Wastewater Collection System Condition Assessment: Putting it all Together
Background

• Regional wholesale provider to 24 communities
• 5 counties
• 133 miles of gravity mains
• 86 miles of force mains
• 25 lift stations
• 14 wastewater treatment plants
The Reason

- CMOM commitment
- SSOI commitment
Corrosion: <10%

Corrosion: >80%
Age is not an accurate indicator of a pipe’s condition.

Rating = 1 (36-50 yrs RUL)
Rating = 2 (21-35 yrs RUL)
Rating = 3 (11-20 yrs RUL)
Rating = 4 (3-10 yrs RUL)
Rating = 5 (0-2 yrs RUL)
The Solution: Multi Sensor Inspection
Gravity
Main
Inspection
Laser/LiDAR
Inspect Unsubmerged Pipe Surface:
• Quantify Corrosion and Wall Loss in Concrete Pipes
• Quantify Holes, Fractures, Deformation of Rigid Pipes
• Measure Deflection, Deformation or Tuberculation

HD CCTV
Video Unsubmerged Pipe Surface:
• Identify Defects, Joint Locations, Pipe and Lining Materials
• Correlate Observed Conditions with Laser/LiDAR Data

Sonar
Inspect Submerged Pipe Surface:
• Measure Flow Depth
• Measure Height and Estimate Debris Volume
• Detect Deformation due to Deflection or Breaks

CUES
RedZone Robotics
HD Video Inspection
Sonar Inspection
<table>
<thead>
<tr>
<th>Manufacturer &amp; Model</th>
<th>Technology</th>
<th>Minimum Diameter</th>
<th>HD CCTV 1080p</th>
<th>Sonar</th>
<th>Live Feed</th>
<th>Average Daily Deployment</th>
<th>PACP Certified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cues SolidFX</td>
<td>LiDAR</td>
<td>18-inch</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>5,000 ft</td>
<td>X</td>
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<tr>
<td>RedZone HDProfiler</td>
<td>Laser</td>
<td>15-inch</td>
<td>X</td>
<td>X</td>
<td></td>
<td>5,000 ft</td>
<td>X</td>
</tr>
</tbody>
</table>
Gravity Main Inspection

Laser/LiDAR

- Video Manhole:
  - Accurate Point Cloud Measurements

- Identify Defects, Pipeline Locations and Inverts, Manholes and Lining Materials

- No Manned Entry Required
- MACP Assessments

CUES

RapidView IBAK North America
<table>
<thead>
<tr>
<th>Manufacturer &amp; Technology</th>
<th>One Pass Inspection</th>
<th>Inspection Time &lt; 3 min</th>
<th>Deployment Depth</th>
<th>MACP Certified</th>
<th>Average Daily Deployment</th>
<th>Viewer</th>
</tr>
</thead>
<tbody>
<tr>
<td>RapidView IBAK PANORAMO® SI 3D Optical Manhole Scanner</td>
<td>X</td>
<td>X</td>
<td>100 ft</td>
<td>X</td>
<td>35 - 50</td>
<td>X</td>
</tr>
<tr>
<td>Cues SPiDER Scanner</td>
<td>X</td>
<td>X</td>
<td>100 ft</td>
<td>X</td>
<td>35 - 50</td>
<td>X</td>
</tr>
<tr>
<td>Pole Camera</td>
<td>X</td>
<td></td>
<td>~20 ft</td>
<td>X</td>
<td>~15</td>
<td></td>
</tr>
</tbody>
</table>

**IBAK PANORAMO® Scanner**

**Cues SPiDER Scanner**
Develop Remaining Useful Life

Developed for each pipe specification

Condition score for concrete pipes based on location of steel reinforcement cage

Condition score for flexible and rigid pipes based on deflection and ovality

Condition score for VCP pipes based on HD CCTV and defects

6.2.2 Reinforcement:

6.2.2.1 Placement—Reinforcement shall be placed as indicated in 5.1.6.2, subject to the tolerances given in 8.2.2. Minimum design protective cover of concrete over the circumferential reinforcement in the barrel of the pipe shall be 1 in. for wall thicknesses of 2½ in. or greater, and ¾ in. for wall thicknesses less than 2½ in., subject to the tolerances given in 8.2.2.
RUL Calculated Based on Data

Outer Wall

Estimated Original Inner Wall

Measured Inner Wall

1.25" of Pipe Wall Remaining
DRY = Deterioration Rate per Year for Concrete Pipe

- Based on Pipe Age and Inspected Maximum Corrosion

- Several Factors for High DRY including:
  - Manufacturing Issues
  - High Turbulence
  - Pipe Bends
  - Siphons, etc.

