English

Project and Applicant Information

Official Project Title	C-7 Basin Canal System Project
Official Applicant Entity Name	Miami-Dade County
Primary Contact Name	Daniel Wall
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Secondary Contact Phone Number	(786) 863-0812
Secondary Contact Email	tcp@miamidade.gov
Mailing Address	Stephen P. Clark Center 111 NW 1st Street, 22nd Floor
Site Address	www.miamidade.gov/grants
FEIN#	596000573
DUNS#	131910254

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Large-Scale Stormwater Mitigation Project in the C-7 Watershed

Project Description

Background

Miami-Dade County's hydrologic characteristics, combined with its generally flat topography, have historically led (prior to land development) to long periods of inundation. In order to manage surface water and allow for development of the land, a primary canal system was constructed by the USACE with secondary canals developed by local governments and various private entities. Today, the canal system in Miami-Dade County consists of over 300 miles of primary canals and over 200 miles of secondary canals.

The secondary canal system is the responsibility of Miami-Dade County. Over the period since 1996, stormwater numerical models have been developed and updated for each watershed in Miami-Dade County. These stormwater master plan updates identify water quantity and water quality challenges and strategies to mitigate impacts to Biscayne Bay, to County properties, and residents.

Numerical models are utilized to facilitate the evaluation of drainage and water quality scenarios. The latest 2019-2020 comprehensive update to the Stormwater Master Plan has identified that improvements to a number of secondary canals are necessary to enhance storage and conveyance capabilities throughout the County's secondary canal system.

Scope of Work

This proposed project includes improvements to secondary canals under Miami-Dade County control within the C-7 Basin. The project is intended to correct deficiencies in elevation in a total of six (6) secondary canals, or approximately 6 miles. Proposed improvements include raising top of bank elevations and implementing upgrades to culverts to enhance canal storage and conveyance capability using the criteria for future conditions in a 2060 scenario with Sea Level Rise. The proposal also includes improvements to existing outfalls in these secondary canal segments for water quality enhancements. Total estimated project cost is $14 million.

The implementation of this project includes survey, soil testing, design, permitting, construction, and construction management. A combination of engineering resources from Miami-Dade County, consultants, and outside contractors are planned to implement this project. A total of 3 to 5 years is anticipated to complete the work. Project matching funding and operational and maintenance costs are fully funded by Stormwater Utility Fees and budgeted in the annual County Budget as approved by the Miami-Dade Board of County Commissioners. Project estimate have been prepared by County engineering staff that will be involved in the design, permitting, bidding, construction, and project management.

NAME	Mean Elevation Defficiency, ft	Repair Length, ft	Repair Cost
CANAL SPUR	1.2	580	$261,000
NW 127 ST CANAL	1.34	7,600	$3,420,000
PALM SPRINGS CANAL	1.42	2,370	$1,067,000
RIO VISTA CANAL	1.54	2,050	$923,000
RED ROAD CANAL NW 57 AVE CANAL	0.68	11,765	$5,795,000
SPUR CANAL No 1	2.09	5630	$2,534,000
	Total	29,995 (~6 Miles)	$14,000,000

Justification & Technical Feasibility

The latest 2019-2020 comprehensive update to the Miami-Dade County Stormwater Master Plan has identified that improvements to a number of secondary canals are necessary throughout the County's secondary canal system.

Comparative simulations were developed assuming that the top of the canal banks follows the County criteria for conveyance and storage capacity for a 25 YR / 72 HR 2060 future model scenario with Sea Level Rise (SLR). Currently, some of the secondary canal banks are below this criterion. This project is anticipated to improve conveyance as well as storage capability and allow for additional storage to be available to detain flows temporarily thus improving the management of flows under storm event conditions, current and future.

The project identified provides opportunities for implementing water quantity and water quality strategies for reducing flooding and water quality impacts to Biscayne Bay. It is anticipated that this project would start upon grant funding approval. The project is otherwise planned to be implemented in a longer than 20-year period. Therefore, funding provided by this grant would greatly help expedite project implementation.

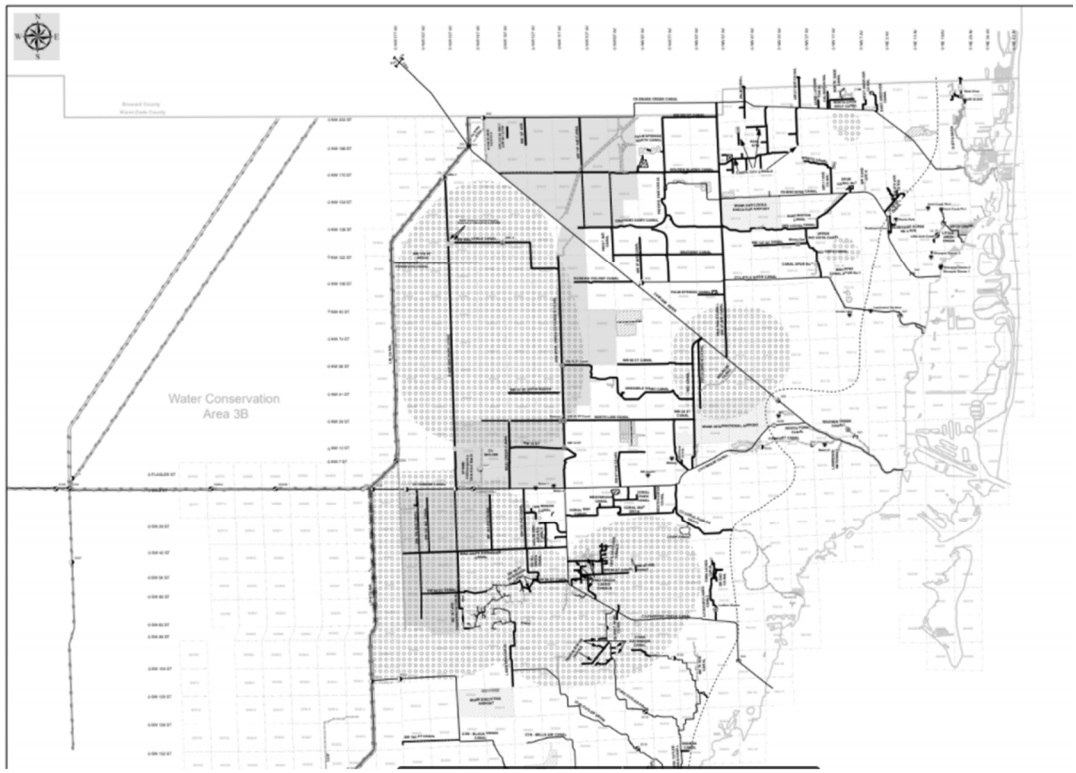
It is anticipated that the implementation of this project will be highly effective in mitigating flood risks by reducing or eliminating damage to property and/or loss of life in the project area. More specifically, the proposed project is anticipated to provide the following benefits:

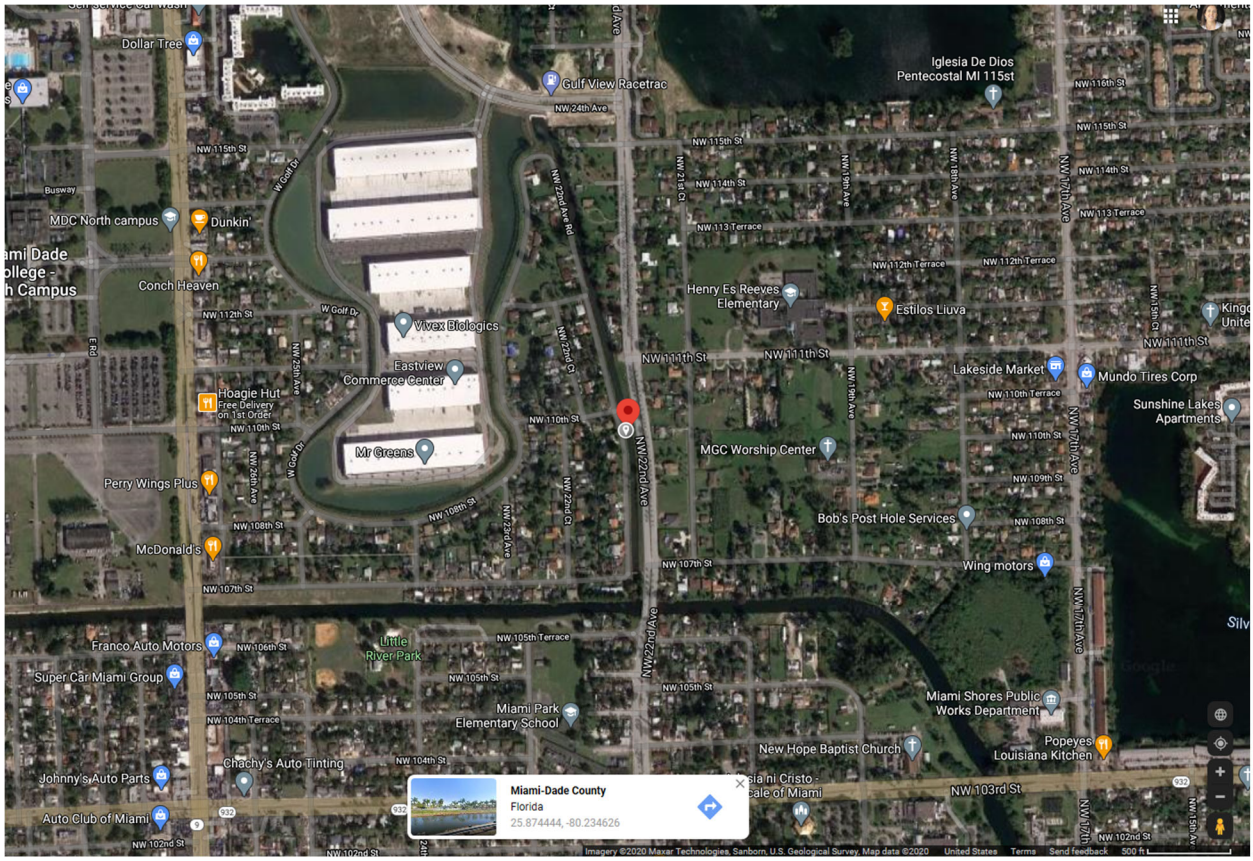
- Restoration of critical infrastructure
- Rehabilitation or construction of stormwater management systems
- Improvements to drainage facilities

A full signed and sealed engineering report is available upon request to document the analysis and identification of the proposed project.

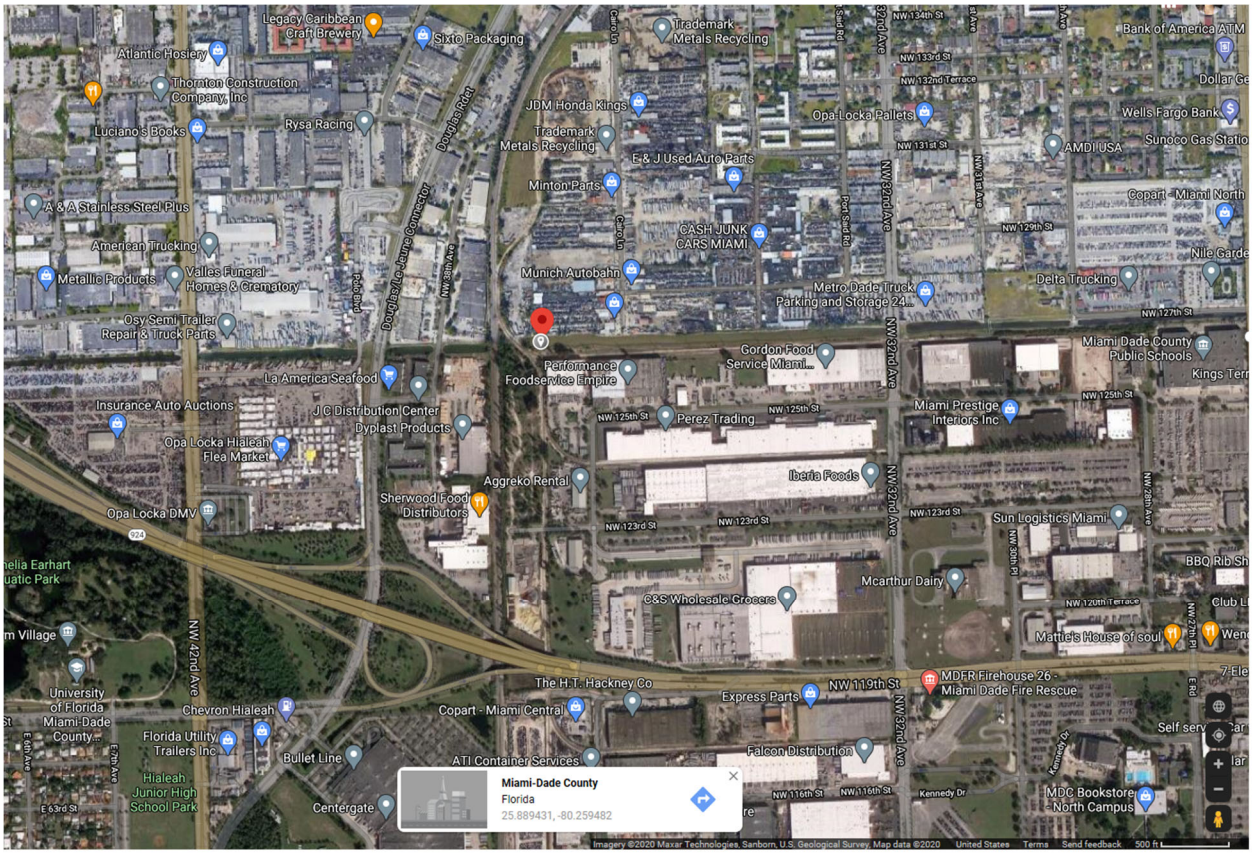
Attached is location information for the proposed project.

Secondary Canal Name	Jurisdiction/Maintenance Responsibility	Commission District	Municipality	Approximate Latitude	Approximate Longitude	Mean Elevation Deficiency, ft	Repair Length, ft	Total Length, ft	Estimated Enhancement Cost
CANAL SPUR	Miami-Dade County	No. 2	UMSA	25.874436	-80.234594	1.2	580	598	$261,000
NW 127 ST CANAL	Miami-Dade County	No. 2	Opa-Locka UMSA	25.889452	-80.259466	1.34	7,600	10,481	$3,420,000
PALM SPRINGS CANAL	Miami-Dade County	No. 13	Hialeah	25.862745	-80.299273	1.42	2,370	5,145	$1,067,000
RED ROAD CANAL NW 57 AVE CANAL	Miami-Dade County	No. 13	Hialeah UMSA	25.869442	-80.291040	0.68	23,530	48,895	$5,795,000
RIO VISTA CANAL	Miami-Dade County	No. 2	UMSA	25.885020	-80.236832	1.54	2,050	2,371	$923,000
SPUR CANAL No1	Miami-Dade County	No. 2	UMSA	25.873426	-80.234490	2.09	5,630	4,068	$2,534,000
						Total	**41,760**	**71,558**	**$14,000,000**

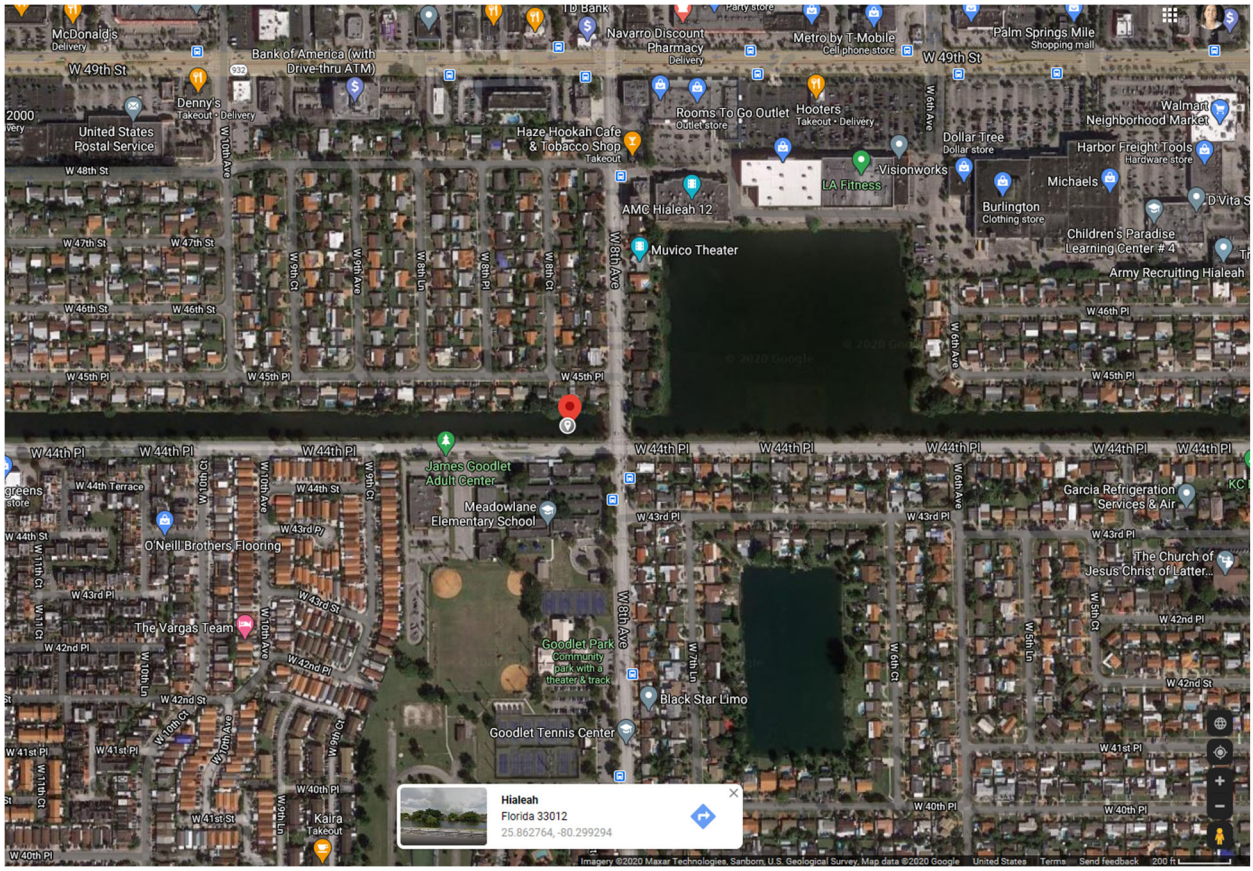




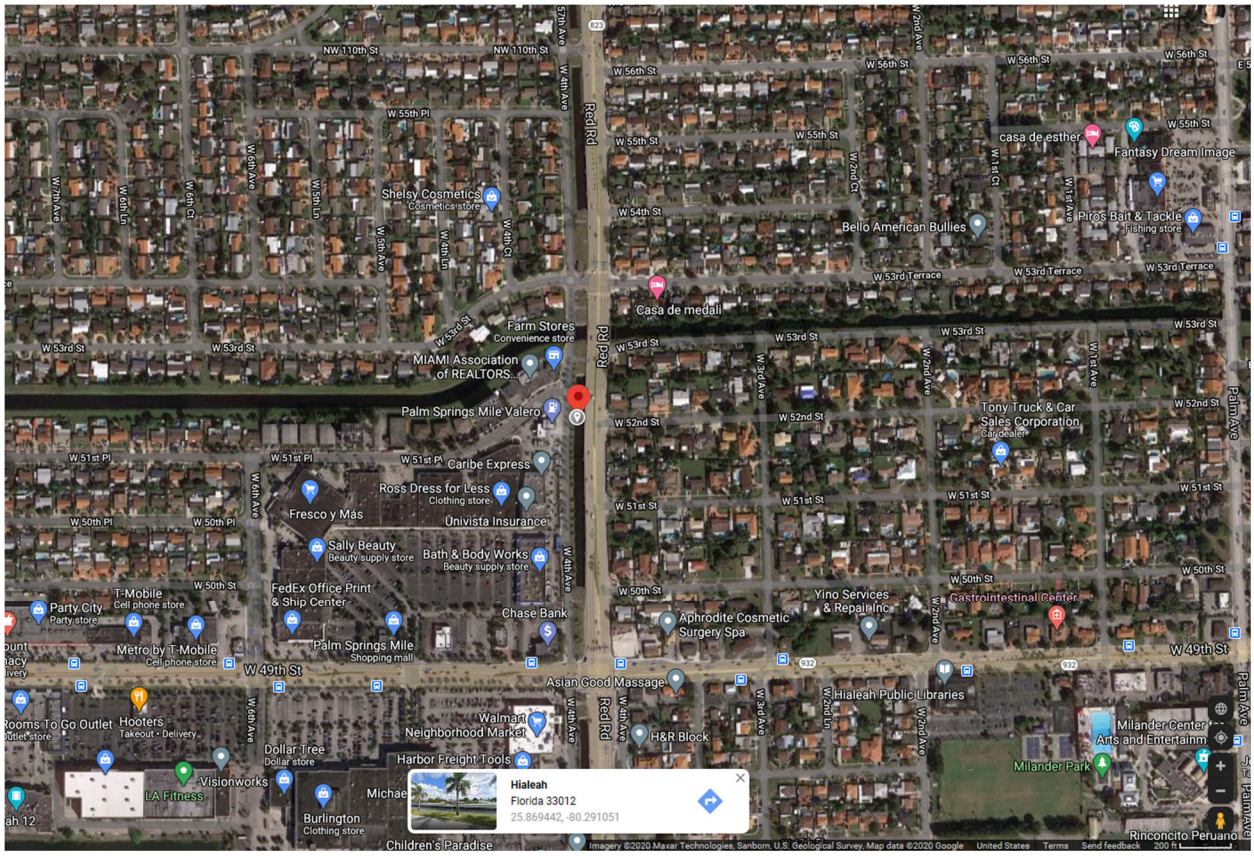
CANAL SPUR - Location Aerial View (approximate centroid coordinates)



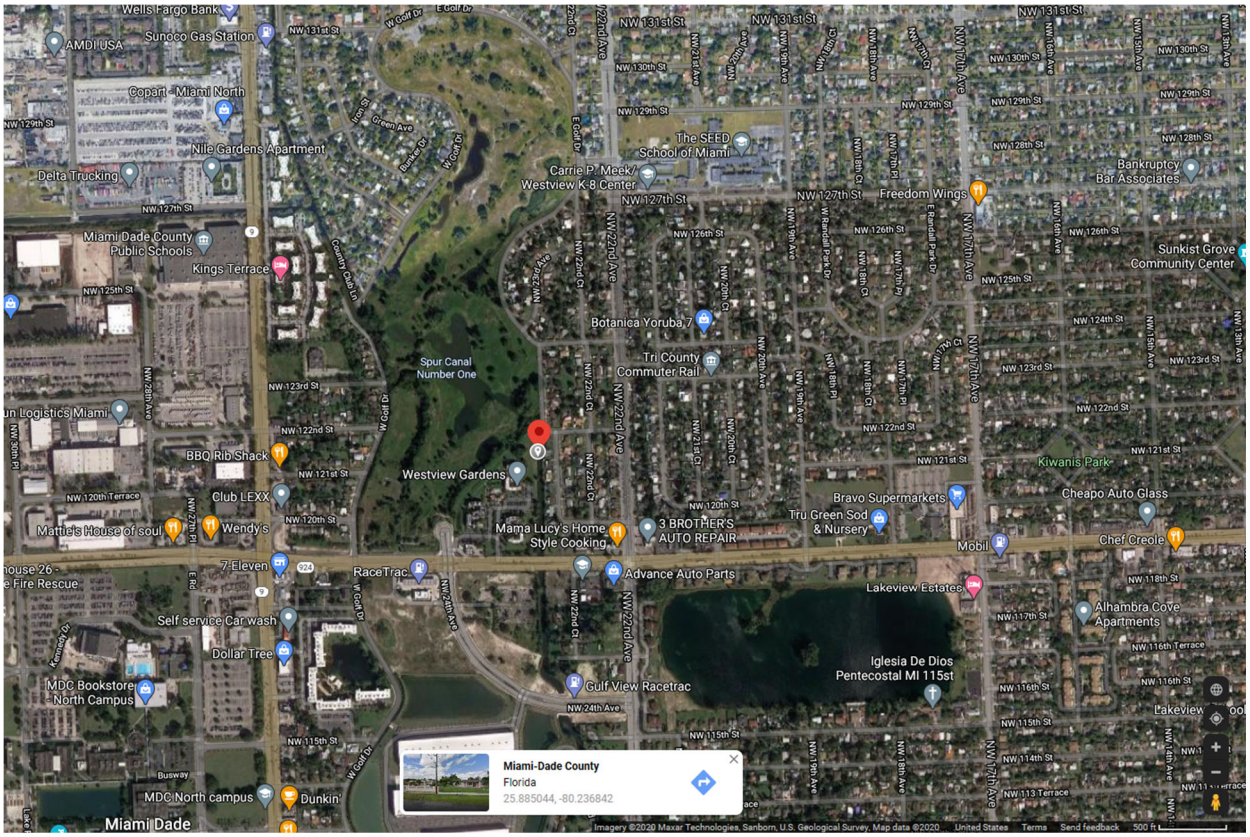
NW 127 ST CANAL - Location Aerial View (approximate centroid coordinates)



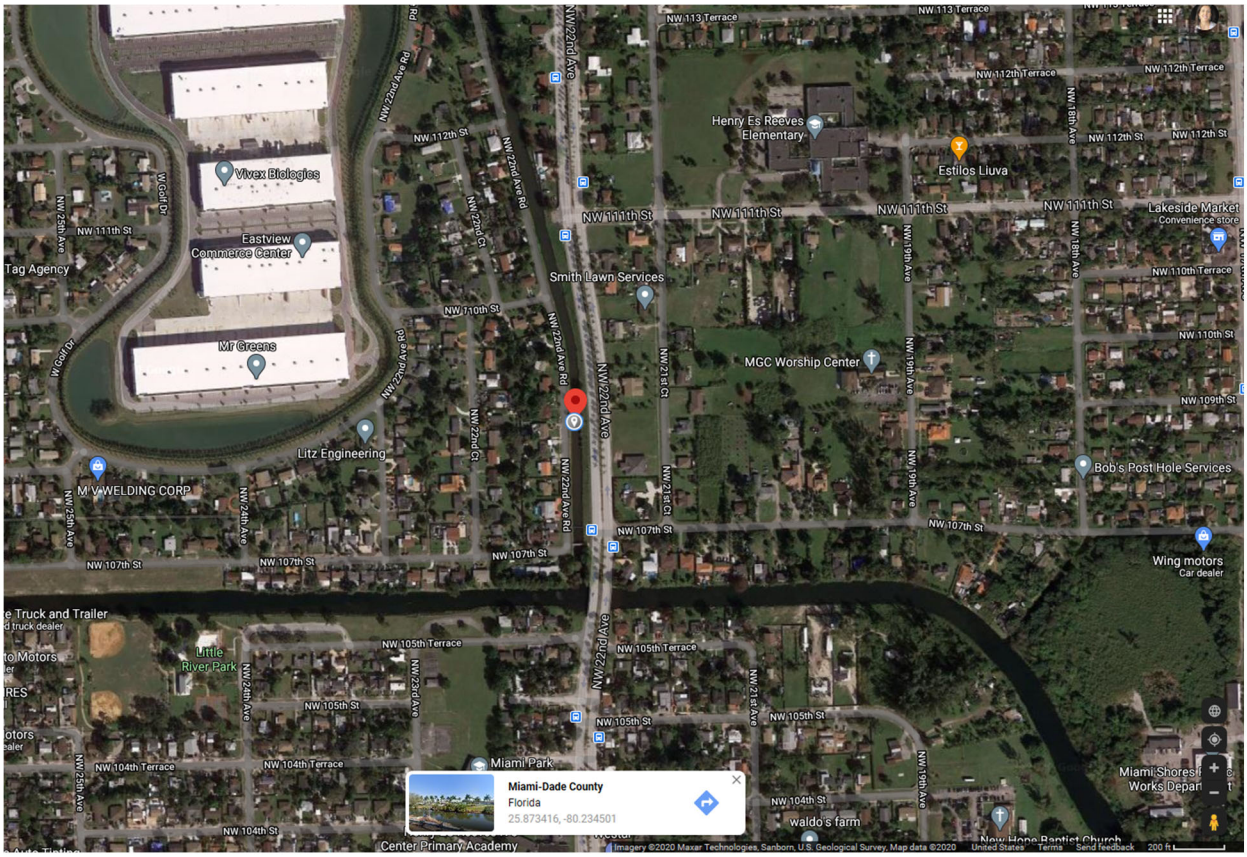
PALM SPRINGS CANAL - Location Aerial View (approximate centroid coordinates)



RED ROAD CANAL NW 57 AVE CANAL - Location Aerial View (approximate centroid coordinates)



RIO VISTA CANAL - Location Aerial View (approximate centroid coordinates)



SPUR CANAL No1 - Location Aerial View (approximate centroid coordinates)

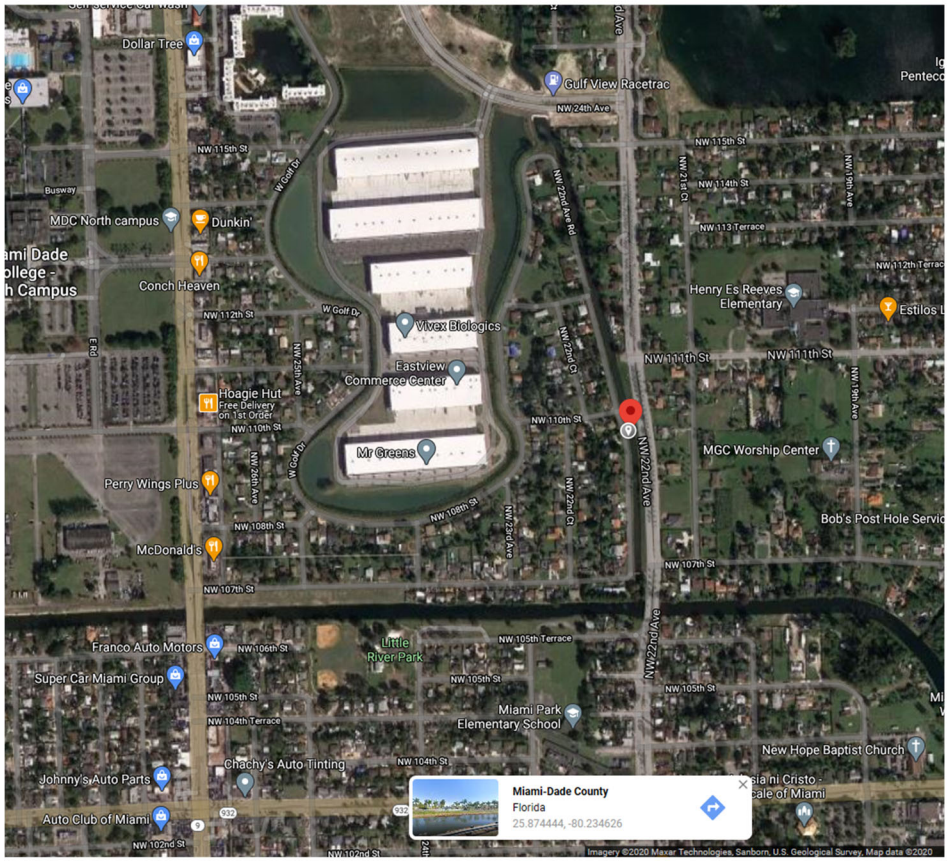
Community Value

Mitigation activities for the stormwater infrastructure have been identified for the C-7 watershed. This basin has older and aging infrastructure and development which will need mitigation to improve performance under current and future scenarios with anticipated Sea Level Rise impact. A number of neighborhoods typically flood, even during small to medium intensity storm events, causing significant community disruption. During high intensity storms, these disruptions are more prolonged and severe.

Improvement to existing stormwater infrastructure in this neighborhood will build resilience and harden the following community lifelines: safety and security; food, water, and shelter; communications; and transportation. The project will help mitigate current and future impacts of flood events which currently endanger the safety and security of residents and may cause loss of homes and businesses. The reduction in flooding will also allow critical services such as medical, energy and transportation to travel through the community to reach endangered community members quickly.

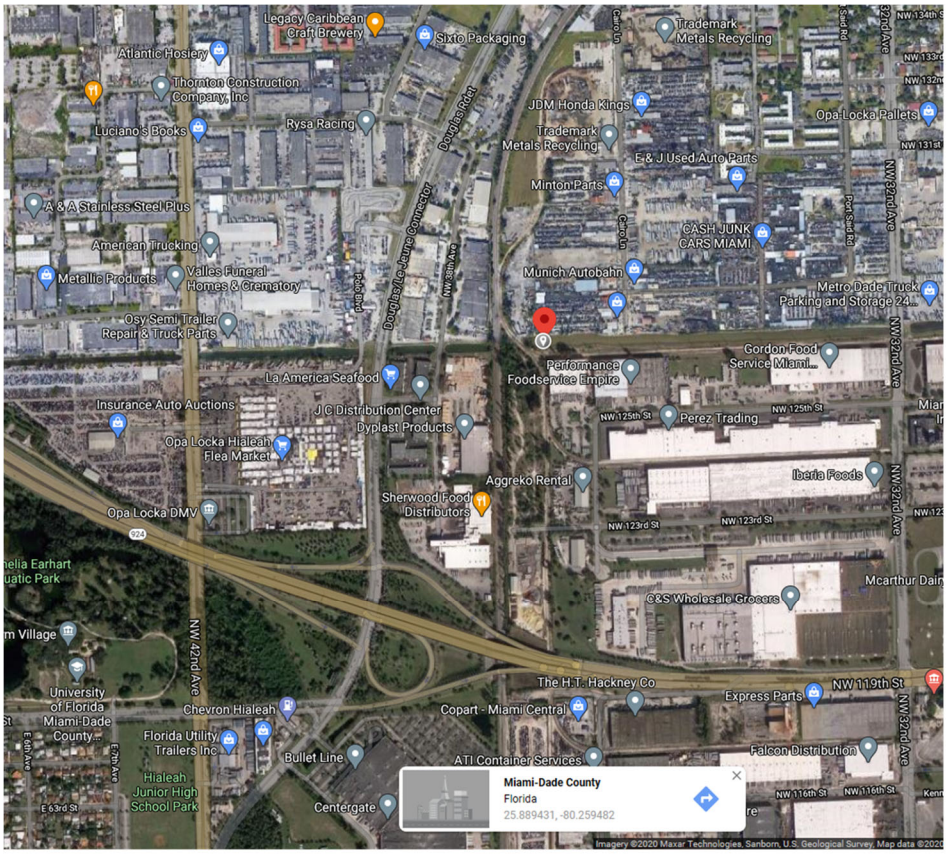
The proposed improvements are intended to reduce flood stage and time of inundation above crowns of and on property grounds. Flood stage and duration reductions will mitigate other risks to buildings and lives as well. The proposed project will implement enhanced storage and conveyance capabilities to meet a higher Level of Service flood protection using a 25 Year/3 Day, 2060 scenario with Sea Level rise. These improvements have been identified by the latest 2019-2020 comprehensive update to the Miami-Dade County Stormwater Master Plan.

