TOWN OF LAKE PARK

VULNERABILITY, RISK AND ADAPTATION ASSESSMENT TO CLIMATE CHANGE AND SEA LEVEL RISE

- SEAWALL/BULKHEAD STRUCTURAL ASSESSMENT
- INUNDATION MAPPING

RAUL MERCADO, PE, CFM

February 17, 2021

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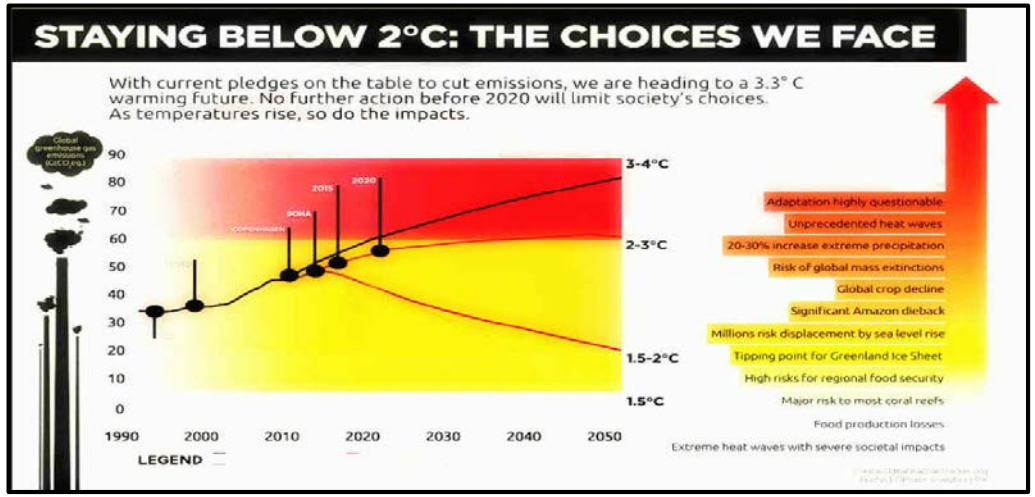
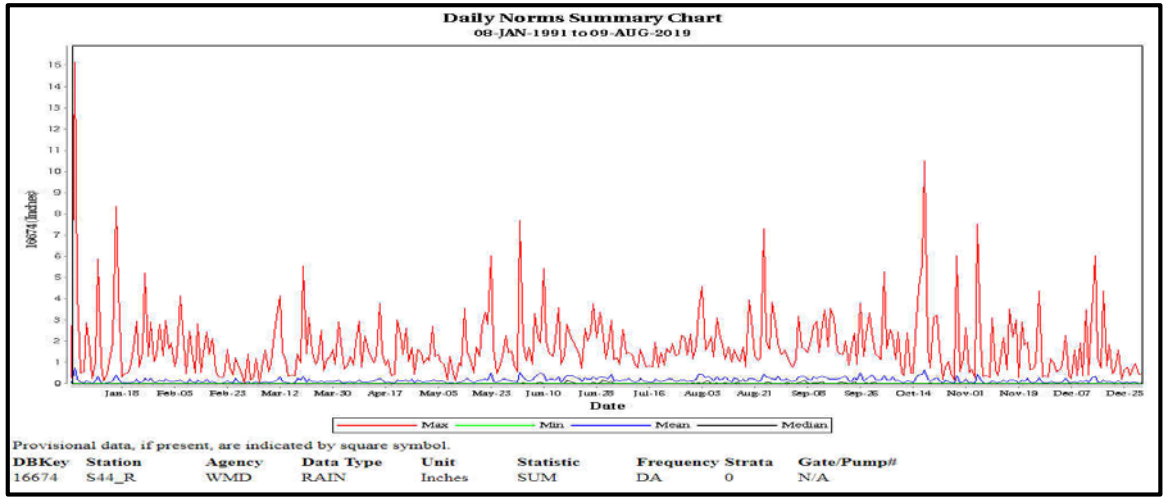
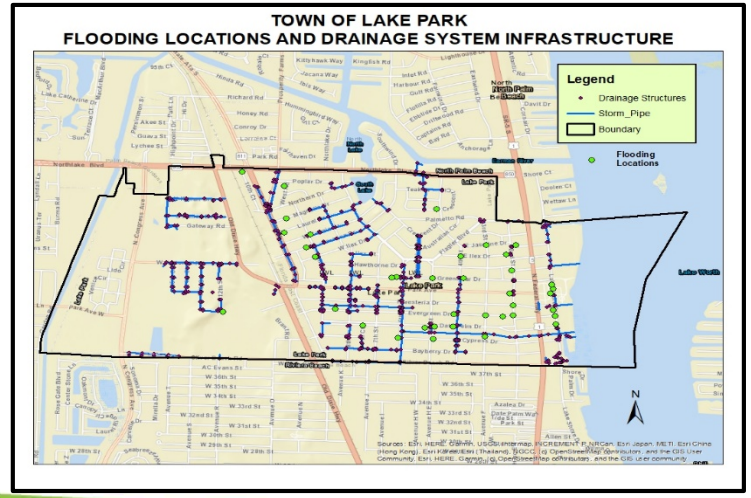
CLIMATE CHANGE STRESSORS/EARTH WARMING

Higher Temperatures, Higher Rainfall Intensities, More Frequent Flooding







4th Street & Evergreen Drive

Ilex Drive

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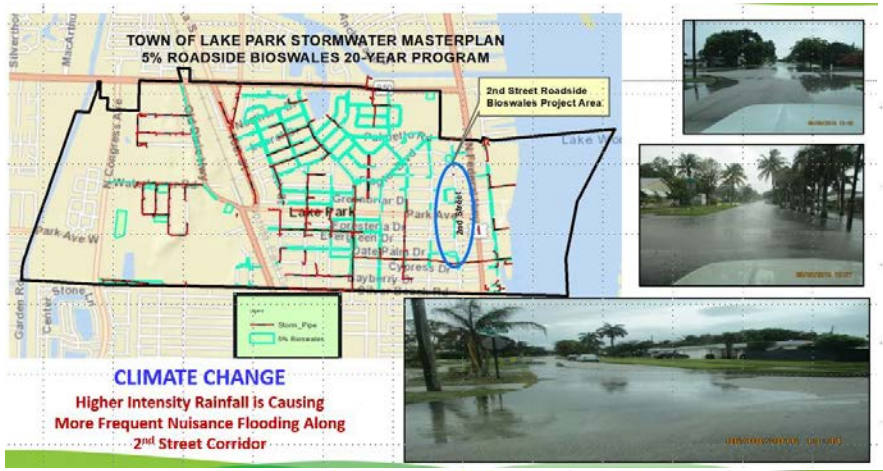
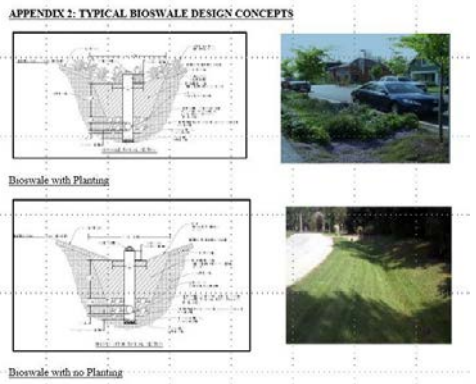
STORMWATER MASTERPLAN UPDATE – GREEN INFRASTRUCTURE

Current Green Infrastructure-Based Projects



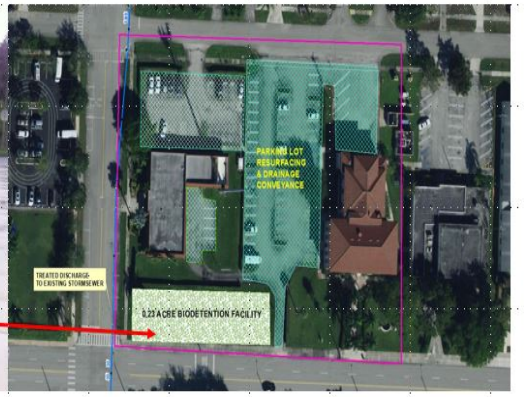
CLIMATE CHANGE

Higher Intensity Rainfall is Causing More Frequent Nuisance Flooding Along 2nd Street Corridor



TOWN MUNICIPAL COMPLEX

Nuisance Flooding Hazard Adaptation



Typical Learning Display Plaque & Observation Area

SOUTHERN OUTFALL PHASE 2

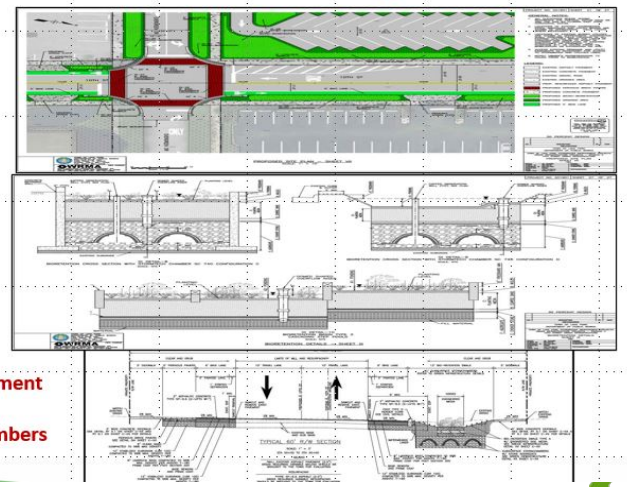
Upstream Peak Discharge Diversion, Attenuation And Water Quality Treatment Using GI/LID-based Underground Chamber Filtration @ Bert Bostrom Park

CLIMATE CHANGE ADAPTATION

SWMP – 10TH Street Green Infrastructure Pilot Project

10th Street Right-Of-Way Corridor Green Infrastructure-Based Drainage Implementation

Treatment Train
- Bioswales
- Pervious Pavement
- Underground Filtration Chambers



The SWMP goal is to convert 10% of impervious areas to GI in the next 20 years to offset warming trends

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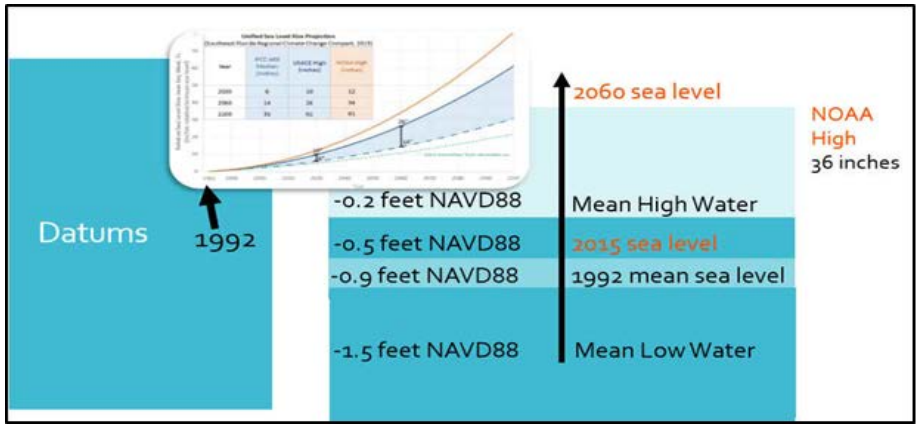
CLIMATE CHANGE STRESSORS – SEA LEVEL RISE (SLR)



NOAA has predicted 36 to 40 inches of sea level rise by 2070.

"Sunny day" flooding is already experienced during "king" fall tides along lake shore drive.

