Stormwater Condition Assessment

Case Study-City of West Palm Beach
Southeast Stormwater Association workshop
Oct 9, 2019

WPB
WEST PALM BEACH

Objectives

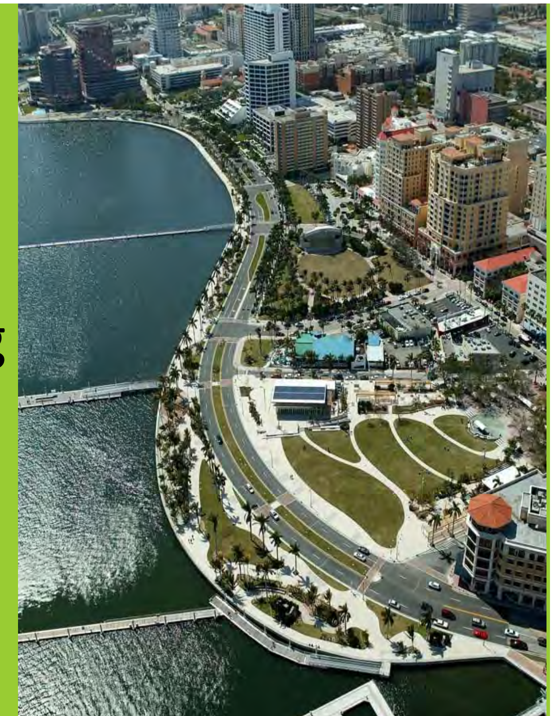
- Define appropriate methods for inspection and rehabilitation of stormwater assets
- Develop technical specifications for the most commonly utilized inspection and rehabilitation methodologies in South Florida, as well as for associated activities (e.g., bypass pumping, plugging, jet cleaning, etc.)
- Create cost models and decision models to assist with selection of inspection and rehabilitation methodologies
- Apply protocols, procedures, and technical specifications to approximately 5,000 LF of priority storm sewer rehabilitation projects as identified in the Stormwater Master Plan (pilot projects)
- Provide the foundation for the implementation of a comprehensive, long-term stormwater asset condition assessment and risk mitigation program

Background:
Stormwater in South Florida

- The City of West Palm Beach is a coastal city, located on the southeast coast of Florida
- Seasonal rains are 50 to 60 inches per year, mostly in summer
- Land is flat and low (one inch per mile) with high groundwater table, so area relies on a system of interconnected primary and secondary canals for regional flood control
- Neighborhood drainage systems are typically comprised of grassed swales and storm sewer system (submerged or partially submerged pipes), which often include exfiltration trenches; excess runoff discharges into the regional system or ICWW / Atlantic Ocean

WEST

Background:
Stormwater in South Florida



- Low-lying coastal areas have started experiencing tidal ("sunny day") flooding in recent years (King tides in October)
- Flooding is expected to worsen due to rising sea levels (and rising groundwater levels)

- Cities are looking for ways to combat sea level rise with methods including rehabilitating and improving existing infrastructure, and building new infrastructure (e.g., pump stations, drainage wells, sea walls, tidal valves, raising roads)

WPB
WEST PALM BEACH

Background:

Stormwater in South Florida

- The City's entire watershed is almost 60 square miles and has over 600 sub-basins
- The City possesses and maintains 186 miles of storm pipes
- Much of the stormwater system in the eastern portion of the City is comprised of vitrified clay pipe and was installed as early as the 1920s
- Newer parts of the system are comprised of corrugated metal pipe, whose useful life is not as long as concrete pipe (now a standard for large diameter pipe in coastal environments)

