Baseline model is also acceptable for evaluation of different sea level rise scenarios and the impact of water levels in the Basin.

6.0 C7 BASIN EXISTING SCENARIO MODEL SETUP (2015)

Establishment of the Existing Scenario model (EXIST) includes implementation of significant land use or canal cross-section changes since the RER Scenario model development, updating the rainfall hyetographs, modification of tidal boundary conditions at each structure for each design storm, and implementation of significant flood control projects since the RER models were developed.

When the RER Scenario models were developed in 2002, most of the C7 Basin was already developed and has remained relatively static. Any development changes, and resulting minor changes in land use, are expected to have a negligible effect on the on the modeling results. Based on this, in conjunction with the RER finding an insignificant difference between the 2002 and 2020 projected land use in the Master Plan, the District decided that the land use has not undergone significant changes and will remain unchanged for the Existing and Future SLR Scenario models. In addition, the District decided the design rainfall depths and distributions were also to remain unchanged for the Existing Scenario FPLOS. If it is decided to modify the rainfall for the Existing Scenario in the future, the District will implement the modifications and complete back runs of the model in-house. The District performed an evaluation of the model performance using the "No Name" storm event of October 3-4, 2000. Based on the results and observations made during the storm event, the District modified the storage in the model to include below-ground basin storage which is not part of the RER models. The method for adding the unsaturated zone basin storage to the model sub-basins is further explained in Section 6.1.1.

6.1 Existing Scenario Boundary Conditions

The Baseline Scenario model boundary conditions were updated at the S-27 outfall. DSS files for the tidal boundary hydrographs at Structure S-27, developed by the Sea Level Rise Team at the District as part of this study, were provided by the District. The tidal boundaries were developed using Hurricane Irene as the base historical event. The development followed the same methodology used in the District 2015 LOS Pilot Project for the C4 Basin with the following exceptions:

1. The extreme tailwater values for each return levels were calculated using a single method (i.e., Monte-Carlo Joint Probability) versus the average of multiple methods used in the C-4 LOS Pilot Project; and
2. The unified sea level rise projection developed by the southeast Florida regional compact on climate change (2015) was used to project sea level change while the USACE sea level change projection was used for C-4 LOS Pilot project.

The resulting hydrograph datasets for the tidal boundary condition, shown in **Figure 6-1**, were used to update the Baseline Model (from Task 2) as part of this study for completion of Task 3: Assessment of FPLOS.

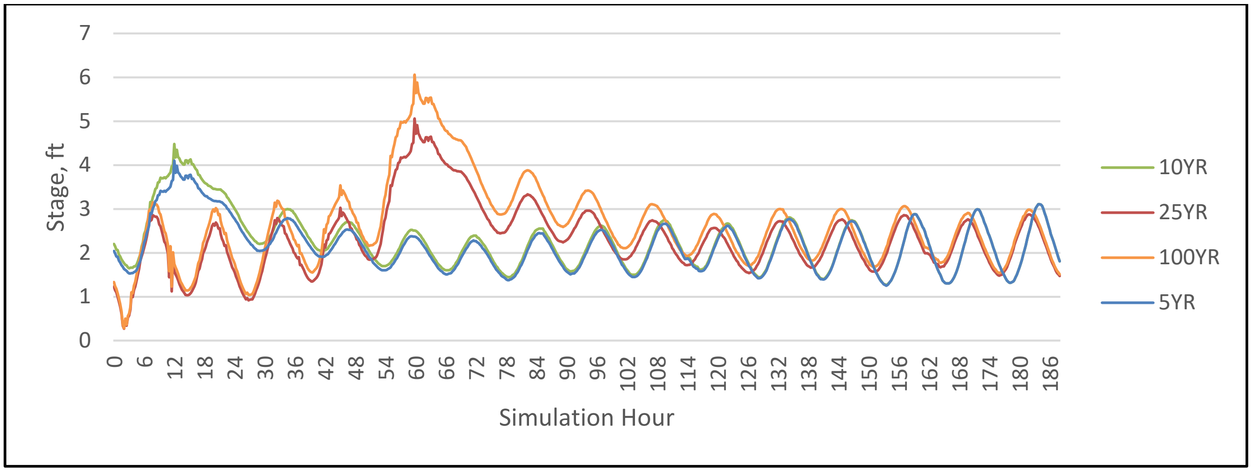


Figure 6-1 - The District EXIST Tidal Boundary Condition

6.1.1 Stage-Storage Curve Update by the District

As part of the model validation, District staff looked at computed water levels in the form of inundation maps (see **Figure 6-2**). These maps show the extent of inundation over the terrain. The inundation maps were created to show ponding depth or depth of inundation computed as the peak stage minus the ground elevation. A color scale is used to show ponding depth range in increments of 0.5 foot. It was observed that the model predicted flooding in some sub-basins during smaller (5-y) storm events when there was no observed flooding. These same basins showed little difference between ponding depths resulting from the 5-yr and the 100-yr event.

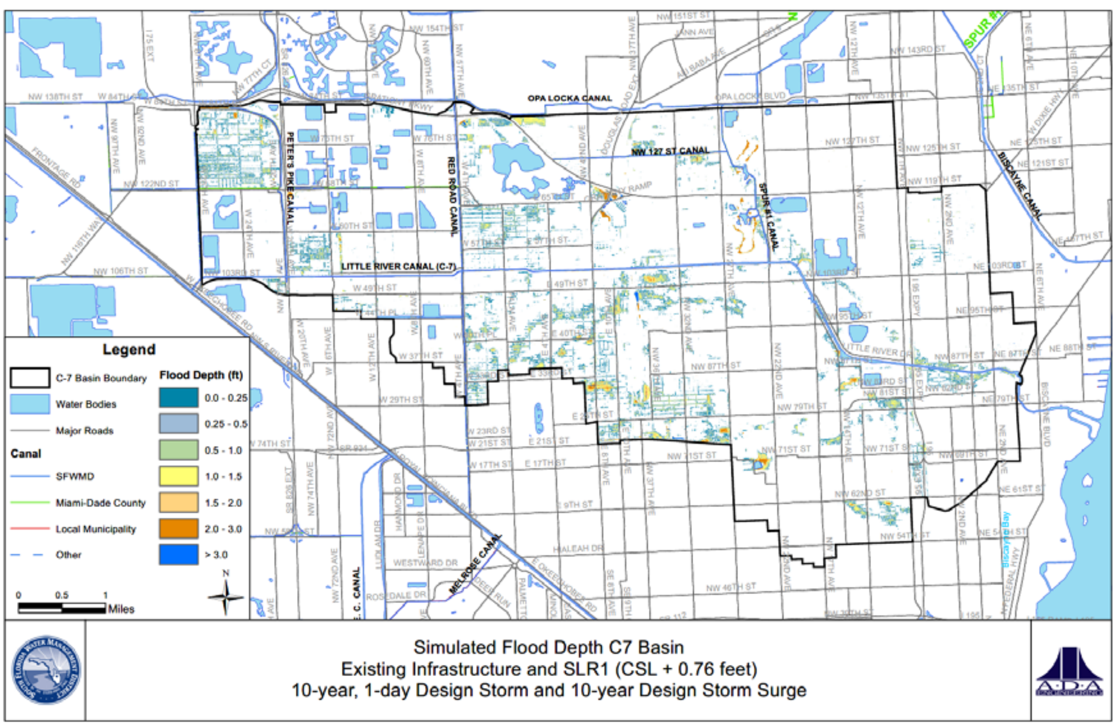


Figure 6-2 – Sample Flood Inundation Map

The reason for this was the lack of underground storage in the sub-basins of the hydraulic model. The original model developed by RER did not include below-ground storage; basin storage started at the ground surface and increased with elevation. The lack of underground storage results in sharp increases of water levels at the beginning of the rainfall in the simulation. The result was very little difference in maximum ponding depths between the 5-yr and 100-yr storm events in some sub-basins. In order to address this issue without having to recalibrate the C7 basin model, below-ground storage was added to the sub-basins until flooding from the 5-year event matched reported flooding from similar storms. This 'soft-calibration' resulted in lower peak stages for the lower return period events. Many subbasins did not show sensitivity to the increase of below ground storage and thus were not changed. Below-ground storage was computed as the area of the sub-basin where infiltration trenches drain the stormwater runoff multiplied by a subsoil porosity of 0.15 for a depth equal to the depth to the groundwater table. The areas of the model which have infiltration computed with the Horton method were established by RER in the original C7 Basin model. Below, the chart shows the original and modified depth-area curves for sub-basin CC7-S-15 in which the modified curve indicates an increase in area at a depth of zero (ground surface elevation) with an increase in area of 28.5 acres.

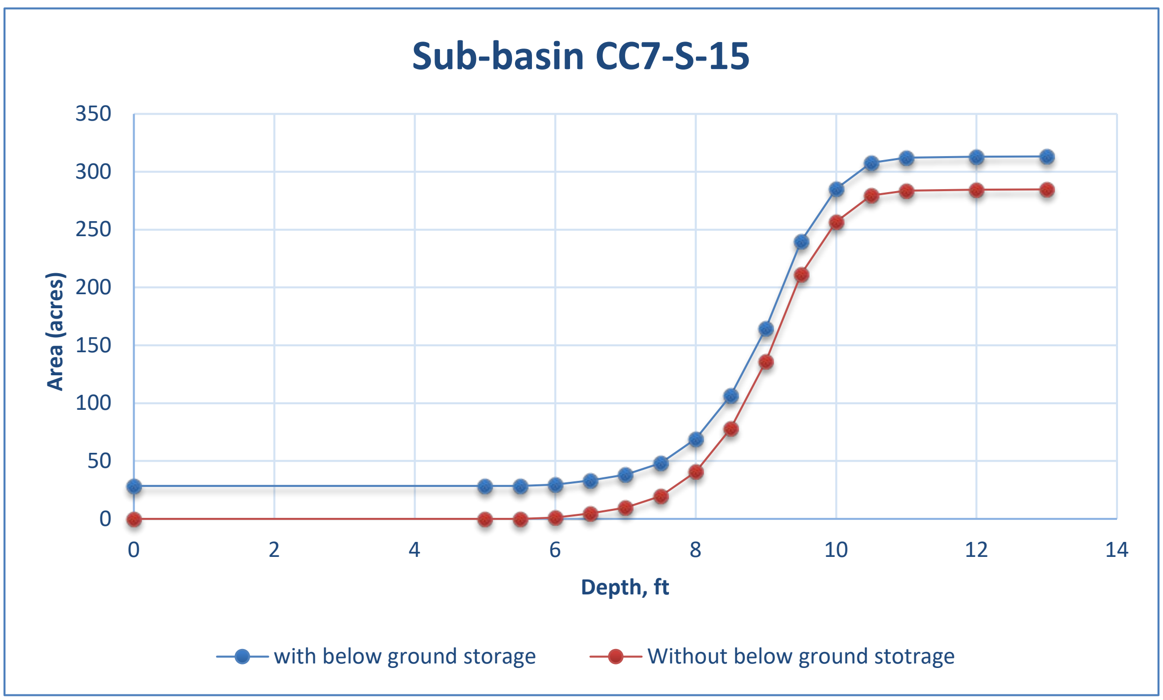


Figure 6-3 – Original and Revised Depth-Area Curves with Increased Below-ground Storage for Subbasin CC7-S-15

Table 6-1 shows the sub-basins in the model which were modified with the below-ground storage.

Table 6-1 – Sub-basin Total Area, Area Served by Exfiltration Trenches and Increased Storage Area

Storage Node	Total Subbasin Area (acres)	Area Served by Exfiltration Trenches (acres)	Increased Storage Area (acres)
CSPUR-E-2	806.5	104.6	16.7
127ST-N-1	214.5	174.8	26.2
127ST-N-2	112.1	112.1	16.8
127ST-N-3	35.0	30.9	4.6
127ST-N-4	162.2	141.9	21.2
127ST-N-5	156.4	113.1	17.0
127ST-S-1	38.2	28.2	4.2
127ST-S-2	50.3	41.6	6.2
127ST-S-3	145.0	111.2	4.7
127ST-S-25	41.9	31.0	16.7
C7-N-10	296.4	136.2	5.2
CC7-N-1	548.0	27.97	9.8
CC7-N-2	249.1	209.8	31.5
CC7-N-5	184.3	32.3	4.8
CC7-S-3	153.2	15.4	2.3
CC7-S-6	133.3	61.9	9.3
CC7-S-10	330.7	34.8	5.2
CC7-S-11	311.8	65.6	9.8
CC7-S-15	346.0	189.9	28.5
CC7-S-16	124.3	61.6	9.2
CC7-S-17	318.7	167.1	25.0
CC7-S-18	160.0	48.9	7.4
CC7-S-21	412.5	208.4	31.3
CC7-S-24	357.3	150.1	22.5
CC7-S-25	278.8	11.9	1.8
CC7-S-26	724.2	54.2	11.0
GTY-N-1	495.8	221.0	33.1

6.2 Drainage Infrastructure Improvements and Modifications.

Improvement projects that have an effect on the primary and secondary drainage systems were investigated using data provided by the District, RER, and FDOT. These recent drainage improvements in the C7 Basin are discussed next.

6.2.1 The District

SFWMD provided projects that have a potential impact to the conveyance capacity of the canals. ADA was provided with the District's Repair Scheduling and Tracking spreadsheet and advised that the replacement of the G-72 culverts was the only project with a potential impact on the hydraulics of the system. However, this structure is only operated for water supply and doesn't experience any flow under the conditions of this study. As a result, this project was not implemented in the model.

The cross-sections upstream and downstream of the structure were modified based on June 2016 survey data provided by the District. The cross-sections implemented in the model are provided in **Appendix G**.

6.2.2 FDOT

The County indicated that the cross-sections for Peters Pike Canal along SR 826 and I-75 need to be updated based on the ongoing managed lane improvements projects (FPID 432687-1-52-01). The Class III Drainage Construction Permit issued on May 22, 2013 and associated Permit Modifications were obtained from FDOT. The cross-sections of the Baseline Scenario model were modified to reflect two (2) new culverts (718 LF of 16' CMP culvert, and 160 LF of 10" CMP) and changes to the canal profile resulting from the location of new steel sheet piles along the canal, as shown in the project as-built plans approved by RER on December 17, 2014. The project location is shown in **Figure 6-4**.

To find any other FDOT projects that may have impacted the drainage in the C7 basin canals, the following process was conducted using the FDOT shapefile "D6Projects072016.shp" obtained from FDOT in July 2016.

1. Clip shapefile to the C7 basin boundary.
2. Filter WorkMix field in the attribute table – Remove records related to road construction, repair or maintenance. Keep records related to bridge replacement or repair, drainage improvements, resurfacing, and miscellaneous construction, and blanks.
3. Filter dates – Screen the dates in all of the seven fields with dates (FY22, FY32, FY52, FY5WP, FYStart, FYEnd). Keep any records with dates after 2005.
4. Filter location – Identify the locations of remaining records and remove records that are not in any of the model canals.

After this process, two additional projects were found that modified the canalconveyance. The first project is a bridge replacement located in North Miami Ave (circled in Red in **Figure 6-4**). The project has not started construction at the time of this study. Based on the clearance criteria for the low chord elevation of bridge structures crossing canals, the replacement of the bridge will not have effect on the flows or the stage in the C-7 Canal, and therefore is not a project that will be implemented in the C7 Existing or Future Scenario models.

The second project is the expansion of Red Road/SW 57th Avenue. The project includes replacement of existing culverts with culverts having a larger diameter and changes in canal cross sections along the Red Road Canal (FID 249941-4-52-01). The canal cross sections and culverts were updated using the project as-built plans obtained from FDOT. The projection location is shown in **Figure 6-4**.

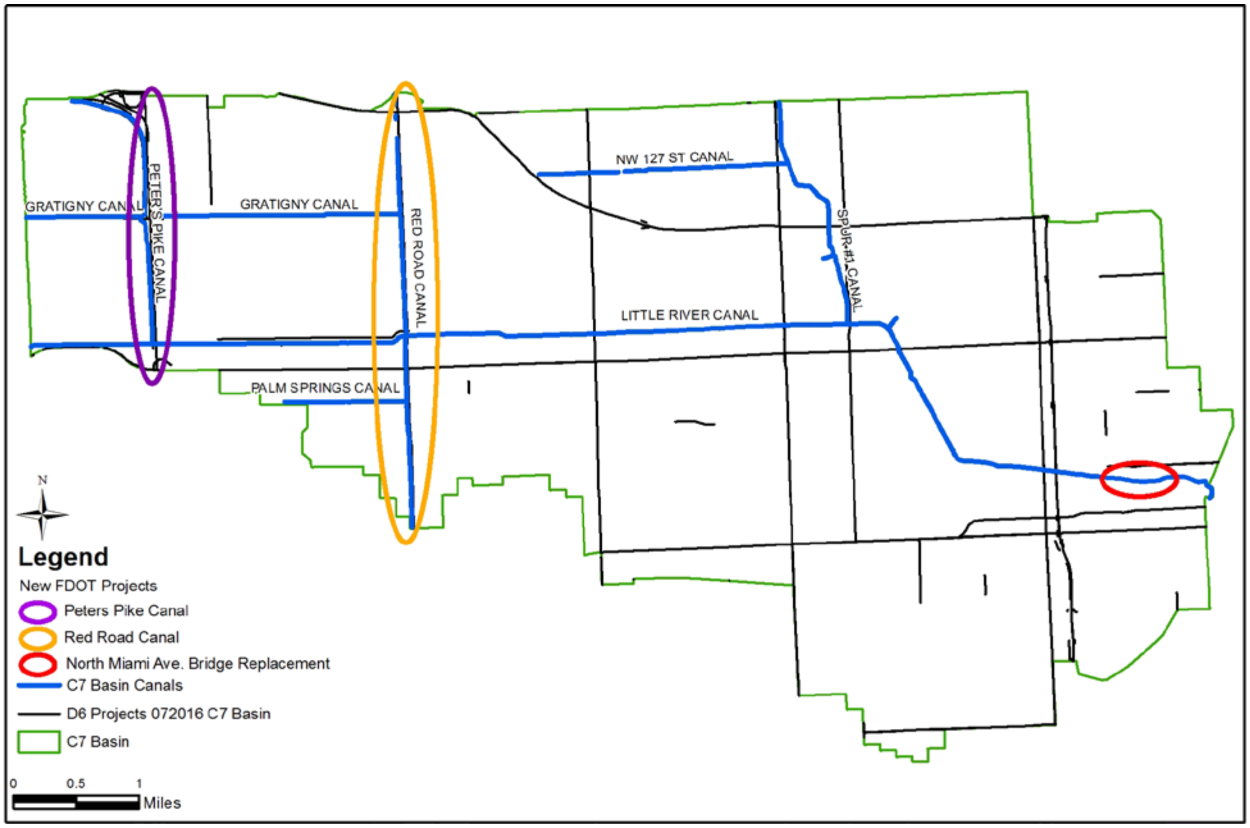


Figure 6-4 - FDOT District 6 Projects in the C7 Basin

6.3 Land Use Projections

It was determined by the District and ADA that the C7 Basin has not undergone a significant land use change since the development of the model. Any changes would have a minor effect on the Basin hydrologic response and do not justify the effort required to update and recalibrate the model.

6.4 Structure S-27 in the C7 Existing Scenario

Due to the update of the cross-sections upstream and downstream of the S-27 Structure, as described in **Section 6.2.1**, the bendable weirs used for the structure operations were adjusted based on the updated cross-section invert for the structure gates opening and closing. The Baseline scenario model setup at structure S-27 was further modified.

6.5 Interconnection with Basins C6 and C8

The C7 Basin interconnects with the C8 Basin at two (2) locations through two (2) culverts in the C7 Spur Canal near NW 27th Avenue and a culvert in the Red Road Canal under Gratigny Expressway, adjacent to NW 57th Avenue. The C7 Basin connects with the C6 Basin at 87th Avenue and the Gratigny Canal, and where the Red Road Canal intersects with the southern boundary of the basin (approximately 81st Street (26th Street in Hialeah)). The location of the interconnectivity with both the C6 and the C8 Basins are shown in **Figure 3-1**. The points of interconnection are represented with a multi-link rating curve based on the relationship between the C-7 Canal stage and flow through the respective culverts simulated for the 2000 “No Name” storm event and the 1989 dry year simulation. The C7 Basin model is executed using the glass wall approach for the boundary conditions at these points of interconnectivity.

6.6 C7 Basin Existing Scenario Model Results

The C7 Basin Existing model was executed for the 5-year, 24-hour; 10-year, 24-hour; 25-year, 72-hour; and 100-year, 72-hour design storm events. The peak stage results for each storm event in all model nodes is provided in **Appendix H**. Stage hydrographs of the S-27 headwater for all the storm events are shown in **Figure 6-5** for the 5-year, 24-hour and 10-year, 24-hour storm events and **Figure 6-6** for the 25-year, 72-hour and 100-year, 72-hour storm events.