THE TOWN OF LAKE PARK JUST COMPLETED A SEAWALL STRUCTURAL ASSESSMENT AND SEA LEVEL RISE INUNDATION MAPPING (FDEP COASTAL RESILIENCY GRANT)

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FLORIDA DEPARTMENT OF ENVIRONMENTAL PROTECTION
$75,000 COASTAL RESILIENCY GRANT

Seawall/Bulkhead Structural Assessment

1. Topographic Survey
   Javier Bidot Associates

2. Structural Condition Assessment
   Coastal Systems International

3. Repair/Replacement Cost
   Coastal Systems International

Inundation Mapping

2. Sea Level Rise
   (2020 through 2070)
   WRMA

1. Coastal Surge + SLR
   (FEMA 100-year Flooding
   2020 through 2070)
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Note: Three (3) Technical Reports Are Available for Download On The Town's Website

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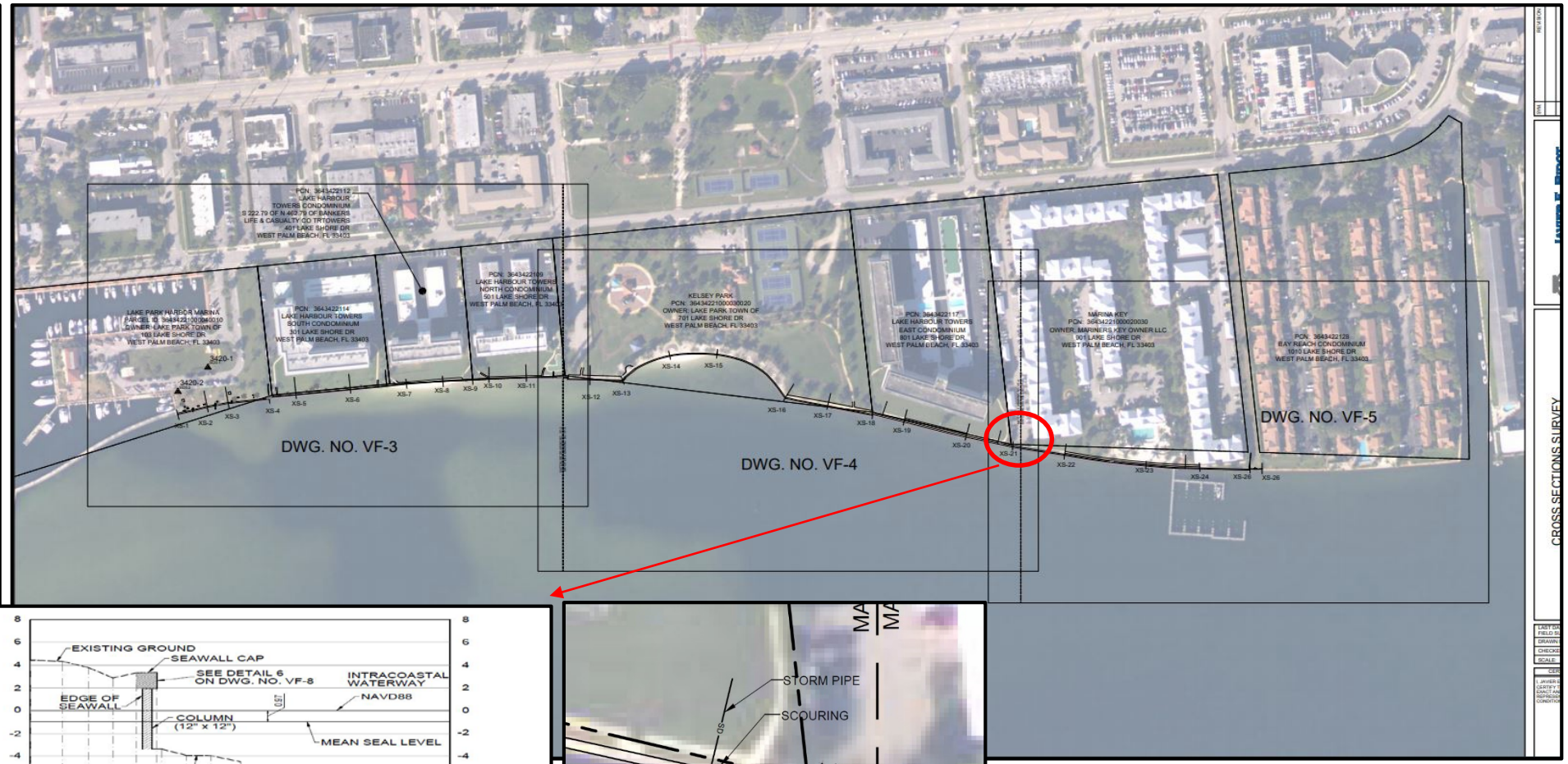
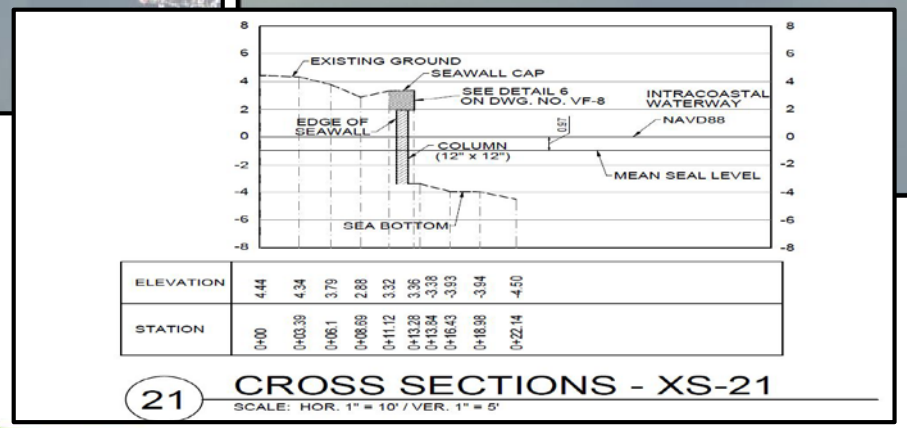
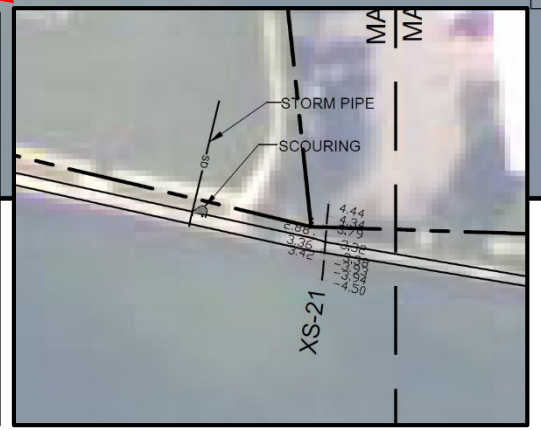
SEAWALL TOPOGRAPHIC SURVEYING







26 Cross Sections
Spaced Fairly Evenly

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STRUCTURAL CONDITION ASSESSMENT – FIELD INVESTIGATION

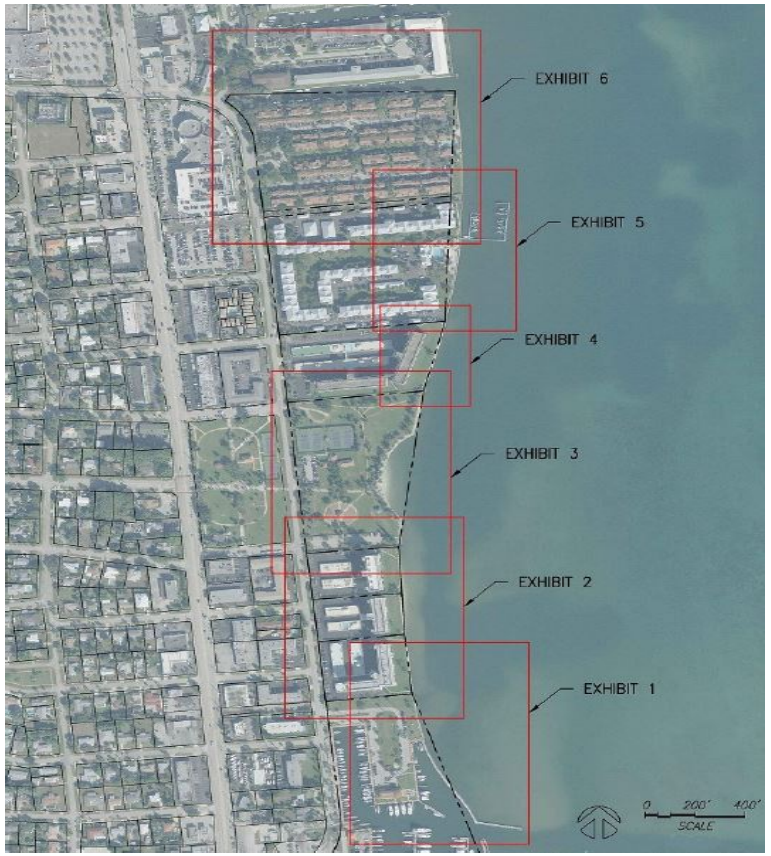


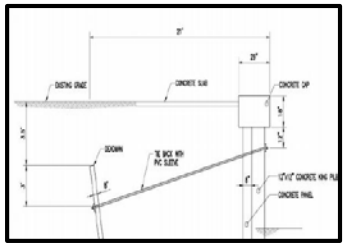
Exhibit 1 – Lake Park Marina
Exhibit 2 – Lake Harbour Towers
Exhibit 3 – Kelsey Park
Exhibit 4 – Lake Harbour Towers East
Exhibit 5 – Marina Key
Exhibit 6 – Bay Reach

Structural Assessment

A team of two engineers used snorkel equipment and completed the above- and below-water inspection.

Exploratory Excavation

Four (4) locations were selected to perform exploratory excavations to reveal the condition of the tie-back systems.



Probing, Coring, Testing

Ten (10) concrete core samples were obtained from the concrete cap and concrete panel of the existing seawall and sent to a laboratory for compressive strength and chloride content testing.

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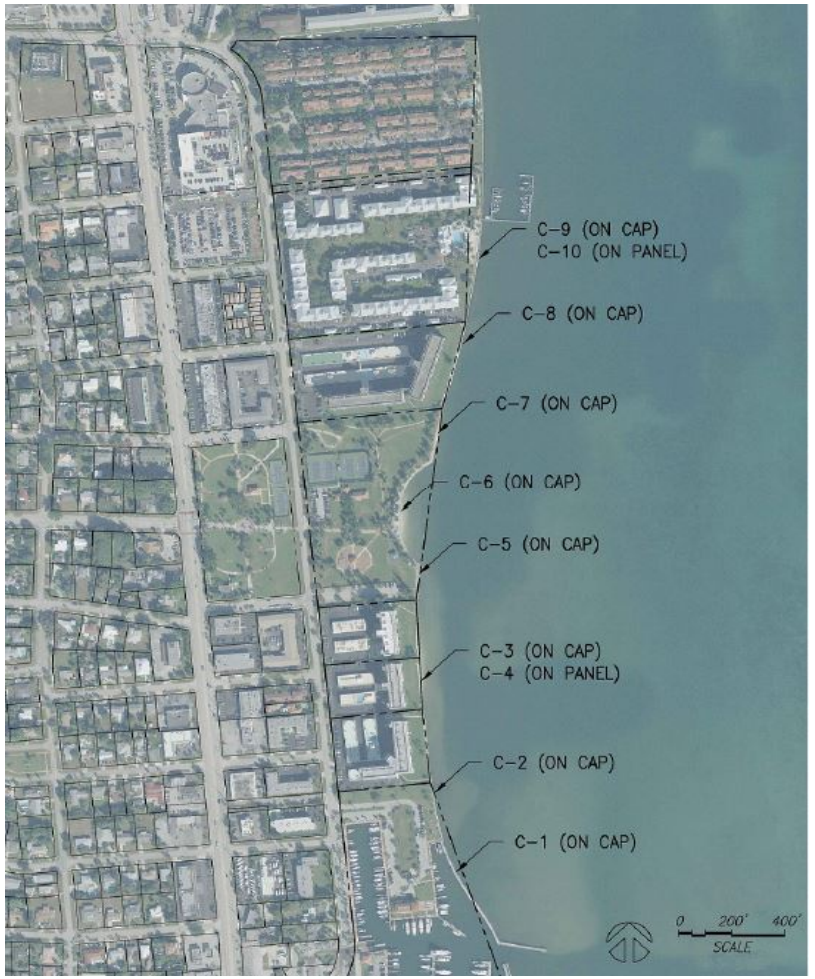
FIELD INVESTIGATION LOCATIONS

Tie-Back Excavation Locations



Concrete Coring Locations

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FIELD INVESTIGATION – TYPICAL OBSERVATIONS

Underwater, Below Deck Assessment Documentation & Tie Back Excavation

Pile Number	Condition	Photo Number
37	Cracks, corrosion stains, spalling	D-47
37-A	Cracks, corrosion stains	D-48
38	Cracks, corrosion stains	D-49
38-A	Cracks, corrosion stains	D-49
39	Cracks, corrosion stains	D-50
39-A	Cracks, corrosion stains	D-50
40	Cracks, corrosion stains	D-51
40-A	Cracks, corrosion stains	D-51
41	Spalling, cracks, corrosion stains	D-52
41-A	Cracks, corrosion stains	D-53
42-A	Breakage (soldier piles)	D-54

Core No.	Core Location	Sample Area	Compressive Strength (psi)	Chloride Content (wt % of cement)
C-1	Exhibit 1- Section 1- Pier 6	Top face of slab	5980	0.54
C-2	Exhibit 1- Section 2- Bulkhead	Waterward face of cap	5650	0.35
C-3	Exhibit 2- 401 Lake Shore Drive	Waterward face of cap	-	3.73
C-4	Exhibit 2- 401 Lake Shore Drive	Panel	5890	2.47
C-5	Exhibit 3- Kelsey Park (South Section)	Top face of cap	6080	0.19
C-6	Exhibit 3- Kelsey Park (Middle Section)	Waterward face of cap	4190	0.11
C-7	Exhibit 3- Kelsey Park (North Section)	Top face of cap	5890	0.08
C-8	Exhibit 4- Lake Harbour Towers East	Top face of cap	5430	0.89
C-9	Exhibit 5- Marina Key	Top face of cap	4760	0.28
C-10	Exhibit 5- Marina Key	Panel	6650	2.15

Photo A-39: Delamination on the bottom of the concrete slab at bent 13-a.