Large-Scale Stormwater Mitigation Project in the C-7 Watershed



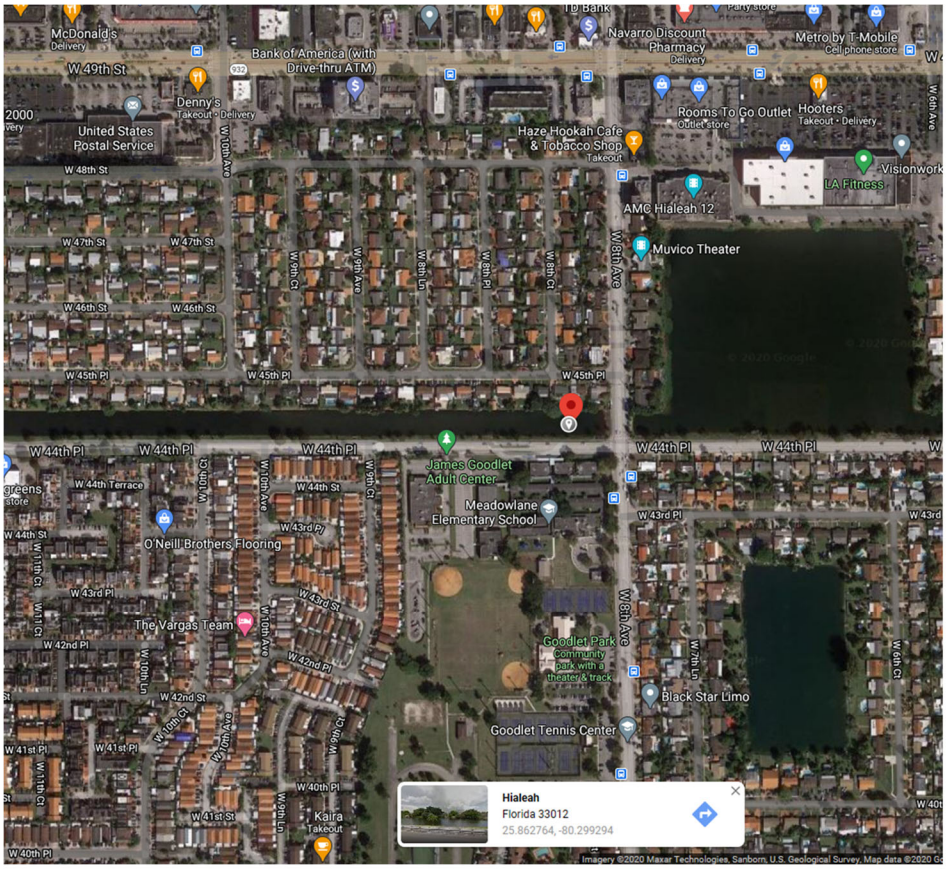
CANAL SPUR - Location Aerial View (approximate centroid coordinates)

Large-Scale Stormwater Mitigation Project in the C-7 Watershed



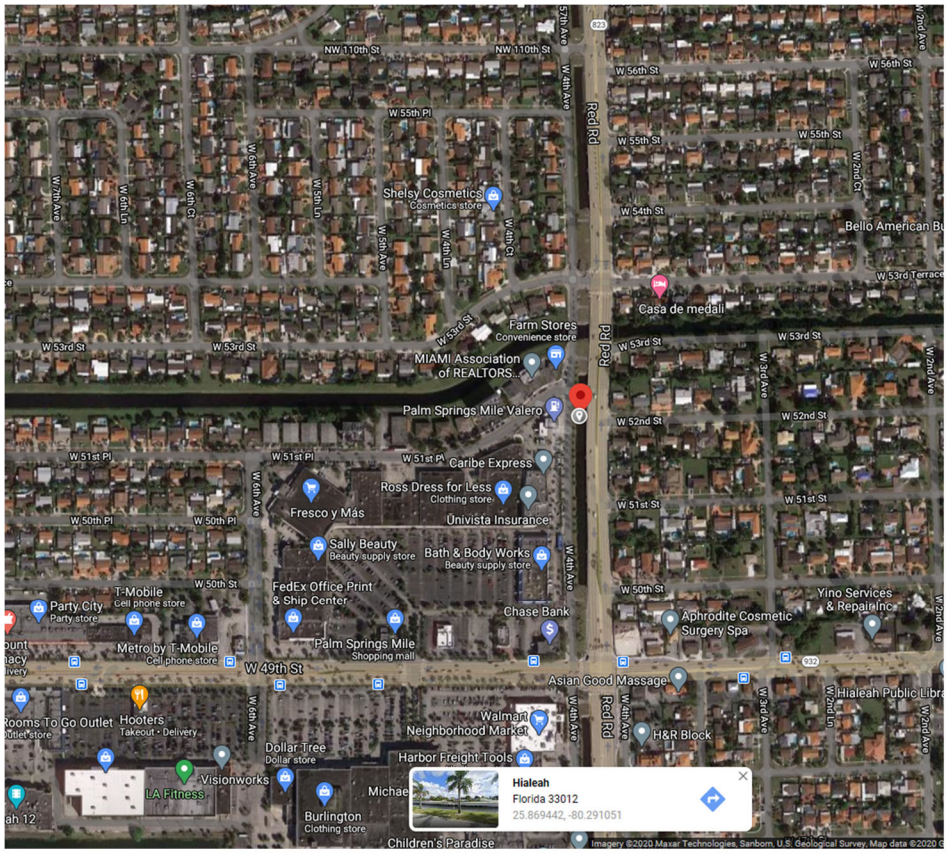
NW 127 ST CANAL - Location Aerial View (approximate centroid coordinates)

Large-Scale Stormwater Mitigation Project in the C-7 Watershed



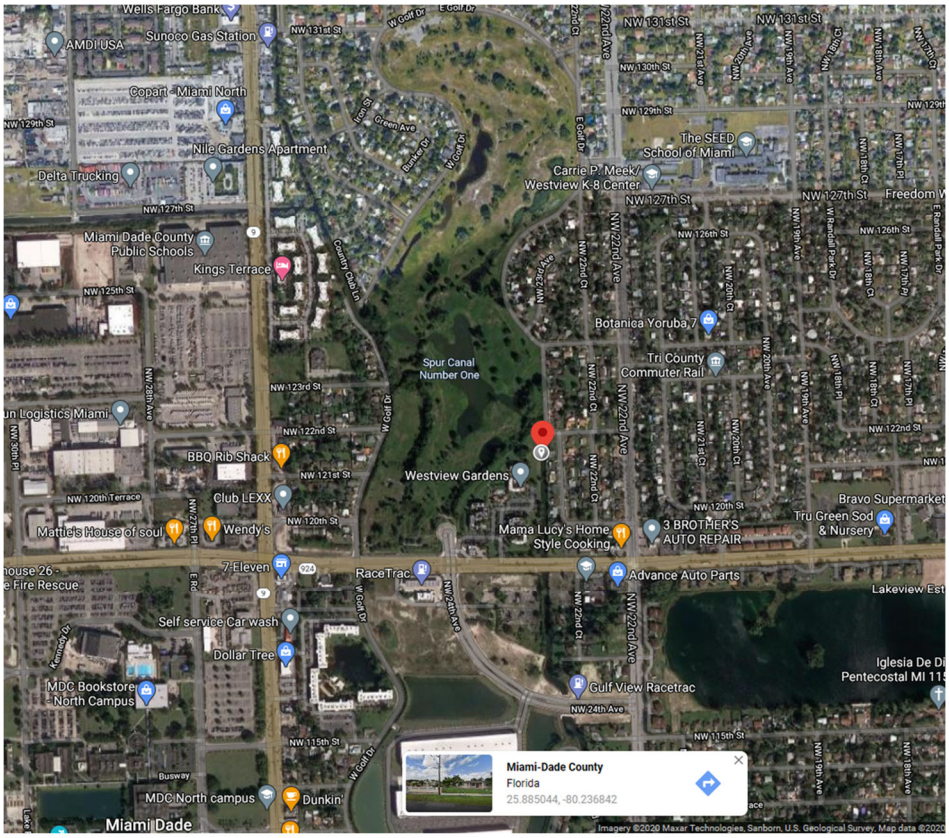
PALM SPRINGS CANAL - Location Aerial View (approximate centroid coordinates)

Large-Scale Stormwater Mitigation Project in the C-7 Watershed



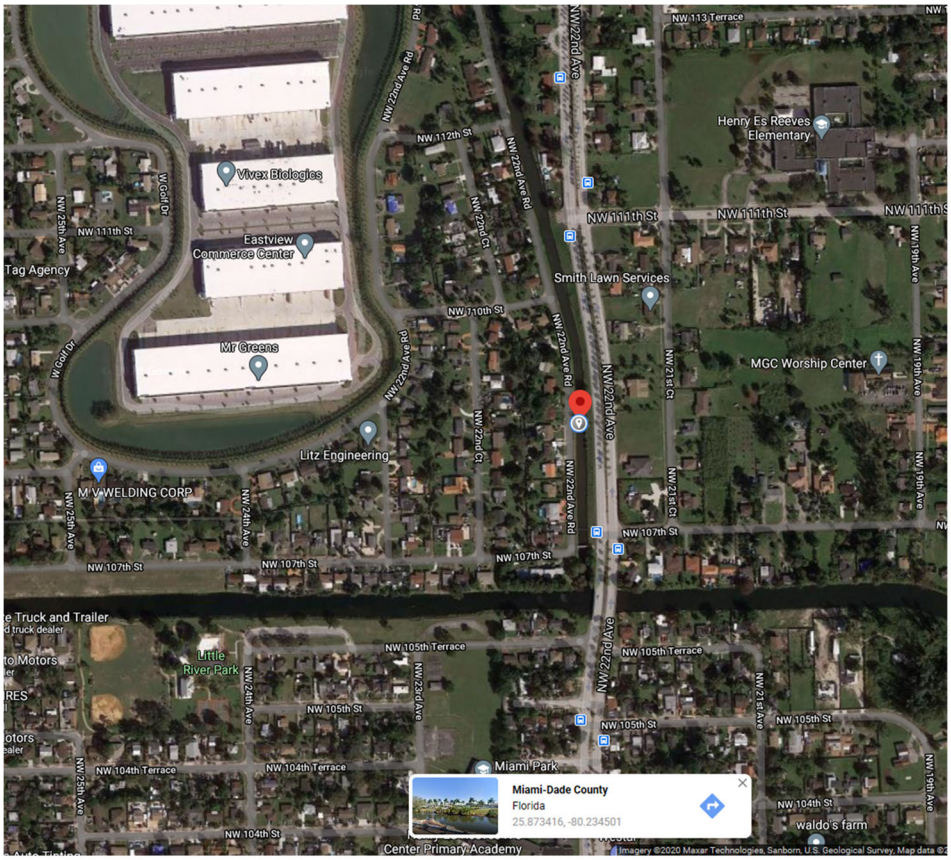
RED ROAD CANAL NW 57 AVE CANAL - Location Aerial View (approximate centroid coordinates)

Large-Scale Stormwater Mitigation Project in the C-7 Watershed



RIO VISTA CANAL - Location Aerial View (approximate centroid coordinates)

Large-Scale Stormwater Mitigation Project in the C-7 Watershed



SPUR CANAL No1 - Location Aerial View (approximate centroid coordinates)

Large-Scale Stormwater Mitigation Project in the C-7 Watershed

Capacity Plan

The goal of the proposed mitigation project is to reduce the flooding hazards, current and future, resulting from aging infrastructure. The project will include improvements to six canals (6 miles) under Miami-Dade County control, C-7 Basin. Improvements include raising top of bank elevations (enhance storage), upgrade culverts (enhance conveyance), and improve outfalls. Future conditions in a 2060 scenario with Sea Level Rise have been used as design criteria. This project includes survey, soil testing, design, permitting, construction, and construction management.

Miami-Dade County will coordinate with stakeholders including other County departments and the South Florida Water Management District. Miami-Dade County's Project Manager will be responsible for implementing the project with assistance from other County departments/staff such as Budget, Risk Management, Finance and Procurement. The Project Manager will oversee the development and implementation of the project and will coordinate with the project team and stakeholders for the duration of the project and completion. The project team will consist of a combination of resources from Miami-Dade County, consultants, and contractors.

As the project nears completion, the Project Manager will be responsible for transferring maintenance information to the Public Works Section that handles canal maintenance. The canal maintenance activities will continue to be the responsibility of the canal maintenance crews in Public Works, just as they are responsible for the current stormwater maintenance infrastructure. The maintenance requirements and schedules will be as provided in the County's SOPs for Canal Maintenance. Canal operations is handled by the same engineering division where the Project Manager is from. After the project is accepted as complete, the operations-engineering staff from the County RER-DERM-Water Management Division will be responsible for the continued canal operations.

The work plan is to bid out these improvements that will be designed by County engineers and hire a contractor. The County will assign a project manager from internal staff and will use a team of staff and consultants to provide construction management services.

The project team will consist of:

• Contractor – The County will hire the contractor to construct the stormwater infrastructure project. The contractor in turn will hire suppliers and subcontractors to provide the construction materials, equipment, additional expertise, and labor necessary to complete the project. The contract and contractor will be managed by Miami-Dade County.

• Project Manager – The Project Manager position will be assigned to one of the County's existing engineering staff with a Professional Engineering License. The Project Manager will oversee the construction of improvements and adherence to the terms of the contract and grant agreement. Staff in the Project Manager position are typically civil engineers with at least ten years of designing and managing experience with these type of construction projects.

• Construction Inspector - The in-house staff and consulting team will provide Construction Services for this project. The Engineering Inspector will be responsible for observing and

documenting the progress of construction and adherence to the construction contract and schedule. Staff in the Engineering Inspector position typically have at least ten or more years of construction experience.

• Construction Manager - The in-house staff- consulting team will provide Construction Services for this project. The Construction Manager will assist the Project Manager by reviewing submittals, responding to contractor requests for information, evaluating contractor progress, reviewing claims, providing design adjustments as needed, advising the on accepting work products and reviewing project adherence to the grant agreement. The Construction Manager will report to the Project Manager.

• Additional County Support - The County will assign existing staff to assist the Project Manager in the implementation of this project as needed, in much the same way as it does for the many other utility construction projects the County undertakes. Under the direction of County management, the Project Manager will assign various budget, permitting, engineering, administrative, department management and accounting support as needed to complete the project as timely and efficiently as possible.

The project contractor will be hired based on the lowest responsible and responsive bid, using the County's standard public bidding process. Staff from the County will administer the bidding process, which consists of public advertisement, pre-bid meeting, posting, and answering questions from prospective bidders, review of bids, assignment of points to minority, women owned and disadvantaged businesses as well as local businesses as required by County regulations, requesting County approval to award the contract and contract execution. The County's bids are posted on-line and are viewable by anyone at no expense.

The Project Manager works very closely with Procurement staff during this process. The County has considerable experience with successful completion of state and federal grant funded projects and requirements such as the Davis Bacon Act. The County has a robustly staffed Water Management Engineering Division and can easily handle the workload resulting from award of this grant. Aside from the external construction manager, and other consulting resources as needed for design and construction management and inspections, the County does not plan to hire new staff for this project.

General Infrastructure Program Implementation Plan Timeline

Entity:	Miami-Dade County
Primary Contact:	Marina Blanco-Pape P.E.
Date:	Thursday, September 2, 2021

Public Notice Dates:

Start Date:	9/2/2021
End Date:	9/16/2021

Milestones and Tasks

Activity	Start	End	Duration	Label
Project Start (Milestone 1)				
Task 1	09/01	08/31	364	Survey, Soik Investigation, Design
Task 2	08/31	12/31	122	Permitting
Construction (Milestone 2)				
Task 1	01/01	04/30	120	Bid & Award
Task 2	05/01	12/31	974	Construction

Close Out (Milestone 3)				
Task 1	01/01	06/30	180	Poject Closeout

General Infrastructure Program Project Budget Template Instructions

This template is customizable to fit the budget proposal for your project. Feel free to edit left-hand segments and add notes when needed.

If a section does not have enough cells for the category that you are working on, you can add cells by highlighting a complete row and right-clicking. A dialogue box will appear that permits you to add a row of cells. Click “Insert” and then select either “Insert Above” or “Insert Below”, depending on where you would like the new row to be placed. The new row will appear above or below the row you highlighted.

Enter project name, primary contact name and phone number and the official applicant entity name.

1. On the left-hand side of the template there is a list of major project items numbered 1 to 3. Beneath each major project are related sub-groups. You may edit each of these areas to fit your proposed budget plan. For example, if you do not have Mechanical Hardening, you may delete that numbered row and the related subgroups.
2. List anticipated and committed sources of other project funding sources in the “Sources of Other Funds” category. These funds are non-CDBG-MIT funds. Include entities you have contacted, even if a funding commitment has not yet been made. Disclose the amount you requested or expect to receive. If you need to add rows in this section, follow the directions for adding rows outlined above.
3. You can use the right-side Justifications column to elaborate on budgeted items as needed.

FL CDBG Mitigation

General Infrastructure Program Project Budget (Template)

Project Name:	Large-Scale Stormwater Mitigation Project in the C-7 Watershed	Primary Contact Name and Phone Number:	Marina Blanco-Pape, P.E.	Official Applicant Entity Name:	Miami-Dade County

Project	**Budget**				**Justifications**
Description	CDBG-MIT Amount	Other non CDBG-MIT Funds	Source of Funds*	Total Funds (CDBG-MIT and Other)	
Design/Survey/Soil Investigation	$350,000	$350,000	County Stormwater Utility Fees	$700,000	Engineering in-house staff and consultants
Permitting	$25,000	$25,000	County Stormwater Utility Fees	$50,000	Engineering in-house staff
Bid & Award	$25,000	$25,000	County Stormwater Utility Fees	$50,000	Engineering in-house staff and consultants
Construction	$5,980,000	$5,980,000	County Stormwater Utility Fees	$11,960,000	Contract award to contractor
Construction Management/Inspections	$600,000	$600,000	County Stormwater Utility Fees	$1,200,000	Engineering in-house staff and consultants
Project Closure	$20,000	$20,000	County Stormwater Utility Fees	$40,000	Engineering in-house staff and consultants
Other					
Totals:	$7,000,000	$7,000,000		14,000,000	

Percentage Amounts:	50%	50%		100%	

*** All funds identified for use on your project must be fully disclosed and detailed to ensure budget accuracy and no duplication of benefits. Show the sources and amounts of other funds needed to complete the project below, including local funds and grants from other agencies. Any anticipated or committed funds must also be included.**

Source of Other Funds	Amount
1. Miami-Dade County Stormwater Utility Fees collected annually by the County's Stormwater Utility. Annual Stormwater Budget approved by the Board of County Commissioners.	$7,000,000
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

English

What percentage of the total project funding will Leveraged Dollars cover?

	0-5%	6-20%	21-35%	41-50%	51-65%	66-100%
Percentage covered by Leveraged Dollars	○	○	○	●	○	○

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English

Select each county that your project benefits. DEO will use this information to assess Most Impacted and Distressed (MID) areas, social vulnerability, rural and fiscally-constrained areas. Only counties eligible for CDBG-MIT funds are listed below.

☐ Alachua	☐ Dixie	☐ Indian River	☐ Monroe	☐ Sarasota
☐ Baker	☐ Duval	☐ Lafayette	☐ Nassau	☐ Seminole
☐ Bradford	☐ Flagler	☐ Lake	☐ Okeechobee	☐ St. Johns
☐ Brevard	☐ Gilchrist	☐ Lee	☐ Orange	☐ St. Lucie
☐ Broward	☐ Glades	☐ Leon	☐ Osceola	☐ Sumter
☐ Charlotte	☐ Hardee	☐ Levy	☐ Palm Beach	☐ Suwannee
☐ Citrus	☐ Hendry	☐ Manatee	☐ Pasco	☐ Taylor
☐ Clay	☐ Hernando	☐ Marion	☐ Pinellas	☐ Union
☐ Collier	☐ Highlands	☐ Martin	☐ Polk	☐ Volusia
☐ Columbia	☐ Hillsborough	☑ **Miami-Dade**	☐ Putnam	☐ Wakulla

DeSoto

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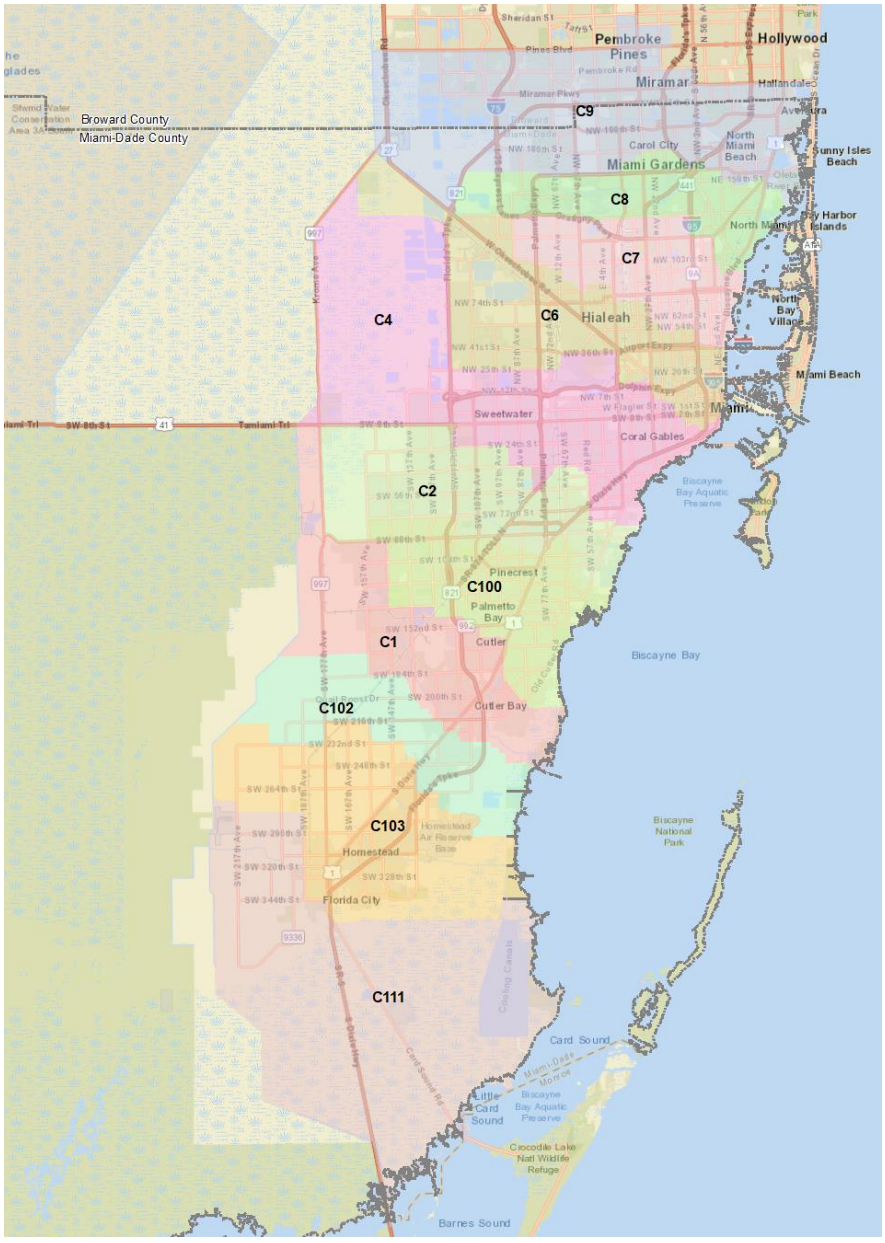
Stormwater Management Program Master Plan Update (FY2021)



Department of Regulatory and Economic Resources
Division of Environmental Resources Management
Water Management Division

Miami-Dade County FY2021
Stormwater Management Program Update

Department of Regulatory and Economic Resources
Division of Environmental Resources Management
Water Management Division
4/15/2021

Prepared for:

Department of Regulatory and Economic Resources
Division of Environmental Resources Management
Water Management Division
701 NW 1st Court, 5th Floor
Miami, FL 33136-3912

Prepared by:

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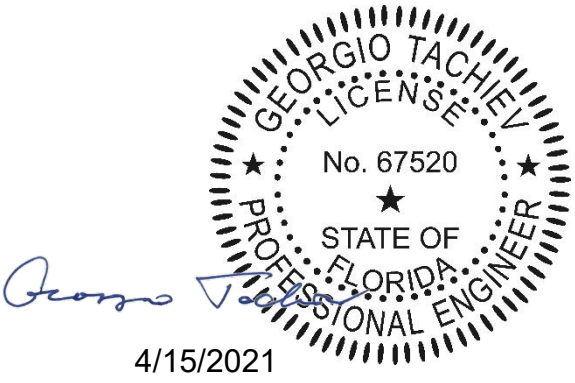
Miami, FL 33146

Prepared in association with individuals from:

CDM Smith, Inc., RER DERM Water Management Division, A.D.A. Engineering Inc., Atkins North America, Inc., SSN Engineering LLC, and Amec Foster Wheeler Environmental & infrastructure, Inc.



4/15/2021

_____
Georgio Tachiev, PE, PHD
FL Professional Engineer #67520
4/15/2021

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APPENDICES

DISCLAIMER

While the information contained within this Stormwater Master Plan Update should be substantially correct, the County does not warrant or guarantee that any of the information stated in this report or depicted on the facilities maps is final and complete. The information contained in the existing facilities maps is based on the current data collection including, field observations, field measurements, and as-built drawings. Anyone interested in determining the actual facilities located within any part of the County should perform their own survey and make an independent determination as to the actual facilities including, but not limited to, culverts, culvert sizes, culvert materials, invert elevations, existing topography, lakes, lake locations, mitigation areas, canal locations and the nomenclature used to identify or describe any of these facilities.

Notwithstanding the contents of the Stormwater Master Plan Update, the County does not and cannot guarantee that there will not be damage or flooding to property or injuries to persons within the watershed as a result of unforeseen events which are beyond the control of the County, including but not limited to, Acts of God, excessive rainfall, landslides or sinkholes, floods, washouts, tidal wave, storm surge, wind storm, hurricane, sea level rise, climate change, or other casualty, disaster or catastrophe; unforeseeable failure or breakdown of pumping facilities; any and all governmental rules, acts or orders, restrictions, regulations, requirements, acts or actions of any governmental authority, commission, board, agency, agent, official or officer, the enactment of any statute, ordinance, resolution, regulation, rule, ruling, order, decree, judgment, restraining order or injunction of any court, or by any other causes, whether or not of the same kind as enumerated herein, not within the sole control of the County and which by exercise of due diligence the County is unable to overcome. This disclaimer shall include other causes beyond the control of the County, whether or not specifically enumerated herein.

EXECUTIVE SUMMARY

The Stormwater Management Program (SWMP) Master Plan update provides the most current representation of the behavior of the interconnected stormwater management system for existing and future hydrologic and hydraulic conditions for Miami-Dade County. The Master Plan provides details of the numerical modeling used to evaluate the impact of sea level rise and climate change, addresses the protection of natural channels, and provides a basis for developing an estimate for dedicated funding sources for implementing SWMP strategies. SWMP Master Plan updates provide analyses that can be used as the basis for conceptual designs to improve water quality, provide aquifer recharge, facilitate infrastructure operations and maintenance, implement capital improvements to stormwater infrastructure, and implement green infrastructure strategies. For this FY 2021 update, existing watershed numerical models were revised to address changes to hydrologic and hydraulic conditions based on the most current available data.

The Miami-Dade County SWMP includes the infrastructure designed and constructed to control discharges from rainfall events. It incorporates methods to collect, convey, store, absorb, inhibit, treat, use, or reuse water for flooding prevention or reduction, to prevent excessive drainage of environmentally sensitive lands, and to restrict environmental degradation and water pollution that would affect the quantity and quality of discharges from the system. The SWMP provides guidance to ensure compliance with Municipal, State and Federal Regulations. In addition, this document evaluates flooding and water quality concerns, and addresses operations and maintenance, climate change adaptation, regulations, and funding for these activities. The Miami-Dade SWMP is implemented using the following elements:

- Watershed Numerical Modeling
- Water Control Maps (WCM)
- County Flood Criteria Map (CFC)
- Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs)
- Capital Improvement Plan (CIP)
- Inspection, Operations and Maintenance Plan (IOM)

The main tool utilized for decision making within the SWMP is the set of integrated hydraulic and hydrologic numerical watershed models that provide a detailed analysis of the simulated performance of stormwater infrastructure, current and future, with forecasts of short- and long-term sea level rise (SLR), for a broad range of design storm events and best management scenarios. The SWMP applies a comprehensive approach for the analysis of the County's stormwater system performance and climate adaptation by evaluating water levels, flow patterns, and water quality. This is the basis for identifying system deficiencies and areas needing capital improvements, updating system operations and maintenance, facilitating agency coordination, developing regulations, and proposing funding for future projects. The SWMP Master Plan is updated as needed, with a minimum cycle of five years.

Miami-Dade County's watershed numerical models are an essential framework for identifying and solving drainage related water quantity and water quality hazards. The calculated surface water stages and discharge volumes for a suite of design events and intensities are critical tools to establish the design criteria for managing stormwater, and for meeting or exceeding Federal, State, and Local regulations. This

Master Plan serves to document the modeling input and results within each watershed of the Miami-Dade County stormwater conveyance system. The results include:

- Identification of the existing stormwater conveyance system's water quantity and water quality levels of service (LOS). The objective of an established stormwater system LOS is generally to reduce flood risk and to improve or maintain water quality. The stormwater LOS standards for Miami-Dade County's SWMP contains both flood protection and water quality components.
- Identification of the future system's LOS both with and without control measures.
- Estimation of the impact of current SLR projections on the infrastructure capacity and performance.
- Identification of infrastructure deficiencies and conceptual development of short-term and long-term planning strategies and capital improvements for adaptation to potential climate and regional water management operational changes.
- Update to the Miami-Dade County Flood Insurance Study Reports and FEMA FIRMs; and
- Update of the Water Control Map and the County Flood Criteria.

For more than 25 years, Miami-Dade County has developed and provided continuous updates of the SWMP. Since the initial numerical hydraulic and hydrologic stormwater modeling in 1993, the SWMP underwent minor modifications with substantial improvements completed in 2005 and 2009. The improvements incorporated completed mitigation and redevelopment projects that have mitigated historical surface water drainage challenges, and addressed hydraulic, hydrologic, and regulatory changes within the county. The SWMP Master Plan provides the basis for identifying sustainable stormwater management solutions to continuously improve and mitigate damage for the protection of lives, property, and public infrastructure from flooding, and evaluating performance and capacity of planned infrastructure and capital improvements.

This SWMP Master Plan documents the most recent improvements to the SWMP using numerical watershed model updates completed in 2020 that can be used to comprehensively review and evaluate the performance of the stormwater system and existing infrastructure owned and operated by Miami-Dade County.

All updates are consistent with Florida Statute 403.0891, the requirements set forth in Chapters 62-40 and 62-43 of the Florida Administrative Code (FAC) , U.S. Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) requirements, South Florida Water Management District (SFWMD) rules, Chapter 24 of the Miami-Dade County code, and the Miami-Dade County Comprehensive Development Master Plan (CDMP) prepared pursuant to the requirements of Chapter 163 Florida Statutes. Additional objectives of the Stormwater Master Plan include mitigating impacts of discharges (both in quantity and quality) to the Biscayne Bay, which is designated as a State Aquatic Preserve and regulated according to the Florida Statute 258.397 and Chapter 24 of the Miami-Dade County Code.

Stormwater Master Plan Update (FY2021)

This SWMP Master Plan update documents development of 11 numerical watershed models completed in 2020, which implemented datum conversion from National Geodetic Vertical Datum of 1929 (NGVD 29) to North American Vertical Datum of 1988 (NAVD 88); 2015 and 2018 laser imaging, detection, and ranging (LiDAR) topographic data; 2014 and 2030 land use coverages; 2018 and 2040 groundwater levels;

2014 precipitation data; 2020, 2060, 2080, and 2100 SLR projections; stormwater infrastructure and soil classification updates; and, watershed delineation and infiltration parameters revisions.

The watershed models cover approximately 780 square miles of inland and coastal land surface area within and adjacent to Miami-Dade County and incorporates the hydrologic and hydraulic factors impacting the urban areas of Miami-Dade County. The watershed numerical models have analyzed the most current and forecasted data available for population growth, topography, SLR scenarios, land use, groundwater levels, and rainfall volume and intensity. An outline of the watershed areas is shown in Figure ES-1. The western boundary of the model watersheds is defined by the L-30, L-31N, and C-111 primary canals.

The impacts of increased urbanization on factors effecting stormwater runoff and infiltration have been captured in the 2020 numerical models. The distribution of vacant land areas within the County watersheds is shown on Table ES-1. A substantial portion of the 184 square miles of vacant area is located near the L-30, L-31N, and C-111 Primary canals. Within the modeled domain of the various watersheds that extend beyond Miami-Dade County, the average vacant land is 24% and varies from 5-9% for highly urbanized areas (watershed C-7, C-9, C-100), 12-16% for medium degree of urbanization (C-2, C-6, C-8), and 26-44% for low urbanization (C-1, C-4, C-102, C-103, and C-111). Most of the eastern C-4 and C-6 Watersheds are also highly urbanized, resulting in increased stormwater runoff.

Table ES-1. Distribution of Vacant Land Areas within County Watersheds

Watershed	Total Area (square miles)	Vacant Areas (square miles)	Fraction Vacant
C-1	59.67	15.63	26%
C-111	150.59	66.35	44%
C-2	55.57	8.64	16%
C-4 (includes original C-3 and C-5)	110.47	30.32	27%
C-6	63.57	7.43	12%
C-7	36.07	1.85	5%
C-8	36.84	4.94	13%
C-9	104.52	8.04	8%
C-100	46.32	2.28	5%
C-102	42.53	14.97	35%
C-103	76.16	23.87	31%
Total	**782.31**	**184.33**	**24%**

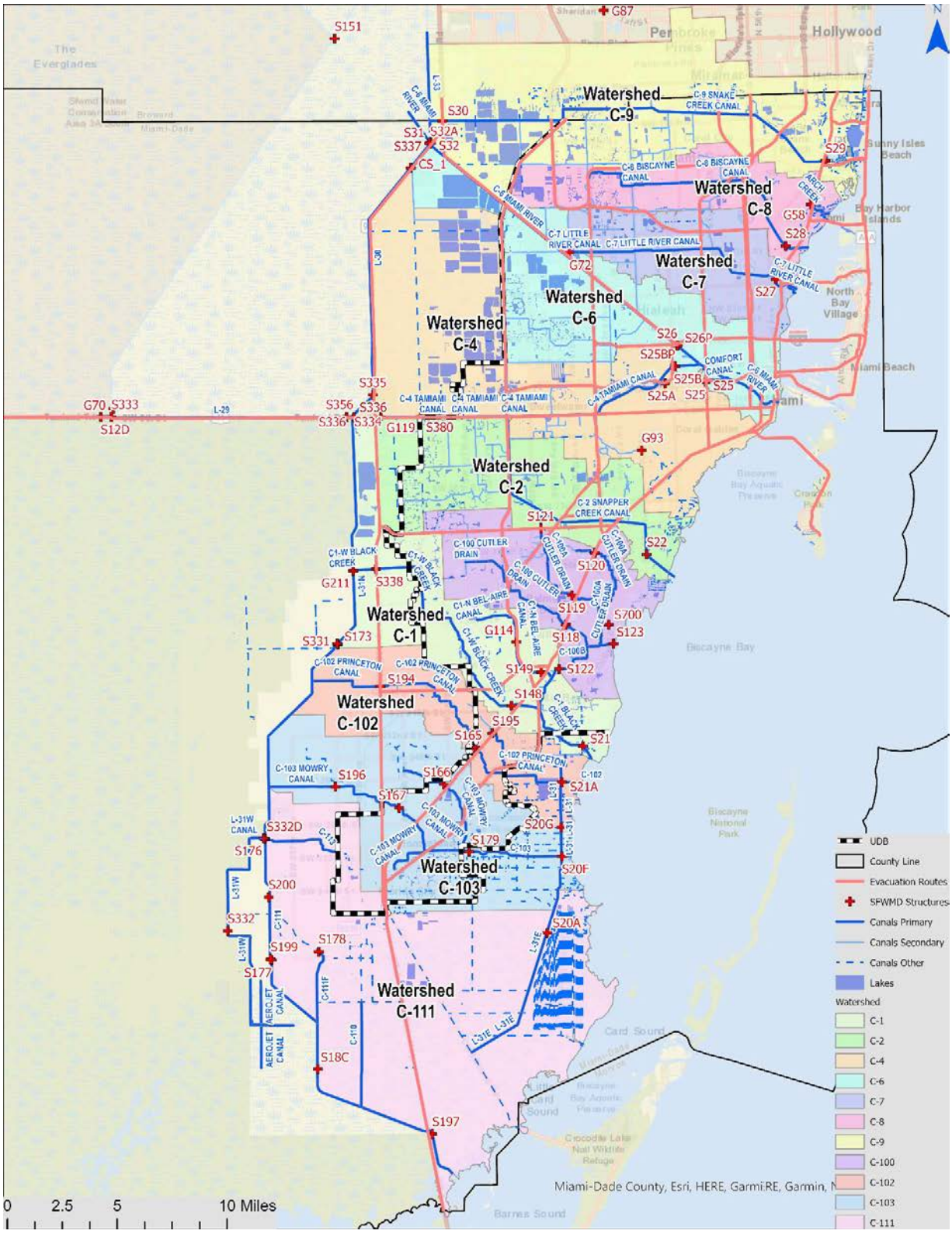


Figure ES-1. Outline of the SWMP Watersheds

Integrated Hydrologic and Hydraulic Modeling: The development of the watershed numerical models was performed with Innovyze's XPSWMM Hydrologic and Hydraulic modeling software, version 2020.1. The modeling follows the methodology adopted by the SWMP and is consistent with the latest Risk Map practices recommended by FEMA. XPSWMM utilizes similar algorithms implemented within the EPA Stormwater Management Model. XPSWMM is accepted by FEMA and has been historically used for FEMA Flood Hazard modeling. The hydrology and hydraulics are modeled simultaneously in XPSWMM, as opposed to separately in other modeling platforms.

XPSWMM is a hydrodynamic model, providing coupled analyses of the processes of rainfall, infiltration, runoff, overland flow, watershed storage, canal and pipe flows during storm conditions, and the influence of tidal and groundwater levels at the model boundaries. This modeling software includes 1D calculations for upstream to downstream flow to represent the behavior of the stormwater system, sewer system, or floodplain based on water flows. XPSWMM also allows integrated analyses of flow, pollutant transport and sustainable design measures (Low Impact Development and Green Infrastructure) in engineered and natural systems including ponds, rivers, lakes, overland floodplains and aquifers.