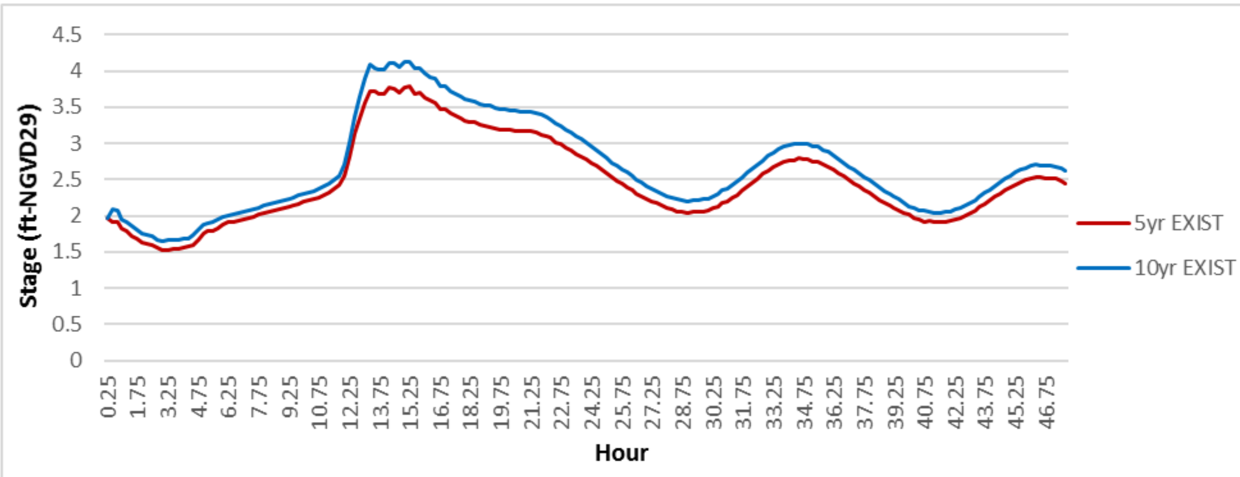


Figure 6-5 - EXIST, 5yr and 10yr-24hr, S-27 Headwater Stage Hydrograph

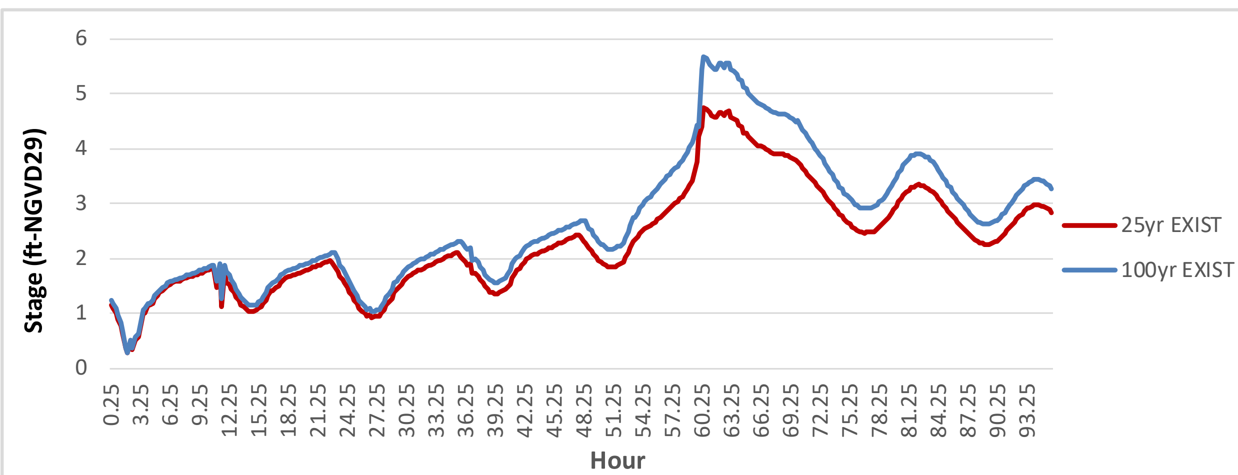


Figure 6-6 - EXIST, 25yr and 100yr-72hr, S-27 Headwater Stage Hydrograph

Flow hydrographs for the design storm events at the S-27 Structure outfall for the Existing Scenario model are provided in **Figure 6-7** for the 5-year, 24-hour and 10-year, 24-hour storm events and **Figure 6-8** for the 25-year, 72-hour and 100-year, 72-hour storm events.

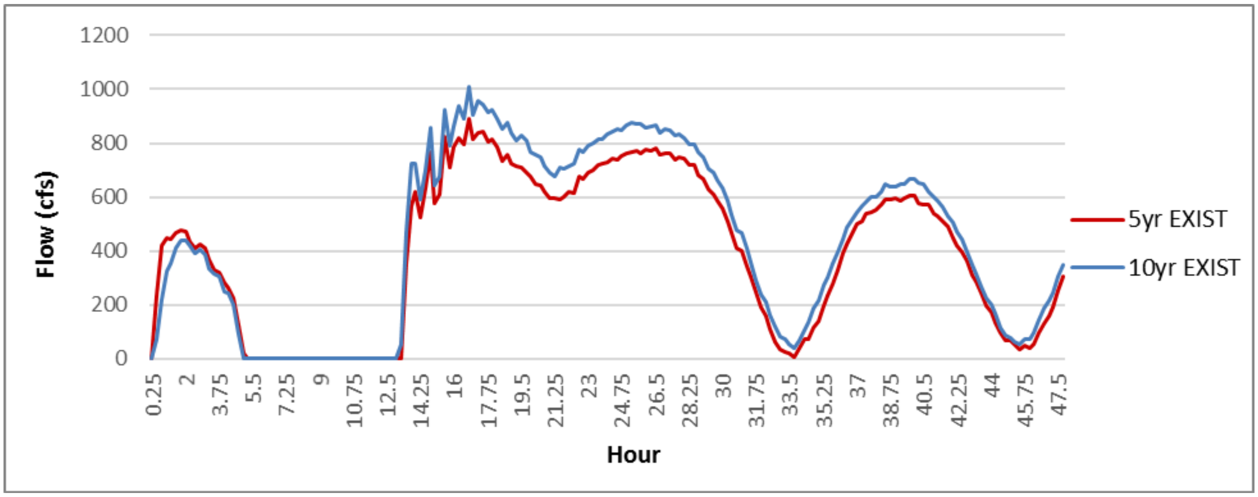


Figure 6-7 - EXIST, 5yr and 10yr-24hr, S-27 Flow Hydrograph

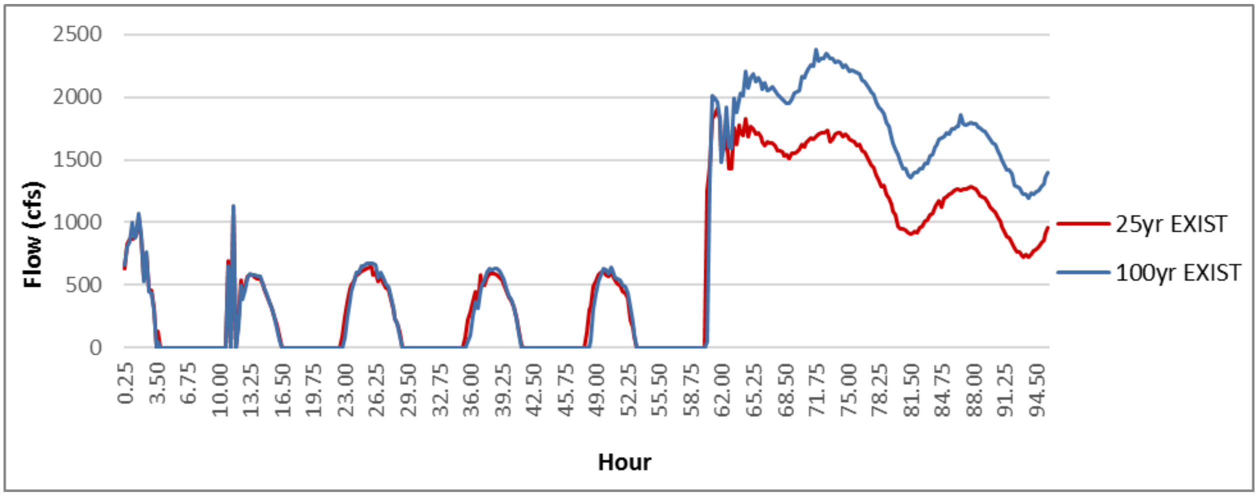


Figure 6-8 - EXIST, 25yr and 100yr-72hr, S-27 Flow Hydrograph

The total volume and peak flow through Structure S-27 are provided in **Table 6-1**.

Table 6-2 - Existing Scenario Total Flow Volume and Peak Flow at S-27

Model Scenario	Total Volume (ac-ft)	Max Flow (cfs)
5yr EXIST	1,561	891
10yr EXIST	1,747	1,009
25yr EXIST	4,948	1,911
100yr EXIST	6,277	2,365

7.0 FPLOS PERFORMANCE METRICS

SFWMD has developed six (6) FPLOS PMs to determine the LOS provided by the water management system. The performance metrics (PMs) consider the systems original design, the current condition of the system with 5.0 inches of sea level rise since the systems design (Existing Scenario), and future condition which includes predicted land use changes, groundwater level increase, and operational changes to structure operations, water deliveries, and well-field withdrawals (Future SLR Scenario). The six (6) FPLOS PMs include:

- #I: Maximum stage in primary canals
- #2: Maximum daily discharge capacity through the primary canals
- #3: Tidal Structure Flow Performance – effects of sea level rise
- #4: Peak storm runoff - effects of sea level rise
- #5: Frequency of flooding – stage based LOS for sub-watersheds
- #6 Duration of Flooding – effects of sea level rise

7.1 FPLOS Performance Metrics

The future condition includes three different projections of sea level rise through the year 2065:

- SLR01 – Low sea level rise projection based on historical data (0.45 ft)
- SLR02 – Medium sea level rise projection (0.91 ft)
- SLR03 – High sea level rise projection (2.37 ft)

The Existing Scenario model will be used to produce the output needed for generating FPLOS PMs documented in South Florida Water Management District, 2015. Flood Protection Level of Service Analysis for the C-4 Watershed. Appendix A: LOS Basic Concepts. H&H Bureau, the District, West Palm Beach, FL. December 2015. The PMs that will be evaluated using the Existing Scenario and Future scenario models include:

- #I: Maximum stage in primary canals
- #2: Maximum daily discharge capacity through the primary canals
- #4: Peak storm runoff - effects of sea level rise
- #5: Frequency of flooding – stage based LOS for sub-watersheds

LOS Performance Measure (PM) #3, Structure capacity evaluation, will be completed by the District and is not part of this investigation. However, the results of PM #3 will be incorporated by the District in the Final Report as part of this study. In addition, the modeling results must be capable of being used in an economic impact assessment for alternative flood mitigation scenarios (developed under a separate Work Order). PM #5 will be modified to adopt the flood protection goals established my Miami-Dade County. As explained in **Section 5.3.1.2**, PM #6 will not be evaluated using the XP-SWMM models developed for this study, due to model set up limitations for accounting for flood volume infiltration into the native soils.

The various FPLOS metrics will be quantified using standard GIS tools to facilitate the analysis of the model results versus the digital elevation model (DEM). The DEM is a 10-

foot resolution raster based developed using 2015 Light Detection and Ranging (LiDAR) topographic data points provided by RER. Individual roadways and canals are visible and general topographic trends can be seen for all areas within the Basins. **Figure 7-1** shows an example LiDAR coverage with visible streets and canal features.

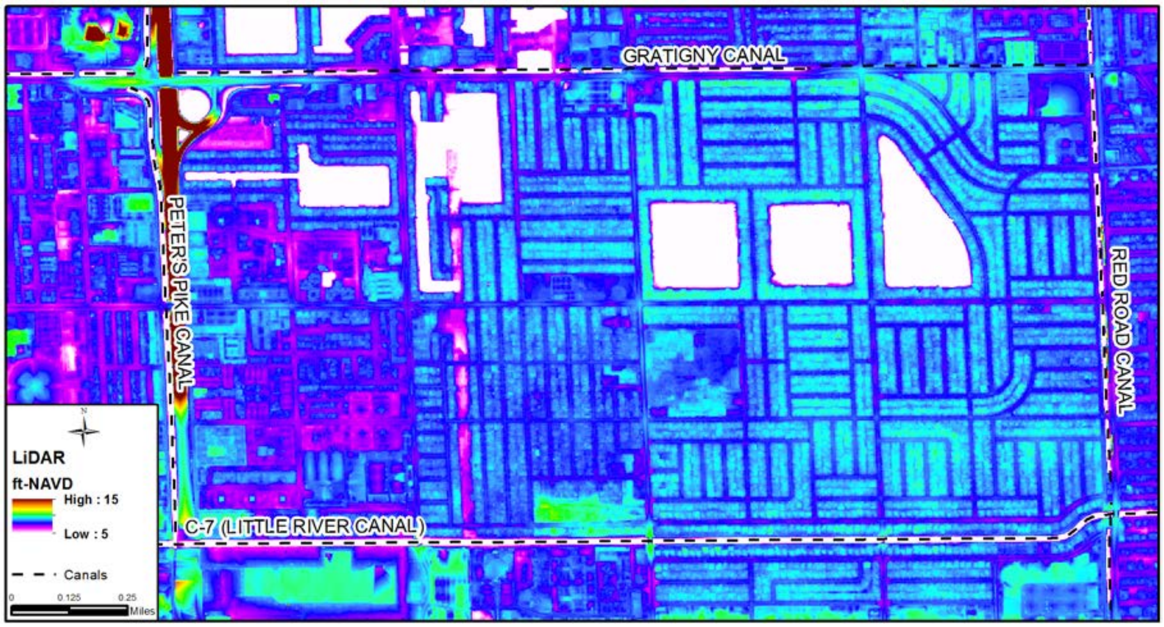


Figure 7-1 - LiDAR Based Raster DEM

7.1.1 LOS PM #1 – Maximum Stage in Primary Canals

LOS PM#1 is the peak stage profile along the primary canal system. This measure aims to determine the conveyance capacity of the primary system along at various locations on the C7 Canal. Stages above design levels reduce the ability to drain the secondary system.

7.1.2 LOS PM #2 – Maximum Discharge Capacity in Primary Canal Network

SFWMD has established discharge rates for the primary canal systems throughout the District. The rates were established using aerially weighted flows associated with the design level of service and were used to size the District discharge structures. Flow hydrographs at select points in the primary canal network will be used to extract the simulated flow hydrographs for each storm event. A 12-hour moving average of the flow data will be generated and along with the geometry of the canal will be used to determine the maximum discharge capacity for the primary canal network.

7.1.3 LOS PM #4 – Peak Storm Runoff

LOS PM #4 shows the maximum conveyance capacity of the watershed by analyzing the flows passing at the tidal structure. The model results from the combined effect of the design storm events, sea level rise, and storm surge are averaged over the tidal cycle. The 12-hour moving average discharge through the tidal structure is compared to the Existing Scenario and the Future Scenario model results for the four (4) design storm events. The analysis quantifies the response of the system as a whole under extreme conditions and serves to determine if the conditions will exceed the system design limits.

7.1.4 LOS PM #5 – Frequency of Flooding

SFWMD developed PM #5 to determine the duration of flooding in sub-watersheds by examining amount of time when stages in each sub-watershed exceed locally defined LOS targets. The PM is used to determine the overall ability of the water management infrastructure to maintain water levels within sub-watersheds needed to protect the local infrastructure, including residential roads, buildings, homes, and major roads.

For this study, the flood protection goals for individual sub-watersheds established by Miami-Dade County will be adopted and used for determination of the LOS PM #5. The following will be quantified within the model domain:

- **NS:** Number of structures flooded by the 100-year flood, which can include commercial, residential, and public buildings. All structures and/or buildings are considered equivalent, regardless of their size or value. Because the elevations of structures within the C7 Basin are not known, this study assumes that structure finish floor elevations are 8 inches above the adjacent roadway crown of road.
- **MER:** Miles of principal arterial roads, including major evacuation routes, which are impassable during the 100-year flood. RER has defined that a principal arterial road is considered impassable if the depth of flooding exceeds 8 inches above the crown of the road during the 100-year design event.
- **MMAS:** Miles of minor arterial roads impassable during the 10-year flood. RER has defined that a minor arterial road is considered impassable if the depth of flooding exceeds the crown of the road during the 10-year design event.
- **MCLRS:** Miles of collector and local residential streets impassable during 5-year flood. RER has defined that collector and local residential streets are considered impassable if the depth of flooding exceeds the crown of the road during the 5-year design storm event.

7.2 Quantification of FPLOS Metrics

In addition to the model results produced from the XP-SWMM model platform for flow and discharge through the C-7 Canal and the peak stages throughout the C7 Basin, GIS files were collected from Miami-Dade County, FDOT, the District, and other entities that represent the roads, properties, buildings, and topography within the Basin limits. Roadway and property coverage's will be projected to the latest LiDAR survey and refined to determine elevation of the roadway crown and to estimate the elevation of building pads. The refined roadway and property files will be combined with model results to quantify the values for each model sub-basin flooding severity.

7.2.1 LOS PM #1 – Maximum Stage in Primary Canals

PM #1 establishes the different frequencies of storm events for which the stage in the canal exceeds the elevation of the canal banks and based on the computed maximum water surface profiles along the C-7 Canal (Little River Canal). The District confirmed only the C-7 Canal will be analyzed for this Metric.

7.2.2 LOS PM #2 – Maximum Discharge Capacity in Primary Canal Network

PM #2 includes the maximum Discharge Capacity curves for the C-7 Canal at locations of secondary canal junctions. A discharge curve downstream of each junction and near the basin outlet (just upstream of S-27) will result in a total of four (4) graphs with 4 storm events presented in each graph. The secondary canals include Spur #1 Canal, Red Road Canal, and Peters Pike Canal. The peak 12-hour moving average discharge rate near the outlet will be divided by the contributing C7 Basin area and compared to the basin's allowable discharge rate.

7.2.3 LOS PM #4 – Peak Storm Runoff

PM #4 includes the maximum 12-hour moving average conveyance capacity through S-27 for 4 storm events for the current Sea Level Scenario and three future Sea Level Rise Scenarios

7.2.4 LOS PM #5 – Frequency of Flooding

For the stage-based LOS, PM#5 follows the County's approach for evaluation of the FPLOS in place of LOS metric #5. PM #5 includes determination of the number of buildings, miles of roadway, and miles of C-7 canal bank with overbank flow. NS, MER, MMAS, and MCLRS metrics will be established for each catchment in the C7 basin.

- **NS**: Number of structures flooded during the 100-year, 3-day design storm event will be determined based on the maximum stage surpassing the pad elevation of the building. Since there is not database available that contains the pad elevation of buildings, the finished floor elevation of buildings will be estimated using the same approach used by RER for various storm water master plans. The nearest street crown elevation plus 8 inches will be projected to the building coverage for small and large buildings obtained from the County GIS Portal.
- **MER, MMAS, MCLRS**: The polyline network of streets is classified based on the FDOT functional classification system. Principal arterial roadways and major evacuation routes (MER) will be evaluated for the 100-year, 3-day design storm event. MER is considered impassable if the depth of flooding exceeds the crown elevation by 8 inches. Miles of minor arterial roadways (MMAS) will be evaluated for the 10-year, 1-day design storm event. MMAS is considered impassable if the flood depth of the 10-year, 1-day design event exceeds the crown elevation. Miles of collector and local roadways (MCLRS) will be evaluated for the 5-year, 1-day design storm event. MCLRS are considered impassible if the depth of flooding exceeds the crown of road during the 5-year, 1-day design storm event.

A polyline roadway network database will be utilized to determine the severity of flooding associated with the roadway network. The GIS roadway coverage represents the approximated centerline of each roadway within each Basin. Each road will have a number classification for the type of road, with values of zero through three (0-3) being minor arterials or highways, and values four through nine (4-9) being collectors or local roads. This number classification allowed each segment of roadway to be classified for determination of the design storm event used to quantify the depth of flooding. Principal arterial roads are evaluated using the 100-year event. Minor arterial roads are evaluated using the 10-year event, and collector or local roads are evaluated using the 5-year event.

The roadway network will be broken into individual segments at intervals of approximately 10-ft. To ensure that each line segment is only counted once, a point will be created at the centroid of each street segment – see **Figure 7-2**. The representative point for each line segment is assigned the length of the street segment it represents and the elevation of the nearest raster cell.

Figure 7-2 – Roadways Lines to Points

The number of structures flooded will be calculated using the existing property appraisers' coverage acquired from Miami-Dade County. The coverage will be converted to a point file from the polygons representing the building footprints. The points created will be located at the centroid of each polygon representing the building footprints.