Photo A-40: Delamination at the bottom of the concrete slab between bent 14 and bent 14-a.

Photo E-55: Deterioration on soldier piles at the easement bulkhead.

Photo E-56: Deterioration on soldier piles at the easement bulkhead.

Photo A-69: Excavation Location 1 at Exhibit 1, Section 2, station 1+35.

Photo A-70: An old bulkhead was revealed behind the existing bulkhead. A tieback was revealed at station 1+34.

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CONDITION ASSESSMENT RATINGS, REMAINING USEFUL LIFE, & RECOMMENDATIONS

Location	*Rating	Initial Repair/Replacement Urgency	Remaining Useful Life after Performing the Repairs
Exhibit 1 – Section 1 (Pier 7)	Fair	Repair within 6 months	20 years w/periodic maintenance
Exhibit 1 – Section 1 (Pier 6)	Fair	Repair within 6 months	20 years w/periodic maintenance
Exhibit I – Section 2 (Bulkhead)	Satisfactory	-	30 years w/periodic maintenance
Exhibit 2	Serious	Replacement within 6 months	Design life ended
Exhibit 3	**Serious	Repair within 6 months	25 years w/periodic maintenance
Exhibit 4	Fair	Repair within 6 months	15 years w/periodic maintenance
Exhibit 5 – Section 1	Fair	Repair of piles and replacement of cap within 5 years	15 years w/periodic maintenance
Exhibit 5 – Section 2 (Easement)	Serious	Replacement within 6 months	Design life ended
Exhibit 6	Good	-	40 years w/periodic maintenance – recently replaced

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SEAWALL RESTORATION FINANCIAL ASSESSMENT

INITIAL REPAIR/REPLACEMENT COST

The initial repair/replacement cost as recommended for the full length of the bulkhead is approximately $5M. This value does not account for the periodic maintenance that is needed for the remaining useful life of the structures.

SEA LEVEL RISE ADJUSTMENT COST

After the initial repair/replacement, raising bulkhead caps and installing tie-backs is recommended to account for sea level rise. The estimated cost for the bulkheads not replaced in the initial phase is estimated to be approximately $2M.

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INITIAL REPAIR/REPLACEMENT COST

Description	Quantity	Unit	Unit Cost	Extended Cost
Exhibit 1				
Pier 7 – Crack Repairs	135	LF	$ 360.00	$ 48,600
Pier 6 – Crack Repairs	523	LF	$ 360.00	$ 18,280
Exhibit 2				
Complete Bulkhead Replacement	775	LF	$ 3,500.00	$ 2,712,500
Exhibit 3				
Cap – Crack Repair	866	LF	$ 120.00	$ 103,920
Piles and Panels – Gap Repair	16	EA	$ 1,500.00	$ 24,000
Exhibit 4				
Batter Piles – Major Repair	41	EA	$ 1,200.00	$ 49,200
King Piles - Repair	9	EA	$ 800.00	$ 7,200
Cap – Crack Repair	370	LF	$ 120.00	$ 44,400
Exhibit 5				
Batter Piles – Repair	25	EA	$ 800.00	$ 20,000
King Piles – Repair	8	EA	$ 800.00	$ 6,400
Cap – Replacement	624	LF	$ 50.00	$ 156,000
Exhibit 5 Easement				
Complete Bulkhead Replacement	32	LF	$ 3,500.00	$ 112,000
Sub-Total				$ 3,472,500
General Conditions (10%)				$ 374,250
Mobilization (5%)				$ 173,625
Bond and Insurance (5%)				$ 173,625
Contractor Overhead and Profit (10%)				$ 347,250
Contingency (10%				$ 347,250
Total Probable Construction Cost				**$ 4,861,500**

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SEA LEVEL RISE ADJUSTMENT COST

Description	Quantity	Unit	Unit Cost	Extended Cost
Exhibit 1				
Raising the Bulkhead Cap	242	LF	$ 250.00	$ 60,500
Additional Tieback Anchors	40	EA	$ 3,000.00	$ 120,000
Exhibit 3				
Raising the Bulkhead Cap	866	LF	$ 250.00	$ 216,500
Additional Tieback Anchors	110	EA	$ 3,000.00	$ 330,000
Exhibit 4				
Raising the Bulkhead Cap	370	LF	$ 250.00	$ 92,500
Additional Tieback Anchors	50	EA	$ 3,000.00	$ 150,000
Exhibit 5				
Raising the Bulkhead Cap	624	LF	$ 250.00	$ 156,000
Additional Tieback Anchors	80	EA	$ 3,000.00	$ 240,000
Sub-Total				$1,365,500
General Conditions (10%)				$ 136,550
Mobilization (5%)				$ 68,275
Bond and Insurance (5%)				$ 68,275
Contractor Overhead and Profit (10%)				$ 136,550
Contingency (10%				$ 136,550
Total Probable Construction Cost				**$1,911,700**

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REPLACEMENT OPTIONS – STRUCTURAL

Steel Sheet Piles Bulkhead

Concrete Pile and Panel

Concrete Sheet Pile Bulkhead

Truline Bulkhead

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REPLACEMENT OPTIONS – SUSTAINABLE

Living Shoreline (Currie Park)

Gabion Bulkhead

Bio-enhanced Concrete Forms

Combination Gabion Bulkhead & Living Shoreline

Preferred Town Option for Kelsey Park Seawall Replacement

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STRUCTURAL & SUSTAINABLE REPLACEMENT OPTIONS COST

Structural Replacement Cost (Per Lineal Foot)

Description	Unit	Unit Cost
Replacement Cost per Linear Feet of Bulkhead		
Concrete King Pile and Panels Bulkhead	LF	$ 1,500.00
ECO Seawall	LF	$ 2,000.00
Steel Sheet Pile Bulkhead	LF	$ 2,500.00
Concrete Sheet Pile Bulkhead with GFRP/CFRP	LF	$ 5,500.00

Sustainable Construction Cost (Unit Cost)

Description	Quantity	Unit	Unit Cost	Extended Cost
Living Shoreline (for 100 Linear Feet of shoreline)				
Riprap Breakwater	185	CY	$ 120.00	$ 22,200
Soil Mix for Planter	370	CY	$ 30.00	$ 11,100
Mangrove	2500	SF	$ 0.40	$ 1,000
Total (for 100 Linear Feet of shoreline)				**$ 34,300**

Eco-Concrete Unit Costs	Unit	Unit Cost
ECO Seawall Panels	SF	$ 70.00
ECO Mat (8 ft by 15 ft)	EA	$ 1,500.00
Tide Pool Armor (4 ft by 4 ft by 4ft block)	EA	$ 900.00

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TIDAL INUNDATION MAPPING - SEA LEVEL RISE

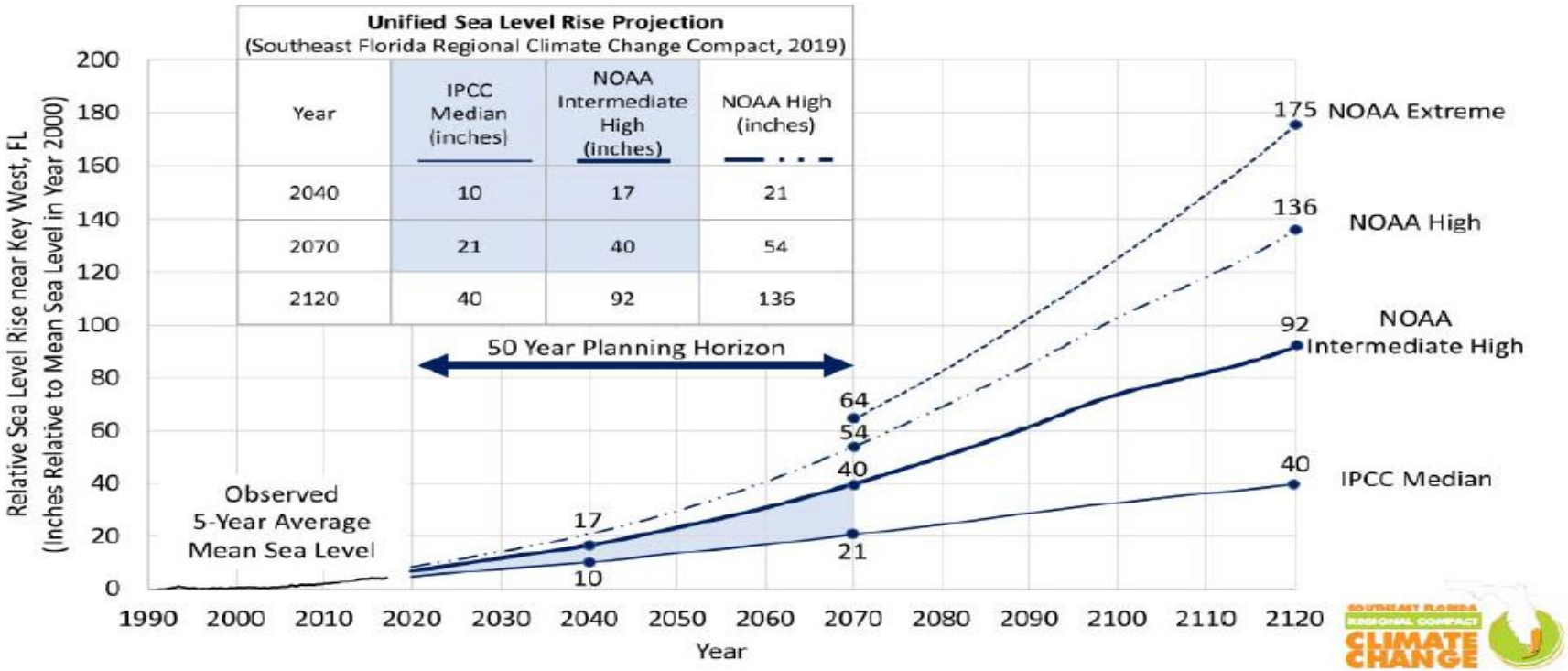
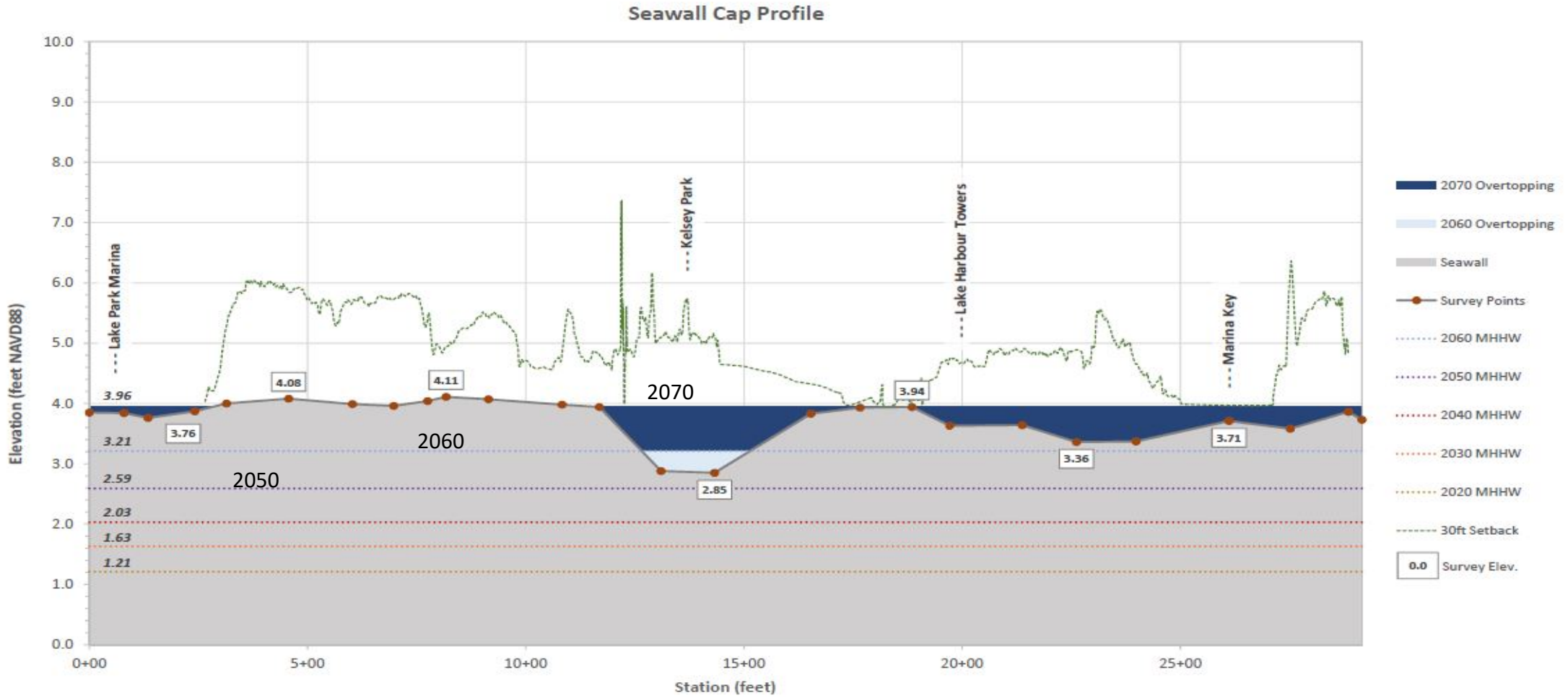


