Utilizing Remaining Useful Life for Asset Management of Critical Wastewater Assets

Jessica Brown, P.E. and Mazen Kawasmi, P.E.
Agenda

• Acknowledgements
• Background and Drivers
• Interceptor Condition Assessment Program
  – Program Management
  – Inspection
  – Cleaning
• Example of Findings
• Remaining Useful Life (RUL) and Condition Scores
• Benefits and Future Actions of ICAP
Acknowledgements

• **Fort Worth Water Department**
  – Darrell Gadberry
  – Frank Crumb
  – Field Operations
  – Engineering

• **White Rock Consultants**
  – Rod Thornhill

• **ACE Pipe Cleaning**
  – Bruce Jameson

• **IT Pipes**
  – Cori Criss

• **Freese and Nichols, Inc.**
  – Thomas Haster
  – Steven Rhodes
• 2000 – 2010 growth increased system footage by 33%.

• However 46% of the wastewater system is still over 40 years old.

• Recent growth places increased burden on aging infrastructure

• Fort Worth provides Wastewater service to over 1,000,000 people, including 24 wastewater wholesale customers.

• City of Fort Worth over 3,000 miles of sewer assets
City of Fort Worth was allocating a significant amount of resources to clean wastewater mains that did not clean.

From ground level, the manhole appeared to have sediment but the actual line did not.

City of Fort Worth was conducting destructive testing of wastewater mains to measure corrosion.

With this approach, the City could not confirm the severity of corrosion throughout the interceptor.

Structural rating and condition scores were subjective.

Scores are based off of low resolution CCTV with no actual field measurements.

City of Fort Worth needed to extend the life wastewater mains.

With limited rehab budgets, the City needed to prioritize rehab work, spending it on the lines nearest failure.
Interceptor Condition Assessment Program (ICAP)

- Estimate the remaining useful life of critical sewer infrastructure
- Utilize latest technology of 3D laser, Sonar, and HDTV to measure level of corrosion/structural performance (Condition) and debris (Capacity Restrictions)
- Provide critical data to assess rehabilitation and CIP needs
- Provide recommendations for near term and long term capital improvements
Interceptor Condition Assessment Program (ICAP)

**Inspection and Comprehensive Pipe Condition Report**

*Contract 1*
- HDTV, Sonar, and Laser Inspection
- Comprehensive Pipe Condition Report

**Cleaning**

*Contract 2*
- “Post” Contract 1 Cleaning
  - or
- “Pre” Contract 1 Cleaning

**Program Management**
- Pipe Wall Thickness Research
- Risk Based Assessment (RBA)
- Remaining Useful Life (RUL)
- Wall Loss Due to Corrosion
- GIS Update of Major Interceptors
- CIP Impact Review
- Condition Assessment Reports

**Prioritized WWMP CIP Projects with ICAP Results**
Program Management

- Program Management
- Pipe Wall Research (material, steel location, thickness)
- QC of Inspection and Post Processed Data
- Condition Assessment
- Estimate Remaining Useful Life
- Enhance GIS
- Emergency Rehabilitation or Replacement Authorization
2.2 REINFORCED CONCRETE SEWER PIPE: Pipe for sewer construction 27 inches in diameter and larger shall be reinforced concrete pipe conforming to the current specifications for Extra-Strength Reinforced Concrete Culvert, ASTM Designation C76, Table II, with the following additional specific requirements:

(a) All pipe shall be machine made.
(b) Pipe shall have a minimum wall thickness of one-twelfth (1/12) the nominal pipe diameter plus one (1") inch.
(c) Minimum compressive strength of concrete shall be 4500 pounds per square inch at 28 days.
(d) Concrete shall have a slump not to exceed two (2") inches.
(e) Maximum permissible absorption shall be 6-1/2 per cent.
(f) Length of pipe joints shall not be less than six (6) feet.
(g) All pipe shall have a single cage of elliptical reinforcement of not less than the amounts tabulated below:

