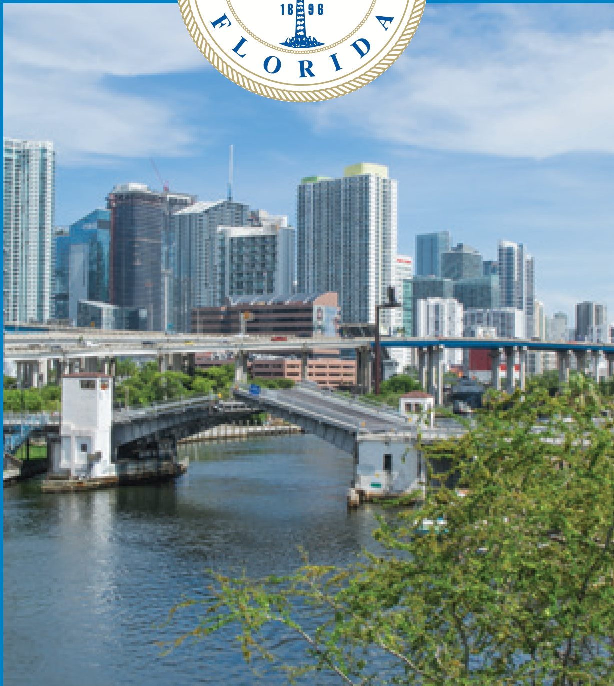
DRAFT

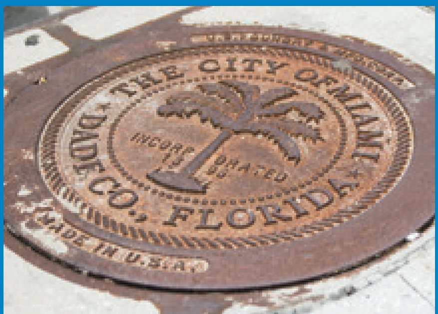
EXECUTIVE SUMMARY

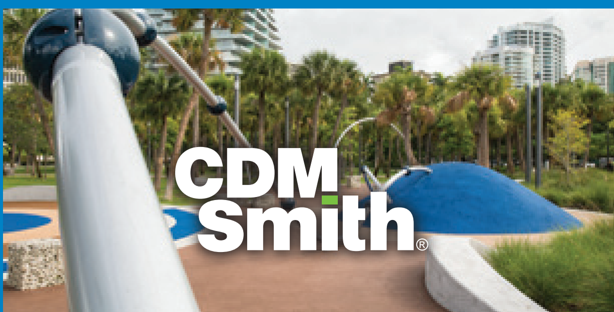
March 2021

The City of Miami's Comprehensive Stormwater Master Plan (B-30632A)

THE CITY OF MIAMI
INCORPORATED 1896
FLORIDA







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This Executive Summary (ES) presents the findings of the analyses performed and associated recommendations for the City of Miami's (City) Comprehensive Citywide Stormwater Master Plan (SWMP), City Project No. B-30632A.

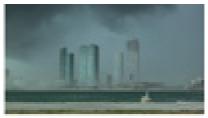
BACKGROUND & PURPOSE

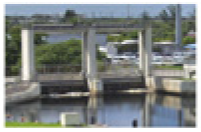
Stormwater management planning is necessary to protect public safety and infrastructure from local and regional flooding while meeting regulatory requirements which protect the environment. Due to changes in land use from redevelopment, increasing sea levels, extreme rainfall, and the changing regulatory environment over time, the development of a new and comprehensive Citywide SWMP was desirable. The SWMP provides the structure to establish a database, stormwater model, and capital improvement program (CIP), as well as a policy framework that would protect public safety, infrastructure, and the environment.

The City has planned for the initial funding of projects that will mitigate flooding, protect and enhance the water quality of Biscayne Bay, and strengthen the shorelines from tidal storm inundation. This Citywide comprehensive SWMP was required to study, analyze, and provide the engineering recommendations and planning-level costs for capital projects and operational recommendations implemented over time for the best use of that funding. This approach will meet the City's desired level of service (LOS) for stormwater management, plan for sea level rise and storm surge impacts on the system, and enhance the protection of Biscayne Bay.

- Flood protection
- Water quality & environment
- Land use
- Sea level rise
- Storm surge
- Resilient coastal features
- Saltwater intrusion
- Changes in groundwater levels
- Protection of Biscayne Bay
- Current and future regulations

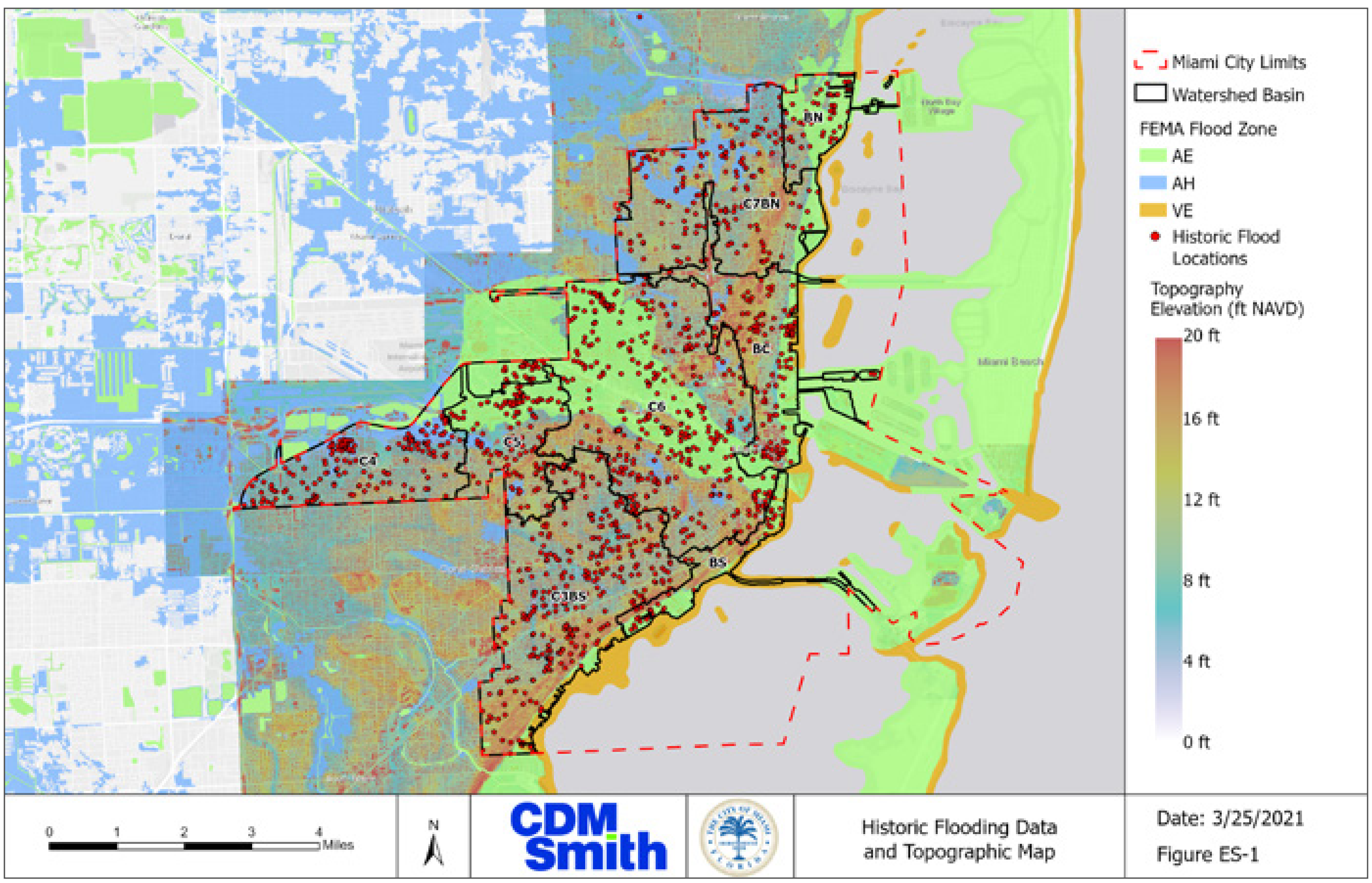
Allowing the City to establish a **policy framework** with **public support protecting** and **enhancing** the City's future over time.





Stormwater management is not confined by jurisdictional boundaries. A SWMP helps stakeholders understand the big picture of the natural conditions, constraints, and opportunities to manage stormwater in a safe, regulatory compliant, and sustainable manner. The SWMP considers design storm flooding predictions using stormwater models simulating topography and land use, the physical attributes of the stormwater management system, its controls and limitations and the runoff generated by rainfall, to identify deficiencies and recommend corrective actions. The City experiences significant flooding from rainfall and tidal events as identified in the Miami-Dade County 311 flooding complaint system, the Federal Emergency Management Agency (FEMA) repetitive loss system, as well as from Flood Insurance Rate Maps (FIRMs) and other reported flooding complaints, as shown in **Figure ES-1**.

Figure ES-1. Current Flooding Complaints and FEMA Repetitive Loss Areas Citywide



The SWMP project provides the City:

- A new detailed, dynamic, and comprehensive Citywide stormwater model to simulate predicted rainfall flooding and the effects of sea level rise and storm surge on the existing and proposed stormwater management system. The model can be modified and enhanced in the future as new projects come online or system conditions change.
- A Citywide CIP to cost-effectively mitigate flooding issues for two alternative levels of service and a prioritized list of project areas and improvements with planning-level budgets at the neighborhood scale.
- Increased aquifer recharge to reduce saltwater intrusion for future potable water supply and water quality treatment improvements to protect Biscayne Bay.
- A benefit-cost analysis for the proposed improvement alternatives.
- A modern GIS database with digital mapping and metadata to archive and access the City's vast stormwater assets and record document plans linked to the stormwater model.
- A foundation and roadmap plan for stormwater and coastal resiliency in the future.
- A comprehensive, Citywide planning-level stormwater management strategies which are permittable and can be implemented in a prioritized, phased program. These strategies help address the City's chronic flooding, improve stormwater and coastal resiliency, and provide strategies for sea level rise. The end result is a cost-benefit balanced suite of both conventional and innovative approaches, which utilizes the natural environment as an asset, and protects Biscayne Bay.

The City will be implementing the first group of recommendations developed in the SWMP in a phased, prioritized Citywide stormwater management Capital Improvements Program (CIP). These improvements will be funded by a portion of its 2017 Miami Forever General Obligation Bond Program, as well as from other funding sources. The City's intent for the Miami Forever General Obligation Bond is to build a stronger, more resilient future for Miami. This is achieved by alleviating existing and future risks to the residents, economy, tourism, and by protecting the City's legacy. The Bond funds a series of immediate, near-term, and long-term projects with the goal of transforming the future of Miami in key categories which align with the City's most pressing needs, including addressing sea-level rise and flood prevention. The objectives of the stormwater-related bond projects are to minimize flooding frequency, severity, duration and impact, and to protect critical infrastructure and high-use areas. This, in turn, reduces financial and economic vulnerability.

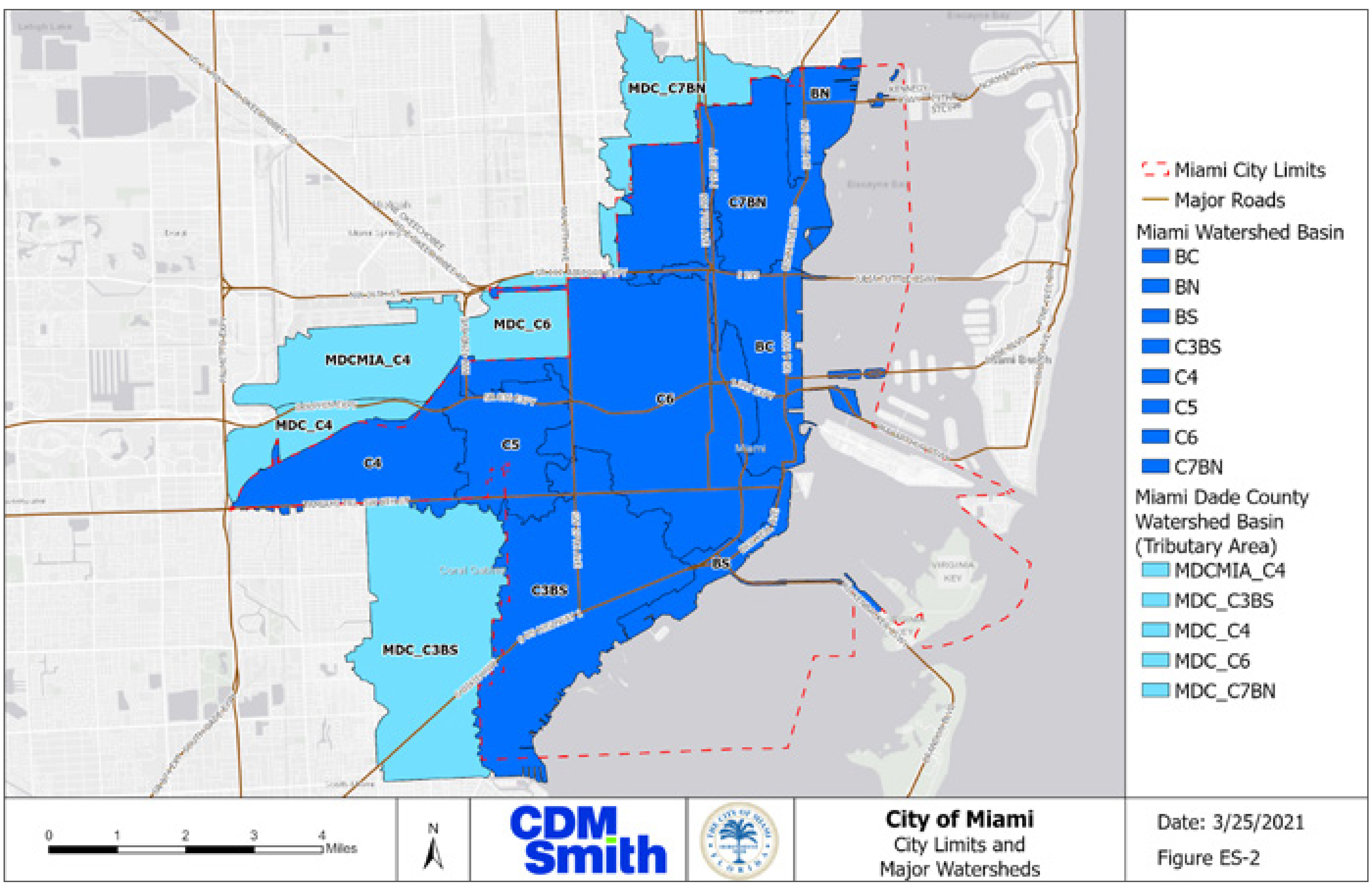
MIAMI FOREVER
GENERAL OBLIGATION BOND

PROJECT OVERVIEW

The SWMP project was divided into four major work phases:

1. **Data Collection and Evaluation Phase.** This phase developed and analyzed the required information describing the physical details of the existing stormwater management system, the physical characteristics of the study area and its topography, rainfall, and groundwater, and established the boundary conditions for the models to be used. When all of the City's available data was analyzed, a data gap analysis was performed, and survey teams were deployed to the field to discover and fill-in the minimum missing data required to continue the analysis and complete the model. A new, modern Geographic Information System (GIS) and geodatabase was developed, and the data was digitally converted to provide electronic, one-click, visual access to their stormwater system data to all City departments.
2. **Stormwater Modeling Phase.** This phase included the development and application of the USEPA StormWater Management Model (SWMM) for the City's primary stormwater management system (PSMS) covering the City's eight drainage basins, as shown on **Figure ES-2**. The models are used to determine LOS for flooding and evaluate mitigative measures for the capital improvements program (CIP). The stormwater models were developed on a neighborhood scale of detail and were used to simulate rainfall, infiltration, runoff, and flows and stages in pipes, exfiltration systems, channels, rivers, wells, outfalls, and pump systems for design storm rainfall events and various tidal and sea level rise conditions. The evaluations considered both rainfall and tidal conditions, groundwater levels, and interconnections with surrounding adjacent Florida Department of Transportation (FDOT), South Florida Water Management District(SFWMD), and Miami-Dade County (MDC), and other municipal stormwater and water management systems. The models were validated to actual conditions for historic storms, and then were used to predict existing and future sea level condition flood flows, depths, and durations for SFWMD-required design storms as a way to determine the causes of the flooded areas and to evaluate alternatives of mitigative capital improvement projects. The models were also used to identify potential maintenance issues and needs in chronic flooding areas.
3. **Sea Level Rise Evaluation and Resiliency Considerations Phase.** This phase included using the stormwater models to evaluate the effects of future sea level rise, at levels of 18 and 30 inches, and then determine the impacts on the existing and proposed stormwater management systems. This includes shoreline armoring and outfall backflow prevention for tidal surge protection and resiliency planning.
4. **Capital Improvement Program Phase.** This phase developed the Citywide CIP for two alternative LOS scenarios for stormwater flooding (one more restrictive, one less restrictive) and created a benefit-cost analysis for each LOS to help decision makers plan the most beneficial projects under available budget. An initial action plan was developed where Group 1 projects would be implemented first, and future Groups 2-4 projects would be implemented successively in the future as funding becomes available.