Figure 1 – Unified Sea Level Rise Projection

The Unified Sea Level Rise Projection, seen in **Figure 1**, consists of three planning horizons:

1. **short term**: by 2040, sea level is projected to rise 10 to 17 inches above 2000 mean sea level.
2. **medium term**: by 2070, sea level is projected to rise 21 to 54 inches above 2000 mean sea level.
3. **long term**: by 2120, sea level is projected to rise 40 to 136 inches above 2000 mean sea level.

TIDAL INUNDATION BY DECADES



(Gray fill) – profile of the seawall cap
(Small dotted lines and blue fill) – elevations of the decadal MHHW
(Green dashed line) – ground elevation profile set back 30 feet westward from the seawall face

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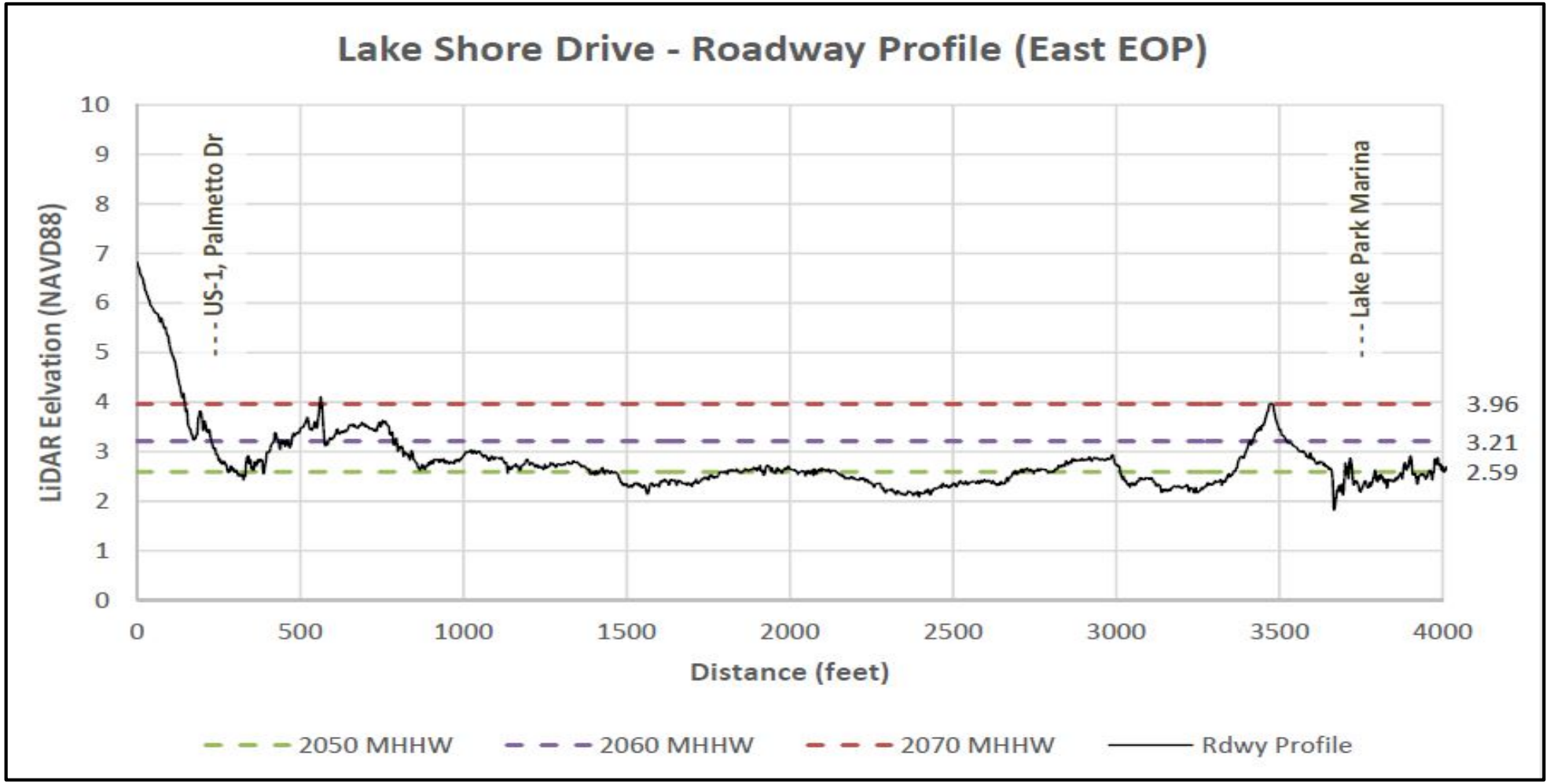
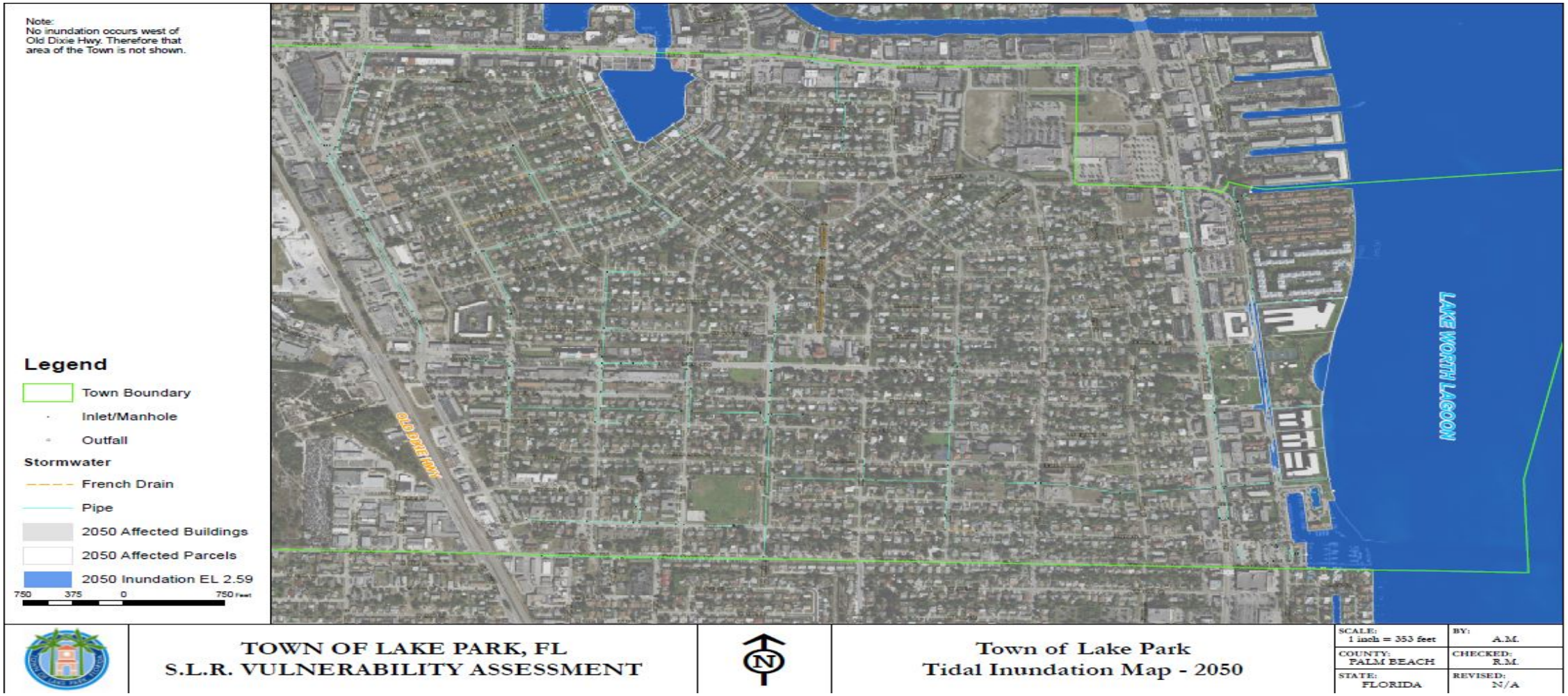
LAKE SHORE DRIVE INUNDATION



SEA LEVEL RISE INUNDATION MAPPING (2050)

2020 to 2040 King Tide Drainage Impacts Only (Sunny Day Flooding)



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SEA LEVEL RISE INUNDATION MAPPING (2060)

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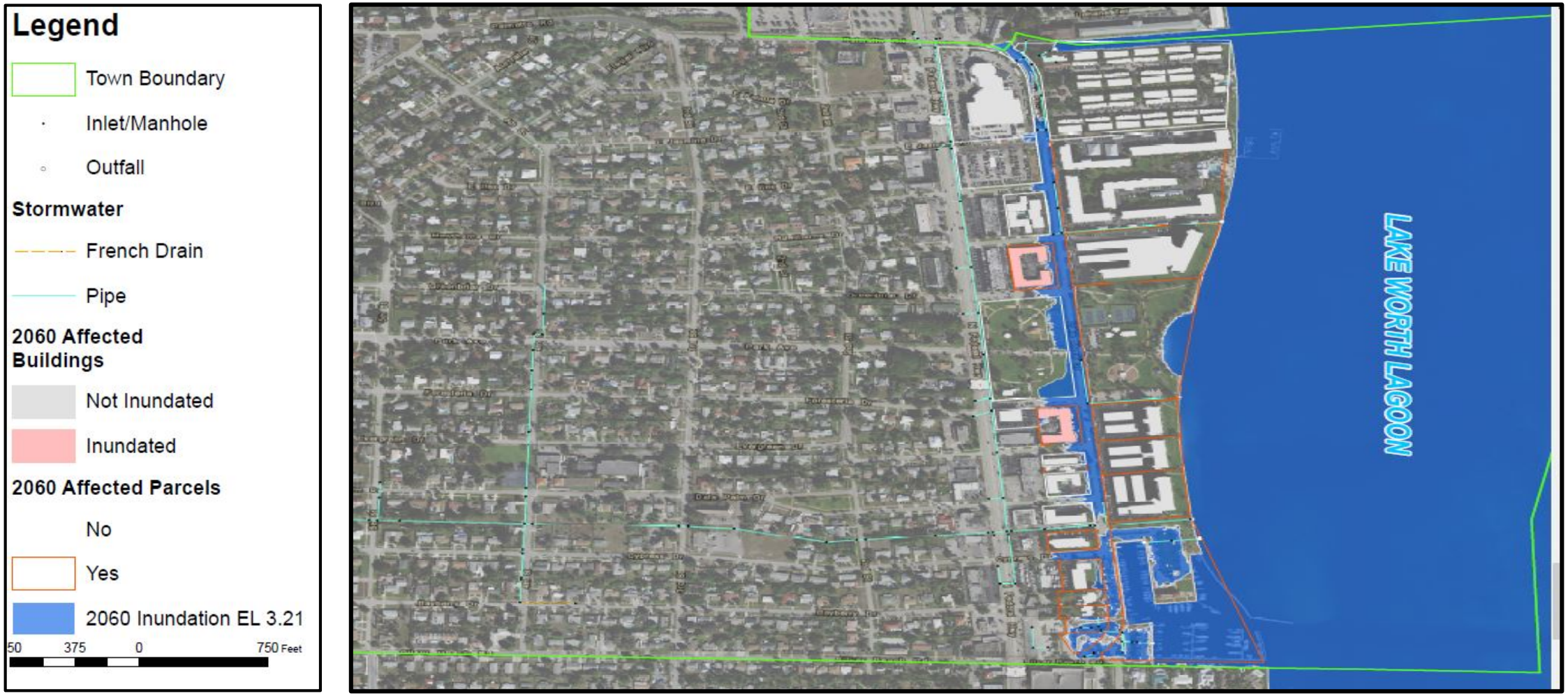
SEA LEVEL RISE INUNDATION MAPPING (2060 ENHANCED)