- Incorporate DRY into rating matrix
## Determining Remaining Useful Life

- RUL is automatically calculated for each corrosion observation.
- Pipe’s age, maximum corrosion, RUL in years remaining, and RUL calendar year of failure are automatically calculated.

### Table: Pipe Assessment

<table>
<thead>
<tr>
<th>Distance</th>
<th>Code</th>
<th>Remarks</th>
<th>Dir. 1</th>
<th>Deterioration Rate/Year</th>
<th>RUL (yr)</th>
<th>Fail Date (yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 LSC</td>
<td>General Observation - Corrosion to 0°</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>5 LSC</td>
<td>Point of Interest - Spalled joint &amp; buildup</td>
<td>0</td>
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<td></td>
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<td></td>
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<tr>
<td>12 LSC</td>
<td>Water on lens - At 10 o'clock, until end of line</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 LSC</td>
<td>Maximum Corrosion - To 2.8&quot;</td>
<td>2.3</td>
<td>0.0522</td>
<td>11</td>
<td>2022</td>
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<tr>
<td>15 LSC</td>
<td>Point of Interest - Rebar evident &amp; lateral</td>
<td>0</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>45 LSC</td>
<td>Point of Interest - Rebar evident</td>
<td>0</td>
<td></td>
<td></td>
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<tr>
<td>50 LSC</td>
<td>General Observation - Corrosion to 0.9&quot;</td>
<td>0.9</td>
<td>0.01667</td>
<td>100</td>
<td>2111</td>
<td></td>
</tr>
<tr>
<td>51 LSC</td>
<td>Point of Interest - Rebar evident</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>51 LSC</td>
<td>Point of Interest - Rebar evident</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>100 LSC</td>
<td>General Observation - Corrosion to 0.9&quot;</td>
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<td>0.01667</td>
<td>100</td>
<td>2111</td>
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<td>118 LSC</td>
<td>Point of Interest - Rebar evident</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150 LSC</td>
<td>General Observation - Corrosion to 1.1&quot;</td>
<td>1.1</td>
<td>0.02037</td>
<td>100</td>
<td>2111</td>
<td></td>
</tr>
<tr>
<td>150 LSC</td>
<td>General Observation - Corrosion to 1.1&quot;</td>
<td>1.1</td>
<td>0.02037</td>
<td>100</td>
<td>2111</td>
<td></td>
</tr>
<tr>
<td>200 LSC</td>
<td>General Observation - Corrosion to 1.5&quot;</td>
<td>1.5</td>
<td>0.02778</td>
<td>71</td>
<td>2082</td>
<td></td>
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<tr>
<td>250 LSC</td>
<td>General Observation - Corrosion to 1.0&quot;</td>
<td>1</td>
<td>0.01852</td>
<td>100</td>
<td>2111</td>
<td></td>
</tr>
<tr>
<td>300 LSC</td>
<td>General Observation - Corrosion to 0.6&quot;</td>
<td>0.6</td>
<td>0.01111</td>
<td>100</td>
<td>2111</td>
<td></td>
</tr>
<tr>
<td>300 LSC</td>
<td>General Observation - Corrosion to 0.6&quot;</td>
<td>0.6</td>
<td>0.01111</td>
<td>100</td>
<td>2111</td>
<td></td>
</tr>
<tr>
<td>300 LSC</td>
<td>Match to Reference Shape and Size - #331&quot;</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>320 LSC</td>
<td>General Observation - Corrosion to 0.5&quot;</td>
<td>0.5</td>
<td>0.00526</td>
<td>100</td>
<td>2111</td>
<td></td>
</tr>
</tbody>
</table>

### Category: 5 PIPE ASSESSMENT

- **Pipe Age**: 54 years
- **Deterioration Rate**: 0.0537
- **RUL Estimated**: 11 years
- **RUL Calculated**: 11 years
- **Est. Fail in yrs**: 2022
- **Calc. Fail in yrs**: 2022
- **Fail Point Calc**: 0.75
- **Struc Obs count**: 0
- **Corr Obs Count**: 11