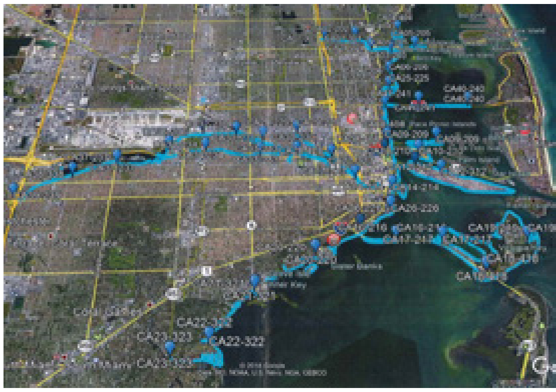
Figure ES-2. City of Miami Drainage Basins and Model Boundaries

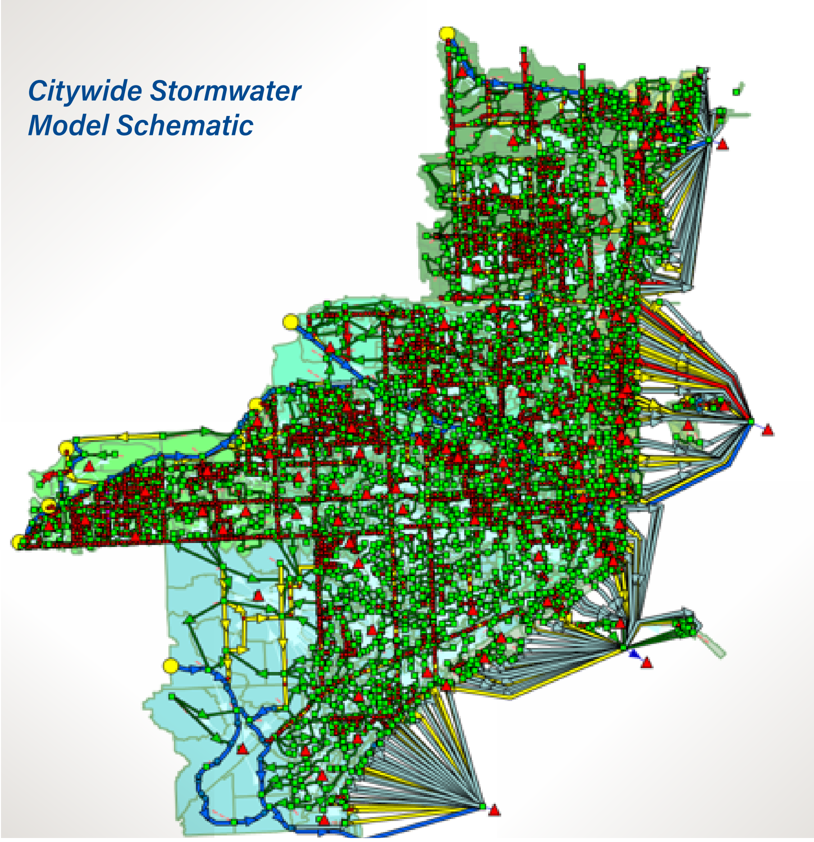


DATA COLLECTION & EVALUATION PHASE OVERVIEW

The data collection phase researched, acquired, and reviewed tens of thousands of paper and scanned record documents of stormwater infrastructure from the City's archives, and from other agencies and stakeholders. Once gathered, the next task was to *systematically build and transform the information into a new and modern digital stormwater management Geographic Information System (GIS) geodatabase for "one-click" access to archived records compiled into a single source data file, electronic graphical viewing, map creation for future analyses, and data query by selected City departments.*

Areas of missing information or conflicting records were identified and re-created in sufficient detail for the modeling analyses and then added to the data set where required by inspection, using field survey crews. Features captured and provided in the new comprehensive GIS data layers include LiDAR topography, impervious area coverage, seawalls, soils data, groundwater data, City emergency management critical structure and finished-floor elevations, primary rivers, canals, and ditches, stormwater outfalls and ownership, backflow preventers, control structures, weirs and gates, stormwater pump stations, catch basins, inlets, pipes, manholes, boxes, culverts, drainage wells, exfiltration systems and slab covered trenches, invert elevations, stormwater management ponds, and County 311 and FEMA repetitive loss information. It is intended that the created GIS will be a living digital document, and the City will be expanding the asset data as new projects are completed. *The stormwater model input data is linked to the GIS so that planning updates can be created as needed. Planning updates can then be run in the future with the latest asset information to update the plan for implementation of capital improvements* and potential changes in rainfall, groundwater table elevation, land use from development and redevelopment, or increasing sea levels beyond the scenarios evaluated in this SWMP. A citywide flood stage gauge monitoring network was conceptually developed for potential future implementation by the City to provide and record real-time flood level reporting at identified critical sites around the City. This will provide emergency management, key performance indicator metrics on the effectiveness of capital improvements post installation and will be used for future model refinement.





STORMWATER MODELING PHASE OVERVIEW

The stormwater modeling phase included the development and application of detailed hydrologic and hydraulic (H/H) models of the City's PSMS covering eight drainage basins, using the USEPA SWMM to evaluate flood control LOS and alternative improvements to meet the desired LOS. To support the planning-level analysis required for the master plan capital improvements program, the developed models analyzed multiple size design rainfall events and various downstream tidal boundary conditions through the City's stormwater PSMS. The data collected and created was brought into the model as input for the analyses.

Stakeholder Workshops

A public information program and a community awareness and outreach plan was developed and implemented at the start of the project. These plans identified a variety of approaches and tools to be used throughout the course of the project, including social media, websites with active feedback capacity, and in-person meetings and presentations to neighborhood associations and other civic groups in the neighborhoods. Throughout the project, multi-lingual stakeholder and resident workshops were held in the various Commission Districts at critical points and milestones during the assessment, as a way to keep the public informed of the project progress and goals. Residents were educated through visual presentations about the City's SWMP initiative, and stormwater and sea level rise issues. They were then provided the opportunity to place markers on maps identifying the notable flooding locations in their neighborhoods that would require further study by the consultant team. This input was used for both verifying the models and applying the CIP elements for flood mitigation.

Additional interactive workshops were held with the City's resiliency committee and the scientific community at-large in an Industry Experts' Workshop which was conducted for transparency of the scope of work, techniques, and methodology being used for analysis, and to gain input and feedback from the regulatory, academic, engineering, and scientific communities.

Existing Conditions (EC) and Current Level of Service (LOS) Analysis

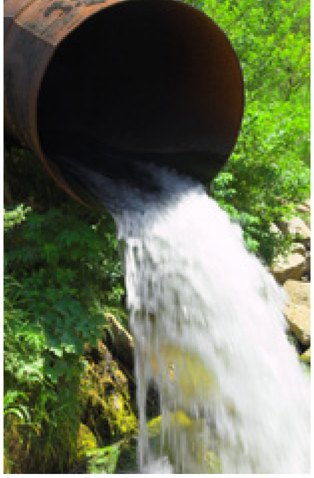
The study area and model boundaries shown on Figure ES-2 were developed using the major stormwater management basins defined by both topography and interconnected primary stormwater management systems (i.e., interconnected canals and pipe/pump systems). Sub-basin boundaries were further defined on a smaller neighborhood scale within each major drainage basin using the same criteria for more detailed analyses. Importantly, offsite contributions of stormwater into the City from surrounding areas were also accounted for by incorporating Miami Dade County stormwater model data.

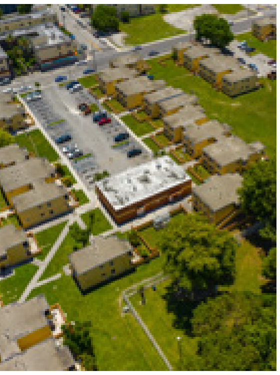
Common stormwater terms used to describe system performance are defined below:

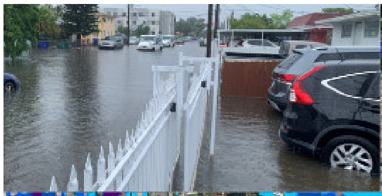
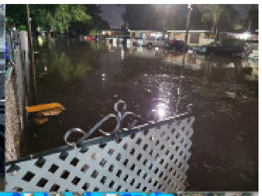
- A **"design storm"** is a rain event characterized by a specific total depth of rainfall and intensity, the storm's duration and timing, and its return period (e.g., 5- or 100- year event). The chosen design storm refers to a rainfall hyetograph that exhibits the characteristics critical to the success of a project design (i.e., no flooding).
- A storm **"return period"** is the average period of time in years that a storm of a given size (duration and intensity) can be expected to occur or be exceeded.
- Level of Service (LOS) is a **"performance metric"** used to determine how well the stormwater management system is operating as compared to a goal or standard appropriate to the needs and desires of the City. Higher levels of service will cost more to achieve, and in terms of most stormwater infrastructure, there is a point where it becomes exponentially more costly to achieve only a small additional improvement in the LOS. Based on competing needs for available funding, system owners or operators need to choose a balance between the cost of fully achieving the desired LOS goal versus allowing safe, short-term shallow "ponding" in known areas and for a known duration, for the less frequent larger return interval storm events. Analyzing two alternative LOSs, as was performed for the SWMP, allows a range of effort and cost to be determined for two end goals which can be compared to the available funding for a more realistic implementation plan.

For this SWMP analysis, *two alternative level of service goals were analyzed to provide a range of potentially achievable LOSs and the associated implementation costs:*

1. **LOS Alternative 1.** The primary LOS goal chosen by the City was zero flooding over the crown of all roads in the 10-year recurrence interval design storm event. This also includes keeping inundation out of buildings for the 100-year design storm wherever practicable.
2. **LOS Alternative 2.** The secondary LOS goal chosen achieves the same roadway and building criteria, but for a smaller 5-year recurrence interval design storm event. This allows for temporary flooding of a safe predictable depth, for short durations of time, in known areas, for the 10-year event to provide a more practicable or potentially more affordable solution for comparison purposes.



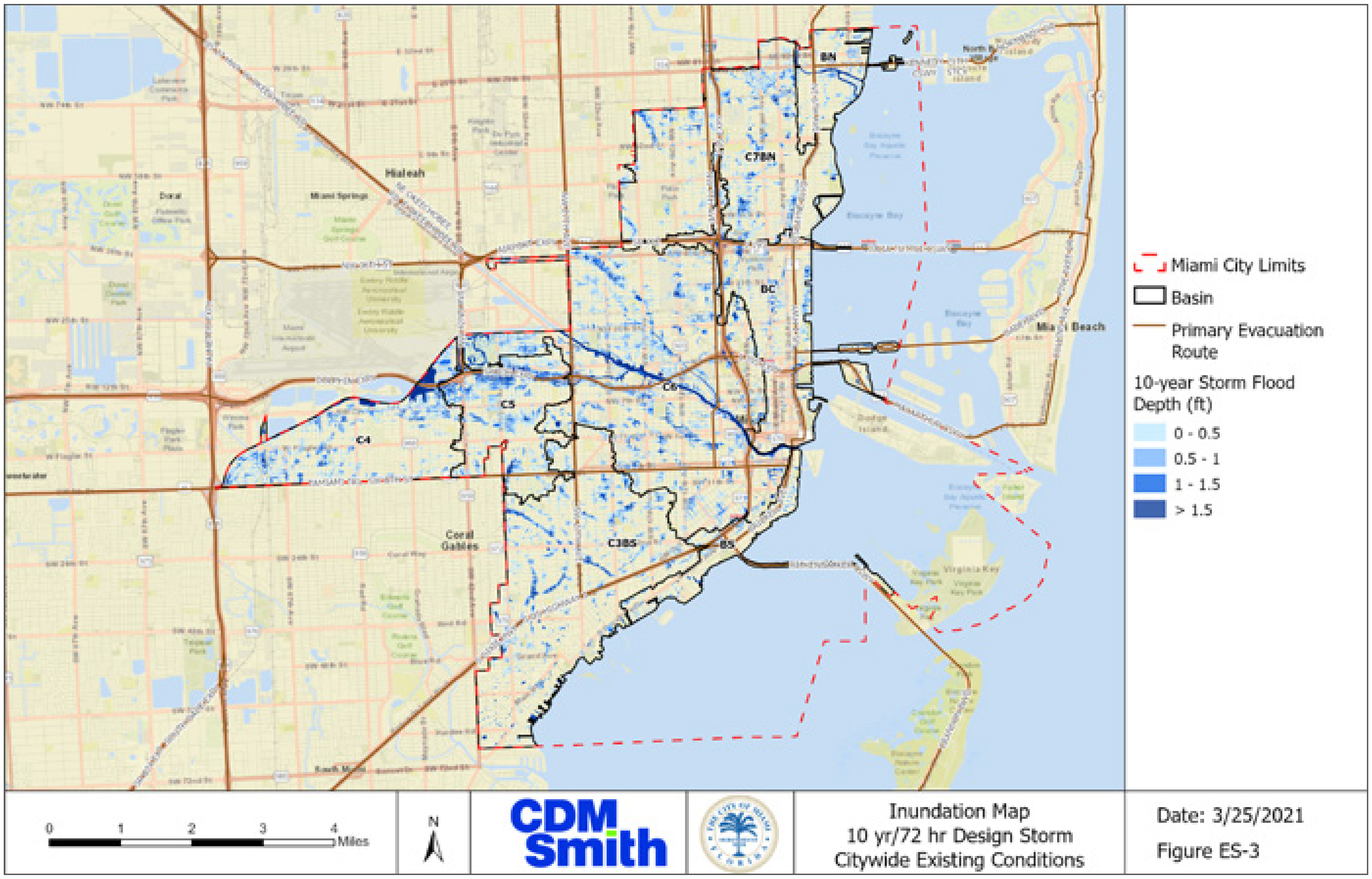

The City has chosen to implement a mixture of the Alternative 1 and 2 LOS goals for the SWMP and CIP program. The City recognizes that the primary Alternative 1 (10-year LOS) goal may not be achievable everywhere. Where it cannot be achieved, or where it is not economically feasible, the Alternative 2 (5-year LOS) will be used, realizing that the ALT 2 LOS is also a robust design goal due to the peak rainfall intensity being compressed into a shorter period of time. This secondary goal will still provide the needed relief for storms causing many of the City's recurrent reported flooding problems.

Using the validated models, predicted flood stage and inundation maps of the City were developed for the 5-, 10-, 25-, and 100-year design storms. The maps depict the extent and depth of flooding under the storm conditions, for comparison, and for the identification of flood prone areas. These maps are used as follows:

1. The **5-yr design storm** provides information for the secondary LOS goal flood areas for a more frequently recurring storm. The Alternative 2 CIP is subsequently run with the 10-year storm as well, in order to determine the location, depth, and duration of ponding for this LOS.
2. The **10-yr design storm** provides information for the City's primary LOS goal, and for major roadway flooding analyses.
3. The **25-year storm** provides the information required for regulatory permitting to the SFWMD for flows and levels in the major canal systems and their impact to the Bay, for pre- and post-CIP implementation.
4. The **100-year storm** provides information for the recommended finished floor elevations and for critical structure elevation vs predicted flood stages. It is re-run with sea level rise conditions to demonstrate the future impact to structures.

Figure ES-3 shows the citywide flooding inundation predicted for the City's primary LOS goal of the 10-year storm under existing conditions (EC). **Figure ES-4** presents the EC inundation map for the 100-year recurrence interval design storm used for predicting the amount of flooding into structures. The existing conditions simulation results show that approximately 20% of the City's area currently floods beyond the desired primary LOS goal. Approximately 5,000 buildings were predicted to be inundated in a 100-yr event.