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SEA LEVEL RISE INUNDATION MAPPING (2070)

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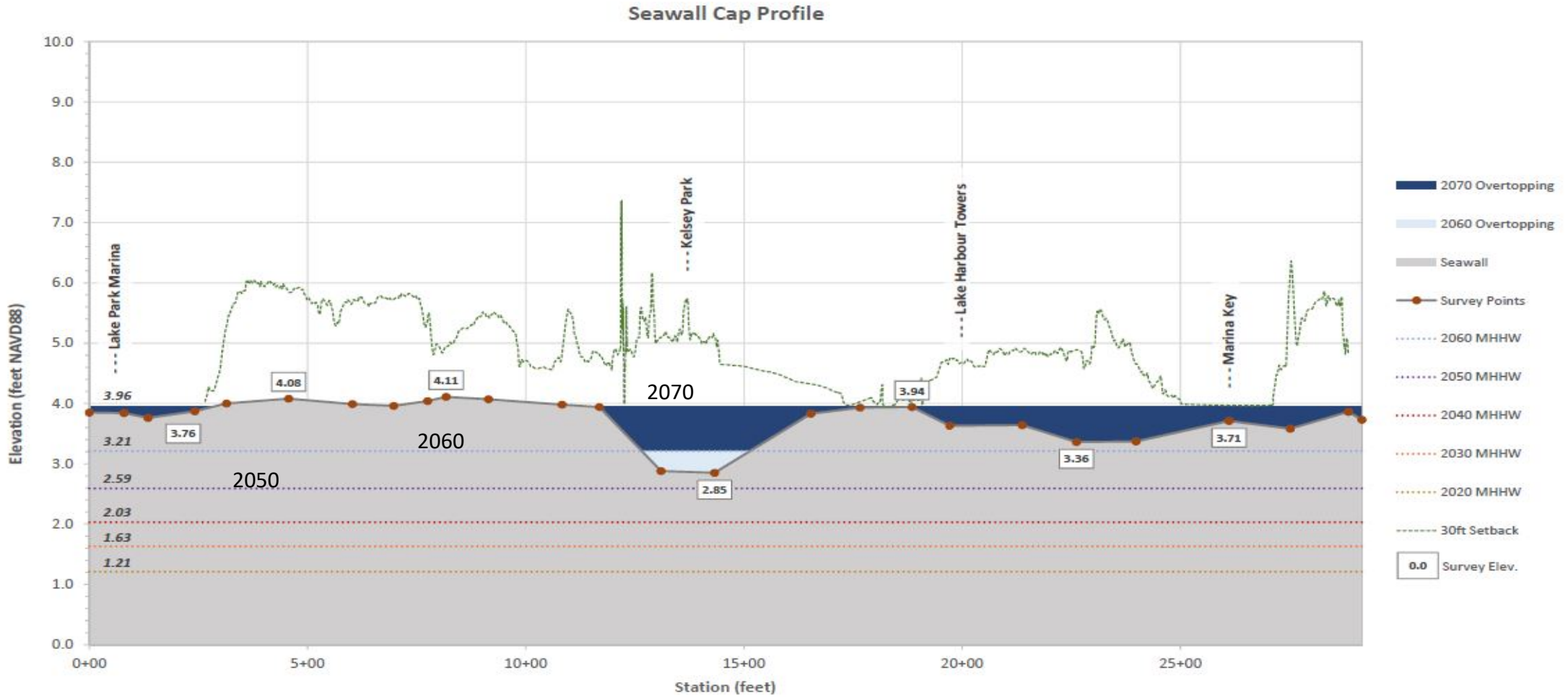
TIDAL INUNDATION BY DECADES



(Gray fill) – profile of the seawall cap
(Small dotted lines and blue fill) – elevations of the decadal MHHW
(Green dashed line) – ground elevation profile set back 30 feet westward from the seawall face

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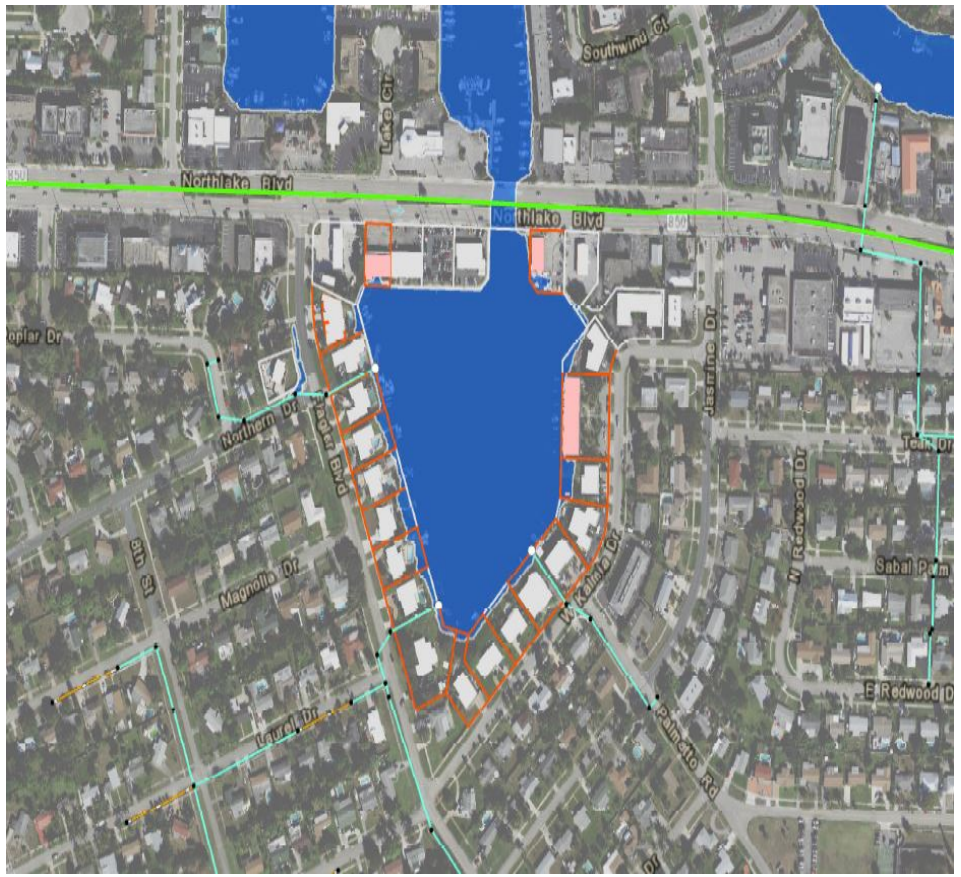
SEA LEVEL RISE INUNDATION MAPPING (2070 ENHANCED)



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MONETARY COST ESTIMATION FOR SEA LEVEL RISE INUNDATION – METHODOLOGY

- Evaluating flood risk reduction interventions is balancing the costs of intervention versus avoided damages (benefits). This is known as benefit-cost analysis (BCA). WRMA estimated monetary damages incurred in each decadal SLR scenario, for both tidal inundation and coastal floods separately.

- Tidal inundation will occur on a daily basis (potentially twice per day). Because of this, damages due to projected tidal inundation are associated with a permanent loss of function (PLOF).

- PLOF is taken to be the result of the irrecoverable physical loss of structures by repetitive tidewater damage, and/or the blocking of property access by tidewaters to the point where they are functionally uninhabitable. PLOF damages were assumed to be a total loss at market value.

- To determine the PLOF for each inundated parcel, WRMA applied 2019 real property tax assessment data from the Palm Beach County Property Appraiser's office. The PLOF was calculated as the sum total market value of each building within an inundated parcel.

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TIDAL INUNDATION DAMAGES & RISK ASSESSMENT

Scenario Year	Buildings Inundated	Buildings Blocked	Parcel Units (PLOF)	PLOF Costs	Risks	Overall Risk Assessment
2020	0	0	0	-	-	Low
2030	0	0	0	-	King Tides	Low
2040	0	0	0	-	King Tides	Low
2050	0	0	0	-	Drainage + King Tides	Moderate
2060	3	31	433	**$105,362,000**	Drainage + King Tides	High
2070	15	107	692	**$154,675,000**	Drainage + Overtopping	Severe

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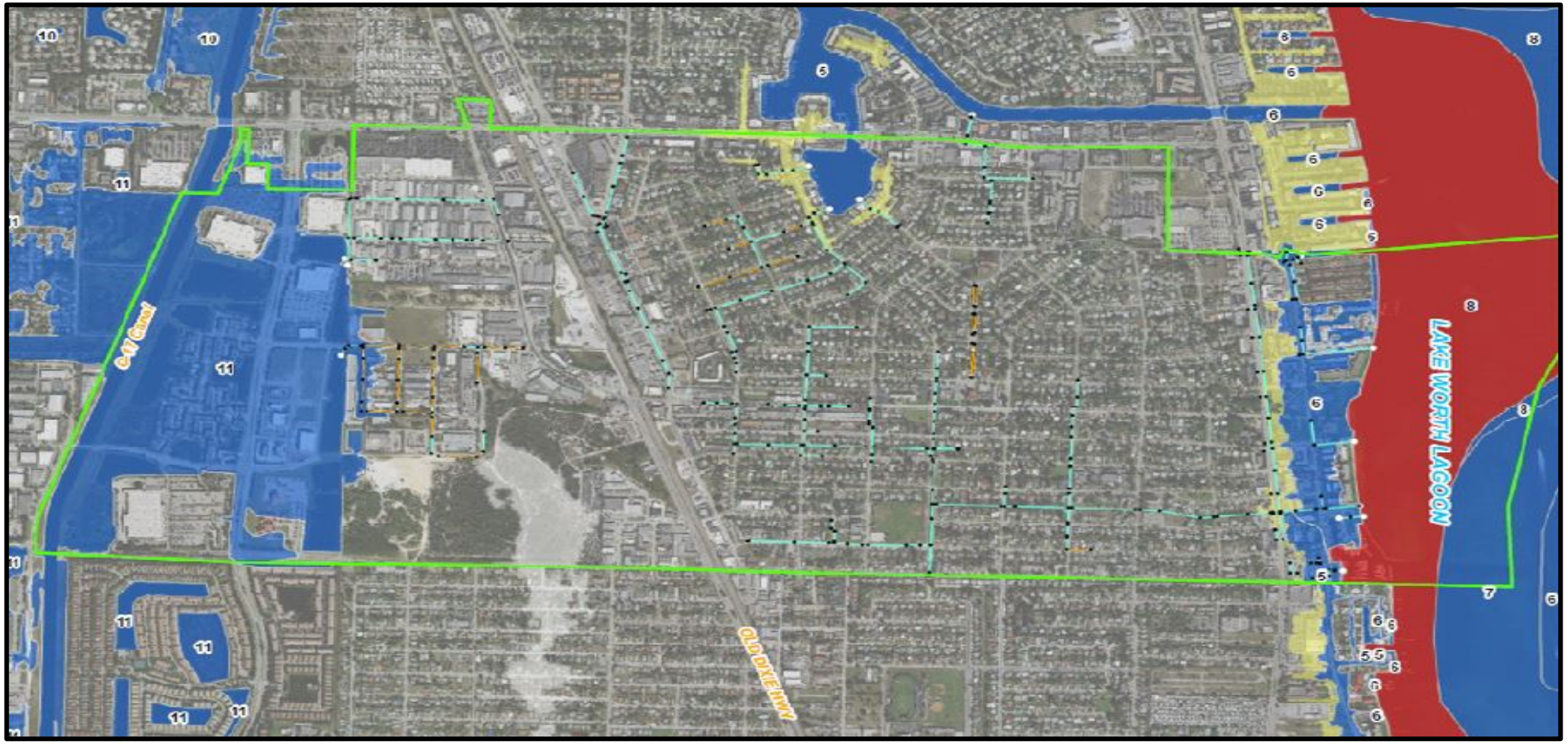
COASTAL SURGE INUNDATION MAPPING