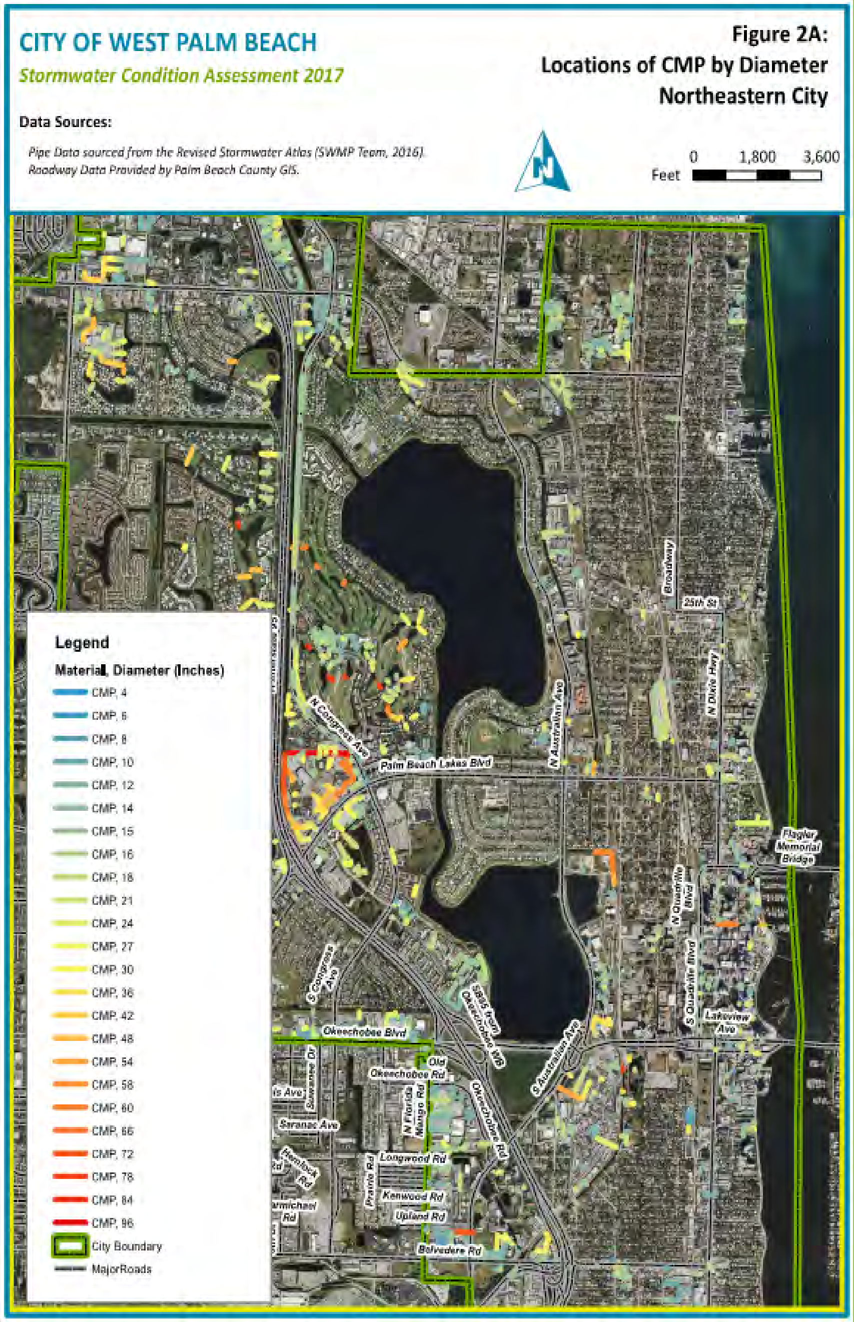
Stormwater Asset Summary

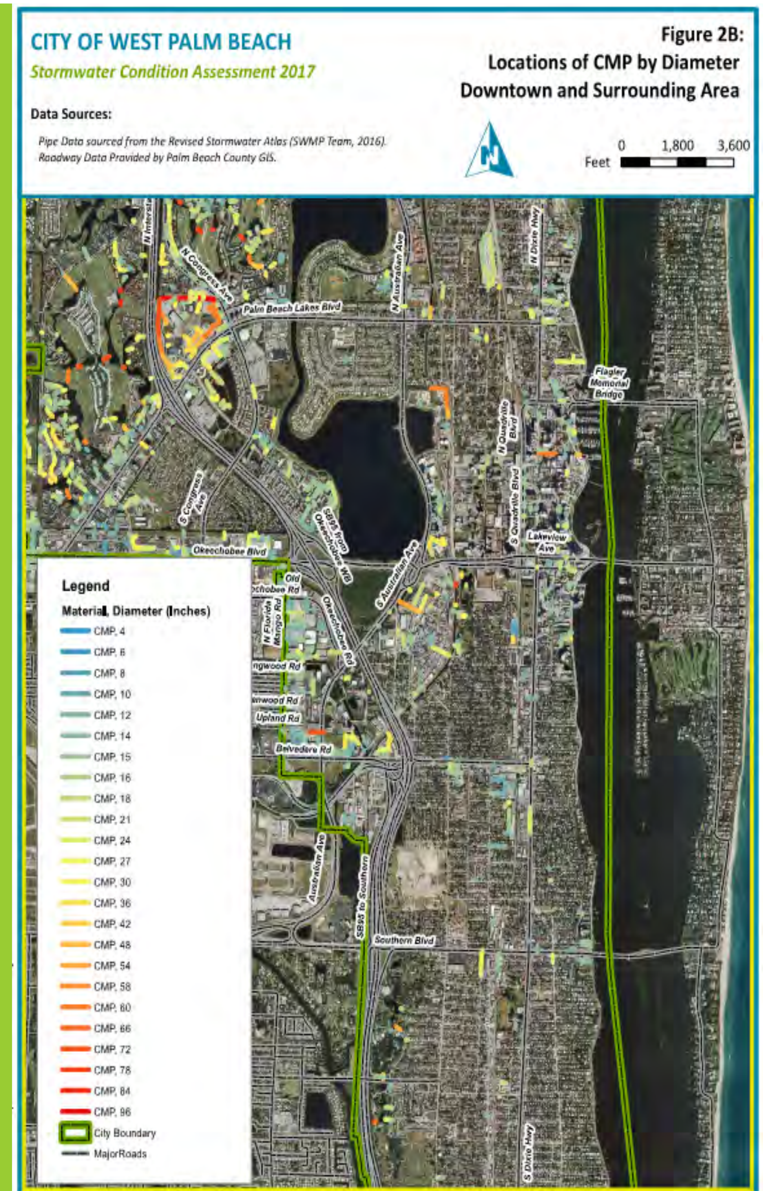
Material	Feet	Miles
not designated	47,757	9.0
ABS	589	0.1
CAS	682	0.1
CMP	72,811	13.8
CP	467	0.1
CSB	72	0.0
CSU	380	0.1
CT	817	0.2
DIP	19,905	3.8
HDPE	40,718	7.7
OTH	1,842	0.4
PE	1,261	0.2
PVC	34,829	6.6
RCP	591,397	112.0
Reinforced Concrete	2,006	0.4
RPM	153	0.0
SP	110	0.0
UNK	10,769	2.0
VCP	155,622	29.5
Grand Total	**982,187**	**186.0**

Diameter (in)	Feet	Miles
not designated	48,893	9.3
1	106	0.0
2	158	0.0
4	1,531	0.3
6	7,075	1.3
8	14,520	2.8
10	8,976	1.7
12	94,670	17.9
14	634	0.1
15	189,922	36.0
16	4,435	0.8
18	195,888	37.1
20	1,584	0.3
21	4,171	0.8
24	144,883	27.4
26	264	0.1
27	1,954	0.4
30	58,608	11.1
36	75,662	14.3
42	15,206	2.9
48	41,606	7.9
54	19,906	3.8
60	28,354	5.4
66	7,973	1.5
72	10,982	2.1
78	53	0.0
84	686	0.1
96	3,432	0.7
Grand Total	**982,186**	**186.0**

CITY OF WEST PALM BEACH
Stormwater Condition Assessment 2017
Figure 1A:
Locations of VCP by Diameter
Northeastern City
Data Sources:
Pipe Data sourced from the Revised Stormwater Atlas (SWMP Team, 2016).
Roadway Data Provided by Palm Beach County GIS.
N
0 1,125 2,250
Feet
Australian
Greenwood Ave
Broadway
45th St
NB95 to 45th
N Interstate 95
N Australian Ave
25th St
N Dixie Hwy
Palm Beach Lakes Blvd
N Quadrille Blvd
Flagler Memorial Bridge
Legend
Material, Diameter (Inches)
VCP, 4
VCP, 6
VCP, 8
VCP, 10
VCP, 12
VCP, 15
VCP, 16
VCP, 18
VCP, 20
VCP, 21
VCP, 24
VCP, 27
VCP, 30
VCP, 36
VCP, 42
VCP, 48
VCP, 54
VCP, 60
VCP, 66
City Boundary
MajorRoads

CITY OF WEST PALM BEACH
Stormwater Condition Assessment 2017
Figure 1B:
Locations of VCP by Diameter
Downtown and Surrounding Area
Data Sources:
Pipe Data sourced from the Revised Stormwater Atlas (SWMP Team, 2016).
Roadway Data Provided by Palm Beach County GIS.
N
0 1,300 2,600
Feet
N Congress Ave
Palm Beach Lakes Blvd
N Australian Ave
N Dixie
Flagler Memorial Bridge
N Quadrille Blvd
S Quadrille Blvd
S Congress Ave
SB95 from Okeechobee WB
S Australian Ave
Lakeview Ave
Okeechobee Rd
S Dixie Hwy
SB95 to Southern
Southern Blvd
Legend
Material, Diameter (Inches)
VCP, 4
VCP, 6
VCP, 8
VCP, 10
VCP, 12
VCP, 15
VCP, 16
VCP, 18
VCP, 20
VCP, 21
VCP, 24
VCP, 27
VCP, 30
VCP, 36
VCP, 42
VCP, 48
VCP, 54
VCP, 60
VCP, 66
City Boundary
MajorRoads