Figure ES-3. Existing Conditions 10-year Storm Predicted Inundation Map



Analysis of the existing conditions flooding reveals that the existing system issues are caused primarily by a mixture of the following factors:

1. High amount of impervious area, and a relatively flat terrain, with high groundwater table and limited amounts of surface storage area.
2. Existing structures and roads built at low elevations in historic floodplains where stormwater runoff naturally collects.
3. Lack of positive drainage systems to catch and convey stormwater in many areas surrounded by ridges trapping runoff.
4. Tidal backflow and seawall overflow from high tide events (e.g., King tides) and hurricane and tropical storm surges.
5. Maintenance issues with older stormwater systems, including system clogging with sediment and debris in redeveloping areas where ongoing construction restricts the ability of the pipes to flow at their full design capacity. This results in backups upstream, flooding, and slow time to drain the surface after a storm.
6. Undersized pump stations, as well as a limited number of existing pump stations, to effectively move water out of depressional areas where it accumulates and cannot flow out by gravity.
7. Areas where runoff flows into the City from outside the City limits. These occupy a portion of the limited capacity of the City's system and exacerbate the flooding within areas of the City.

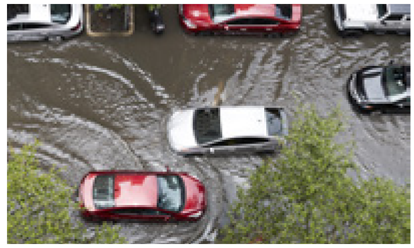
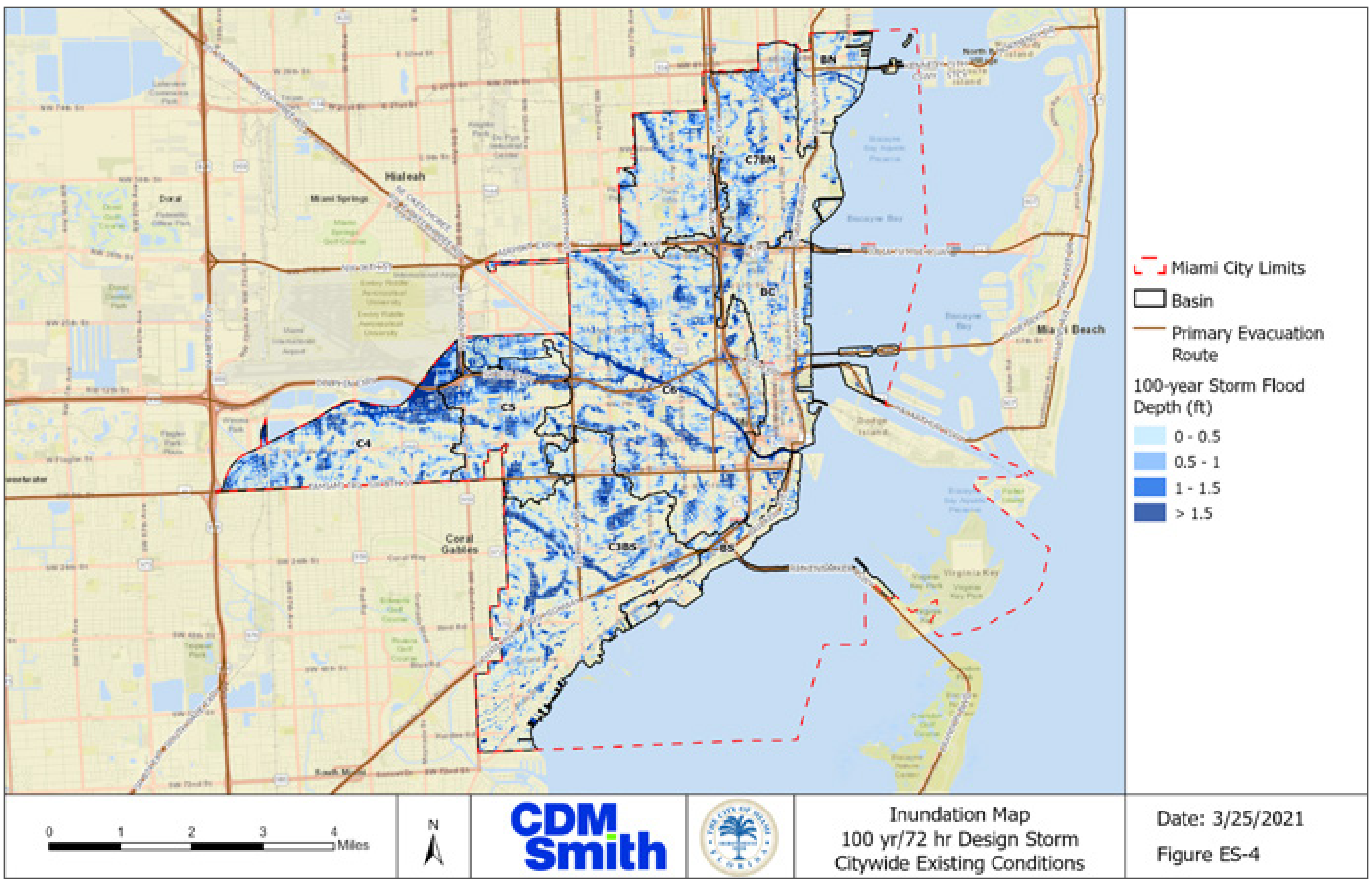
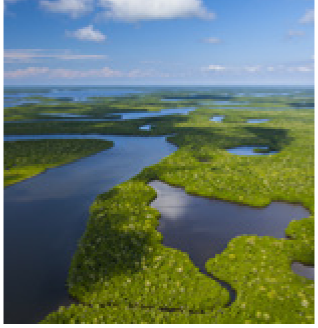
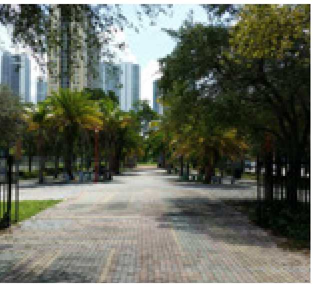
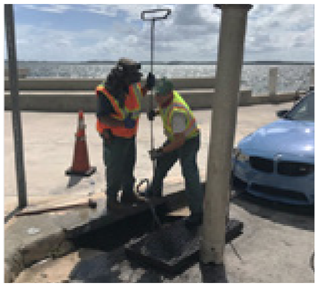


Figure ES-4. Existing Conditions 100-year Predicted Storm Inundation Map



CIP Alternatives Analysis

For the CIP alternatives analyses, the delineated neighborhood-size sub-basins were combined logically into 78 discrete "CIP Areas" which considered in-common topography and PSMS elements of adjoining neighborhoods. Capital improvements to the stormwater management system were systematically added Citywide, and iterative simulations were run testing the proposed infrastructure until the City-desired LOS for each alternative was achieved.

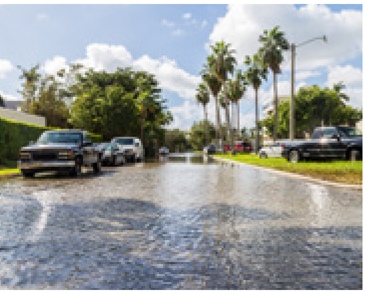

Constraints Affecting the CIP

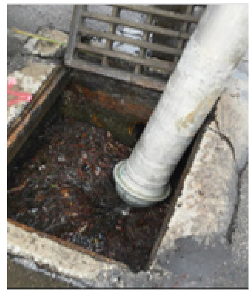
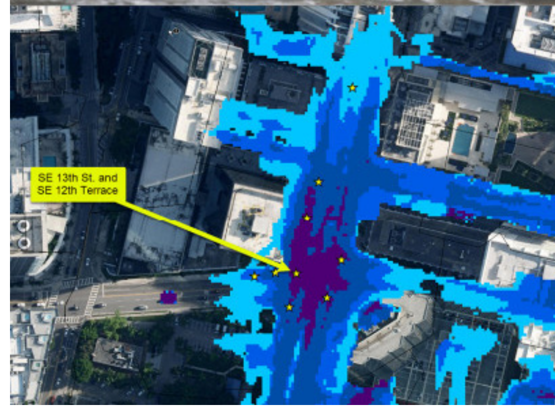
Factors which added complexity, cost, and magnitude to the City's CIP solutions for stormwater management included the following:

1. **Low-Lying Undulating Topography.** Many areas of the City are at an elevation too low to allow effective stormwater measures (such as exfiltration or positive gravity systems) to function properly. These areas are typically surrounded by small ridges which capture the runoff. In these areas, many of the existing building's finished-floor elevations are below the FEMA floodplain elevation. These areas, which can be envisioned as "bottoms of the bowls" will require local gravity collection systems to collect stormwater at centrally located pump stations and provide the energy to move the stormwater out of the confined areas and "uphill" to outfalls or into dedicated forcemains. Pump stations are more costly to operate and maintain. They require dedicated land, easements, proper power supply in the area, standby power generation systems and fuel storage for when power goes out during a storm. They also require pollution control systems, landscape for aesthetics, and large force mains for the station discharge. Installation of pump stations may still not fully resolve flooding issues for areas where structures or roads were built at too low an elevation, or where off-site flow into the City from other areas consumes a portion of the station's capacity.
2. **High Groundwater Table Elevation.** Groundwater table elevations vary across the City and are near the ground surface close to the coast and the rivers. This can limit the amount of infiltration and causes increased amount of runoff.
3. **Salinity Front and Aquifer Classification Constraints for Underground Disposal.** Restrictions exist on allowable locations where recharge/drainage wells discharge and treat stormwater runoff, so it does not have to be collected and conveyed in pipes and canals. Two applicable regulatory rules govern where these systems can be installed:
   - A saltwater/freshwater interface exists beneath the City where the ocean meets the inland freshwater aquifer, the exact location of which inland varies from North to South with seasonal rainfall, tides, canal operations, potable water well pumping, rainfall, and sea-level rise. This situation is commonly referred to as saltwater intrusion, as it detrimentally affects the area's potable water supply. The saltier layer where stormwater is permitted to be injected into the ground is defined as groundwater with a chloride concentration of 10,000 milligrams per liter (mg/L) (parts per million, ppm), or greater. This area is generally only the eastern portions of the City from just west of I-95 to the Bay.
   - The use of the Biscayne Aquifer for recharge/drainage wells is permittable in areas as long as injection of runoff is also restricted to zones where there are no impacts to Class G-II potable water supply aquifers, (i.e., water treatment plant wellfield water supply sources). These areas generally coincide with the zones where chloride concentrations exceed the saltwater intrusion front rule.

4. **Tidal Backflow, Tidal Surge, and Future Increasing Tide and Groundwater Elevations.** As sea levels continue to rise, several detrimental effects occur in the City's existing and future stormwater management system:
   - The water surface boundary conditions at the stormwater outfalls also rise in elevation. The drainage will therefore become less efficient for non-pumped systems, restricting the hydraulics which allow gravity flow from upstream, and exacerbating flooding over time. Citywide, the remaining and new outfalls will be required to be retrofitted with backflow prevention devices in order to prevent the flow of the rising sea levels backward into the land areas through the open stormwater pipe system (referred to as: sunny day flooding). These devices add additional headloss to the pipe system and often require larger conveyance systems and storage in order to balance the additional driving head required to push water through the valves, adding more cost to the systems.
   - Groundwater elevations inland will rise concurrently with sea levels at a tapering level as it extends inland away from the coast or from the rivers, rendering the exfiltration and gravity recharge/drainage well systems nearest these areas less effective, and also requiring eventual additional pumped systems. A requirement for new exfiltration trenches to consider future higher groundwater elevations (i.e. 1 foot above today's groundwater elevation) will result in additional trench length to be designed in addition to an already costly and extensive proposed exfiltration network in the CIP.
   - The resiliency requirements being implemented for shoreline protection in the form of armoring (i.e., seawalls) will also, as a side effect, trap stormwater runoff from free-flowing overland into the Bay and will require additional stormwater mitigative measures, such as more surface/yard storage and/or higher cost pumped systems in these areas.



5. **Protection of Biscayne Bay.** The dynamic and diverse ecosystem of Biscayne Bay is governed by several sets of rules. These include the Historic Sites Act, Endangered Species Act, National Environmental Policy Act, Clean Water Act and other Title 36 rules. It is further designated as an impaired Water and an Outstanding Florida Waters (OFW) by FDEP/SFWMD, a water body that requires the highest protection and allows stricter scrutiny for permitting. As the Bay is the ultimate discharge point for above ground stormwater runoff for the City (whether by overland flow, or gravity piped or pumped outfalls), this regulatory situation results in additional restrictions on discharge of untreated water into the Bay. These include requirements for enhanced pollution control, limits to shoreline development, and the addition of pre-post development flow constraints, thus limiting stormwater management options and increasing costs for treatment.
6. **Management of Flows Entering the City from Off-Site and Maintaining Pre-Post Stage and Flow Conditions.** To be permittable for construction, stormwater projects are required to demonstrate that they both maintain the existing historic stormwater flow paths and they do not result in adverse impacts to existing flood levels upstream or downstream of the proposed improvements. Several areas in the City are lower than their surrounding communities and, during large rainstorms, significant flow can enter from other "off-site" areas. This exacerbates the flooding within the City and results in larger capacity City infrastructure capital improvement requirements, as a portion of the system capacity is being occupied by non-City flows. In many situations, due to localized hydraulic conditions, further increasing the capacity of the City's stormwater infrastructure resulted in more flow entering from off-site areas, diminishing the effectiveness of the City's CIP to address its own flooding LOS.
7. **No Available Dedicated Stormwater Management Lands.** The City is near buildout, and little, if any dedicated stormwater management lands exist to store stormwater runoff, attenuate the peak flows, and treat the runoff generated from the highly impervious land areas. This is exacerbated by development at, or near, existing grade elevations within the many natural riverine sloughs and floodplains of the Miami River, and infill of lands over time without compensating floodplain storage, both resulting in increased runoff. At this time, the City is not creating or converting existing recurrent flood areas into dedicated storage areas as part of the initial CIP. Accordingly, all of the generated runoff to meet the LOS alternatives must all be handled with constructed retrofit conveyance, treatment, and disposal infrastructure.