EFFECTIVE 2017 FEMA 100-YEAR (1%) FLOODING (2019 DFIRM'S UNDER FINAL REVIEW)



Blue: 100-Year Flood Boundaries / Yellow: 500-Year Flood Boundaries

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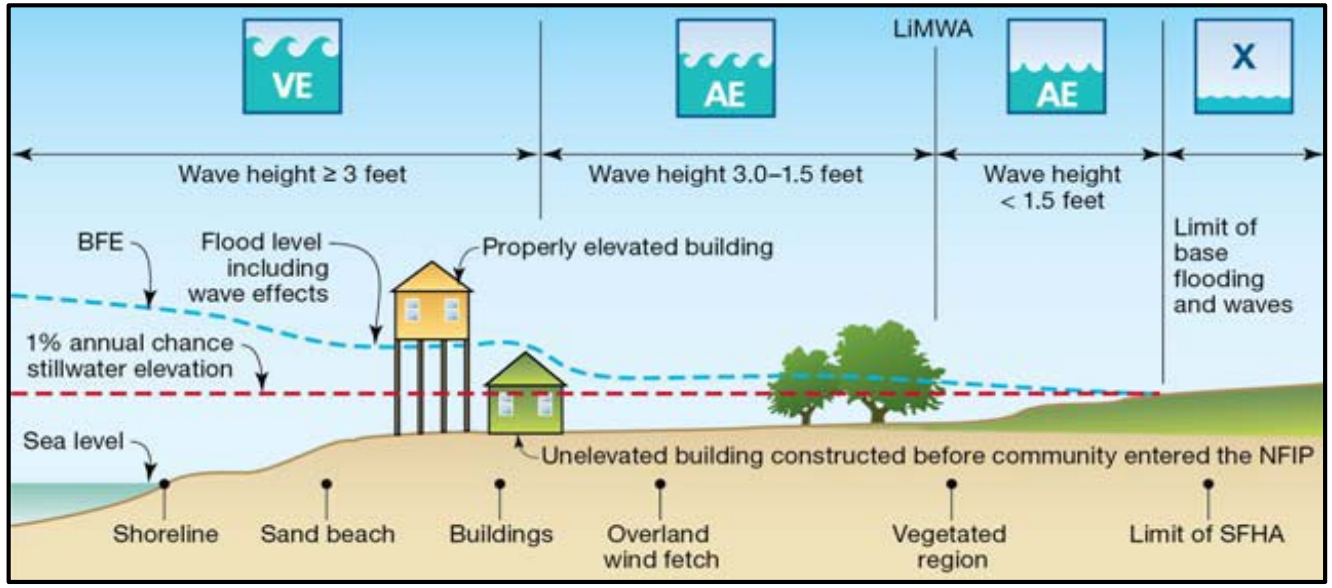
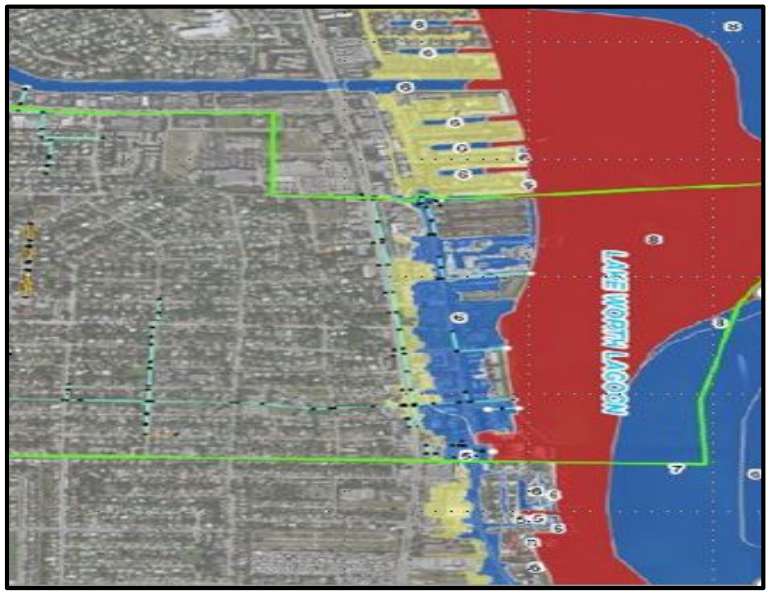
COASTAL SURGE INUNDATION MAPPING METHODOLOGY





- Due to the limited scope of this study, WRMA did not fully model the future base flood in the same manner as FEMA, but instead used an approximate method that is practically representative of FEMA's end product (Current 1% Still Water Elevation (SWEL) + SLR Method).

- The depth of flooding was approximated by the current BFE + SLR.

- WRMA included those riverine areas that are flooded in the current FEMA base floodplain map for the C-17 Canal along the western boundary.

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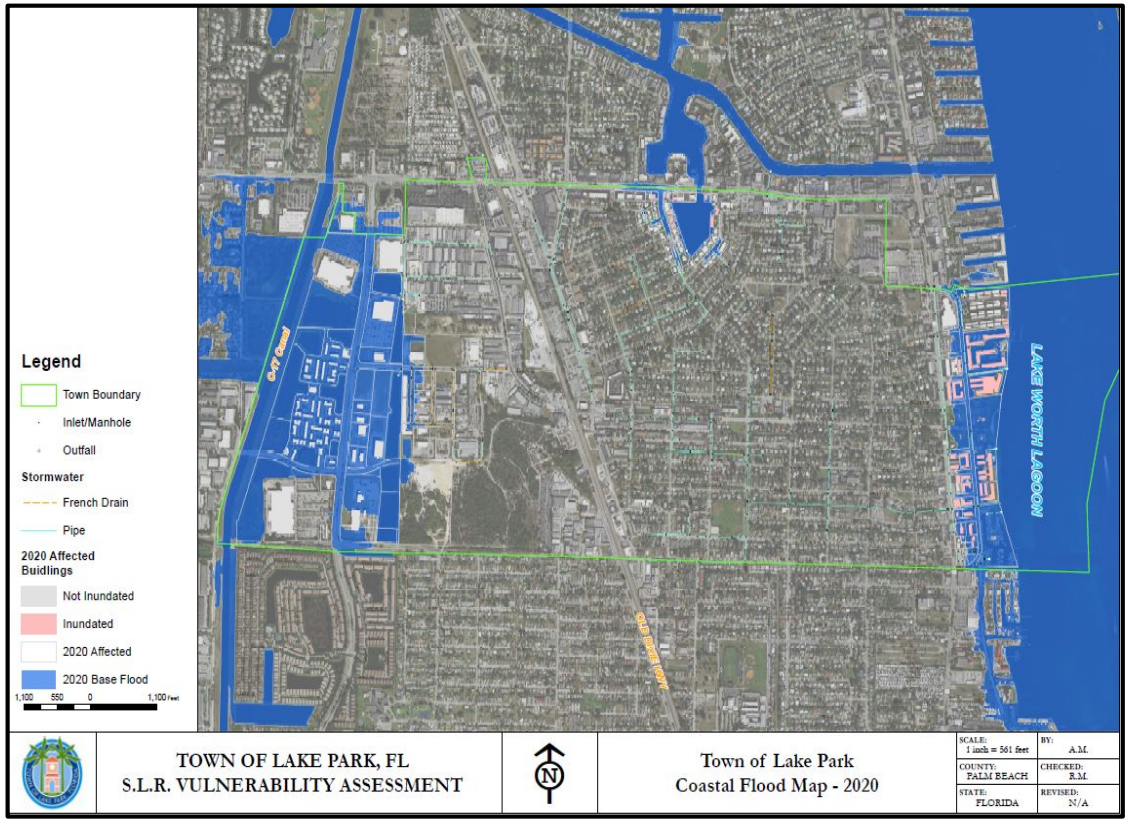
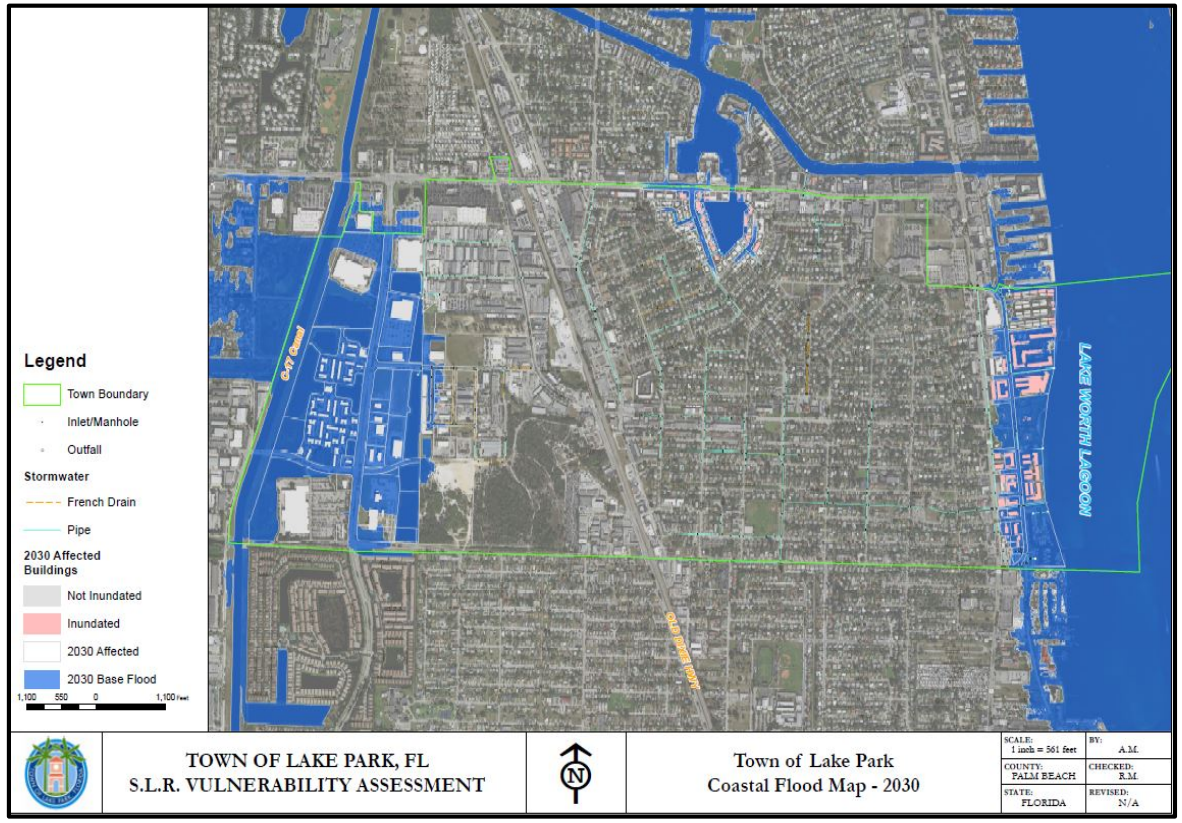
COASTAL SURGE INUNDATION MAPPING (2020 & 2030)