The county does not maintain a GIS database of finished floor elevations for the buildings. Because of this, finished floor elevations had to be estimated utilizing a methodology like what is used by the County. The Z value, or the finished floor elevation, for the buildings was estimated using the same approach used by RER in numerous stormwater management master plans. This approach estimates the finished floor elevation of a lot based on the closest adjacent crown of road elevation. The road crown plus an additional eight (8) inches added is used to obtain the floor elevation. For this investigation, this will be done in GIS by performing a spatial join of the property points and the roadway points. The resulting property points will be assigned the elevation based on the closest roadway point, plus eight (8) inches.

The maximum stage output for each storm event will be converted to raster format to show the location and severity of the flood conditions developed under this investigation. Flood maps for the C7 Basin for each scenario and each storm event will be generated.

8.0 EXISTING SCENARIO FPLOS METRICS RESULTS

8.1 LOS PM #1 – Maximum Stage in Primary Canals

Figure 8-1 shows the maximum surface water profile in the C-7 Canal for the simulated current conditions during the four design storm events. The plot includes the left and right bank elevations. Since the orientation of the cross-section is defined looking downstream, the left side is the north side of the canal. The elevations of the bridges along the C-7 Canal are also included in the plot. For the bridges that are not included in the model, the elevation was entered as 10 ft-NGVD.

The 5-year and 10-year events show a relatively flat stage profile, with an average stage elevation of 3.9 and 4.3 ft-NGVD, respectively. The 25-year and 100-year events result in over a foot of head loss throughout the channel, with a maximum stage of 6.1 and 7.1 ft-NGVD, respectively.

In the first mile of the Little River or C-7 Canal, upstream of the Peter Pike's Canal junction and just west of SR-826, the simulated maximum water levels are within the canal banks during all four design events.

Between the Peter Pike's Canal and the Red Road Canal junctions, the next two miles downstream, the maximum stages exceed the C-7 canal north bank in the section just west of 16th Avenue during the 25- and 100-year events.

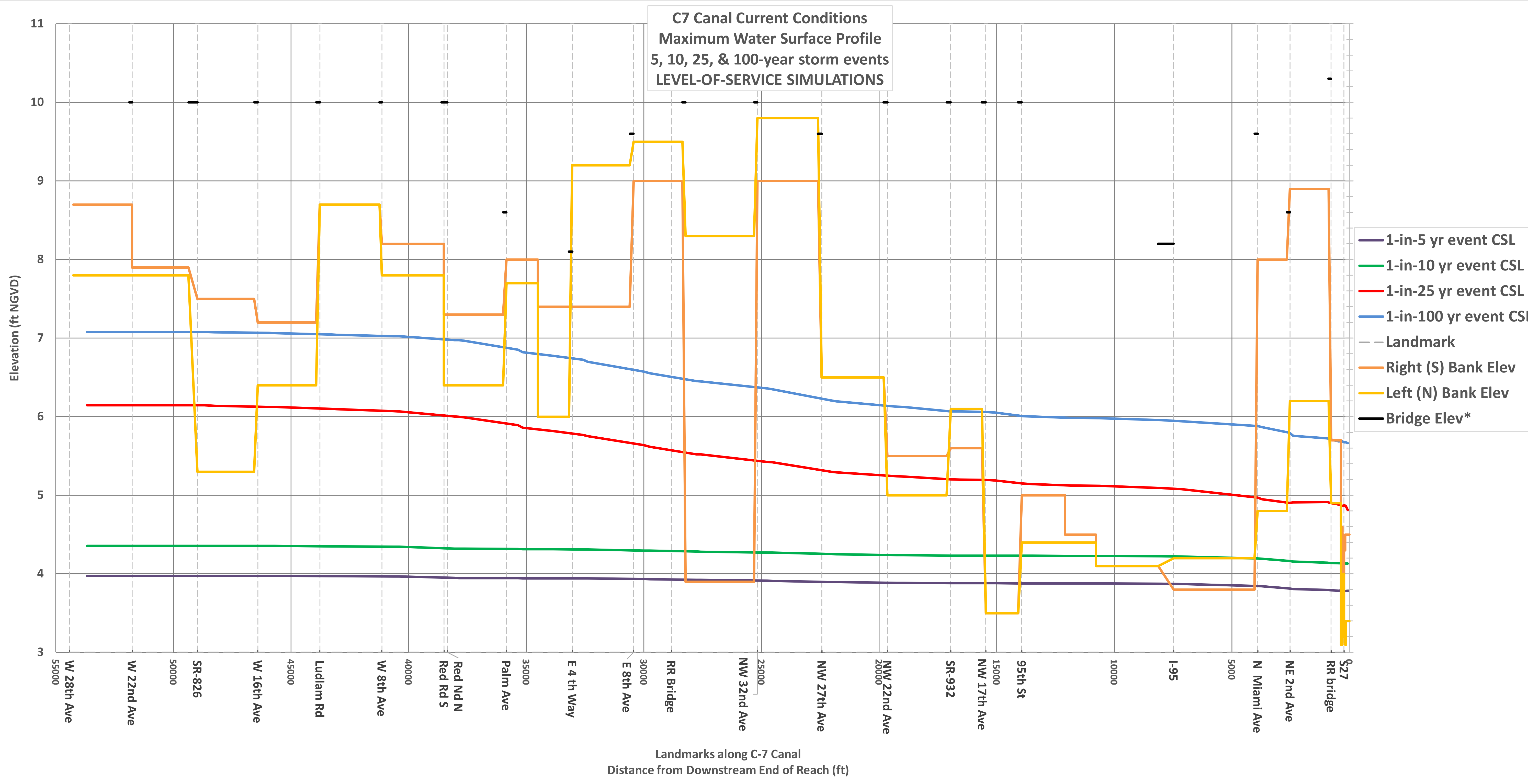
Between the Red Road canal and the Spur Canal #1 junctions (west of 22nd Avenue), the maximum stages exceed the south bank elevation during all storms in the section between the rail road bridge and the NW 32nd Avenue. In addition, the maximum stages exceed the north bank elevation during the 100-year event west of E 4th Avenue.

Downstream of the Spur Canal junction (NW 22nd Avenue), the maximum stages between NW 17th Avenue and N Miami Avenue exceed the canal bank elevations in all events. West of 17th Avenue the stages exceed the canal bank elevation during the 25- and 100-year events.

Table 8-1 shows the maximum stages simulated for current conditions at the secondary canal junctions and at the headwater and tailwater of the S-27 structure in each storm event.

Table 8-1 – Maximum Stages (ft-NGVD) at Selected Locations along the C-7 Canal for Current Conditions

Design Storm	Peter Pike's Canal Junction	Red Road Canal Junction	Spur Canal Junction	S-27 HW	S-27 TW
5-year	4.0	3.9	3.9	3.8	4.1
10-year	4.4	4.3	4.2	4.1	4.5
25-year	6.1	6.0	5.2	4.9	5.1
100-year	7.1	7.0	6.1	5.7	6.1



*For the bridges not included in the model, the elevations were entered as 10 ft-NGVD.

Figure 8-1 – Performance Measure #1, Simulated Current Conditions Maximum Stage Profile in the C-7 Canal.

8.2 LOS PM #2 – Maximum Discharge Capacity in Primary Canal Network

Figure 8-2, **Figure 8-3**, **Figure 8-4**, and **Figure 8-5** show the 12-hour moving average flow during the four design storm events along the C-7 Canal downstream of the three secondary canal junctions and near the basin outlet. During the 5-year event the maximum 12-hour average positive flow simulated downstream of the Peter's Pike Canal, Red Road Canal, Spur #1 Canal, and at the basin outlet is 64, 219, 427 and 737 cfs, respectively. During the 10-year event the maximum 12-hour average flow simulated at the same locations is 75, 252, 488, and 836 cfs, respectively. During the 25-year event the maximum 12-hour average flow simulated is 224, 486, 937, and 1,666 cfs, respectively. During the 100-year event the maximum 12-hour average flow simulated is 257, 582, 1,056, and 2,156 cfs, respectively.

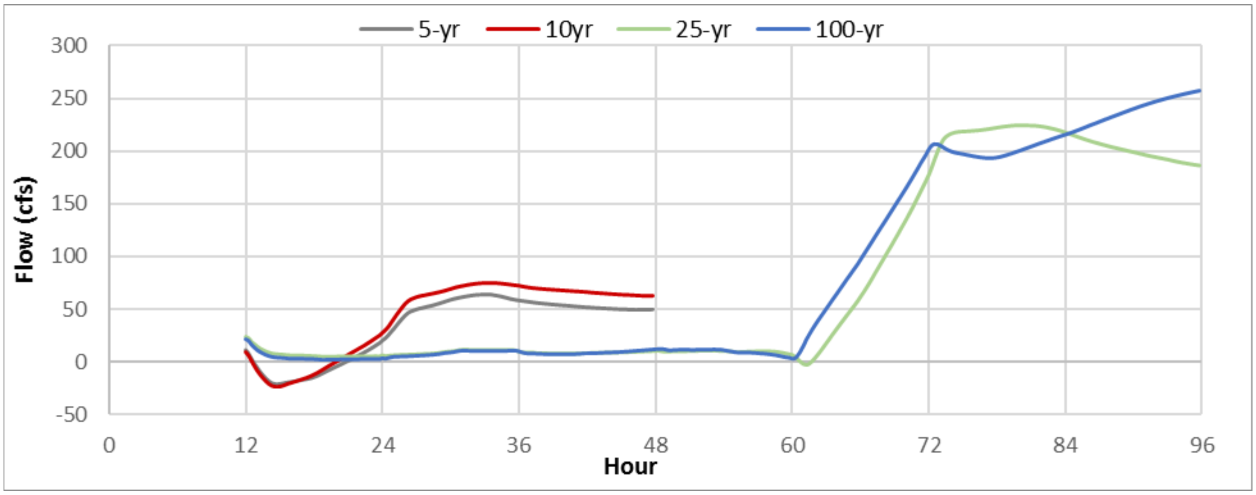


Figure 8-2 – EXIST, 5yr, 10yr-24hr, 25yr and 100yr-72hr Flow at the C-7 Canal Downstream of Peter's Pike Canal, 12-Hour Moving Average

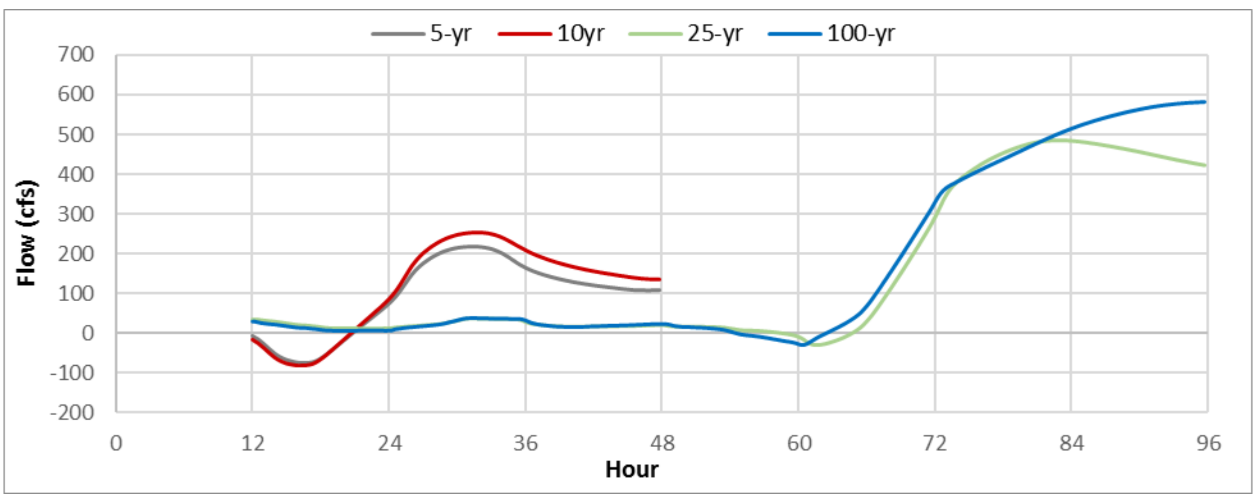


Figure 8-3 – EXIST, 5yr, 10yr-24hr, 25yr and 100yr-72hr Flow at the C-7 Canal Downstream of Red Road Canal, 12-Hour Moving Average

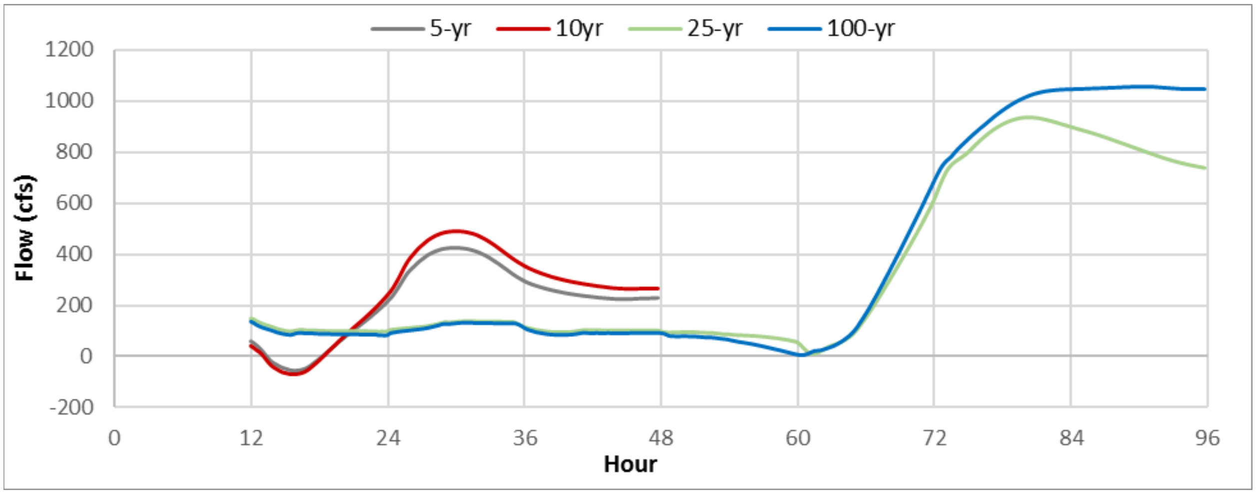


Figure 8-4 – EXIST, 5yr, 10yr-24hr, 25yr and 100yr-72hr Flow at the C-7 Canal Downstream of Spur #1 Canal, 12-Hour Moving Average

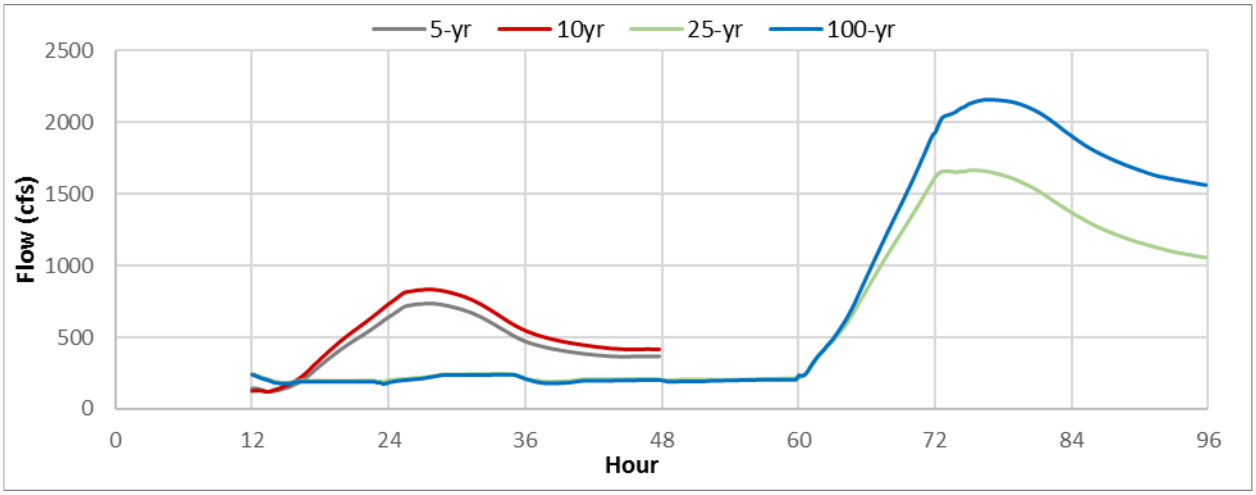


Figure 8-5 – EXIST, 5yr, 10yr-24hr, 25yr and 100yr-72hr Flow at the C-7 Canal Outlet Upstream of S-27, 12-Hour Moving Average

Table 8-2 shows the maximum flow at the C-7 Canal at basin outlet (just upstream of the S-27 structure) and flow divided by the C7 Basin area in cubic feet per second per square mile (CSM).

Table 8-2 – Simulated Current Conditions Canal Discharge Capacity*

Storm Event	Maximum Flow (cfs)	Flow per Area (CSM)
5-yr	737	23
10-yr	836	26
25-yr	1,666	52
100-yr	2,156	67

*Discharge capacity is defined as the peak canal discharge from a design storm. Flow is averaged over the 12-hour tidal cycle to filter out tidal effects and normalized over the watershed area.

8.3 LOS PM #4 – Peak Storm Runoff

Figure 8-6 shows the 12-hour moving average flow through the S-27 structure during the 5-year and 10-year events. **Figure 8-7** shows the 12-hour moving average flow through the S-27 structure during the 25-year and 100-year events. The maximum 12-hour average flow at this location is 731, 831, 1,660, and 2,163 cfs during the 5-year, 10-year, 25-year and 100-year events, respectively.

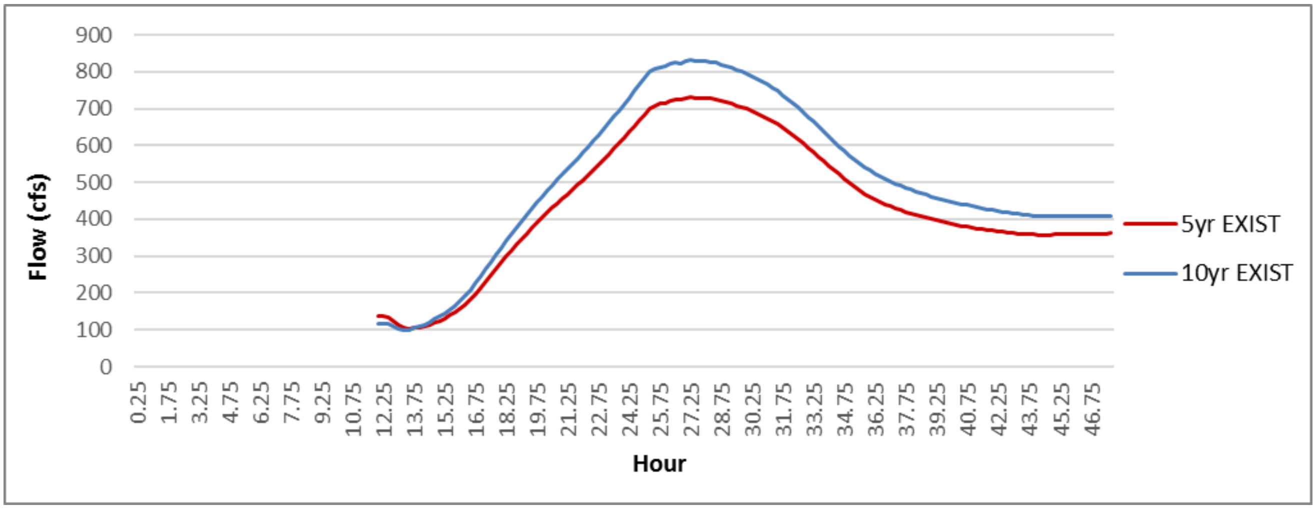


Figure 8-6 – EXIST, 5yr and 10yr-24hr, Flow at the C-7 Canal Through S-27, 12-Hour Moving Average

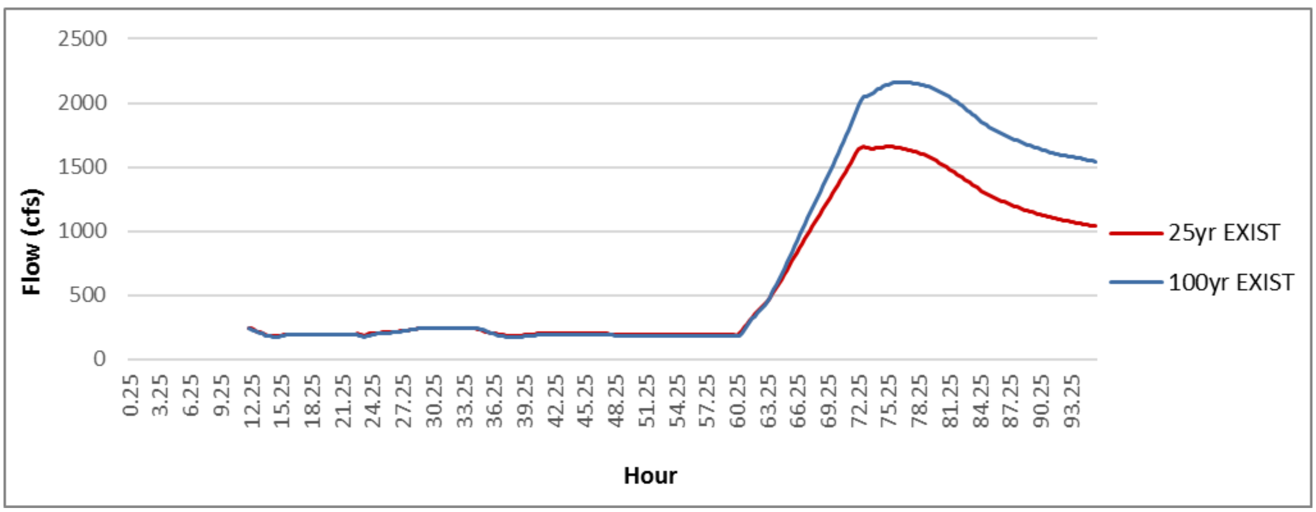


Figure 8-7 – EXIST, 25yr and 100yr-72hr, Flow at the C-7 Canal Through S-27, 12-Hour Moving Average

8.4 LOS PM #5 – Frequency of Flooding

Table 8-3 shows the total C7 Basin values calculated for each parameter in the performance measure #5, as described in **Section 7.1.4**., from the output of the EXIST model. These LOS baseline values will be compared to the future SLR scenarios in the following sections.