Figures ES-5 through ES-8 provide the resultant flooding reduction after the proposed CIP is in place under the primary goal Alternative 1 with the developed 10-yr LOS CIP in place for the 10 year and 100-year storm event, and the secondary goal Alternative 2 with the 5-yr LOS CIP in place for the 10 year and 100-year storm event. As shown on the figures, *both alternatives provide a substantial improvement in flood reduction Citywide as compared to the existing conditions LOS flooding.*

Figure ES-5. Inundation Map With Alternative 1 CIP for the 10 year Design Storm

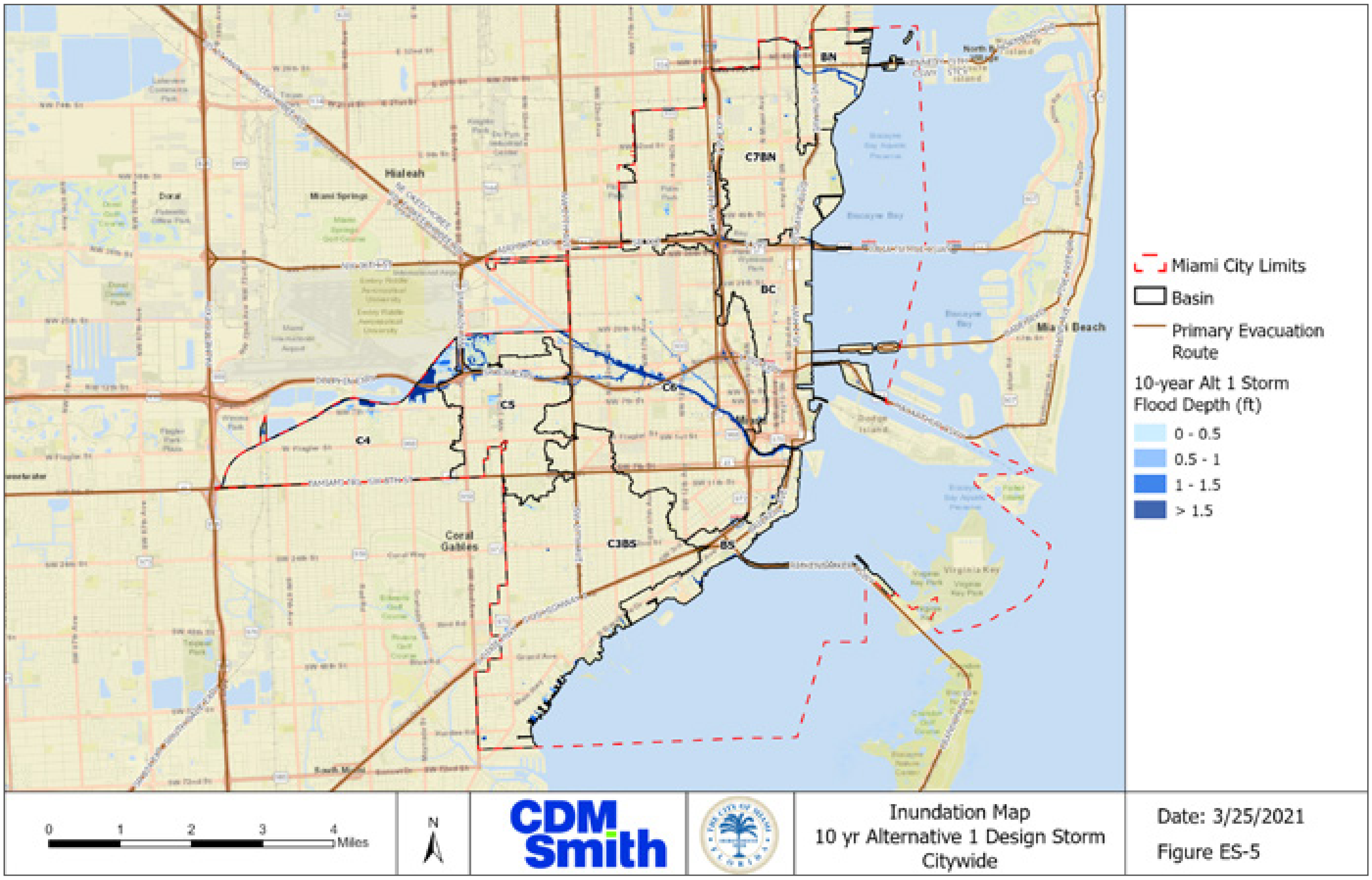


Figure ES-6. Inundation Map With Alternative 1 CIP for the 100 year Design Storm

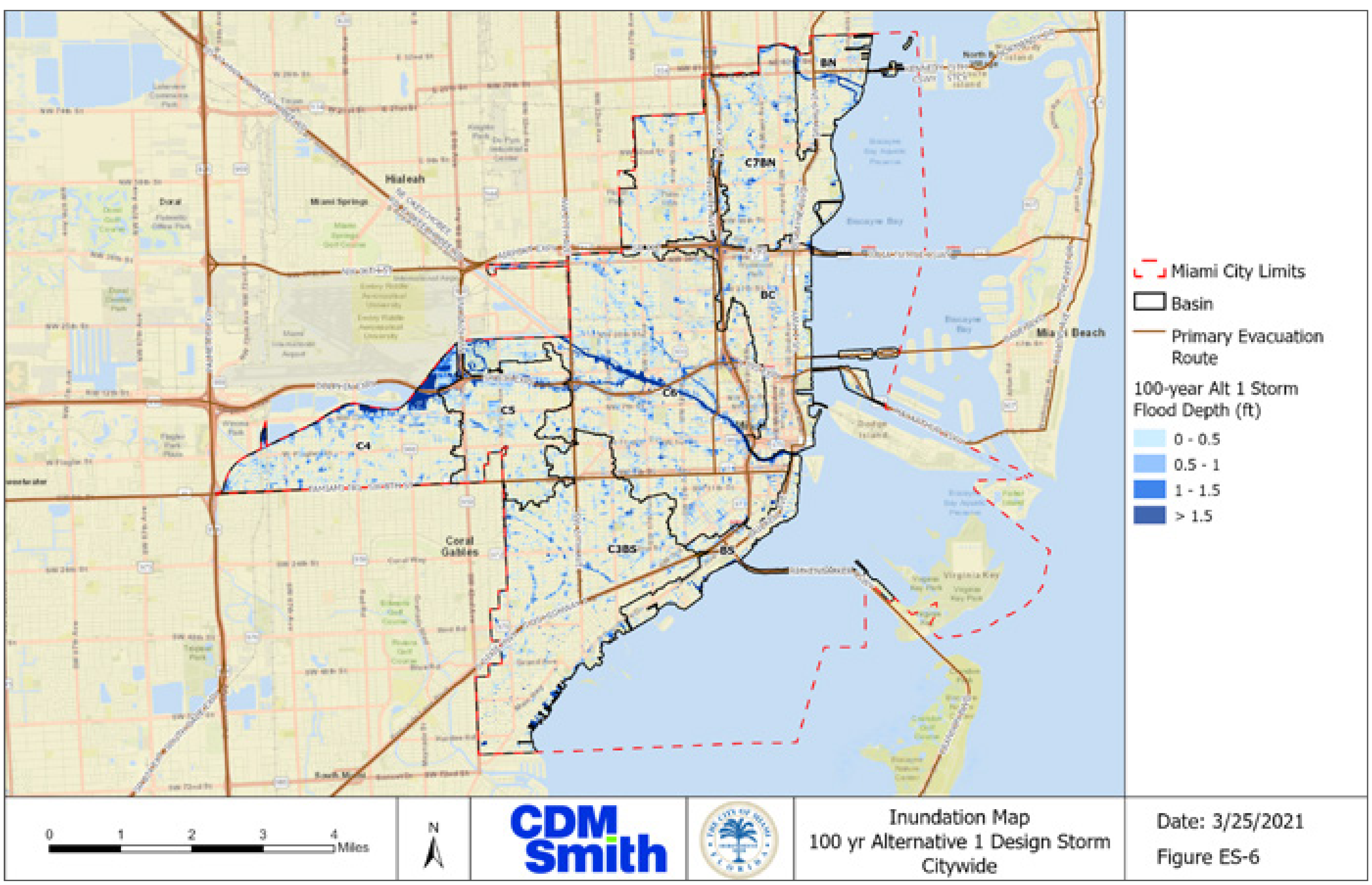


Figure ES-7. Inundation Map With Alternative 2 CIP for the 10 year Design Storm

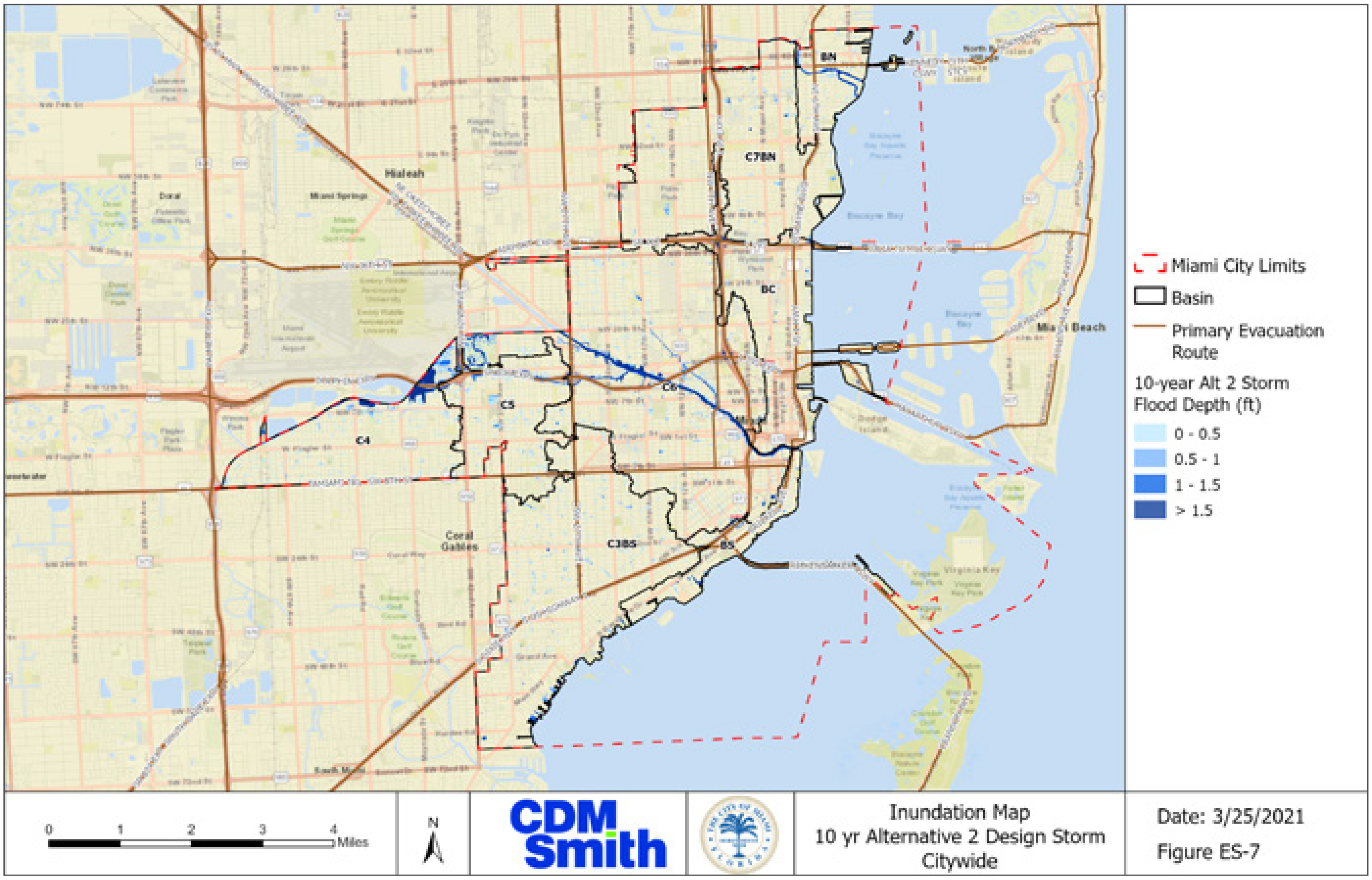
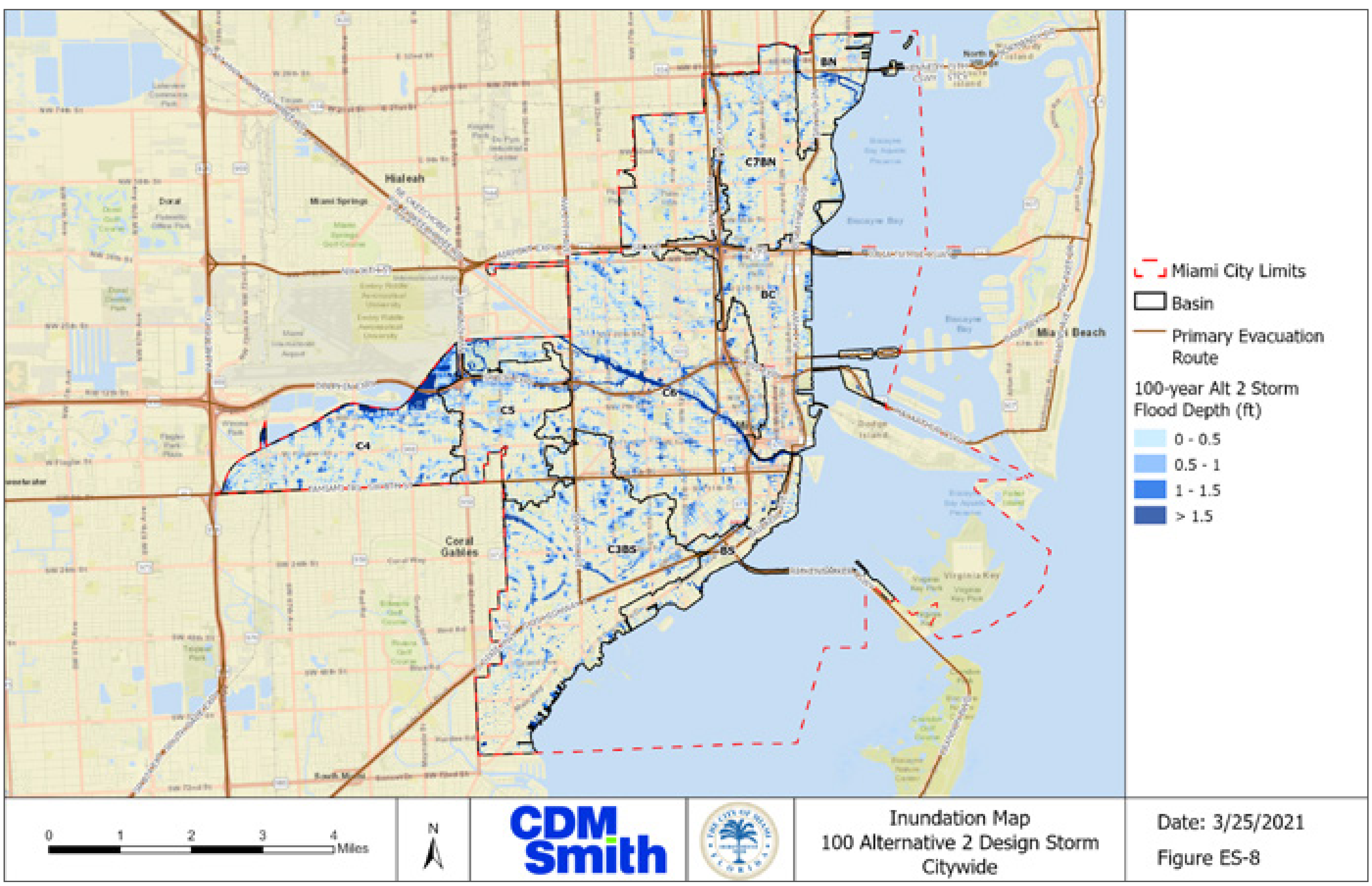
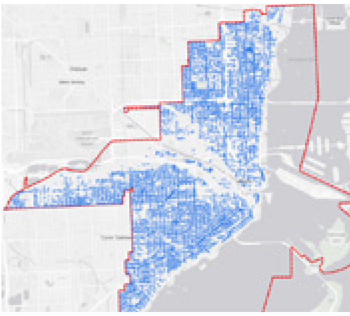


Figure ES-8. Inundation Map With Alternative 2 CIP for the 100 year Design Storm



Stormwater Management Opportunities and Needs

Opportunities and considerations for rainfall and tidal flood mitigation components included the following elements which are implemented for both flood control and water quality, aquifer recharge, and saltwater intrusion reduction benefits.



1. **Exfiltration Systems.** *The most cost-effective stormwater management components for the Miami area are exfiltration systems due to the high flow capacity (conductivity) of the Biscayne Aquifer, their modular implementation flexibility, and delivery of multiple benefits.* These systems collect, store, infiltrate, treat, and convey stormwater in the City's available rights-of-way (ROWs) and easements, generally for the lowest cost. They are comparatively straight-forward and modular to design, permit, and construct, and they can be phased as needed or as opportunities arise (as street, water, sewer, park, and landscape improvements are implemented). The multiple benefits of these systems include flood mitigation, water quality treatment credits and aquifer recharge for reduction of saltwater intrusion and protection of groundwater supplies. These systems rely on the hydraulic grade of the water collected at the land surface to infiltrate stormwater into the porous, surficial aquifer. Due to the naturally high groundwater table elevation in the City, just below the ground surface in many of the lower-lying areas, these systems will not work everywhere as there is not sufficient hydraulic grade to effectively overcome the driving head required to flow into the aquifer below, and thus other, more expensive systems are required in those areas. Therefore these systems are recommended in areas with topographic elevations greater than 5.5 feet referenced to the North American Vertical Datum of 1988 (ft-NAVD). These systems will also be impacted by sea level rise in the future but have been evaluated to be effective through the SWMP planning horizon.
2. **Recharge/Drainage Wells.** These wells can be used to discharge stormwater to surficial aquifer zones east of the salinity line. This is generally in the eastern portion of the City. They can be retrofit into existing stormwater management system manholes to augment the exfiltration systems. Pre-treatment is provided for oil-grease, trash, and debris. These systems provide discharge capacity and treatment credits, since dissolved nutrients that would be harmful to Biscayne Bay are discharged into the brackish surficial aquifer. This also assists with creating a saltwater intrusion barrier for current and future sea level conditions. In some cases, these wells can be augmented by pumps to increase the recharge flow rate and reduce flows, volumes, and pollutants loads to the Bay, canals, and rivers.
3. **Green Infrastructure.** Green infrastructure is the use of natural planted systems to collect, store, treat, and infiltrate stormwater. These systems can be implemented on individual sites or for capital improvement projects along streets and buildings, and in parks. These can be raingardens, and/or landscape planter swales. These systems also can reduce precious potable water use for irrigation since they are watered by both rainfall and runoff and receive some of their nutrient requirements from the stormwater. *The synergistic effect of the installation of many green infrastructure systems spread throughout the City can become helpful for chronic flooding areas and allow each resident to participate in the flood solutions on their own sites.*

4. **Backflow Preventers.** The City has more than 480 stormwater outfalls and these can backflow during high tide and tidal surge events. Outfalls will require backflow preventers to keep the rising seas out of the system and provisions for the increased head loss to open them must be considered in the CIP implementation.
5. **Pump Stations.** The SWMP considered the maximum amount of exfiltration and recharge wells possible, but due to the limitations of these systems and locations where they work, the need for new stormwater pump stations still remains to provide flood protection in many low-lying areas.
6. **Seawalls.** There are approximately 90 miles of Bay and River coastline in the City that will need seawall upgrades for current tidal surge, and for future sea level rise and those associated tidal surges. The SWMP has included these seawalls along the entire coast perimeter to demonstrate the extent, benefits, and costs for these systems. These seawalls are largely privately owned and must upgraded in a consistent manner. The City has drafted an Ordinance to address seawall standards and criteria.