CITY OF WEST PALM BEACH
Stormwater Condition Assessment 2017
Figure 2A:
Locations of CMP by Diameter
Northeastern City
Data Sources:
Pipe Data sourced from the Revised Stormwater Atlas (SWMP Team, 2016).
Roadway Data Provided by Palm Beach County GIS.
0 1,800 3,600
Feet
Legend
Material, Diameter (Inches)
CMP, 4
CMP, 6
CMP, 8
CMP, 10
CMP, 12
CMP, 14
CMP, 15
CMP, 16
CMP, 18
CMP, 21
CMP, 24
CMP, 27
CMP, 30
CMP, 36
CMP, 42
CMP, 48
CMP, 54
CMP, 58
CMP, 60
CMP, 66
CMP, 72
CMP, 78
CMP, 84
CMP, 96
City Boundary
MajorRoads
Broadway
25th St
N Dixie Hwy
N Australian Ave
N Congress Ave
Palm Beach Lakes Blvd
Flagler Memorial Bridge
N Quadrille Blvd
S Quadrille Blvd
Lakeview Ave
S Congress Ave
Okeechobee Blvd
Old Okeechobee Rd
S Australian Ave
Saranac Ave
Longwood Rd
Kenwood Rd
Upland Rd
Belvedere Rd


CITY OF WEST PALM BEACH
Stormwater Condition Assessment 2017
Figure 2B:
Locations of CMP by Diameter
Downtown and Surrounding Area
Data Sources:
Pipe Data sourced from the Revised Stormwater Atlas (SWMP Team, 2016).
Roadway Data Provided by Palm Beach County GIS.
0 1,800 3,600
Feet
Legend
Material, Diameter (Inches)
CMP, 4
CMP, 6
CMP, 8
CMP, 10
CMP, 12
CMP, 14
CMP, 15
CMP, 16
CMP, 18
CMP, 21
CMP, 24
CMP, 27
CMP, 30
CMP, 36
CMP, 42
CMP, 48
CMP, 54
CMP, 58
CMP, 60
CMP, 66
CMP, 72
CMP, 78
CMP, 84
CMP, 96
City Boundary
MajorRoads
N Congress Ave
Palm Beach Lakes Blvd
N Australian Ave
N Dixie Hwy
Flagler Memorial Bridge
Okeechobee Blvd
Lakeview Ave
Belvedere Rd
Southern Blvd
S Dixie Hwy

Condition Assessment Scope

Task 1: Existing Storm Sewer System Data and Technical Literature Evaluation

Task 2: Condition Assessment Data Acquisition and Technical Specifications Criteria Development

Task 3: Rehabilitation Methodology and Technical Criteria Development

Task 4: Condition Assessment, Rehabilitation Methodology Application

WPB
WEST PALM BEACH

Task 1: Existing Storm Sewer System Data and Technical Literature Evaluation

- City’s policies, activities, and processes
- Stormwater Master Plan and project recommendations
- Geodatabase of storm sewers
- FDOT manuals and specifications
- Compile list of storm sewer inspection and rehabilitation bids
- Contractor interviews

Storm Sewer CCTV Inspection and Rehabilitation Bids

- Budgeting tool for future work
- Data grouped by pipe diameter and location (Florida, regional, and national)
- Costs obtained for:
  - CCTV inspection
  - Pipe cleaning
  - CIPP lining
  - Sliplining

Exhibit 9. Florida Cost Information - CCTV Inspection

Pipe Diameter (inches)	Unit Cost Per LF (Low)	Unit Cost Per LF (High)	Unit Cost Per LF (Average)	Unit Cost Per LF (Median)
18" to 24"	$1.00	$6.00	$3.00	$2.00
25" to 36"	$2.00	$6.00	$3.33	$2.00
37" to 48"	$2.00	$6.00	$3.67	$3.00
> 48"	$3.00	$8.00	$6.00	$7.00

Exhibit 12. Florida Cost Information – Pipe Cleaning

Pipe Diameter (inches)	Unit Cost Per LF (Low)	Unit Cost Per LF (High)	Unit Cost Per LF (Average)	Unit Cost Per LF (Median)
18" to 24"	$1.75	$7.50	$4.19	$4.00
25" to 36"	$3.43	$11.00	$7.22	$8.00
37" to 48"	$6.00	$17.00	$10.46	$9.75
> 48"	$10.00	$75.00	$29.94	$25.75

Exhibit 14. Florida Cost Information – CIPP Lining

Pipe Diameter (inches)	Unit Cost Per LF (Low)	Unit Cost Per LF (High)	Unit Cost Per LF (Average)	Unit Cost Per LF (Median)
18" to 24"	$60.00	$140.00	$89.14	$87.50
25" to 36"	$110.00	$221.00	$143.69	$144.00
37" to 48"	$185.00	$338.00	$235.19	$232.50
> 48"	$400.00	$950.00	$685.83	$690.00

Exhibit 17. Florida Cost Information – Slip Lining

Pipe Diameter (inches)	Unit Cost Per LF (Low)	Unit Cost Per LF (High)	Unit Cost Per LF (Average)	Unit Cost Per LF (Median)
18" to 24"	$45.00	$103.00	$69.58	$65.00
25" to 36"	$85.00	$300.00	$158.20	$148.00
37" to 48"	$145.00	$450.00	$288.22	$268.18
> 48"	$225.00	$765.00	$430.42	$395.00

WPB
WEST PALM BEACH

Interview with Local Contractor

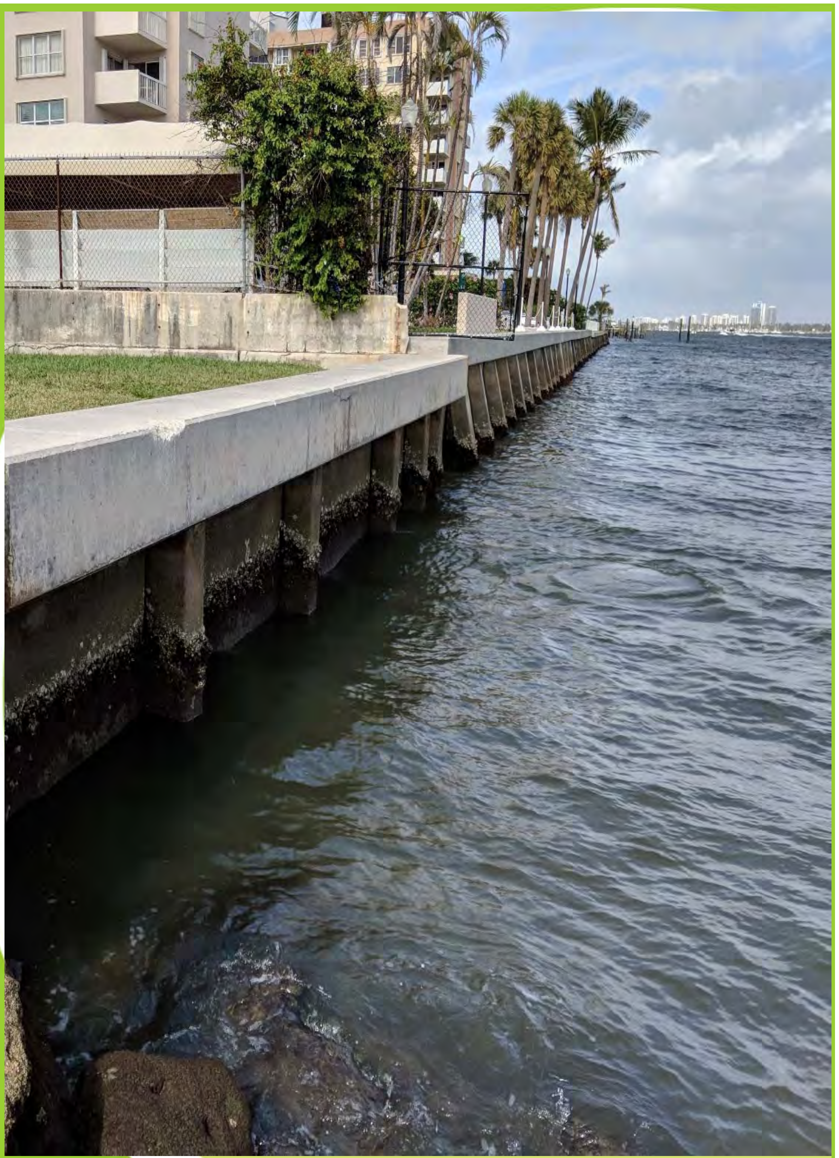
- National Association of Sewer Service Companies (NASSCO) rating system can effectively be applied to storm sewers

