# HOW LONG WILL THAT FORCE MAIN LAST?

A Planning Approach for Evaluating, Assessing, and Rehabilitating Ductile Iron Force Mains

ENVIRONMENTAL PARTNERS

— An Apex Company —

# SPEAKERS

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# AGENDA

- Force Main Background
- Common Causes of Force Main Failure
- Force Main Condition Assessment Approach
- Recent Force Main Failure Case Study
- Design Considerations and Planning for New Sewer Force Mains
- Questions

# FORCE MAINS BACKGROUND

Definition | Materials | Failures | Prevention

# SEWER FORCE MAIN PIPE MATERIAL

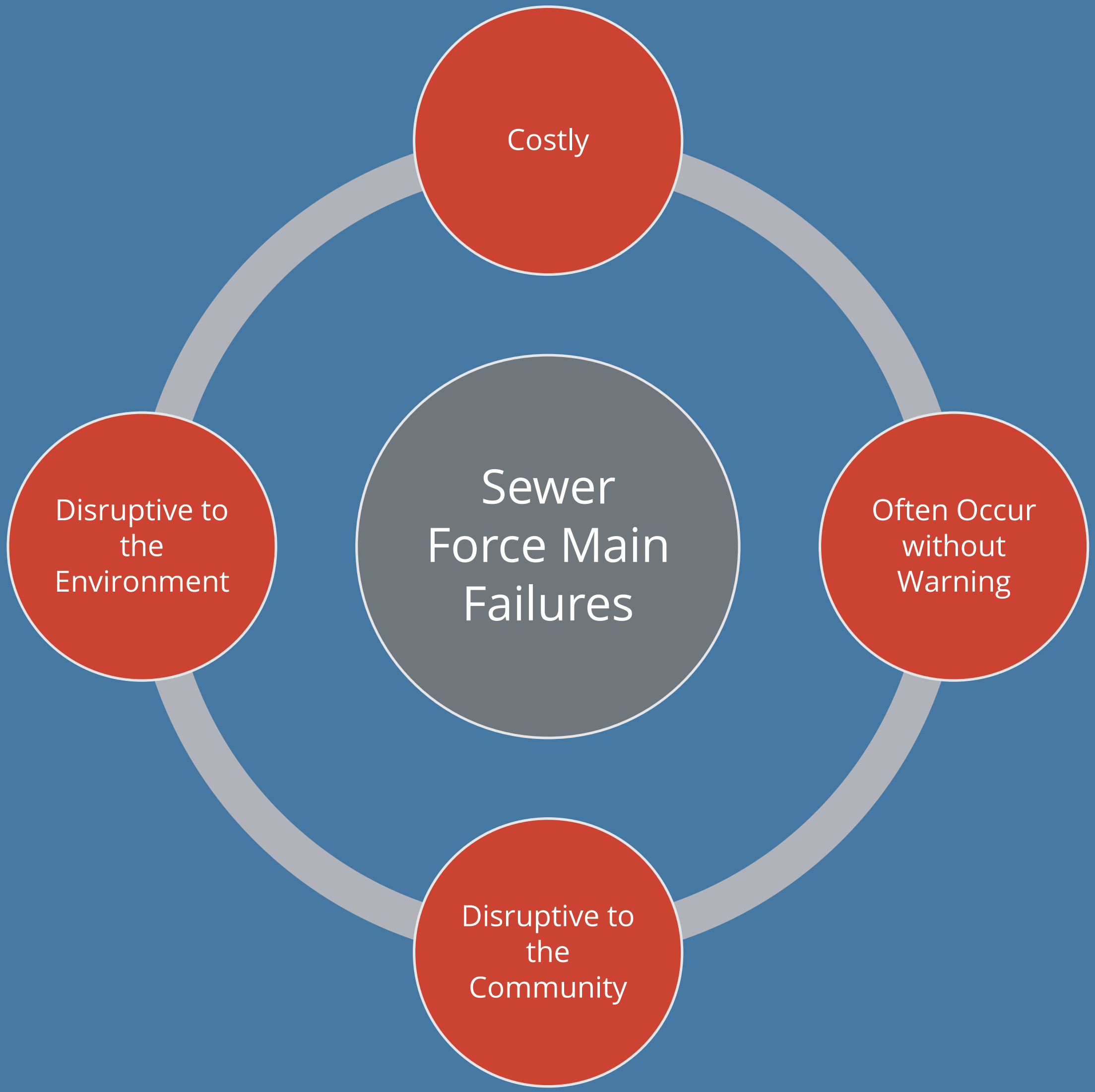
FORCE MAINS BACKGROUND

- Cast Iron (CI)
- Asbestos Cement (AC)
- Ductile Iron (DI)
- Polyethylene (PE)
- Polyvinyl Chloride (PVC)
- High Density Polyethylene (HDPE)
- PE/HDPE-lined DI/CI

HDPE Force Main For Slip-Lining

PVC Force Main Installation

# SEWER FORCE MAIN FAILURES




Emergency Response to FM Break

Emergency Response to FM Break

# PROACTIVE VS. REACTIVE COSTS

- Average emergency repair cost for 20-inch: $1M to $2M
- Structural rehab is approximately 200% of lining rehab
- Condition assessment cost is approximately 2% to 5% of replacement value
- Proactive Costs:
    - Condition assessment; Phased rehab
- Reactive Costs:
    - Emergency response,  rehab and possible fines

* *Figures presented above are based on recent cases and may vary by location*

# SEWER FORCE MAIN FAILURE PREVENTION

FORCE MAINS BACKGROUND

- Sewer force mains constructed between the 1970s – 1990s may be nearing their end of life

- Preventative measures include:

1. Understanding the vulnerability of the force main to common failure causes based on its age, hydraulic characteristics, and material
2. Perform routine maintenance on the force main
3. Consideration for Force Main Condition Assessment
4. Assess vulnerability and risk