Watershed Hydrology

Watershed Delineation: The watershed numerical model update provides a refinement of sub-watershed delineation to address current and future conditions. The contributing areas to the Primary Water Conveyance System (managed by SFWMD) and the Secondary drainage systems (managed by Miami-Dade County) were subdivided into more than 3,500 sub-watersheds. The delineation process was performed according to the procedures established in the Stormwater Master Plan developed by CH_2MHill in 1993 and includes: the most current topography (based on LiDAR data collected in 2015), revised roadway crown elevations based on surveys and FDOT projects, the location and extent of stormwater infrastructure facilities which provide storage and conveyance, the location of additional stormwater components including culverts, backflow preventers, drainage wells, cross drains or other components that can affect the flows and distribution of stormwater, the review of flood maps, and iterative revisions or refinements of model components to improve the representation of the stormwater system and sub-watershed hydrology. Addition of nodes or renaming of nodes took place along the boundary lines and within each watershed to improve representation of exchange between adjacent watersheds, and to be able to join watershed models as needed. A summary of sub-watershed delineation parameters is included in Table ES-2. Sub-watersheds larger than 640 acres are prevalent in the undeveloped areas of the model, west of the 2020 UDB and along the Biscayne Bay shoreline.

The runoff generated from each sub-watershed is calculated from rainfall, infiltration, groundwater, evapotranspiration, and other model parameters reflecting the hydraulics and hydrology of the sub-watershed. Primary model parameters related to the sub-watershed include area, slope, width, length, infiltration capacity, and directly connected impervious area.

The topography for all watersheds was derived from the Digital Elevation Model (DEM) containing georeferenced digital representation of the ground surface elevations providing the vertical position above NAVD 88 in feet, with horizontal resolution of a 5-foot square grid cell. The DEM dataset was provided by the Miami-Dade County Information Technology Department in 2017 and is based on classified LiDAR Data from 2015. The DEM represents a 5-foot bare-earth surface and does not include vegetative and building features. Estimates of water edges at the time of data collection, were performed

using orthophotography. The DEM was used to develop sub-watershed stage-storage relationships, to adjust the sub-watershed boundaries, to develop overland flow parameters, and to modify other vertical geometric parameters of the area.

Table ES-2. Summary of Sub-watershed Delineation Parameters

Basin	Total Watershed Area, Acre	Number of Sub-watersheds	Avg. Acre Sub-watershed	Min. Sub-watershed, Acre	Max Sub-watershed, Acre
C-1	38,179	184	207	1.39	2,368
C-2	35,562	385	92	0.14	868
C-4*	70,700	517	137	0.26	2,200
C-6	40,686	392	104	0.27	1,778
C-7	23,083	198	117	3.67	724
C-8	23,578	335	72	0.32	699
C-9	66,925	359	199	1.06	7,820
C-100	29,647	446	66	3.82	839
C-102	27,217	334	81	0.53	824
C-103	48,746	282	173	0.39	1,565
C-111	96,378	156	618	7.07	12,853
Total	500,701	3588	157	0.14	12,853
*Watershed C-4 includes areas previously outlined as Watersheds C-3 and C-5					

Stage-Storage Relationship: The stage-storage relationship for each sub-watershed was developed using the combined 2015 and 2018 DEM with raster resolution of 5 feet, and stages from 0 to 20 feet NAVD 88 in 0.25-foot increments. All storage areas, including natural low-lying areas, lakes, and water bodies which are not part of the canal cross sections, are represented at nodes by using the storage option and specifying a stage-storage curve. The stage-storage relationships were determined by excluding the footprint of the large buildings.

Land Cover and Imperviousness: Watershed imperviousness was estimated by analysis of Land Use information obtained for 2014 (approximates existing conditions) and 2030 (future conditions) from Miami-Dade County's Planning Department. The typical total impervious areas and DCIA were estimated by land use categories such as commercial, medium density residential, or light industrial. Additionally, imperviousness values obtained from United States Geological Society (USGS) based on remote sensing data from the most recent National Land Cover Database were used to review and refine imperviousness values.

Soils Information: The soil category types within the watershed were determined from the United States Department of Agriculture Natural Resources Conservation Service's (NRCS) Soil Survey. Soil classification is based on Hydrologic Soil Groups. For a large portion of the County, the NRCS provides a classification of "U" for urban land. As a result of urbanization, the underlying soil may be disturbed or covered by a new layer. In this case, the type D classification (poorly drained soil) is substituted for the Type U as the

dominant soil classification. Soils types with dual classifications (e.g., Type B/D) generally represent areas where there is a lens of poorly drained soils lying above a section of better draining soils. Typically, the lower (Type-D) classification is used in the model, unless the soil is disturbed, such as a field of row crops where it is likely the upper lens has been penetrated.

Infiltration: Infiltration from pervious areas was determined using the Curve Number (CN) methodology described in Urban Hydrology for Small Watersheds TR-55. The CN is a dimensionless number which depends on the predominant hydrologic soil group, cover type, treatment, hydrological condition, and antecedent moisture conditions. In XPSWMM, the CN value is assigned only to the pervious area. Delineating the pervious and impervious areas within each catchment allows infiltration to be restricted to the pervious areas. An area weighted composite number is generated by XPSWMM using the assigned CN for the pervious area and 98 for the impervious area. The XPSWMM input for impervious area is restricted to the directly connected areas, while the remaining area within a sub-watershed is a combination of the actual pervious area and the non-directly connected impervious area. Since there should be no infiltration under the NDCIA surface, a correction is applied to estimate a composite number for just the pervious surface.

Groundwater: Groundwater elevations are an initial boundary condition for the watershed models. The County watersheds predominantly have a flat topographical relief and are highly urbanized areas drained by a network of canals. Typical South Florida hydrogeology is represented with a high groundwater table that is characteristic of the unconfined and highly transmissive Biscayne Aquifer. The canal systems intercept the shallow groundwater table, which provides most of the base flow. The intersection of the canals with the groundwater table assures that a portion of the baseflow is contributed to by seepage from the surrounding landscape. The groundwater elevations were developed by interpolating groundwater well data within the County. Groundwater in Miami-Dade County is at a seasonal high in the month of October, which is used in the watershed models to simulate the most stress on surface-water control infrastructure. The initial groundwater boundary condition used in the models was based on averaging the daily values for October 2018. Results from the groundwater model provided by the Miami-Dade County Water and Sewer Department and the USGS simulations of the seasonally high groundwater elevation for the year 2040 were used to estimate future groundwater elevations.

Green Infrastructure and Low Impact Development: The purpose of Green Infrastructure and LID is to reduce and/or eliminate the altered areas of the post-development hydrograph, by reducing the peak discharge rate, volume, and duration of flow through the use of site design and stormwater quality control measures. The benefits of diminished stormwater runoff volume include reduced pollutant loadings and increased groundwater recharge and evapotranspiration rates. This update takes into consideration implementing the principles of Green Infrastructure on block, neighborhood, and parcel scales. The main Green Infrastructure and LID strategies evaluated include use of bioretention/infiltration landscape areas, disconnected hydrologic flow paths, reduced impervious areas, functional landscaping, and grading to maintain natural hydrologic functions that existed prior to development, such as interception, shallow surface storage, infiltration, evapotranspiration, and groundwater recharge.

Watershed Hydraulics

The hydraulic model in XPSWMM provides calculation of the hydrodynamics of flow between nodes and determines the stages for each design event. The Primary Water Conveyance System (managed by

SFWMD) and the Secondary drainage systems (managed by Miami-Dade County) are modeled using the hydraulics block of the model. The hydraulics block uses nodes and links to define the hydraulic network.

Model Nodes and Links: Model nodes are placed at inlets, manholes, the ends of pipes and culverts, at locations where the canal cross-section changes, and locations representing low areas of sub-watersheds where pipes are not explicitly modeled. Model links may represent channels (canals, streams, ditches, etc.), bridges, culverts, pipes, weirs, orifices, pumps, rating curves (seepage), gated structures, and overland flow links. Each canal reach is represented in the hydraulic model by cross-section data obtained from completed surveys. The Primary conveyance system in the watersheds covers more than 280 miles.

Stormwater infrastructure: The stormwater infrastructure implemented in the models includes components operated by SFWMD and Miami Dade County such as pumps, weirs, orifices, culverts, and bridges, and is represented by separate links for each infrastructure component. Culvert inventory included length, material, diameter, invert elevations, and headwall information. Infrastructure mapping information is maintained by the Miami-Dade County Department of Regulatory and Economic Resources – Division of Environmental Resources Management – Water Management Division.

Hydrologic records: SFWMD maintains records of gate operations, headwater elevations, and tailwater elevations at each structure for various time intervals through a Web accessible database, known as DBHYDRO. The DBHYDRO data are subject to extensive Quality Assurance and Quality Control (QA/QC) procedures and integrates data acquired from NOAA, USGS, National Park Service, and other agencies.

Model Calibration and Validation. Data from DBHYDRO were used for model boundary conditions and for model calibration and validation targets. Validation of the simulated design events was determined using USGS methodology for watershed discharges and Log Pearson III analysis for extreme events.

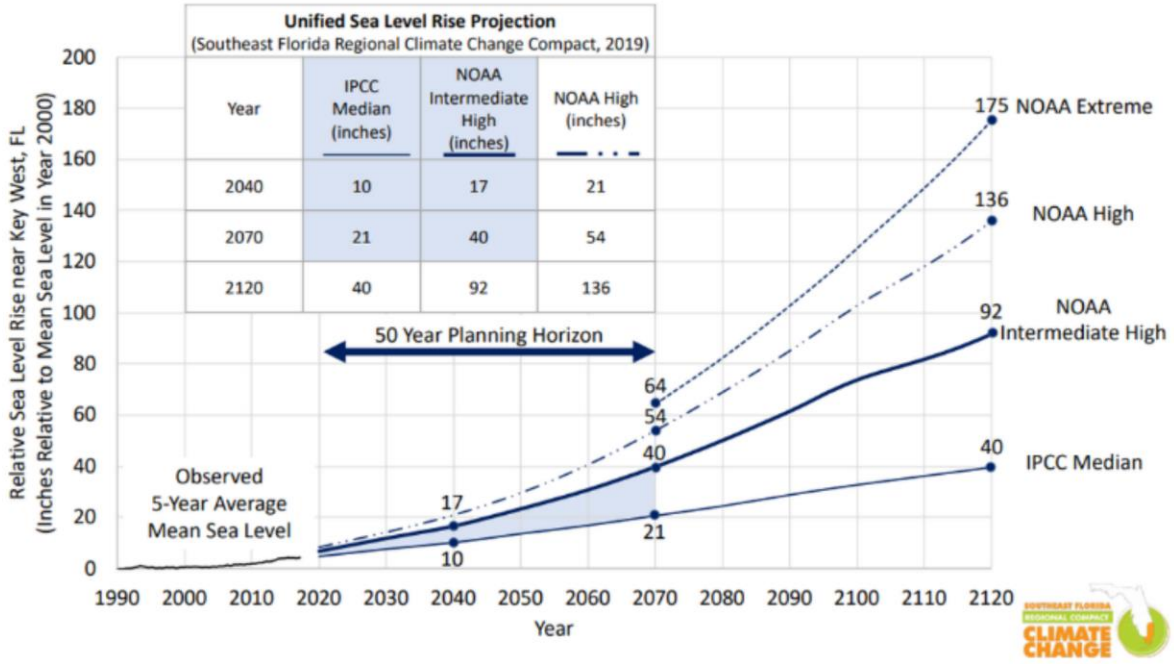
Design Events for Current and Future Conditions

Design Events for Current Hydrologic Conditions: Rainfall hyetographs for the design events are based on NOAA's rainfall atlas from 2014 for rainfall volumes per storm, and the SFWMD 24-hour and 72-hour rainfall distributions. The design events use the calibrated and verified models and the stages and flows that occur for various storm events, under both existing and future land use conditions. The predicted stages (magnitude and duration) indicate the flood LOS and the predicted flow volumes provide an assessment of the capacity of the stormwater system. The results of these production runs are referred to as "baseline" conditions. Standard hydrologic and hydraulic methods were used to determine the flood hazard data required for this study. Flood events of a magnitude that are expected to be equaled or exceeded at least once on average during any 10-, 25-, 50-, 100-, or 500-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 10-, 25-, 50-, 100-, and 500-year floods, have a 10%, 4%, 2%, 1%, and 0.2% annual chance, respectively, of being equaled or exceeded during any year.

Design Events for Future Hydrologic Conditions: Future land use has not been projected past 2030 and future groundwater levels have not been projected past 2040, therefore; for all future conditions, the 2030 future land use and 2040 projected future ground water were used. To address potential climate change conditions, one existing (2020) and four future scenarios were modeled:

1. **Year 2040** with outfall boundary conditions relevant to projected SLR in 2040 (tidal conditions for 2020 +0.5 ft of SLR), future land use (2030) and projected future ground water (2040).
2. **Year 2060** with outfall boundary conditions relevant to projected SLR in 2060 (tidal conditions for 2020 +2.0 ft of SLR), future land use (2030) and projected future ground water (2040).
3. **Year 2080** with outfall boundary conditions relevant to projected SLR in 2080 (tidal conditions for 2020 +4.0 ft of SLR), future land use (2030) and projected future ground water (2040).
4. **Year 2100** with outfall boundary conditions relevant to projected SLR in 2100 (tidal conditions for 2020 +6.0 ft of SLR), future land use (2030) and projected future ground water (2040).

The Unified SLR Projections from the Southeast Florida Regional Climate Change Compact from 2015 and subsequent revision in 2019 (see Figure ES-2) were utilized for the future SLR scenarios. The tidal elevation current scenario used was the observed median sea level for the current NOAA epoch (ending in 2001), adjusted by adding the first harmonic constituent obtained from the Virginia Key NOAA tidal station. Using the increments from the Compact projections shown in Figure ES-2, the NOAA Intermediate High curve, was selected as a conservative approach for 2060, 2080, and 2100 SLR estimates.



Scientists with the Southeast Florida Regional Climate Change Compact updated 2015 sea level rise predictions for 2019. These projections guide development in the counties. *SOUTHEAST FLORIDA REGIONAL CLIMATE CHANGE COMPACT*

Figure ES-2. 2019 Unified Sea Level Rise Projections

The outfall conditions to the Biscayne Bay were developed for water elevations shown in Table ES-3 and reflecting potential SLR using NOAA's intermediate high rate, which is slightly greater than the U.S. Army Corps of Engineers (USACE) high rate of SLR.

For each of the five scenarios (2020, 2040, 2060, 2080, 2100), ten simulations were used to develop flood maps for 24-HR storms with recurrence intervals of 5-, 10- and 25-years and for 72-hour storms with recurrence intervals of 5-, 10-, 25-, 50-, 100-, 500- and 1000- years.

Table ES-3 Projected Water Elevations SLR Scenarios (2040, 2060, 2080 and 2100) in Feet Above the Observed Median Sea Level in 2020 (estimated -0.38 ft NAVD 88)

Year	Sea Water Level increase in feet above the 2020 median	Sea Water Level Increase in inches above the 2020 median
2040	+0.5	6
2060	+2.0	24
2080	+4.0	48
2100	+6.0	72

Flood Mapping

In addition to the hydraulic and hydrologic analysis completed to determine runoff rates and drainage system performance, peak flood geospatial mapping was applied to determine the maximum flood depths. For each of the eleven watersheds, the flood depth was determined using the full hydrodynamic model which represents the relationships between rainfall, soil characteristics, topography, geometry of the sub-watersheds and canal network. The peak stages within each sub-watershed were used to develop flood maps depicting flood depths.

Evaluation of Control Measures

A series of alternative model simulations were developed in sequential manner to analyze strategies for stormwater improvements, mitigation of remaining repetitive losses, and addressing climate change potential impacts. For each alternative simulation, a new set of inundation maps were developed and compared with baseline conditions.

- **Top of canal banks** – Comparative simulations were developed assuming that the top of the canal banks follows the County criteria for conveyance and storage capacity for a 25-YR/72-HR 2060 future model with SLR for the canals. Currently some of the banks of the primary and secondary canals are below the required elevations to meet these criteria. This analysis identifies areas that will be improved by elevating the banks of the Secondary canals above the design stage in the 25-YR /72-HR 2060 future model with SLR scenario.
- **Interconnectivity Improvements** – Comparative analyses are provided to determine areas subjected to flooding which can be mitigated by providing interconnectivity of drainage areas, Secondary canals, and storage features. The interconnectivity is for model areas which are currently not connected to the rest of the stormwater system. This alternative shows the benefits of additional infrastructure to mitigate flooded areas that are disconnected.
- **Backflow for high tides** – Comparative analyses is provided to determine the effects of installing backflow preventers at selected outfalls to eliminate flooding caused by backflow in canals and at coastal areas caused by high tides.

- **Storage addition or increase** – Alternatives are developed to determine areas which can be used for dry detention, such as parks, and low-lying areas with long-term history of repetitive losses. This simulation alternative shows the effect of additional storage.
- **Exfiltration trenches and drainage wells** – The topographic areas with elevation above 4 ft NAVD 88 were analyzed to determine locations for addition of exfiltration and drainage. The alternative determines the benefits from improved drainage rates particularly during the initial period of the storms.
- **Upgrades in capacity** – Alternative simulations are developed to determine conceptual designs for conveyances that may require upgrades of capacity to provide flood mitigation.
- **Additional Pumping to storage** – Alternative simulations are provided with forced water movement to enhance area drainage that was identified as deficient in previous modeling steps.

Support of FEMA's Flood Mapping Activities

Criteria established by the SWMP have been in use for over 20 years at the planning, design, and construction levels in both private and public projects. These design criteria, derived from the watershed models, are used to determine maximum allowable discharges and changes in flood stages caused by new development, redevelopment, and infill projects. Furthermore, the results of the watershed analysis have been used as the basis for FEMA's Flood Hazard Mapping and FEMA FIRM updates, as well as for the analysis and mitigation of repetitive losses throughout the County.

Updates of County Flood Criteria

The purpose of the CFC is to provide the minimum elevations to which parcels and street centerlines shall be filled in low areas prior to building construction, and was last updated in 1982. The CFC sets the minimum finished grade elevation of developed sites, finished secondary canal banks, and roads except as subject to higher localized standards. The watershed models in the FY 2021 Master Plan were used to update CFC using the latest topographic, hydrologic, and weather data. The CFC is approved by the Board of County Commissioners and recorded in the Public Records of Miami-Dade County as a Plat Map. The CFC was revised with elevations defined by the highest of the following:

1. Miami-Dade CFC of 1982 (PB 120 PG 13-1 OF 5 of the Public Records of Miami-Dade County), which is based on a 10-YR/24-HR design event;
2. Surface water level predicted by the 2060 scenario, 10YR/24HR design event models developed in 2020, and documented in the FY 2021 Master Plan;
3. Groundwater level determined from more than 30 years (1990-2020) of daily groundwater stage observations; or,
4. Ground surface elevation based on 2015 LiDAR.

The following general requirements have been established based on analysis of the revised CFC elevations:

- A minimum seawall elevation of 6.0 feet NAVD 88 along all coastal areas and along Miami-River.
- A minimum ground surface elevation of 5.0 feet NAVD 88.

Updates of County's Water Control Map

The purpose of the WCM is to establish guidelines and requirements for designing water control facilities for land development, and to show the general locations of proposed canals, levees, dams, control structures, pump stations, drainage divides (all subject to changes dictated by new developments and Miami-Dade County Environmental Policies), and other drainage features of the Miami-Dade County Water Control System.

The WCM is approved by the Board of County Commissioners and recorded in the Public Records of Miami-Dade County as a Plat Map. The WCM outlines the Secondary conveyance system under the direct control of Miami-Dade County and includes existing and planned conveyance infrastructure. New development and improvements to existing development, where post-development conditions show stormwater related impacts beyond pre-development, must provide the required conveyance system components and/or related improvements per the WCM in effect at the time of permitting. The WCM updates incorporate new infrastructure and major improvements recommended as countermeasures from the watershed models.

The Water Control Map uses surface water levels from the 25-YR/72-HR 2060 future model scenario with SLR, for countywide storage and conveyance ratings for the Secondary Canals, except where higher regulatory requirements apply. The surface water level for this model scenario was calculated using NOAA mean sea level (http://bit.ly/NOAA_MSLnavd) at the Virginia Key Station in NAVD 88, epoch 1983-2001 for the base level, plus 2 feet for SLR to account for uncertainties in future tidal elevation forecasts.

The revised WCM requires that the elevation of secondary canal banks shall be the highest of:

1. Current Miami-Dade CFC;
2. Surface water levels from the 25YR/72HR design event with 2060 future model with SLR;
3. Elevations as dictated by the Miami-Dade County Public Works Manual, Section D4;
4. Existing topography; or,
5. Higher regulatory standards such as those required within Cut and Fill areas.

The water quantity and water quality flood protection LOS requires all Primary canals to operate per the USACE established Standard Project Flood (SPF), with an effective canal and control structure capacity based on passing the rated design flood, typically established as a percent of the SPF, with four distinct goals to: 1) maintain upstream flood design stage; 2) restrict downstream flood stages and canal flow velocities to avoid excessive erosional impacts; 3) convey sufficient discharge during low-flow periods to maintain minimum downstream stages; and 4) prevent overtopping of control structures by wave action during a storm, including tidal effects for coastal structures. Storage and conveyance ratings of Secondary canals discharging to the Primary canal system are bound by the Primary system operational rating established by the USACE/SFWMD.

Roadway drainage systems are designed to meet County and SFWMD criteria. This Master Plan provides updated 5-, 10-, and 100-YR design events that can be used in assessing whether existing roads are not flooded above the crown and where improvements are needed. Principal arterial roads including major evacuation routes should be passable during the 100-YR design event. Minor arterials (4-lane roads) are designed to be passable during the 10-YR design event. Collector and local residential streets are designed

to be passable during the 5-YR design event. Additionally, the water quality LOS requires design of storage and detention components to reduce pollution in compliance with the NPDES program requirements.

The minimum elevation of the top of the lowest building floor for new construction and substantial improvements are required to use the 100-YR/72-HR flood event and apply corresponding freeboard depending on the building category per the current Florida Building Code and FEMA FIRMs in effect. The updated flood event elevations in this Master Plan can be used to assess new construction and substantial improvements meet the Code and FEMA FIRMS.

All new developments and substantial improvements are required to meet stormwater retention and detention as required by the County and SFWMD criteria. New development and those with substantial improvements must demonstrate no impact between pre- and post-development conditions. If this requirement cannot be satisfied, hydrologic and hydraulic analysis is required to demonstrate that the downstream Secondary canal banks will not be overtopped for peak stages of 25-YR/72-HR, 2060 future model with SLR (Storage Rating), while assuring conveyance for 25-YR/72-HR, 2060 future model with SLR (Conveyance Rating), and to propose and implement the necessary conveyance system improvements to mitigate anticipated impacts. The updated peak stages and duration for the models documented in the FY 2021 Master Plan can be used for conceptual designs to demonstrate that stormwater retention and detention meet required criteria.

1 INTRODUCTION AND BACKGROUND

The Stormwater Master Plan for Miami-Dade County provides updates of analyses to reduce flooding, improve water quality, provide aquifer recharge, facilitate operation and maintenance, implement capital improvements to stormwater infrastructure, and to implement Green Infrastructure strategies. This 2021 update reports the results of revisions performed to existing watershed numerical models that incorporate the most recent hydrologic and hydraulic data.

1.1 Goals and Objectives

The overall goals of the Stormwater Master Plan Update are to review and evaluate the existing facilities owned and operated by Miami-Dade County and to identify sustainable stormwater management solutions that:

- Protect infrastructure from flooding;
- Evaluate performance and capacities of existing infrastructure;
- Protect and improve water quality;
- Provide aquifer recharge where practicable to protect and enhance existing and potential future water supplies;
- Facilitate operation and maintenance; and,
- Provide potential recommendations for improvements.

Additional goals of the updates are to:

- Revise the numerical stormwater models to reflect current hydrologic and hydraulics conditions.
- Identify the existing system's water flooding and water quality Levels of Service (LOS);
- Identify the future system's LOS with and without control measures;
- Develop a capital improvement plan of control measures in identified priority areas that do not meet the County's stormwater LOS;
- Quantify and improve flood control LOS;
- Quantify economic impact of flooding;
- Facilitate and prioritize operation and maintenance; and,
- Recommend new or retrofitting of seawalls for anticipated future sea level increases.

Specifically, the 2021 Stormwater Master Plan update includes:

- Identification of the Miami-Dade County's Stormwater Management Program (SWMP) system's water quantity and water quality LOS;
- Estimation of the impact of sea level rise (SLR) on the infrastructure capacity and performance;
- Identification of infrastructure deficiencies and development of short-term and long-term planning strategies and capital improvements for adaptation to potential climate and regional water management operational changes;
- Updates to the Miami-Dade County Flood Insurance Study Reports and Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs); and,

- Updates of the Miami-Dade County Water Control Map (WCM) and the County Flood Criteria (CFC).

1.2 Miami-Dade County Urbanization and Watersheds

Miami-Dade County is highly urbanized and most of the land inside the Urban Development Boundary (UDB) is already developed. The fraction of watershed which is considered urban area is shown on Table 1. Acreage of vacant land areas within each watershed are presented in Table 1. Note that the entirety of Watersheds C-100, C-7 and C-8 are within the UDB. Additionally, Watersheds C-3 and C-5, which have been incorporated into Watershed C-4 are entirely within the UDB.

Table 1. Fraction of Watershed Urban Areas.

Watershed	Within Urban Boundary (square miles)	Outside Urban Boundary (square miles)	Percent Urban
C-1	37.04	22.63	62%
C-2	48.01	7.56	86%
C-4	57.23	53.24	52%
C-6	56.26	7.31	88%
C-7	36.85	-	100%
C-8	36.07	-	100%
C-9	40.80	63.71	39%
C-100	46.32	-	100%
C-102	7.82	34.70	18%
C-103	31.15	45.01	41%
C-111	6.03	144.56	4%
Total	**403.58**	**378.73**	**52%**

Figure 1 shows an outline of all watersheds and conveyance systems in Miami Dade County.

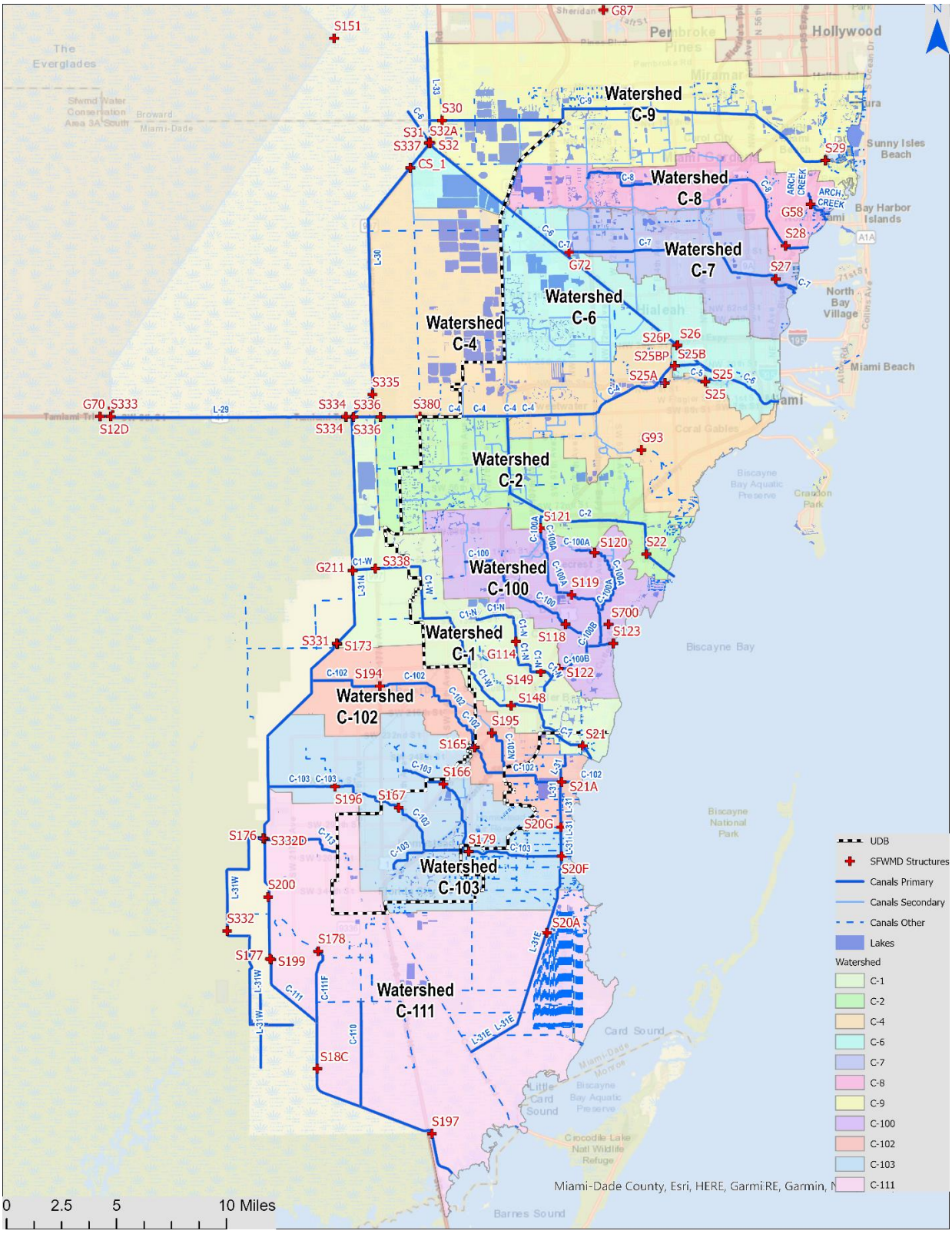


Figure 1 Watersheds and the Conveyance System within Miami-Dade County.

There are 56,734 (6.23%) vacant properties out of 910,353 properties within the entire County. Table 2 shows area and percent of vacant land for each watershed. The results are reported for the areas east of the L-30, L-31N, and C-111 Primary canals. Approximately 24 % of the land area (east of the listed Primary Canals) is vacant, however only 6% of the total count of the properties are vacant which indicates that the vacant properties are much larger in size than the non-vacant.

Table 2. Distribution of Vacant Land Areas within Miami-Dade County Watersheds.

Watershed	Total Square Miles	Vacant Square Miles	Fraction Vacant
C-1	59.67	15.63	26%
C-2	55.57	8.64	16%
C-4 (includes C-3+C-5)	110.47	30.32	27%
C-6	63.57	7.43	12%
C-7	36.07	1.85	5%
C-8	36.84	4.94	13%
C-9	104.52	8.04	8%
C-100	46.32	2.28	5%
C-102	42.53	14.97	35%
C-103	76.16	23.87	31%
C-111	150.59	66.35	44%
Total	**782.31**	**184.33**	**24%**

The summary of vacant areas and parcels indicates that the average vacant land is 24% and varies from 5-9% for highly urbanized areas (watersheds C-7, C-9, and C-100), 12-16% for medium degree of urbanization (C-2, C-6, and C-8), and 26-44% for low urbanization (C-1, western C-4, C-102, C-103, and C-111). Much of the eastern portions of the C-4 and C-6 Watersheds are highly urbanized.

The watershed numerical models represent more than 780 square miles of inland and coastal areas. The 2021 Stormwater Master Plan reports the results of the eleven watershed numerical models that were revised to account for current and future County hydrologic and hydraulic conditions. The original C-3, C-4, and C-5 Watersheds, were combined into a single numerical model, namely the C-4 Watershed model, due to the watersheds' size, connectivity, and low-lying boundaries. An outline of the modeled watersheds within the entire Miami-Dade County is shown in Figure 1. The western boundary of the modeled watersheds is defined by the L-30, L-31N and C-111 Primary canals. The northern boundary includes the southern watersheds of the South Broward Drainage District (SBDD). The watershed numerical models cover all the areas having a direct impact on the urbanized portions of Miami-Dade County excluding the urbanized portions of the County on the barrier islands and Miami Beach in particular, and also the cities north of Miami Beach, and Key Biscayne.

This update of the watershed numerical models accounts for changes in hydrology and hydraulics due to current and future projected population growth, ground elevation, SLR scenarios, land use, groundwater levels (current and forecast), rainfall volumes and intensity, and surface water stages and flows related to specified precipitation events.

The models from previous County SWMP iterations for of all watersheds were updated with Innovyze's XPSWMM program, version 2020.1. The XPSWMM numerical model is similar to and uses many of the same algorithms as the U.S. Environmental Protection Agency (EPA) Stormwater Management Model (SWMM). The hydrology and hydraulics are modeled simultaneously in XPSWMM, as opposed to separately in other modeling platforms. The XPSWMM Hydrologic and Hydraulic numerical model is accepted by FEMA for flood mapping.

This report summarizes the available information compiled for updating the hydrologic and hydraulic modeling and presents a summary of results and recommendations for the updates of all watersheds within the stormwater management master plan. The update addresses both current and future watershed conditions and provides recommendations for stormwater improvements within each watershed.

1.3 Authorization

The Miami-Dade County Department of Regulatory and Economic Resources (RER) Water Management Division has developed and maintains a Stormwater Management Master Plan supported by a hydraulic and hydrologic model of the County's drainage watersheds. The Stormwater Management Master Plan is based on a 20-year planning period and is to be updated at least once every five years in conformance with Florida Statute 373.036.

The Florida Air and Water Pollution Control Act, Chapter 403 sub-section 403.0891 of the Florida Statutes, authorizes the South Florida water Management District (SFWMD) to develop and maintain a Stormwater Management Program. The SFWMD has delegated this authority to Miami-Dade County. This Stormwater Master Plan Update is a component of the Stormwater Management Program and is consistent with the requirements set forth in Chapters 62-40 and 62-43 of the Florida Administrative Code (F.A.C.), EPA National Pollutant Discharge Elimination System (NPDES) requirements, SFWMD rules, Chapter 24 of the Miami-Dade County Code, and the Miami-Dade County Comprehensive Development Master Plan prepared pursuant to the requirements of Chapter 163 of the Florida Statutes. Additionally, mitigation of quantity and quality impacts to Biscayne Bay, which is designated as a State Aquatic Preserve and regulated according to Florida Statute 258.397, are authorized through Chapter 24 of the Miami-Dade County code.

1.4 Historical Overview

Miami-Dade County's hydrologic characteristics, combined with its generally flat topography, have historically (prior to land development) led to long periods of inundation. To manage surface water and allow for development of the land, a primary canal system was constructed by the U.S. Army Corps of Engineers (USACE) with secondary canals developed by local governments and various private entities. Currently, the canal system in Miami-Dade County consists of over 970 miles laid out in approximate one- to two-mile grids. The canal system is divided into 360 miles of primary canals, 260 miles of secondary canals, 350 miles of smaller ditches under private jurisdiction, and 75 miles of coastal waterways. The primary system, including most of the salinity control structures, is operated by the SFWMD. The secondary system (Figure 1) is the responsibility of Miami-Dade County [29].

The canal system serves to provide drainage during periods of excess rainfall and maintains adequate groundwater levels in the Biscayne aquifer to prevent salt-water intrusion and protect the public water supply. In general, the water levels in the canal system are lower than the groundwater levels except during high precipitation events. The canal system can be used to recharge the Biscayne aquifer during the dry season when flow is conveyed from Lake Okeechobee and the water conservation areas into the urbanized areas to the east. Conversely, during the wet season, groundwater flows from the aquifer into the canals and is discharged to the ocean, as needed, to prevent flooding [29].

Pursuant to requirements set forth in regulations and statutes detailed in Section 1.3 of this report, Miami-Dade County has developed and maintained a stormwater model which incorporates the operational strategies of the primary and secondary canal system. In 1993, the engineering firm Ch_2MHill established the criteria for developing a watershed stormwater model for each of the 11 SFWMD drainage watersheds within the limits of Miami-Dade County. The SWMP plan covered urbanized areas mainly east of Canals C-111 and L31-N and west of FEC. Between 1996 and 1998 stormwater models were developed for each watershed as part of the initial Miami-Dade County Stormwater Master Plan.

The Miami-Dade Master Plan was subsequently updated in segments for the major watersheds in the years between 2003 and 2008. These plans identified the main water quantity and quality problems and provided strategies for reducing drainage and water quality impacts to Biscayne Bay and its tributaries. Numerical models were utilized to facilitate the evaluation of the stormwater drainage and water quality data. The original plan includes estimates of the effects of existing and future land uses on flood protection and water quality and identifies infrastructure and management strategies to accommodate those uses.

Continuous updates to the Stormwater Master Plan were performed in-house by Miami-Dade County staff on individual watersheds until the development of this comprehensive 2021 Stormwater Master Plan Update, which includes the modeling results for all the watersheds in Miami-Dade County. This information was used to create flood hazard maps for the entire county. The updated watershed modeling was performed by Miami-Dade County staff and external consultants.

1.5 Miami-Dade County Level of Service

The objective of an established stormwater system LOS is generally to reduce flood risk and to improve or maintain water quality. The stormwater LOS standards for Miami-Dade County's SWMP have both a flood protection and a water quality component.

The flood protection LOS is achieved through compliance with the FEMA National Flood Insurance Program (NFIP), the USACE Standard Project Flood, elements of the SFWMD Environmental Resource Permit (ERP) program, the Florida Department of Transportation (FDOT) state road drainage design standards, and Miami-Dade County's CFC and WCM described in Sections 1.5.7 and 1.5.8 , respectively.

The water quality LOS is achieved through compliance with the EPA NPDES program and Miami-Dade County local regulations described herein.