- Cured-in-place pipe (CIPP) lining is the preferred option for repairs, as it can be installed in larger runs

- Sliplining is useful in more limited applications, particularly where access is difficult (e.g., under busy roads or outfalls)

Interview with Local Contractor

- Challenges of working in a coastal environment:
  - Cleaning barnacles/heavy sedimentation, and working in water to inspect/repair outfalls due to boat traffic
  - Extensive dewatering required due to high groundwater table
  - Working in tidally-influenced areas makes work possible at only certain times of the day



WPB

WEST

Task 2: Condition Assessment Data Acquisition and Technical Specifications Criteria Development

- Condition assessment technology options
  - Equipment
  - Cleaning requirements
  - Dewatering and bypass pumping requirements
  - Decision model
- Technical specifications
  - Inspection equipment requirements
  - Inspection data and reporting requirements
  - Condition rating scale

Condition Assessment Technology Options

- Equipment
  - Closed Circuit Television (CCTV)
  - Subaqueous CCTV
  - Zoom Camera
  - Laser Profiling
  - Sonar

Conventional CCTV	Subaqueous CCTV
Industry standard approach	Specialty inspection
Numerous contractors available	Limited contractors
Equipment directly linked to NASSCO compliant direct entry software	No linkage (at this time) to NASSCO compliant direct entry software (requires post processing)
May require pipeline/structure cleaning	May require pipeline/structure cleaning
May requires dewatering and/or bypass pumping to maintain water levels below 20 percent full pipe	May require multi-technology approach for partially full pipes
	Quality of image will be dependent on water color and suspended sediment levels

Condition Assessment Technology Options

- Cleaning Requirements
  - Mechanical
    - Rodding – primary application is small diameter pipe
    - Bucket machine – typically cylindrical drive with jaws to pull debris from pipe or structure
  - Hydraulic
    - Jetting – high velocity water used to wash sediment from pipe; typically used on smaller diameter pipe in parallel with vacuum truck
- Dewatering and Bypass Pumping Requirements
  - If water level is greater than 10 to 20 percent of pipe diameter, dewatering is required to complete a comprehensive inspection using conventional CCTV
  - Submerged or partially submerged pipes require an upstream and downstream plug
  - Bypass pumping may be required if upstream segment of pipe surcharges and has potential to cause surface flooding

Tiered Approach for Inspection and Decision Logic

Tier 1: Preliminary Inspection	Tier 2: Condition Assessment	Tier 3: Inspection to Support Engineering Design Activities

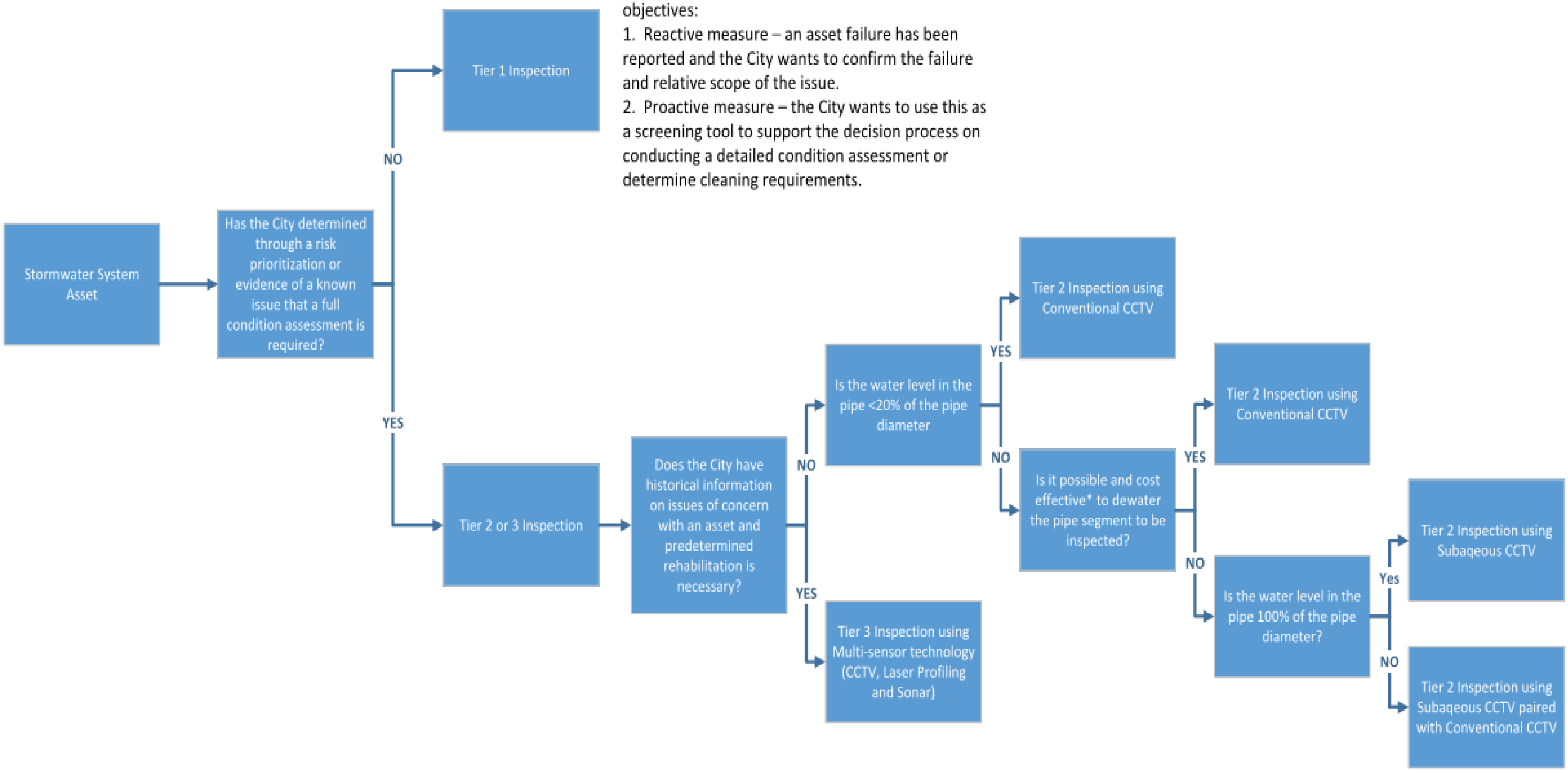
• Qualitative screening
• No condition rating
 	
• Technology
  o Subaqueous CCTV
  o Zoom camera
	• Detailed visual inspection over length of asset
	• Produces structural and O&M condition rating
	• Data can be used to define limits of more intensive Tier 3 inspections
	
	• Technology
	  o CCTV (convention or subaqueous)
	  o Zoom camera (for manholes/inlets)
	  o Visual inspection (for large culverts)
		• Detailed data inputs for engineering analysis to define appropriate rehab technique
		
		• Technology
		  o CCTV
		  o Laser profiling

City of West Palm Beach Stormwater Program Asset Inspection Decision Logic Diagram

Objective: to achieve an asset inspection that yields a NASSCO compliant result.