SEA LEVEL RISE & RESILIENCY CONSIDERATIONS OVERVIEW

The sea level rise and resiliency analysis in the SWMP focused on three primary areas:

1. Simulating future sea level rise conditions with the associated higher tides and groundwater levels to predict the impact on effectiveness of the proposed CIP alternatives in the future.
2. Simulating coastal armoring and seawall protection at different storm surge heights.
3. Resiliency planning simulation for a "worst case" storm occurring coincidently with a peak high tide and storm surge event.

Sea level rise predictions used for the analyses were in accordance with the City-adopted Unified Sea Level Rise Projection and Guidance Report (2019) produced by the Southeast Florida Regional Climate Change Compact. The results are used to aid in understanding the vulnerabilities of the City and its stormwater management system with relation to surge and sea level rise, and to provide a basis for adaptation strategies, policies, and infrastructure design. If sea levels and groundwater levels continue to rise over time as projected, eventually the shallow aquifer disposal and recharge CIP elements (which rely on a minimum hydraulic depth to the water surface elevation) will begin to become less effective over time. Other more costly and difficult to permit options such as more and larger pumps will need to be considered to offset the loss of stormwater infrastructure capacity. Discrete sea level rise scenarios of 18-inches and 30-inches were simulated within the two CIP alternative stormwater models to gauge the effect on the proposed CIP. **Figures ES-9** and **ES-10** show the increased inundation resulting from the decreased effectiveness of the system under the two future sea level rise scenarios.

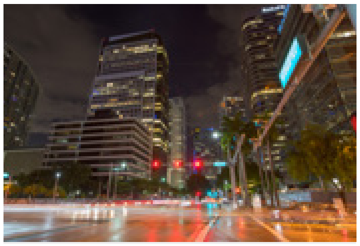


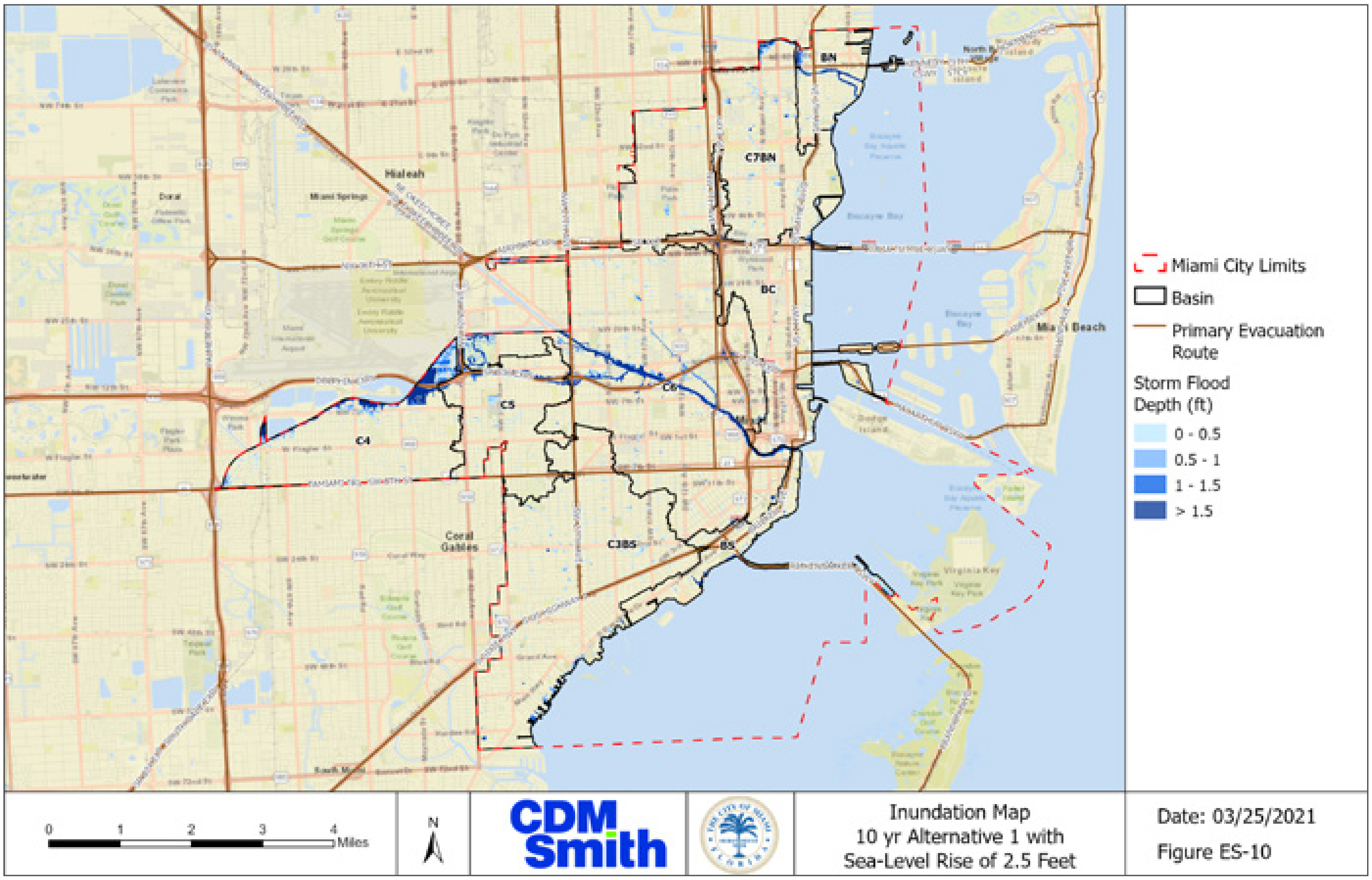
Figure ES-9. Inundation Map Showing Effect of Sea Level Rise of 18-inches on the Alternative 1 CIP

Near-Term Resiliency Planning and Actions

Near-term resiliency (20- to 50-year planning horizon) measures include both structural and non-structural actions, many of which are currently in place or in progress in the City, and include the following:

- **Risk Assessments and Strategic Action Plans.** Planning studies such as this comprehensive stormwater masterplan, which define the highest risk areas of the City, can assist local governments in identifying and assessing the risks that climate change poses to their current and planned assets, and operations and services. It can also help prioritize risks that require further action as a basis for decision-making and adaptation planning, and funding solutions.

Figure ES-10. Inundation Map Showing Effect of Sea Level Rise of 36-inches on the Alternative 1 CIP

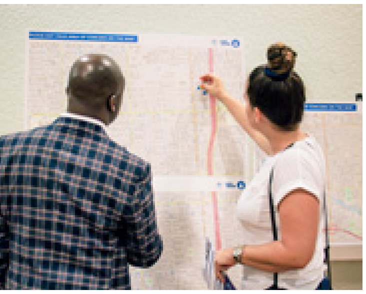


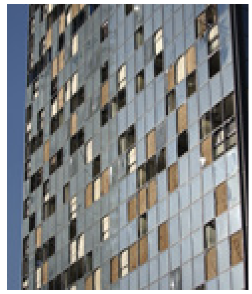
- **Emergency Operations Center.** The City's division of emergency management and emergency operations center is well established and includes officials from City government, police, fire rescue, disaster specialists, and public information officers.
- **Building Code Strategies.** Risk mitigation requires a citywide response using adaptation strategies. These include starting with revisions and updates to building and land development codes, focusing on evaluating minimum structure finish-floor elevations compared to predicted water surface elevations, and piled or stilted structures to consider future sea level rise (which is only effective if roadways and building access are raised as well).
- **Flood Insurance.** The National Flood Protection Insurance Program (NFIP) allows property owners in participating communities to buy insurance to protect against flood losses. Participating communities are required to establish management regulations in order to reduce future flood damages. This is intended to be furnished as an insurance alternative to disaster assistance and reduces the rising costs of repairing damage to buildings and their contents caused by flooding. The more NFIP/Community Rating System (CRS) measures the City has in place, the better the discounted flood insurance rate will be for the residents.



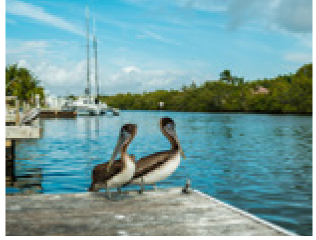

- **Dedicated Sources of Financing.** Implementation of specific financing instruments designed to create diversified, scaled pools for investment tailored to a targeted class of measures that share a similar risk-reward profile such as portfolio-based loans, catastrophe bonds, re-insurance, securitization, or other structured finance instruments should be considered. Some options for additional funding may include: FEMA Building Resilient Infrastructure and Communities (BRIC) grants, FEMA Hazard Mitigation Grant Program (HMGP) for post-storm repairs and upgrades, HUD Community Block development Grants (CBDG), State Revolving Fund (SRF) loans, USEPA Water Infrastructure Finance and Innovation Act (WIFIA) loans, additional bonding, potential funding from proposed State of Florida coastal resilience grants, and public-public partnerships with Miami-Dade County, FDOT, and SFWMD.
- **Public Awareness.** Public awareness campaigns to understand adaptation policy and its benefits to the City are crucial to gain the trust, buy-in, and engagement of residents and developers/investors into the resiliency programs.
- **Preserving or Creating Natural Coastal Wetlands.** Creating, protecting, and strengthening natural infrastructure living shorelines such as coral reefs, oyster reefs, and marshes which are the City's first lines of defense with their inherent ability to dissipate wave energy and block surge flow similar to the effect of artificial defenses such as seawalls.
- **Shoreline Armoring.** Traditional "grey infrastructure" such as seawalls and breakwaters are common along the City's shorelines and canals but are lacking in many areas. For example, some seawall areas have fallen into disrepair, some are at too low an elevation to be effective, and several areas have no protection. The shoreline armoring is only as strong as its weakest link as encroaching waters will find the low spot or break in the armor and flooding will occur. This is why it is critically important, for the expense that will be required, to pay careful attention to the continuity and seamlessness of the shoreline system (including private properties) to seal the barrier and prevent the onset of flooding.
- **Backflow Prevention.** The City's stormwater systems typically have open outfall pipes into the receiving waters that are vulnerable to water freely flowing back onto the land as the receiving water level rises, resulting in non-rainfall related flooding in low lying areas at high tides. Backflow prevention devices are used to provide a one-way valve in the pipes that allow flow only out toward the receiving water, and then seal shut when conditions would result in flow in the opposite direction back toward the land.
- **Update Evacuation Route Design Standards.** Although technically the responsibility of the roadway owners, the City can do its part to address flooding in local streets and areas along these routes allowing for safe access to the roadways. The local City roadway upgrade initiative portion of the Miami Forever Bond is addressing some of these issues.





- **Emergency Standby Power Systems for Critical Infrastructure.** Power outages result from electrical system failures at the grid, local, or facility level and are frequent in South Florida where typical, strong convective thunderstorms and tropical systems can down powerlines, lightning causes electrical power surge, and floodwaters can inundate and short electrical equipment. If weather events become more frequent or extreme, the likelihood of power failures and pump shutdown events increase. As the City's current and proposed stormwater management systems rely on a network of pump stations working in concert to keep flood waters at the desired LOS, having a dedicated, maintained standby power system at all critical stormwater pump stations in the system is key for resiliency and keeping flooding events at a minimum.
- **Flood Stage Gauge Network.** A dry-land and canal stage monitor network can report real-time flooding city wide and assist emergency managers in providing public safety information in flood-prone areas. The monitors can also provide historical water surface elevation data correlated with rainfall to see real time stormwater systems response, CIP effectiveness, and aid in locating future improvements or trouble areas where clogging may be occurring and maintenance is required. The monitors will also pick up trends over time for areas where sea level rise is beginning to diminish the effectiveness of the stormwater systems.
- **Raising of Critical Infrastructure.** Using the predicted peak stages for the masterplan tables, the City's critical infrastructure can be raised to the appropriate resiliency height chosen. This can be performed by relocation and building new, constructing watertight berms or containment walls and stairs at entrances, or adding new stories and relocating from the first floor. City public works infrastructure can be heightened by adding new concrete pads and slabs, watertight hatches, and raising electrical equipment.
- **Planning for Future Relocation of At-Risk Population and Infrastructure.** Over time, as the City implements the CIP and adapts to rising seas, it may be appropriate to consider purchase and removal, or relocation, of the repetitive loss structures and infrastructure. The SWMM models and FEMA Hazard United States (HAZUS) tool can be used to further assess the benefits versus costs for the flood risk and protection of public safety and the environment. Purchasing floodprone structures can also provide locations for future flood storage and treatment in concert with park departments.
- **Discussions for Regional Solutions.** The City should engage discussions with its neighboring municipalities for co-operative solutions that assist with runoff flows entering the City from off site, shared projects for flood mitigation, and regional solutions for flood mitigation coordination. These include neighboring cities and Miami-Dade County. Some considerations could be for discussions with United States Army Corps of Engineers (USACE), South Florida Water Managemnt District (SFWMD), Florida Department of Transportation (FDOT), or Miami-Dade County to reduce runoff from their systems or to consider diverting flows to the west as practicable for combination with flood mitigation, water supply, and ecosystem restoration projects and integrated water solutions.

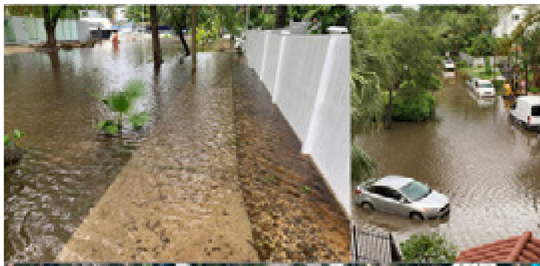



Long-Term Resiliency Planning and Sea Level Rise Adaptation of the SWMP

Long-term resiliency (defined as at the end of the century) measures also include both structural and non-structural activities. Most long-term measures are conceptual in nature because they require funding and policy decisions beyond what the City can realistically generate or implement today. They also include decisions that could significantly affect the entire South Florida population, way of life, and local economy, and would require coordination and agreement amongst multiple stakeholders. Often, the long-term solutions compete with environmental protection initiatives. Considering standard engineering solutions, it is likely that at a certain point in the future, the energy required to continually pump water out of the City (assuming the pump option is affordable) might, in terms of fossil-fuel emissions, have a carbon footprint more detrimental to climate change initiatives. The City of Miami has committed to community-wide carbon neutrality by 2050.

Because climate change cycles occur over such a long period of time, in general it is sometimes hard for officials and regulators to begin to commit funding, adopt, or enforce long-term solutions now, as there are many competing current interests for the funding. It is speculated that future bank mortgage and development lending risk, flood insurance rates and availability, long-term (99 year) municipal land leasing, and the real estate market will ultimately drive the urgency for implementing long-term resiliency action. Long-term resiliency planning includes the following:

- **Regional Protection System Concept for Miami and Vicinity.** For Miami and its neighboring coastal municipalities, the eventual requirement of floodwall protection and an associated impermeable aquifer curtain wall with locks controlling the waterways and large pumps to move rainfall accumulation is likely. There are many issues to overcome before this scenario can become reality including cost, environmental impact, and physical location.