<table>
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<tr>
<th>INTERNAL PIPE DIAM.</th>
<th>MIN. WALL THICKNESS</th>
<th>MINIMUM REINFORCEMENT SQ.IN. PER LINE. FT. OF PIPE</th>
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Example of data needed for ICAP: Pipe Wall Thickness
ICAP - Inspection (HDTV, 3D Laser and Sonar)

• Contract structure provides for 190,000 LF/year of inspection
• FlyEye technology developed by Cleanflow Systems used for Laser/Sonar/HD Video inspection
• Processed data delivered to Fort Worth using IT Pipes CCTV software.
ICAP Technology: Inspect IT

- Customizable user interface
- Quick access to previous inspections allows the “life” of an asset to be viewed
- Integrates HDTV, 3D Laser and Sonar data, Hydraulic model results into one software package
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**Flow Model**
- Dry Avg Depth (in.): 25.4
- Dry Max Depth (in.): 30
- Wet Avg Depth (in.): 59
- Wet Max Depth (in.): 129.6
- Dry Avg Velocity (ft/s): 3.1
- Dry Max Velocity (ft/s): 3.3
- Wet Avg Velocity (ft/s): 3.3
- Wet Max Velocity (ft/s): 4.5

**Pipe Wall**
- Pipe Wall Thickness: 10
- Steel Row 1 (in.): 2.5
- Steel Row 2 (in.): 8.75
- Wall Spec: thickwall
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</table>

**Remarks:**

- **LSO:** 1. Water on lens at 11 o'clock - Throughout line
- **LSC:** 2. General Observation - Corrosion to 2.5"
- **LSC:** 3. General Observation - Corrosion to 2.5"
- **LSC:** 4. General Observation - Corrosion to 3.2"
- **LSO:** 5. Point of Interest - Splashing blocks laser briefly
- **LSC:** 6. Maximum Corrosion - to 4.9"
- **LSO:** 7. Point of Interest - Intruding seal
- **LSO:** 8. Point of Interest - Intruding seal
- **LSC:** 9. Point of Interest - Rebar evident
- **LSC:** 10. General Observation - Corrosion to 1.8"
- **LSC:** 11. Debris to 2.7"
- **LSC:** 12. General Observation - Corrosion to 1.8"
- **LSC:** 13. General Observation - Corrosion to 2.0"
ICAP Technology: FlyEye Laser

- 3D Laser provides a high definition profile of the interior pipe wall above the water surface.
- Sonar provides a high definition profile of the interior pipe wall below water surface.
- HD TV provides HD video of the interior of the pipe
ICAP – Inspection, Year 1  (HDTV, 3D Laser and Sonar)

- Lower Big Fossil (M402A)
  Work Order #1
- Little Fossil (M292)
  Work Order #2
- Village Creek
  (M244,M503, M257)
  Work Order #3
- Lower Sycamore Creek
  (M164R,M245,M53R,M275)
  Work Order #4
- 190,000 LF +/-
ICAP – Pipe Cleaning

- Large diameter cleaning is expensive.
- ICAP only requires cleaning of segments confirmed by inspection.
- When cleaning is complete, sonar is used to verify cleaning.
ICAP – Cleaning, Year 1

- Inspection and Comprehensive Condition Reports show 40% of lines selected needed cleaning
- 75,102 LF selected for cleaning
- 100% of required cleaning completed
- 63% of Cleaning budget expended

Lines Cleaned

Lines Inspected
ICAP Technology: FlyEye Laser

- Laser measures the distance from a center point to the inside pipe wall above the water level.
- Laser data identifies:
  - Corrosion in concrete
  - Deflection in non-rigid pipes
  - Deformation in rigid pipes
  - Holes, gaskets, offset joints
  - Protruding steel reinforcement
  - Changes in corrosion amounts or structural defects since any previous laser inspection
Example of Findings: Corrosion

- Outer Wall
- Estimated Original Inner Wall
- Measured Inner Wall (Purple Line)

1.25” of Pipe Wall Remaining
Example of Findings: Corrosion

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<th>Steel 2 (in.)</th>
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1.25” of Pipe Wall Remaining
Example of Findings: Debris

- Observed Maximum Debris: 17.4 inches
- Volume of Debris: 63 cubic yards
Example of Findings: Ovality