1.5.1 FEMA National Flood Insurance Program

The NFIP is a federal program managed by FEMA intended to reduce the impact of flooding on private and public structures by providing affordable insurance and encouraging communities to adopt and enforce floodplain management regulations aimed at mitigating the effects of flooding on new and improved structures. Flood hazard mapping and the Community Rating System (CRS) are key components of this program.

Under the latest CRS review completed in 2020, Miami-Dade retained Class 5 rating although received credits exceeding Class 4. Two of the pre-requisites for Class 4 are still pending review (trailer requirements in pre-FIRM parks and analysis of levee). As such, Miami-Dade County policy holders who live in a flood zone have a 25% discount on their flood insurance premiums since October 1, 2003 when Miami-Dade's Class 5 rating was first achieved. A 10% discount on flood insurance is also available for those who live outside of flood zones, except on preferred risk policies.

1.5.2 Flood Hazard Mapping

Flood hazard mapping is an important part of the NFIP, as it forms the basis of the NFIP regulations and flood insurance requirements. Data is maintained and updated through the FIRMs. The FIRM is the official map which shows roads and map landmarks, shows the community's base flood elevations, and the delineated the flood zones and floodplain boundaries. To identify a community's flood risk, FEMA conducts a Flood Insurance Study. The study includes information on canal and stream flows, storm tides, hydrologic and hydraulic analyses, and rainfall and topographic surveys. FEMA uses this data to create the FIRMs that outline each community's different flood risk areas.

FEMA periodically updates the FIRMs and is currently updating the map for Miami-Dade County, expected to be issued at the end of 2021. FIRMs are available online at the following web address: https://msc.fema.gov/portal/home

Miami-Dade County flood zone maps can also be viewed through the counties' interactive GIS portal at the following web address: http://gisweb.miamidade.gov/floodzone/.

The current FEMA maps became effective on September 11, 2009 (Figure 2). Miami-Dade County officially adopted the maps in July 2009 as required for the County to continue participating in the NFIP, which guarantees the availability of flood insurance to residents within unincorporated Miami-Dade. FEMA is currently in the process of updating the areas covered by watersheds C-9 and C-8 using the modeling updates of these watersheds from this SWMP.

Flood hazard areas identified on the Flood Insurance Rate Map are identified as a Special Flood Hazard Area (SFHA). SFHA are defined as the area that will be inundated by the flood event having a 1-percent chance of being equaled or exceeded in any given year [ref 43]. The 1-percent annual chance flood is also referred to as the base flood or 100-year flood. SFHAs are labeled as Zone A, Zone AO, Zone AH, Zones A1-A30, Zone AE, Zone A99, Zone AR, Zone AR/AE, Zone AR/AO, Zone AR/A1-A30, Zone AR/A, Zone V, Zone VE, and Zones V1-V30. Moderate flood hazard areas, labeled Zone B or Zone X (shaded) are also shown on the FIRM, and are the areas between the limits of the base flood and the 0.2-percent-annual-chance (or 500-year) flood. The areas of minimal flood hazard, which are the areas outside the SFHA and

higher than the elevation of the 0.2-percent-annual-chance flood, are labeled Zone C or Zone X (unshaded).

Below are FEMA's definitions for flood zone designations shown in Miami-Dade County's FIRMs.

Zone A (unnumbered) (High Flooding Risk): Because detailed analyses are not performed for such areas, no depths or base flood elevations are shown within these zones. There is at least a one-in-four chance of flooding during a 30-year mortgage. Mandatory flood insurance requirements also apply.

Zone AE (Moderate to High Flooding Risk): This is the flood insurance rate zone that corresponds with flood depths greater than three feet. Mandatory flood insurance purchase requirements apply.

Zone AH (Moderate to High Flooding Risk): This is the flood insurance rate zone that corresponds to areas of shallow flooding with average depths between one and three feet. Mandatory flood insurance purchase requirements apply.

Zone D: (Areas with possible but undetermined flood hazards). No flood hazard analysis has been conducted. Flood insurance rates are commensurate with the uncertainty of the flood risk. In Miami-Dade County, most of these areas fall within Everglades National Park (ENP).

Zone VE (High Flooding Risk): This is the flood insurance rate zone that corresponds to coastal areas that have additional hazards associated with storm waves. There is at least a one-in-four chance of flooding during a 30-year mortgage. Mandatory flood insurance requirements apply.

Zone B and X (shaded) Area of moderate flood hazard, usually the area between the limits of the 100-year and 500-year floods. B Zones are also used to designate base floodplains of lesser hazards, such as areas protected by levees from 100-year flood, or shallow flooding areas with average depths of less than one foot or drainage areas less than 1 square mile.

Zone C and X (unshaded) Area of minimal flood hazard, usually depicted on FIRMs is outside and higher than the elevation of the 500-year flood level. Zone C may have ponding and local drainage problems that do not warrant a detailed study or designation as base floodplain. Zone X is an area of moderate flood hazard that is determined to be outside the Special Flood Hazard Area between the limits of the base flood and the 0.2 percent annual chance (or 500-year) flood. .

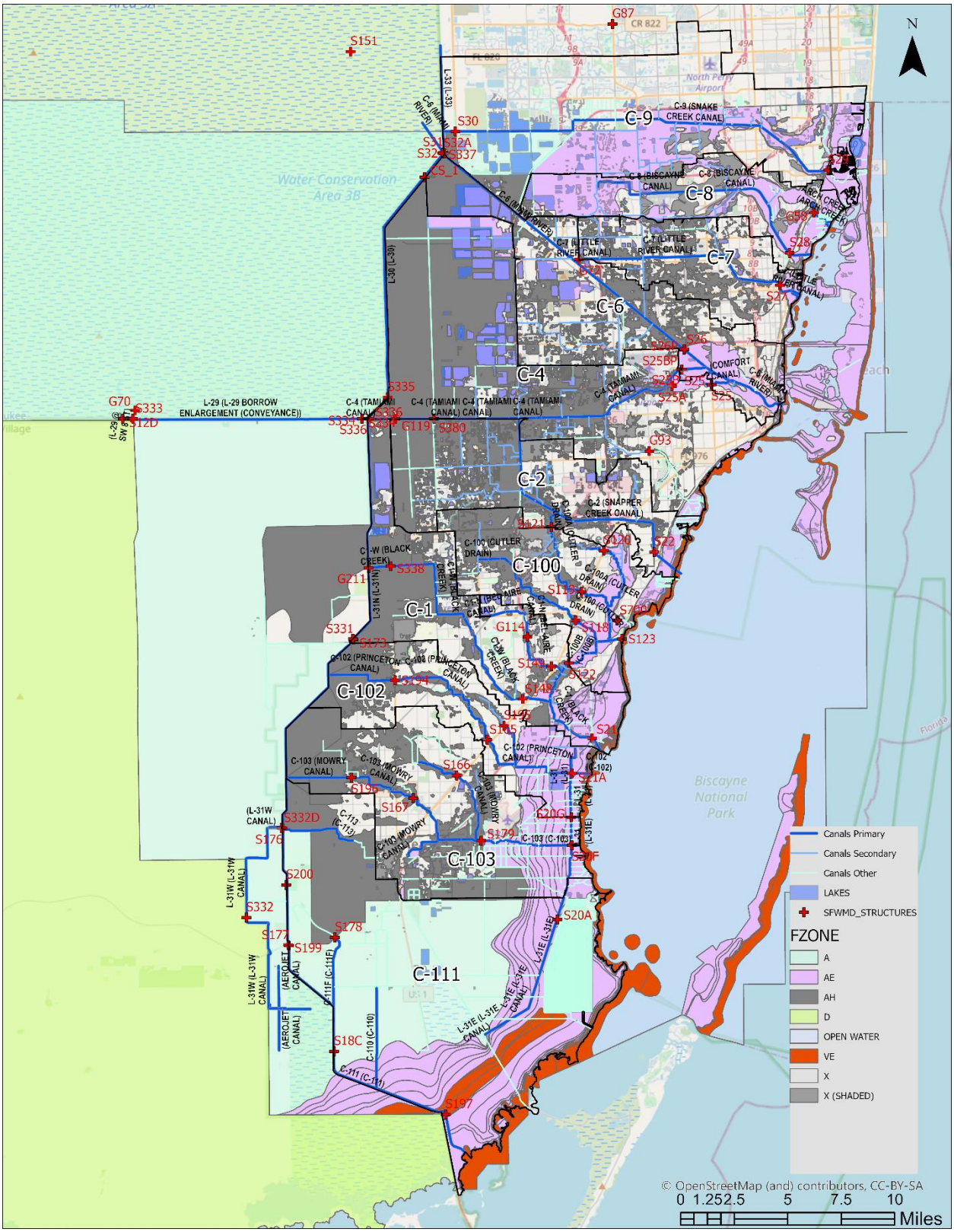


Figure 2 Miami-Dade County Flood Zones (September 2009)

1.5.3 USACE Standard Project Flood

The USACE establishes specifications for the Standard Project Storm (SPS) and the resulting Standard Project Flood (SPF). The SPS for a particular drainage area represents the most severe flood-producing rainfall depth-area relationship and isohyet pattern of any storm that is considered reasonably characteristic of the region in which the drainage basin is located, giving consideration to the runoff characteristics and existence of water regulation structures in the basin (SPF).

The Primary drainage system in South Florida consists of the canals and associated features that are managed by the SFWMD and USACE. The primary canals are designed to hold water at stages estimated to occur during the SPF, which amounts to the runoff generated by SPS, defined as the 100-year storm increased by 25%. The capacity of a canal and its structures may be given as a percentage of the SPF (e.g., 40 percent SPF typical rating). The storm that would generate this amount of runoff is given by its frequency (e.g., 1-10 years) for antecedent weather conditions that are assumed to generate runoff from the storm. The amount of runoff to be expected per unit area for design storms at various recurrence intervals, antecedent conditions, and land use can be found in the USACE General Design Memoranda for the Dade Conveyance System [7]. The runoff calculated to occur for a given set of storm frequency, antecedent conditions, and land use is the design discharge.

The water quantity and water quality flood protection LOS requires all primary canals to operate per the USACE SPF, with an effective canal and control structure capacity based on passing the rated design flood, typically established as a percent of the SPF, with four distinct goals:

1. Maintain upstream flood design stage;
2. Restrict downstream flood stages and canal flow velocities to avoid excessive erosional impacts;
3. Convey sufficient discharge during low-flow periods to maintain minimum downstream stages; and,
4. Prevent overtopping of control structures by wave action during a storm including tidal effects in coastal structures.

The secondary drainage system consists of canals and features that are managed by designated drainage districts or private entities, which may discharge to the coast or receiving lakes, or into the primary system. Such secondary systems operate under permits issued by the SFWMD. The tertiary drainage system consists of canals and features generally located on private lands that provide localized drainage and discharge into retention/detention areas or into secondary systems.

1.5.4 EPA National Pollutant Discharge Elimination System

The EPA NPDES permit program addresses water quality by regulating point source discharges to waters of the United States. The Florida Department of Environmental Protection (FDEP) has delegated authority through 403.0885 F.S. to implement the federal NPDES permit program. Under NPDES, Miami-Dade County holds a State of Florida Municipal Separate Storm Sewer System (MS4) permit as a co-permittee with municipalities and entities that fall within Miami-Dade County limits.

Miami-Dade County MS4 permit number FLS000003-004 issued on December 29, 2017 and expiring on December 28, 2022 outlines the water quality LOS that shall be achieved through the implementation of a SWMP inclusive of pollution prevention measures, treatment or removal techniques, stormwater

monitoring, and use of legal authority. Water quality standards are outlined in Part VIII of the MS4 permit, inclusive of references to the relevant portions of the F.A.C.

1.5.5 South Florida Water Management District

The SFWMD, pursuant to Chapter 373 F.S. and Chapter 62-330 F.A.C., manages the ERP Program. An ERP is required for development or construction activities to prevent flooding, protect the water quality of Florida's lakes and streams from stormwater pollution, and protect wetlands and other surface waters. The SFWMD regulates residential and commercial developments, roadway construction, and agriculture; while the FDEP oversees power plants, ports, wastewater treatment plants, and single-family home projects. The ERP Information Manual developed by FDEP and Florida's five water management districts establishes the types of permits, permit thresholds, and exemptions under the ERP Program.

The secondary and tertiary systems generally operate and are regulated under an ERP by the SFWMD. Storage and conveyance ratings of secondary canals discharging to the primary canal system are bound by the primary system operational rating established by the USACE/SFWMD. As per this SWMP, Miami-Dade County requires the secondary and tertiary conveyance systems to be designed for a 25-YR/72-HR assuming average sea level elevations for year 2060 and 2.0-feet of sea level rise in comparison to 2020.

Miami-Dade County has delegated authority to oversee surface water management general permits in accordance with the operating agreement between SFWMD and Miami-Dade County entered into on March 9th, 1995. Additionally, Miami-Dade County has delegated authority in accordance with the Operation and Delegation Agreements incorporated by reference in Chapter 62-113 F.A.C. and accessible at the following web address:

https://floridadep.gov/ogc/ogc/content/operating-agreements#localprograms

1.5.6 Florida Department of Transportation

The drainage design standards establishing LOS for these roads are contained in the FDOT Drainage Manual, in conformance with Chapter 334 F.S. latest version of the FDOT Drainage Manual can be accessed at the following web address:

https://www.fdot.gov/roadway/drainage/manualsandhandbooks.shtm

The FDOT roads and evacuation routes are shown in Figure 3.

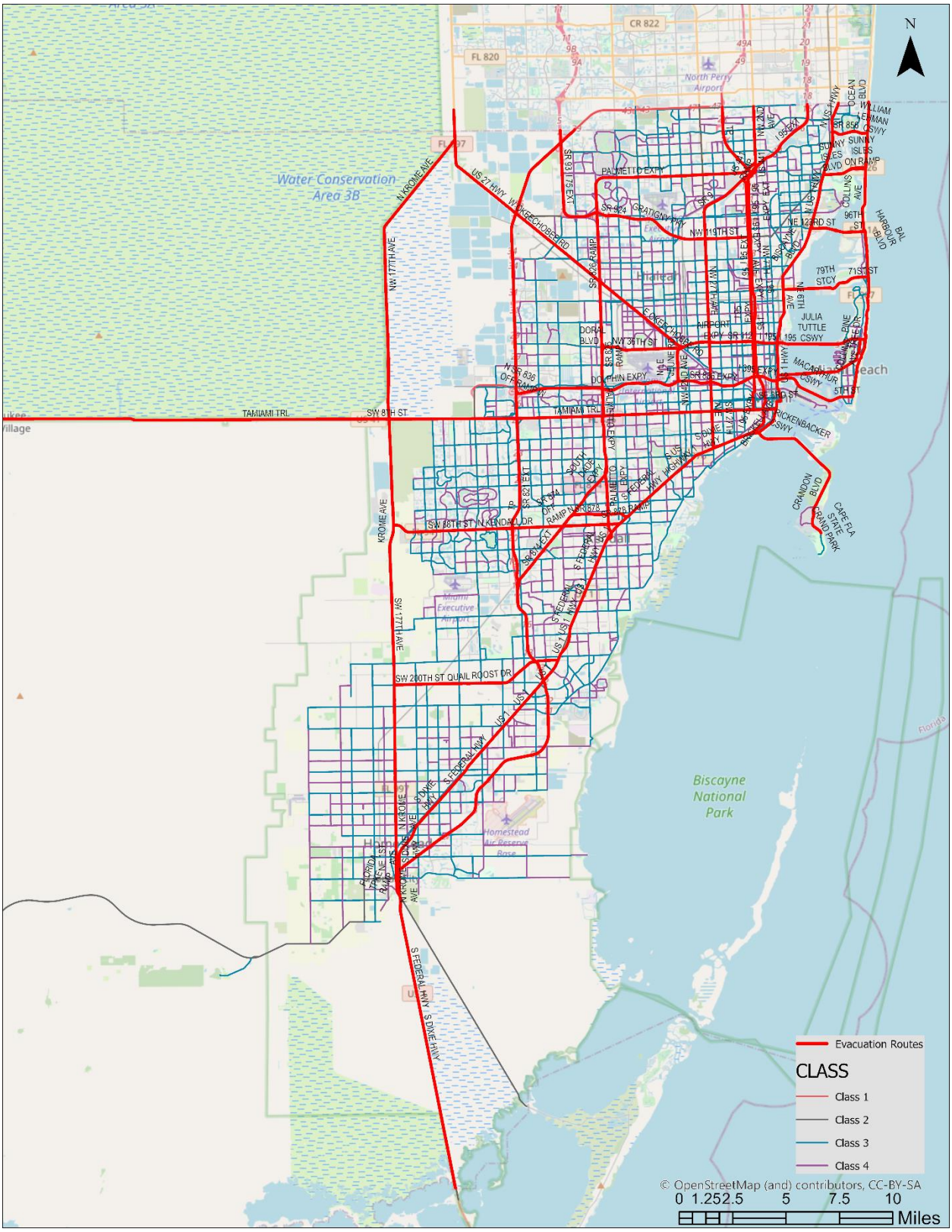


Figure 3 Map of FDOT roads and evacuation routes in Miami-Dade County.

1.5.7 County Flood Criteria Map

The CFC is applied to develop the minimum acceptable FPLOS standard for Miami-Dade County for lot elevation, which shall be protection from the degree of flooding that would result from a 10-year 24-hour storm, with exceptions where additional development to this base standard would pose a risk to existing development.

The purpose of the Miami-Dade CFC map is to determine the minimum ground surface elevation of properties and the crown/grade of roads unless higher elevations are required by other regulatory applicable standards. The CFC is a Plat approved by the Board of County Commissioners (plat book 120, page 13-1) which sets the minimum finished grade elevation of developed sites, finished Secondary canal banks, and roads except as subject to higher localized standards.

Elevations higher than the minimum Miami-Dade County Flood Criteria may also be required to meet stormwater drainage systems, water and wastewater systems, and septic tank-drainage field design standards as per applicable codes. A minimum elevation of 5.0 feet NAVD 88 applies to all areas except where indicated on the Plat/Digital Map and a minimum seawall elevation of 6.0 feet NAVD 88 applies to all coastal areas.

All structures shall be constructed at, or above, the minimum floor elevation specified in the FIRMs for Miami-Dade County, or as specified in Chapter 11-C of the Miami-Dade County Code, whichever is higher [29].

Contactors, engineers, developers, or other agencies are encouraged to use the higher resolution digital files of the Miami-Dade CFC Map available at https://gis-mdc.opendata.arcgis.com/.

1.5.8 Water Control Map

The purpose of the WCM of Miami-Dade County is to establish guidelines and requirements for designing water control facilities for land development, and to show the general locations of proposed canals, levees, dams, control structures, pump stations, drainage divides (all subject to changes dictated by new developments and Miami-Dade County Environmental Policies), and other drainage features of the Miami-Dade County Water Control System.

The WCM uses surface water levels from the 25-YR/72-HR 2060 future model scenario with SLR for countywide storage and conveyance ratings for the Secondary Canals, except where higher regulatory requirements apply. The surface water level for this model scenario was calculated using NOAA mean sea level (http://bit.ly/NOAA_MSLnavd) at the Virginia Key Station in NAVD 88, epoch 1983-2001 for the base level, plus 2 feet for SLR to account for uncertainties in future tidal elevation forecasts.

The Miami-Dade County WCM is a Plat approved by the Board of County Commissioners (plat book 126, page 39) which includes the Secondary Conveyance system under the jurisdiction, operation, and maintenance responsibility of Miami-Dade County. The WCM includes existing and planned conveyance infrastructure. New development and improvements to existing development, where post-development conditions show stormwater related impacts beyond pre-development, must provide the required conveyance system components and/or related improvements per the WCM in effect at the time of permitting. The WCM is available at https://gis-mdc.opendata.arcgis.com/.

The Miami-Dade County Stormwater Conveyance System is comprised of a Primary Conveyance System under the jurisdiction of the USACE, maintained and operated by SFWMD, and a Secondary Conveyance System under the jurisdiction, maintenance, and operation of Miami-Dade County. The Stormwater Conveyance System serving Miami-Dade County is bound to the north by Broward County, to the west by Canals L-30 and L-31N, to the east by Biscayne Bay, and to the south by Florida Bay.

In summary, the Stormwater Management (Drainage) LOS Standards for Miami-Dade County contain both a Flood Protection (FPLOS) and Water Quality (WQLOS) component.

Watershed-specific FPLOS standards have been established through the adoption of the most recent Stormwater Master Plan approved by the Miami-Dade County Board of County Commissioners and the South Florida Water Management District. Until the approval of watershed specific FPLOS standards through this coordinated process, the following additional exceptions shall apply:

a) Wherever Miami-Dade County has adopted cut and fill criteria pursuant to Chapter 24-48.3(6) of the County Code (November 30, 2004) including fill encroachment limitations necessary to prevent unsafe flood stages in special drainage watersheds, the minimum applicable FPLOS standard shall be the degree of protection provided by the applicable cut and fill criteria;
b) Where cut and fill criteria have not been established north of S.W. 152 Street inside the Urban Development Boundary (UDB), the minimum acceptable FPLOS standard for lot elevation shall be protection from the degree of flooding that would result from a 10-year 24-hour storm, using the CFC;
c) West of Levee 31N, there shall be no off-site drainage, all septic tank drain fields shall be elevated above the 100-year flood elevation, and the extent of land filling shall be minimized as provided in applicable provisions of the Miami-Dade County East Everglades Zoning Overlay Ordinance. The County shall review these criteria when the water management facilities programmed in the N.E. Shark River Slough General Design Memorandum and the C-111 General Reconnaissance Review are fully operational.

The Stormwater Management WQLOS component of the standard shall be met when the annual geometric mean for each of the twelve priority NPDES pollutants does not exceed the target criteria for each of those pollutants within a canal watershed, or sub-watershed, as determined in accordance with procedures established by Miami-Dade County's RER. Additionally, recommended NPDES parameters may not exceed established Federal, State or Local Criteria for the water body, as listed in Table 2, in "Guidance for Preparing Monitoring Plan as recommended for Phase I MS4 Permits," FDEP August 1, 2009.

Applicants seeking development orders in canal watersheds, or sub-watersheds that do not meet either the FPLOS or the WQLOS shall be required to conform to Best Management Practices (BMPs) as provided by Miami-Dade County Code. Owners of commercial or industrial properties where BMPs are required, shall, at a minimum, demonstrate that their on-site stormwater system is inspected two times per year and maintained and cleaned as required. Private residential developments in areas where BMPs are required shall demonstrate that their on-site stormwater systems are inspected two times per year and maintained and cleaned as required [29].

2 STORMWATER MODEL UPDATE

The surface water management watersheds in eastern Miami-Dade County, Florida, were first delineated in the 1950's by the USACE in their General Design Memorandum for the Central and Southern Florida Flood Control Project. Based on the hydrology of the watersheds, the USACE designed and constructed a system of canals, levees, and control structures to provide flood protection for southern and central Florida. Since the initial design, new surface water management infrastructure has been constructed and the existing infrastructure has is being continuously modified to meet the changing needs of southern Florida. Most of the works constructed under the Project are now under the management of South Florida Water Management District. The Miami-Dade stormwater infrastructure was designed and constructed to prevent or reduce flooding, over-drainage, environmental degradation, and water pollution and to control discharges resulting from rainfall events. The stormwater system is a critical infrastructure component which preserves quantity and quality of discharges from the stormwater management system and ensures compliance with Municipal, State and Federal Regulations. The system incorporates methods to collect, convey, store, absorb, inhibit, treat, use, or reuse water.

The control structures in Miami-Dade County regulate the flow of water in the Primary Canals (Figure 1). The Primary Canals are used to discharge excess water from the watersheds during flooding and to maintain minimum water levels in the canals during drought periods. Some structures are usually set closed to prevent water from passing from one watershed to another but can be opened to supply water from one watershed or canal to another, as necessary. The coastal structures have the additional function of preventing saltwater from a tidal or storm surge from entering canals discharging to tidewater.

For the past 25 years, Miami-Dade County has developed and provided continuous updates of the Stormwater Master Plan that integrates the SWMP. The SWMP has been developed as defined by Section 403.031(15), Florida Statutes and it includes the County's institutional strategy for stormwater management in urban, agricultural, and undeveloped areas.

The County watersheds were revised and updated using Innovyze's XPSWMM numerical software, version 2020.1 following the methodology adopted by the Miami-Dade County Stormwater Masterplan from 1993 [3], and consistent with the latest Risk Map practices recommended by FEMA. The XPSWMM Hydrologic and Hydraulic modeling software uses many of the same algorithms as the EPA Stormwater Management Model, though the Innovyze program is proprietary and has diverged from the base SWMM. In this update, the hydrology and hydraulics are modeled concurrently within XPSWMM, as opposed to separately in other types of modeling platforms. XPSWMM is accepted by FEMA for flood mapping.

XPSWMM is a hydrodynamic model, capable of representing the processes of rainfall, infiltration, runoff, overland flow, watershed storage, and canal and pipe flows during storm conditions, while incorporating the influence of tide and groundwater boundary levels. Its use over the last 25 years, as well as its FEMA approval and UK Environment Agency benchmark testing, has made it one of the most stable and well-used simulation software programs available. XPSWMM also allows integrated analysis of flow, pollutant transport and sustainable design measures in engineered and natural systems including ponds, rivers, lakes, overland floodplains, and aquifers.

XPSWMM uses a node-link architecture to provide hydrology, hydraulics, and water quality analysis of stormwater systems. Nodes symbolize intersection of canals, ends of cross drains, points along the canal

where the canal cross section shape begins to vary considerably, and junctions of hydraulic links. Nodes are used for input of flow and pollutants into the drainage system or as a storage component such as a pond or lake, or for the assignment of boundary conditions. Links represent hydraulic elements for flow and element transport between nodes. Examples of elements modeled as links include stormwater pipes, natural channel cross sections, pumps, weirs, and culvert crossings. The routing in XPSWMM is performed as dynamic flow routing, using the one-dimensional Saint-Venant's flow equations.

XPSWMM has three computation modes (or blocks). In Runoff mode, the software computes hydrology and water quality and simulates surface runoff and subsurface flow based on rainfall hyetographs, antecedent conditions, land use, soils, hydrologic properties, and topography. This mode also generates groundwater hydrographs that may be added to the surface runoff hydrograph for each sub-watershed or directed to specified node of the canal system.

In Hydraulics mode, the program simulates the storage and transport of water through a drainage network. The results from the Runoff mode, i.e. the groundwater interflow hydrographs and surface runoff hydrographs from open sub-watersheds, are combined and loaded to the Hydraulic block (EXTRAN). The specific function of EXTRAN is to route inlet hydrographs through the network of pipes, junctions, and flow diversion structures of the main storm water system to the receiving water outfalls. The fully dynamic model allows for looped networks, backflow, and flat or adverse sloped pipes and canal reaches. EXTRAN includes hydraulic elements as conduits: pipes, canal reaches, and links to simulate the overland flow that occurs between sub-watersheds during major storms; and hydraulic elements as diversions: pumps, weirs, orifices, and rating curves. Within EXTRAN, there are storage nodes located in each sub-watershed, except for "canal" sub-watersheds where the storage is provided in the link cross-section. EXTRAN nodes may also include inflow hydrographs from canals outside the model boundary, time-stage boundary conditions in canal nodes at the boundary of the model, or tidal boundary conditions at the watershed discharge. Groundwater interflow (seepage) links are modeled as rating curves to simulate the underground hydraulic connections among regions (between western ENP and the canal system).

In Sanitary mode, the water quality component may be added to a rainfall-runoff model to generate a time series of pollution concentration in the stormwater runoff. When the water quality option is invoked, timeseries are calculated for each contaminant at each active runoff node. These hydrographs and timeseries are stored on interface files that are input to the Sanitary mode to model storage and treatment processes. The interface files may also be used as input to the Hydraulics mode to model the transport of contaminants through the network.

The updated models were based on the previously published County models and were converted to the latest XPSWMM version (version 2020.1 from December 2020). The model updates increased the spatial coverage of watersheds to represent in greater detail the interconnected stormwater management system. The updates incorporate additional hydrologic information to account for the most recent hydrologic conditions in South Florida. Additionally, this modeling update includes datum conversion from National Geodetic Vertical Datum of 1929 (NGVD 29) to North American Vertical Datum of 1988 (NAVD 88). In Miami-Dade County, NAVD 88 ranges from about 1.50 ft to 1.60 ft lower than NGVD 29 (i.e. NAVD = NGVD – 1.5 as a general rule). The modeling update also includes the implementation of the most recent land use, groundwater levels, and stormwater infrastructure, and the corresponding revisions of model components. The updated models currently cover more than 780 square miles (more than 500,000 acres).

For each watershed, the updated models were calibrated for the rainfall event, upstream boundary conditions and the outfall tidal conditions during Hurricane Irma in September 2017. The models use hydrologic data obtained from SFWMD database of rainfall, flow, headwater stage, and tailwater stage data. Design event simulations were developed for 5-, 10-, and 25-Year recurrence intervals with a 24-hour duration, and 5-, 10-, 25-, 50-, 100-, 500- and 1000-Year recurrence intervals with a 72-hour duration.

2.1 Watershed Hydrology

2.1.1 Miami-Dade County Topography

The topography for this project was derived from the Digital Elevation Model (DEM) containing georeferenced digital representation of the ground surface elevations providing the vertical position above NAVD 88 in feet. Data is encapsulated in grid format (raster), based on Light Detection and Ranging (LiDAR) for ground elevations and conventional surveys for canal cross sections. The DEM dataset was provided by Miami-Dade County Information Technology Department using the classified LiDAR Data from 2015 and subsequently updated in 2018. The DEM represents a 5-foot square bare-earth surface grid, which does not include vegetative and building features. Estimates of water edges at the time of data collection, were performed using orthophotography.

The LiDAR data horizontal accuracy follows the National Standard for Spatial Data Accuracy Root Mean Square Error (RMSE) estimation of elevation data in support of 2.0-ft contour mapping products as it is referenced in the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping. Horizontal accuracy was tested to meet or exceed a 3.8-foot horizontal accuracy (2.2-ft RMSE) at 95 percent confidence level using RMSE(r) x 1.7308 as defined by the Federal Geographic Data Committee's (FGDC) Geospatial Positioning Accuracy Standards, Part 3: NSSDA. The Fundamental Vertical Accuracy was tested to meet or exceed a 0.60-ft fundamental vertical accuracy in open well-defined terrain at 95 percent confidence level using RMSE(z) x 1.9600 as set forth in the FGDC Geospatial Positioning Accuracy Standards, Part 3: NSSDA.

Miami-Dade County is characterized by flat and relatively low-lying topography with elevations generally below 10-feet NAVD 88 (Figure 4). Miami-Dade County is susceptible to flooding from tidal surges associated with tropical storms and hurricanes. Additional problems are presented by ponding in the very flat, poorly drained areas and drainage canals that traverse portions of the county. The western and southern areas are mostly marsh with a mean elevation of approximately four feet NAVD 88. Approximately one-third of Miami-Dade County falls within the ENP. Drainage is mainly into the Biscayne Bay and Atlantic Ocean or in the wetlands to the south and west. Biscayne National Park covers all of Biscayne Bay south of Key Biscayne to the Miami-Dade/Monroe County line.

2.1.2 Sub-watershed Delineation

Miami-Dade County's watersheds are characterized by flat topographical relief and urbanized areas drained by a network of man-made canals. These canals intercept the shallow groundwater table of the unconfined and highly transmissive Biscayne Aquifer, which provides most of the base flow. The intersection of the canals with the groundwater table assures that a portion of the baseflow is contributed by inflow from the surrounding aquifer.

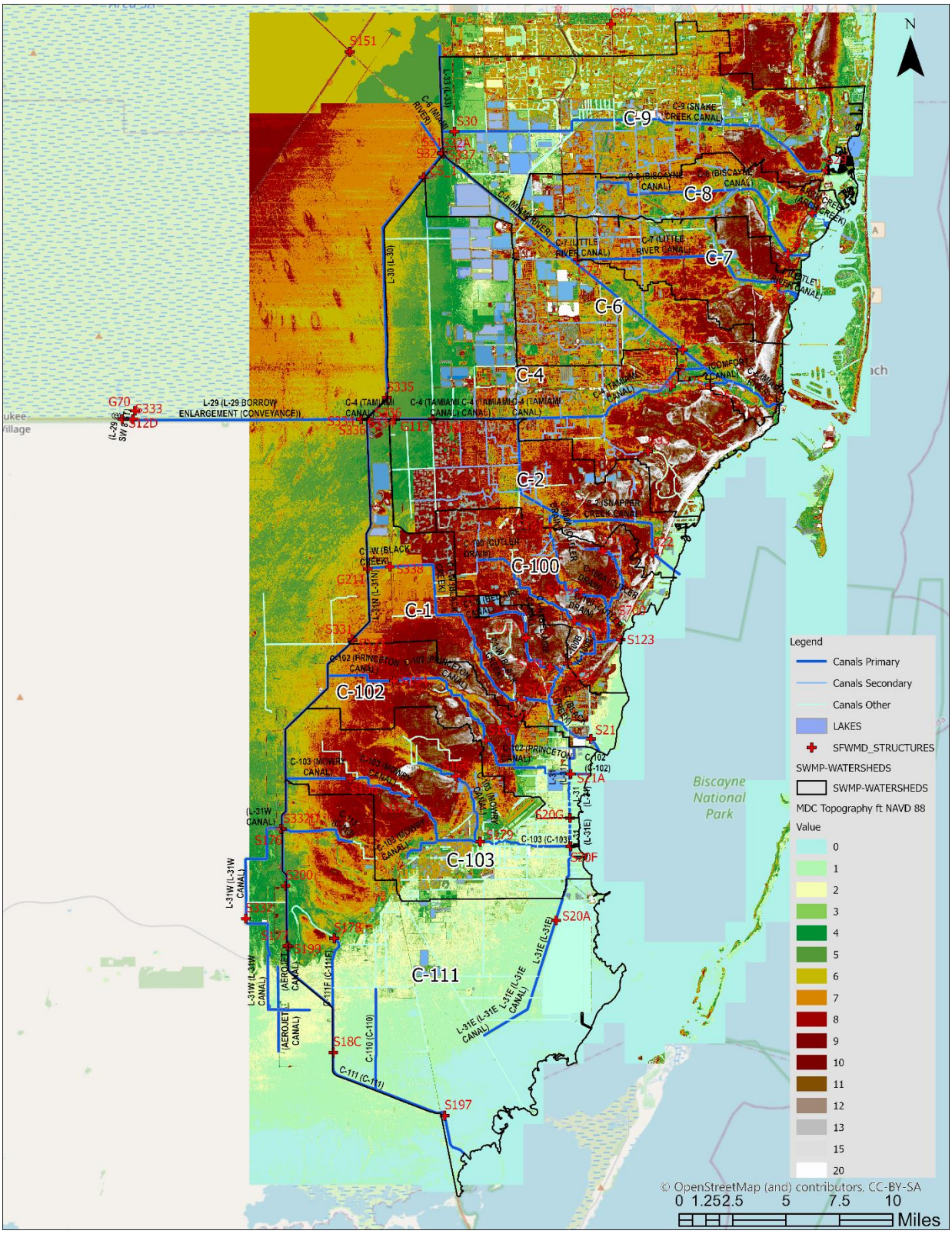


Figure 4 Topography of Miami-Dade County and South Broward County.

The original thirteen County watersheds were grouped into eleven watershed models (C-3 and C-5 Watersheds are combined with the C-4 Watershed), with more than 3,500 sub-watersheds. The sub-watershed delineation process was performed according to the procedure established in the Report "Stormwater Master Plan, Volume 2, Hydrologic and Hydraulic Modeling of Existing and Future Conditions without Control Measures, September 1997" [4].

Additional nodes were needed or renaming of nodes was performed along the boundary lines to indicate shared nodes between adjacent watersheds. The following information was used to revise and update the sub-watershed delineation.

- Topography of the watershed, based on LiDAR data collected in year 2015 and 2018 where available (The 2015 LiDAR provided full coverage of the model domain; however, the 2018 LiDAR only partially covered the southwest model domain);
- Revised canal cross-sections based on surveys within the last 5 years of the Primary drainage system of canals and features managed by SFWMD and USACE;
- Revised canal cross-sections of the Secondary drainage system and features managed by designated drainage districts or private entities, based on recent survey updates;
- Roadway crown elevations based on revised surveys and FDOT projects; and,
- Review of flood maps and iterative revisions or refinements of model components to improve the representation of the stormwater system.

Additionally, the stormwater infrastructure was reviewed and updated: to include the locations and extent of stormwater infrastructure facilities which provide storage and conveyance as well as the location of stormwater components including culverts, backflow preventors, drainage wells, cross drains or other components that can affect flows and distribution of stormwater during design or calibration events.

The final watershed delineation was obtained by revising and adjusting sub-watershed boundaries using LiDAR topographic data, road crown elevation data, and the revised secondary system. Each sub-watershed was given a name based on the proximity to one of the secondary and major canals or tributaries, or proximity to a major roadway or landmark. The final watershed and sub-watershed delineation are shown in the sections corresponding to each watershed.

The sub-watershed's name refers to the corresponding node in the RUNOFF layer. In XPSWMM, up to five sub-watersheds may be applied to a given runoff node; however, in this update each sub-watershed delineated within a watershed was assigned to a unique node in the model. Note that the nodes (and node names) are consistent through all three model layers, so the resultant RUNOFF hydrograph for each sub-watershed is loaded to a unique node in the hydraulic (EXTRAN) layer.

