Condition Assessment for Managing Underground Assets

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American Society of Civil Engineers Infrastructure Score Card

The American Society of Civil Engineers on their website www.asce.org/asce.cfm gave the nations infrastructure an overall grade of D in their 2009 study. The drinking water and wastewater underground infrastructure both received grades of D in this study. ASCE estimates an investment need of over $2.2 Trillion in the next 5 years.
Effective Utility Management

U.S. Environmental Protection Agency in conjunction with AMWA, APWA, AWWA, NACWA, NAWC, and WEF issued the Effective Utility Management Primer to establish guidelines for communities to use.

10 Attributes of Effectively Managed Water Sector Utilities

- Product Quality
- Customer Satisfaction
- Employee and Leadership Development
- Operational Resiliency
- Community Stability
- Water Resource Adequacy
- Stakeholder Understanding and Support
- Operational Optimization
- Financial Viability
- Infrastructure Stability
Infrastructure Stability Includes

- Understanding the condition of and cost of critical infrastructure
- Maintaining and enhancing the condition of all assets over the long-term at the lowest possible life-cycle cost
- Maintaining acceptable risk levels
- Maintaining regulator supported service level
- Anticipating growth of service area
- Assuring asset repair, rehabilitation, and replacement
- Minimizing disruptions and other negative effects

Typical Underground Assets

- Large and small diameter sewers
- Forcemains
- Interceptor/collector sewers
- Watermains
- Water tunnels and aqueducts
- Reservoirs
- Pump stations, junction chambers, meter chambers
- Treatment facility structures
Negative Effects

• Sinkholes
• Collapsed pipes
• Wash outs
• Damaged structures
• Contaminated water

Potential Causes

• Loss of lateral support
• Piping of soils through cracks and openings
• Overloading
• Undermining
• Subsidence
Planning

- Mapping – Where are the assets located
- Geographic Information System – GIS
- Asset numbering
- Asset specific data – design, as-built, maintenance history
- Surface features – roads, railroads, rivers, other utilities
- Geotechnical and groundwater information
- Geologic features

Prioritization Systems

- Based on age and material type
- Based on defect/maintenance history
- Based on evaluating probability of failure versus consequences of failure
- Based on weighted average of impact factors
Probability Based Systems

- WERF developed – Sewer Cataloging, Retrieval, and Prioritization System (SCRAPS)
- EPA – Check Up Program for Small Systems (CUPSS) incorporates a similar probability system for critical assets.
- AWWA – WaterGEMS Criticality

Example from WERF Publication SAM3R06

<table>
<thead>
<tr>
<th>Consequence of Failure</th>
<th>Likelihood of Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>A</td>
<td>Medium</td>
</tr>
<tr>
<td>B</td>
<td>Medium</td>
</tr>
<tr>
<td>C</td>
<td>Medium</td>
</tr>
<tr>
<td>D</td>
<td>Low</td>
</tr>
<tr>
<td>E</td>
<td>Low</td>
</tr>
</tbody>
</table>
Weighted Average Impact Factors

- National Research Council Canada – Guidelines for Condition Assessment and Rehabilitation of Large Sewers (>1500 mm, about 60-inches)

- Impact factors include:
  - ✓ Sewer location
  - ✓ Embedment soil
  - ✓ Sewer size
  - ✓ Burial depth
  - ✓ Sewer function
  - ✓ Seismic zone

Impact Weighting and Impact Rating

\[ I_W = (0.2)f_l + 0.16fs + (0.16)f_z + (0.16)f_d + (0.16)f_f + (0.16)f_g \]

Where “l” is location, “s” is embedment soil, “z” is diameter, “f” is function, and “g” is seismic; ranges of values are shown on Table 3.2

The impact rating is obtained from Table 3.3 failure impact rating
Table 3.2 Failure impact factors and weights

<table>
<thead>
<tr>
<th>Failure impact factor</th>
<th>Weighting factor</th>
<th>Symbol</th>
<th>Degree of failure impact</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Low</td>
</tr>
<tr>
<td><strong>Local</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewer location (Table 3.4)</td>
<td>0.2</td>
<td>$I_L$</td>
<td>1.0</td>
</tr>
<tr>
<td>Embedment soil (Table 3.5)</td>
<td>0.16</td>
<td>$I_s$</td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Global</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sewer size (Table 3.6)</td>
<td>0.16</td>
<td>$I_z$</td>
<td>1.0</td>
</tr>
<tr>
<td>Burial depth (Table 3.7)</td>
<td>0.16</td>
<td>$I_d$</td>
<td>1.0</td>
</tr>
<tr>
<td>Sewer function (Table 3.8)</td>
<td>0.16</td>
<td>$I_f$</td>
<td>1.0</td>
</tr>
<tr>
<td>Seismic zone (Table 3.9)</td>
<td>0.16</td>
<td>$I_q$</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 3.3 Failure impact rating