Failed Force Main Section

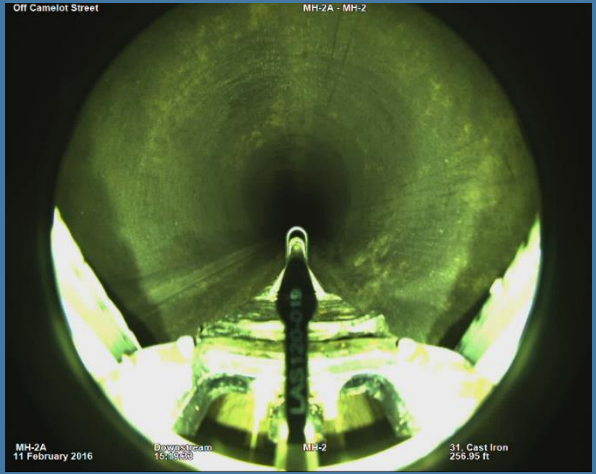
# COMMON CAUSES OF FORCE MAIN FAILURE

Internal Corrosion | External Corrosion |
Workmanship Error | Lack of Routine Maintenance

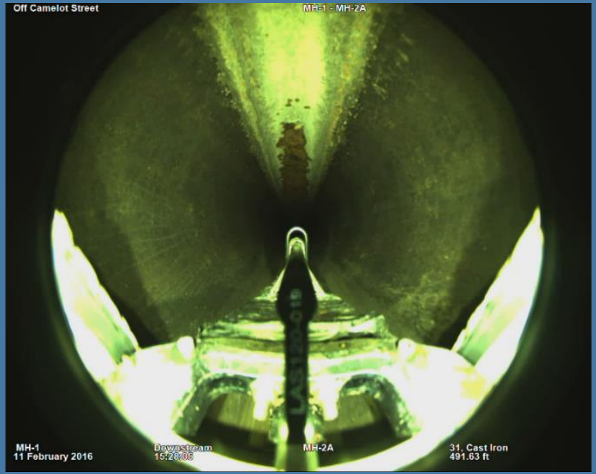
## COMMON CAUSES OF FORCE MAIN FAILURE

# INTERNAL CORROSION

- $H_2S$ Attack
- Microbial Attack
- Calcium Leaching (Conc. Pipe)
- Abrasion/Scour








## WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

Ductile Iron Pipe

Cast Iron Pipe

## COMMON CAUSES OF FORCE MAIN FAILURE

# EXTERNAL CORROSION

- Corrosive Soils
- Loss of Coating
- High Chloride and Sulfate environments
- Damage of ferrous pipe during installation

## WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

Ductile Iron Pipe

Cast Iron Pipe

Asbestos Cement Pipe

## COMMON CAUSES OF FORCE MAIN FAILURE

# STRUCTURAL FAILURE

- Point Load Failure
- Cyclic Fatigue
- Bell Failure
- Pipe deflection to external loads
- Third party damage
- Joint leakage
- Surge and transient pressures

## WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

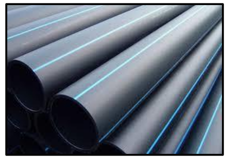
Ductile Iron Pipe

Cast Iron Pipe

Asbestos Cement Pipe

PVC Pipe

Polyethylene Pipe

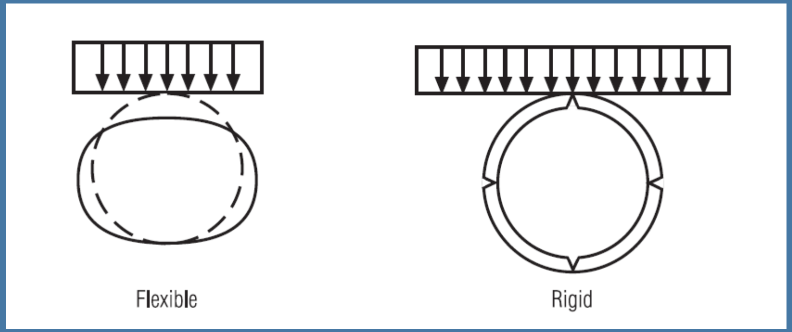


HDPE Pipe

## COMMON CAUSES OF FORCE MAIN FAILURE

# WORKMANSHIP ERROR

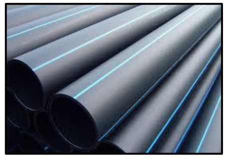
- Joint Fusion (HDPE Pipe)
- Pipe Bedding
- Excessive Push (Plastic Pipe)




## WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

Ductile Iron Pipe

PVC Pipe



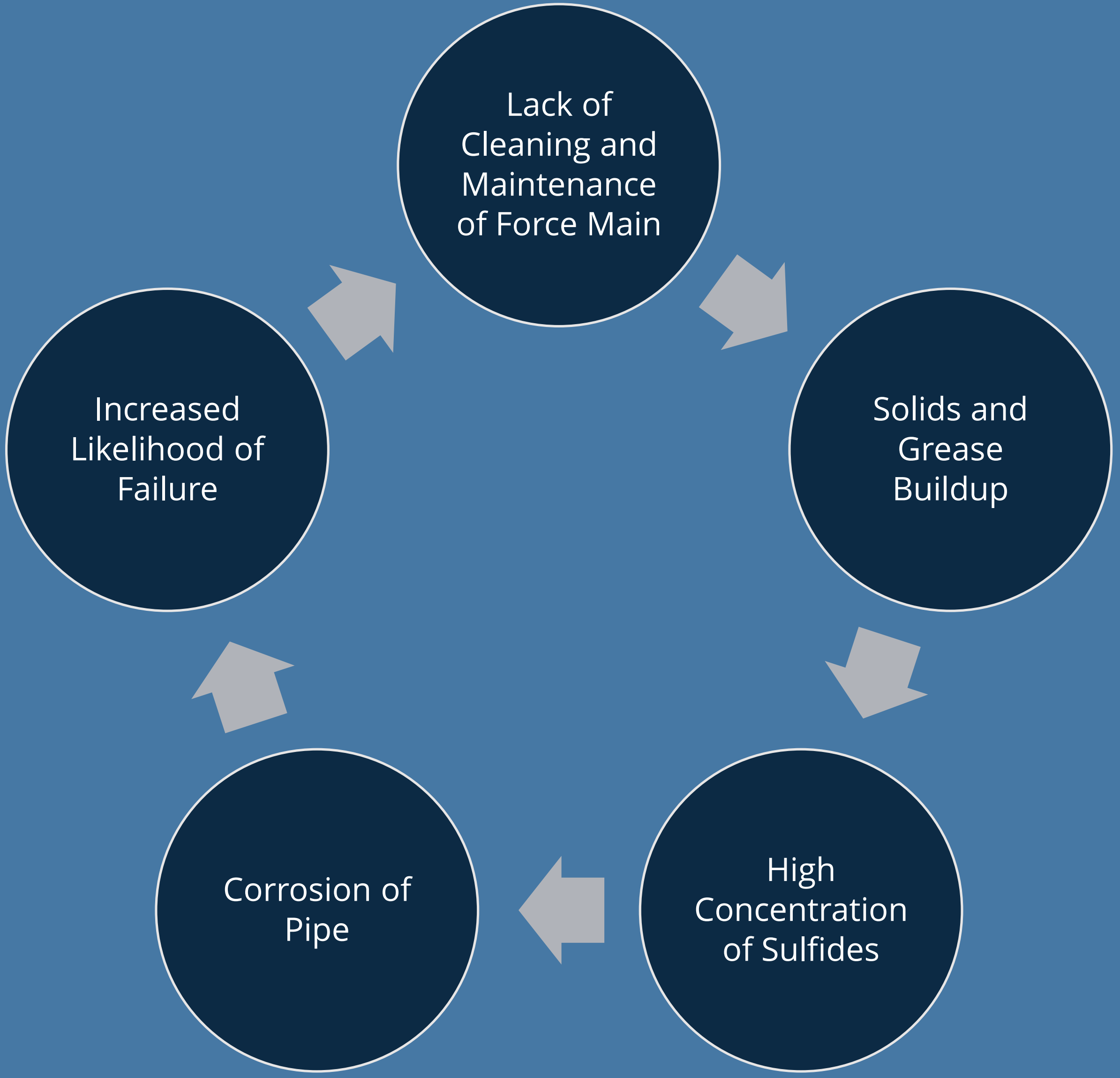
HDPE Pipe

Asbestos Cement Pipe

Cast Iron Pipe

# LACK OF ROUTINE MAINTENANCE

## COMMON CAUSES OF FORCE MAIN FAILURE




## WHICH SEWER FORCE MAINS ARE AT HIGH RISK?

Ductile Iron Pipe

Cast Iron Pipe

Asbestos Cement Pipe

PVC Pipe

Polyethylene Pipe

HDPE Pipe

# FORCE MAIN CONDITION ASSESSMENT APPROACH

Site Reconnaissance | Desktop Study

Assess Extent of Failure and Condition

Assess Rehabilitation Options

Identify Permanent Solution

# PERFORM SITE RECONNAISSANCE

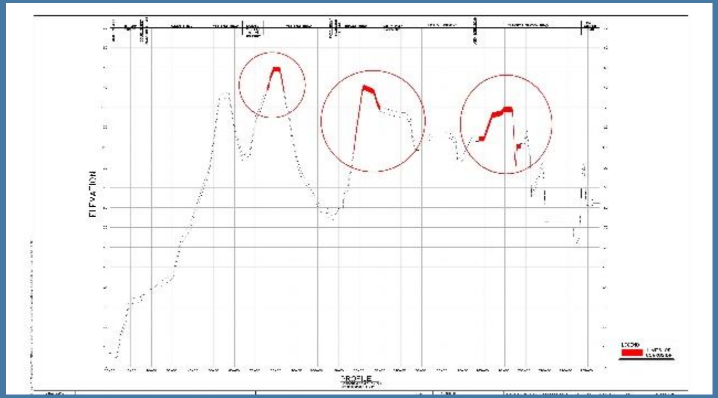
- Conduct Site Visit to relevant areas including Pump Stations and/or Treatment Plants
- Obtain records, operation and maintenance manuals, and pump station data
- Coordinate with Town staff
- Walk the entirety of the force main alignment
    - Gather notes
    - Note any concerns