The runoff generated from each sub-watershed is calculated from rainfall, infiltration, groundwater, evapotranspiration, and other model parameters reflecting the hydraulics and hydrology of the sub-watershed. The area, slope, width, and total impervious percentage for all sub-watersheds were determined using GIS tools. In SWMM, width is defined as catchment area divided by a representative flow-path length and the widths were generated based on the sub-watershed geometry in GIS. The average overland slope of each sub-watershed was estimated based generally on one average flow path. Directly Connected Impervious Area (DCIA) values were obtained from the sub-watershed land use distribution and compared to the USGS National Land Cover Database.

2.1.3 Stage Storage

The storage volume for lakes and other depressional areas, and above inlets within each sub-watershed are represented at nodes by using the storage option and specifying a stage-storage area curve. Stage-storage area curves for each sub-watershed were modeled as stepwise linear reservoirs (area increases linearly with stage). The stage-storage area relationships for each sub-watershed were developed using the 2015 and 2018 DEM for stages from 0 to 20 ft NAVD 88 at 0.25 ft increments. The stage-storage relationships were determined by excluding the footprint of the large buildings layer obtained from Miami-Dade County. The footprint of ditches and canals that are explicitly modeled as model links, i.e., the storage is already contained in the model link cross-sections, were also excluded from the storage calculation. Because LiDAR measures topography of lakes and other waterbodies at the surface, the bathymetry is not included in the storage area curve. Generally, this means the model includes no storage volume below the normal water level. For design storm models, this is not an issue because this "dead" storage is not available for flood protection.

2.1.4 Land Use Information

The existing and future land use information published in the Comprehensive Development Master Plan (CDMP), adopted in 2013 and amended through 2019 [29], was used in the update to develop estimates for the DCIA parameter required by the XPSWMM software to estimate infiltration and stormwater runoff from each sub-watershed. For modeling purposes, wetlands and water bodies are treated as undeveloped impervious land surfaces as there should be no infiltration below the outline of these areas. Additionally, SFWMD's Land Cover Land Use 2014-2016 dataset was used for refinement of the wetland areas [4]. There are more than 100 land use codes in the Miami-Dade County classification system. Details are provided in the CDMP and published as a geodatabase. Additionally, a printable map is available at https://bit.ly/3cP429K . The Land use maps for current (2014) and future (projected for 2030) are shown for each watershed in the corresponding watershed sections (2.6 to 2.16).

2.1.5 Land Cover and Imperviousness

Watershed imperviousness in the model update was obtained by analysis of two sources:

- Land Use information obtained from Miami Dade County's planning department and the typical total impervious areas (TIA) and DCIA values per land use provided in Table 3.
- Imperviousness values obtained from USGS based on remote sensing data from the most recent National Land Cover Database (NLCD) based on 100 ft horizontal resolution [38].

The typical TIA – Total Impervious Area, DCIA – Directly Connected Impervious Areas, NDCIA – Non-Directly Connected Impervious Areas, PERV – Pervious Areas for generalized land use categories for current and future conditions are listed in Table 3 and

Table 4. The land-use layers were overlain with the sub-watershed delineation to determine area-weighted DCIA values for each sub-watershed.

Table 3 Imperviousness Parameters for Generalized Land Uses for Current Conditions

Generalized Category	TIA (%)	DCIA (%)	NDCIA (%)	PERV (%)
Agriculture	0.01	0	0.01	99.99
Airports	27	4	23	73
Biscayne National Park	0.01	0	0.01	99.99
Cultural/Entertainment	78.42	53	25.42	21.58
Everglades National Park	0.01	0	0.01	99.99
Golf Courses/Municipal Parks	3	0	3	97
Government/Institutional	56.1	26	30.1	43.9
Hospitals/Medical	59.72	26	33.72	40.28
Hotels/Motels	61.53	30	31.53	38.47
Industrial Intensive	82.6	53	29.6	17.4
Junk Yards/Equipment Storage	74.71	45	29.71	25.29
Light Industrial	74.55	45	29.55	25.45
Mixed Use Commercial	75.5	45	30.5	24.5
Mobile Homes	74.93	45	29.93	25.07
Multi-Family Residential	70.5	38	32.5	29.5
Office Building with Parking	74.55	45	29.55	25.45
Parking Lots	79.73	53	26.73	20.27
Religious Facilities	64.62	30	34.62	35.38
Retail Commercial	82.6	53	29.6	17.4
Single Family Residence - Low Density	64.62	30	34.62	35.38
Single Family Residence - Other	69.63	38	31.63	30.37
Transportation	82.6	53	29.6	17.4
Utilities	27	4	23	73
Vacant Land	0.01	0	0.01	99.99
Water	100	100	0	0

Table 4 Imperviousness Parameters for Generalized Land Uses for Future Conditions

Generalized Category	TIA (%)	DCIA (%)	NDCIA (%)	PERV (%)
Agriculture	0.01	0	0.01	99.99
Business and Office	75.5	45	30.5	69.5
Environmental Protection	0.01	0	0.01	99.99
Environmentally Protected Parks	0.01	0	0.01	99.99
Estate Density Residential (EDR) 1-2.5 DU/Ac	64.62	30	34.62	65.38

ESTATE DENSITY RESIDENTIAL With DENSITY INCREASE 1	69.63	38	31.63	68.37
High Density Residential (HDR) 60-125 DU/Ac	70.5	38	32.5	67.5
Industrial and Office	74.55	45	29.55	70.45
Institutions, Utilities and Communication	56.1	26	30.1	69.9
Low Density Residential (LDR) 2.5-6 DU/Ac	64.62	30	34.62	65.38
Low Density Residential with Density Increase 1	69.63	38	31.63	68.37
Low Medium Density Residential W/ Density Increase 1	70.5	38	32.5	67.5
Low-Medium Density Residential (LMDR) 6-13 DU/Ac	70.5	38	32.5	67.5
Medium Density Residential (MDR) 13-25 DU/Ac	70.5	38	32.5	67.5
Medium Density Residential W/Density Increase 1	75.5	45	30.5	69.5
Medium-High Density Residential (MHDR) 25-60 Du/Ac	75.5	45	30.5	69.5
Office/Residential	75.5	45	30.5	69.5
Open Land	0.01	0	0.01	99.99
Parks and Recreation	0.01	0	0.01	99.99
Restricted Industrial and Office	74.55	45	29.55	70.45
Terminals	79.73	53	26.73	73.27
Transportation (Row, Rail, Metrorail, Etc.)	82.6	53	29.6	70.4
Water	100	100	0	100
Zoo Miami Entertainment Area	3	0	3	97

2.1.6 Soils Update

The soil types within the County were determined from the United States Department of Agriculture (USDA) Natural Resources Conservation Service's (NRCS) Soil Survey and are known as Soil Survey Geographic (SSURGO) and State Soil Geographic (STATSGo) databases.

The SSURGO database contains information about soil which can be displayed in tables or as maps. The information was gathered by walking over the land and observing the soil and by laboratory analysis. The maps outline areas are called map units and are linked in the database to information about the component soils and their properties for each map unit.

Each map unit may contain one to three major components and some minor components. The map units are typically named for the major components. Examples of information available from the database include available water capacity, soil reaction, electrical conductivity, and frequency of flooding; yields for cropland, woodland, rangeland, and pastureland; and limitations affecting recreational development, building site development, and other engineering uses.

Table 5 lists the soils in Miami-Dade County and their major engineering properties related to drainage. The primary soil types, which cover over 5% of the model area are: Urban land 0 to 2 % slopes (28%); Krome very gravelly loam; Lauderhill muck, frequently ponded, 0 to 1 percent slopes; and Udorthents, limestone substratum-Urban land complex.

Table 5 Major soil types within Miami-Dade County

Map Unit Name	Total Area (ac)	Fraction %	Drainage Classification	Hydro-Group	Depth to Water Table inch	Ksat ft/day	Slope %
Urban land, 0 to 2 percent slopes	129473.92	28.08%	0	C	201	85.21	1.00%
Krome very gravelly loam	57827.62	12.54%	Moderately well drained	D	137	33.64	1.00%
Lauderhill muck, frequently ponded, 0 to 1 percent slopes	35919.23	7.79%	Very poorly drained	A/D	0	88.63	0.50%
Udorthents, limestone substratum-Urban land complex	32464.29	7.04%	Somewhat poorly drained	A	92	91.07	1.00%
Perrine marl	26929.88	5.84%	Very poorly drained	C/D	0	27.76	0.50%
Udorthents-Water complex	19758.04	4.29%	Well drained	A	201	65	28.00 %
Biscayne marl, drained	17339.57	3.76%	Poorly drained	B/D	15	34.46	1.00%
Chekika very gravelly loam	16727.67	3.63%	Somewhat poorly drained	D	61	39	1.00%
Dania muck, frequently ponded, 0 to 1 percent slopes	14368.9	3.12%	Very poorly drained	A/D	8	86.7	0.50%
Water	14002.29	3.04%	0	C	201	0	0.00%
Perrine marl, drained	11901.91	2.58%	Poorly drained	C/D	0	25.99	0.50%
Biscayne marl	9685.76	2.10%	Poorly drained	B/D	15	33.38	0.50%
Perrine marl, tidal	8762.74	1.90%	Very poorly drained	C/D	0	12.61	0.50%
Terra Ceia muck, tidal	8600.49	1.87%	Very poorly drained	A/D	0	92	0.50%
Pahokee muck, depressional	7129.71	1.55%	Very poorly drained	A/D	0	90.9	0.50%
Udorthents, limestone substratum, 0 to 5 percent slopes	5108.29	1.11%	Moderately well drained	A	92	90.37	2.00%
Biscayne gravelly marl, drained	4879.32	1.06%	Poorly drained	B/D	15	42.64	1.00%
Hallandale fine sand, 0 to 2 percent slopes	4691.26	1.02%	Poorly drained	B/D	30	69.93	1.00%
Pennsuco marl	4332.38	0.94%	Poorly drained	B/D	15	26.15	0.50%
Opalocka sand-Rock outcrop complex	3774.85	0.82%	Well drained	D	152	157.2	1.00%
Margate fine sand, occasionally ponded, 0 to 1 percent slopes	3743.7	0.81%	Poorly drained	A/D	15	88.7	0.50%
Pennsuco marl, tidal	3536.58	0.77%	Very poorly drained	B/D	0	13	0.50%

Plantation muck	3418.13	0.74%	Very poorly drained	A/D	15	90.37	0.50%
Udorthents, marl substratum-Urban land complex	3155.88	0.68%	Somewhat poorly drained	B	92	38.28	1.00%
Pennsuco marl, drained	3043.33	0.66%	Poorly drained	B/D	15	25.05	0.50%
Tamiami muck, depressional	2764.57	0.60%	Very poorly drained	B/D	0	74.92	0.90%
Demory sandy clay loam-Rock outcrop complex	2371.34	0.51%	Poorly drained	C/D	15	26.94	1.00%
Cardsound silty clay loam-Rock outcrop complex	2256	0.49%	Well drained	D	168	40.35	1.00%
Dade fine sand	814	0.18%	Well drained	A	168	193.29	1.00%
Biscayne marl-Rock outcrop complex	711.93	0.15%	Poorly drained	B/D	15	50.5	1.00%
Matecumbe muck	643.55	0.14%	Moderately well drained	D	69	84.22	1.00%
Pomello sand	519.07	0.11%	Moderately well drained	A	84	110.95	3.00%
Basinger fine sand	226.77	0.05%	Poorly drained	A/D	15	92	1.00%
Waters of the Atlantic Ocean	130.26	0.03%	0	C	201	0	0.00%

2.1.7 Infiltration

Infiltration from pervious areas was computed in the modeling update using the Curve Number (CN) methodology described in USGS published “Urban Hydrology for Small Watersheds (TR-55)”. The CN is a dimensionless number depending on hydrologic soil group, cover type, treatment, hydrological condition, and antecedent moisture conditions. This number has a valid range from 0 to 100 with typical values between 60 and 90 for most encountered conditions and ranging up to 98 for impervious surfaces.

In XPSWMM, CN is applied only for the pervious area and the input for impervious area is restricted to the directly connected area. Internally, an area weighted composite number is generated using the input CN for the pervious area and 98 for the impervious area. Essentially, the entire sub-watershed area is subject to infiltration using this internally generated composite number. The remaining area within a sub-watershed is a combination of the actual previous area and the non-directly connected impervious area (NDCIA). Since there should be no infiltration under the NDCIA surface, a correction is applied to estimate a composite number for just the pervious surface. Soil data were obtained via the NRCS Web Soil Survey, [21]. For a large portion of the County, the NRCS provides a classification of “U” for urban land. As a result of urbanization, the underlying soil may be disturbed or covered by a new layer. In this case, the Type D (poorly draining) classification is substituted for the Type U as the dominant soil classification. Additionally, soil types with dual classifications (e.g., Type B/D) generally represent areas where there is a lens of poorly-drained soils lying above a section of better draining soils. Typically, the lower (Type-D) classification is used in the model, unless the soil is disturbed, such as a field of row crops where it is likely the upper lens has been penetrated.

Soil classification is based on Hydrologic Soil Groups (HSG). Typical soil classifications are Types A (>10 in/hr infiltration rate), B (7-10 in/hr), C (5-7 in/hr) and D (less than 5 in/hr). For fully developed urban areas (vegetation established), the CN values were obtained from Urban Hydrology for Small Watersheds TR-55 and summarized in the following table:

Table 6 CN values for land use and hydrologic soil group

Land Use	Hydrologic Soil Group			
	A	B	C	D
Urban Areas				
Open Space Poor Condition (grass cover < 50%)	68	79	86	89
Open Space Fair Condition (grass cover 50 to 75%)	49	69	79	84
Open Space Good Condition (grass cover > 75%)	39	61	74	80
Developing Urban Areas				
Newly graded areas (pervious only, no vegetation)	77	86	91	94

The hydrologic soil group listed for each map unit were used to derive the Curve Number (CN).

- **Group A** is sand, loamy sand or sandy loam types of soils characterized by low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.
- **Group B** is silt loam or loam with a moderate infiltration rate when thoroughly wetted and consists mainly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
- **Group C** soils are sandy clay loam with low infiltration rates when thoroughly wetted and consist mainly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
- **Group D** soils are clay loam, silty clay loam, sandy clay, silty clay or clay characterized by the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist mainly of clay soils with a high swelling potential, soils with a permanent high-water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

For model development, an Open Space Poor Condition (grass cover 50% to 75%) was used for assigning the CN values.

Three categories can be used to provide the impact of the preexisting soil conditions:

- ARC I (dry soils),
- ARC II (typical conditions)
- ARC III (saturated soil after heavy rainfall)

The model uses ARC II (typical conditions), and therefore no adjustments to CN values were performed based on antecedent moisture conditions. The soil layer HSG types were joined to the corresponding CN

values form Table 6, then spatially joined to the sub-watershed delineation to determine the weighted average CN value for each sub-watershed. Additionally, Land Use data were used to adjust the CN for NDCIA using the following formula:

$$CN_{NDCIA} = \frac{98 * NDCIA + CN * PERV}{\text{PERV} + \text{NDCIA}}$$

The NRCS method assumes that infiltration follows an exponential decay curve with time. Storage capacity of the soil, S (i.e., the potential maximum retention after runoff begins) is a dimensionless variable calculated from the curve number by:

$$S = \frac{1000}{\text{CN}} - 10$$

The initial hydrologic input data (primarily CN and DCIA) were additionally adjusted by inspecting each individual sub-watershed. Model revisions included adjustments to DCIA using USGS published impervious values in the National Land Cover Database (2014), and aerial inspection. Some CN values were adjusted within the range of +/- 10%, between poor and good conditions during calibration to reduce or increase computed runoff.

The SCS Curve number method was used to estimate infiltration rates, and the XPSWMM runoff method was used to develop the runoff hydrograph for each sub-watershed.

The model update uses the following additional hydrologic parameters:

- Initial Impervious Area Depression Storage (IDS): The initial value for the impervious area depression storage was generally set to be 0.1 inches.
- Initial Pervious Area Depression Storage (PDS): The initial baseline value of pervious area depression storage (PDS) is based on land use and generally is between 0.1 and 0.25 inches.
- Impervious Area Manning's Roughness Coefficient (IMPN): The value used for impervious area Manning's Roughness Coefficient (IMPN) was typically 0.015.
- Pervious Area Manning's Roughness Coefficient (PERVN): The value used for the pervious area Manning's Roughness Coefficient (PERVN) was typically 0.3. Manning roughness values are higher for runoff over pervious surfaces in the hydrologic model compared to similar surfaces in the hydraulic model. This is because the depth of flow for runoff is significantly less than the depth of flow in a canal, for instance. When the depth of flow is similar to the height of grass, roughness can be significant.

Testing of model results indicated that the model was not sensitive to these additional hydrologic parameters over the typical range of parameter values.

2.1.8 Groundwater

Groundwater baseflow supplies a significant portion of the flows in the Miami-Dade County canal system. Much of this flow is generated west of the modeled watersheds, as the groundwater flows west to east from the ENP to Biscayne Bay. These regional flows are modeled in the hydraulic layer with seepage (inflow) curves, not with the XPSWMM groundwater routines. However, local infiltration may also cause the groundwater table to rise to the ground surface. The SCS Curve Number method that was used to simulate infiltration processes provides an input hydrograph to the model's groundwater layer. The groundwater level is increased by the infiltration up to the ground elevation, and when the groundwater level reaches the surface, infiltration stops. Groundwater levels may also decrease due to groundwater outflow modeled by XPSWMM, which routes the groundwater flow to a previously defined node.

For sub-watersheds with large surface waterbodies, groundwater flows were directed to the sub-watershed (i.e., the groundwater outflow is combined with the sub-watershed's runoff). For all other sub-watersheds, the groundwater outflow was directed to receiving nodes that were the closest canal nodes in the groundwater flow direction taken from the average October water table contours. During storm events, groundwater levels respond rapidly due to the high transmissivity of the underlying Biscayne Aquifer. XPSWMM groundwater parameters were developed using engineering judgement and previous experience with models in Miami-Dade County to produce a groundwater table response that reasonably matches measured surface water hydrographs within the sub-watersheds. Work conducted by Prinos and Dixon in 2016 [39] provided statistical analyses and groundwater maps for the period 2000-2009.

Figure 5 shows the temporal and spatial variations in water levels in Miami-Dade County, Florida and covered the Biscayne aquifer, water conservation areas (WCAs), and the ENP. The values were used as the initial groundwater levels of the model. Well data from SFWMD's DBHYDRO and USGS were obtained for the entire period of record (1953-2020) and are in the process of analysis to provide:

- Review of historical records of groundwater elevation data, data reports, and relevant data, including relevant well parameters (depth of casing, reference elevation);
- Analysis for discrepancy and outliers;
- Conversion to ft NAVD 88 using published conversion factors (USACE, or SFWMD);
- Long-term trends of groundwater table elevations within the county and development of statistical summaries for daily, monthly, annual, and seasonal water table fluctuations;
- Analysis of exceedance and cumulative density, for the entire period and for seasonal variation (wet and dry season), spatial analysis and progression of historic changes;
- Development of maps showing annual averages for each decade, and average monthly elevation for the last decades;
- Data analysis to account for historic Sea Level Rise Impacts, correlating tidal and groundwater elevations;
- Correlations between coastal and groundwater elevations and determinations of the influence of the tidal water elevations on the groundwater elevations with contour maps showing correlation statistics between groundwater and tidal elevations; and,
- Extreme Value Analysis of the groundwater elevations for 5, 10, 25, 50, 100-year exceedances and generation of rasters and contours.

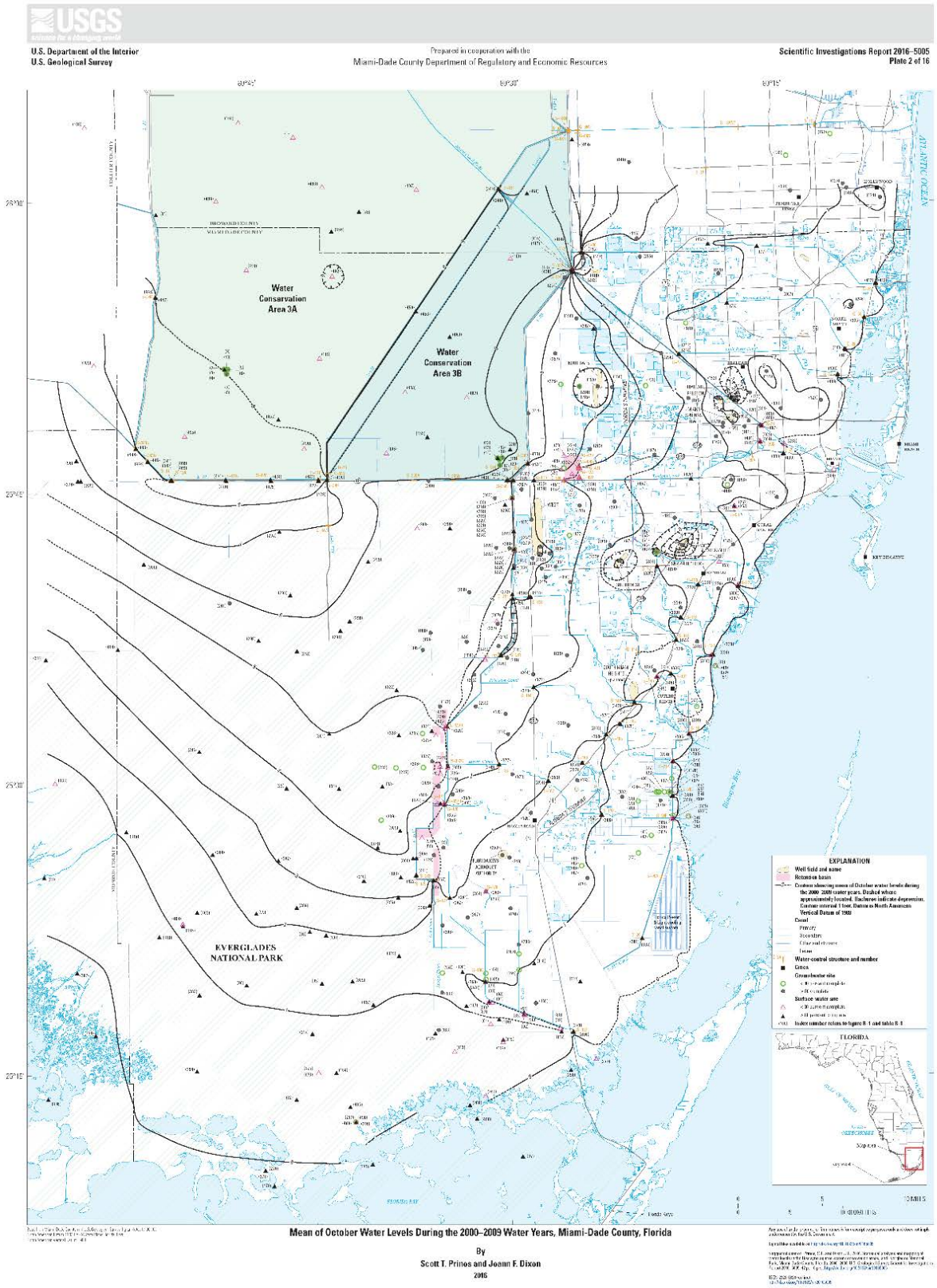


Figure 5 Mean of October Water Levels During the 2000–2009 Water Years

A geodatabase which contains information for each parcel has been developed and includes information for surface water observations, simulation results, topography, maximum observed rainfall, adjacency to infrastructure, surface water elevations for design storms, other previously collected hydrologic data developed for each parcel, and groundwater table elevations.

A global database record was created for the model sub-watersheds. The following lists describe some of the input variables that defined the groundwater portion of the model.

- Depth of Upper Zone (DWT1): Depth of the upper zone (depth to groundwater) is estimated as the depth from the ground to the average October water table level.
- Depth of Lower Zone (D1): The depth of the lower zone is calculated by adding the receiving channel depth (BC) plus the depth from channel bottom to aquifer base (BO). This variable is estimated using a constant aquifer depth throughout the watersheds.
- Channel Depth (BC): The channel depth is calculated by subtracting the receiving canal invert elevation from the October water table level.
- Depth from Channel Bottom to Aquifer Base (BO): This depth is estimated assuming a constant aquifer depth throughout the basin and limited to two times the width of the canal. The canal width is derived by averaging the width (distance from top of bank to top of bank) determined for several cross sections of the project's canals.

The Infiltration/Percolation Parameters are summarized below:

- Saturated hydraulic conductivity (HKSAT): typical value is 4 in/hr
- Porosity (PR): expressed as a fraction, typical values of 0.4
- Curve fitting parameter: typical value is 50
- Initial upper zone moisture (TH1): expressed as a fraction, typical value is 0.08
- Coefficient for unquantified losses (DP): typical value is 0.025 in/hr
- Average slope of the soil tension versus soil moisture curve (PCO): 0.05

Additional groundwater parameter values needed to solve the groundwater flow equation are as follows:

- Groundwater flow coefficient (A1)
- Groundwater flow exponent (B1)
- Channel water influence coefficient (A2)
- Channel water influence exponent (B2)
- Groundwater/Channel water coefficient (A3)

The model uses a linear approximation for groundwater flow (Q) where B1 = B2 = 1.0 and A3 = 0.0. In general, the values for A1 and A2 can be calculated by multiplying the hydraulic conductivity (K) by the depth of the lower zone and the ratio of the width of the groundwater flow area (A), to the length of the groundwater flow area and dividing by the sub-watershed area (I). These calculations intend to approximate the methodology to the concepts behind the Darcy Equation (Q = KIA).

2.2 Watershed Hydraulic Characteristics

The purpose of the hydrologic/hydraulic modeling of the canal watersheds is to develop flood discharges and stages for the main canals and their tributaries, and to estimate depth of flooding throughout the County.

Ten of the eleven modeled watersheds in the County outfall to Biscayne Bay through SFWMD Structures, which are gated salinity control structures. Most of these structures are in proximity to Biscayne Bay. However, a few of the SFWMD salinity control structures are located inland, primarily up the Miami River near the Miami International Airport to allow unimpeded navigation. The C-111 Watershed outfalls south to Florida Bay through a SFWMD Structure that is near the bay.

All primary canals and tributaries within the County are modeled in this Stormwater Master Plan Update. A list of the Primary Conveyance System Canals within Miami-Dade County is provided in Table 7:

Table 7 List of Primary Conveyance System Canals included in the SWMP models.

Canal	Watersheds	Length (miles)	Drain Area (mi^2)	Associated Structure(s)
C-1, C-1W, C-1N,	C-1, C-100, C-100B, SDCS	25.3	57	S21, S148, S338, S149, and S122, S173, S335, S336, S338, S331
C-100, C-100A, C--100B, C-100C	C-2, C-100, C-1	25.1	41	S118, S119, S120, S121, S123, S122
C-102, C-102N	C-102, C-111	20	25	S21A, S195, S194, S165
C-103, C-103S, C-103N	C-103, L-31N, C-111	23.5	41	S20F, S179, S167, S166,
(Dade County Canals**)	Dade County Canals, C-103	20.5	53	S20G, S20F, S20
C-111, C-111E, C-113	C-111, C-111E, C-113, L-31N, C-1	24	100	S331. S173, S194, S196, S176, S174, S332, S175, S177, S- 178, S18C, and S197
C-2	C-2, C-4, C-100, C-100C	12.65	53	S22, S121
C-3	C-3, C-4	7.57	18	G119, G97
C-4	C-4, C-3, C-2, C-5	16.7	61	S32A, S25B, S336, G119, S25A, S334
C-5	C-4, C-5, C-6	3.25	2.3	G119, S25A, S25
C-6 (Miami Canal)	C-4, C-6, C-5	20	69	S26, S31, G72 S32, S32A, S25B, S25
C-7	C-7, C-6	8.41	35	S27, G72
C-8	C-8	9.29	31.5	S28
C-9, C-9 EXT	C-9	19.6	98	S29, S30
South Dade Conveyance System (SDCS)	C-6, C-4. C-1; C-102, C-103,			S335, S151, S336, S337, S338

	C- 113, and C-111, C-304			
L-30	C-4, SDCS			S335, S32A, S337,
Dad-Broward Levee	C-4			
L-31N	C-4, C-1, C-102, C-103, C-111, SDCS	10.3		S335, S338, S194, S196, S173, S331, S176, S174
L-31E	Dade County Canals, C-103, C-111	18.8	58	S20
L-31W	C-111	11.2	879 (ENP)	S174, S332, S175,
L-29	C-1, C-4, C-102, SDCS	23.1	771 (WCA3)	S334, S333

Most of the canal reaches in the model are represented by cross-sections obtained from survey data completed in 2015 and provided by RER Water Management Division. A portion of canal reaches use legacy cross-sections from previous versions of the model or are estimated from aerial photographs and topography data. The limits of the reach are generally located at canal intersections, culverts, bridges, or where the geometry of the canal changes significantly. Canal reach lengths were measured using GIS, aerial photographs, or the XPSWMM "Calculate Length" option.

The primary and secondary drainage systems are modeled using the hydraulics block of the model. The hydraulics block uses nodes and links to define the hydraulic network. Nodes are also referred to as junctions in the hydraulics module of XPSWMM.

2.2.1 Model Nodes

The parameters defining model nodes include invert elevations, ground (spill crest) elevations, initial depths, storage node data flags, and outfall data flags. Nodes with the storage flag checked are generally provided stage-storage-area curves as discussed in Section 2.1.3. A small amount of constant storage (typically 100 square feet) may also be provided to model nodes to provide numerical stability. The model nodes with outfall flags activated are used to provide boundary conditions to the model.

The numerical models use storage curves above inlets to estimate flood depth, and overland flow links to allow floodwater to be conveyed between sub-watersheds, as such the spill crest elevation cannot be set at ground level. The modeled spill crest should be higher than the rim of the storage curve and the highest point of all connecting overland flow links. For these models, the spill crests are set above ground to not interfere with these above-ground model elements. In lieu of using an initial surface water elevation for every model node, uniform initial starting elevations are applied to the sub-watersheds using the hydraulic job control "Initial Water Surface Elevation". For example, if this is set at 0.4 feet NAVD 88, the model will start the simulation with all water levels at elevation 0.4 feet NAVD 88, in all nodes, except for those where an initial elevation was set higher than this value (behind a structure for instance).

2.2.2 Model Links

Model links may represent channels (canals, streams, ditches, etc.), bridges, culverts, pipes, weirs, orifices, pumps, rating curves (seepage), gated structures, and overland flow links. The links are identified by their conduit name. A link is defined as a connection between two nodes. Links cannot exist without nodes at the end points and have a sense of direction indicated by an arrow line. However, XPSWMM is a dynamic model and thus allows for backflow in model links. If the hydraulic grade produces flow in the opposing direction to the initial setup (arrowed direction), the flow is simply reported as negative values. Two types of links were used:

- Single conduit link: This represents a drainage path between nodes such as a circular pipe, rectangular pipe, trapezoidal section or an open channel of any cross-section, including natural shaped cross-sections.
- Multiple conduit links: multiple conduit links may be representative of:
    - Pipes or culverts with 2 or more barrels (typically with differing size or inverts, otherwise the number of barrels parameter would be used in a single conduit link).
    - Pipes or culverts parallel to an overland flow link.
    - Diversion Links: an alternative flow path between nodes, such as a weir, orifice, pump or special rating curve.

Canals: Natural channel shapes are defined by cross-sections which are station/elevation pairs measured normal to the direction of flow. Stationing is from left to right as the observer is looking downstream. Natural channels or canals are segmented so the cross-section for the segment is representative of the entire reach between upstream and downstream nodes. Each cross-section link is associated with a natural channel reference in the XPSWMM's global database.

Multiple links may use the same channel reference (i.e., the same cross-section) if the shape and roughness values have not changed. The flow area between the banks uses the main channel Manning's roughness value. The areas outside of the banks use a left bank and right bank Manning's roughness value, respectively for these overbank floodplain areas. Generally, the overbank roughness values are higher than the main channel, but in some cases may be lower, such as when the floodplain includes a paved area.

The County watersheds are modeled with sub-watershed delineation boundaries very close to the channel banks, and storage nodes with stage-storage elevation curves often representing floodplain areas. This is because the primary and secondary canals often have berms separating the main channel from the historic, pre-development floodplains. Since the models are too large to properly implement the 2-D capabilities of XPSWMM, these canals were modeled by using overland links to intermittently pass water back and forth between channels and floodplains over the berms. The cross-section of the overland flow link represents the top of berm, generally for the length of the adjacent sub-watersheds.

Bridges: Bridges are modeled similarly to a short section of channel, if the lower elevation of the bridge deck is above the likely peak flood level in the canal. Thus, the flow under the bridge cannot become pressurized. However, if the bridge deck is low enough to impede flow, a closed conduit is used to represent the bridge. Often a parallel overland flow link accompanies the closed conduit bridge link, to model water that may flow over the bridge deck.

Culverts: The comprehensive culvert inventory supplied by the RER Water Management Division was used to enter the culvert data into the model. Culvert inventory included length, material, diameter, invert elevations and headwall information for all culverts within the basin. Most culverts were assigned an entrance loss of 0.5, though depending on the headwall, entrance loss may range from 0.5 to 1.0. For culverts exiting to moving water an exit loss of 0.5 was provided to the link. For culverts exiting to still water, an exit loss of 1.0 was provided to the link.

Pipes: The comprehensive pipe inventory supplied by the RER Water Management Division was used to enter the pipe data into the model. The pipe inventory generally included length, material, diameter, and invert elevations for all pipes within the basin. Entrance and exit losses for pipes are set in the hydraulic job control at 0.3. Additional exit losses were added to pipes with internal bends and pipes that connect to the downstream system at an angle. For pipes exiting to moving water (i.e., a canal reach) an exit loss of 0.5 was provided to the link. For pipes exiting to still water, an exit loss of 1.0, was provided to the link.

Overland Flow Links: In County model updates, depth of flooding and movement of flood waters is controlled by two methods: stage-storage area curves in the storage nodes, and overland flow conduits. Overland flow conduits convey flood waters when the subsurface stormwater system is overwhelmed by a large volume and/or a high intensity storm. In some neighborhoods, the storage and conveyance of floodwaters in streets is a feature of the stormwater system and therefore it was included in the modeled updates. Because the above-ground storage is accounted for in the storage nodes, the overland flow links have minimal storage and act as irregular weirs between sub-watersheds. There is generally a hydraulic boundary between two sub-watersheds, such as a (relative) high point in a road, a major road centerline crossing, or the berm between the canal and floodplain. A (flat) weir may be used to represent the boundary between the sub-watersheds, but typically the boundary is irregular and therefore, the overland flow link is represented by a cross-section representative of the street or other defined boundary between the sub-watersheds. The length of these channels is typically short (< 50 feet) to minimize additional storage while maintaining computational stability. The cross-section widths are on the order of 50 to 300 feet (though some may be much wider). Flow occurs in these links when ponding on either side of the link reaches the height of the topographic boundary (e.g., road crown, curb, and landscape berm). During high intensity storm events, surface ponding is prevalent and flow transfer can occur from one sub-watershed to another.

Weirs: Weirs are implemented in the model at the locations of smaller (non-gated) structures and occasionally at the ends of slab covered trenches, where data is found in the County GIS coverages.

Pumps: The SFWMD operates multiple pumps which are included in the models along with local municipality pump stations. Where pump curves of rate vs water level elevation were not available, the station capacity is used as a constant rate. For design storm simulations, there is not expected to be a significant variation in flow rates when the pumps are operating, since the head difference is relatively low. The pump on/pump off elevations were determined from observed data unless other data were provided by the SFWMD.

Exfiltration: Miami-Dade County has extensive exfiltration systems, primarily consisting of slab covered trenches, French Drains, and gravity wells (vertical French Drains). For the modeling update purposes, generalizations were made on the effectiveness of each system, based on length of trench and/or number of wells. Conservative estimates of saturated hydraulic conductivity, depth and width were applied to each system to get an approximate rating curve for each sub-watershed, based on SFWMD equations. The

rating curve diversion or the XPSWMM "Special Pump" diversion was used to drain water from the sub-watersheds based on the calculated rating curves.

Baseflow: Miami-Dade County experiences groundwater baseflow in the Biscayne Aquifer from west to east (from the Everglades Conservation Areas to Biscayne Bay). Generally, surface water stages are maintained in the conservation areas using a series of berms. However, since the underlying Biscayne Aquifer is highly transmissive, there are large groundwater baseflows associated with the gradient between these stages and the Bay. Because the primary and secondary canals are incised into the aquifer, the baseflows contribute to canal flow. The updated models use rating curve diversions to simulate the baseflow from west to east. However, not all the contribution to flow is at the west end of the watersheds' systems and multiple locations were used to spread this baseflow contribution.