- **Adaptation Considerations.** A long-term option for the City would be to adapt and live with the rising water and over time, raise the lowest-lying elevations in the City of Miami, as well as portions of Miami-Dade County and Broward County, in a phased reconstruction of most structures and roadways below 10-ft NAVD. The lowest-lying areas would be excavated creating large, dedicated storage areas for stormwater and potentially providing fill for some of the remaining areas.
- **Co-Existing with Water.** Forward-thinking, resiliency analyses and studies, in conjunction with preparations for co-existing with stormwater flooding and adaptation to future sea level rise, consider modifying the basic design of the City. These considerations include building code changes for finished floor evaluation and ground floor sacrifice, applying Low Impact Development/Green Infrastructure (LID/GI) requirements, and exploring the possibility of conceptual measures such as future elevated pile roadway networks, elevated houses, floating neighborhoods and platform communities in low-lying areas over the created water catchments, sealing underground utilities, and conversion of low-lying streets to an interconnected canal system for transportation and flood control.

The CIP components proposed in this SWMP for stormwater management infrastructure may be beyond their design life by the time regional options are significantly accepted and in place. If groundwater levels are maintained close to existing levels or lower, either with a City installed local floodwall/curtain or a regional perimeter floodwall/curtain by other agencies, exfiltration and injection into the Biscayne Aquifer should still provide flood relief for large rainfall events. Large gravity systems and pump stations should be able to continue to move floodwaters from flood prone areas to the Bay. The freshwater pumped into the aquifer may be used for potable aquifer recharge, as there will be additional bounding of the aquifer within the curtain, and eventually Biscayne Bay may also be a source of freshwater. This would however, alter the ecosystem severely.

CAPITAL IMPROVEMENTS PROGRAM OVERVIEW

The strategy to address and mitigate flooding requires a multi-tiered solution which includes:

- *Maximizing catchment of runoff on the existing "uphill"* areas to minimize the flow of runoff downhill into the lower-lying areas where it accumulates as ponding or flooding.
- *Installation of systems that direct stormwater into the ground* and out of the primary conveyance system via new exfiltration systems, positive gravity drainage systems and recharge wells, new systems in non-storm sewered areas where conditions (groundwater elevation and hydraulics allow) to the maximum extent possible. This ultimately creates capacity in the existing system.
- *Addition of new pump stations, forcemains and injection wells* into areas that are too low to positively drain by gravity and uphill catchment is not sufficient due to topography. This may also occur in areas where new required seawalls will block and catch historic overland flows and result in ponding.
- *Installation of backflow preventers in the stormwater outfalls* to the waterways to prevent the flow of seawater back into the neighborhoods during king tide and future sea level rise conditions.
- *Installation of coastal armoring with new or raised seawalls* or equivalent protection will be needed for approximately 90 miles of Bay and river coastline (City and private) to manage current tidal surge and for future sea level rise and associated tidal surges.

These stormwater management systems are required to be installed Citywide and work together to meet the chosen LOS goals as each provides a portion of the water quantity and water quality solution, as none of these elements by themselves are sufficient to resolve all areas of the City. A few of the lowest-lying areas are noted in the analysis where additional or larger capacity CIP did not lower flood stages to warrant further infrastructure. The City might consider the future conversion of these areas to dedicated stormwater management lands. **Figure ES-11.1** and **ES-11.2** show an overview map of the full CIP to achieve the City's primary goal of the 10-year Alternative 1 LOS and secondary goal of Alternative 2, respectively. As shown, Alternative 2 is similar but requires less total infrastructure at a cost reduction.

Figure ES-11.1. CIP Components to Meet the Alternative 1 LOS

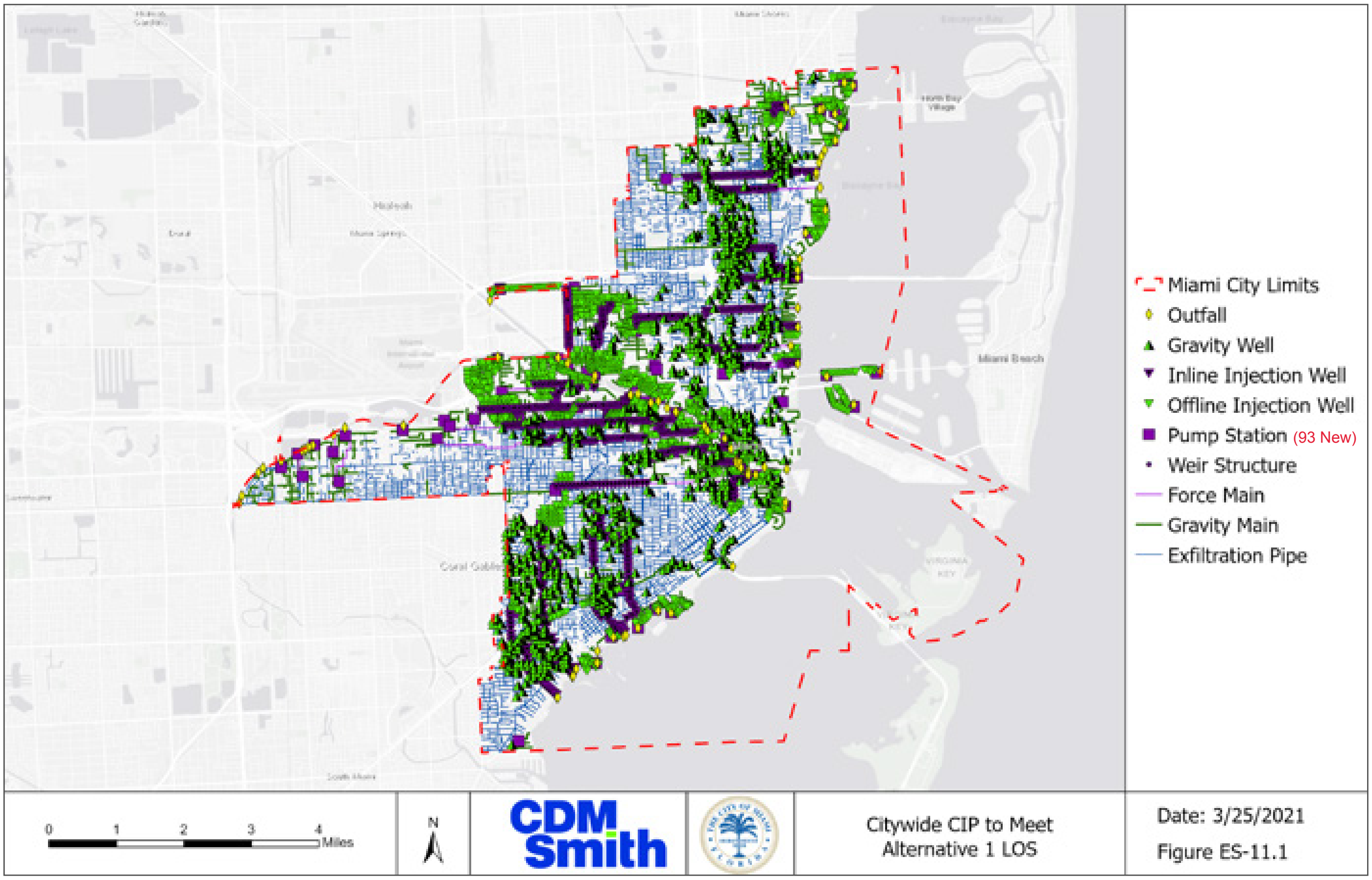


Figure ES-11.2. CIP Components to Meet the Alternative 2 LOS

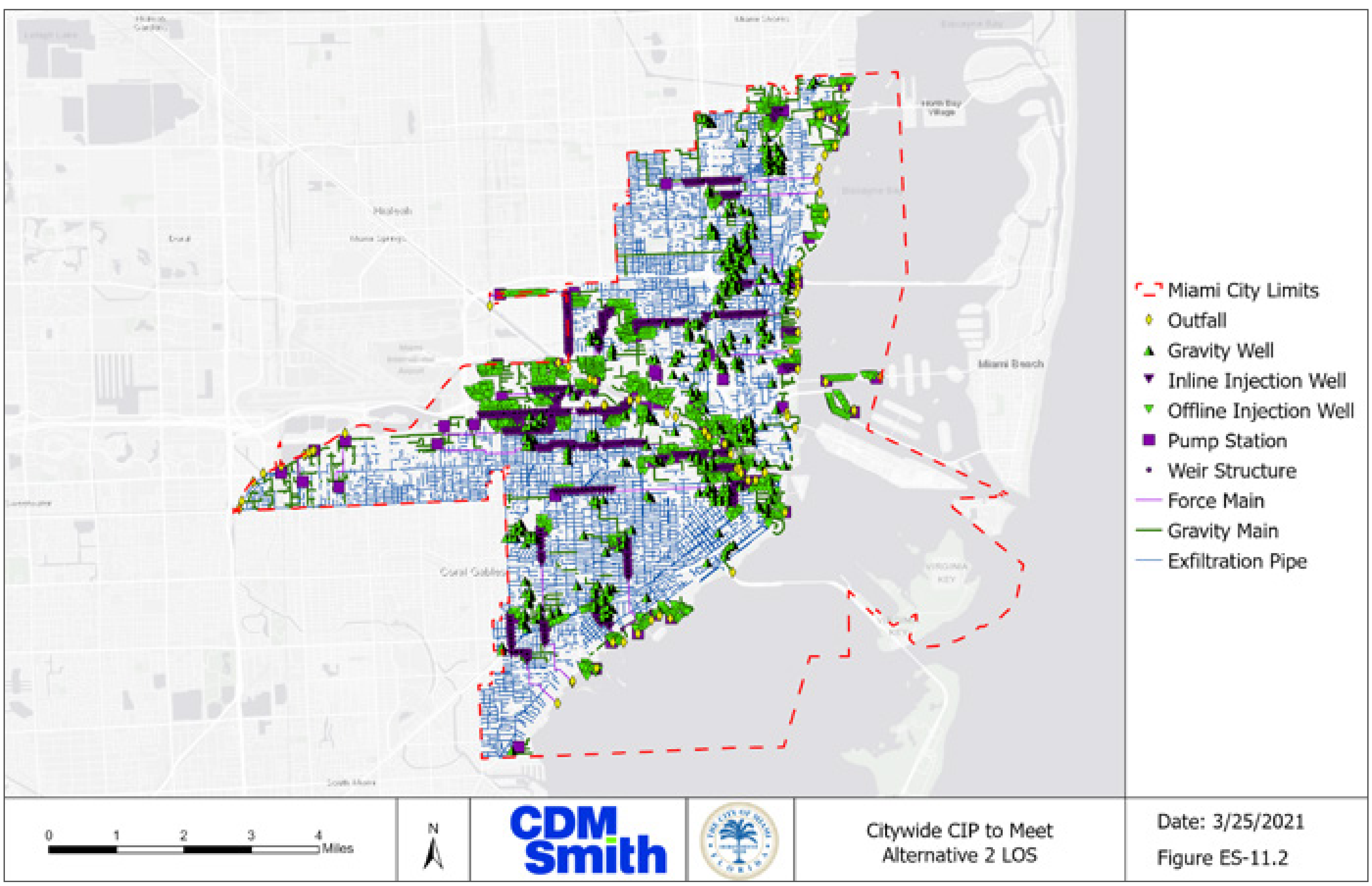


Table ES-1 provides the flood reduction summary for both Alternatives.

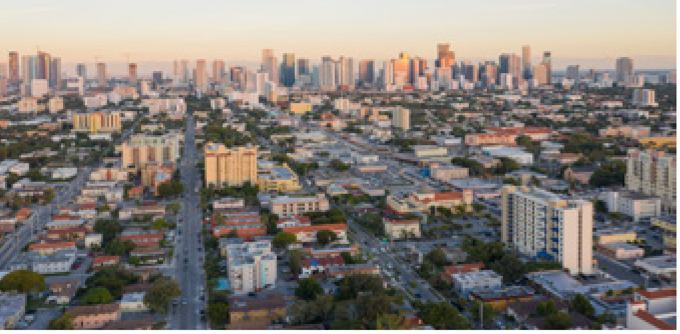
Table ES-1. Approximate Flooding Reduction Summary for CIP Alternatives

Condition	Percent of City Inundated (10-Yr)[1]	Length of Streets Not Meeting LOS in 10-Yr (mi)	Estimated Structures Inundated (100-Yr)[3]
Existing Conditions	24	250	5,390
Alternative 1 CIP	3.6	2	239
Alternative 2 CIP	6.4	54[2]	799

[1] *Total area that shows flooding during the design storm and includes private roads, dead ends, street elevation anomalies, parks, swales, depressions, parking lots.*
[2] *Remaining flooding length above road crown is a few tenths of a foot and of short duration (less than 4 hrs). Total length of streets used is 795 miles.*
[3] *Building FFEL approximation is based on 1 foot above the LiDAR average perimeter at the structure, total structures used is 90,672 (>500sqft)*

CIP Implementation Sequencing and Planning-Level Costs

Due to the magnitude of the widespread flooding in the study area, and the inherent sensitivity-interaction-interconnectivity of the collective impacts on flood reduction from all the proposed CIP elements working together, it is not possible in many flooded areas to assign a single CIP project to solve a particular flooding area issue. *Analysis shows that typically several projects implemented together are required to resolve the flooding collectively for many common areas.* Examples include catching water "uphill" in surrounding areas to limit inflow into a lower neighboring area, lowering canal stages to provide the capacity for additional flow, and reducing capacity and stages in existing pipes to be able to accept new flow by implementing exfiltration, diversion, interconnection of systems, and recharge wells in other areas. As a result, a direct one-to-one small project to flooding problem relationship for any particular area is usually not applicable. Because of this, it is not practical nor affordable for the City to immediately begin the CIP program in the "most vulnerable" areas first. This occurs because many of these projects are large and require complex solutions that rely on other areas parallel CIP implementation to be put in place first, require extensive engineering, time consuming resolution of regulatory and permitting issues, and long construction periods. This may result in expending the majority of available funding on one or two areas of the City, and still not having tangible results in flood mitigation in those areas for several years. *The most likely acceptable project sequencing approach will be to construct several parallel phased portions of the final full CIP in many areas simultaneously in order to provide some immediate partial relief to many locations Citywide, and then over time implement additional subsequent phases of the work to continue to reduce the flooding. This may not resolve the flooding fully in all locations immediately.*




Initial CIP Project Areas (Group 1)

The prioritization strategy to address flooding by resolving solvable, impactful and chronic flood areas was based on several factors important to the City, its residents, and City Leaders. This prioritization strategy was ultimately selected by the City for the first series of stormwater improvements projects. The factors that were important to the City include:

- A high number of flooding complaints
- Highly visible and repetitive problems
- Addressing areas of known capacity shortfalls already on the City's priority list for action
- Spreading of the CIP projects throughout the City area in accordance with the guiding themes of the of the Miami Forever Bond
- Taking advantage of opportunities for coordination with private development and other City projects
- Attaining several quick LOS improvements with measurable results for readily solvable flooding issues
- Flexibility so that the projects can be readily sub-phased to remain within the funding parameters of remaining Miami Forever bond capacity
- Selection of some projects of less complex design and permitting to take advantage of potential stimulus funds for shovel ready projects