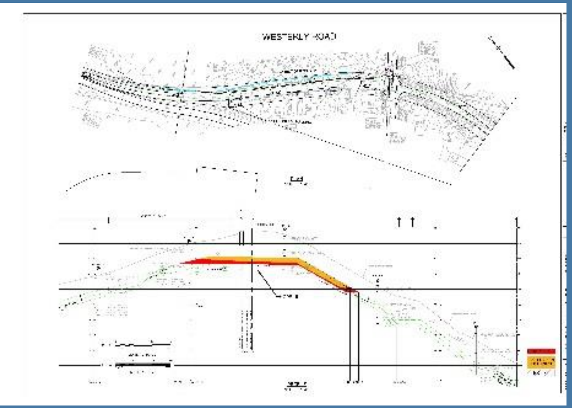
Force Main Alignment Walk Through

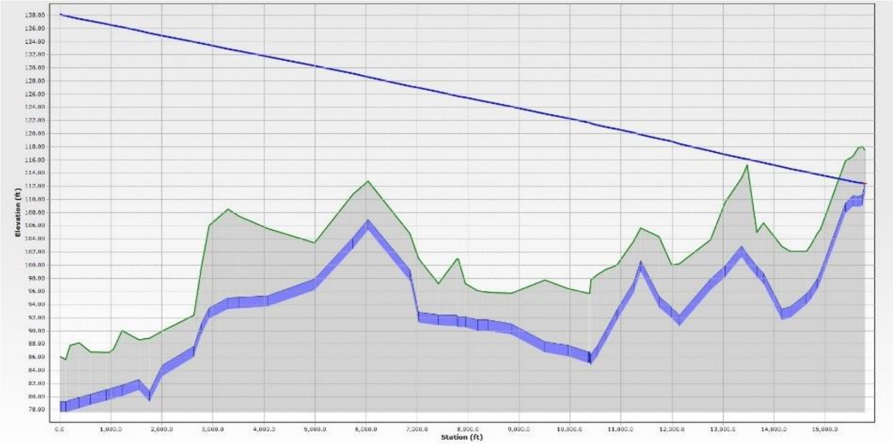
Site Visit to Pump Station

# PERFORM DESKTOP STUDY

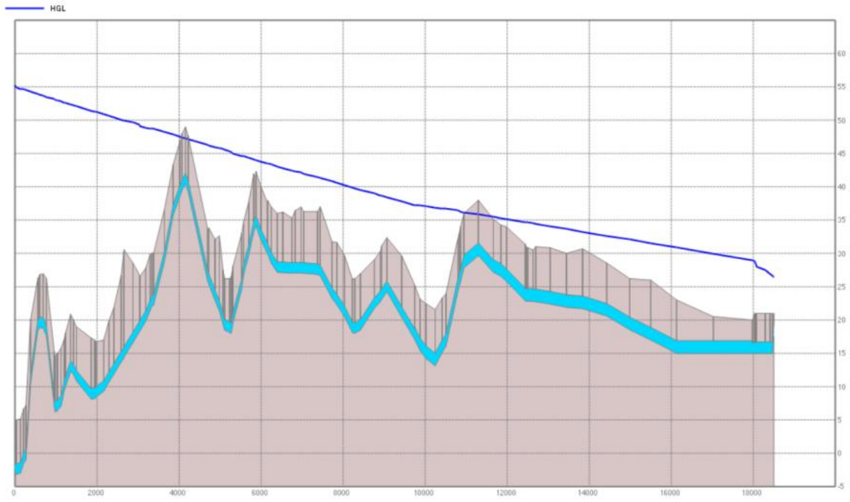
- Gather and Review As-Built/Record Plans
- Gather and Review Flow Data
- Gather and Review Pump Station Data
  - Pump Cycles, Operation Data, Pressures
- Construct Hydraulic Model of Force Main







SewerGEMS Hydraulic FM Model

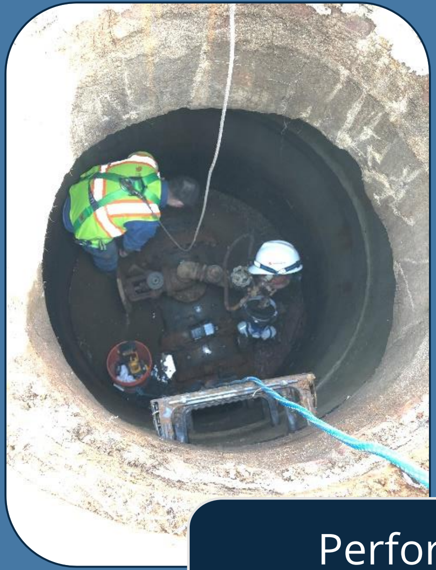


PCSWMM Hydraulic FM Model

# EXTERIOR CONDITION ASSESSMENT

Gain Access to Force Main

- Via Existing Access Manholes (if present)
- Via Excavated Access Pits



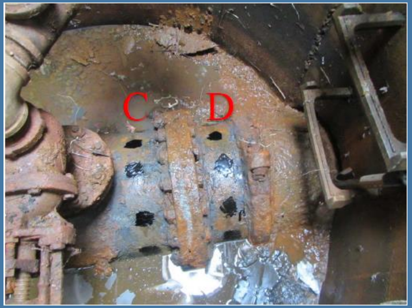
Perform Exterior Condition Assessment

- Multiple Methods Available

# EXTERIOR CONDITION ASSESSMENT

## METHODS AND TECHNOLOGIES

- Ultrasonic Thickness Scan
  - Determine if a loss of wall thickness has occurred in the pipe using a non-destructive, non-invasive method
- Geoprobe/Boring Drilling and Sampling
  - Determine if corrosive soils are present and whether the force main is at risk of external corrosion (AWWA 10-Point System)




POLYETHYLENE ENCASEMENT FOR DUCTILE-IRON PIPE SYSTEMS 13

Table A.1 Soil-test evaluation

| Soil Characteristics Based on Samples Taken Down to Pipe Depth | Points* |
|---|---|
| Resistivity—ohm-cm (based on water-saturated soil box) | |
| <1,500 | 10 |
| ≥1,500–1,800 | 8 |
| >1,800–2,100 | 5 |
| >2,100–2,500 | 2 |
| >2,500–3,000 | 1 |
| >3,000 | 0 |
| pH: | |
| 0–2 | 5 |
| 2–4 | 3 |
| 4–6.5 | 0 |
| 6.5–7.5 | 0† |
| 7.5–8.5 | 0 |
| >8.5 | 3 |
| Redox potential: | |
| > +100 mV | 0 |
| +50 to +100 mV | 3.5 |
| 0 to +50 mV | 4 |
| Negative | 5 |
| Sulfides: | |
| Positive | 3.5 |
| Trace | 2 |
| Negative | 0 |
| Moisture: | |
| Poor drainage, continuously wet | 2 |
| Fair drainage, generally moist | 1 |
| Good drainage, generally dry | 0 |

*Ten points indicates that soil is corrosive to ductile-iron pipe; protection is needed.