Table 8-3 – Simulated Current Conditions Flooding Indicators in the C7 Basin in the Updated Model

NS (-)	MER (mi)	MMAS (mi)	MCLRS (mi)
2,842	1.6	1.9	74.1

The baseline LOS indicators show that there are 2,842 structures that were flooded by the 100-year event, 1.6 miles of principal arterial roads impassable during the 100-year event, 1.9 miles of minor arterial roads impassable during the 10-year event, and 74 miles of collector and local residential street impassable during the 5-year event.

The LOS results were compared with the 2005 model. To eliminate numerical differences due to the XP-SWMM version and post-processing differences, the 2005 model was rerun in version 2012 and the results were processed using the same methodology as described above. **Table 8-4** shows the resulting values for the PM# 5 parameters, which are higher than the updated model. This is to be expected since storage was added to the some of the subbasins in the updated model to account for below-ground storage (**Section 6.1.1**).

Table 8-4 – Simulated Current Conditions Flooding Indicators in the C7 Basin in the 2005 Model

NS (-)	MER (mi)	MMAS (mi)	MCLRS (mi)
6,408	2.3	6.2	198.7

Figure 8-8 shows the model subbasin maps color coded according to the number of structure flooded during the 100-year event. The maps show that the differences in the number of structures between the updated model and the 2005 model occur in subbasins in which storage has been added (**Section 6.1.1**).

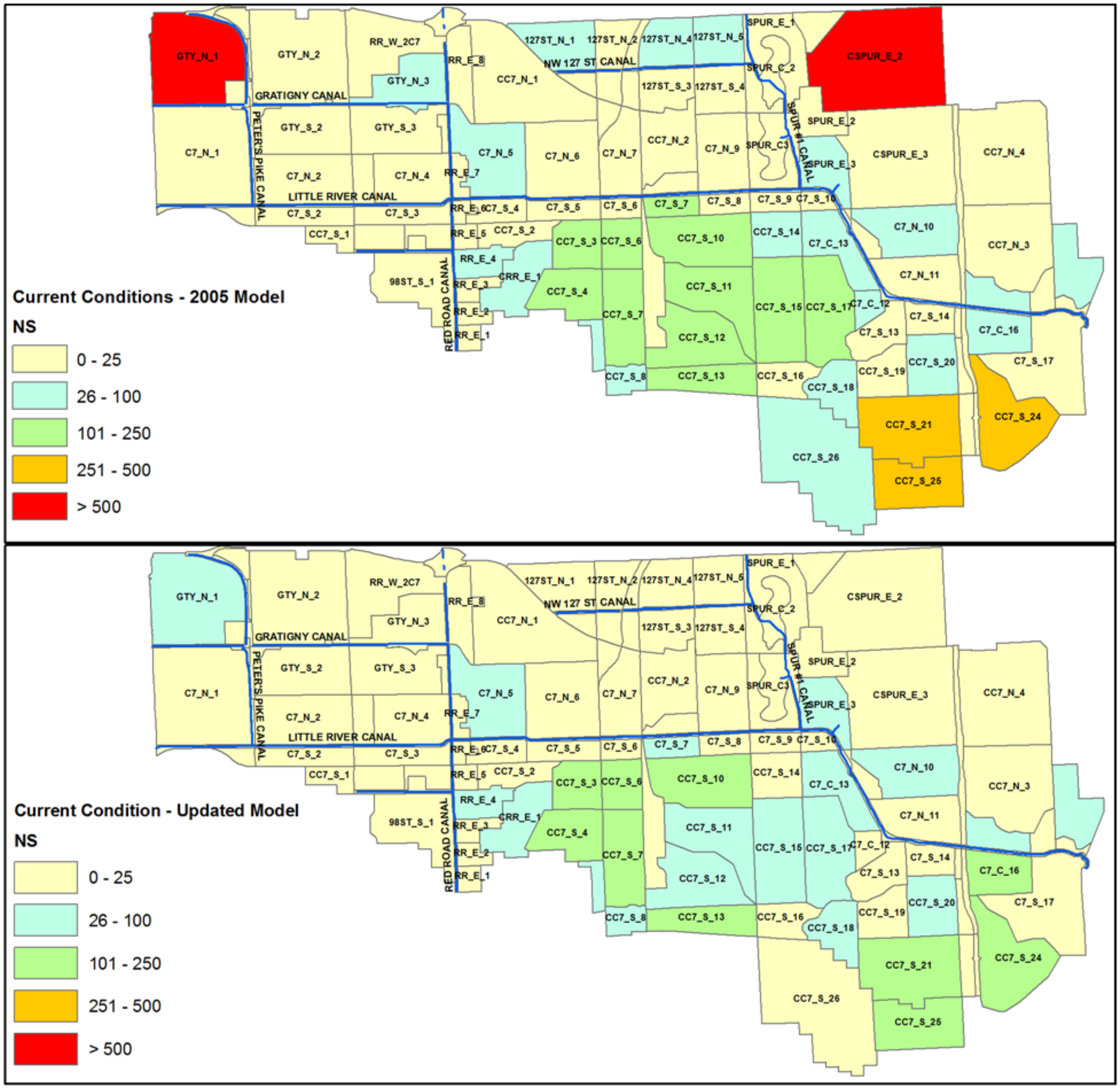


Figure 8-8 – Comparison of the Number of Structures Flooded in the Updated versus the 2005 Model

Table 8-5 shows the top ten most impacted sub-basins for each PM# 5 LOS parameter for the updated EXIST simulation. A ranking of 1 means that the subbasin has the highest value of each parameter.

The subbasins south of the C-7 canal show a higher number of flooded structures during a 100-yr flood (NS). The subbasins near I-95 south of the C-7 Canal and north of NW 54th St rank among the most number of impacted structures (C7-S-16, CC7-S-24, CC7-S-25, and CC7-S-21). The sub-basins surrounding the Tri-Rail station CC7-S-3, -4, -6, -7, -10, and -13 between E 49th St/ NW 103rd St and E 21nd St. also ranked in the top ten largest number of structures flooded.

The most extensive (0.5 miles) major road flooding occurs at the interchange between SR 826 and the Gratigny Pkwy and along SR 826 near the C-7 canal. The segment of I-

95 south of the canal, shows about 0.2 miles of road flooding during a 100-yr flood (MER). MMAS flooding is shown in subbasins near the Tri-Rail station, most notably CC7-S-7, -8, and -12. MCLR flooding also repeats in this area, with approx. 8.1 miles of flooded local roads during a 5-year flood in sub-basin CC7-S-12. In addition, MCLR flooding is found in basins C7-N-5 and -6 north of the C-7 Canal and south of Amelia Earhart Park.

Table 8-5 – Top 10 Ranked Subbasins for the PM# 5 LOS Parameters under Current Conditions

Rank	NS (-)		MER (mi)		MMAS (mi)		MCLR (mi)	
	Subbasin	Value	Subbasin	Value	Subbasin	Value	Subbasin	Value
1	C7-C-16	178	PP-C-1C7	0.52	CC7-S-12	0.40	CC7-S-12	8.1
2	CC7-S-6	175	PP-N-1	0.51	CC7-S-7	0.33	C7-N-5	5.9
3	CC7-S-24	174	95-S-2	0.17	CC7-S-8	0.16	CC7-S-25	4.4
4	CC7-S-3	161	C7-C-15	0.11	CC7-S-23	0.13	CC7-S-7	4.2
5	CC7-S-25	152	C7-S-1	0.08	C7-N-7	0.12	CC7-S-13	3.6
6	CC7-S-4	127	C7-C-15	0.05	98ST-N-1	0.09	CRR-E-1	3.6
7	CC7-S-21	124	C7-S-2	0.04	C7-S-7	0.07	C7-N-6	3.2
8	CC7-S-10	115	C7-C-2	0.03	CC7-S-25	0.07	CC7-S-3	2.9
9	CC7-S-13	107	C127ST-S-1	0.02	98ST-C-1	0.06	CC7-S-4	2.8
10	CC7-S-7	102	C7-N-7	0.02	CC7-N-4	0.05	C7-N-2	2.6

Values for the LOS parameters for each subbasin are provided in **Appendix I**. Flood maps for the design storm events for the simulated current conditions and the sea level rise scenarios are shown in **Appendix J**.

9.0 C7 BASIN FUTURE SLR SCENARIO MODEL SETUP

Establishment of the Future SLR Scenario model (FUT) includes modification of tidal boundary conditions at each structure for each design storm and modification to the groundwater levels based on the projections of sea level rise provided by the District and increase in groundwater projected by USGS.

9.1 Sea Level Rise Scenarios

The IPCCAR5-Median sea level change at the Key West Tide Gauge occurring since 2006 was used for the current sea level (CSL). The CSL, 0.12-ft, was then subtracted from the projected sea level rise occurring for the three (3) future scenarios by the year 2065, as published by USACE. The resulting SLR values used for implementation in the C-7 FUT scenarios are as follows:

- SLR01 – Low sea level rise projection based on historical data (0.76 ft)
- SLR02 – Medium sea level rise projection (1.09 ft)
- SLR03 – High sea level rise projection (2.21 ft)

Further details on the calculation of these projections can be found in Appendix C: Preparation of Boundary Conditions at the Tidal Structures, of the December 21, 2016 the District Flood Protection Level of Service (LOS) Analysis for the C-7, C-8 and C-9 Watersheds report.

9.2 Boundary Conditions

The FUT Scenario model boundary conditions were updated at the S-27 outfall. DSS files for the tidal boundary hydrographs at Structure S-27, developed by the Sea Level Rise Team at the District as part of this study, were provided by the District. The tidal boundaries were developed using Hurricane Irene as the base historical event. The development followed the same methodology used in the District 2015 LOS Pilot Project for the C4 Basin with the following exceptions:

1. The extreme tailwater values for each return levels were calculated using a single method (i.e., Monte-Carlo Joint Probability) versus the average of multiple methods used in the C-4 LOS Pilot Project; and
2. The unified sea level rise projection developed by the southeast Florida regional compact on climate change (2015) was used to project sea level change while the USACE sea level change projection was used for C-4 LOS Pilot project.

The resulting hydrograph datasets for the tidal boundary condition, for each SLR projection, were used to update the EXIST Scenario Model. The hydrograph datasets for each SLR projection are shown in **Figure 9-1, Figure 9-2, and Figure 9-3,** respectively.

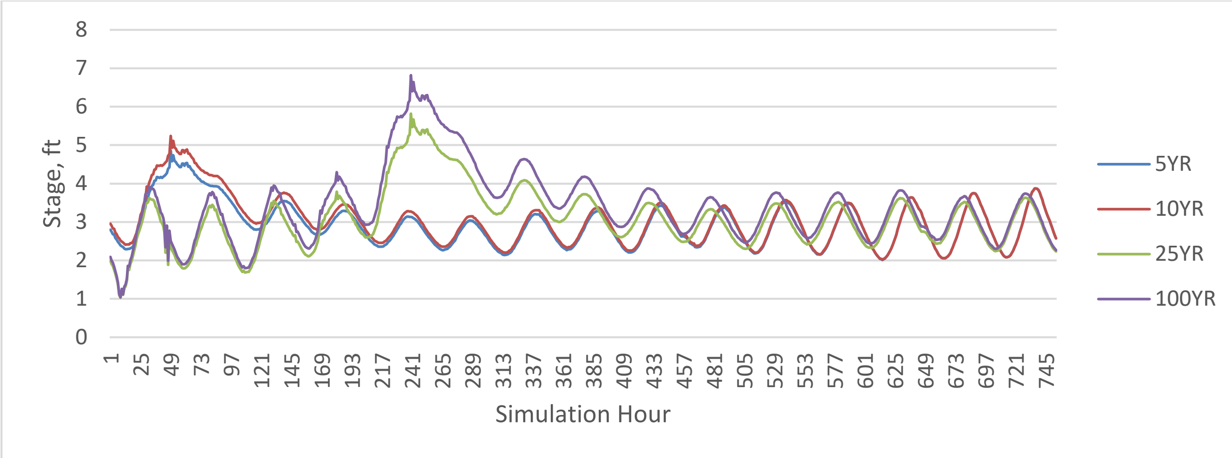


Figure 9-1 -The District FUT Tidal Boundary Condition for SLR1

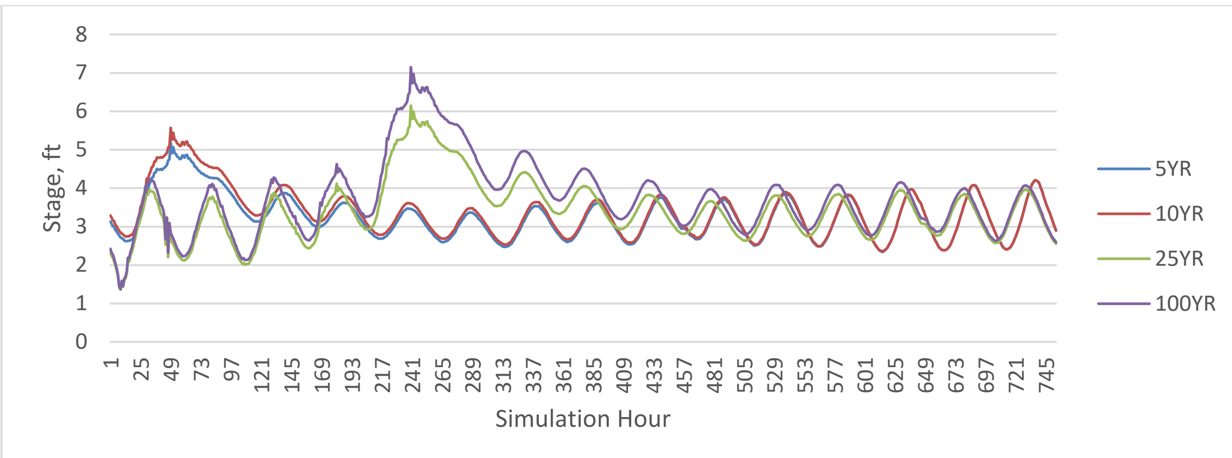


Figure 9-2 -The District FUT Tidal Boundary Condition SLR2

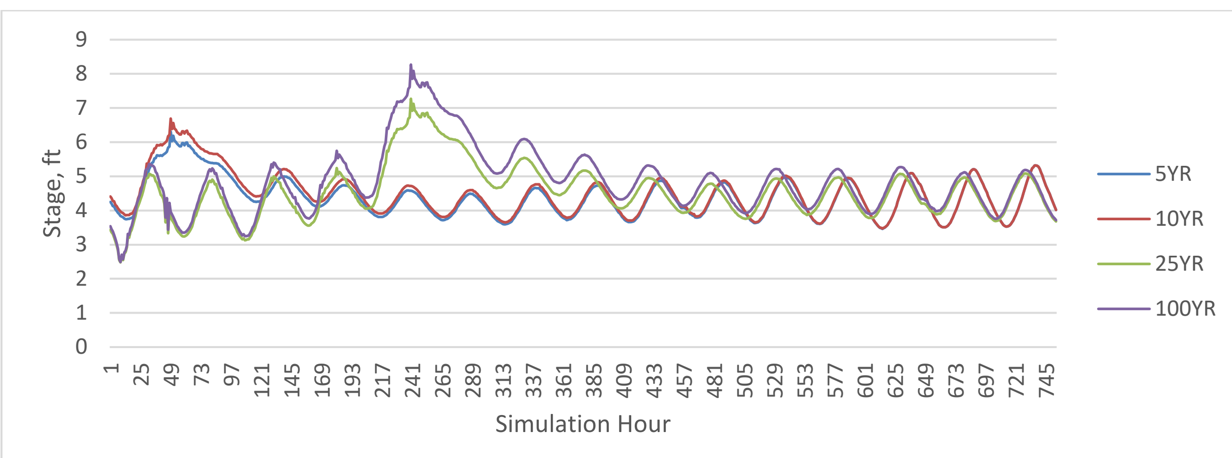


Figure 9-3 -The District FUT Tidal Boundary Condition SLR3

9.3 Groundwater

Using GIS, ADA created a groundwater coverage from the projected groundwater elevation map in the 2014 USGS Scientific Investigations Report 2014-5162. The USGS coverage map is based on an increase of 1.0-ft in sea level. The coverage created is shown in **Figure 9-4**. The groundwater contours obtained from the report were extrapolated to assign a groundwater increase for each node in the XP-SWMM model.

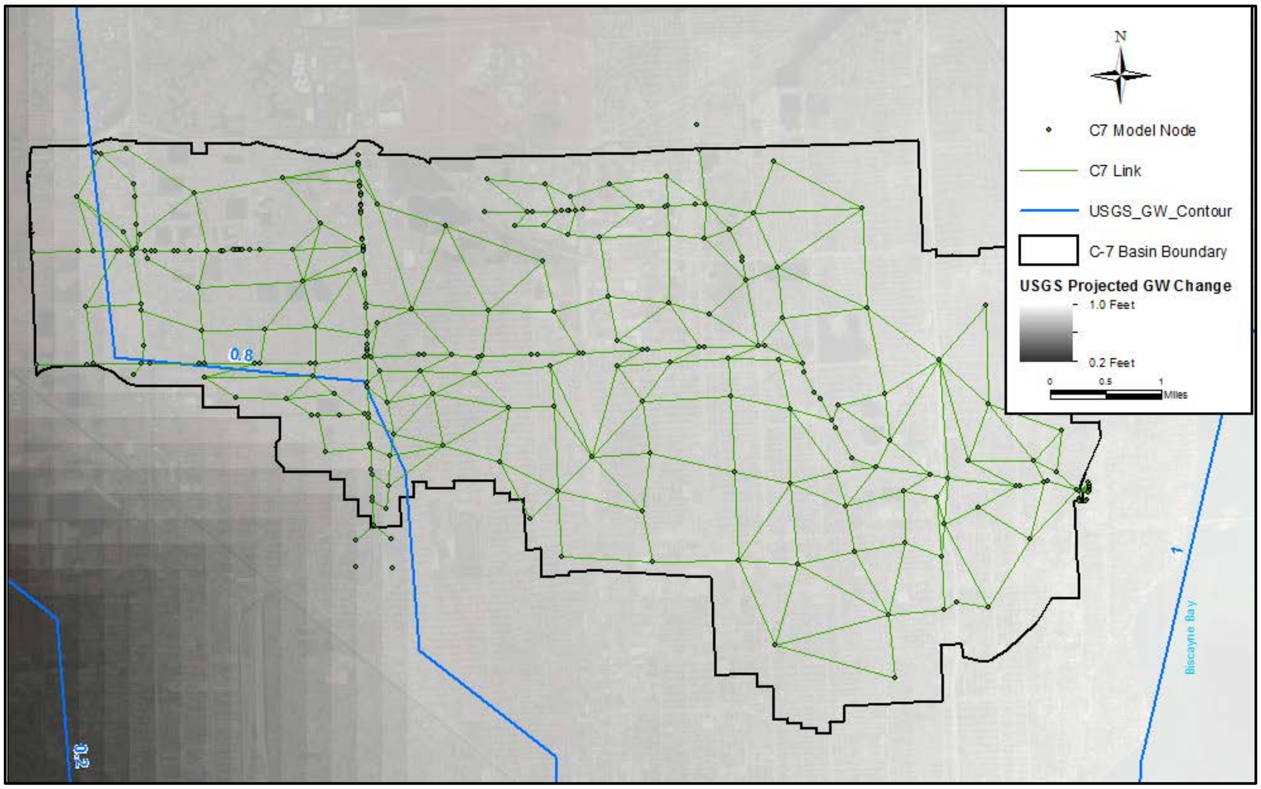


Figure 9-4 - USGS Projected Increase in Groundwater with 1.0-ft Rise in Sea Level

Using the increase in groundwater level from a 1.0-ft rise in sea level, a ratio of SLR:1.0-ft was used to create scaling factors. These scaling factors were applied to each node, for each SLR projection, to obtain an increase groundwater rise. The scaling factors are as follows:

- SLR1 has sea level rise of 0.76 feet, relative to Current Sea Level. Scaling factor is 0.76.
- SLR2 has sea level rise of 1.09 feet, relative to Current Sea Level. Scaling factor is 1.09.
- SLR3 has sea level rise of 2.21 feet, relative to Current Sea Level. Scaling factor is 2.21.