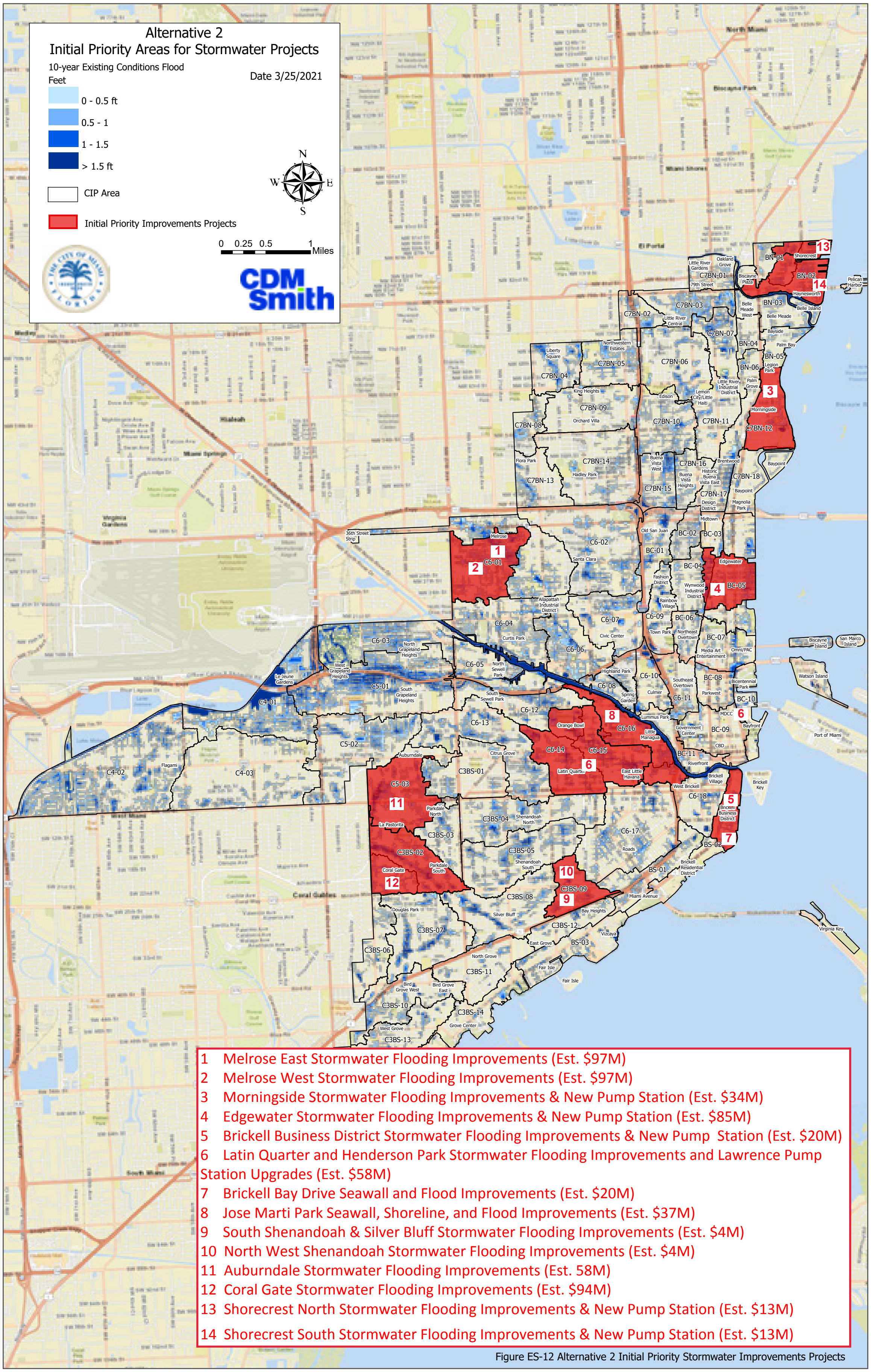
The initial selected projects are the Group I (Red), equal in priority, and total approximately $545M in budgetary costs. Due to known initial budget limitations, the City will be implementing the Alternative 2 LOS for these areas. The City has stated that these projects will likely need to be further sub-phased to stay within its remaining Bond funding until additional funding is secured. The project areas and the neighborhoods they serve are shown on **Figure ES-12**.

Future CIP Project Areas (Groups 2, 3 and 4)

The remaining projects prioritization strategy is to continue the stormwater improvements into areas in discrete pieces. The goal is to select projects that will show some immediate improvement in the LOS while these projects begin to cumulatively contribute to the citywide flood-stage elevation situation (i.e., lowering peak stages in canals, rivers, and lakes). In this way, the remaining large multi-basin projects can utilize the created system capacity they will eventually require in order for those to be installed in the future. The future-phase priority includes consideration for the following:

1. Highly visible and repeated flooding conditions even in smaller storms
2. Areas slated by the City previously for flooding improvements
3. Standalone areas of flooding citywide that are resolved or partially attenuated by impactful exfiltration systems able to be rapidly designed, permitted, and constructed
4. Interconnected areas of flooding along the Miami River, Wagoner Creek, and Little River in FEMA flood zones
5. Areas of flooding along the coastal shorelines
6. Areas containing shared downstream infrastructure required to be in place before upstream improvements can be installed

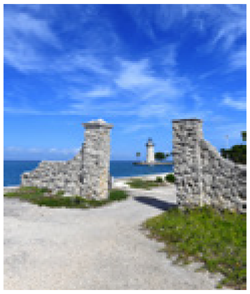
Figure ES-12. Initial Phase CIP Projects Alternative 2





The City understands it will need to be prepared to re-prioritize projects internally to take advantage of any of the following influencing factors and opportunities:

- **Funding and Grant and Loan Availability.** Disbursement of funds will ultimately control the implementation schedule and prioritization of the City's Stormwater CIP projects, accelerating some and decelerating others due to cost, and likely splitting projects into smaller, more affordable phases, to meet the available funding draw over time. Certain projects may qualify for various grant monies and economic stimulus funding due to their type, location, or economic zone, including resiliency and hardening, green infrastructure, and infrastructure renewal. These project candidates may be required to be tailored in size to meet funding requirements and potentially accelerated to meet the deadlines imposed for submission of "shovel-ready" contract documents to qualify for the funding.
- **Coordination with Other Utility and Roadway Work.** CIP projects should be prepared to be accelerated, or moved around in priority, to an alternate schedule in order to coordinate with other utility work or projects being performed by the City of Miami, Miami-Dade County, FDOT, neighboring cities, and private developers. This is primarily to take advantage of shared savings, to avoid multiple contractor work area conflicts, and most importantly, to not have to dig up a road twice or be delayed by a roadway moratorium once new asphalt is in place.
- **Public-Private-Partnerships (PPP) and Development Concurrency.** Private entities may take on a significant amount of the risk for projects resulting in faster project completions. Municipalities may require large developments to fund or agree to install their "fair share of impact" to improve City infrastructure, streets, and utilities within their planned areas that may contain stormwater CIP projects, or portions of CIP projects. This may result in the acceleration or deceleration of these projects.
- **NPDES/MS4 Program Requirements.** Areas of lesser water quality (identified in the City's NPDES sampling program affecting stormwater discharge to the rivers or Biscayne Bay) may require acceleration of certain Best Management Practices (BMP) for water quality specific improvements within a time schedule to avoid potential enforcement or fines.
- **Sociopolitical Policy Decisions.** The City may have other influencing factors originating at a high-level within the City that will raise or lower the priority of certain projects from the priority ranking, depending on the location and committed initiatives set in place by local governance.
- **Design and Permitting Constraints and Project Execution Period.** The City may wish to accelerate the large projects due to their length, or defer longer lead time projects to meet more attainable, near-term implementation goals.
- **New Seawall Areas.** New seawalls are being installed or raised throughout the City as a component of the shoreline armoring initiative for resiliency. While the seawall will help keep storm surge and rising tides from entering the neighborhoods at lower elevations, they will also trap stormwater from naturally flowing out off of the mainland in areas of historic overland flow. This can result in significant flooding where there was less, or none predicted before. These projects need to be accelerated or coordinated as necessary.



To aid the City in its next project selections, remaining projects were divided into three groups ordered generally from less complex to more complex. For example, the longest lead time projects that rely on permit negotiations, other CIP areas being in place, or lengthy construction times were grouped together and will be implemented toward the end of the program. These next-phase CIP Area selections were derived from an engineering perspective on implementation since they are not able to take into consideration any of the unknown future influences listed above which might modify the prioritizations accordingly during actual project execution.

Similar to the first priority project group, these CIP project areas have equal importance with respect to flood mitigation and can be interchanged as the factors listed above influence the implementation strategy. These project areas can also be broken into smaller sub-phases, as available funding allows, and can start with the installation of the exfiltration systems and gravity wells. **Figure ES-13** provides the remaining CIP areas for the Alternative 2 LOS. The Alternative 1 project groupings are the same, but some of the CIP Area boundaries changed slightly due to the larger infrastructure requirement to meet the greater LOS.

Regulatory and Water Quality CIP Considerations

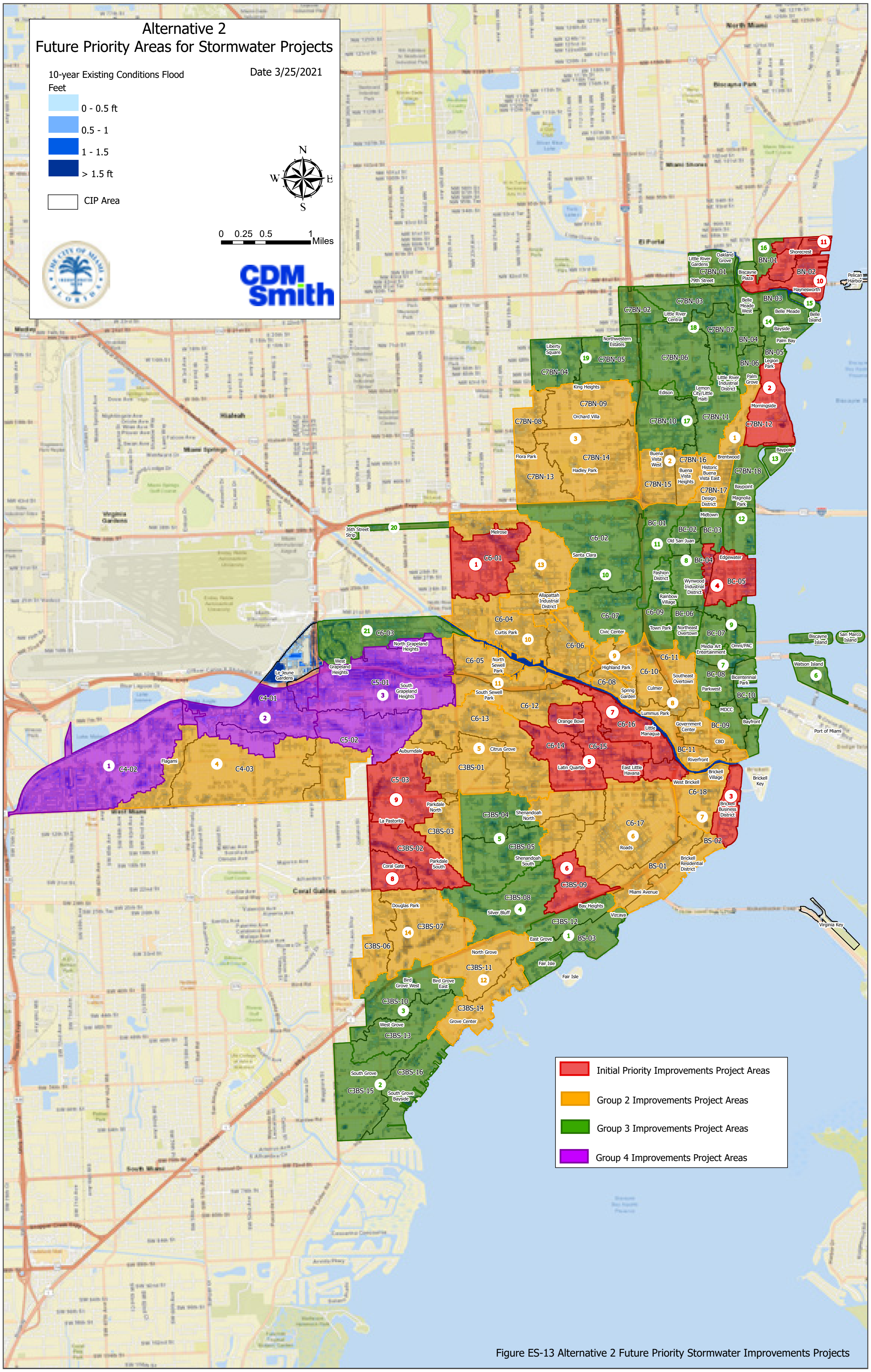
A stormwater Best Management Practice (BMP) is a method, or combination of methods, found to be effective and feasible to prevent or reduce the amount of pollution generated by nonpoint sources to a level compatible with water quality goals or requirements.

BMPs are classified as:

1. **Prevention** - avoiding the generation of pollutants.
2. **Reduction** - reducing or redirecting of pollutants.
3. **Treatment** - capturing and treating pollutants.

The proposed CIP implementation will be restricted or governed by the City's ability to find a publicly and regulatory acceptable balance between reducing flooding in the City for its residents, and the level of protection provided to Biscayne Bay. It should also consider the associated additional costs of stormwater treatment. *Due to the changing regulatory landscape for stricter limitations for new discharges to the Bay, the SWMP CIP Alternatives include the maximum amount of stormwater recharge/disposal and water quality treatment potentially required, prior to discharge to the Bay. This is so the City is prepared for the likely requirement they will need to implement that stricter regulatory scenario.* The treatment systems can then be selectively eliminated during design if found to be cost prohibitive, or if regulators can agree to a balanced approach between flood reduction and environmental protection.

Figure ES-13. Future Phase CIP Projects Alternative 2



A summary of the water quality achievements of the SWMP CIP are listed below:

- **Pre-Post CIP Water Quality.** *Both Alternatives 1 and 2 exceed the water quality treatment regulatory requirements Citywide.*
- **Pre-Post CIP Impact on Biscayne Bay.** *Both Alternatives 1 and 2 significantly reduce the total volume of non-point source stormwater runoff that eventually makes its way to the Bay.* This is one of the City's primary goals of the stormwater master plan. Further, the recommended enhanced operations and maintenance procedures for increased street sweeping and system cleaning will also significantly improve the water quality of the discharge from the existing outfalls. As another water quality benefit, the shallow aquifer BMPs disposing runoff prior to discharge at the outfalls will reduce the thermal heat load to the Bay from the land surface runoff which can be harmful to the aquatic environment, and the freshwater injection into the aquifer will help dilute and push back the saltwater interface intruding inland into the local water supply.
- **Pre/Post CIP Canal Stages and Flows Impact to Receiving Waters.** The analysis shows that the *proposed CIP has demonstrated no impact to the canals and waterways*, in addition to no detrimental flow increase to the Bay.
- **Maintaining Existing Historic Off-Site (Outside of City) Flow Paths.** Runoff generated by portions of the neighboring municipalities which historically have flowed "eastward and downhill" through the City of Miami and into the receiving waters were maintained. The combined flows from off-site are necessarily accounted for in the master plan, the models, and subsequently handled within the capacity of the City's proposed CIP. The magnitude of the off-site flow contribution can be significant (several hundreds of cfs during the 10-year design storm) into the City from all the combined off-site sources.

Planning-Level Costs and Benefit-Cost Analysis

Planning-level conceptual costs are used to estimate the implementation fiscal planning needs, financing of capital improvements needs, and for cost benefit analyses. At the conceptual, master-planning level, an ASCE Class 4 Estimate is appropriate for concept screening, feasibility, and study. Class 4 estimates are prepared for further detailed strategic planning, business development, project screening at more developed stages, alternative scheme analysis, confirmation of economic or technical feasibility, preliminary budgeting or approval to proceed to next phases. At the SWMP 10% level of design concept completeness, the conceptual costs factor in information on system capacity through models and specific initial needs of equipment and materials and can be expected to be -50% to + 50% range in variation.

CIP elements were extracted from the model alternatives, assigned to the CIP areas for accounting purposes, translated into tables of specific quantities, assigned appropriate unit costs, and totaled by CIP element type, CIP area, major drainage basin, and summed City wide. Cost elements included pump stations, forcemains, injection wells, exfiltration systems, gravity storm sewer collection and transmission piping, gravity wells, control structures, and outfalls. Ancillary costs included pavement and roadway installation, design, permitting, inspection and contractor general conditions.

Table ES-2 provides the conceptual cost for the Primary LOS Alternative 1 CIP elements by CIP Project. A CIP budget value of approximately $5.4B for the program can be used for planning purposes. **Table ES-3** provides the conceptual cost for the Primary LOS Alternative 2 CIP elements by CIP Project. A CIP budget value of approximately $3.8B for the program can be used for planning purposes.