†If sulfides are present and low or negative redox potential results are obtained, add three points for this range.

AWWA 10-Point System for Soil Corrosivity

FORCE MAIN CONDITION ASSESSMENT APPROACH

# ASSESS EXTENT OF FAILURE & CONDITION OF FORCE MAIN

## FOR INTERIOR CONDITION ASSESSMENT:

**Bypass Force Main**

- Via Existing Standby FM (if present)
- Via Constructed Bypass

→

**Gain Access to Force Main**

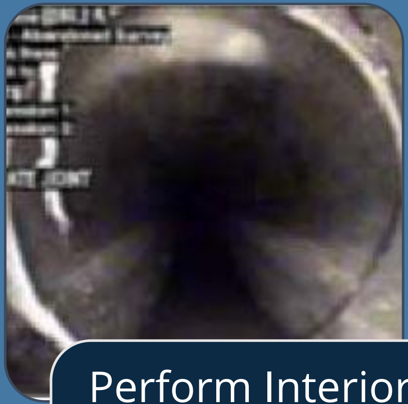
- Via Existing Access Manholes (if present)
- Via Excavated Access Pits

→

**Clean/Jet Force Main**

- Via Existing Access Manholes (if present)
- Via cut and entry into force main

→



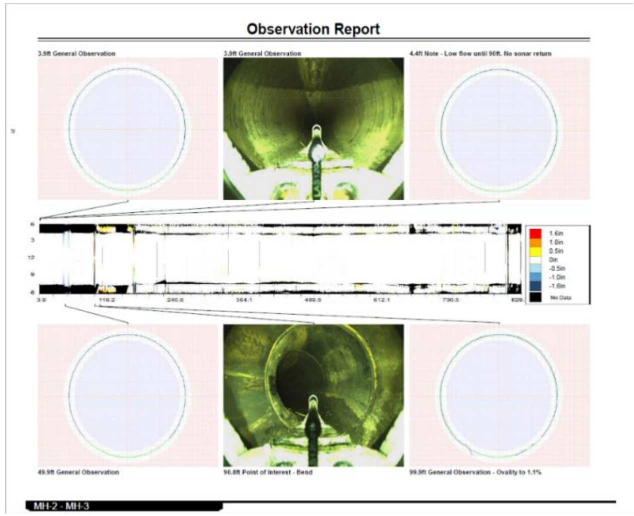
**Perform Interior Condition Assessment**

- Multiple Methods Available

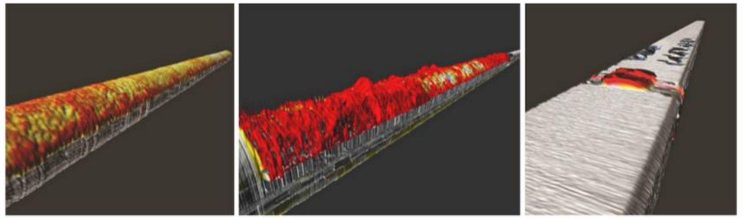
# METHODS & TECHNOLOGIES (PIPE OFFLINE)

## INTERIOR CONDITION ASSESSMENT

- Closed-Circuit Television (CCTV) Inspection
  - Visual of pipeline condition
- Multi-Sensor Condition Assessment
  - 2-D laser scan, sonar data, traditional HD CCTV Inspection to determine levels of corrosion and deformation
  - Helps determine if CIPP or Sliplining is a viable option
  - Only functions above water level
  - Can be influenced by buildup on pipe or tuberculation




Sample Multi-Sensor Scan Report

COURTESY OF REDZONE ROBOTICS

# DEVELOPMENT OF EMERGENCY ACTION PLAN

- Risks and Vulnerabilities
- Emergency Notification
- Vendor Contact Information
- Equipment and Materials on standby
- Plan for Funding

# EVALUATE ALTERNATIVE REHABILITATION OPTIONS

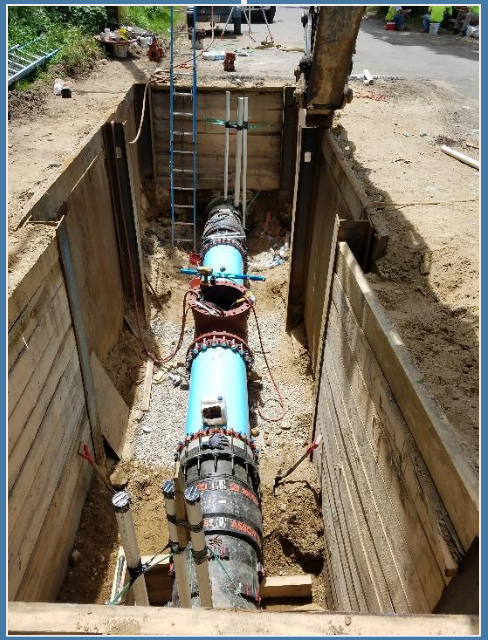
FORCE MAIN CONDITION ASSESSMENT APPROACH

Repair?


Replace?

Re-Use?