The model networks include more than 10,000 links. The following parameters were used in the hydraulic module of XPSWMM in the update, for the pipes and channels:

- Length: the conduit length, in feet. This information was based in the Miami-Dade County Stormwater Atlas.
- Shape: shape of pipe or link: circular, rectangular, arch, semi-circular, natural, trapezoidal, elliptical, and user-defined (bridge). This information was based in the Miami-Dade County Stormwater Atlas. Additionally, multi-link diversions may include pumps, orifices, weirs, and "special" links.
    - Special Links: the following special links are used for simulating real time control in the drainage network: inflatable weirs, bendable weirs, special pumps, and internal rating curves.
- Diameter (or Height): diameter of the circular conduit, in feet. This field also represents the height of the conduit for non-circular shapes. This information was based in the Miami-Dade County Stormwater Atlas.
- Width: width of pipe or link (not used for circular pipes or natural, multi-link or special shapes). This information was based in the Miami-Dade County Stormwater Atlas.
- Slope: the bottom slope of pipe or channel. It is calculated by the model, based on pipe invert elevations or natural cross section bottom elevations.
- Roughness Coefficient (Manning): Conduit roughness as described by Manning's n for all pipes shapes, and open trapezoidal and open rectangular conduits. A range of Manning's n values were used, depending on the pipe materials and the open conduit bottom material. For natural shapes, the Manning's n values are provided with the transect data.
- Cross-section Coordinates (only applied to natural shapes): are entered as an array of x-coordinate positions in feet and elevations at each coordinate entry in feet. The arrays are taken from the nearest survey data.
- Left and Right Overbank Positions: (only applied to natural shapes) the overbank positions (in feet) are the x-coordinate positions which are assigned as the top of the bank positions.
- Left and Right Overbank Manning's Roughness Coefficients: (only applied to natural shapes) the Manning's Roughness Coefficient for the cross-sectional area from the left side of the transect to the left overbank station; and the Manning's Roughness Coefficient for the cross-sectional area from the right overbank station to the right side of the transect.
- Main Channel Manning's Roughness: (only applied to natural shapes). The Manning's Roughness Coefficient for the cross-sectional area between the bank stations. Note that this value overrides

the link roughness provided above. Manning's n was used as a calibration parameter and a range of values can be expected, depending on vegetation coverage and channel bottom characteristics.

- Upstream and Downstream inverts - the upstream and downstream invert elevations for pipes, culverts and equalizers were obtained through as-built drawings and surveys. The inverts for channels were estimated from the cross-sections, where available. The upstream invert for the overland flow links were estimated from the low point of the hydraulic ridge between sub-watersheds. The downstream invert is typically set at a slightly lower elevation for numeric stability.

For the update, model pipe roughness values were estimated based on clean, maintained systems. Therefore, reinforced concrete pipes (RCP) were assigned Manning's roughness values of 0.013 and corrugated metal pipe (CMP) roughness values was set to 0.024. For open channels, roughness values for channel centers ranged from approximately 0.025 to 0.06 based on level of vegetation and engineering judgment. Roughness in the overbanks ranged from 0.015 to 0.12 based on level of vegetation and engineering judgment. For overland flow links, roughness values ranged from 0.02 to 0.1 depending on whether flow was over concrete or asphalt, vegetation, or a combination of both. As previously discussed, most of the canal links are not provided wide floodplains in these models; therefore, the models are not sensitive to canal overbank roughness values.

2.2.3 Control Structures

The SFWMD operates multiple control structures and water level gauges within Miami-Dade County. The District provides records of gate operation schedules headwater and tailwater elevations at each structure. A description of these structures is included in report sections describing the individual watershed models (Sections 2.6 through 2.16, from the SFWMD operation Control Center Structure Books).

Structure information include gate opening size, invert elevation, seasonal operations, and the estimated design flow rate. The reported flow is an estimate based on headwater, tailwater and rating curves. For calibration in this update, gates were modeled with time-varying orifices to simulate the observed operation. However, for design storm simulations, most of the gates were modeled as fully open because the SFWDM generally locks the gates in open positions prior to large storms. The remaining gates were modeled as completely closed, based on operational guidelines that require the gates to be closed during wet weather events.

2.3 Model Calibration and Validation

Recent hydrologic data from Hurricane Irma (September 2017) was selected for calibration of the models to predict flood water levels and flow during major storm events. The waterhsed models were calibrated to observed data records from SFWMD control structure stage gauges and estimated control structure discharges (SFWMD estimates discharge based on headwater, tailwater and rating functions).

Model input parameters were adjusted as necessary to obtain output that closely matches calibration targets of observed data. The calibration process is a critical step model development to improve the level of confidence in design event simulations for current and future conditions. Because the primary interest of the model is to predict flood water levels and flow during major storm events, it was necessary to

choose a major storm event that occurred in the recent past to adequately calibrate/verify the models. For each calibration target the following metrics were calculated:

- BIAS (systematic difference between observed and computed values, accepted are values between 0.2 and -0.2 ft);
- Mean Absolute Error (MAE – errors between paired observed and computed values, accepted are values less than 0.2 ft);
- Root Mean Square Error (RMSE - square root of the average of squared errors);
- Standard Deviation (STD - standard deviation of its sampling distribution);
- Correlation (COR – ratio of computed and observed standard deviations, accepted are values above 0.8) ;
- Nash-Sutcliffe Efficiency (NS - defined as one minus the ratio of the error variance of the modeled time-series divided by the variance of the observed time-series, accepted are values above 0.8); and,
- Percent Explained Variance (PEV – defined as the proportion to which the numerical model accounts for the variation of observed data, accepted are values above 0.8).

Additionally, the difference between peak maximum and the timing were calculated.

2.3.1 Model Boundaries

For calibration of the models, recorded water levels at the tailwater of the basin outfalls' SFWMD Salinity Control Structures were used as stage-elevation boundary conditions. For some models, the location of the furthest downstream control structure was upstream in the watershed. In that case, the recorded tailwater was still used as the boundary condition for the upstream area tributary to the station and an estimate of the sea level elevation in Biscayne Bay was used as the boundary condition for the area downstream of the structure. For most of the models with upstream control stations, the SFWMD stage record at Station MRMS4 (located near the mouth of the Miami River at Brickell Avenue) was used to simulate stages in Biscayne Bay.

For design storm models, a sinusoidal time series representing tidewater in Biscayne Bay (Manatee Bay in the case of the C-111 Watershed) is set as the boundary condition at the mouth of each watershed.

2.3.2 Calibration Rainfall Data

Calibration rainfall data were obtained from the South Florida Water Management District database (DBHYDRO). Fifteen-minute interval historical rainfall records for each of the rainfall stations located within or near the watersheds were obtained from the SFWMD's DBHYDRO database. The locations of model calibration rainfall gauges within and in the vicinity of Miami-Dade County are shown in Figure 6.

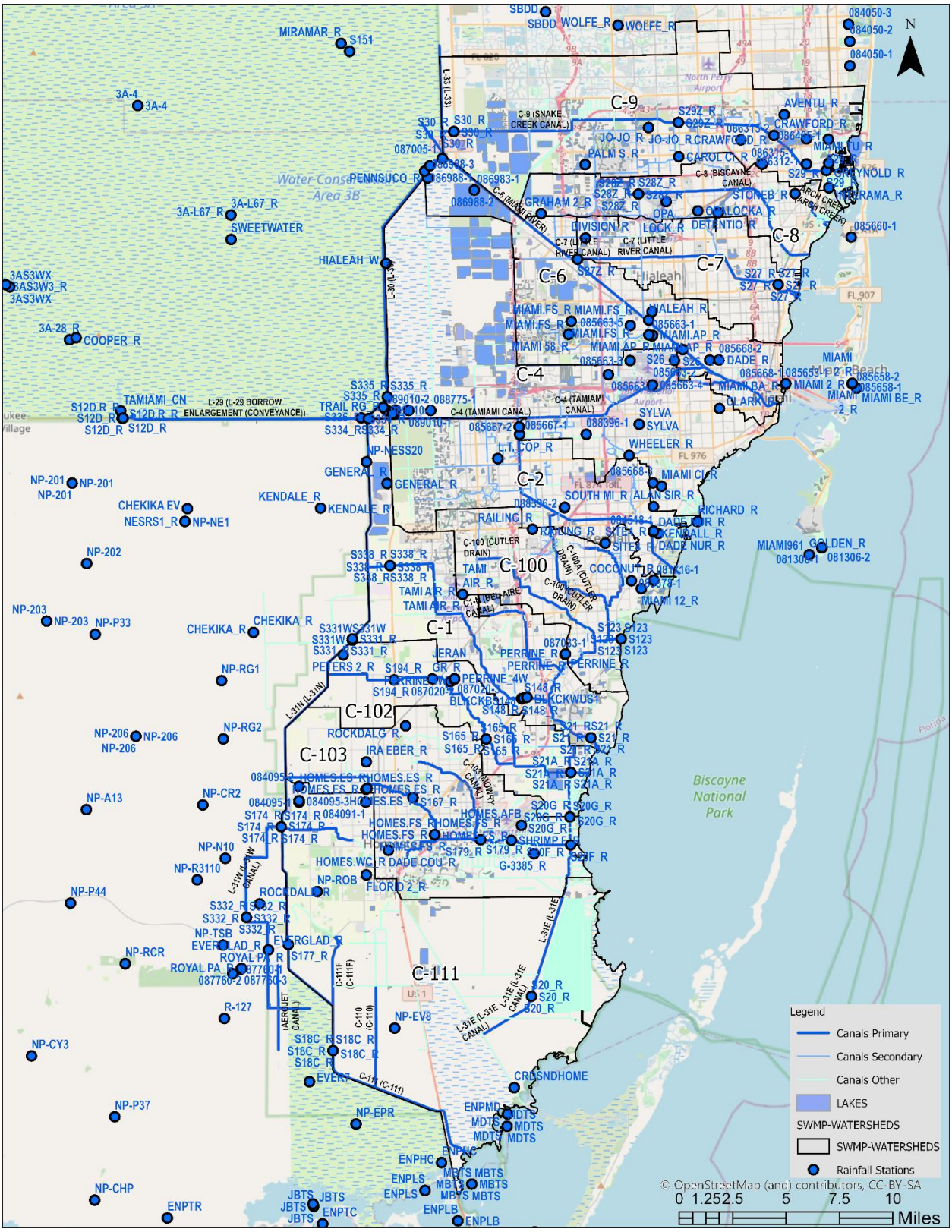


Figure 6 Locations of Calibration Rainfall Gauges

2.4 Design Events

2.4.1 Rainfall

After calibration, the models were used to develop a series of design event simulations to predict flows and stages within each watershed. The predicted stages (magnitude and duration) indicate the flooding levels of service, and the predicted flow volumes provide information to assess the capacity of the stormwater system. The results of these production runs are summarized below as “baseline” conditions.

Standard hydrologic and hydraulic study methods were used to determine the flood hazard data required for this study. Flood events of a magnitude that are expected to be equaled or exceeded at least once on the average during any 5-, 10-, 25-, 50-, 100-, 500- or 1000-year period (recurrence interval) have been selected as having special significance for floodplain management and for flood insurance rates. These events, commonly termed the 5-, 10-, 25-, 50-, 100-, 500-, and 1000-year floods, have a 20%, 10%, 4%, 2%, 1%, 0.2%, and 0.1% annual chance, respectively, of being equaled or exceeded during any year.

Rainfall hyetographs for the design events are based on NOAA Atlas 14, which provides precipitation frequency estimates based on historical records for rainfall volumes per storm, and the SFWMD 24-hour and 72-hour rainfall distributions. NOAA’s statistical analysis [1] did not discern an increasing trend in precipitation frequency over the available 70-year rainfall datasets for Miami-Dade County. Furthermore, the Fourth National Climate Assessment report [34] estimated that the projected changes in seasonal and total annual precipitation for our region of South Florida would be minimal and less than 5%. The rainfall volume data obtained from NOAA was applied as a multiplier to the unit hydrograph of SFWMD’s rainfall distribution curves as input boundary condition for simulating design events and computing peak water surface and depth of inundation on a 5-ft grid.

The design events use the calibrated watershed models and the stages and flows that occur for various storm events, under both existing and future land use conditions. The predicted stages (magnitude and duration) indicate the flood level of service and the predicted flow volumes provide an assessment of the capacity of the stormwater system. The results of these production runs are referred to as “baseline” conditions.

2.4.2 Tidal Data and Sea Level Scenarios

Recorded Sea Levels for station 8723214, Virginia Key, Biscayne Bay FL in September 2017 are shown on Figure 7. Data show that the highest recorded levels during Hurricane Irma were approaching 3.84 ft NAVD 88 on September 10, 2017.

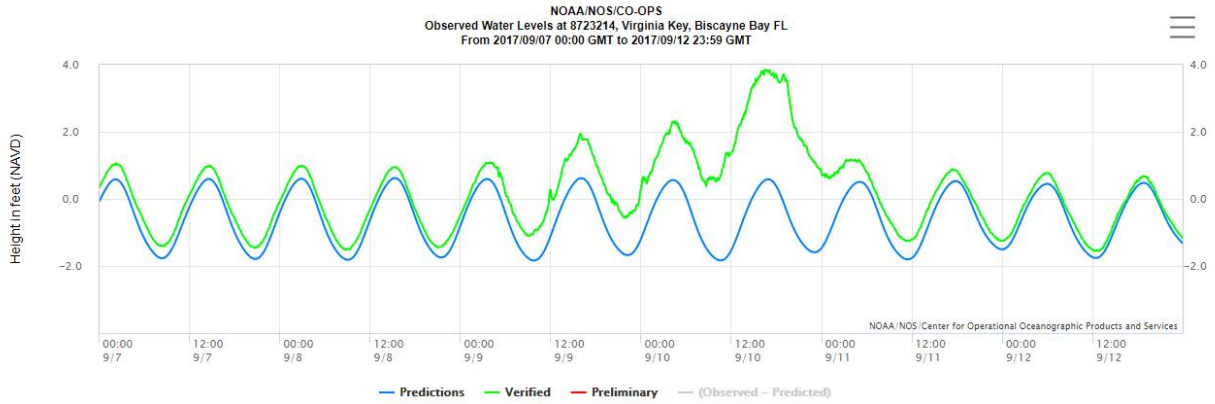


Figure 7 September 2017 Tidal Elevation at Virginia Key, Biscayne Bay FL

Data from NOAA for Virginia Key Station ID 8723214 were downloaded for the available period of record for years 1996-2020 grouped on annual basis and analyzed to determine current tide levels and historical changes of the sea level. Figure 8 shows the selected probability exceedance curves for SLR.

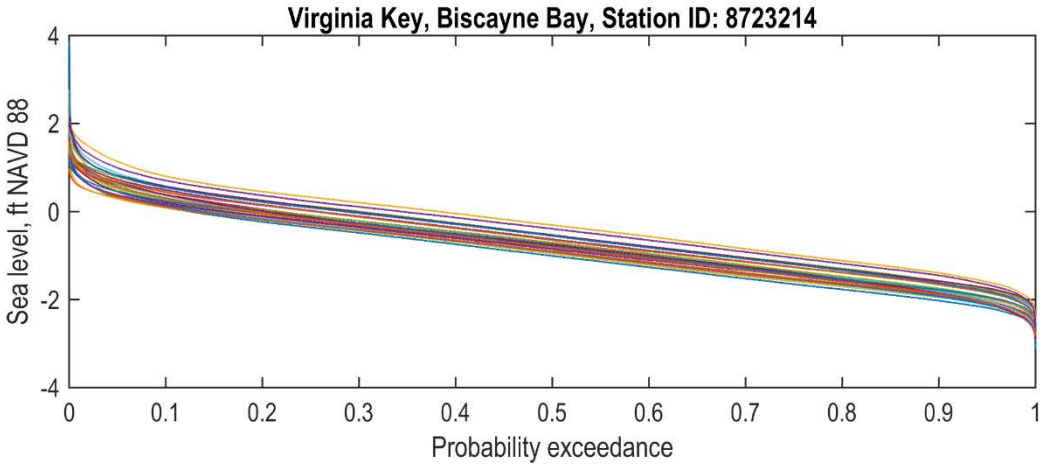


Figure 8 Selected Probability Exceedance curves for Sea Level Rise

This data used more than 2,165,800 points to provide statistical analysis of the historical data including nearly 86,000 observations per year (6-minute intervals):

- The probability exceedance (PE) curves for each year were determined and selected years were plotted (Figure 8)
- The PE values of 0.01, 0.05, 0.10, 0.25, 0.50, 0.75, 0.90, 0.95, and 0.99 were extracted and listed in Table 8
- Trends in the data are shown on Figure 9. (Note that for this station ft NAVD 88 is 0.87 ft. lower than ft MSL)

The data demonstrates that the 1% exceedance for the current conditions (2020 based on analysis including data to December 31, 2020) is approximately 1.52 ft NAVD 88. 1% exceedance means that for 3.65 days of the year the tidal water elevations are greater than 1.52 ft NAVD 88.

Table 8 Probability Exceedance Values of Observed Data at Virginia Key in ft NAVD 88

Year	Max	1%	5%	10%	25%	50%	75%	90%	95%	99%	Min	Total Annual Observations
1996	1.37	0.80	0.33	0.09	-0.36	-1.01	-1.65	-2.03	-2.19	-2.46	-3.12	87840
1997	0.98	0.59	0.32	0.12	-0.28	-0.93	-1.56	-1.91	-2.09	-2.35	-2.70	78971
1998	1.74	0.62	0.29	0.09	-0.31	-0.95	-1.59	-1.95	-2.10	-2.34	-2.67	80160
1999	2.76	1.03	0.61	0.38	-0.09	-0.73	-1.37	-1.76	-1.95	-2.26	-2.70	87600
2000	1.59	0.98	0.54	0.28	-0.14	-0.78	-1.41	-1.81	-1.98	-2.25	-2.61	87840
2001	1.43	0.97	0.45	0.17	-0.28	-0.90	-1.53	-1.94	-2.13	-2.48	-2.92	87596
2002	1.48	0.94	0.46	0.21	-0.22	-0.85	-1.45	-1.86	-2.06	-2.37	-2.83	87600
2003	1.22	0.79	0.37	0.14	-0.30	-0.91	-1.53	-1.93	-2.11	-2.45	-2.91	87600
2004	1.53	0.81	0.35	0.10	-0.30	-0.91	-1.52	-1.88	-2.06	-2.34	-2.91	87840
2005	2.78	1.06	0.50	0.24	-0.18	-0.78	-1.38	-1.77	-1.97	-2.28	-2.75	87600
2006	1.41	0.80	0.38	0.17	-0.24	-0.86	-1.45	-1.84	-2.03	-2.31	-2.76	87600
2007	1.60	1.09	0.62	0.36	-0.09	-0.70	-1.35	-1.75	-1.93	-2.21	-2.61	87600
2008	1.92	1.12	0.65	0.36	-0.13	-0.75	-1.39	-1.82	-2.03	-2.37	-2.84	87840
2009	1.63	1.10	0.66	0.38	-0.13	-0.75	-1.39	-1.86	-2.08	-2.44	-2.91	87600
2010	1.75	0.84	0.46	0.24	-0.16	-0.79	-1.42	-1.78	-1.95	-2.20	-2.77	87600
2011	1.43	0.98	0.57	0.31	-0.18	-0.81	-1.46	-1.87	-2.08	-2.42	-2.81	87600
2012	2.16	1.26	0.70	0.46	0.01	-0.63	-1.27	-1.65	-1.82	-2.12	-2.62	87840
2013	1.70	1.14	0.73	0.49	0.02	-0.63	-1.26	-1.64	-1.81	-2.06	-2.41	80640
2014	1.54	1.13	0.79	0.55	0.12	-0.53	-1.17	-1.58	-1.77	-2.02	-2.42	87600
2015	2.05	1.41	0.87	0.58	0.11	-0.54	-1.20	-1.64	-1.81	-2.08	-2.46	87600
2016	2.09	1.35	0.82	0.57	0.12	-0.54	-1.18	-1.58	-1.74	-2.00	-2.39	85076
2017	3.86	1.32	0.82	0.55	0.09	-0.55	-1.20	-1.62	-1.81	-2.12	-2.52	87600
2018	1.60	1.07	0.68	0.44	0.01	-0.65	-1.26	-1.66	-1.84	-2.15	-2.55	87600
2019	2.19	1.66	1.14	0.80	0.33	-0.31	-0.98	-1.39	-1.60	-1.92	-2.52	87600
2020	2.18	1.52	0.99	0.71	0.23	-0.39	-1.05	-1.45	-1.66	-1.99	-2.66	87827

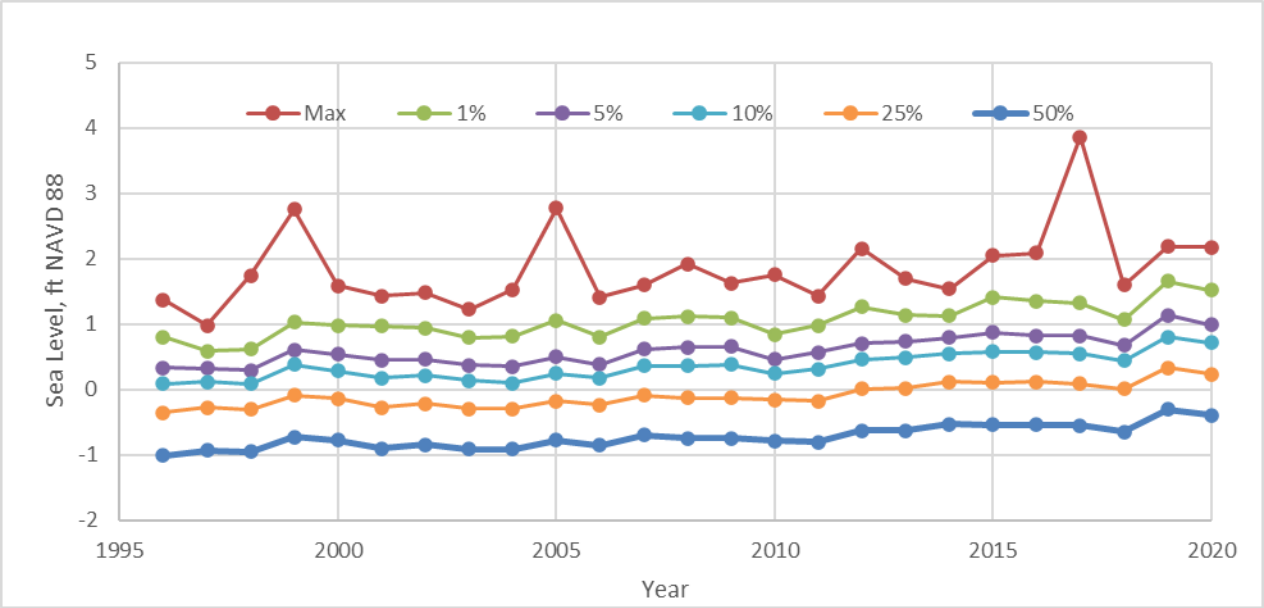


Figure 9. Annual changes of probability exceedance values for Virginia Key observed data

Data for the Key West station since year 1914 shows that the highest sea level of 3.03 ft NAVD 88 was recorded in year 2005. Annual maximum elevations of sea levels are shown on Figure 10.

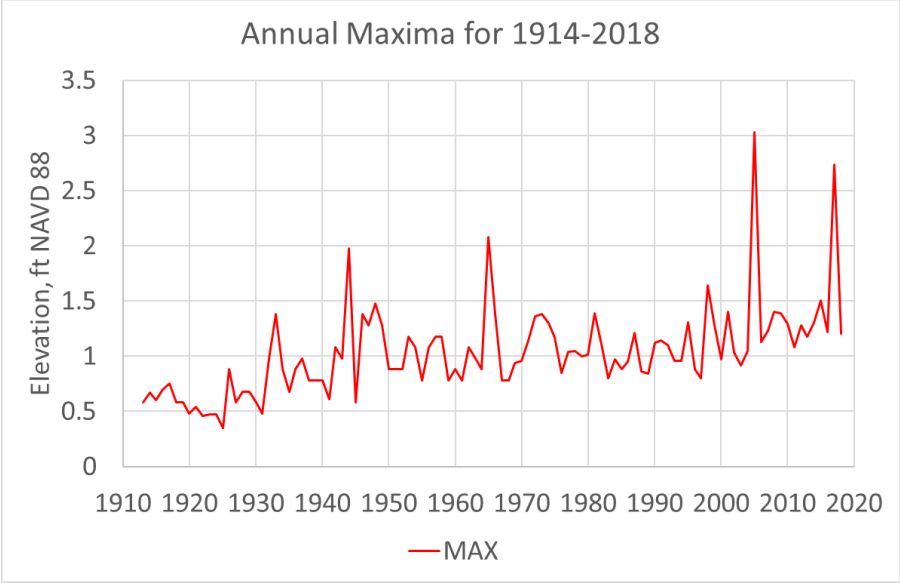


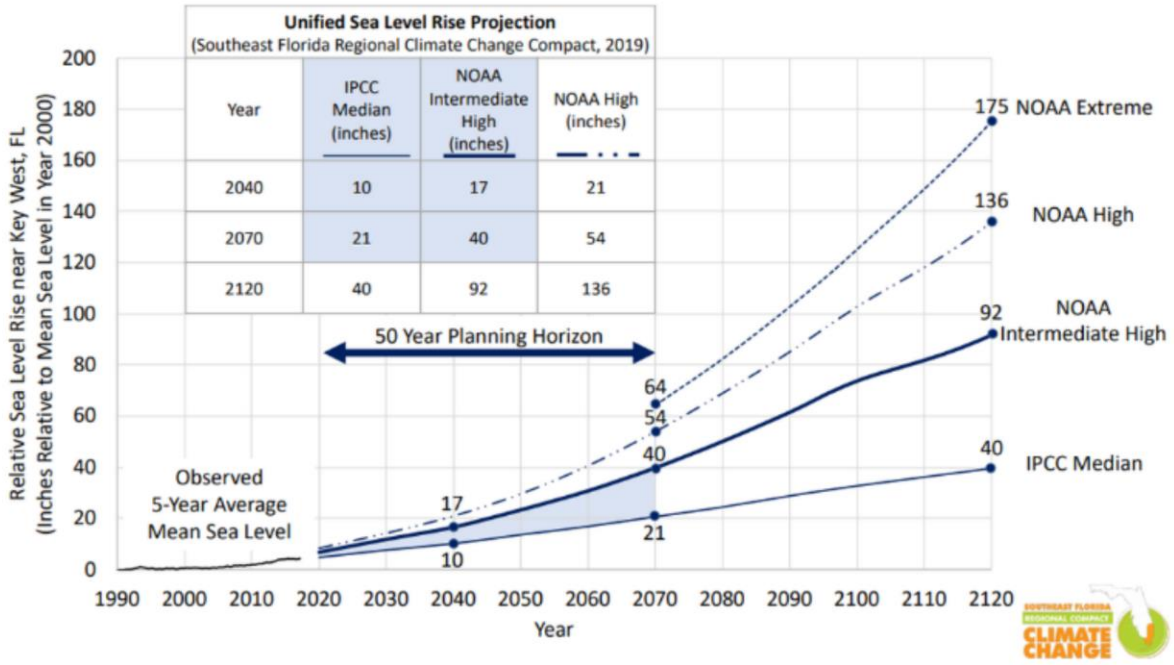
Figure 10. Annual maximum elevations of sea levels for the period 1914-2020 at Key West

The current condition tidal elevation is the observed median sea level (MSL) for the current NOAA epoch (ending in 2001), adjusted by adding the first harmonic constituent obtained from the Virginia Key NOAA tidal station.

To determine the boundary elevation at the outfalls, the following methodology was applied for existing conditions (2020 models):

- Based on the 50% probability exceedance for 2020, the median elevation of sea levels for current conditions is -0.39 ft NAVD 88, for the last 10 years the average of the 50% median is -0.56 which was used as current base elevation.
- Using the first harmonic constituent (M2) of the tidal fluctuation observed in Virginia Key, 0.978 ft amplitude was added to the median sea level elevation for 2020.
- Therefore, existing condition (2020 models) use a sinusoidal time series with amplitude of 0.978 ft a max elevation of 0.39 and a min elevation of -1.57.

The Unified SLR Projections from the Southeast Florida Regional Climate Change Compact from 2015 and subsequent revision in 2019 (see Figure 11) were utilized for the future SLR scenarios at the watershed boundaries. Using the increments from the compact projections, the NOAA Intermediate High curve was used as a conservative approach to add SLR for 2040, 2060, 2080 and 2100 simulations. (Figure 11). The figure indicates that in comparison to 1992, a SLR of up to 18 inches (IPCC Median) to 40 inches (NOAA High) can be expected for year 2060. Compared to 2020 levels, a SLR of approximately 14 inches to 32 inches can be expected for year 2060. All SLR increase estimates are computed based on the difference between future projections and sea levels in 1990.



Scientists with the Southeast Florida Regional Climate Change Compact updated 2015 sea level rise predictions for 2019. These projections guide development in the counties. *SOUTHEAST FLORIDA REGIONAL CLIMATE CHANGE COMPACT*

Figure 11. Unified Sea Level Rise Projections from 2019

Design Events for Future Hydrologic Conditions: Because future land use has not been projected past 2030 and future groundwater levels have not been projected past 2040, for all future conditions, the MDC

future land use (2030) and projected future ground water (2040) were used to address potential climate change conditions beyond those time periods. Model simulations for SLR include one for present conditions (2020) and four future scenarios:

i. **Year 2040** with outfall boundary conditions relevant to projected SLR in 2040 (tidal conditions for 2020 +0.5 ft of SLR), the MDC future land use (2030) and projected future ground water (2040);
ii. **Year 2060** with outfall boundary conditions relevant to projected SLR in 2060 (tidal conditions for 2020 +2.0 ft of SLR), the MDC future land use (2030) and projected future ground water (2040);
iii. **Year 2080** with outfall boundary conditions relevant to projected SLR in 2080 (tidal conditions for 2020 +4.0 ft of SLR), the MDC future land use (2030) and projected future ground water (2040);
iv. **Year 2100** with outfall boundary conditions relevant to projected SLR in 2100 (tidal conditions for 2020 +6.0 ft of SLR), the MDC future land use (2030) and projected future ground water (2040);

For each of the boundary conditions shown in Table 9, ten simulations were used to develop flood maps for 24-HR storms with recurrence intervals of 5-, 10- and 25-year and for 72-HR storms with return frequencies of 5-, 10-, 25-, 50-, 100-, 500- and 1000-year. The outfall conditions to the Biscayne Bay shown in Table 9 reflect potential SLR using NOAA's Intermediate High rate, which is slightly greater than the USACE high rate of SLR.

Table 9 Projected water elevations SLR scenarios (2040, 2060, 2080 and 2100) in feet above the observed median sea level in 2020 (estimated -0.38 ft NAVD 88)

Year	Sea Water Level increase in ft above the 2020 median	Sea Water Level Increase in inches above the 2020 median
2040	+0.5	+6
2060	+2.0	+24
2080	+4.0	+48
2100	+6.0	+72

2.5 Independent Quality Assurance/Quality Control Reviews

Independent QA/QC reviews were performed for technical and regulatory adequacy, completeness of required information, and supporting data and documentation. The reviews focused on, but not limited to, the use of acceptable models, use of appropriate methodologies, comparison with gauge data and/or regression equation if appropriate, and comparison with discharges for contiguous reaches or flooding sources throughout the watershed.

The independent QA/QC reviews included reviews of digital profiles of the 20% (5-year), 10% (10-year), 4% (25-year), 2% (50-year), 1% (100-year), and 0.2% (500-year) annual storm events, metadata files, digital hydraulic modeling (input and output) files, digital tables with ranges of input parameters (e.g. Manning's "n" values), and explanations for unresolved messages from XPSWMM, as appropriate.

A written detailed summary report was provided by the independent reviewers that describes the model update, findings of the independent QA/QC reviews, and recommendations to resolve any problems that were identified during the review.

2.10 C-7 Watershed (Little River Canal)

In this update, the C-7 model has been extended to cover 36.07 square miles and include the coastal area previously not included east of I-95 (2.34 square miles). The model has been updated for current hydrologic and hydraulic conditions. Eight incorporated municipalities intersect the C-7 Watershed, including El Portal, Hialeah, Hialeah Gardens, Miami, Miami Lakes, Miami Shores, North Miami, and Opa-Locka along with unincorporated areas.

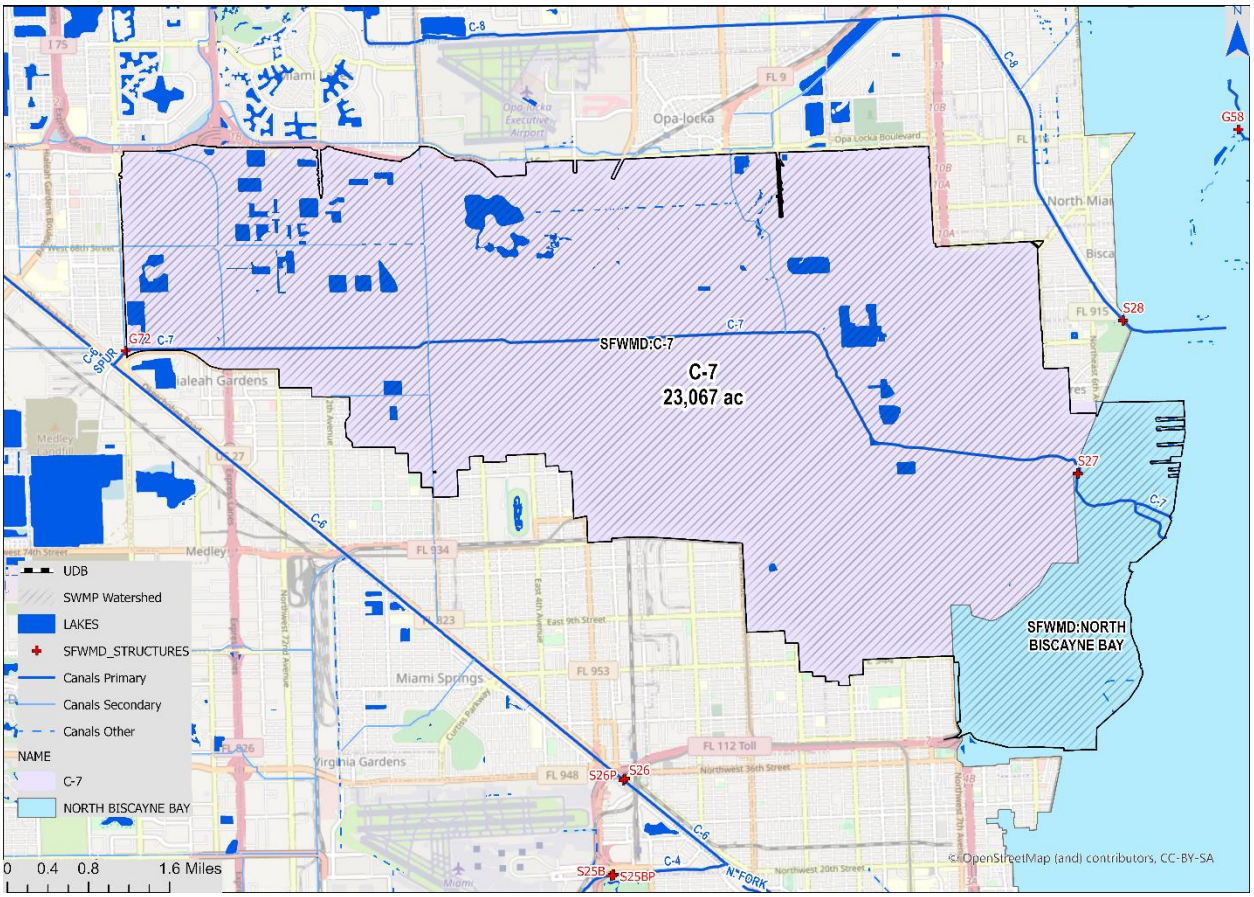


Figure 93 Coverage of SMWP C-7 Watershed and Corresponding SFWMD Watersheds (North Biscayne Bay and C-7)

The C-7 Watershed is entirely within the urban boundary. The major land use and land cover categories according to the FLUCCS classifications (based on Level 1 - the top-level designation in the hierarchical coding scheme, SFWMD [41]) within and outside of the urban boundaries are listed in Table 10. A portion of the C-7 Watershed west of the Palmetto Expressway is in Area B. Area B has limited drainage capability and is subject to limitations on development.

The main Land Use and Land Cover categories are listed in Table 42. More than 93% is in category Urban and Built Up, and the remaining two categories of Water and Agriculture are respectively 4% and 3% each.

Table 42 Land Use and Land Cover FLUCCS Level 1 categories for watershed C-7

FLUCCS Category and Code	Watershed Total (square miles)
Agriculture: 2000	1.03
Upland Forests: 4000	0.05
Upland Non-forested: 3000	0.02
Urban and Built Up: 1000	33.52
Water: 5000	1.44
Wetlands: 6000	0.01
Total	**36.07**

2.10.1 C-7 Watershed Hydrology

The C-7 Watershed is located in northeastern Miami-Dade County. C-7 is the only Primary canal in the C-7 Watershed. C-7 is a bifurcation of C-6, beginning one mile west of the intersection of West 49th Street (Hialeah) and the Palmetto Expressway. Flow in the canal is to the east with discharge via SFWMD Structure S27 to North Biscayne Bay. The canal has two functions:

1. Provide flood protection and drainage for the C-7 Watershed and
2. Maintain a groundwater table elevation adequate to prevent saltwater intrusion into local groundwater.