The decision on conducting a Tier 1 inspection would be driven by the City's desire to achieve 2 different objectives:

1. Reactive measure – an asset failure has been reported and the City wants to confirm the failure and relative scope of the issue.
2. Proactive measure – the City wants to use this as a screening tool to support the decision process on conducting a detailed condition assessment or determine cleaning requirements.



Technical Specifications

- Inspection equipment and software technical requirements
  - CCTV camera
  - Camera for manhole/inlet inspections
  - Zoom camera for inspection
  - Compatibility with City's current CCTV software (GraniteNet)
- Data and reporting requirements
  - Data acquisition (mandatory fields)
  - Video, images, and measurement
  - Deliverables
  - Quality control and acceptance of deliverables

Condition Rating Scale

- Although typically applied to wastewater collection infrastructure, we have recommended applying a modified version NASSCO condition rating system for the City's stormwater to standardize the inspection process

Condition grade	General description	Detailed description	Recommended inspection frequency[a]
0	New or excellent condition	Asset with no defects. No action needed.	No more frequent than the inspection cycle period
1	New or excellent condition	Asset with very few minor defects. Inspection frequency would be at the end of the planned system inspection cycle period.	No more frequent than the inspection cycle period
2	Good condition – minor defects only	Asset in good structural and maintenance condition but there are several minor defects or one or two more moderately severe defects. Inspection frequency could be 60 to 80% of the planned system inspection cycle period.	60-80% of inspection cycle period
3	Fair Condition – moderate deterioration	Defects have degraded to a moderate level and are affecting the performance of the asset. Could be a combination of a number of minor and moderate defects. Point repairs or maintenance could be required. Inspection frequency should be within a 3 to 5 year time frame.	3-5 years
4	Poor condition – significant deterioration	Several moderate defects and at least one or more major defects. Point repairs or maintenance may correct deficiency or may need more comprehensive repair or replacement such as lining. May need frequent maintenance. Inspection frequency should be within a 1 to 3 year time frame.	1-3 years
5	Failing or failed asset	Several severe defects are found in most sections of the asset. Replacement, comprehensive rehab, should be scheduled. Emergency repair may be required. Inspection frequency should be on a monthly basis and no greater than one year.	<1 year

[a] Inspection cycle period would be defined programmatically by the City to define inspection frequency for all linear assets.

- Rating scale takes into account number, type, and severity of defects

NASSCO'S PIPELINE ASSESSMENT CERTIFICATION PROGRAM® (PACP®)

Section 4 — Structural Defect Coding

C CRACK 4-3
- CL Longitudinal
- CC Circumferential
- CM Multiple
- CS Spiral
- CH Hinge (2, 3, 4)

F FRACTURE 4-9
- FL Longitudinal
- FC Circumferential
- FM Multiple
- FS Spiral
- FH Hinge (2, 3, 4)

B BROKEN 4-17
- BSV Soil Visible
- BVV Void Visible

H HOLE 4-21
- HSV Soil Visible
- HVV Void Visible

D DEFORMED (Rigid) 4-25
- DR Deformed Rigid

No modifiers used.

D DEFORMED (Flexible) 4-25
- DFBR Bulging Round
- DFBI Bulging Inv.Curv.
- DFC Creasing
- DFE Elliptical

D DEFORMED (Brick) 4-25
- DTBR Bulging Round
- DTBI Bulging Inv.Curv.

X COLLAPSE 4-37
- X Collapse

No descriptors and no modifiers used.

J JOINT 4-43
- JOS Offset Small
- JOM Offset Medium
- JOL Offset Large

J JOINT 4-43
- JOSD Offset Small Defect
- JOMD Offset Medium Defect
- JOLD Offset Large Defect

J JOINT 4-43
- JSS Separation Small
- JSM Separation Med.
- JSL Separation Large

J JOINT 4-43
- JAS Angular Small
- JAM Angular Medium
- JAL Angular Large

S SURFACE DAMAGE 4-51
- SRI Roughness Increased
- SAV Aggregate Visible
- SAP Aggregate Projecting
- SAM Aggregate Missing

S SURFACE DAMAGE 4-51
- SRV Reinforcement Visible
- SRP Reinforcemt.Projecting
- SRC Reinforcemt.Corroded
- SMW Missing Wall

S SURFACE DAMAGE 4-51
- SSS Surface Spalling
- SSC Surface Spalling Coating
- SCP Chemical Attack
- SZ Other

LF LINING FEATURES 4-67
- LFAC Abdn'd Connection
- LFAS Annular Space
- LFB Blistered Lining
- LFCS Service Cut Shifted

LF LINING FEATURES 4-67
- LFD Detached
- LFDC Discoloration
- LFDE Defective End
- LFDL Delamination

LF LINING FEATURES 4-67
- LFOC Overcut Service
- LFRS Resin Slug
- LFUC Undercut Service
- LFW Wrinkled
- LFZ Other

WF WELD FAILURE 4-85
- WFC Circumferential
- WFL Longitudinal
- WFM Multiple
- WFS Spiral
- WFZ Other

RP POINT REPAIR 4-89
- RPL Liner
- RPLD Liner Defective
- RPP Patch
- RPPD Patch Defective

RP POINT REPAIR 4-89
- RPR Replacement
- RPRD Replmt. Defective
- RPZ Other
- RPZD Other Defective

BRICKWORK 4-97
- DB Displaced
- MB Missing
- DI Dropped Invert

BRICKWORK 4-97
- MMS Mortar Missing Small
- MMM Mortar Missing Med.
- MML Mortar Missing Large

<u>Task 3:</u> Rehabilitation Methodology and Technical Criteria Development

- Develop technical specifications for 5 rehabilitation methodologies
  - CIPP lining
  - Sliplining
  - Chemical grouting
  - Pipe bursting (replacement)
  - Open cut (replacement)

Task 3: Rehabilitation Methodology and Technical Criteria Development

- Assess and provide guidance for technical issues related to bypass pumping, jet/pressure cleaning, directional drilling, and coffer damming (outfalls)
- Develop decision logic to help standardize rehabilitation decision-making process