Observed Maximum Ovality: 21.2%

Vylon PVC Pipe Spec: ASTM F794
- Short Term: 5% Deflection
- Long Term: 7-12% Deflection
Example of Findings: Hydraulic Model Comparison

- Sonar measurement of 22 inches was recorded
- Modeled average water level was 23 inches

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<td>Average Water Level</td>
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<td>Debris Volume</td>
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## Remaining Useful Life

**City of Fort Worth**

### Remaining Useful Life Scoring System

Reinforced and Prestressed Concrete Pipe

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<td>72&quot; AWWA E-301 Class 150</td>
<td>0.5% 0.5% 0.7% 1.0% 1.35 1.50 1.7% 2.0% 2.25 2.50 2.7% 3.0% 3.25 3.50 3.7% 4.0% 4.25 4.50 4.7% 5.0% 5.25 5.50 5.7% 6.0% 6.25</td>
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<td>48&quot; Thickwall</td>
<td>0.5% 0.5% 0.7% 1.0% 1.35 1.50 1.7% 2.0% 2.25 2.50 2.7% 3.0% 3.25 3.50 3.7% 4.0% 4.25 4.50 4.7% 5.0% 5.25 5.50 5.7% 6.0% 6.25 6.50 6.75</td>
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<td>60&quot; Thickwall</td>
<td>0.5% 0.5% 0.7% 1.0% 1.35 1.50 1.7% 2.0% 2.25 2.50 2.7% 3.0% 3.25 3.50 3.7% 4.0% 4.25 4.50 4.7% 5.0% 5.25 5.50 5.7% 6.0% 6.25 6.50 6.75</td>
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<tr>
<td>54&quot; Thickwall</td>
<td>0.5% 0.5% 0.7% 1.0% 1.35 1.50 1.7% 2.0% 2.25 2.50 2.7% 3.0% 3.25 3.50 3.7% 4.0% 4.25 4.50 4.7% 5.0% 5.25 5.50 5.7% 6.0% 6.25 6.50 6.75 7.0% 7.25 7.50 7.75 8.0% 8.25 8.50 8.75 9.0% 9.25 9.50 9.75</td>
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**Rating System**

- **Rating = 1 (36 to 50 years of RUL)**
- **Rating = 2 (21 to 35 years of RUL)**
- **Rating = 3 (11 to 20 years of RUL)**
- **Rating = 4 (3 to 10 years of RUL)**
- **Rating = 5 (0 to 2 years of RUL)**
Remaining Useful Life

- Remaining Useful Life developed for each concrete pipe wall specification.
- Condition Score for concrete pipes based on location of steel reinforcement cages.
- Developed in AutoCAD to maintain a 1:1 scale.
Remaining Useful Life:
Example of Matrix Criteria

• Rating 1: 0 to 0.5 inch from inner pipe wall.
• Rating 2: 0.5 to face of first row of steel.
• Rating 3 (Yellow): Face of 1\textsuperscript{st} row of steel to half distance to 2\textsuperscript{nd} row of steel.
• Rating 4: Half the distance to 2\textsuperscript{nd} row of steel to face of 2\textsuperscript{nd} row of steel.
• Rating 5: Face of 2\textsuperscript{nd} row of steel to outer pipe wall surface.
Condition Scores, Year 1

Pipe Length (ft)

- Rating = 1 (36 to 50 years of RUL)
- Rating = 2 (21 to 35 years of RUL)
- Rating = 3 (11 to 20 years of RUL)
- Rating = 4 (3 to 10 years of RUL)
- Rating = 5 (0 to 2 years of RUL)

Represents 23,561 out of 186,161 Linear Feet in need of Near Term Rehabilitation or Replacement.
Condition Scores by Construction Date

Date of Construction
- 1950's
- 1960's
- 1970's
- 1980's
- 1990's
- 2000's
- 2010's

Pipe Length (ft)

Rating = 1 (36 to 50 years of RUL)
Rating = 2 (21 to 35 years of RUL)
Rating = 3 (11 to 20 years of RUL)
Rating = 4 (3 to 10 years of RUL)
Rating = 5 (0 to 2 years of RUL)
Condition Scores, Year 1