The portion of the C-7 Watershed west of the Palmetto Expressway is in an area which is characterized as poorly drained and is subject to limitations on development. If the stage in C-6 or C-8 is high or low enough, water will flow between C-7 and C6 and C-8 by way of the borrow canal along the Palmetto Expressway and Red Road Canal.

C-7 was designed to pass the runoff from a 100-year storm. However, much of this watershed (west of Red Road) was in agricultural production at the time the canal was designed and constructed. Subsequent development of the area to residential and commercial properties have significantly increased the runoff and decreased the flood protection provided by the canal. The location for S27 was chosen so that the canal could be used to raise local water table elevations high enough to prevent saltwater intrusion into local groundwater.

2.10.1.1 Sub-watershed Delineation

The C-7 Watershed is subdivided into 201 sub-watersheds ranging in size from 0.27 to 724 acres, with a mean size of 113 acres. Generally, sub-watershed delineation is determined from topography and the location of inflows to the PSMS, i.e., inlets, catchments, and tributary canals. The C-7 Watershed sub-watershed delineation is shown in Figure 110.

The runoff generated from each sub-watershed is calculated from rainfall, infiltration, groundwater, evapotranspiration, and other model parameters reflecting the hydraulics and hydrology of the watershed. Primary model parameters related to the sub-watershed include area, slope, width, length,

infiltration capacity, and DCIA. The average overland slope of the sub-watersheds was estimated based on averaging up to three representative flow paths, depending on sub-watershed shape. The slope is calculated based on flow path length, and upstream and downstream ground elevations, using GIS tools. The sub-watershed width was calculated by dividing the sub-watershed area by the average flow path length.

DCIA values were obtained from the USGS National Land Cover Database, land-use, and aerial photography. Impervious area was primarily derived from land use and compared to the USGS reported coverage. Additionally, local inspection of aerial photography was used to revise the impervious value of a given sub-watershed where land use and the USGS values showed a significant difference. The USGS coverage and aerial inspection provides the total impervious area of each sub-watershed; however, the model input is a lesser value comprised of only the directly connected impervious area. Examples of impervious areas which are not directly connected, include roof areas where the rainfall is directed to a pervious yard. Therefore, these are impervious areas where the runoff is directed to a pervious area, prior to entry to the PSMS. For master-planning purposes, land-use (see Section 2.1.4) is used to determine approximate percentages of DCIA versus non-DCIA. For modeling purposes, water bodies and wetlands are provided 100% DCIA values.

2.10.1.2 Watershed Topography

The DEM described in Section 2.1.1 was used to develop stage-storage area relations for each sub-watershed, to delineate the sub-watershed boundaries, to develop overland flow transects between sub-watersheds, and to modify other vertical geometric parameters of the area to provide most realistic vertical elevation for the model. The C-7 Watershed topography is shown in Figure 95.

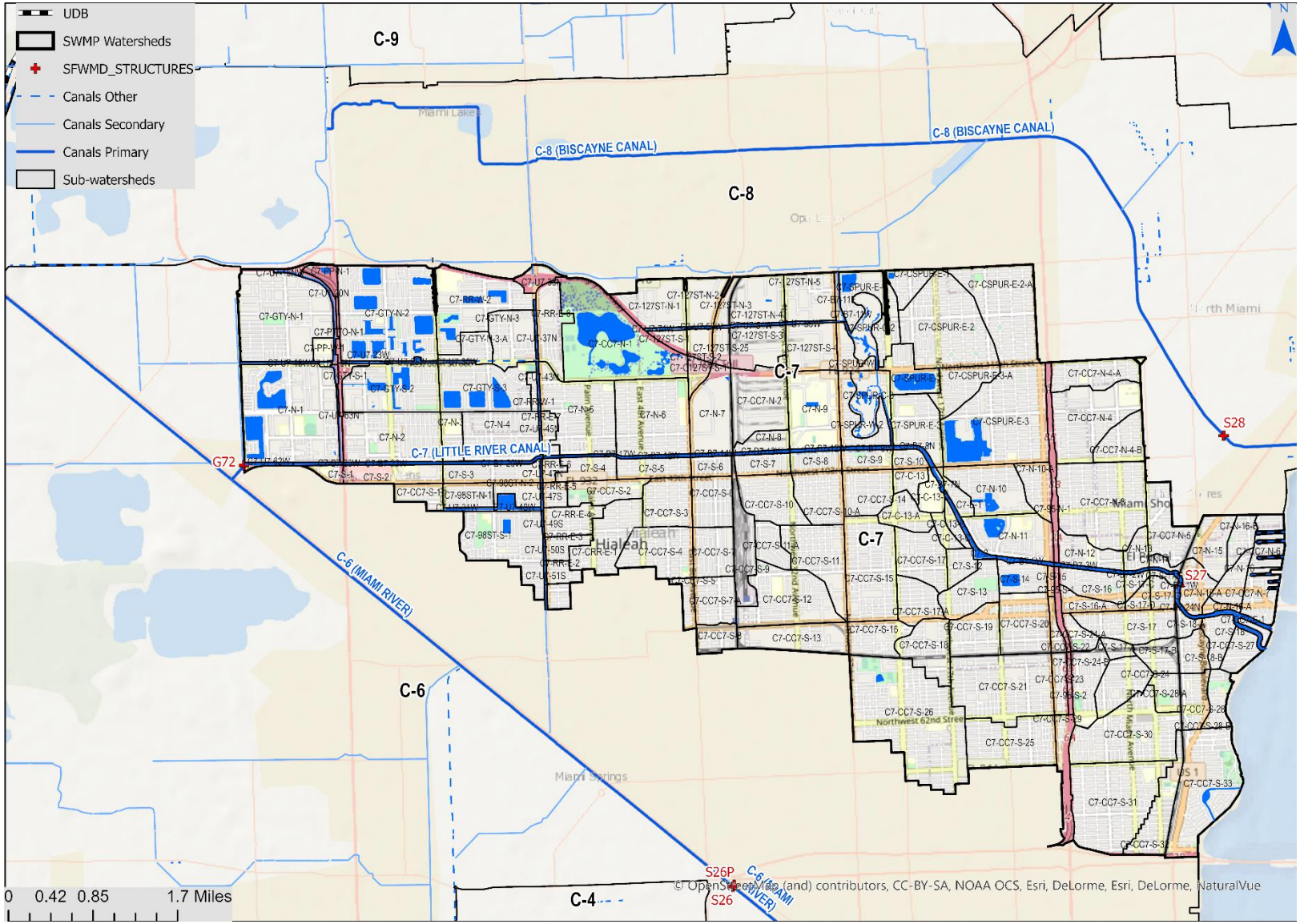


Figure 94 C-7 Sub-watershed delineation

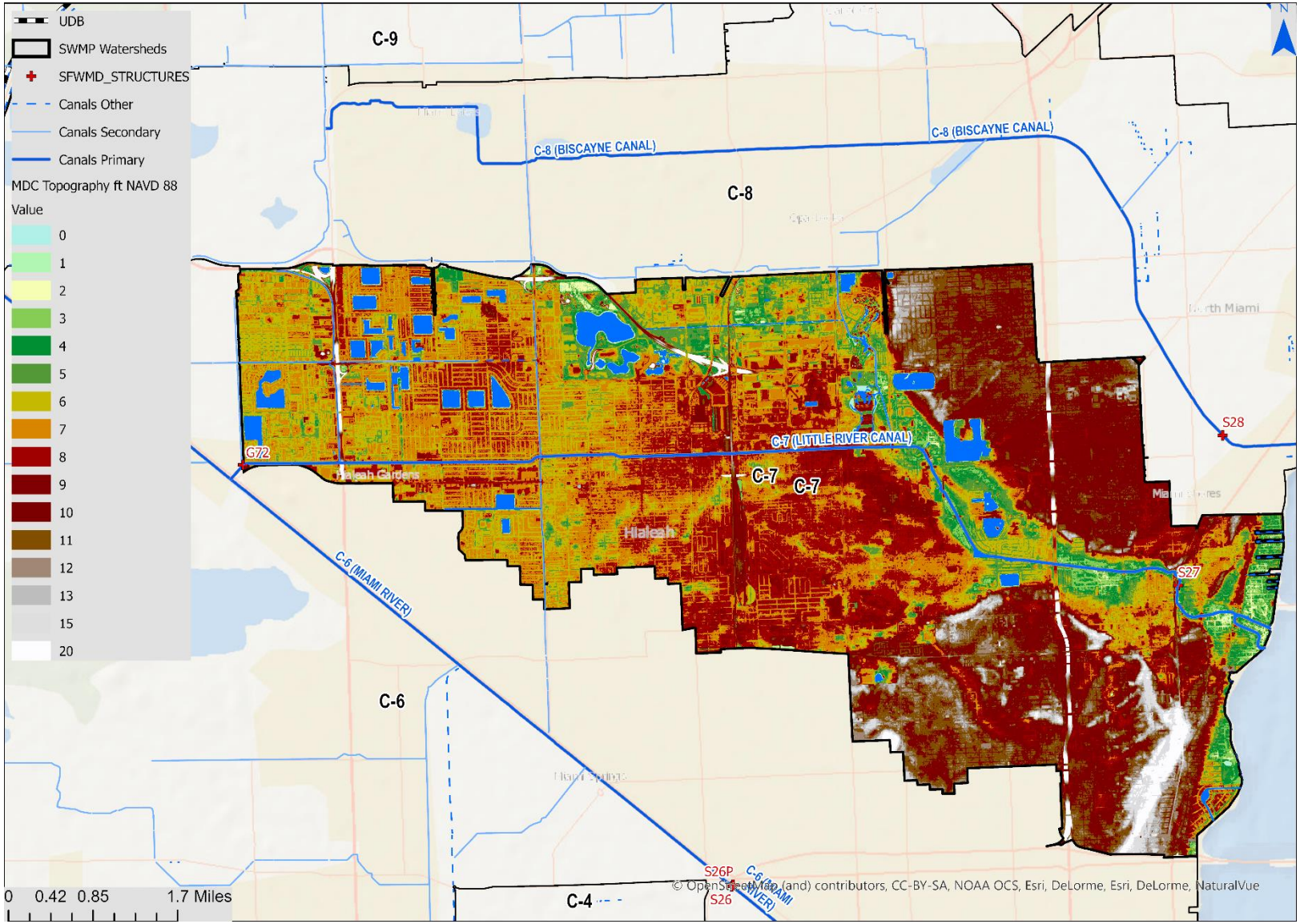


Figure 95 C-7 Watershed Topography

2.10.1.3 Land Use Information

The existing and future land use information published in the CDMP is used to develop estimates for the DCIA parameter required by XPSWMM to model infiltration and stormwater runoff from each sub-watershed. CDMP is published as a geodatabase and as printable map at http://www.miamidade.gov/planning/maps.asp for current (2014) and future (projected for 2030) conditions. There are approximately 101 different land use codes in the Miami-Dade County classification system. The Land use maps for current (2014) and future (projected for 2030) conditions are shown in Figure 97 and Figure 98, respectively. The land-use codes have been grouped to ten major categories (such as medium density residential, industrial, etc.) to approximately estimate the ratios between model parameter DCIA and the measured total impervious areas.

2.10.1.4 Land Cover and Imperviousness

Watershed imperviousness was obtained from Land Use information obtained from Miami Dade County's planning department and the application of typical total impervious areas and Directly Connected Impervious Areas values per land use. The Imperviousness values were compared to USGS published imperviousness using remote sensing data from the most recent NLCD and adjusted as needed.

2.10.1.5 Soils Information

The soil types within the watershed were determined from the USDA NRCS Soil Survey. The primary soil types are Urban land, 0 to 2 percent slopes, Margate fine sand, Plantation muck.

Table 43 Major soil types within the watershed

Soil Type	Acres	Percentage
Hallandale fine sand, 0 to 2 percent slopes	97	0.42%
Margate fine sand, occasionally ponded, 0 to 1 percent slopes	185	0.80%
Plantation muck	714	3.09%
Udorthents, limestone substratum, 0 to 5 percent slopes	4	0.02%
Udorthents, limestone substratum-Urban land complex	201	0.87%
Udorthents-Water complex	264	1.14%
Urban land, 0 to 2 percent slopes	20151	87.35%
Water	1454	6.30%

Dominant soil type is Urban Land (87%) defined as land covered by more than 70-percent impervious urban development such as airports, shopping centers, parking lots, large buildings, streets, sidewalks and/or other structures, so that natural soil is not readily observed.

As discussed in Section 2.1.7, Urban Land are treated as poorly draining prior to adjustments made during calibration, if necessary.

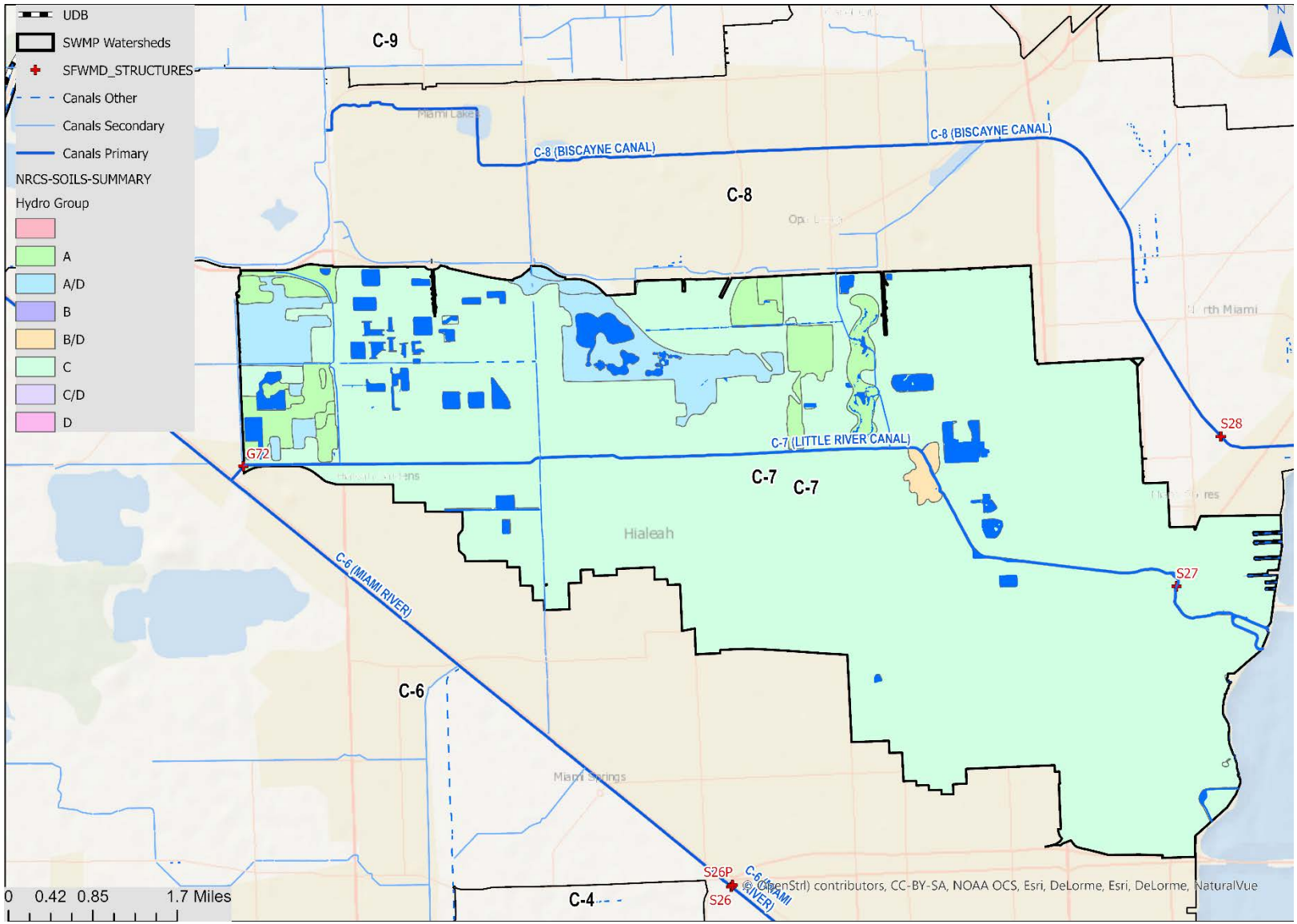


Figure 96 Soil Hydrologic Group Coverage within Watershed C-7

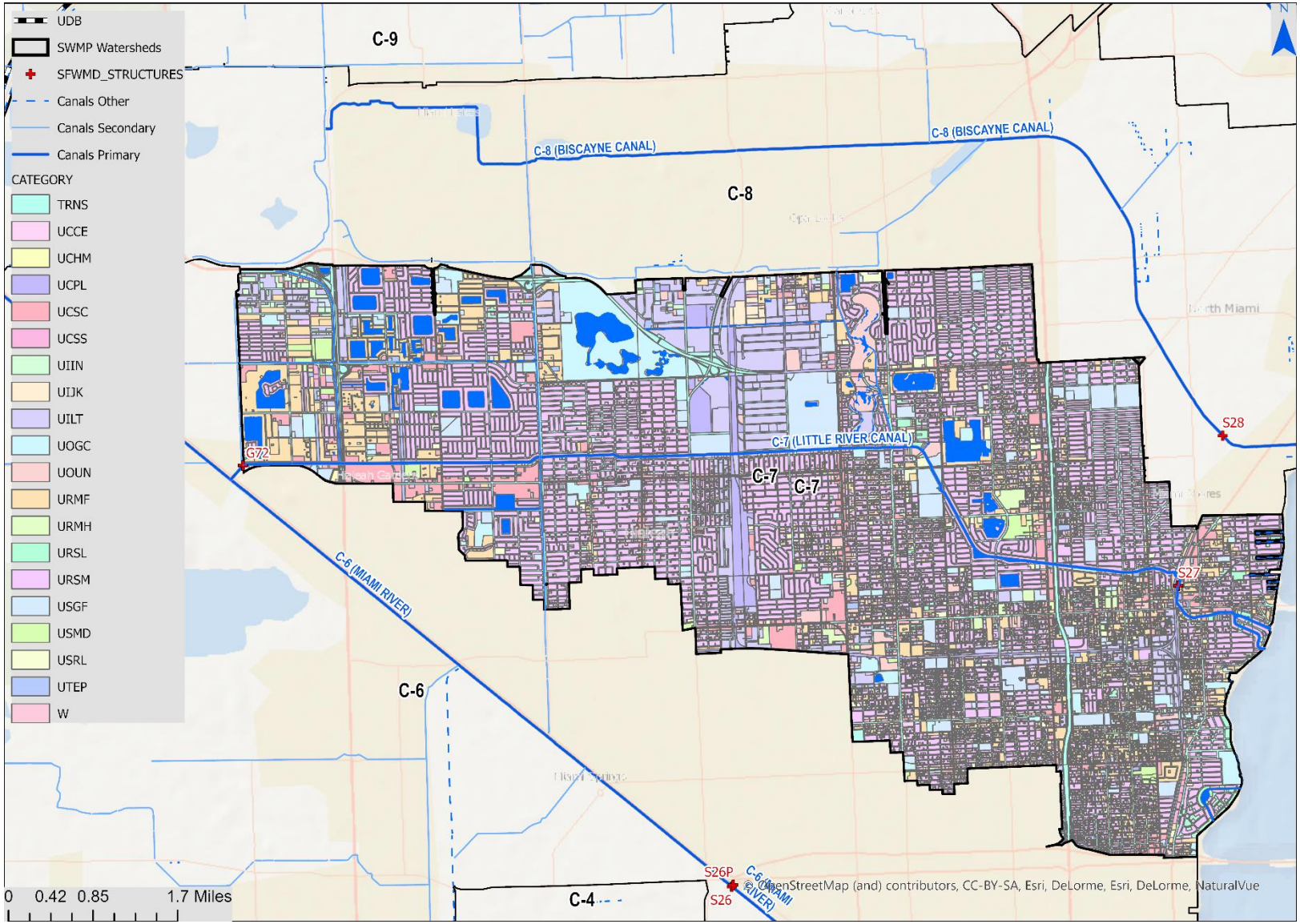


Figure 97 Miami-Dade County Existing Land Use

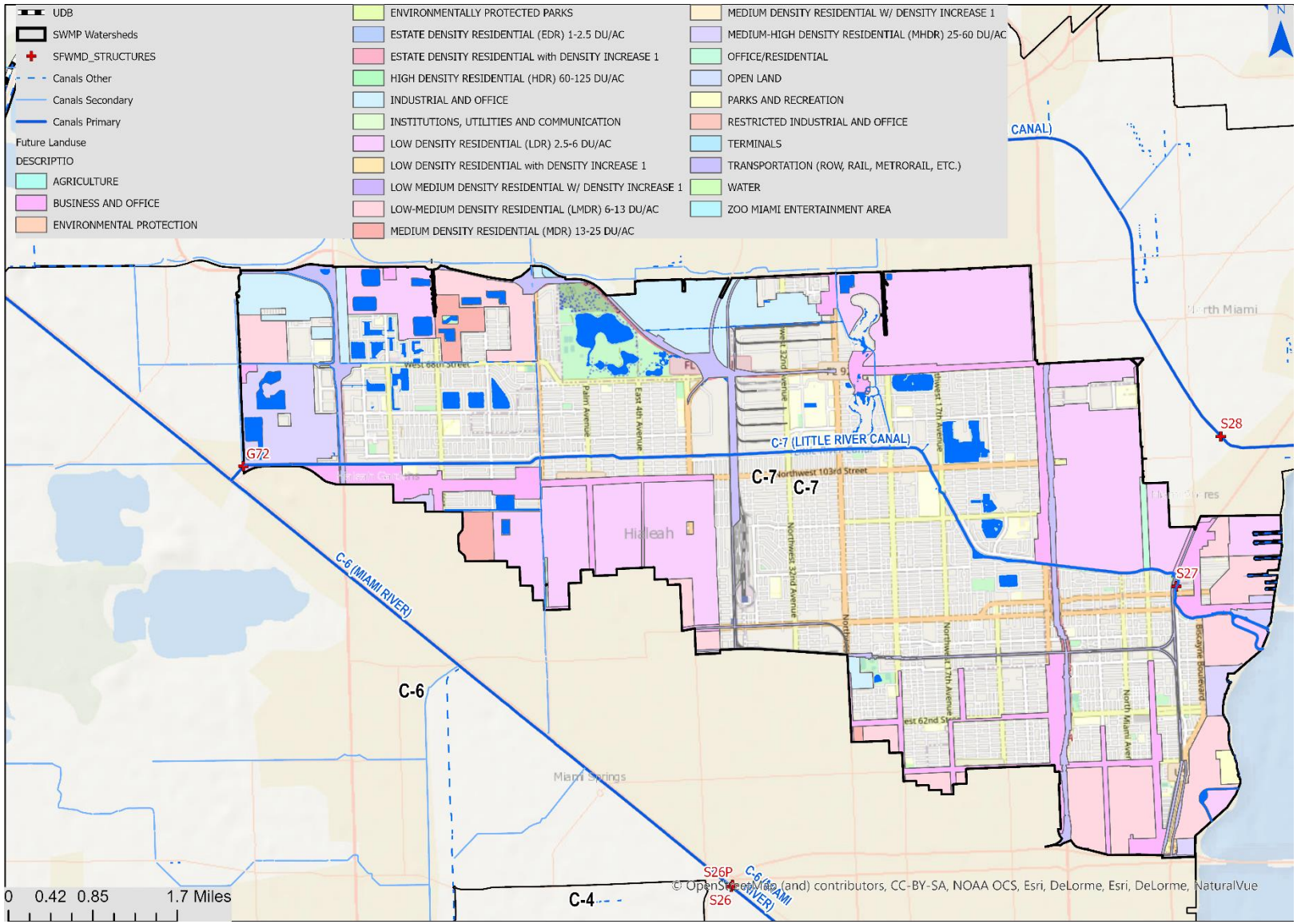


Figure 98 Miami-Dade County Future Land Use (2030)

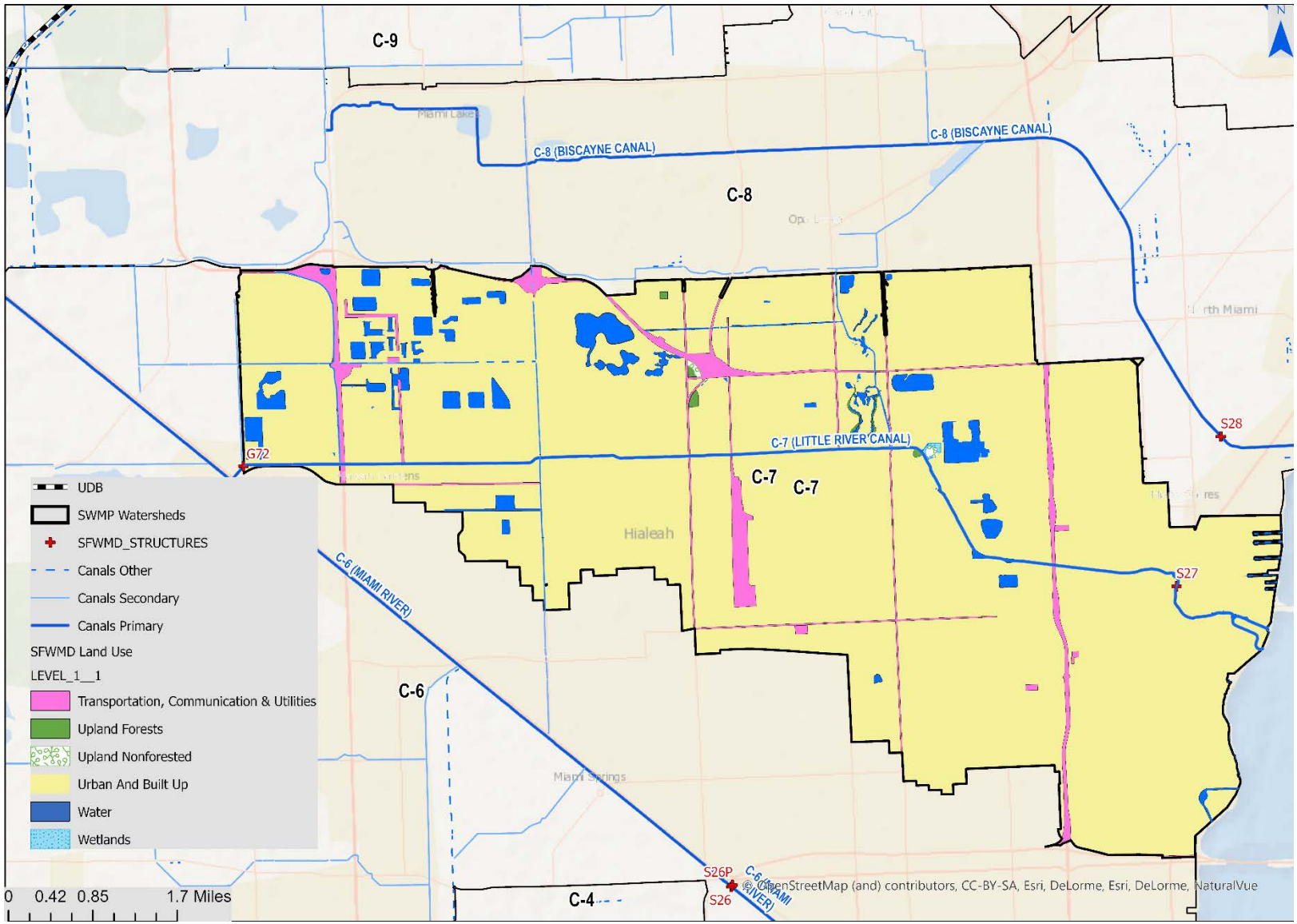


Figure 99 SFWMD Land Use and Land Cover FLUCCS Level 1

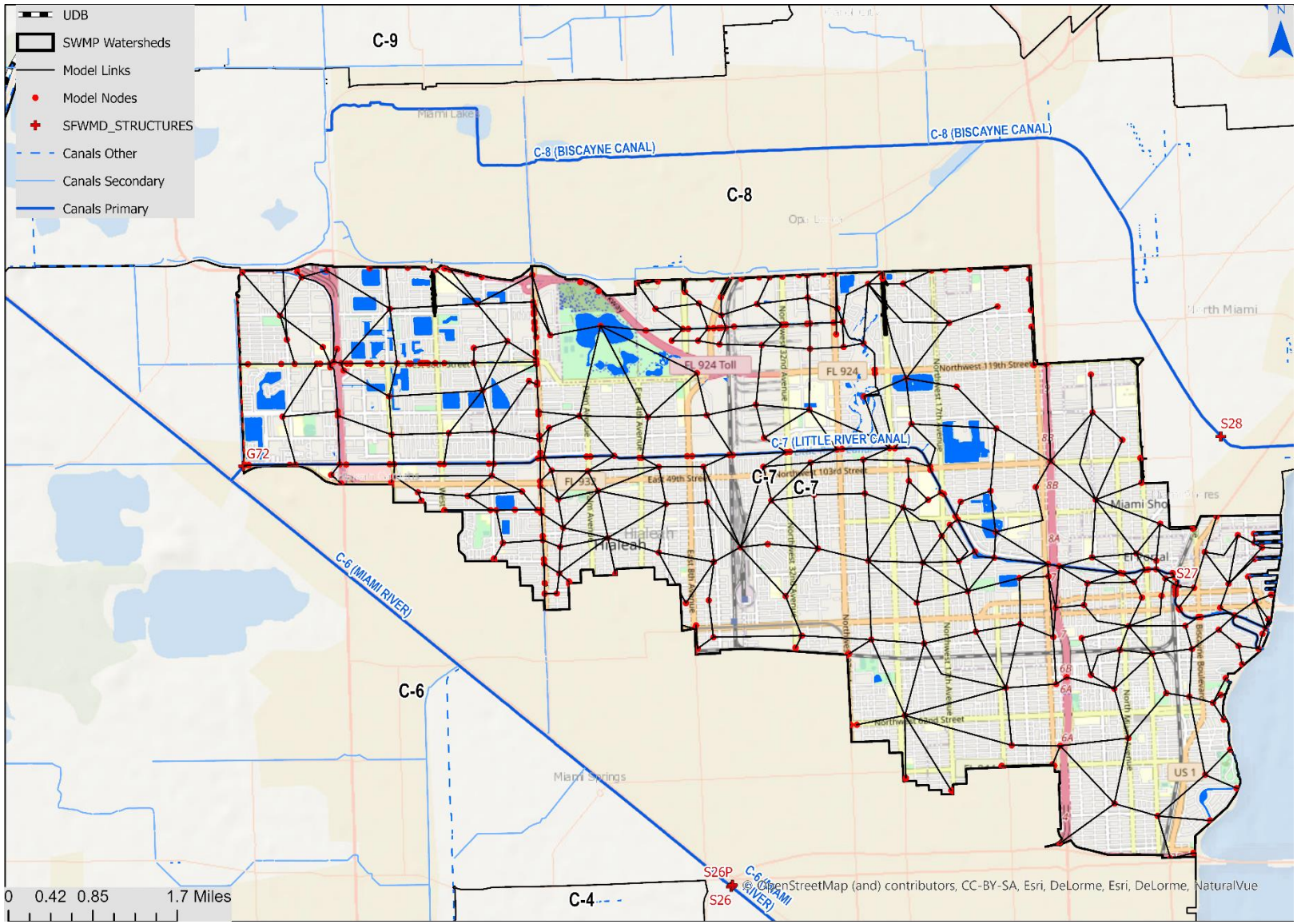


Figure 100 C-7 Model Nodes and Links

2.10.2 C-7 Hydraulic Characteristics

The major canals and minor tributaries within the watershed that are modeled in the stormwater master plan (SWMP) are shown in Figure 100. Each canal reach is represented in the hydraulic model by cross-section data obtained from surveys completed in 2015 and provided by RER Water Management Division. The limits of the reach are generally located at canal intersections, culverts, bridges, or where the geometry of the canal varies significantly. The primary and secondary drainage systems are modeled using the hydraulics block of the model. The hydraulics block uses nodes and links to define the hydraulic network. Nodes are also referred to as junctions in the hydraulics module. The model network is represented by 382 nodes and 548 links. A map of the model network is shown on Figure 100. Section 2.2 provides detailed discussion of model node, link, and cross-section parameters.

2.10.2.1 Stormwater Management Infrastructure

South Florida Water Management District operates multiple control structures and water level gauges within Miami-Dade County. The District provides records of gate operations, headwater and tailwater elevations at each structure.

Table 52 lists the structure operational criteria:

Table 44 Summary of operating conditions of structures within watershed C-7

Structure	Type	Design HW Stage (ft NGVD)	Design TW Stage (ft NGVD)	Optimum Stage (ft NGVD)	Design Flow (cfs)
S27 Stage divide	Spillway. 2 gates 27 ft x 15 ft crest length=54 ft crest Elev=11.0 NGVD	3.2	2 7	≈ 1.7	2800
G72 Divide C-7 and C-6 Watersheds	Culvert 4-72 in x 75 ft CMP Flashboards Variable invert Elev = 12.44 to -1.97 ft NGVD=	0	0	0	Divide structure water supply

During periods of low natural flow, water is supplied to the watershed from C-6. There are two SFWMD control structures in the C-7 Watershed: S27 and G72.

- S27 is a gated spillway located in C-7 between the Florida East Coast Railway crossing and NE 82nd Street, just west of Biscayne Boulevard. It controls stages in C-7, and it regulates discharges to tidewater. A headwater stage is maintained by S27 adequate to prevent saltwater intrusion into local groundwater.
- G72 is a gated culvert located in C-7 at the canal's bifurcation of C-6 near NW 103rd Street (W. 49th Street in Hialeah) and SR 27. G72 is normally closed and acts as a divide between the C-6 and C-7 Watersheds. It can be opened to supply water from C-6 to the C-7 Watershed when the stage in C-7 is below optimum.

Additional pumping facilities within the C-7 Watershed are operated by MDC, and are included in the model, controlling stages within sub-watersheds which may frequently flood. The County pump stations have a normal operation, flood operations and high tide operations. Pump data: the pump curve data was obtained from vendor catalogs and from the Miami-Dade Stormwater Atlas.

2.10.2.2 Model roughness coefficients

For stormwater master planning purposes, pipe roughness values in the model assume a clean, maintained system. Therefore, RCP were assigned a Manning's roughness value of 0.013 and corrugated metal pipe (CMP) roughness values were set to 0.024. The C-7 Watershed model also includes pipes made of PVC and HDPE material, which have lower roughness values (0.011). Table 43 provides summary of the roughness factors which were used within the C-7 model for open channels and overland flows.

Most of the channel links are not provided wide floodplains in this model; therefore, the model is not sensitive to overbank roughness values except for the few links where floodplains are wider.

Table 45 C-7: Roughness coefficients used for the canals and the overland areas

Flooding Source	Channel "n"	Overbank "n"
Bridges (submerged)	0.035-0.045	-
Bridges (Open)	0.035-0.045	0.08
Little River Canal (C-7)	0.035	0.040-0.100
Overland Flows	0.02-0.08	0.02-0.07

2.10.3 C-7 Model Calibration

The model was calibrated to the Hurricane Irma which occurred in September 2017, using observed stages and estimated flows at structures G72 and S27. The calibration model was compared to available stage gauges within the watershed. Flows were compared to the flow estimates at the outfall structure at the downstream end of the watershed. The SFWMD estimates flows at the gated structures based on upstream and downstream head. The flow estimates are not well calibrated for times when tailwater is higher than headwater as during Hurricane Irma, so generally, flow estimates were used for guidance, but not calibration. Due to the inconsistencies in the estimated flow data for the S27 during Hurricane Irma, a verification test was performed for a July 2013 storm.

For both calibration and verification, the boundary connections with the C-6 and C-8 Watersheds were not included. The design storm models use Biscayne Bay as the boundary condition. G72 is typically closed during storm events and flows between watersheds are unlikely to affect peak stages when all three watersheds are under design storm conditions.

2.10.3.1 Calibration Rainfall Records

Fifteen-minute interval historical rainfall records for each of the rainfall stations located within or near the watershed were obtained from the SFWMD. The cumulative rainfall used for calibration is shown in Figure 101 for Hurricane Irma and for the 2013 verification storm. The western portion of the watershed,

west of approximately NW 27th Avenue, received the lower S28Z rainfall hyetographs for the 2013 verification storm.