The resulting groundwater increase was added to the groundwater elevations in the Existing Scenario Model. For implementation of the groundwater change in XP-SWMM, nodes in both the Runoff Model and the Hydraulics Model must be modified.

9.3.1 Runoff Model

Nodes that are active in the runoff mode will require modification of the parameters presented in **Figure 9-5**.

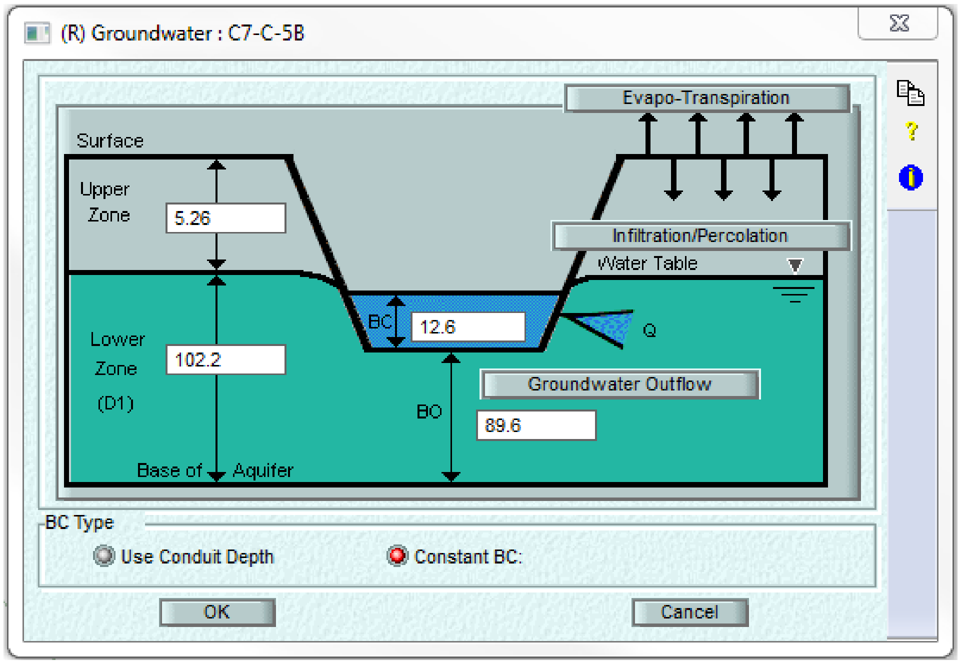


Figure 9-5 – Runoff Node Groundwater Parameters Dialog

9.3.2 Hydraulic Model

The initial groundwater depth of each junction requires to be updated with the higher values of the groundwater table elevation. Currently, the model uses the average October groundwater elevations.

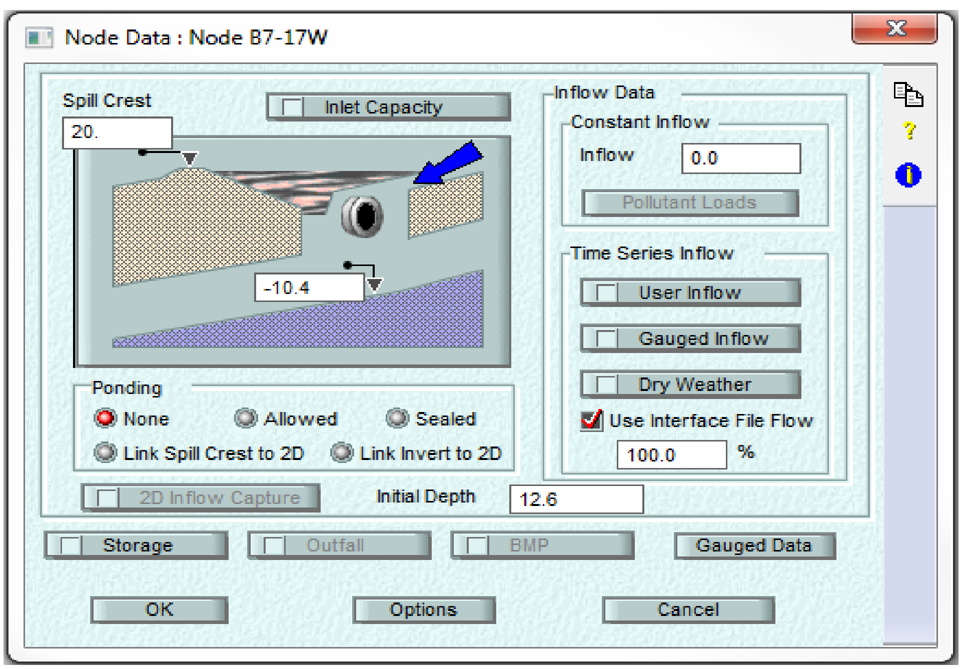


Figure 9-6 – Hydraulic Node Input Parameter Dialog

9.4 Rainfall

It was decided by the District that the rainfall will not be modified for the development of the Future SLR Scenario. The rainfall will remain as described in **Section 4.1**. There are no reliable trends currently available that indicate observed rainfall intensities will increase or decrease. A 2016 study performed by the District titled "Determination of Future Intensity-Duration-Frequency Curves for Level of Service Planning Projects, Deliverable 2.1 Conduct an extreme rainfall analysis in climate model outputs to determine temporal changes in IDF curves" served as a basis for this determination.

9.5 Interconnection with Basins C6 and C8

The C7 Basin interconnects with the C8 Basin at two (2) locations through two (2) culverts in the C7 Spur Canal near NW 27th Avenue and a culvert in the Red Road Canal under Gratigny Expressway, adjacent to NW 57th Avenue. The C7 Basin connects with the C6 Basin at 87th Avenue and the Gratigny Canal, and where the Red Road Canal intersects with the southern boundary of the basin (approximately 81st Street-26th Street in Hialeah). The location of the interconnectivity with both the C6 and the C8 Basins are shown in **Figure 3-1**. The points of interconnection are represented with a multi-link rating curve based on the relationship between the C-7 Canal stage and flow through the respective culverts simulated for the 2000 "No Name" storm event and the 1989 dry year simulation. The C7 Basin model is executed using the glass wall approach for the boundary conditions at these points of interconnectivity.

9.6 Future Scenario Model Results

The C7 Basin Future Scenario Models were executed for the four (4) design events for each of the three (3) SLR scenarios with the resulting groundwater and tailwater boundary increase projections. This section includes the resulting total runoff volume and instantaneous plots flow and headwater stages at the S-27 structure for the three SLR scenario and a comparison to the current conditions simulation (EXIST) results. The FPLOS performance metrics for the SLR scenarios are presented in **Section 10.0**.

9.6.1 Total Runoff Volume S-27

Table 9-1, **Table 9-2**, **Table 9-3** show the total volume and maximum flow rate at the S-27 structure for the three SLR scenarios and a comparison to the EXIST. The decrease in volume is due to the reduced ability of the structure to discharge to tide against a higher tailwater head due to sea level rise. Compared to the EXIST model results, the SLR1 scenario resulted a decrease in total volume for all events, except for the 25-year event, and in a small decrease in the maximum flow for all events, except for the 100-year event, where the maximum flow increased. The SLR2 scenario resulted in a decrease in total volume for all events, except for the 25-year event, and an increase in maximum flow for all events. The SLR3 scenario resulted in a decrease in runoff volume for all events and an increase in the maximum flow for all events. A decrease in the simulated runoff volume is the SLR scenarios indicates a reduced conveyance of the system to compared to current conditions.

Table 9-1 – Total Volume and Maximum Flow in the C-7 Canal at the S-27 Structure for SLR1 and Comparison to the EXIST Results

Model Scenario	Total Volume (ac-ft)	Volume Difference (SLRn-EXIST) (ac-ft)	Max Flow (cfs)	Flow Difference (SLRn-EXIST) (cfs)
5yr FUT-SLR1	1,398	-163	874	-17
10yr FUT-SLR1	1,609	-137	997	-12
25yr FUT-SLR1	4,969	21	1,904	-7
100yr FUT-SLR1	6,247	-30	2,605	239

Table 9-2 – Total Volume and Maximum Flow in the C-7 Canal at the S-27 Structure for SLR2 and Comparison to the EXIST Results

Model Scenario	Total Volume (ac-ft)	Volume Difference (SLR2-EXIST) (ac-ft)	Max Flow (cfs)	Flow Difference (SLR2-EXIST) (cfs)
5yr FUT-SLR2	1,355	-206	895	4
10yr FUT-SLR2	1,593	-153	1,048	39
25yr FUT-SLR2	4,948	0.2	2,018	107
100yr FUT-SLR2	6,174	-103	2,703	338

Table 9-3 – Total Volume and Maximum Flow in the C-7 Canal at the S-27 Structure for SLR3 and Comparison to the EXIST Results

Model Scenario	Total Volume (ac-ft)	Volume Difference (SLR3-EXIST) (ac-ft)	Max Flow (cfs)	Flow Difference (SLR3-EXIST) (cfs)
5yr FUT-SLR3	1,316	-245	1,132	241
10yr FUT-SLR3	1,561	-186	1,307	298
25yr FUT-SLR3	4,887	-61	2,338	427
100yr FUT-SLR3	6,144	-133	3,205	840

Figure 9-7, **Figure 9-8**, **Figure 9-9**, and **Figure 9-10** show the instantaneous flow hydrographs for all future SLR scenarios and current conditions during the 5-year, 10-year, 25-year, and 100-year events, respectively. The hydrographs show increased flow peaks and a delayed response, i.e., increased timing to reach the flow peaks, with increasing SLR.

9.6.2 S-27 Flow Hydrograph

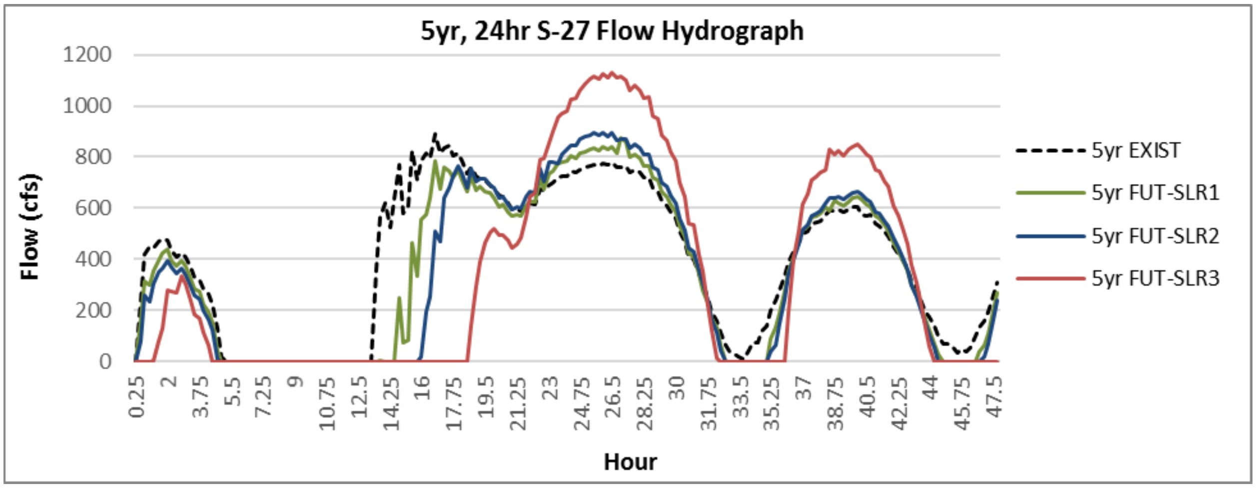


Figure 9-7 – FUT 5yr, 24hr S-27 Flow Hydrographs

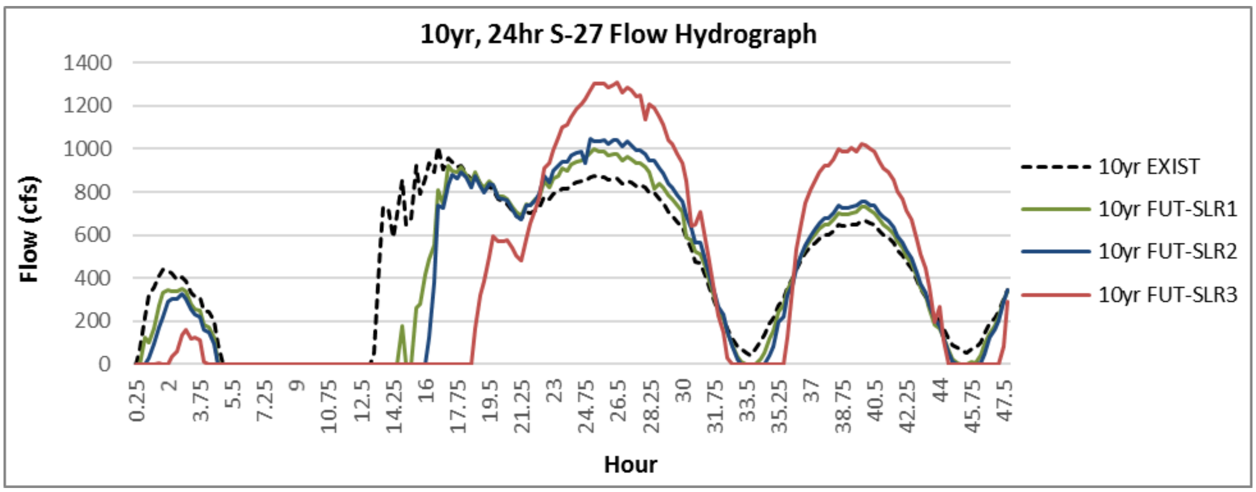


Figure 9-8 – 10yr, 24hr S-27 FUT Flow Hydrographs

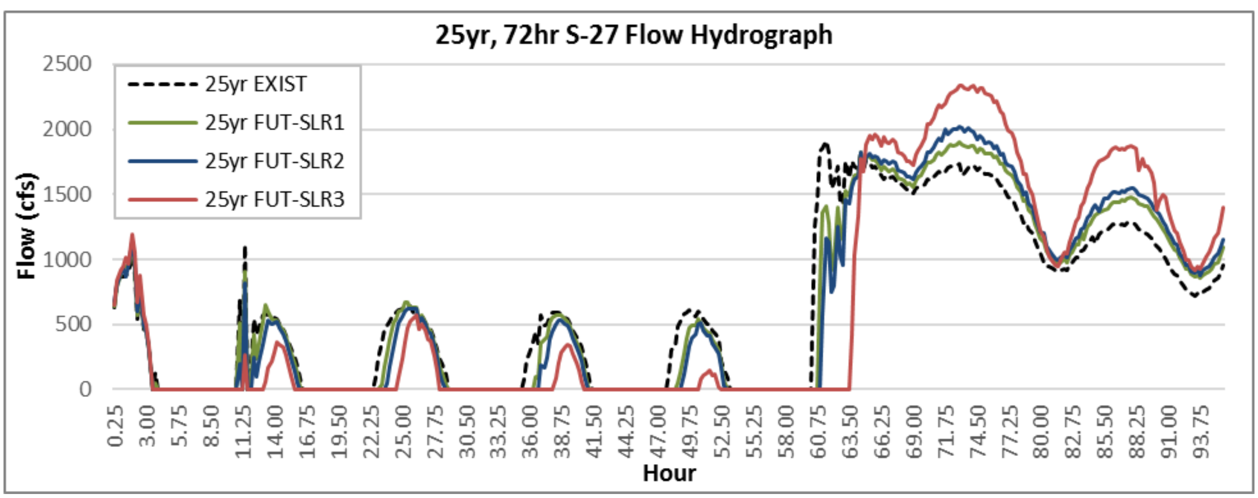


Figure 9-9 – 25yr, 72hr S-27 FUT Flow Hydrographs

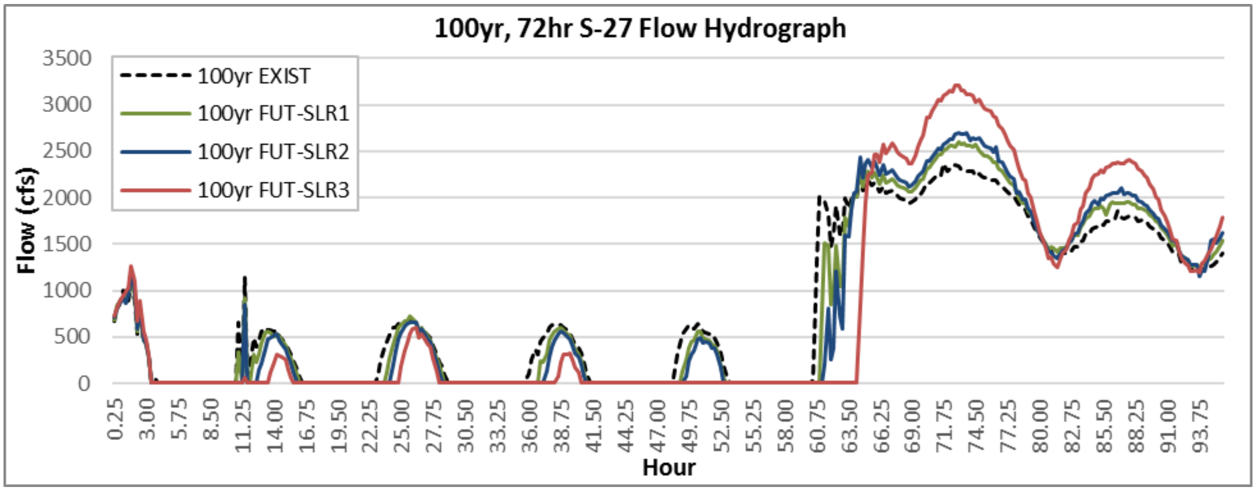


Figure 9-10 – 100yr, 72hr S-27 FUT Flow Hydrographs

9.6.3 S-27 Headwater Stage Hydrograph

Figure 9-11, **Figure 9-12**, **Figure 9-13**, **Figure 9-14** show the headwater stages at S-27 for the three future SLR scenarios and simulated current conditions in 5-year, 10-year, 25-year and 100-year events, respectively. The magnitude of the average change in the S-27 headwater stage for all events in SRL1, SLR2, and SLR3 is 0.7, 1.0, and 1.7 feet, respectively.

The peak stage results for each of the future SLR scenario for each storm event in all model nodes are presented in **Appendix H**.