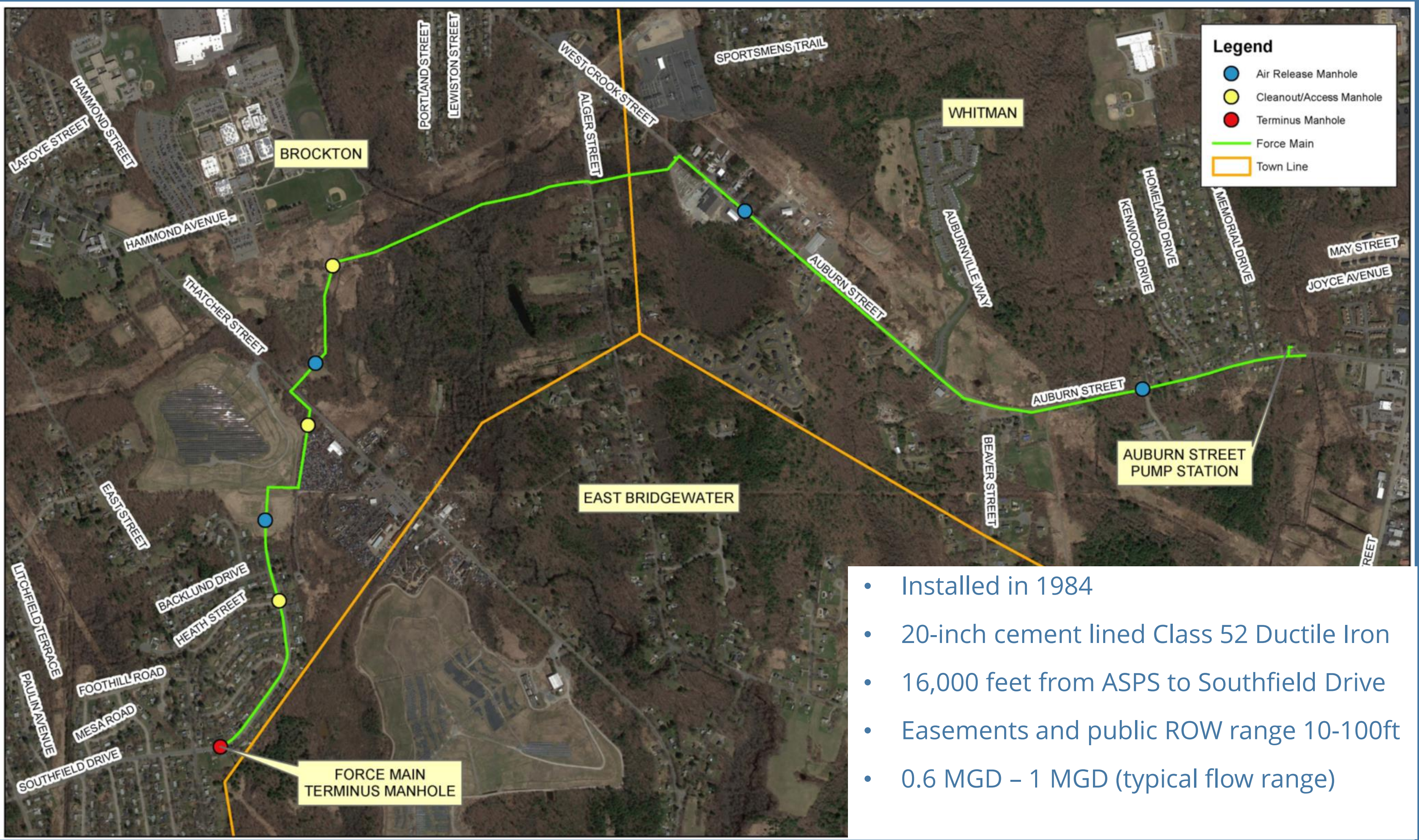
Combination?



# RECENT FORCE MAIN FAILURE CASE STUDY

Town of Whitman, Massachusetts

# 20-INCH SEWER FORCE MAIN BACKGROUND

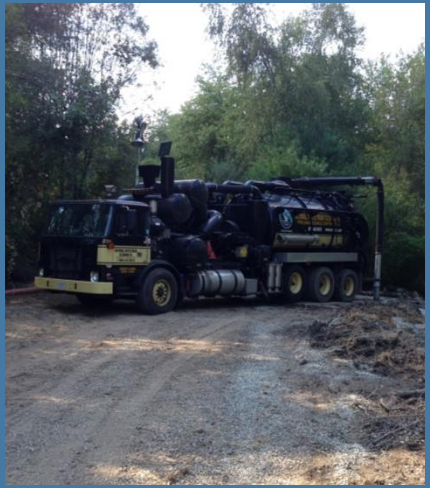



- Installed in 1984
- 20-inch cement lined Class 52 Ductile Iron
- 16,000 feet from ASPS to Southfield Drive
- Easements and public ROW range 10-100ft
- 0.6 MGD – 1 MGD (typical flow range)

# 20-INCH SEWER FORCE MAIN FAILURES

- Location:  Alger Street
- Dates: 9/16 and 10/17
- Emergency Response
  - Tanker truck brigade from Auburn Street Pump Station to Brockton AWRF
- Approximate Cost of Emergency Response: $500,000 Each Occurrence






# PIPELINE ASSESSMENT OBJECTIVES

1. Provide uninterrupted access to the force main (30 years of overgrown easements)
2. Review hydraulic performance
3. Complete field sampling and testing
4. Determine the probable cause of failure
5. Identify pipe repair/replacement alternatives
6. Make a final recommendation

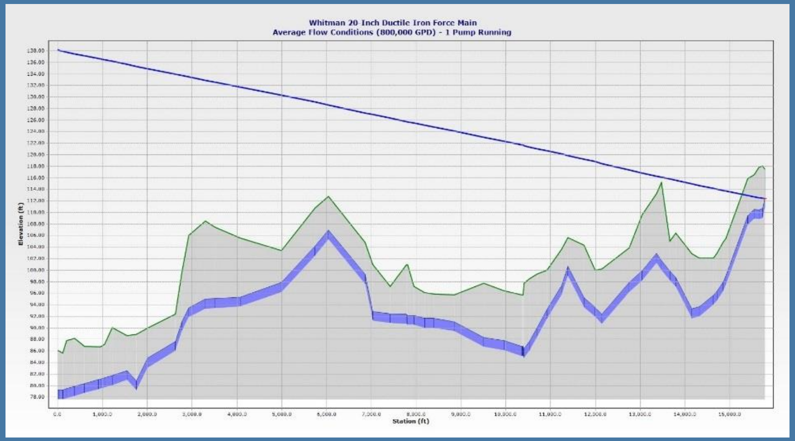
# FORCE MAIN ASSESSMENT APPROACH

Geoprobe Drilling

Laboratory Soil Testing

Ultrasonic Scan


Hydraulic Analysis



# LABORATORY SOIL TESTING

- Testing Parameters
  - Soil Acidity
  - Soil Chloride Content
  - Soil Conductivity
  - Soil pH
  - Soil Moisture Content
  - Redox Potential
  - Soil Sulfate Content