Pipeline Rehabilitation Approaches

METHOD	OPEN CUT	SLIPLINING	CURED-IN-PLACE PIPE LINING (CIPP)	FOLD-AND-FORM LINING	SPIRAL WOUND LINING	DIE-DRAW LINING/ ROLL-DOWN LINING	PIPE BURSTING/ PIPE REAMING	SPOT REPAIRS	CROWN SPRAYING	CHEMICAL GROUTING	CEMENT MORTAR LINING	SPRAY APPLIED POLYMER LINING
DESCRIPTION	Traditional method of excavating, bedding, laying, and backfilling a pipeline.	Placement of a solid or segmented pipeline inside an existing pipeline. Typical materials include PVC, HDPE, steel, and VCP.	Insertion of a felt liner impregnated with thermosetting resin inside an existing pipe, forming a new structural pipe inside the old pipe. For pressure pipe applications, felt may be reinforced with fiberglass, polyester, or carbon fibers.	Similar to sliplining, insertion of a plastic pipe (either PVC or HDPE) inside an existing pipe.	Strips of ribbed PVC are spun inside an existing gravity pipe to create a new pipe within the old pipe.	Method that reduces the diameter of a PE pipe to facilitate insertion into an existing pipe.	Class of methodologies in which the existing pipe is broken and replaced with a new pipe of equal or larger diameter.	Various methods to repair short sections of pipe. Common methods include internally or externally applied fiber reinforced polymer methods and internal pipe seals.	Application of magnesium hydroxide to protect concrete gravity sewers and retard corrosion.	Involves the use of a packer and grouter to test the seal of individual gravity pipeline joints and, if necessary, apply grout to seal the joint.	Mechanical cleaning followed by spray-applied mortar, per ANSI/AWWA Standard C602. Oldest pipeline rehab method; introduced in the 1960s.	Mechanical cleaning followed by spray applied epoxy, polyurethane, or polyurea, or fiber-reinforced geopolymers. Applicable to water, wastewater, or storm drainage pipelines.
ADVANTAGES	1) Has been used for thousands of years 2) Numerous contractors with experience	1) If butt-fusion pipe is used, number of joints is limited 2) Typically, only one pit is required (to pull pipe into the line) 3) If segmented pipe used, bypassing of wastewater is not required	1) Structurally, provides a full replacement pipe 2) Small reduction in cross section 3) No entrance or exit pits required 4) Liners can be cured with hot water, steam, or ultraviolet light 5) Can be used for non-circular conduits	1) Small reduction in cross section 2) Excavation pit not required	1) Adds more competition among lining methods 2) Can be used for non-circular conduits 3) Relatively long installation lengths possible	1) Small reduction in cross section 2) Adds more competition among lining methods	1) Allows existing pipe to be upsized 2) Cost is less than open-cut 3) Reduces surface disruption	1) Minimal surface disruption 2) Small reduction in cross section with internal repairs	1) Low unit cost 2) Provides protection of corroded concrete pipes 3) Can be applied quickly	1) Proven and relatively low cost 2) Does not require bypassing 3) Not affected by active infiltration	1) Proven, low cost, several competing companies 2) Improves water quality and hydraulics – stops internal corrosion, and provides internal corrosion protection 3) No work needed to restore services	1) Proven, low cost, several competing companies 2) Improves water quality and hydraulics – stops internal corrosion, and provides internal corrosion protection 3) Cured material can have compressive strength as high as 8,000 psi to provide structural improvement
DISADVANTAGES	1) Significant surface disruption 2) Significant geotechnical requirements 3) Typically most costly, depending on existing surface improvements	1) Significant reduction in cross-sectional area of pipe 2) Laterals must be externally reinstated 3) Failures include separation of pulling head from pipe, joint failure, excessive pulling loads leading to pipe failure, and missed laterals	1) Bypassing required 2) Unit costs are somewhat high, relative to other lining methods and, sometimes, open-cut 3) Failures have occurred due to improper wet-out, delays in transport, equipment failure during cure, poor design, lack of cleaning, and hydrostatic forces 4) Styrene – a byproduct of some liners – has an identified potential to interfere with WWTP biological processes	1) Bypass required 2) Failures can result from operator error, equipment failure, improperly sized pipe, and liner slippage in service	1) Relatively high cost compared to other lining methods 2) Failures caused by equipment breakdown, and unexpected obstructions	1) Relatively high cost compared to other lining methods 2) Failures caused by equipment breakdown, and unexpected obstructions	1) Need geotechnical information in pipe zone and in trench over the pipe 2) Can cause ground heave 3) Failures caused by equipment breakdown, insufficient ground cover, curved pipes, narrow previous trenches, and rocky soils 4) Pipe reaming is a patented process that requires licensed contractors	1) Requires excavation for external repairs 2) High unit cost due to limited length of pipe replaced	1) Temporary (1-2 year expected life) 2) Only protects pipe above the flow zone	1) Subject to failure when used in areas with fluctuating groundwater levels 2) Grout materials may be banned or limited in use in the near future 3) Failures include operator error, wet/dry cycling, equipment failure, and improper mixing	1) Minimal structural improvement 2) Only applicable to unlined cast iron and steel water mains 3) Not recommended for soft water	1) Ability for thick linings to serve as "fully structural" rehabilitation not proven 2) ANSI/AWWA Standard C620 exists for 1 mm epoxy lining only

Rehabilitation Methods: Open Cut

- Key components
  - Excavation, bedding, laying and backfilling of a pipeline
- Advantages
  - Used for thousands of years
  - Numerous contractors with experience
  - Full renewal of host pipe
- Disadvantages
  - Significant surface disruption
  - Significant geotechnical requirements
  - Typically most costly
  - Construction duration

Rehabilitation Methods: Cured-in-Place-Pipe (CIPP)

- Key components
  - Insertion of a liner impregnated with thermosetting resin within an existing host pipe
- Advantages
  - Fully structural replacement
  - Small reduction in cross-sectional area – minimal impact to hydraulics
  - No entrance or exit pits required – minimal surface disruption
- Disadvantages
  - Dewatering/Bypassing required during construction
  - Sometimes more costly compared to other lining methods

WPB WEST PALM BEACH

Rehabilitation Methods: Sliplining

- Key components
  - Placement of a solid or segmented pipeline inside existing pipeline
- Advantages
  - Typically only one pit required
  - Number of joints can be limited
  - Minimal/moderate surface disruption
- Disadvantages
  - Significant reduction in cross-sectional area
  - Laterals must be externally reinstated
  - Excessive pulling loads can lead to pipe failure

WEST PALM BEACH

Rehabilitation Methods: Pipe Bursting

- Key components
  - Existing pipe broken and replaced with new pipe of equal or greater size
- Advantages
  - Existing pipe can be upsized (without open cut)
  - Less costly than open cut
  - Eliminates old pipe material
- Disadvantages
  - Geotechnical information required in pipe zone – minimize adjacent obstructions
  - May cause ground heave if shallow
  - Bypassing of flow necessary
  - Failures possible due to equipment breakdown, curved pipes, and rocky soils