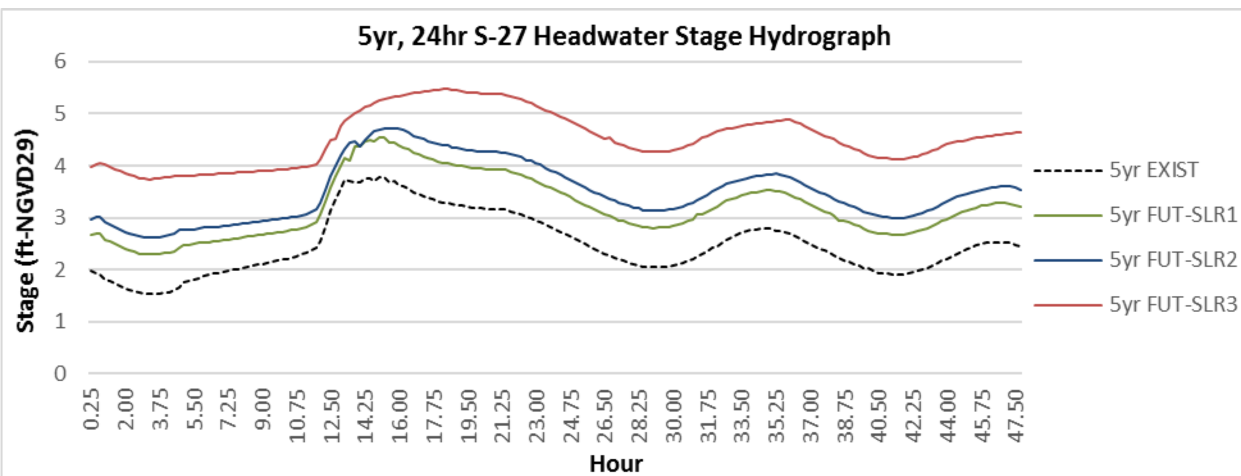


Figure 9-11 – 5yr, 24hr S-27 FUT Headwater Stage Hydrograph

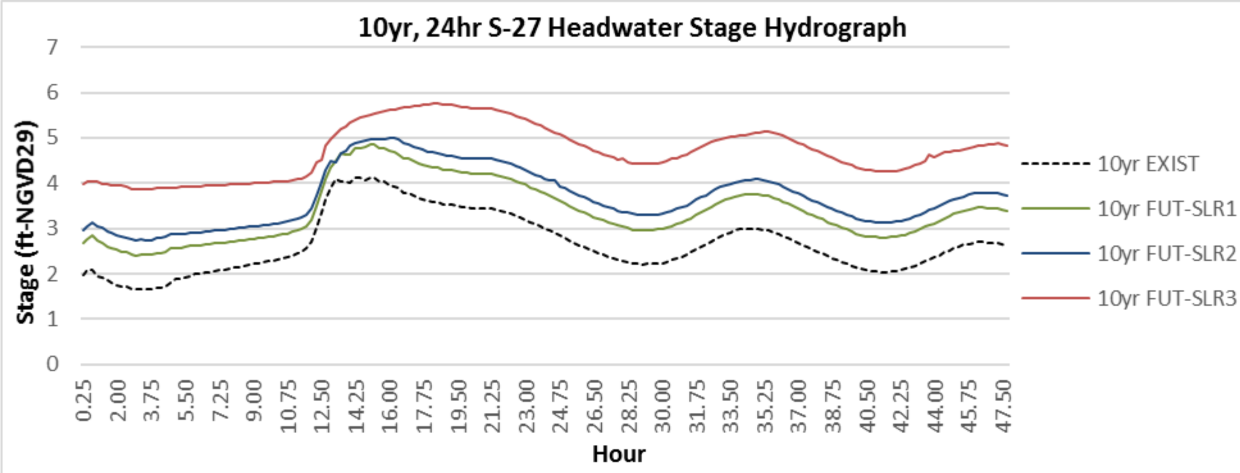


Figure 9-12 – 10yr, 24hr S-27 FUT Headwater Stage Hydrograph

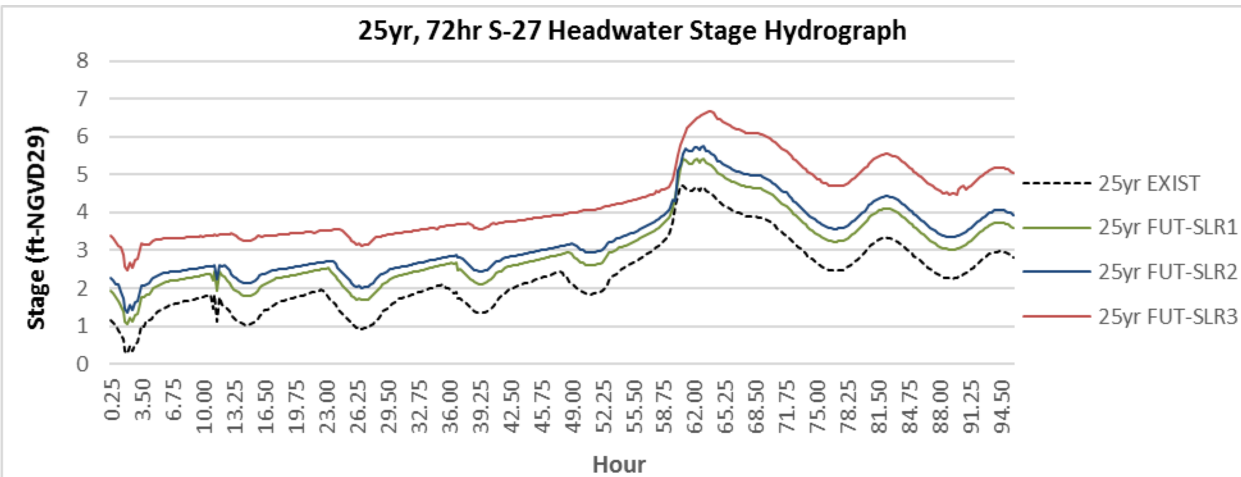


Figure 9-13 – 25yr, 72hr S-27 FUT Headwater Stage Hydrograph

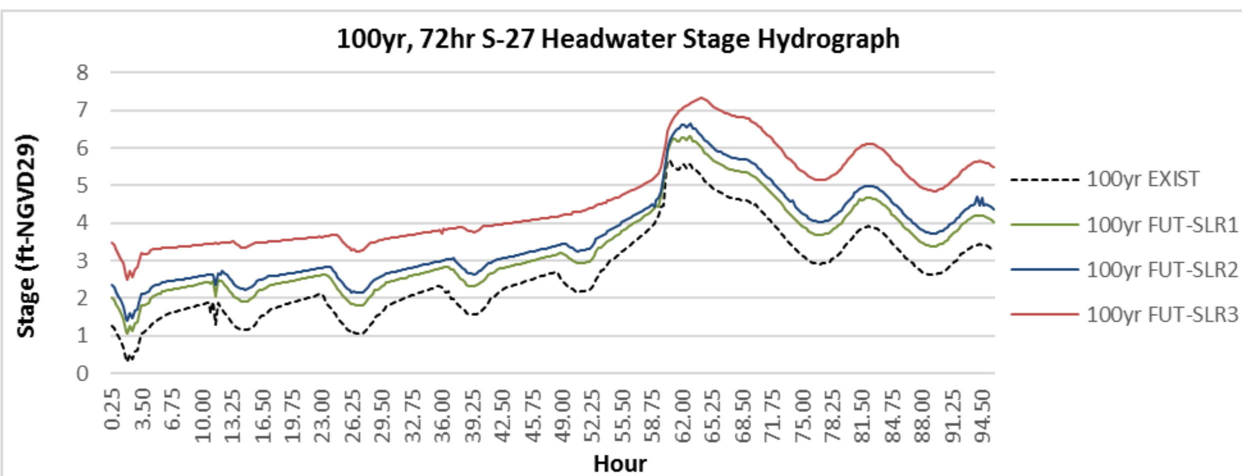


Figure 9-14 – 100yr, 72hr S-27 FUT Headwater Stage Hydrograph

10.0 FUTURE SEA LEVEL RISE SCENARIOS FPLOS METRICS

10.1 LOS PM #1 – Maximum Stage in Primary Canals

Figure 10-1, **Figure 10-2**, and **Figure 10-3**, show the resulting stage profiles along the C-7 canal for all simulated future SLR scenarios and current conditions for the 5-year, 10-year, 25-year, and 100-year events, respectively. **Table 10-1**, **Table 10-2**, and **Table 10-3** show the maximum stages at the secondary canal junctions and at the headwater and tailwater of the S-27 structure for SLR1, SLR2, and SLR3, respectively.

Similar to the simulated current conditions, the SLR scenarios resulted in relatively flat stage profiles during the 5-year and 10-year event, increasing an average of 0.6, 0.8, and 1.6 feet for SLR 1, 2, and 3, respectively.

Although the 25- and 100-year events show larger head losses along the C-7 Canal than the 5- and 10-year events, as is the case in the EXIST output, the total head loss along the channel decreases with increased sea level rise. For example, the total head loss along the channel for EXIST, SLR1, SLR2, SLR3 is 1.3, 1.1, 1.0, 0.6 feet, respectively, for the 25-year event and 1.4, 1.1, 0.9, 0.6 feet, respectively for the 100-year event. Moreover, the difference in stage between scenarios increases from the upstream end to the downstream end. For example, the difference between SLR3 and EXIST is 0.8 and 1.7 feet at the upstream and downstream ends, respectively.

Under SLR1 conditions, larger portions of the north canal bank are overtopped in the section between the Peter Pike's Canal and the Red Road Canal during the 25-year event and larger portions of the south canal bank are overtopped during the 100-year event. The same is true for the section just downstream of the Red Road Canal, west of E 4th Way. Downstream of the Spur Canal and west of I-95, flooding occurs in the south canal bank during the 25-year storm. Sections east and west of I-95 are overtopped during the 5-year event of both sides of the canal and just upstream of the S-27 structure, the north bank is overtopped during the 100-year event.

Under SLR2 conditions, the extent of the canal bank overtopping similar to the SLR1 but with stages somewhat higher.

Under SLR3 conditions, the north canal bank is overtopped upstream of the Peter Pike's Canal junction during the 100-year event. East of this junction, the north bank is overtopped during the 5-year event and the southern bank is overtopped during the 25-year event. Downstream of the Red Road Canal junction, the south bank is more extensively overtopped during the 100-year event. South of the Spur Canal junction, the 5-year event causes stages to overtop both sides of the canal in most of the section between NW 22nd Avenue and N Miami Avenue and just upstream of the of the S-27 structure the north bank is overtopped during the 25-year event.

Table 10-1 – Maximum Stages (ft-NGVD) at Selected Locations along the C-7 Canal for SLR1

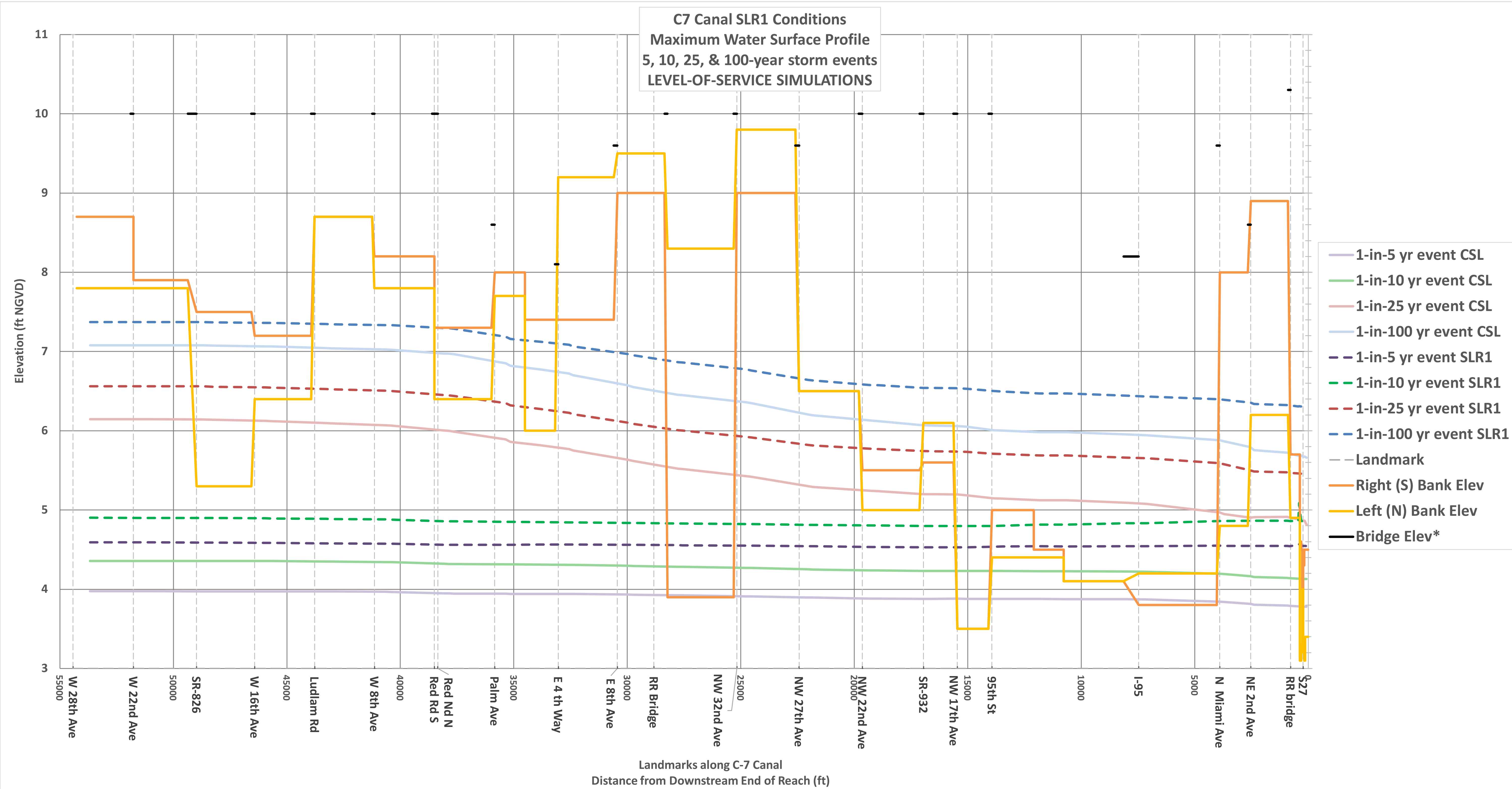
Design Storm	Peter Pike's Canal Junction	Red Road Canal Junction	Spur Canal Junction	S-27 HW	S-27 TW
5-year	4.6	4.6	4.5	4.6	4.9
10-year	4.9	4.9	4.8	4.9	5.2
25-year	6.6	6.4	5.8	5.5	5.8
100-year	7.4	7.3	6.6	6.3	6.8

Table 10-2 – Maximum Stages (ft-NGVD) at Selected Locations along the C-7 Canal for SLR2

Design Storm	Peter Pike's Canal Junction	Red Road Canal Junction	Spur Canal Junction	S-27 HW	S-27 TW
5-year	4.8	4.7	4.7	4.7	5.2
10-year	5.1	5.1	5.1	5.0	5.6
25-year	6.7	6.6	6.0	5.7	6.2
100-year	7.5	7.4	6.8	6.6	7.2

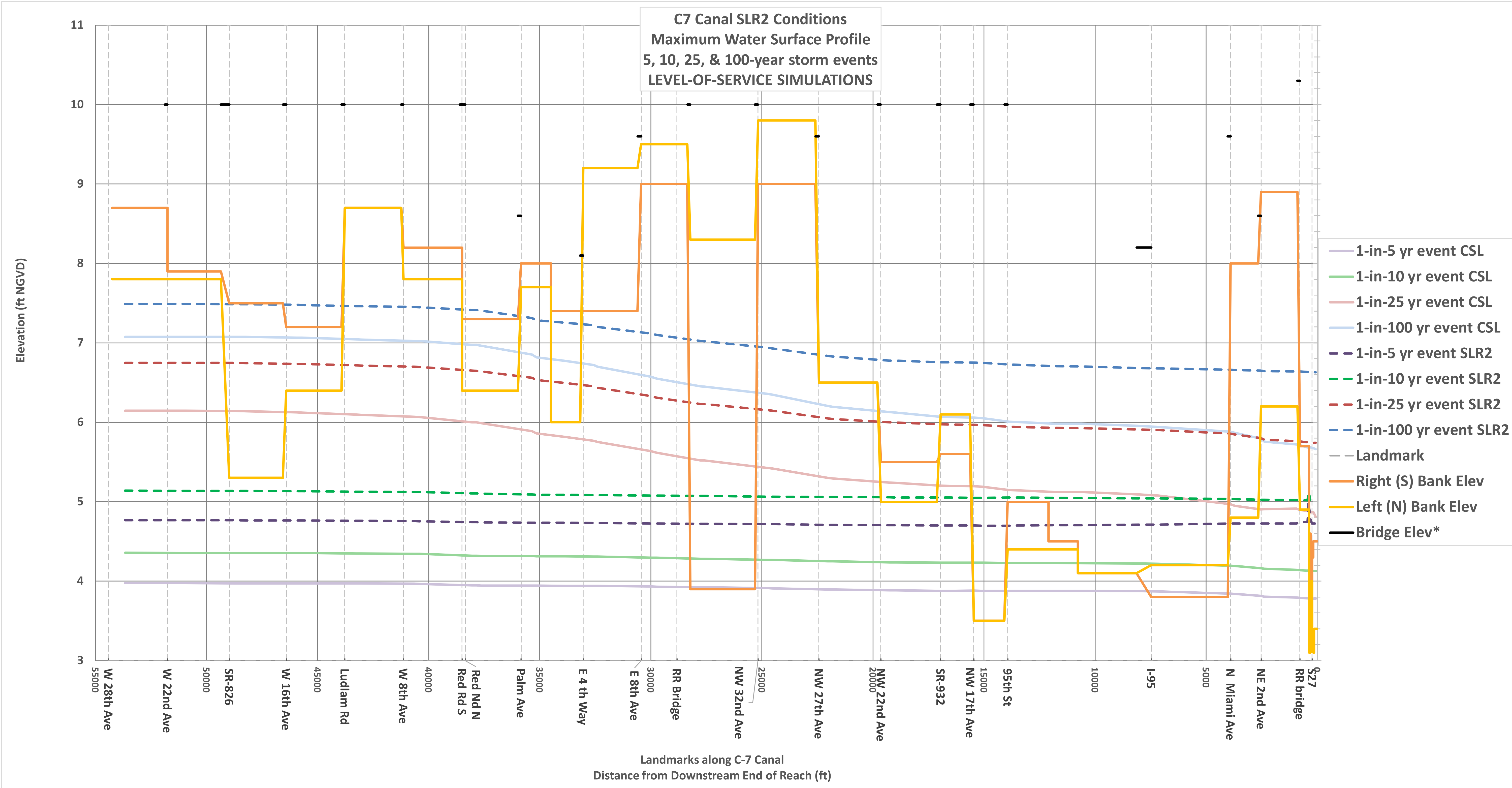
Table 10-3 – Maximum Stages (ft-NGVD) at Selected Locations along the C-7 Canal for SLR3

Design Storm	Peter Pike's Canal Junction	Red Road Canal Junction	Spur Canal Junction	S-27 HW	S-27 TW
5-year	5.6	5.6	5.5	5.5	6.3
10-year	5.9	5.9	5.8	5.8	6.7
25-year	7.3	7.2	6.8	6.7	7.3
100-year	7.9	7.8	7.4	7.4	8.3



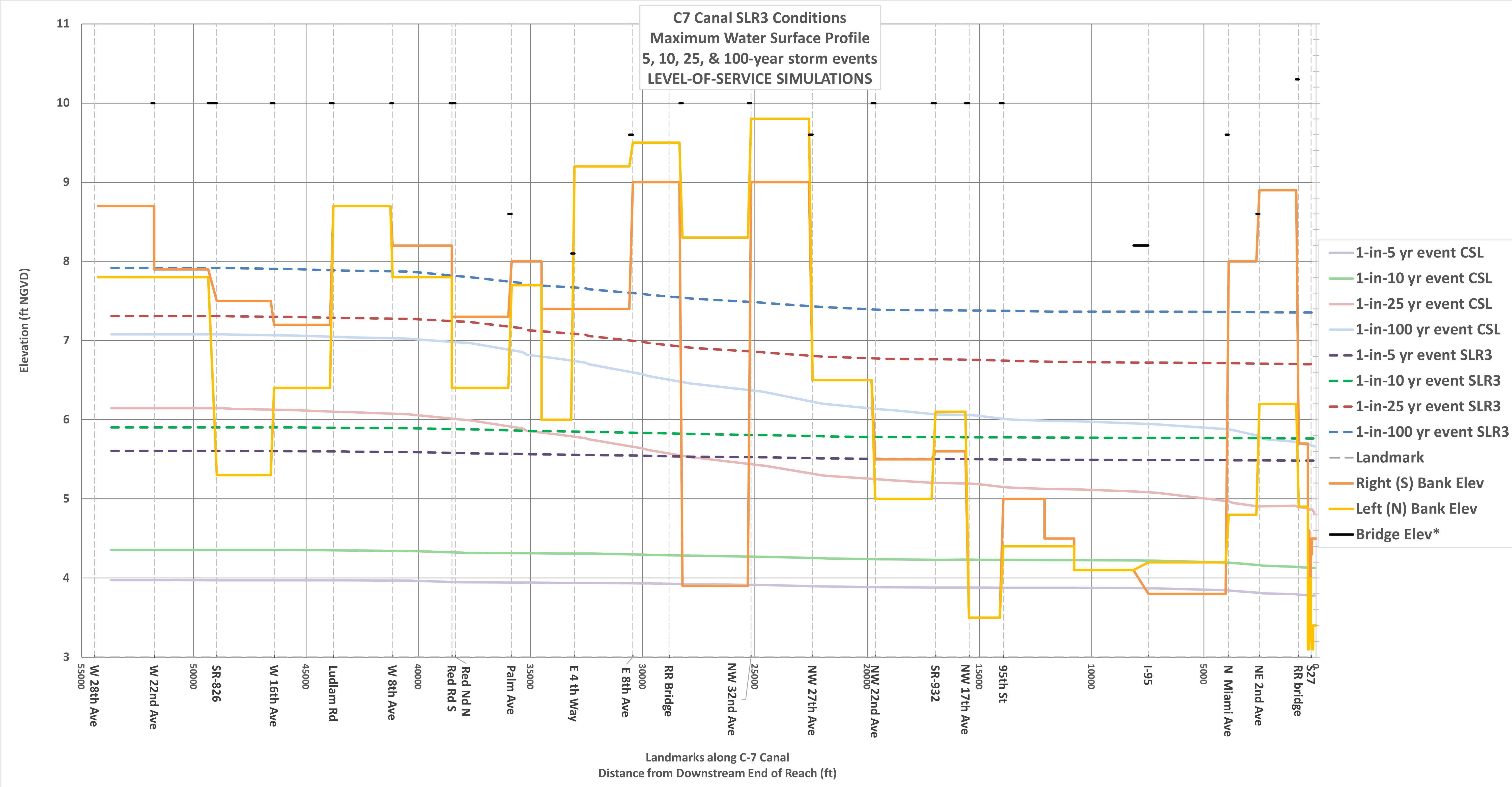
*For the bridges not included in the model, the elevations were entered as 10 ft-NGVD.