The individual rainfall event and long-term 50-year economic losses associated with flooding in the City were evaluated using the HAZUS tool, which was designed to produce loss estimates for use by federal, state, regional and local governments and private enterprises in planning for risk mitigation, emergency preparedness, response and recovery. By using this FEMA tool to analyze the SWMP results, the City will benefit in the coordination of future activities related to flood proofing, grant assistance, and management of repetitive loss properties. Flood damages were estimated using HAZUS to define the potential impacts in dollars for storm related damages for comparison with each LOS improvement alternative to define flood damage reduction and benefits versus costs. This approach will also serve as documentation for potential FEMA Hazard mitigation grants.

A range of design storms was selected to evaluate the rainfall related flooding ranging from the 5-year to the 100-year storm, following SFWMD guidelines for storm duration ranging from 24 to 72 hours. Tides are inherently considered in the tidal stillwater boundary condition. As the flooding model for the Alternative 1 LOS also included seawalls at a height 6 ft NAVD, and at a height of 3.5 ft NAVD for the secondary LOS ALT 2, an approximation of the additional seawall cost is considered in the total costs. The results of this analysis can be used to determine the annual return on the CIP investment.

The analysis consists of estimating the potential savings after the project for individual storm events and their respective frequency. By combining the individual savings into an average yearly savings, it is possible to quantify the rate of return on the investment. The flood damage analysis shows that the existing conditions in Miami have significant potential economic losses associated with flood events for both rainfall and tidal flood sources. *The tidal flood sources can be mitigated with shoreline armoring including seawall, back flow preventers, and flood proofing of structures, and the rainfall flooding can be mitigated by a combination of exfiltration systems, gravity and pumped recharge wells, and pump stations.*

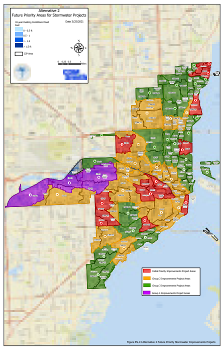
Table ES-4 provides the summary of *the benefit-cost ratio (BCR) results which range from 2.8 to 3.3. A BCR greater than 1.0 indicates that the value of flood damage reduction is greater than the CIP costs over the time planning horizon so these numbers are favorable for demonstrating CIP project value and for grant funding documentation.*

Table ES-4. Summary of Benefit-Cost Ratios for Scenarios

Condition	B:C ALT 1 LOS	B:C ALT 2 LOS
Current SLR Conditions	2.8	3.3
1.5 ft SLR (18 inches)	3.2	3.7
2.5 ft SLR (30 inches)	3.8	2.8

The HAZUS tool indicates, for a 50-year design life, the benefit to cost ratio conservatively ranges from approximately 2.8 for Alt 1 LOS to 3.3 for Alt 2 LOS for current sea level conditions. This indicates a net economic benefit for either the Alt 1 or Alt 2 LOS CIP. Alternative 2 is a better value in the short term (base sea-level case), but the cost benefit is shown to improve with the higher seawall in the long-term under Alternative 1.

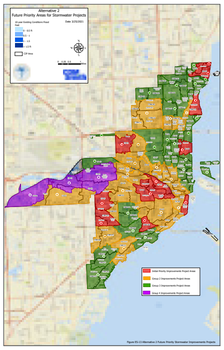
Table ES-1. Cost Summary of CIP for Alternative 1 LOS



See Figure ES-13 on page 35 for full size map.

PROJECT	TOTAL PLANNING BUDGET ($M)
1	$123.66
2	$43.66
3	$31.68
4	$53.77
5	$155.75
6	$38.90
7	$78.47
8	$219.50
9	$96.45
10	$50.93
11	$18.35
SUBTOTAL	**$911.12**
1	$24.80
2	$103.28
3	$139.37
4	$113.33
5	$136.48
6	$156.52
7	$35.63
8	$121.47
9	$43.62
10	$149.83
11	$123.36
12	$66.95
13	$186.11
14	$198.02
SUBTOTAL	**$1,598.77**
1	$81.14
2	$44.70
3	$107.77
4	$91.00
5	$209.95
6	$36.83
7	$52.30
8	$81.24
9	$52.45
10	$181.55
11	$73.51
12	$68.16
13	$11.88
14	$67.06
15	$7.73
16	$13.19
17	$126.32
18	$225.50
19	$220.86
20	$30.56
21	$76.17
SUBTOTAL	**$1,859.86**
1	$268.48
2	$347.77
3	$406.16
SUBTOTAL	**$1,022.41**
TOTAL	**$5,392.16**

Table ES-2. Cost Summary of CIP for Alternative 2 LOS



See Figure ES-13 on page 35 for full size map.

PROJECT	TOTAL PLANNING BUDGET ($M)
1	$53.36
2	$26.51
3	$24.33
4	$46.74
5	$113.01
6	$6.41
7	$59.87
8	$90.83
9	$63.51
10	$44.08
11	$16.64
SUBTOTAL	**$545.30**
1	$29.01
2	$68.51
3	$155.51
4	$74.30
5	$85.86
6	$107.11
7	$32.74
8	$96.77
9	$39.02
10	$112.63
11	$94.92
12	$57.86
13	$141.94
14	$112.78
SUBTOTAL	**$1,208.95**
1	$64.97
2	$30.36
3	$61.58
4	$66.67
5	$93.52
6	$31.59
7	$39.48
8	$68.09
9	$47.91
10	$123.94
11	$59.86
12	$51.89
13	$7.78
14	$41.52
15	$7.65
16	$7.16
17	$105.32
18	$192.18
19	$110.56
20	$20.90
21	$57.52
SUBTOTAL	**$1,290.44**
1	$205.06
2	$293.95
3	$276.64
SUBTOTAL	**$775.65**
TOTAL	**$3,820.34**

STORMWATER MASTER PLAN CIP IMPLEMENTATION

This SWMP is intended to be a flexible, living document to be used as the City's guide to resilience. As projects are built, the GIS and stormwater models should be updated with the as-built information. The models should then be re-run, and the latest output files made accessible to project designers. Accelerated projects or deviations from the ideal sequencing due to funding limitations, coordination, or other influencing factors should be tested for effectiveness in the model. A determination can then be made for the potential necessary inclusion of parallel projects to make the stormwater management system work as intended. The SWMP implementation requires coordination of several areas of practice. These include CIP design, permitting, and construction; resiliency initiatives such as building code, design standards updates, and potential land use changes; ordinance enforcement for shoreline armoring; joint project agreements with neighboring municipalities and government agencies; funding sustainability and financial planning; and initiation of discussions for regional solutions. *The SWMP results are provided digitally for publishing in the City's GIS environment for open use by designers as a single source of common information. This way the program can expedite the design, review, and permitting processes.*

The overall sequence of implementation for the SWMP and CIP is as follows:

1. Program initialization Immediate Action Plan (IAP).
    a. Implement a Citywide deep cleaning program of the entire existing stormwater system including CCTV inspections where warranted, to identify and remove silt, trash, and debris that has been shown to be constricting the existing infrastructure from providing the designed performance. This proactive action alone may reduce flooding complaints in many areas for most of the frequent storms.
    b. Apply for and obtain a Citywide SFWMD Conceptual Environmental Resource Permit (ERP) permit for construction of the adopted elements of the SWMP CIP as soon as possible. Regulators will need reasonable assurance that the City is committed to the overall SWMP goals, CIP, funding, phasing, and environmental protection concepts. Additional regulatory requirements may be imposed on the City and may change the cost and timing of the CIP implementation.
    c. Continue the installation of backflow prevention devices. Sea-level rise "sunny day flooding" issues, although not a result of a storm or its runoff, are inherently part of the required CIP as the outfalls for the stormwater systems are directly connected to the tidal fluctuations of the receiving water Biscayne Bay.
    d. Develop and publish a Stormwater Design Standards manual to be used as the guideline for all City stormwater CIP projects. The manual should provide the necessary information and a step-by-step procedure for consistency and conformance with the SWMP, and should refer to the published GIS-based SWMP results.
2. Design and construct the Group 1 initial Citywide stormwater improvements projects. The 11 initial priority area projects are intended to be implemented first and simultaneously under the Miami Forever GO Bond funding. These projects were selected in concurrence with the City based on available funding, spreading the work over multiple areas of the City, chronic flooding, high visibility and highly impactful results, and pre-coordination with current development and other City projects. These projects can be sub-phased to meet budget limitations.
3. Design and construct the remaining Groups 2-4 projects. The order of future CIP Area projects will need to be re-analyzed when future available budgets are obtained following the general guide of the provided logical groupings of next-phase projects provided in the SWMP as the influencing factors will re-prioritize these projects as the CIP program progresses.
4. Update the SWMP model with the implemented CIP so that the existing conditions are up to date for the next designs.

SWMP IMPLEMENTATION

As the City develops a roadmap toward resiliency, the SWMP must be more than an adopted, shelved report. *The planning process must continue into the future, with the integration of recommendations into existing policies and procedures. It should also have contingency plans for adaptable features in the future as conditions may change, such as regulations, sea level rise, and implementation opportunities.* Guidance documents will need to be updated and re-issued in order to match the recommendations of the SWMP. These include the City's Stormwater Design Standards, and Building Code Design Criteria Manuals, Coastal and Shoreline Ordinances, System Operations and Maintenance Standard Operating Procedures Manuals, and web-based interactive GIS interface portals for sharing and viewing design parameter data and results and for tracking of project progress.

Conceptual Permit Application

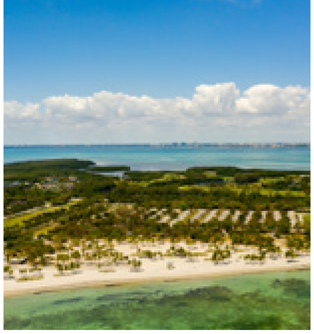
Because of the potentially unknown regulatory constraints that may be imposed on the design, construction, and implementation of the chosen CIP, and to streamline the future permitting process, it is highly recommended that the City immediately open a dialogue with regulators and apply for a SFWMD "Conceptual ERP" Permit. The SWMP should be used as the basis of a Conceptual City-wide SFWMD Environmental Resource Permit Application which, when adapted conceptually by the regulators, will streamline the permitting efforts with the County and the District for individual projects and smooth the overall execution, efficiency, and schedule of the CIP. The conceptual ERP, when approved, serves as the guide for designers and it expedites the processing of individual project permits that are covered under the approved overall conceptual permit. Issuance of a conceptual approval permit is a regulatory determination that the conceptual stormwater master plan is, within the extent of detail provided in the application, consistent with applicable rules at the time of issuance. The conceptual approval permit then provides the permit holder with a rebuttable presumption that, during the duration of the conceptual approval permit, the design and environmental concepts upon which the conceptual approval permit is based will meet applicable rule criteria for issuance of permits for subsequent phases of the project. The primary concerns of the regulatory agencies reviewing the ERP will be to ensure continuity between phases and satisfactory completion and operation of individual phases if the overall project is not completed as planned.




Future SWMP Updates

The SWMP models were provided to the City. This way, *the models can now be maintained by the City in order to address future needs, and to incorporate changes that occur in the system.* The training on the use of the model to City Staff by CDM Smith's certified instructors was performed so the City can become proficient and self-sufficient in continuing the process internally. As projects are implemented and completed, the GIS will need to be updated to reflect the new information, and the models periodically revised to the as-built configuration. Accelerated or decelerated projects can be modeled to show the individual impacts and top existing conditions to assist with timing and implementation. As the CIP program progresses, and new infrastructure is installed, the existing conditions (EC) model should be updated to reflect the changes provided in the record drawing information.

The first selected CIP projects should be able to be completed and on-line within 3-5 years. Due to the comprehensive and detailed model and plan, the individual CIP areas can be updated in the models as they are completed, and a brief technical memorandum created annually to show the progress and effects of the phased installation of the CIP over time. The only major modifications would be if there were significant deviations in the overall master plan approach or land use (such as raising of land areas, elevation of roadways, conversion of urban lands to create dedicated stormwater management areas, or the installation of large regional stormwater management projects by the County, USACE, or State/SFWMD). This updated document, in conjunction with the approved conceptual ERP, can also be used for the FEMA 5-year update cycle and the MS4 cycle throughout the 20-year CIP program.


Funding Assistance

Special funding or grant opportunities are usually available for the piloting of new approaches to stormwater management, especially for water quality and resiliency. These should be actively pursued. Several sources of funding should be pursued to further leverage the City's Stormwater Utility and Miami Forever Bond funds, including the City's Stormwater Utility, FEMA Building Resilient Infrastructure and Communities (BRIC) grants, FEMA Hazard Mitigation Grant Program (HMGP) for post-storm repairs and upgrades, HUD Community Block development Grants (CBDG), State Revolving Fund (SRF) loans, USEPA Water Infrastructure Finance and Innovation Act (WIFIA) loans, additional bonding, potential funding from proposed State of Florida coastal resilience grants, and public-public partnerships with Miami-Dade County, FDOT, and SFWMD. At the time of this SWMP, the USACE has also proposed a flood resilience barrier from the Back Bay Study and that project may qualify for federal funding under the Water Resources Development Act (WRDA). The implementation of the USACE project may reduce the length of seawall retrofits for the City and individual landowners.

Operations and Maintenance Program Expansion

As the stormwater system assets expand rapidly as part of the CIP implementation, the associated operational and maintenance costs (O&M) will increase accordingly. Maintaining a clean, operable system free of clogging and breaks is paramount to flood control and to meeting imposed water quality requirements. The USEPA, FDEP, and SFWMD all have published recommended guidelines, tools, and procedures for stormwater maintenance best practices, controls, maintenance schedules, fact sheets, cost estimating tools, and inspection forms. Considering the cost of the City's investment in stormwater CIP infrastructure, an enhanced O&M program and budget is required in parallel to ensure the investment meets the desired LOS and functions as designed when needed. Whether performed in-house or contracted out to vendors, the O&M funding sources can be supplemented by enhancing the City's stormwater utility or impact fees.

City Management Considerations

Several factors will shape how the CIP will be implemented, including the City's funding capacity over time as well as the bonding capacity and capabilities of the contractors able to perform the work. Whether internal or external, the City will need to engage the oversight of a program management team and proper support staff to administer and coordinate the CIP. These would include project managers, construction managers, design consultant managers, permit managers, design standards and quality control managers, joint project agreement coordinators, construction inspectors, money managers, and schedulers.

From a general perspective, for the desired 20-year CIP (assuming an average project size of $50M), a $5B program (ALT 1 LOS) will require five $50M projects annually for a total of 100 program projects. This program will also result in construction on and under City streets, and this associated disruption throughout the City will occur on a continuous basis for the next 25 years. For large programs with similar work areas and specialties (i.e., stormwater components), it is recommended that the City pre-qualify a rotating pool of qualified contractors to streamline the procurement process. Projects can then be assigned based on contractor specialty and availability, and the next assignment of work can be based on an annual review of performance and their capacity for new work.

Public Information Program Continuation

The residents of Miami are an essential component of the resiliency of the community and are also an important part of the stormwater system maintenance and operations. The use of crowd-sourced data solicitation, while encouraging residents to stay informed about the key services that their stormwater systems provide, will help to build long lasting support for the management of these critical systems. As part of the SWMP for the City, an educational campaign about stormwater, water quality, and sea level rise was developed. This public awareness initiative was the start of an informative, prolonged educational campaign. There will continue to be a need for consistent and continued public outreach and information, especially for actions that residents can do for their own properties. This outreach includes item about seawalls, trash and yard debris disposal methods, information about the overall City SWMP program as well as complex topics like stormwater and sea level rise. It also should provide information on water quality including a constant reminder of good practices and the consequences of non-compliance. The City has a role in educating its residents on the methods they can use to assist in the reduction of pollutants that end up in the coastal water bodies. The provided materials, and future campaigns, should be easily understandable, graphical, and in multiple languages in order to ensure inclusivity for all members of Miami's diverse community.

The City's existing and proposed new stormwater system are an essential component of the health of Biscayne Bay and for the comprehensive flood protection of the City. The City should continue to promote the Stormwater Master Plan as the foundation of a strong resilience and education program for the community and the overall plan of continued education through social media, newsletters, and other City communications should be maintained. Opportunities to further educate the residents of Miami about the importance of the stormwater system should be continued. This can be done through information in utility bills or at community engagement workshops, as an opportunity to communicate to residents about stormwater and resiliency issues, as well as the 311 or other reporting systems. As the City embarks on an ambitious capital improvement program, the SWMP document should be referred to often as successes are realized, as this will build credibility in the community for the Master Plan and the City's overall improvement program.

Prepared by

CDM Smith

For

THE CITY OF MIAMI
INCORPORATED 1896
FLORIDA