Overall Corrosivity-Rated
(AWWA "10-Point System")



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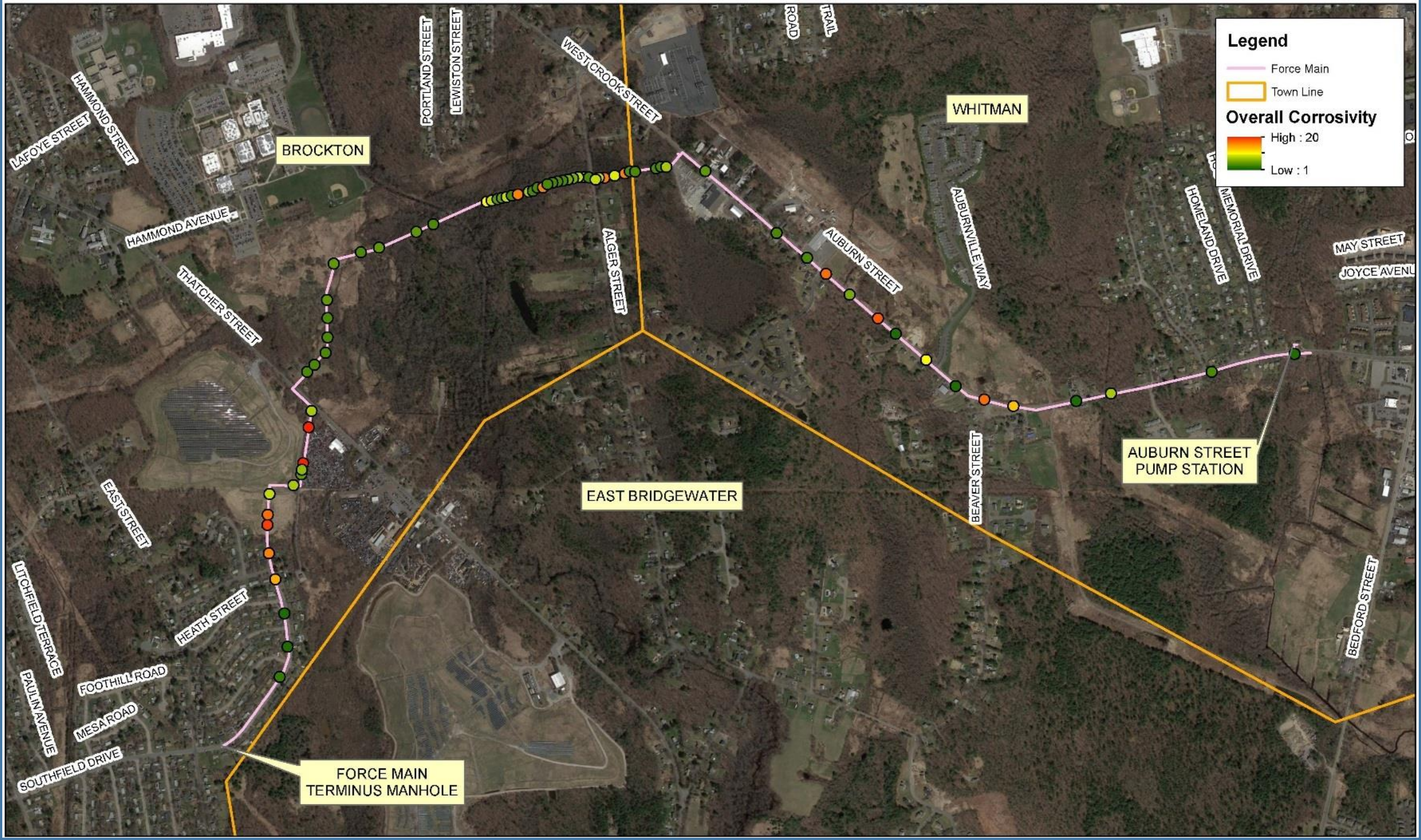
*Ten points indicates that soil is corrosive to ductile-iron pipe; protection is needed.