Figure 10-1 – Performance Measure #1, Simulated Maximum Stage Profiles in the C-7 Canal for SLR1 During Four Storm Events



*For the bridges not included in the model, the elevations were entered as 10 ft-NGVD.

Figure 10-2 – Performance Measure #1, Simulated Maximum Stage Profiles in the C-7 Canal for SLR2 During Four Storm Events



*For the bridges not included in the model, the elevations were entered as 10 ft-NGVD.

Figure 10-3 – Performance Measure #1, Simulated Maximum Stage Profiles in the C-7 Canal for SLR3 During Four Storm Events

10.2 LOS PM #2 – Maximum Discharge Capacity in Primary Canal Network

Figure 10-4 shows the flow along the C-7 Canal downstream of the secondary canal junctions and near the outlet of the C7 Basin for each storm event and for all scenarios.

During the 5- and 10-year events, the C-7 Canal flow downstream of the Peter Pike's Canal (the westernmost secondary canal junction), the flow increases according to the magnitude of SLR increase. However, during the 25-year and 100-year event, the maximum flow either decreases with increased SLR or is delayed, suggesting a decreased conveyance capacity with increased SLR.

The flow hydrographs downstream of the Red Road Canal junction during the 5- and 10-year events are relatively similar for all scenarios except for the SLR3, where the hydrograph shows a similar magnitude of the flow peak, but the timing is delayed by a few hours and the recession is slower. During the 25-year event the flow peaks are of similar magnitude, but the timing is delayed with increase SLR and during the 100-year event the flow peaks decrease with increased SLR.

Downstream of the Spur #1 Canal the magnitude of the peaks are similar in all scenarios during the 5- and 10-year events, except of the SLR3, where the magnitude decreased by 65 and 90 cfs, respectively. The timing of the peak increased with increasing SLR at this location in all scenarios. The 25- and 100-year event show relatively similar flow peak magnitudes, but the timing of the peak with increases and the recessions are slower with increasing SLR.

The flow at the outlet and the timing of the peak increased with SRL increase for all events.

Table 10-4 shows the 12-hour moving average maximum flow at the S-27 Structure divided by the C7 Basin area, for Current Conditions and SLR1, SLR2, and SLR3. As shown above, in most cases the discharge capacity increases at the outlet with increasing SLR and storm event.

Table 10-4 – C-7 Canal Discharge Capacity* (CSM)

Tidal Conditions	Return Period of the Design Storm			
	5-year	10-year	25-year	100-year
Current	23	26	52	67
SLR1	23	28	55	73
SLR2	24	28	57	76
SLR3	26	30	65	87

*Discharge capacity is defined as the peak canal discharge from a design storm. Flow is averaged over the 12-hour tidal cycle to filter out tidal effects and normalized over the watershed area.

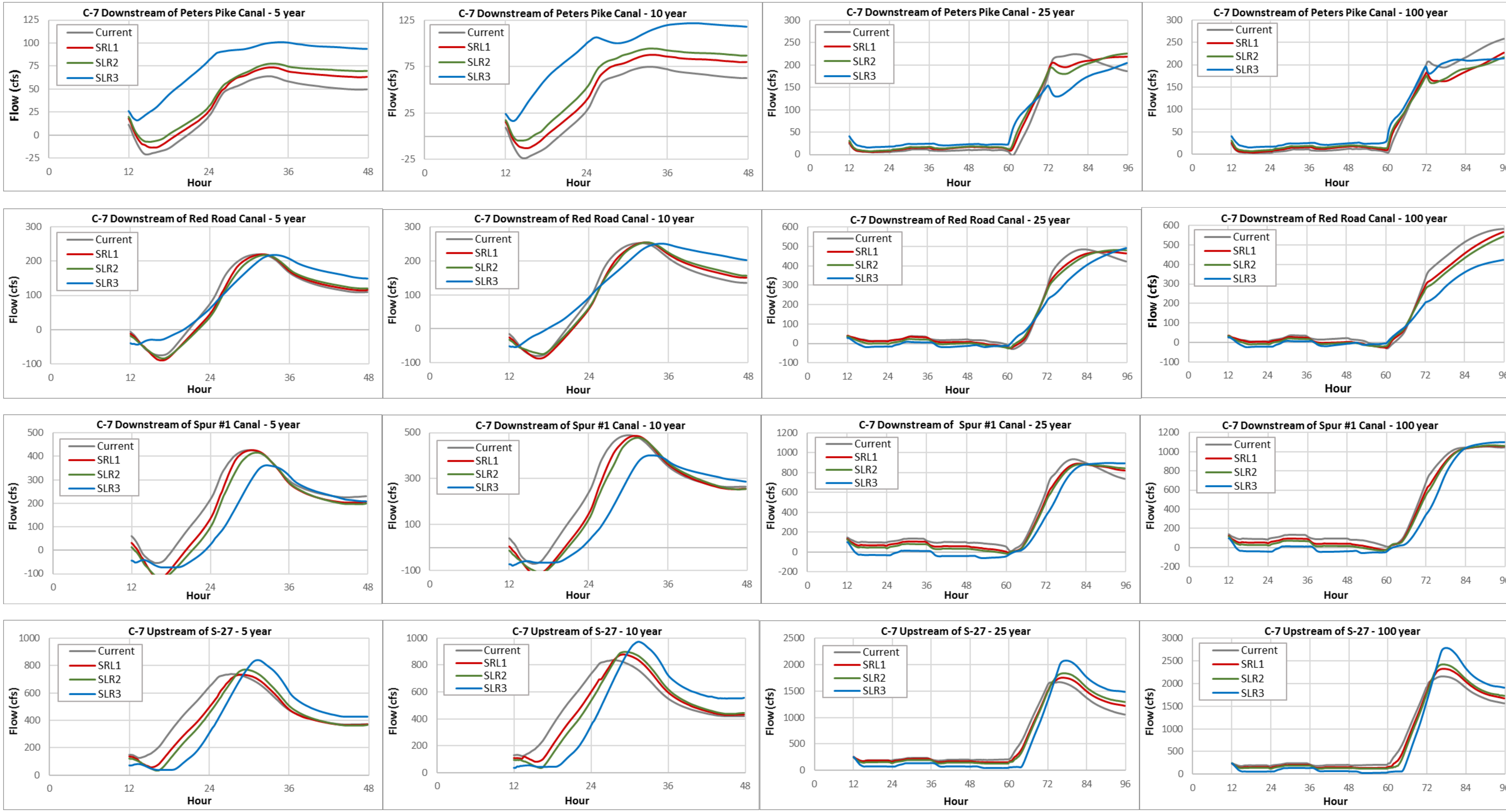


Figure 10-4 – Simulated Flow at the C-7 Canal, 12-Hour Moving Average, for All Scenarios

10.3 LOS PM #4 – Peak Storm Runoff

Figure 10-5, **Figure 10-6**, **Figure 10-7**, and **Figure 10-8** show the 12-hour moving average flow at the S-27 structure for all scenarios during the 5-, 10-, 25-, and 100-year events, respectively.

As shown in the PM#2 results above, the flow at the C7 Basin outlet increases with increased SRL, due to the larger volume of water in the system. However, the timing to reach the flow peak also increases, which is indicative of a decreased conveyance capacity in the C-7 Canal due to higher tailwater stages.

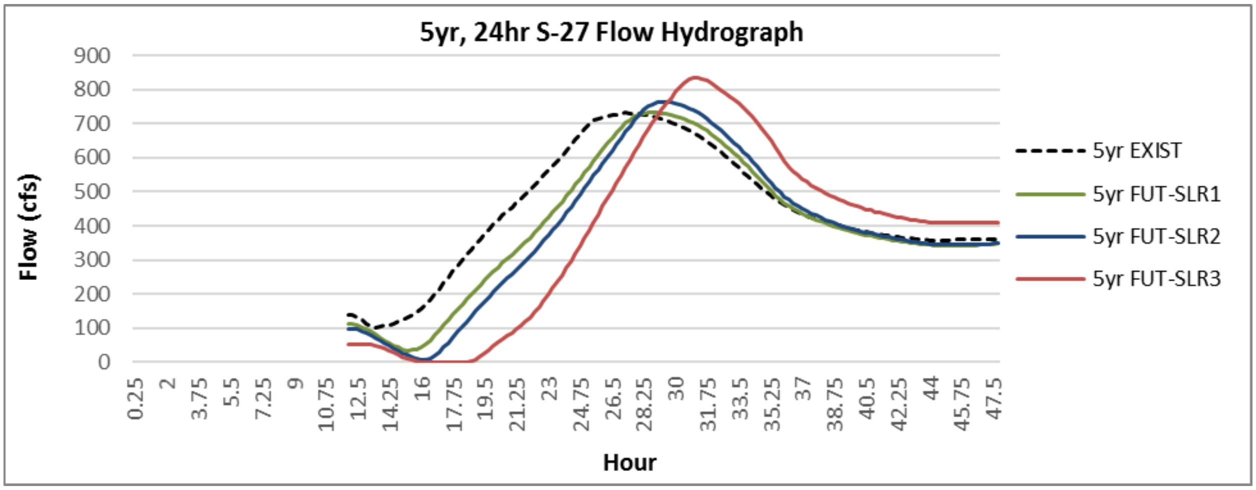


Figure 10-5 – Flow at the C-7 Canal Through S-27, 12-Hour Moving Average, During the 5-year, 24-hour Event for All Scenarios

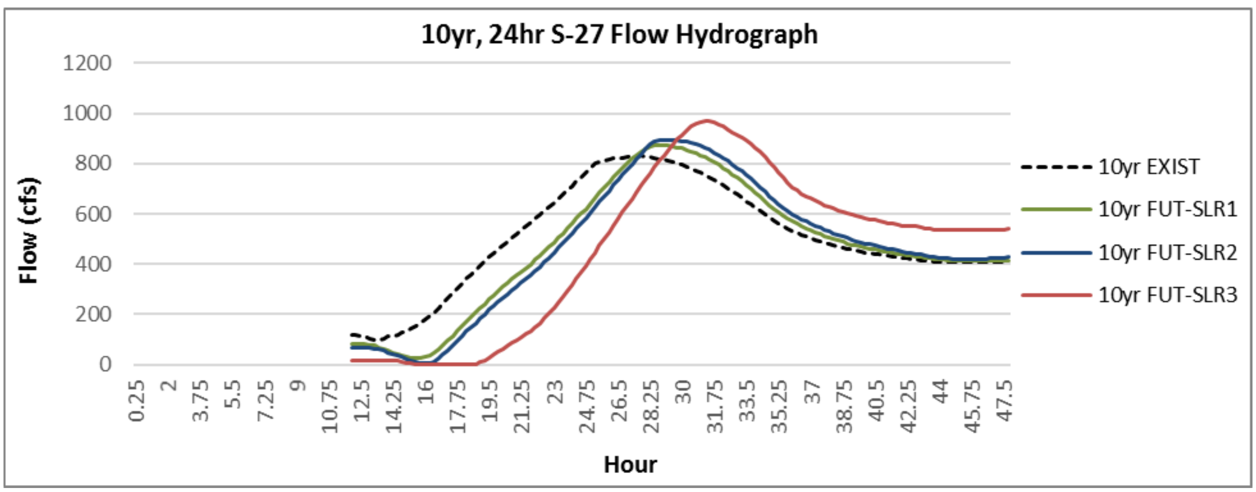


Figure 10-6 – Flow at the C-7 Canal Through S-27, 12-Hour Moving Average, During the 10-year, 24-hour Event for All Scenarios

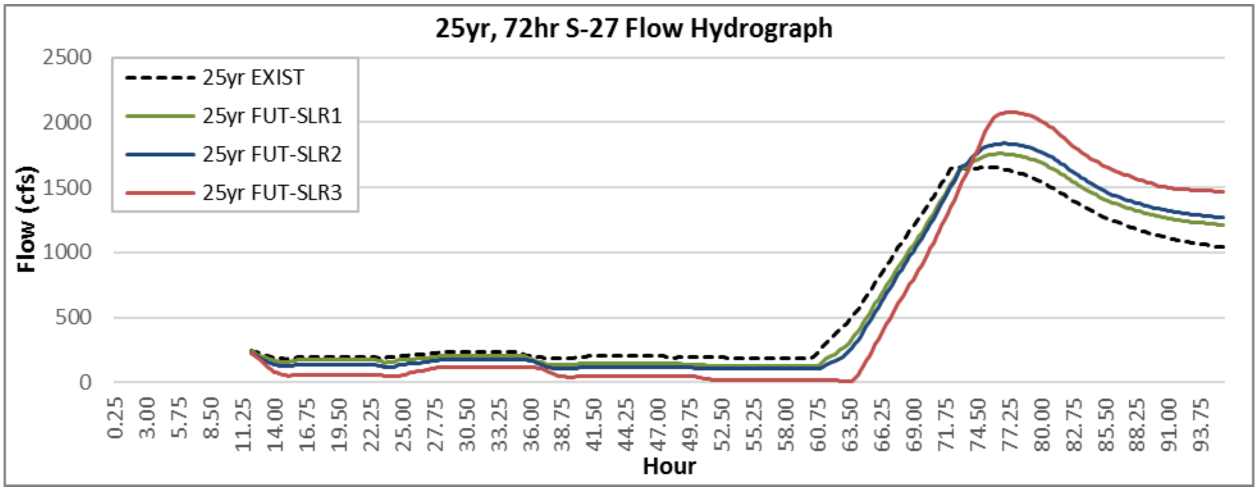


Figure 10-7 – Flow at the C-7 Canal Through S-27, 12-Hour Moving Average, During the 25-year, 72-Hour Event for All Scenarios

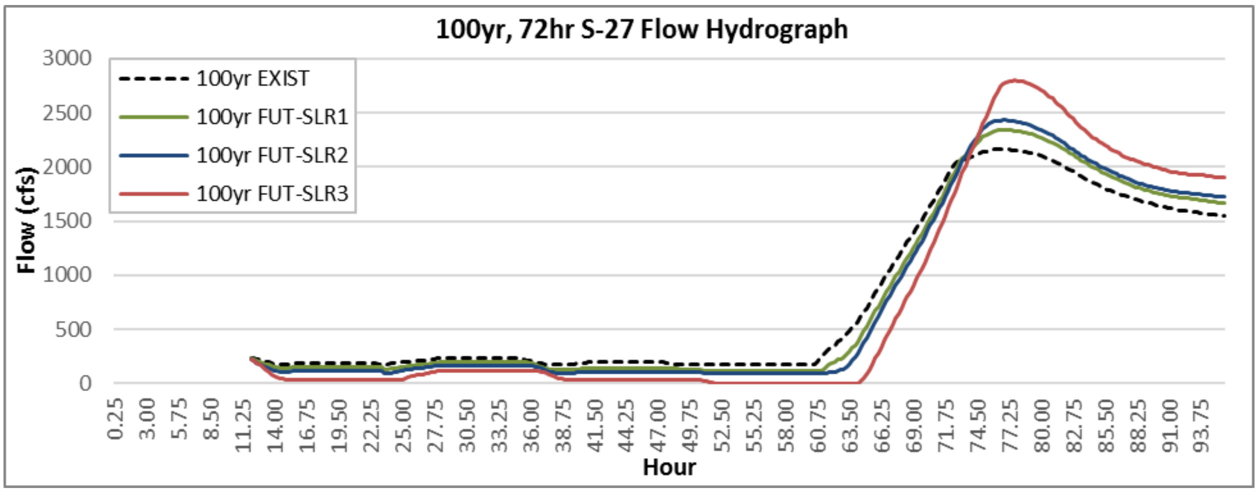


Figure 10-8 – Flow at the C-7 Canal Through S-27, 12-Hour Moving Average, During the 100-year, 72-Hour Event for All Scenarios

Figure 10-9 shows the impact of sea level rise on the maximum 12-hour flow through the S-27 structure for all storm events.

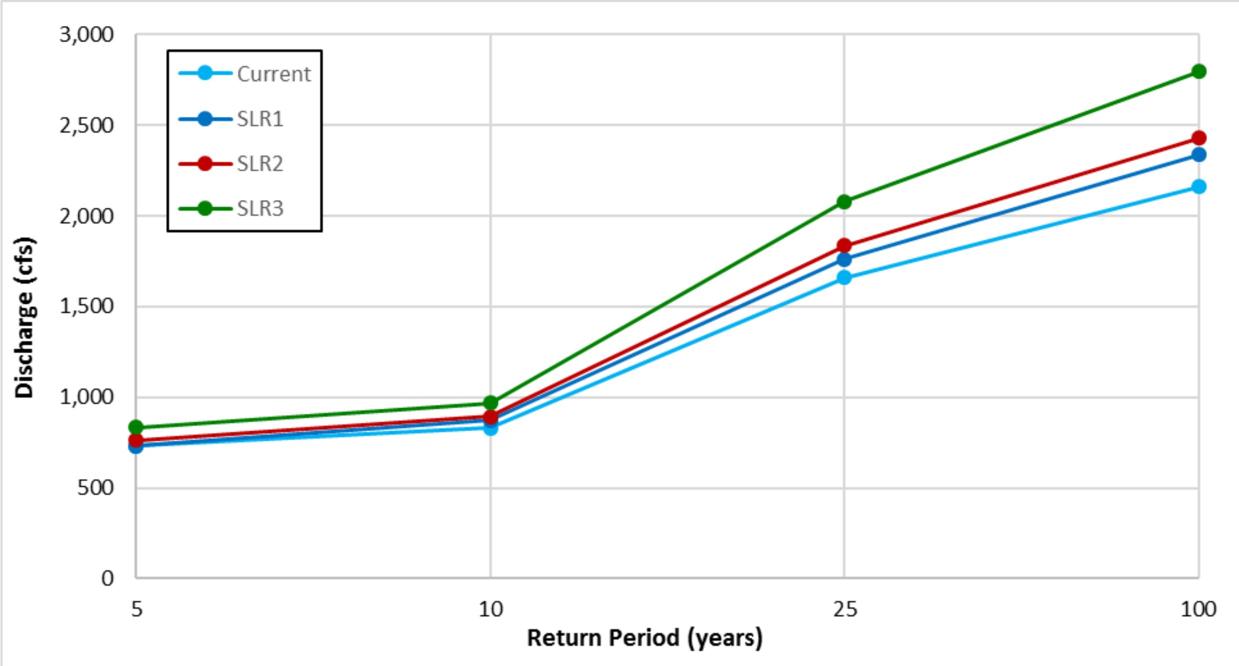


Figure 10-9 – Impact of Sea Level Rise on the Structure Flow at S-27

10.4 LOS PM #5 – Frequency of Flooding

Table 10-5 shows parameters calculated for performance measure #5 as a comparison with the simulated current conditions. The values in the table are expressed as a difference (SLR Scenario N minus EXIST).

Table 10-5 – Frequency of Flooding Parameters in the SLR Scenarios and a Comparison between the Current Conditions Model (SLRn minus EXIST).

Scenario	NS (-)		MER (mi)		MMAS (mi)		MCLS (mi)	
	Total[1]	Diff[2]	Total	Diff	Total	Diff	Total	Diff
SRL1	3,533	691	1.9	0.0	2.1	0.1	79.1	5.0
SRL2	4,217	1,375	2.1	0.5	2.2	0.2	82.4	8.3
SRL3	6,197	3,355	2.6	1.1	2.4	0.5	104.0	29.9

[1]Total – total value of the parameter in each scenario.
[2]Diff – difference between SLR and EXIST (SLRn – EXIST) for each parameter.