### Rating Scale

- **Rating = 1**: 1 (71 to 100 years of RUL)
- **Rating = 2**: 2 (41 to 70 years of RUL)
- **Rating = 3**: 3 (11 to 40 years of RUL)
- **Rating = 4**: 4 (3 to 10 years of RUL)
- **Rating = 5**: 5 (0 to 2 years of RUL)
Determining Remaining Useful Life

- Example Inspection (96-inch line)

*Remaining Wall Thickness Estimated using DRY
Case Study: Significant Wall Loss

699.9ft General Observation - Corrosion to 2.6"

730.6ft Point of Interest - Rebar apparent

739ft Maximum Corrosion - To 3.0"

749.9ft General Observation - Corrosion to 2.9"

749.9ft General Observation - Corrosion to 2.9"

799.9ft General Observation - Corrosion to 2.3"

Legend:
- 2.5in
- 1.6in
- 0.8in
- 0in
- -0.8in
- -1.6in
- -2.5in
- No Data
Case Study: Structural Failures

387.6ft Point of Interest - Cavity in soffit to 3.9"

380.4ft Point of Interest - Cavity moves into depression within soffit to 6.1"

378ft 3D Laser Scan - Cavity moving into depression visible

350.1ft General Observation - Corrosion to 1.5"

301.4ft Point of Interest - Hole in soffit

301.4ft Point of Interest - Hole in soffit
Determining Remaining Useful Life

- RUL is automatically calculated for each ovality observation

<table>
<thead>
<tr>
<th>Ovality Observation</th>
<th>Remaining Useful Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 - 5.0%</td>
<td>36 - 50 years</td>
</tr>
<tr>
<td>5.0 - 10.0%</td>
<td>21 - 35 years</td>
</tr>
<tr>
<td>10.0 - 12.5%</td>
<td>11 - 20 years</td>
</tr>
<tr>
<td>12.5 - 15.0%</td>
<td>3 - 10 years</td>
</tr>
<tr>
<td>&gt; 15.0%</td>
<td>0 - 2 years</td>
</tr>
</tbody>
</table>

Pipe Manufacturers Specify
5.0 – 7.5% Maximum Initial Deflection
Determining Remaining Useful Life

Develop RUL Criteria for Vitrified Clay Pipe
Determining Remaining Useful Life

Rigid Pipe Remaining Useful Life using Overall Pipe Rating Index (OPRI)

- **PACP OPRI = 0.0 - 0.9**
  - 36-50 years

- **PACP OPRI = 1.0 - 1.9**
  - 21-35 years

- **PACP OPRI = 2.0 - 2.9**
  - 11-20 years

- **PACP OPRI = 3.0 - 3.9**
  - 3-10 years

- **PACP OPRI = 4.0 - 5.0**
  - 0-2 years
Case Study: Ovality in Flexible Pipe
Case Study: Ovality in Rigid Pipe

183.4ft 3D Laser Scan - Pipe overview

199.9ft General Observation - Ovality to 5.9%

219.9ft Point of Interest - Longitudinal cracking

23.9ft Maximum Ovality - To 8.3%

249.9ft General Observation - Ovality to 5.4%

277.9ft Closest Match to Reference Size - ø48
Our Project
Our Project

- 138 manholes inspected
- 29 unmapped manholes found
- 97 need rehabilitation or repair
Our Project

Represents 400 out of 38,652 Linear Feet in need of Near Term Rehabilitation or Replacement.
Our Project
Our Project
Benefits of Multi Sensor Inspection

- Enhanced Understanding and Knowledge of Asset Condition and Life Cycle
- Reduction in the Risk of Failure and Better Sustainability
- Reduced Reactive Maintenance and Cleaning Costs
- Enhanced Knowledge of Asset Status and Life Cycle
Benefits of Multi Sensor Inspection

- Restoring capacity through detailed cleaning and debris removal
- Replacing portions of interceptors instead of the whole interceptor
Benefits of Multi Sensor Inspection

Reduction in:

• Emergency repairs and reactive maintenance
• Odor control chemicals and facilities
• “Cleaning to inspect” vs. “inspecting to clean”
Benefits of Multi Sensor Inspection

- Remaining useful life linked to GIS
- Baseline condition assessment
- Improved hydraulic model
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