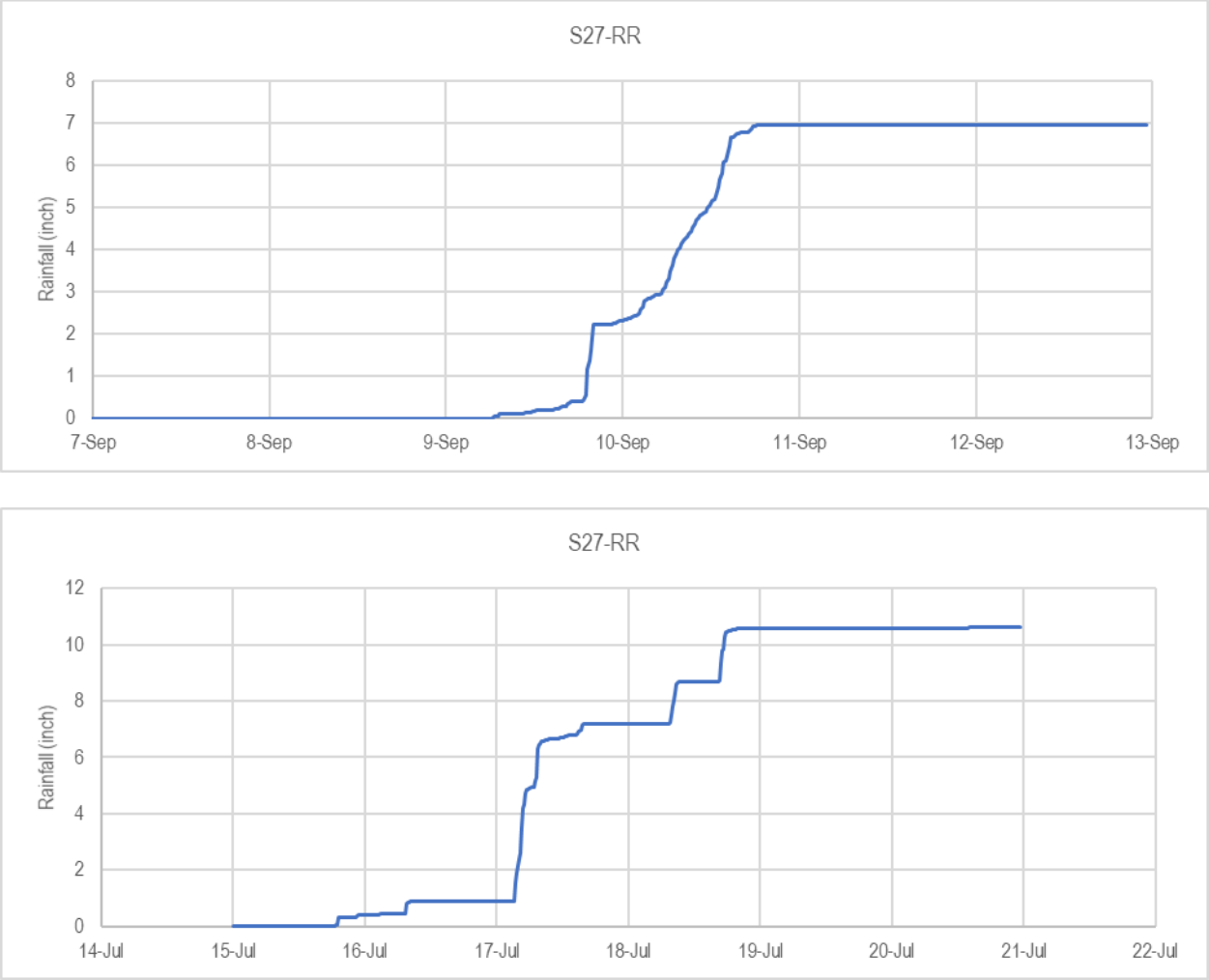


Figure 101 Cumulative rainfall for Hurricane Irma, 9/7/2017-9/12/2017 and a verification stormwater event in 7/15/13 – 7/25/13

2.10.3.2 Evapotranspiration

The model uses the XPSWMM default values of 0.1 inch of evapotranspiration per day. The model is not sensitive to this parameter for design storm simulations. If the model were to be run for a year-long continuous simulation, it is recommended this be changed to variable rates by month.

2.10.3.3 Stage and Discharge Boundaries

The model has two stage boundary conditions

- S337_T – The stage is used to represent seepage from Water Conservation Area

- S27_T – Boundary conditions at the S27 structure

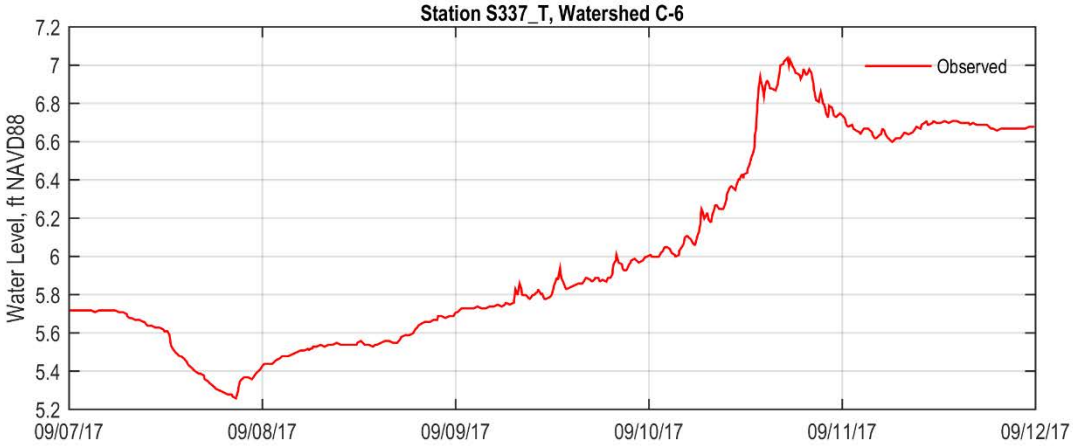


Figure 102 Seepage boundary condition to the west at Node C7-WCA representing seepage from Water Conservation Area

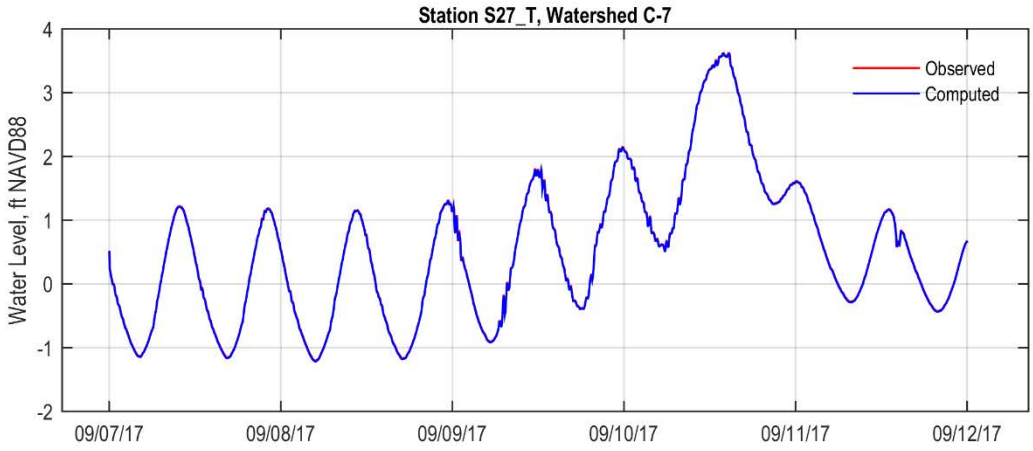


Figure 103 Tidal Boundary condition at node C27_TW

2.10.3.4 Calibration Targets

The calibration model used stage gauges within the watershed. The only flow estimate is at the outfall structure at the downstream end of the watershed.

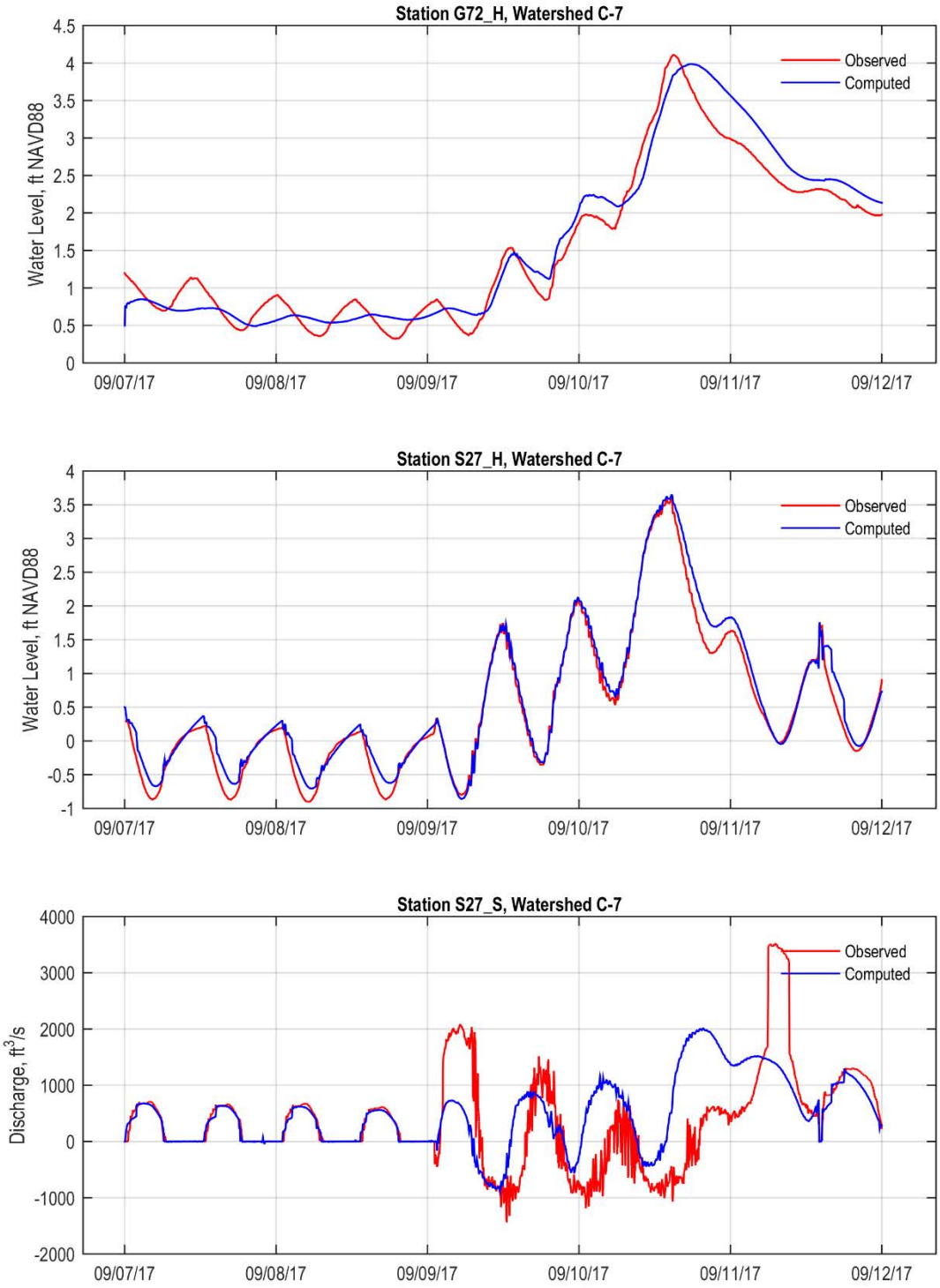


Figure 104. Model Calibration Results for G72-H, S27_H and S27_S

As discussed above, the SFWMD flow estimates are based on rating curves and are not well-defined when tailwaters exceed headwaters. Considering that the discharges through S27 showed unusual patterns

during Hurricane Irma (maximum estimated discharge exceeded 3,600 cfs, while the structure is rated only up to 3070 for the SPF), the model was verified with a separate storm event: for the period 7/15/2013 to /7/22/2013 for which the peak stages were more reasonably represented.

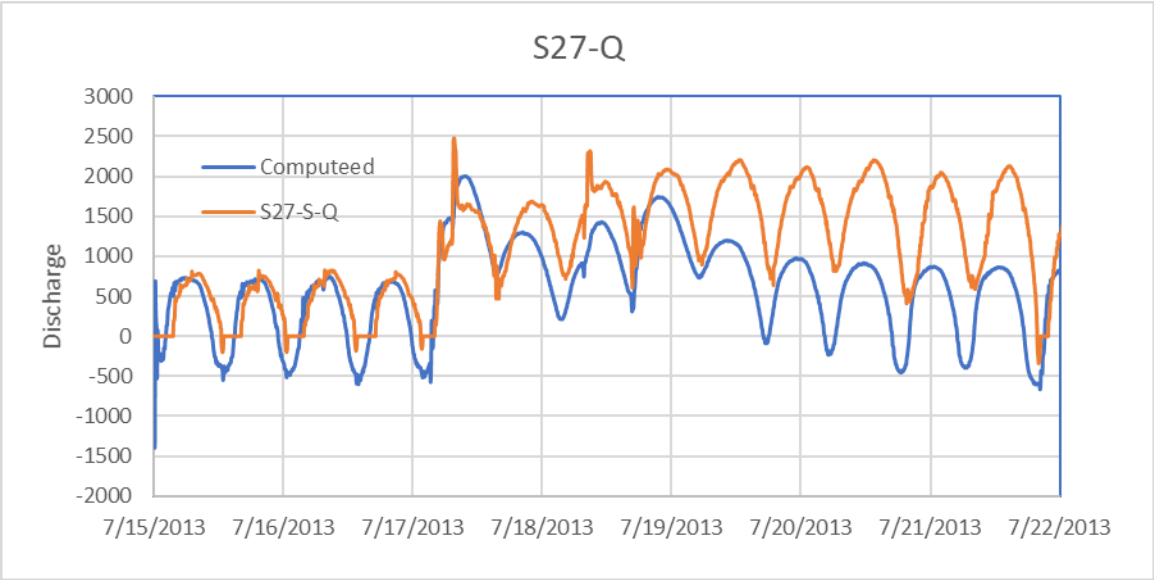


Figure 105. Model Calibration Results for S27_S for the Period 7/15/2013 to /7/22/2013

The calibration statistics for the C-7 Watershed are shown in Table 14 and Table 15 (see Section 2.3 for a description of these statistics). Based on the overall calibration metrics, which reports the stages with BIAS within 0.2 ft; and the review of the NS, PEV and COR coefficients, which were greater than 0.9 for stages, it was concluded that the model is reasonably calibrated.

Table 46. Calibration metrics for watershed C-7

Station	No. Records	BIAS	MAE	RMSE	STD	COR	PEV	NS
G72_H	888	-0.05	0.22	0.26	0.26	0.97	0.94	0.94
S27_H	1630	-0.09	0.12	0.18	0.15	0.99	0.98	0.97
S27_S	4321	-102.55	396.25	697.03	689.53	0.42	0.07	0.05

Table 47. C-7: Peak Differences Between Observed and Computed Data

Station	Max Obs	Max Comp	Fraction Difference	T Max Obs	T Max Comp	Time Diff Peak (hr)
G72_H	3.99	4.11	0.02	9/10/17 14:55	9/10/17 17:50	2.92
S27_H	3.65	3.61	-0.01	9/10/17 14:39	9/10/17 14:40	0.01
S27_S	2014.08	3525.24	0.40	9/11/17 7:11	9/10/17 19:40	-11.52

2.10.4 C-7 Design Events

Flood events of a magnitude that are expected to be equaled or exceeded at least once on the average during any 5-, 10-, 25-, 50-, 100-, 500- or 1000-year period (recurrence interval) have been selected as having special significance for floodplain management and were used to determine peak stages and discharges. These events have a 20%, 10%, 4%, 2%, 1%, 0.2% and 0.1% annual chance, respectively, of being equaled or exceeded during any year.

2.10.4.1 Rainfall Events

Rainfall data was obtained from NOAA Atlas 14, Volume 9, Version 2 [1]. The SFWMD rainfall distributions are used to create rainfall hyetographs for the design storm events.

Table 48 C-7 Point Precipitation Frequency Estimates in Inches from NOAA Atlas 14

Frequency	24-hr	72-hr
5	6.99	8.86
10	8.46	10.6
25	10.7	13.2
50		15.4
100		17.8
500		24.1
1000		27.1

2.10.4.2 Design Events Discharge

Validation of the computed design events was determined using the USGS methodology for watershed discharges and Log Pearson III analysis for extreme events. First, the peak discharges through structure S27 were determined for the period of record. Table 57 lists the observed extreme discharges (minima and maxima) on an annual basis:

Table 49 DBHYDRO Observed Min and Max Peak Discharges for S27 (DBKEY Key 65069)

Year	Mean (cfs)	Maximum (cfs)	Std. Dev. (cfs)
1985	79.038	860.146	174.82
1986	63.231	1,048.44	223.51
1987	47.152	770.107	179.11
1988	81.451	2,151.57	207.3
1989	181.931	1,301.14	221.15
1990	204.98	1,225.41	221.03
1991	236.879	2,137.91	240.93

1992	54.194	1,534.79	211.29
1993	184.477	1,941.92	186.77
1994	128.442	908.778	231.06
1995	120.604	1,470.02	296.44
1996	146.729	1,316.31	193.69
1997	183.661	1,283.18	199.02
1998	218.923	1,226.83	212.63
1999	224.985	2,368.57	294.52
2000	185.409	1,749.46	228.94
2001	232.859	2,151.26	266.35
2002	239.403	3,836.31	276.32
2003	200.062	893.818	202.04
2004	150.159	1,369.92	199.33
2005	155.197	1,800.94	209.58
2006	147.833	1,071.91	175.69
2007	181.374	871.303	204.93
2008	156.234	1,193.71	194.53
2009	136.965	1,348.77	186.73
2010	160.622	1,329.00	194.74
2011	104.458	1,010.70	175.98
2012	180.7	917.565	207.58
2013	216.566	2,736.76	292.87
2014	196.605	2,955.36	248.16
2015	180.032	2,340.20	236.33
2015	180.032	2,340.20	236.33
2016	180.901	1,507.69	220.51
2017	228.957	3,525.24	285.6
2018	190.766	2,002.97	238.41
2019	264.121	2,528.12	321.51
2020	439.853	2,901.35	515.22

The Log Pearson III probability distribution parameters were determined using the HEC-SPS software. Confidence intervals of 5% and 95% were used as criteria of fitting computed discharges as function of return frequencies.

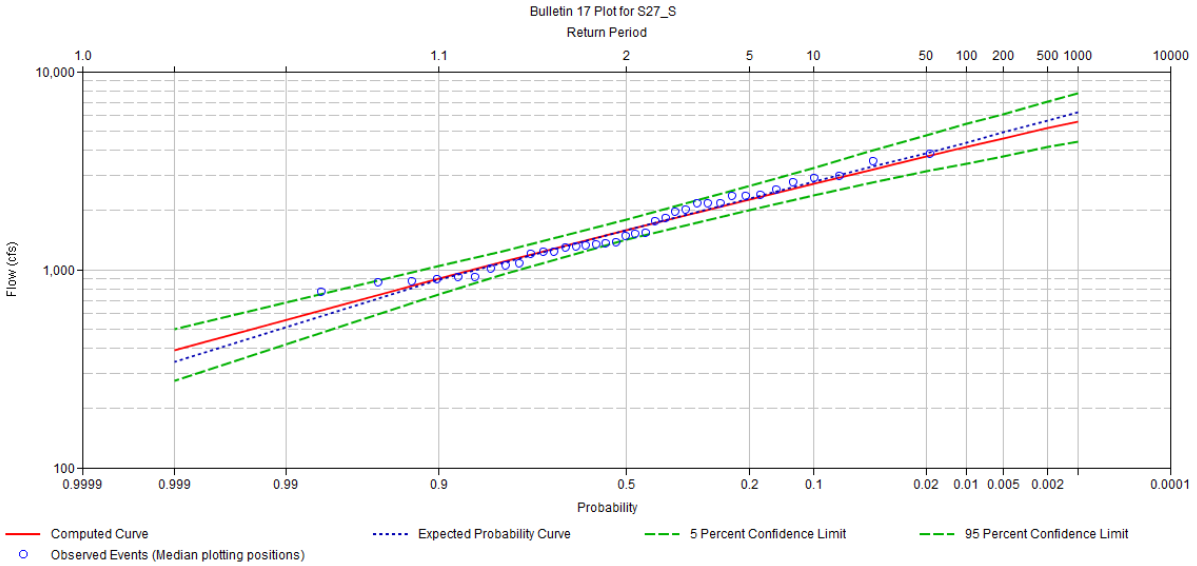


Figure 106. Log-Pearson III Analysis of Return Period for Discharges in Structure S27_S

The computed peak discharges for structure S27_S for each design event and SLR scenario are shown in Figure 107. The results show that SLR scenario reduces the peak discharges in the structure, which indicates that the drainage capacity of the system will be reduced as the SLR increases.

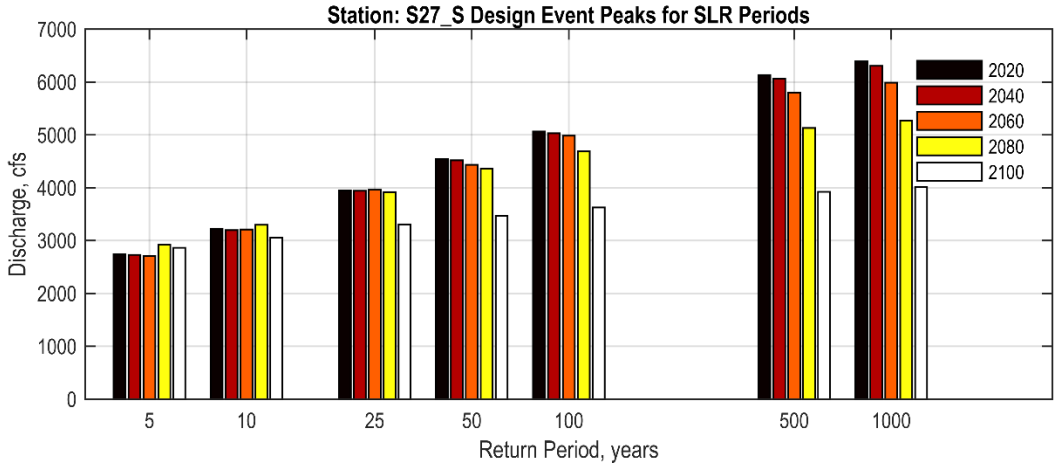


Figure 107 Design Events Peak Discharges in structure S27_S for SLR

The structure flows for all SLR scenarios were within the 95% confidence limits of the Log-Pearson III extrapolated discharges as shown on Figure 108.

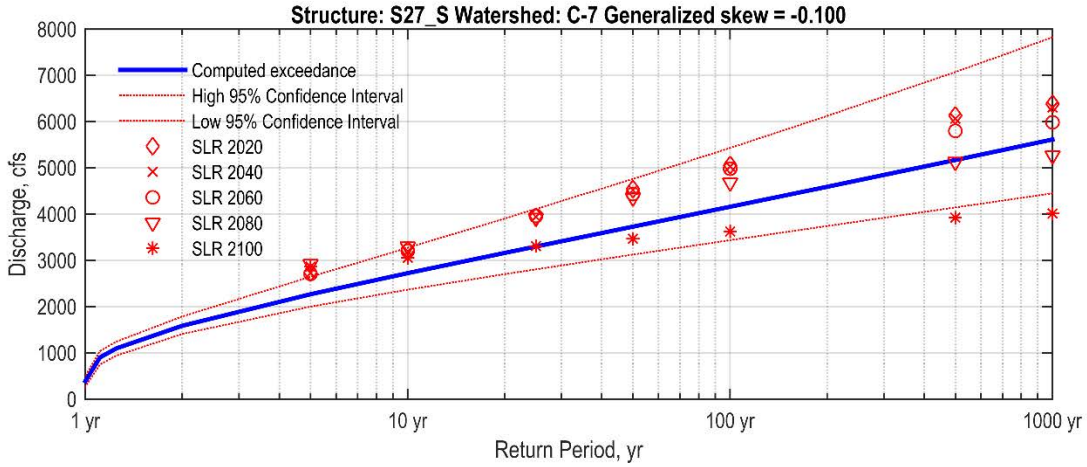


Figure 108. S27_S Exceedance probabilities

PUBLIC NOTICE INFORMATION

NOTICE OF MIAMI-DADE COUNTY'S SUBMISSION OF A GRANT APPLICATION TO THE FLORIDA DEPARTMENT OF ECONOMIC OPPORTUNITY UNDER THE REBUILD FLORIDA GENERAL INFRASTRUCTURE PROGRAM

PUBLIC NOTICE INFORMATION

The Public is hereby advised that Miami-Dade County will submit a Rebuild Florida General Infrastructure Program (GIP) application to the Florida Department of Economic Opportunity on September 17, 2021. These funds were made available to the State for areas impacted by presidentially declared disasters. In April 2018, the U.S. Department of Housing and Urban Development (HUD) announced that the state would receive $633,485,000 in funding to support long-term mitigation efforts (following Hurricanes Hermine, Matthew, and Irma) through HUD's Community Development Block Grant Mitigation (CDBG-MIT) Program. On February 2, 2021, HUD announced an additional $46.9 million in federal mitigation funding for communities impacted by Hurricane Michael, for a total CDBG-MIT allocation of $680,385,000. Grant funds are intended to fund disaster mitigation programs to better protect Florida from future disasters. Under the GIP Program, a total of $175 million is available in Round 2 to fund data-informed investments through high-impact projects that will reduce risks attributable to natural disasters, with particular attention to repetitive losses of property and critical infrastructure. Miami-Dade County's grant application seeks a CDBG-MIT grant request of $14M.

Grant funds requested will be used to make infrastructure improvements to "Secondary Canals" under Miami-Dade County control within the C-7 Basin. The project is intended to correct deficiencies in elevation in a total of six (6) secondary canals, or approximately six (6) miles. Proposed improvements include raising top of bank elevations and implementing upgrades to culverts to enhance canal storage and conveyance capability using the criteria for future conditions in a 2060 scenario with Sea Level Rise. The proposal also includes improvements to existing outfalls in these secondary canal segments for water quality enhancements.

The secondary canal system is the responsibility of Miami-Dade County. Over the period since 1996, stormwater numerical models have been developed and updated for each watershed in Miami-Dade County. These stormwater master plan updates identify water quantity and water quality challenges and strategies to mitigate impacts to Biscayne Bay, to County properties, and residents. Numerical models are utilized to facilitate the evaluation of drainage and water quality scenarios. The latest 2019-2020 comprehensive update to the Stormwater Master Plan has identified that improvements to several secondary canals are necessary to enhance storage and conveyance capabilities throughout the County's secondary canal system. The estimated project cost is $14M.

The grant application is posted online at http://miamidade.gov/grants. To allow for a 14-day Public Comment Period as required by U.S. HUD's CDBG-Mitigation program funded by HUD under Public Law 115-123, this Public Notice requirement is mandated by the Florida Department of Economic Opportunity. Comments will be received beginning September 2, 2021 until 9 AM on September 16, 2021. The contact person for the application and written comments is Daniel T. Wall, Assistant Director. The email address is Daniel.Wall@miamidade.gov.

More information about Rebuild Florida's Mitigation Programs can be found online for review at https://floridajobs.org/rebuildflorida/mitigation.

Miami-Dade County does not discriminate based on race, sex, color, religion, marital status, national origin, disability, ancestry, sexual orientation, gender expression, gender identity, age, pregnancy, familial status, source of income, actual or perceived status as a victim of domestic violence, dating violence or stalking in the access to, admissions to, or employment in programs or activities. If you need a sign language interpreter or materials in accessible format for this event, call (786) 469-4157 at least five days in advance. TDD/TTY users may contact the Florida Relay Service at 800-955-8771.

INFORMACIÓN SOBRE AVISO PÚBLICO

AVISO SOBRE ENVÍO DE SOLICITUD DE SUBVENCIÓN DEL CONDADO DE MIAMI-DADE AL DEPARTAMENTO DE OPORTUNIDADES ECONÓMICAS DE LA FLORIDA PARA EL PROGRAMA DE INFRAESTRUCTURA GENERAL DE RECONSTRUCCIÓN DE LA FLORIDA

INFORMACIÓN SOBRE EL AVISO PÚBLICO

Por este medio, se avisa al público que el 17 de septiembre del 2021 el Condado de Miami-Dade enviará al Departamento de Oportunidades Económicas de la Florida una solicitud para el Programa de Infraestructura General de Reconstrucción de la Florida (GIP, por sus siglas en inglés). El estado recibió estos fondos para su uso en las áreas afectadas por desastres declarados por el presidente. En abril del 2018, el Departamento de Vivienda y Desarrollo Urbano de los EE. UU. (HUD, por sus siglas en inglés) anunció que el estado recibiría $633, 485,000 en fondos para financiar medidas de mitigación a largo plazo (luego del paso de los huracanes Hermine, Matthew, e Irma) mediante el Programa de Mitigación de la Subvención Global para el Desarrollo Comunitario del HUD (CDBG-MIT). El 2 de febrero del 2021, el HUD anunció otros $46.9 millones en fondos federales para mitigación destinados a las comunidades afectadas por el huracán Michael, para un total de asignación de CDBG-MIT de $680, 385,000. Los fondos de la subvención están destinados a financiar programas de mitigación de desastres a fin de proteger mejor a la Florida de futuros desastres. Conforme al Programa GIP, en la Ronda 2 hay disponible un total de $175 millones para financiar inversiones, con base en datos y mediante proyectos de alto impacto, que disminuirán los riesgos atribuibles a los desastres naturales, con atención particular en la pérdida repetitiva de propiedades e infraestructura vital. La solicitud de subvención del Condado de Miami-Dade se refiere a una subvención de $14 millones del Programa CDBG-MIT.

Los fondos de subvención solicitados se utilizarán para hacer mejoras de infraestructura a los "canales secundarios" bajo control del Condado de Miami-Dade en la Cuenca C-7. El propósito del proyecto es corregir las deficiencias de elevación en un total de seis (6) canales secundarios, o alrededor de seis (6) millas. Las inversiones propuestas incluyen elevar la parte superior de la elevación de las márgenes y mejorar las alcantarillas y la capacidad de escurrimiento, con base en los criterios para las condiciones futuras en un panorama del 2060 con el aumento del nivel del mar. Asimismo, la propuesta incluye mejoras a los emisarios actuales en estos segmentos de los canales secundarios para mejorar la calidad del agua. El sistema de canales secundarios es responsabilidad del Condado de Miami-Dade. En el período a partir de 1996, se han desarrollado y actualizado los modelos numéricos de las aguas pluviales en cada una de las vertientes en el Condado de Miami-Dade. Estas actualizaciones al plan maestro de aguas pluviales identifican los desafíos y las estrategias en cuanto a la cantidad y la calidad del agua con el fin de mitigar el impacto en la bahía de Biscayne, las propiedades y los residentes del Condado. Los modelos numéricos se utilizan para facilitar la evaluación de los panoramas de escorrentías y calidad del agua. En la última modernización integral 2019-2020 al Plan Maestro de Aguas Pluviales se identificó la necesidad de hacer mejoras en varios canales secundarios para elevar la capacidad de almacenamiento y emisión en todo el sistema de canales secundarios del Condado. El costo estimado del proyecto es $14 millones.

La solicitud de subvención se encuentra en el sitio web http://miamidade.gov/grants. A fin de cumplir con el período de 14 días de presentación de comentarios del público, conforme a lo exigido por el Programa de Mitigación de la CDBG del Departamento de Vivienda y Desarrollo Urbano de los EE. UU. financiado por el HUD bajo la Ley de Derecho Público 115-123, el Departamento de Oportunidades Económicas de la Florida exige la publicación de este Aviso Público. Los comentarios se recibirán a partir del 2 de septiembre del 2021 hasta las 9:00 a. m. del 16 de septiembre del 2021. La persona de contacto para la solicitud y los comentarios escritos es Daniel T. Wall, vicedirector. La dirección de correo electrónico es Daniel.Wall@miamidade.gov.

En el sitio web https://floridajobs.org/rebuildflorida/mitigation se ofrece más información acerca de los Programas de Mitigación para la Reconstrucción de la Florida.

El Condado de Miami-Dade no discrimina en base a raza, sexo, color, religión, estado civil, país de origen, discapacidad, procedencia, orientación sexual, expresión de género, identidad de género, edad, embarazo, condición familiar o fuente de ingreso, estatus real o percibido como víctima de violencia doméstica, violencia en el noviazgo o acoso, en cuanto al acceso a empleos o aceptación en los programas o actividades. Si necesita los servicios de un intérprete del lenguaje de señas o materiales en formato accesible para este evento, llame al (786) 469-4157, por lo menos con cinco días de antelación. Los usuarios del sistema de retransmisión TDD/TTY pueden comunicarse con el Servicio de Retransmisión de Florida (Florida Relay Service) por el 800-955-8771.

ENFÒMASYON AVI PIBLIK

AVI KONTE MIAMI-DADE SOUMÈT YON APLIKASYON POU SIBVANSYON NAN DEPATMAN OPÒTINITE EKONOMIK FLORID ANBA PWOGRAM REBATI ENFRASTRIKTI JENERAL FLORID

ENFÒMASYON AVI PIBLIK

Nou fè Piblik la konnen ke Konte Miami-Dade va soumèt yon aplikasyon pou Pwogram Rebati Enfrastrikti Jeneral Florid (GIP) bay Depatman Opòtinite Ekonomik Florid nan dat 17 septanm 2021. Fon sa yo te disponib nan Eta a pou zòn dezas ki nan deklarasyon prezidansyèl la. Nan mwa avril 2018, Depatman Lojman ak Devlopman Iben Etazini (HUD) te anonse ke eta a ta resevwa $633,485,000 finansman pou sipòte efò alontèm alèjman (apre siklòn Hermine, Matthew, ak Irma) atravè Pwogram Community Development Block Grant Mitigation (CDBG-MIT)HUD la. Nan dat 2 fevriye 2021, HUD te anonse yon lòt $46.9 milyon finansman federal alèjman pou kominote ke siklòn Michael i te afekte, pou yon alokasyon total CDBG-MIT $680,385,000. Fon sibvansyon yo dwe finanse pwogram alèjman katastwòf pou pwoteje Florid pi byen kont katastwòf ki ap vini. Anba Pwogram GIP a, gen yon total $175 milyon ki disponib nan Faz 2 pou finanse envestisman ki chita sou done atravè pwojè a gran enpak ki va redui risk ki ka mache ak katastwòf natirèl, avèk atansyon patikilye a pèt repetitif pwopriyete ak enfrastrikti enpòtan. Aplikasyon pou sibvansyon Konte Miami-Dade la ap chache yon demann sibvansyon $14 Milyon CDBG-MIT.

Yo va itilize lajan sibvansyon yo mande a pou fè amelyorasyon enfrastrikti nan "Kanal Segondè" anba kontwòl Konte Miami-Dade nan Basen C-7. Pwojè a gen objektif pou korije defisyans an elevasyon nan yon total sis (6) kanal segondè, oswa apeprè sis (6) mil. Amelyorasyon yo pwopoze yo gen ladan ogmante elevasyon arebò rivyè yo ak fè amelyorasyon nan dren yo pou amelyore kapasite kanal ak kapasite konveyans lè yo sèvi avèk kritè pou kondisyon a lavni nan ka yon ogmantasyon nivo lanmè an 2060. Pwopozisyon an gen ladan tou amelyorasyon nan sorti ki deja egziste nan segman kanal segondè sa yo pou amelyorasyon kalite dlo.

Sistèm kanal segondè a se responsablite Konte Miami-Dade. Pandan peryòd apati 1996, yo te devlope ak fè mizajou modèl nimerik dlo lapli pou chak basen vèsan nan Konte Miami-Dade. Mizajou plan prensipal dlo lapli sa yo idantifye kantite dlo, defi kalite dlo ak estrateji pou bese enpak yo sou Biscayne Bay, sou pwopriyete Konte a, ak rezidan yo. Yo itilize modèl nimerik yo pou fasilite evalyasyon drenaj ak senaryo kalite dlo. Dènye mizajou konplè 2019-2020 nan Plan Prensipalt Dlo Lapli a te idantifye nesesite amelyorasyon nan plizyè kanal segondè pou amelyore kapasite nan tout sistèm kanal segondè Konte a. Pri pwojè a estime a $14 Milyon.

Aplikasyon pou sibvansyon an afiche sou entènèt nan http://miamidade.gov/grants. Pou pèmèt pou yon Peryòd 14 jou pou Komantè Piblik jan pwogram HUD's CDBG-Mitigation Etazini egzije sa anba Lwa Piblik 115-123 HUD, Depatman Florid Opòtinite Ekonomik egzije Avi Piblik sa a. Yo va resevwa kòmantè yo apati 2 septanm 2021 jiska 9 AM nan dat 16septanm 2021. Pou aplikasyon ak kòmantè ekri, kontakte Daniel T. Wall, Direktè Adjwen. Adrès imel la se Daniel.Wall@miamidade.gov.

Ou ka jwenn plis enfòmasyon sou Pwogram Alèjman Rebati Florid yo sou entènèt pou revizyon nan https://floridajobs.org/rebuildflorida/mitigation.

Konte Miami-Dade pa fè diskriminasyon ki baze sou ras, sèks, koulè, relijyon, eta sivil, orijin nasyonal, andikap, zansèt, oryantasyon seksyèl, ekspresyon sèks, idantite seksyèl, laj, gwosès, estati familyal, sous revni, aktyèl oswa konnen estati kòm yon viktim vyolans domestik, vyolans mennaj oswa aksè, admisyon, pwogram oswa aktivite anplwa. Si ou bezwen yon entèprèt lang siy oswa materyèl nan fòma aksesib pou evènman sa a, rele (786) 469-4157 omwen senk jou davans. Itilizatè TDD / TTY ka kontakte Sèvis Relè Florid nan 800-955-8771.

Pou piblisite legal sou entènèt, ale nan http://legalads.miamidade.gov