Unchanged Flooding Boundaries

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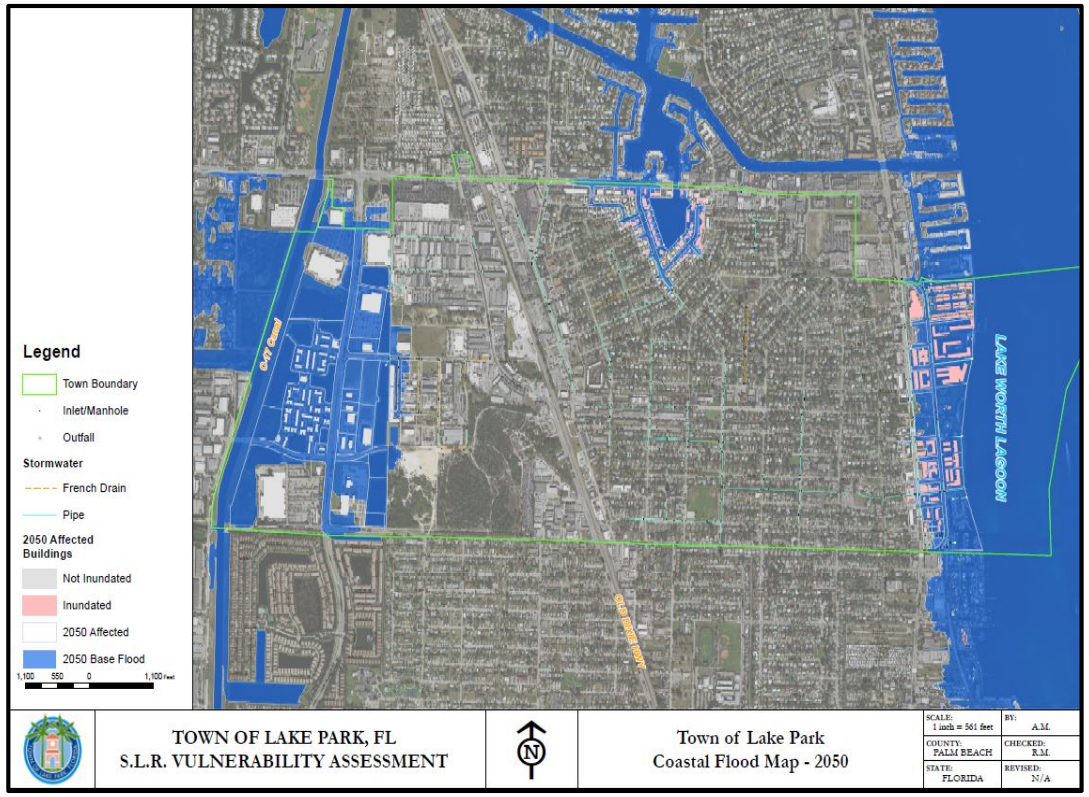
COASTAL SURGE INUNDATION MAPPING (2040 & 2050)



More flooding occurs in 2050 around South Lake and at the northern end of Lake Shore Drive.

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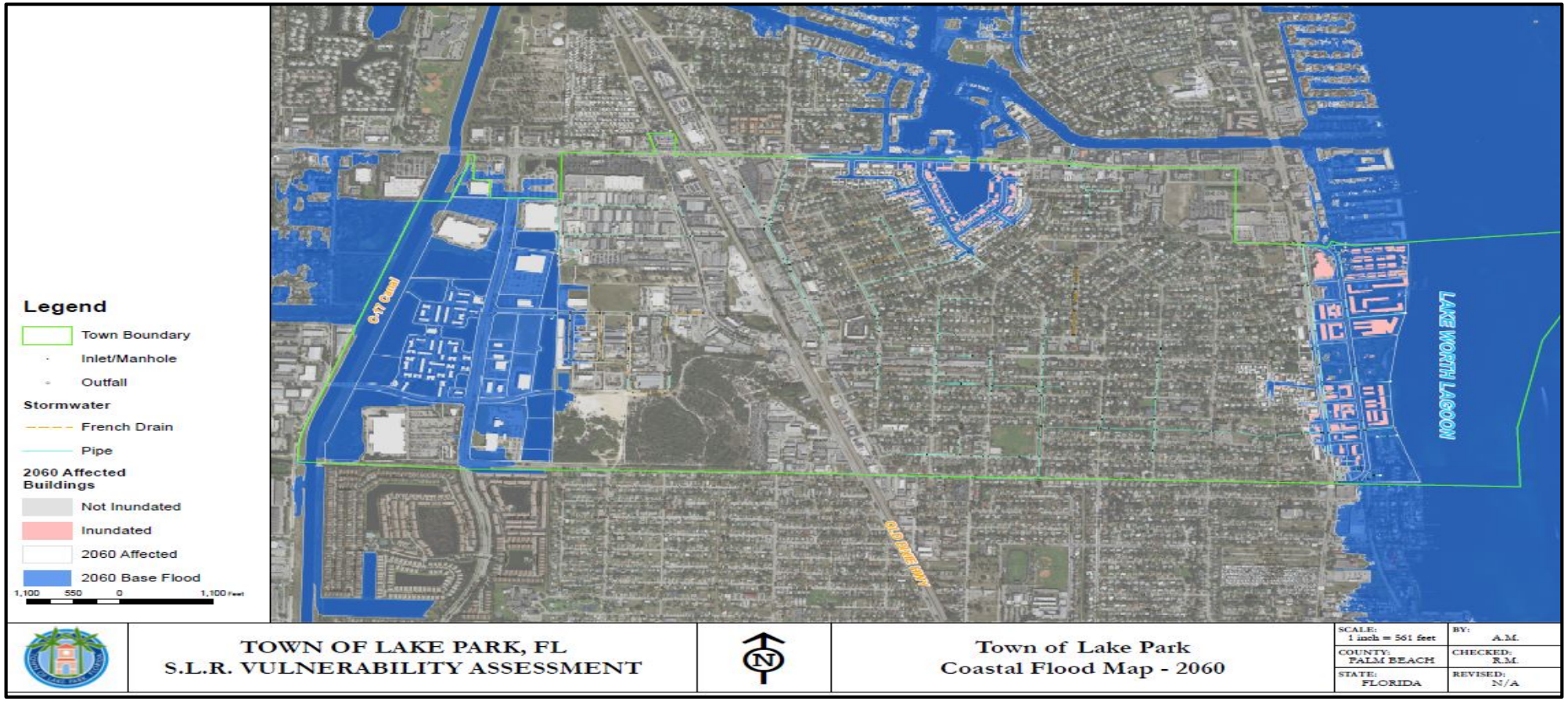
COASTAL SURGE INUNDATION MAPPING (2060)



Flooding in 2060 extends around South Lake and west of US Highway 1 between Date Palm Drive and Foresteria Drive.

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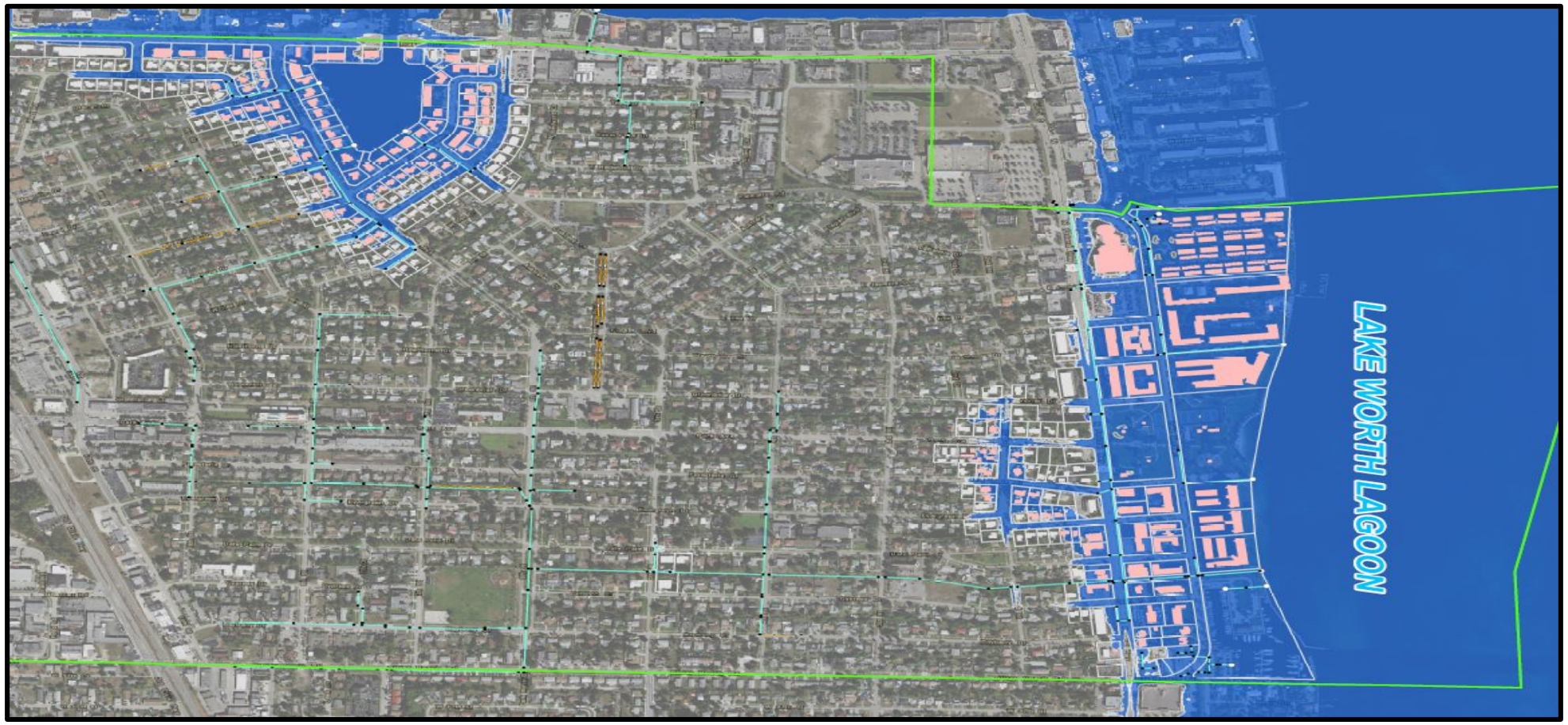
COASTAL SURGE INUNDATION MAPPING (2070)



More substantial flooding occurs in 2070 around South Lake and west of US Highway 1 between Date Palm Drive and Foresteria Drive.

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MONETARY COST ESTIMATION FOR COASTAL SURGE INUNDATION – METHODOLOGY

To determinate monetary damages incurred in each decadal coastal flood scenario, three types of costs were estimated for every flooded building using the FEMA/US Army Corps of Engineers Methodology:

Structural damage – includes physical damage to the building structure for a given flood depth, as a percentage of the building's replacement value;

Contents damage – includes damage to items within the structure that are not permanently installed and below a given flood depth, as a percentage of the estimated contents value;

Temporary Loss of Function (TLOF) – includes the costs associated with not being able to inhabit the structure until physical damages are restored.