Condition Scores by Concrete Wall Spec

Pipe length (ft)

Concrete Wall Spec
- Class III Wall B
- Class III Wall B with Wall A Steel
- Modified Class II
- Thickwall
- Lined Concrete
- AWWA C - 302 Extra Thick
- AWWA E-301 Class 150
- Class IV Wall C

Rating = 1 (36 to 50 years of RUL)
Rating = 2 (21 to 35 years of RUL)
Rating = 3 (11 to 20 years of RUL)
Rating = 4 (3 to 10 years of RUL)
Rating = 5 (0 to 2 years of RUL)
Condition Scores, Year 1

- Concrete: 69%
- Ductile Iron: 14%
- PVC: 17%

### Lower Sycamore Creek Condition Scores

- **Condition Score 1**: 25%, 12,000 ft
- **Condition Score 2**: 16%, 10,000 ft
- **Condition Score 3**: 47%, 18,000 ft
- **Condition Score 4**: 10%, 6,000 ft
- **Condition Score 5**: 1%, 3,000 ft

% = percent of total work order length
Benefits and Future Actions of ICAP

**Managing Critical Wastewater Assets**
- Establish baseline condition of existing interceptors
- Identify emergency repairs before total failure occurs
- Extend RUL of existing interceptors
- Restore Interceptor to original design capacity

**Odor Control**
- Reduce or eliminate cause/source of H2S
- Reduce or eliminate collection system odor control stations/chemicals

**Prioritizing Rehabilitation CIP**
- Improve Hydraulic Model Accuracy and CIP Priorities
- Develop Prioritized Rehabilitation Projects
Fort Worth Launches Unique, Aggressive Sewer Inspection/Cleaning Program

The city of Fort Worth, TX, sanitary sewer system serves 22 communities with a total population of more than 900,000. It contains approximately 3,011 miles of underground pipe infrastructure that collects and carries an average of 168.5 million gallons a day to the Village Creek Water Reclamation Facility.

As with all cities, maintaining sewer infrastructure is a never-ending and costly task. One key to keep piping in good condition is acquiring and analyzing accurate data about its condition in order to anticipate potential problems and address them in a timely manner.

To accomplish this, Fort Worth is committed to a multiyear inspection program for all sanitary sewer lines of 24 inches in diameter and larger. However, Fort Worth’s approach to inspections is different than typical programs which clean sections of pipe, then conduct inspections with closed-circuit television (CCTV) cameras.

The city has reversed the process, inspecting pipes before cleaning. Fort Worth’s inspection process for large-diameter sewer pipes is more comprehensive than simply using CCTV video: instead, it employs high-definition video, laser profiling and sonar, then cleans only segments needing attention.

To implement these assessment technologies, the Fort Worth Water Department (FWWD) developed and initiated the Interceptor Condition Assessment Program (ICAP). Under the program, the city has committed to a multiyear plan to inspect all of the sanitary sewers that are 24-inches in diameter or larger.

**Inspection**

Darrell Godberry, FWWD field operations division regulatory and environmental coordinator, said conventional CCTV inspections can identify defects such as cracks, breaks and roots, but does not provide a means of evaluating the severity of wall loss due to corrosion. To do that, the only option has been to excavate, take core samples, repair the pipe and restore the site, a costly and time-consuming process.

“The recent introduction of 3-D laser technology for large-diameter sewers demonstrated the ability to solve this problem,” he explained. “Coupled with high definition television (HDTV) inspection and gathering sonar data, the FWWD recognized ways to overcome the inefficiencies associated with the conventional approach used throughout the industry for assessing large-diameter sewer pipes.”

FWWD’s inspection contract uses the Fly-Eye HD Profiler System developed by Cleanflow Systems in New Zealand and distributed in the United States as the Fly-Eye Pipeline Inspection System by CUES. The inspection technologies used are complementary to traditional CCTV inspections and improve the quality of the data FWWD is able to collect and analyze. These tools allow the city to make informed decisions and prioritize maintenance efforts more efficiently.

**Q & A**

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