For the SLR1 scenario, the largest change in the number of structures flooded from the current conditions simulation occurred the GTY-N-1 subbasin, located in the northwest corner of the C7 Basin, and C7-C-16 subbasin, located south of the C-7 Canal near the outlet structure. The GTY-N-1 subbasin had 255 more structures flooded in SLR1 than in current conditions and the C7-C-16 subbasin had 100 more structures flooded in SLR1 than in current conditions.

The extent and ranking for the road flooding is similar to the current conditions results. The largest difference in MER from current conditions (0.2 miles) occurred in the PP-C-1C7 subbasin, located in the SR924 (I-75S) interchange with SR 826. The largest difference in MMAS from current conditions (0.07 miles) and in MCLR (1 mile) occurred in the CC7-S-6 subbasin, located south of the C-7 Canal and just east of E 8th Avenue.

Table 10-6, **Table 10-7**, **Table 10-8**, show the top ten most impacted sub-basins for each PM# 5 LOS parameter for the simulated SLR1, SLR2, and SLR3 conditions, respectively. A ranking of 1 means that the subbasin has the highest value of each parameter.

For the SLR1 scenario, the largest change in the number of structures flooded from the current conditions simulation occurred the GTY-N-1 subbasin, located in the northwest corner of the C7 Basin, and C7-C-16 subbasin, located south of the C-7 Canal near the outlet structure. The GTY-N-1 subbasin had 255 more structures flooded in SLR1 than in current conditions and the C7-C-16 subbasin had 100 more structures flooded in SLR1 than in current conditions.

The extent and ranking for the road flooding is similar to the current conditions results. The largest difference in MER from current conditions (0.2 miles) occurred in the PP-C-1C7 subbasin, located in the SR924 (I-75S) interchange with SR 826. The largest difference in MMAS from current conditions (0.07 miles) and in MCLR (1 mile) occurred in the CC7-S-6 subbasin, located south of the C-7 Canal and just east of E 8th Avenue.

Table 10-6 – Top 10 Ranked Subbasins for the PM# 5 LOS Parameters under SLR1 Conditions

Rank	NS (-)		MER (mi)		MMAS (mi)		MCLR (mi)	
	Subbasin	Value	Subbasin	Value	Subbasin	Value	Subbasin	Value
1	GTY-N-1	318	PP-C-1C7	0.70	CC7-S-12	0.41	CC7-S-12	8.1
2	C7-C-16	278	PP-N-1	0.56	CC7-S-7	0.33	C7-N-5	5.9
3	CC7-S-6	175	95-S-2	0.17	CC7-S-8	0.16	CC7-S-25	4.5
4	CC7-S-24	174	C7-S-1	0.10	C7-N-7	0.13	CC7-S-7	4.2
5	CC7-S-3	161	C7-C-15	0.09	CC7-S-23	0.13	CC7-S-13	3.6
6	CC7-S-25	152	CC7-N-2	0.07	98ST-N-1	0.09	CRR-E-1	3.6
7	CC7-S-21	144	C7-S-2	0.06	CC7-S-6	0.09	C7-N-6	3.2
8	CC7-S-10	140	C7-C-2	0.05	C7-S-7	0.09	CC7-S-3	3.0
9	CC7-S-4	127	127ST-S-2	0.04	CC7-S-25	0.06	CC7-S-4	2.8
10	CC7-S-15	120	C127ST-S-1	0.03	98ST-C-1	0.06	CC7-S-6	2.8

As in SLR1, the SLR2 scenario showed the largest change in the number of structures flooded from the current conditions simulation in the GTY-N-1 subbasin and C7-C-16 subbasin. The GTY-N-1 subbasin had 645 more structures flooded in SLR2 than in current conditions and the C7-C-16 subbasin had 145 more structures flooded in SLR2 than in current conditions. The C7-N-10 subbasin, located north of the C-7 canal and west of I-95, also had a large increase in NS, 70 more than the current conditions simulation. The extent and ranking for the road flooding is similar to the current conditions results. The largest difference in MER occurred in PP-C-1C7 (0.25 miles). The largest difference in MMAS from current conditions (0.09 miles) and in MCLR (1.4 miles) occurred in the CC7-S-6 subbasin.

Table 10-7 – Top 10 Ranked Subbasins for the PM# 5 LOS Parameters under SLR2 Conditions

Rank	NS (-)		MER (mi)		MMAS (mi)		MCLR (mi)	
	Subbasin	Value	Subbasin	Value	Subbasin	Value	Subbasin	Value
1	GTY-N-1	708	PP-C-1C7	0.77	CC7-S-12	0.41	CC7-S-12	8.1

Rank	NS (-)		MER (mi)		MMAS (mi)		MCLR (mi)	
	Subbasin	Value	Subbasin	Value	Subbasin	Value	Subbasin	Value
2	C7-C-16	323	PP-N-1	0.59	CC7-S-7	0.33	C7-N-5	5.9
3	CC7-S-24	203	95-S-2	0.17	CC7-S-8	0.16	CC7-S-25	4.6
4	CC7-S-6	175	C7-S-1	0.10	C7-N-7	0.13	CC7-S-7	4.3
5	CC7-S-3	161	C7-C-15	0.09	CC7-S-23	0.13	CC7-S-13	3.6
6	C7-N-10	154	CC7-N-2	0.09	CC7-S-6	0.11	CRR-E-1	3.6
7	CC7-S-25	152	C7-S-2	0.08	C7-S-7	0.10	CC7-S-6	3.3
8	CC7-S-21	144	C7-C-2	0.05	98ST-N-1	0.09	C7-N-6	3.2
9	CC7-S-10	140	127ST-S-2	0.04	CC7-S-25	0.07	CC7-S-3	3.0
10	CC7-S-4	127	C127ST-S-1	0.03	98ST-C-1	0.06	CC7-S-4	2.8

As in SLR1 and SLR2, the SLR3 scenario showed the largest change in the number of structures flooded from the current conditions simulation in the GTY-N-1 subbasin and C7-C-16 subbasin. The GTY-N-1 subbasin had 1,252 more structures flooded in SLR3 than in current conditions and the C7-C-16 subbasin had 275 more structures flooded in SLR2 than in current conditions. The C7-N-10 subbasin also had a large increase in NS, 203 more than the current conditions simulation. This subbasin had the largest increases in NS ranking from current conditions to the SLR3 (i.e., the ranking for EXIST, SLR1, SLR2, and SLR3 was 14, 11, 6, and 3, respectively).

The extent and ranking for the road flooding is similar to the current conditions results. The largest difference in MER occurred in PP-C-1C7 (0.5 miles). The largest increase in MMAS from current conditions (0.13 miles) occurred in the CC7-S-6 subbasin. The largest increase in MCLR from current conditions (6.3 miles) occurred in the C7-C-16 subbasin. Relatively large increases in MCLR also occurred in SPUR-E-3 (3.4 miles) and CC7-S-6 (2.8 miles).

Table 10-8 – Top 10 Ranked Subbasins for the PM# 5 LOS Parameters under SLR3 Conditions

Rank	NS (-)		MER (mi)		MMAS (mi)		MCLR (mi)	
	Subbasin	Value	Subbasin	Value	Subbasin	Value	Subbasin	Value
1	GTY-N-1	1315	PP-C-1C7	1.00	CC7-S-12	0.41	CC7-S-12	8.3
2	C7-S-16	453	PP-N-1	0.74	CC7-S-7	0.32	C7-S-16	7.4
3	C7-N-10	287	95-S-2	0.17	CC7-S-8	0.16	C7-N-5	6.1
4	CC7-S-24	203	C7-S-2	0.13	CC7-S-6	0.15	CC7-S-25	4.9
5	CC7-S-6	196	CC7-N-2	0.11	CC7-S-23	0.13	CC7-S-6	4.6
6	CC7-S-21	191	C7-S-1	0.10	C7-N-7	0.13	CC7-S-7	4.3
7	CC7-S-25	169	C7-C-15	0.10	C7-S-7	0.10	CRR-E-1	3.7
8	C7-N-1	163	127ST-S-2	0.07	98ST-N-1	0.09	CC7-S-13	3.6
9	CC7-S-3	161	C7-C-2	0.06	CC7-S-25	0.08	SPUR-E-3	3.6
10	CC7-S-10	140	GTY-S-1	0.04	CC7-S-10	0.07	C7-N-6	3.2

Figure 10-10 shows the locations of the flooded structures in all scenarios. The dots representing the locations in the figure were placed in order of increasing sea level rise (Existing, SLR1, SLR2, and SLR3) so that the flooded structure locations for each scenario are visible only if the number of structures exceed the previous scenario.

The number of locations increase substantially in the western portion of the basin, west of Peter's Pike Canal (subbasins GTY-N-1 and C7-N-1). The extent of the flooding increases with sea level rise near the C-7 Canal dowstream of the Spur #1 Canal junction, as well as near the Spur #1 Canal. In the northcentral portion of the basin adjacent to the northern model boundary (subbasins 127ST-N-1, -2, -4, and -5) and in the subbasins near the southern portion of the Red Road Canal the number of flooded structures also increase with SLR.

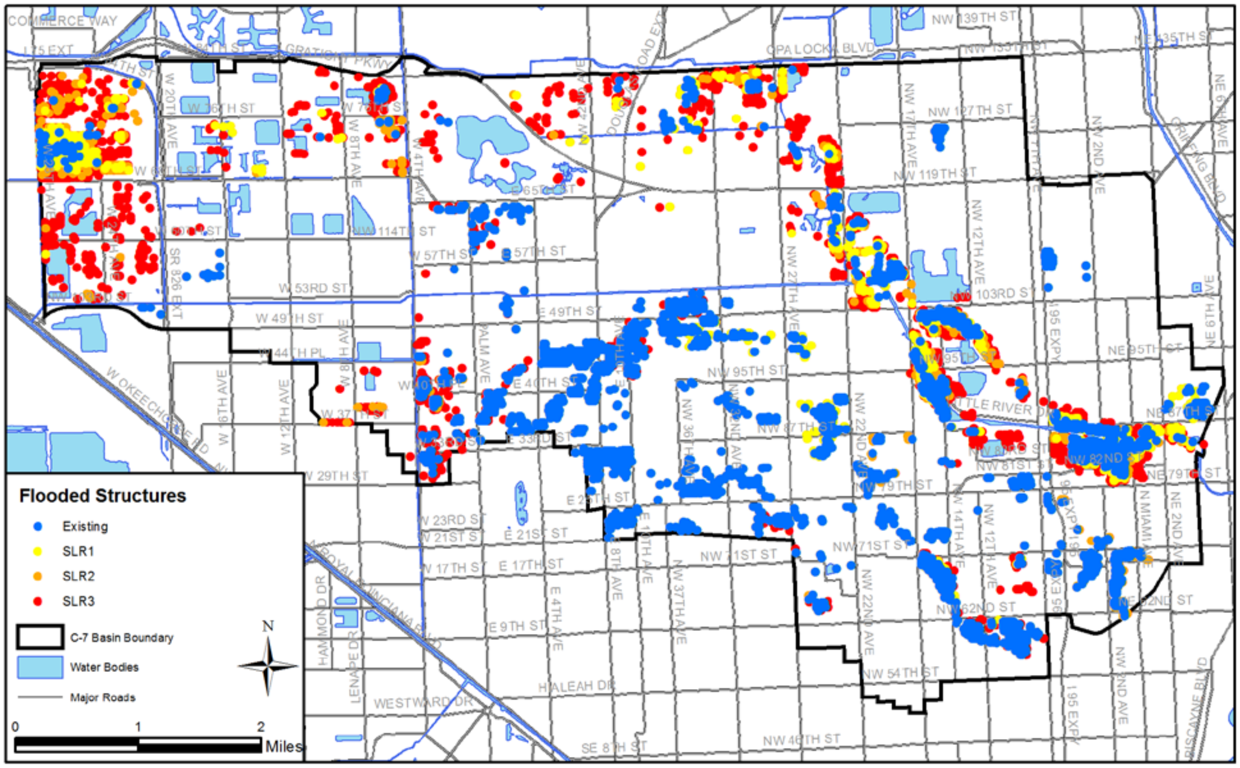


Figure 10-10 – Locations of Flooded Structures for all Scenarios

Figure 10-11 shows the subbasins color coded according to the number of structures flooded in the SLR 3 Scenario. The maximum stages for the subbasins and canals during 100-year event are also included in the figure. The results indicate that the maximum stages in some of the subbasins with large number of structures flooded that are near a primary or secondary canal are same as maximum stages in the canals. Some examples are GTY-N-1 and C7-N-1, west of Peter Pike's Canal, SPUR-E-1, SPUR-E-3, and SPUR-W-2, adjacent to the Spur #1 Canal, and C7-C-16, C7-N-12, C7-N-10, adjacent to the C-7 Canal. Thus, for these basins, there is a high tailwater effect from the primary and secondary canal system. Flooded subbasins in the southern portion of the basin (CC7-S-3, -4, -6, -7, -10, -13, -15, -21, -24, and -25) have higher maximum stages than the C-7 Canal. Thus, flooding in these basins are likely a consequence of limited storage and/or local drainage features.

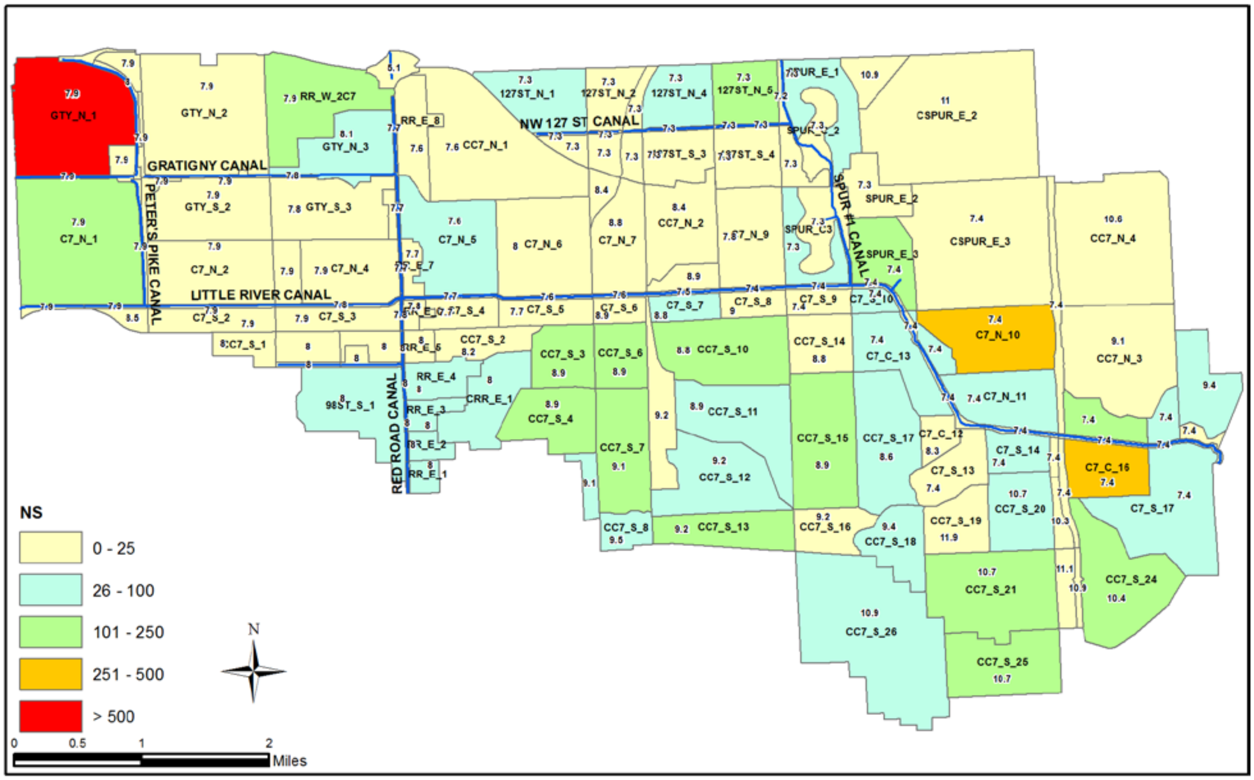


Figure 10-11 – Number of Flooded Structures (NS) and Maximum Stages in Canals and Subbasins in the 100-year Storm and SLR3 Conditions. Stages are shown in bold font and halo background.

The PM#5 parameters values for each subbasin in all scenarios are provided in **Appendix I**. In addition, flood maps for the four design storm events for the simulated current conditions and the sea level rise scenarios are shown in **Appendix J**.

11.0 SUMMARY OF FPLOS METRIC IMPACTS OF FUTURE SLR SCENARIOS

The results of the scenario simulations show that the headwater stages at S-27 structure increased with SLR and the magnitude of the increase in stage is proportional to the magnitude of the projected sea level rise for all events simulated.

Most of the comparisons of storm events between EXIST and the SLR scenarios show that the total simulated volume of runoff at S-27 decreased and the flow peaks increased with increased sea level rise (**Table 9-1**, **Table 9-2**, and **Table 9-3**). The largest increase in the flow peaks between the simulated current conditions and the SLR scenarios occurs during the 100-yr event (239, 338, and 840 cfs for SRL1, SLR2, and SLR3, respectively). The largest decreases in flow volume occurred during the 5-year event (163, 206, 245 ac-ft for SRL1, SLR2, and SLR3, respectively). The decreased in flow volumes is likely due to the delay in the timing of the peak and the slow recession that is caused by increased stages in the C-7 Canal. Thus, it takes longer to move the same volume of water generated by each storm event.

The PM#1 results indicate that the C-7 Canal stage profiles also increased proportionally to the predicted increased SLR. In the 5- and 10-year events the profile is relatively flat, i.e., there is a relatively small head loss between the upstream and downstream ends. In the 25- and 100-year events the head losses along the canal simulated under current conditions decrease with increasing SLR, which indicates that the larger impact of the SLR occurs at the downstream end, near the outlet. The changes in profile with increasing SLR in the larger events show a backwater effect of the tidal boundary propagate up to approximately half of the length of the canal (near NW 32nd Avenue) in the worst case, SLR3.

The PM#2 results show the relative contribution of each secondary canal in the C7 Basin and the relative impacts on increase SLR at each location. The results show that the localized effects vary for various magnitudes of storm events. However, differences in trend between the flow at upstream and downstream locations seems to indicate that the conveyance capability is more impacted in the eastern portion of the basin. For example, during the 5- and 10-year events the flow increases with SLR at the junction with the Peter’s Pike Canal, is of similar magnitude but delayed at the Red Road Canal junction and decreases at junction with the Spur#1 Canal. However, the larger magnitudes of the 25- and 100-year events changes these trends. The total flow at the outlet, show an increasing trend in flow and timing of the peak for all events. This is also, indicated in the results for PM#4. For the C-7 Basin allowable discharge rate is essentially unlimited. SFWMD requires that the post-development peak discharge rate from these projects be maintained at or below the pre-development peak discharge rate for a 25-year, 3-day design storm event. Due to the simulated impacts caused by sea level rise, regulatory limits in the allowable discharge in subbasins should be considered, particularly in the eastern portions of the model.

PM#5 shows moderate increases in the miles of major and minor arterial roads that do not meet the LOS criteria with SLR, just over 1 mile of major roads (MER) and half a mile of minor arterials (MMAS) in the SRL3 (**Table 10-5**). The largest impact is shown by the increase in the number of structures (NS) and minor roads (MCLRS) that do not meet the LOS criteria. The increase in NS in SLR1, SLR2, and SLR3 was 691, 1,375, and 3,355, respectively and in MCLRS 5, 8.3, and 29.9 miles, respectively.

During the review process, it was discovered that the flow output from the S-27 structure was not following the rating curves specified for each flow condition. Thus, the head differential vs. flow relationship were not calculated properly by the model. This seems to be a result of a glitch in the software where the rating curves are not properly calculated if the conduit is activated on the multilinks where the rating curves are specified. The S-27 headwater stages, the flow through the structure, and stages at all of the subbasin nodes were compared before and after fixing the issue. The impact on the headwater stages and the stages in the nodes were small (an average of 3% increase in the peak headwater stages for the 16 simulations (4 storm events x 4 SLR conditions) and an average increase of 0.5 inches in the peak subbasin stages). All of the corrected simulations showed a decrease in flow volume, with an average decrease of 13%. The direction of change in flow peaks varied, but it increased in most of the runs after the flow correction. Nevertheless, the trends observed for the various scenarios in the flow discharge capacity, e.g., PM#2 **Table 10-4**, were similar. The next phase of the project, evaluation of SLR mitigation alternatives, which will include a revised baseline run, will be performed with the corrected structure operation.