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COASTAL SURGE FLOOD DAMAGES (2020-2070)

Scenario Year	Buildings Inundated[4]	Structure Damages	Contents Damages	TLOF Damages	Total Est. Damages
2020	64	$18,211,000	$15,909,000	$4,208,000	**$38.3M**
2030	76	$22,787,000	$25,178,000	$5,198,000	**$53.2M**
2040	95	$29,656,000	$40,269,000	$6,600,000	**$76.5M**
2050	141	$43,871,000	$72,039,000	$8,766,000	**$124.7M**
2060	162	$54,662,000	$86,951,000	$9,686,000	**$151.3M**
2070	219	$70,017,000	$111,440,000	$12,236,000	**$193.7M**

Scenario Year	Residential	Office	Commercial	Industrial	Public/Rec.
2020	69%	5%	17%	2%	7%
2030	69%	5%	17%	2%	7%
2040	71%	4%	16%	2%	6%
2050	75%	4%	15%	2%	5%
2060	75%	4%	14%	1%	5%
2070	78%	3%	14%	1%	4%

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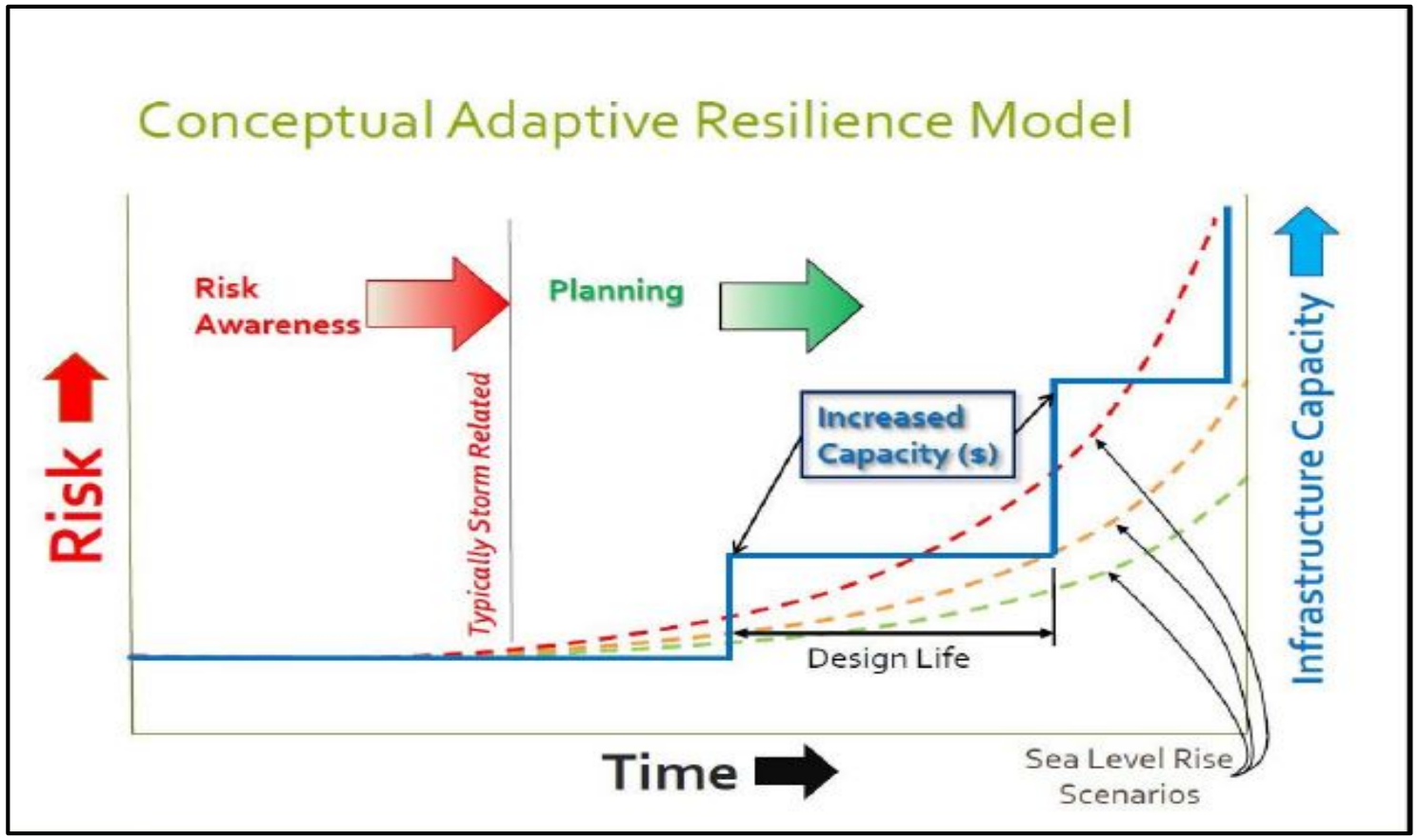
ADAPTATION PATHWAYS & OPTIONS



THE TOWN HAS 20 TO 30 YEARS OF ADAPTATION PLANNING TIME AVAILABLE BUT MUST START AT ONCE

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ADAPTATION PATHWAYS & OPTIONS

DRY FLOOD-PROOFING

- ✓ If ceiling heights permit, raising the first-floor elevation may be practical for facilities near the fringe of the floodplain
- ✓ Floodwalls (permanent or deployable) at an appropriate future BFE
- ✓ A quick estimation for the future BFE is to take the current FEMA BFE and add an amount of sea level appropriate for the expected useful life of the facility

ADAPTATION PATHWAYS & OPTIONS

WET FLOOD-PROOFING

- ✓ **Not occupying the first floor (still usable for storage and access purposes)**
- ✓ **Raising vulnerable utilities and infrastructure within the first floor above the future BFE**

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ADAPTATION PATHWAYS & OPTIONS

RAISING ROADS

- ✓ **Build road base to accommodate additional wearing surface layers later**
- ✓ **Elevate culverts or provide in-line valves**

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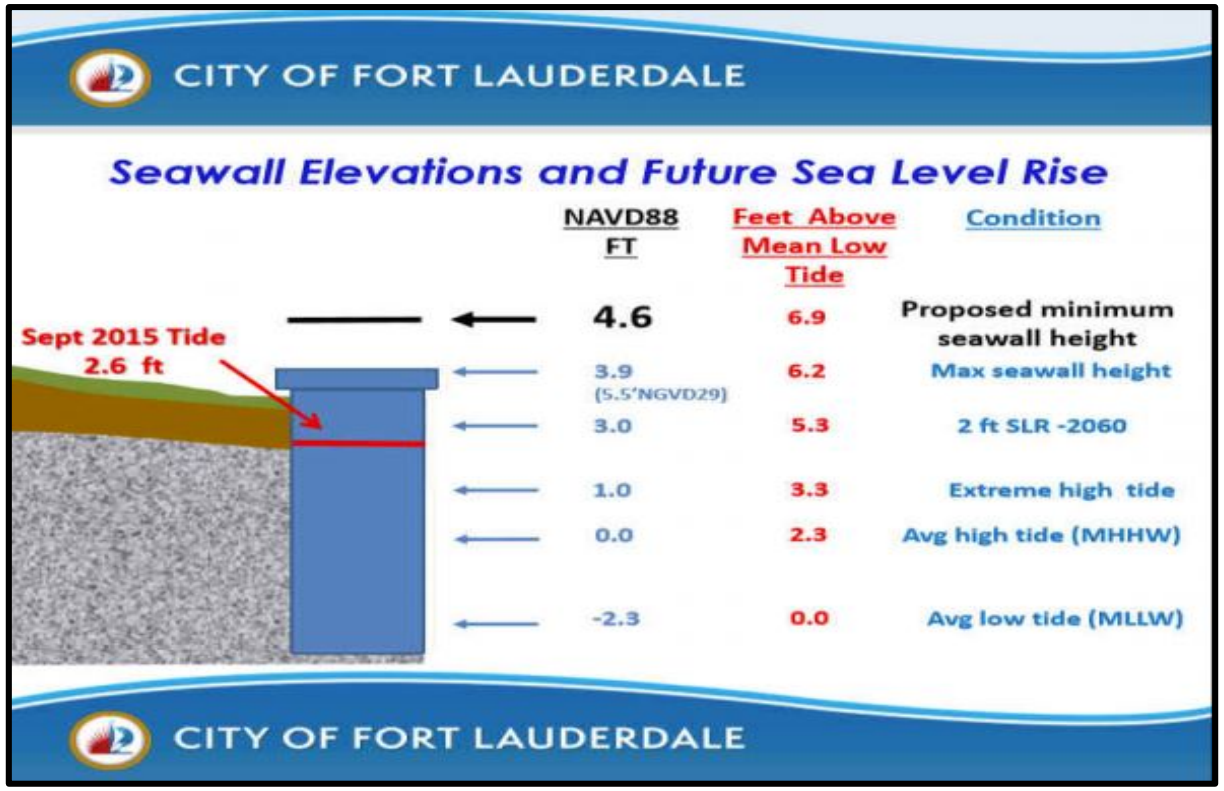
ADAPTATION PATHWAYS & OPTIONS

RAISING SEAWALLS (CAPS)

- ✓ Place caps on existing seawalls (if structurally adequate)
- ✓ Regulate new seawalls height by ordinance



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ADAPTATION PATHWAYS & OPTIONS

TOWN OF LAKE PARK COASTAL ADAPTATION ALONG LAKE SHORE DRIVE

- ✓ Consolidation of outfalls to Lake Worth Lagoon and Valve Placement
- ✓ Installation of Sea Level Rise Pump Stations to offset high tides

- ➢ Transitional (2020-2050) SLR Impact Efforts
- ➢ Will address local drainage deficiency for tide-impacted outfalls
- ➢ Will address "Sunny Day" flooding from King Tides

THESE PROJECTS WILL HOLD OFF SEA LEVEL RISE IMPACTS FOR THE NEXT 30 YEARS ONLY – BEGINNING IN 2050 SEWALLS WILL BE OVERTOPPED AND PUMP STATION EFFICIENCY WILL DECREASE SUBSTANTIALLY

LAKE SHORE DRIVE DRAINAGE IMPROVEMENT PROJECT

SOUTHERN OUTFALL PRIORITY RETROFIT PROJECT

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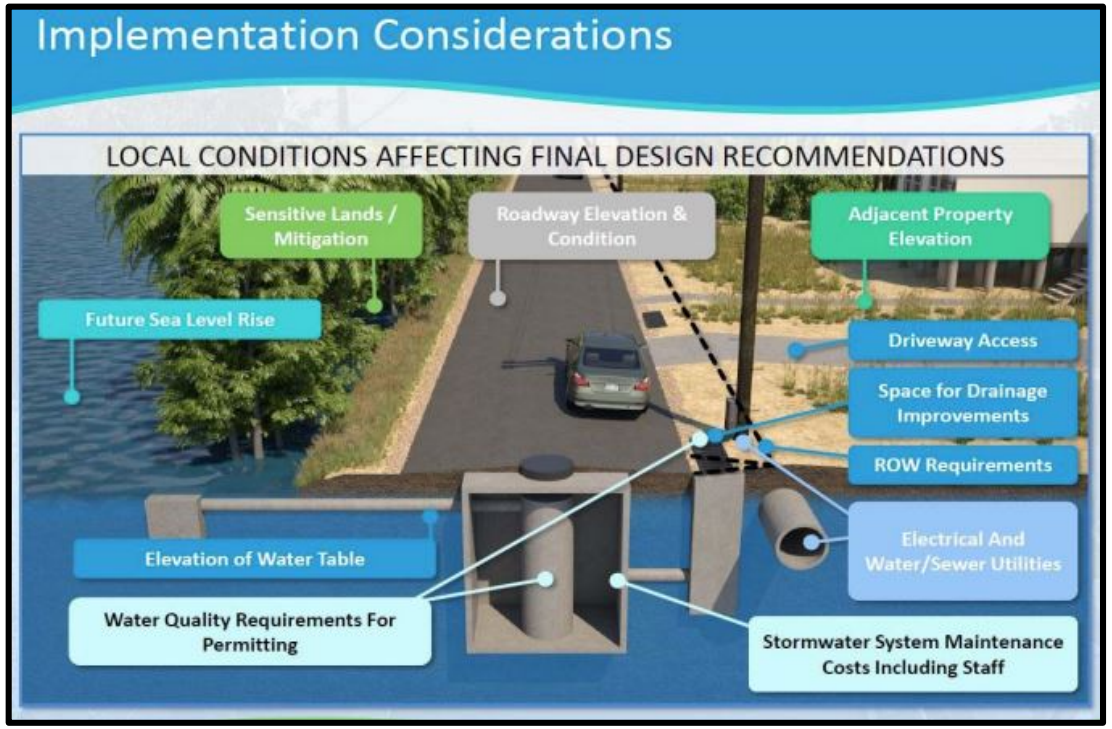
ADAPTATION PATHWAYS & OPTIONS

IMPLEMENTATION CONSIDERATIONS AND COST FOR 2050-2070

✓ **Utilities, Property/Building Elevation, Driveways, Environmental Factors**



Initial Results – Conceptual Cost Estimates for Design Scenarios

	Twin Lakes – Key Largo		Sands Community – Big Pine	
Elevation	Length of Roadway Elevated	Total Roadway and Drainage Cost	Length of Roadway Elevated	Total Roadway and Drainage Cost
6"	0.25 miles	$0.92 million	0.3 miles	$2.22 million
12"	0.7 miles	$4 million	0.35 miles	$2.63 million
18"	0.8 miles	$5.8 million	1.3 miles	$8.9 million
28"	0.9 miles	$7.3 million	1.5 miles	$10.5 million

Costs factored in: Maintenance of traffic, mobilization, design, construction, 15% of costs for construction engineering and inspection, 25% contingency and stormwater features.

Costs not factored in: right-of-way (~12" is threshold), driveway improvements

MORE WILL HAVE TO BE DONE BEFORE 2050 BY THE TOWN OF LAKE PARK

Cost of Raising 0.8 miles of Lake Shore Drive by 1.5 feet = Approximately $5.5 Million

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Thank You

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