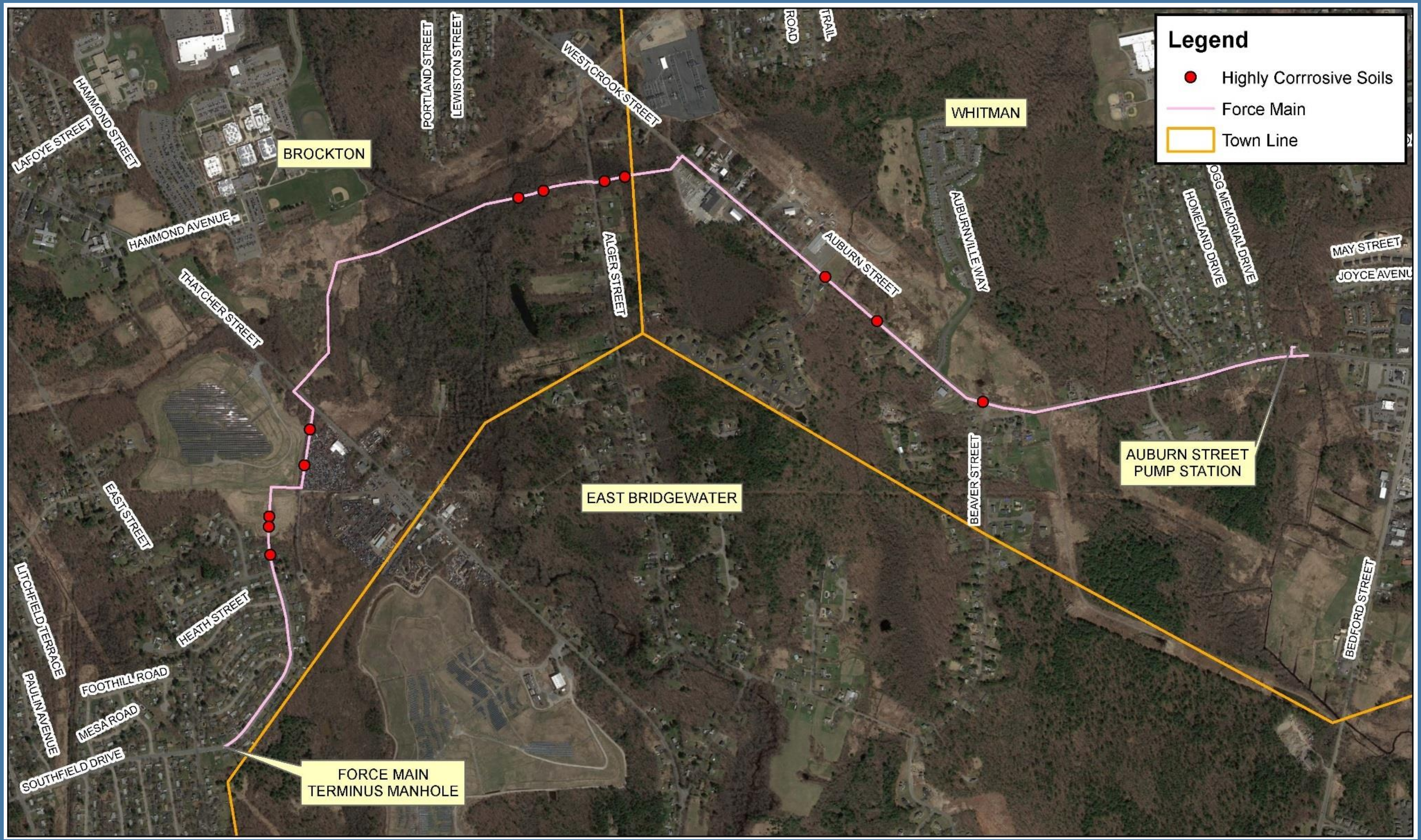
†If sulfides are present and low or negative redox potential results are obtained, add three points for this range.

# FORCE MAIN ASSESSMENT FINDINGS

- 12/70 tested soil samples: highly corrosive to ductile iron pipe (AWWA “10-point system”)



# HIGHLY CORROSIVE SOILS

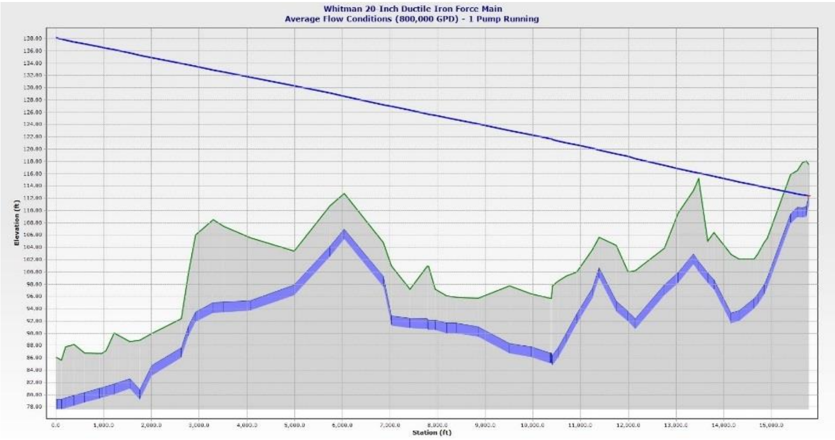


# ULTRASONIC TESTING

- No observed lower UT measurements at crown of pipe
- Force main is constantly flowing full
  - H2S attack is unlikely
- Probable cause of failure - External corrosion via highly acidic localized soils off Alger Street


# HYDRAULIC ANALYSIS

- Force main is constantly flowing full under pressurized conditions
  - Open channel flow is not present
- Under typical conditions, velocity in the pipeline is acceptable: 3.0 feet per second
- Force main and ASPS pumps are appropriately sized to handle current pump station flows



# ALTERNATIVES ANALYSIS

- Existing 20-inch Sewer Force Main is:
  - At risk of failure due to highly corrosive soils along its alignment
  - Nearing end of useful life based on acceptable industry/design standards
- Repair/Replacement Alternatives:

| Alt. | Description |
|---|---|
| 1 | New HDPE/PVC Force Main & Abandon Existing Force Main |
| 2A | New HDPE/PVC Force Main & CIPP Line Existing Force Main (Standby) |
| 2B | Alternative 2A plus Cross-Connection |
| 3 | Partial Replacement and Abandonment of Existing Force Main |

Alternative 1 Selected: OPCC $14.5 Million

# DESIGN CONSIDERATIONS & PLANNING FOR NEW SEWER FORCE MAINS

# DESIGN CONSIDERATIONS & PLANNING

1. Alignment Selection
2. Integration with Pump Station Design
3. Pipe Material Selection
4. Pipe Sizing
5. Construction Considerations
6. Special Considerations
7. Permitting Considerations
8. Cost and Funding Considerations

# Q&A

# THANK YOU

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