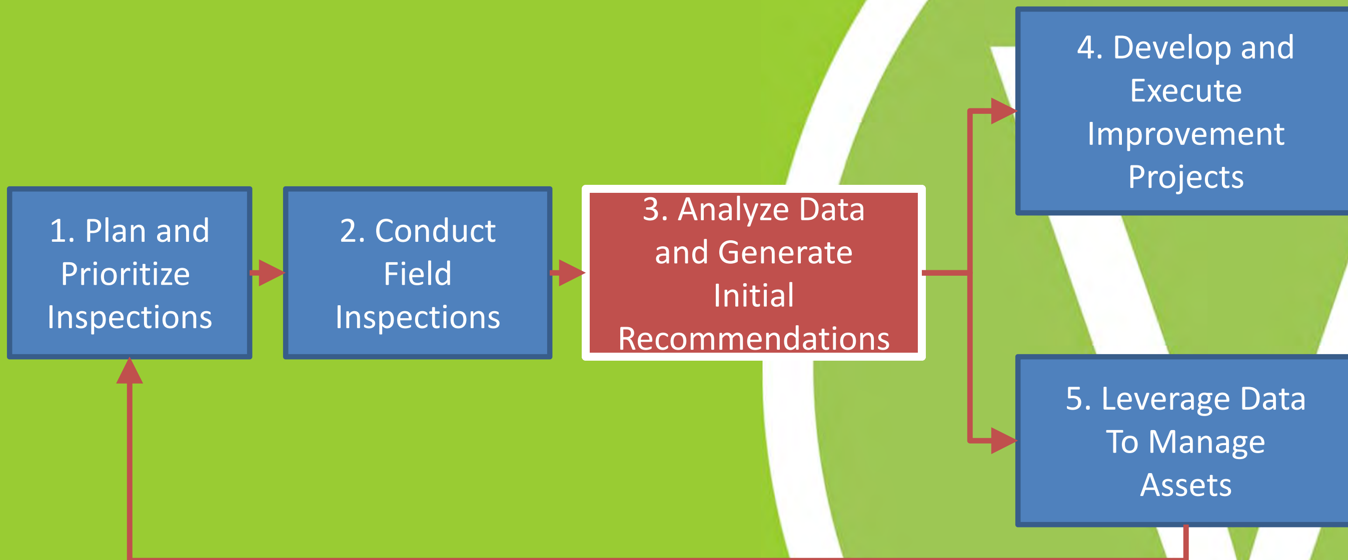
WPB
WEST PALM BEACH

Rehabilitation Methods: Grouting

- Key components
  - Use of packer and grouter to seal individual gravity pipeline joints (inside and/or outside)
  - Alternative can be cementitious grouting
- Advantages
  - Proven technology with relatively low cost
  - Does not require bypassing for outside rehab
  - Not affected by active infiltration
  - Minimal surface disruption
- Disadvantages
  - Subject to failure in areas with fluctuating groundwater levels
  - Potential for failures associated with operator error, wet/dry cycling, and improper mixing
  - Reliant on host pipe structural integrity

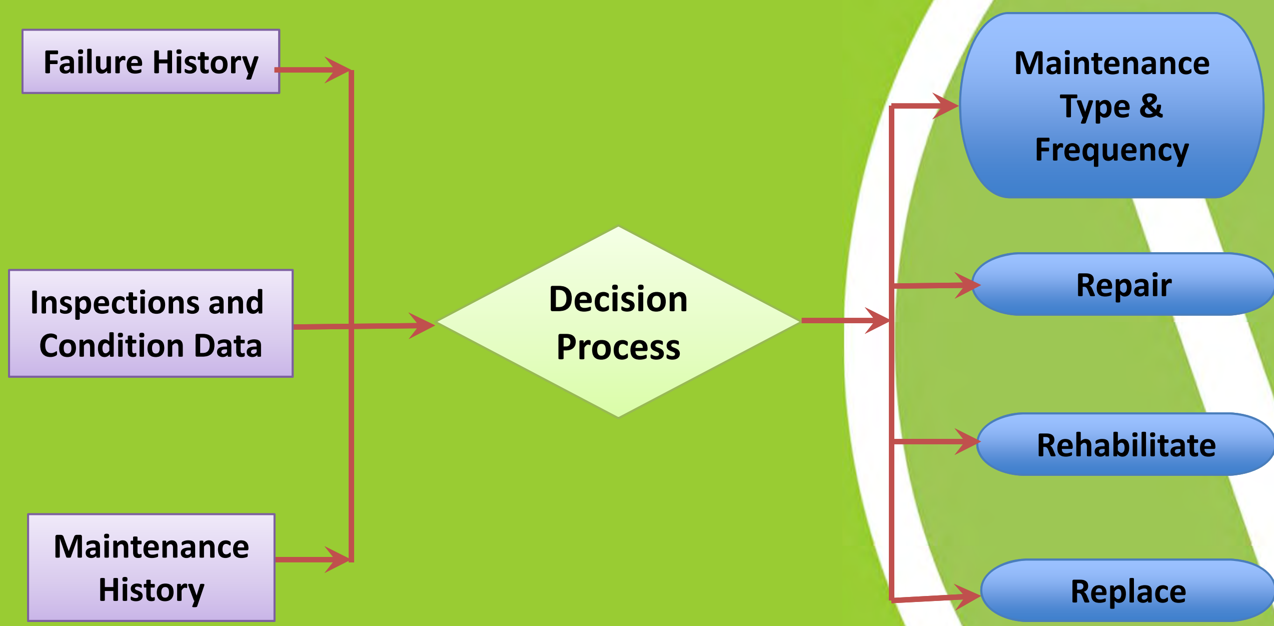
WEST PALM BEACH

Typical Work Flow - Inspection and Condition Assessment Programs



Develop High-Quality Decision Processes

Information **Decisions**



Key Questions / Decision Points	Impact on Decision Logic
Was a defect requiring rehab identified during inspection?	If yes, enter rehab decision logic
Has storm sewer been identified as being undersized?	If yes, pipe bursting or open cut required
Frequency of point defects?	If high frequency, consider lining rather than point repair
What is the existing pipe material?	Impacts feasibility of certain rehab methods
What is the existing pipe size?	Impacts feasibility of certain rehab methods
Is existing pipe deformed or sagging?	Open cut may be required
What are surface conditions above existing pipe?	Open cut may be less cost-effective

City of West Palm Beach - Stormwater Pipe Renewal Decision Logic Diagram

WEST PALM BEACH

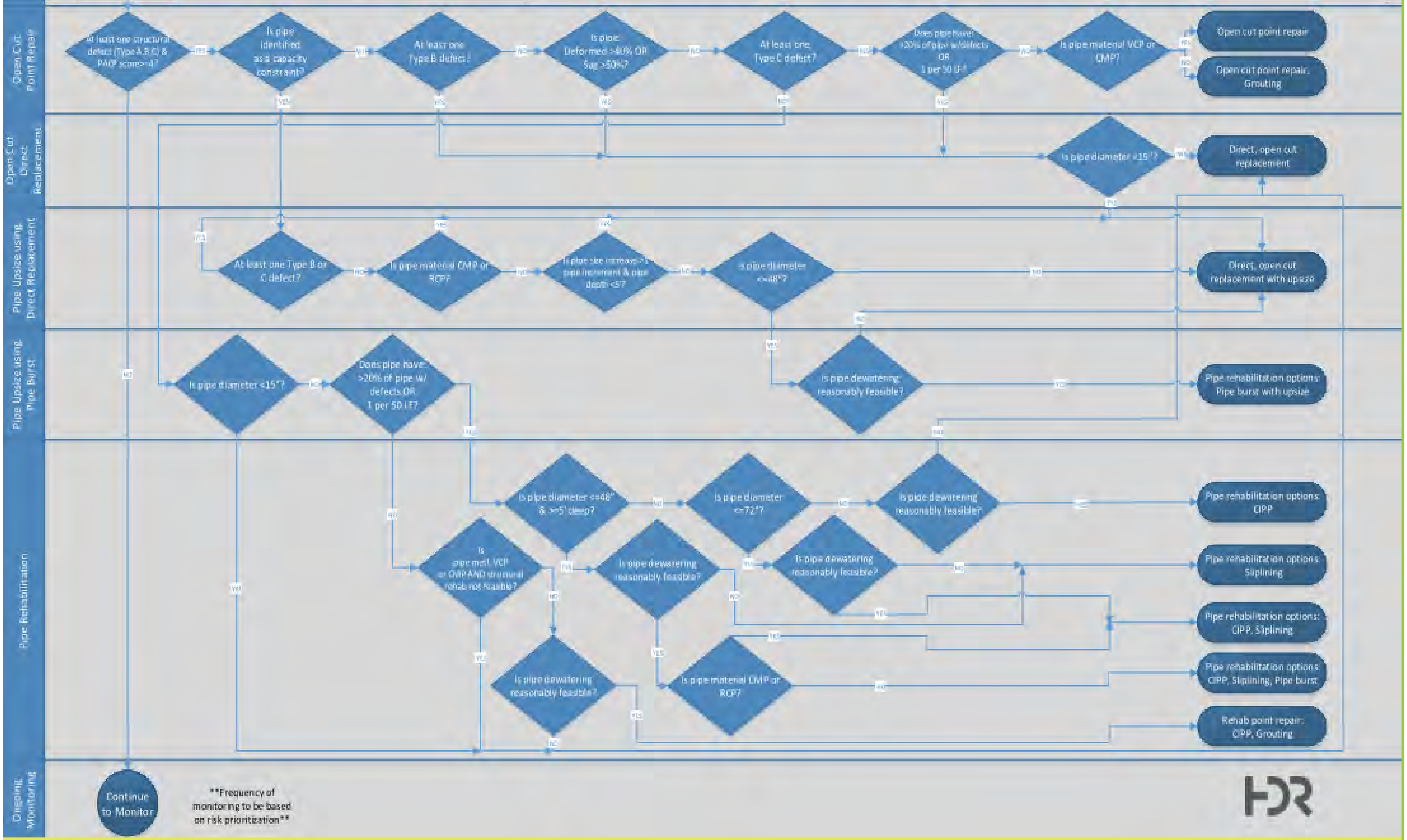
Start - Pipe Inspected

Structural Defect Types

A - Defects typically addressed by rehabilitation
B - Defects typically addressed by replacement
C - Defects typically addressed by point repair or replacement

Logic Guideline

The pipe renewal decision logic is intended to provide a guide for narrowing the appropriate methods based on WPB standards and preferences, as well as appropriate rehabilitation technologies based on best available digital information for pipe segments. The end points in this logic diagram do not remove the responsibilities of the design engineer to validate or supercede the final logic output for a pipe renewal project during the design stage, taking into account all appropriate project details including surface conditions.



Decision Criteria												Methodologies	
PACP Score	Type B Defect	Type C Defect	Type B or C Defect	Capacity Constraint	Deformed >40% or Sag >50%	>20% Pipe w/Defects or at Least One Defect per 50 LF	Material	Pipe Diameter	Pipe size increase is >1 pipe increment and pipe depth <5'	Dewatering Reasonably Feasible	Structual Rehab Method Feasible		
4 or 5	No	Yes	--	No	No	No	Not VCP or CMP	--	--	--	--	Point Repair	Open or Trenchless
4 or 5	No	Yes	--	No	No	No	VCP or CMP	--	--	--	--	Open Cut Point Repair	Open Cut
4 or 5	Yes	--	--	No	--	--	--	≥15"	--	--	--	Direct Replacement	
4 or 5	No	--	--	No	Yes	--	--	≥15"	--	--	--		
4 or 5	No	Yes	--	No	No	Yes	--	≥15"	--	--	--		
4 or 5	No	No	--	No	No	No	--	<15"	--	--	--		
4 or 5	No	No	--	No	No		VCP or CMP	≥15"	--	--	No		
4 or 5	No	No	--	No	No		--	≥15"	--	No	Yes		
4 or 5	No	No	--	No	No	Yes	--	>72"	Yes	No	--		
4 or 5	Yes	--	--	No	--	--	--	<15"	--	--	--	Direct Replacement with Upsize	
4 or 5	No	--	--	No	Yes	--	--	<15"	--	--	--		
4 or 5	No	Yes	--	No	No	Yes	--	<15"	--	--	--		
4 or 5	--	--	Yes	Yes	--	--	--	N/A	--	--	--		
4 or 5	No	No	--	Yes	--	--	RCP or CMP	N/A	--	--	--		
4 or 5	No	No	--	Yes	--	--	Not RCP or CMP	N/A	Yes	--	--		
4 or 5	No	No	--	Yes	--	--	Not RCP or CMP	>48"	No	--	--		
4 or 5	No	No	--	Yes	--	--	Not RCP or CMP	≤48"	No	No	--		
4 or 5	No	No	--	Yes	--	--	Not RCP or CMP	≤48"	No	Yes	--	Pipe Burst	Rehabilitation
4 or 5	No	No	--	No	No	Yes	--	>72"	Yes	Yes	--	CIPP Lining	
4 or 5	No	No	--	No	No	Yes	--	>48" and ≤72"	Yes	No	--	Sliplining	
4 or 5	No	No	--	No	No	Yes	--	>48" and ≤72"	Yes	Yes	--	CIPP Lining or Sliplining	
4 or 5	No	No	--	No	No	Yes	RCP or CMP	≥15" and ≤48"	No	Yes	--		
4 or 5	No	No	--	No	No	Yes	Not RCP or CMP	≥15" and ≤48"	No	Yes	--	CIPP, Sliplining, Pipe Burst	
4 or 5	No	No	--	No	No		--	≥15"	--	Yes	Yes	CIPP Lining, Grouting	
1, 2, or 3	--	--	--	--	--	--	--	--	--	--	--	Monitor	No Construction

Task 4: Condition Assessment, Rehabilitation Methodology Application

Contractor Selection Assistance

Inspect priority 5,000 LF of storm sewer and review submittals

Select rehabilitation approach using decision model
Rehabilitate storm sewers included in pilot project

Incorporate lessons learned from pilot to items developed as part of this assignment

WPB
WEST PALM BEACH

Special Thanks to Daniel Suarez (HDR), Raul Mercado, Liz Perez (Collective Water) and the Stormwater crew at CWPB

WPB

WEST PALM BEACH