<table>
<thead>
<tr>
<th>Weighted impact factor, $I_w$</th>
<th>Impact rating, $R_{imp}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.00</td>
<td>1</td>
</tr>
<tr>
<td>1.01 – 1.50</td>
<td>2</td>
</tr>
<tr>
<td>1.51 – 2.20</td>
<td>3</td>
</tr>
<tr>
<td>2.21 – 3.50</td>
<td>4</td>
</tr>
<tr>
<td>&gt;3.5</td>
<td>5</td>
</tr>
</tbody>
</table>

Example

Given an 8-feet inside diameter collector sewer in Dearborn, Michigan; located under a 6 lane road; 40-feet deep; in fine sands and silts

$$I_w = (0.2)(3)+(0.16)(1.5)+(0.16)(3)+(0.16)(3)+(0.16)+(0.16)(1) = 2.84$$

If $I_w = 2.84; R_{imp} = 5$
Desired Characteristics for Condition Assessment Program

- Objective classification of observations
- Consistent data
- Ability to detect change over time
- Ability to Integrate data from different software providers
- Observations correlated to condition rating

Existing Standards

- Water Resources Centre (WRc)
- NASSCO Pipeline/Manhole/Lateral Assessment Certification Program (PACP/MACP/LACP)
- Sewer Condition Risk Enhanced Asset Model (SCREAM)
First Steps (Homework for the Utility)

- Record drawings into PDF
- Project geotechnical data added to record drawings
- Unique numbering for structures for GIS
- Maintenance and repair records
- Periodic inspection records (converted to standard system selected)
- Construction records
- Acceptance testing records
- Priorities

Primary Inspection Methods

- Closed circuit television
- Geotechnical engineering
- Surface Geophysical Methods (GPR, MASW, Resistivity)
- Environmental engineering
- Materials engineering
- Atmospheric testing
Supplemental Studies

- Laser measurement / profiling (2D and 3D)
- Sonar studies
- Pipe penetrating radar
- Corrosion studies
- Sonic / ultrasonic
- Magnetic / eddy current
- Radiographic

3.7 ID at Clock Positions

The inspected distance displayed below is the distance upstream from the PCI-S-101 manhole.

ID Change at Clock Positions
Other Considerations

- Hydraulic evaluation
- Flow monitoring / management
- Traffic control
Considerations

- Pressurized systems vs. gravity systems
- Ferrous metal vs. non-metal
- Access points types
- Access point spacing
Closed Circuit Television

• Used for small diameter sewers in 1970’s
• Large diameter sewers with rafts mid-1990’s
• Pan and tilt cameras first appeared in the late 1980’s
• Zoom lenses with enhanced lighting and digital signal mid to late 1990’s
• CCTV is considered the inspection standard
• Proper lighting – the bigger it is, the more you need
Pipeline Assessment Certification Program (PACP)

- Developed by the National Association of Sewer Service Companies (NASSCO) to standardize CCTV work,
- Grading system developed for defects noted
- Grading numbers coordinated with remaining life
- Rating evaluation based on defect grades for a given sewer reach

PACP Grading and Remaining Life

Grade 1: Excellent, minor defects, failure unlikely in foreseeable future

Grade 2: Good, defects have not begun to deteriorate, unlikely to fail in next 20 years

Grade 3: Fair, moderate defects that will continue to deteriorate, pipe may fail in 10 to 20 years

Grade 4: Poor, severe defects that will become Grade 5 within foreseeable future, pipe will probably fail in 5 to 10 years

Grade 5: Immediate attention, defects are present that require immediate attention
Examples of Pipe Defects

Grade 2 Defect
Spalling Concrete

Grade 1 Defect
Circumferential Crack

Grade 3 Defect
Longitudinal Fracture

Grade 4 Defect
Exposed/Projecting Aggregate

Grade 2
Weeping Infiltration

Grade 3
Dripping Infiltration

Grade 4
Running Infiltration

Grade 5
Gushing Infiltration
Multi-Channel Analyses of Surface Waves Results

Plan and Profile

Shear Wave Velocity (FT/Sec)

Almost Free Data

- Results of air quality monitoring during condition surveys
- GPS data from surveys
- pH test results from liner wall
- Field measurements
Quality Assurance

When contracting for underground inspection services remember President Ronald Reagan’s admonition “Trust but Verify”

Utility owners should perform or should contract someone to perform a quality assurance evaluation of CCTV and other test data.

EVALUATION

- PACP/MACP provide objective data base
- Periodic inspections using PACP/MACP needed for site specific service life estimate
- Evaluation combines CCTV data with geotechnical, geophysical, physical observation, and materials data
- Prediction of corrosion – Pomeroy and others
Evaluate in Historical Perspective

- As-constructed conditions vs. laser scans
- Post-construction changes

Prioritization

- Prioritize based on PACP Grades
- Consider either impact or probability methods
Remedial Measures

- Temporary support
- Sliplining
- Close-fit lining
- In-situ repair

Selecting Rehabilitation Method

- Trenchless Assessment Guide for Rehabilitation (TAG-R) - NASSCO and NUCA
- EPA guidelines
- Chemical resistance
- Constructability
- Service conditions
Temporary Support

Temporary Steel Ribs and Skeleton Wood Lagging

In-situ Repairs
Sliplining

Close-Fit Lining
New Access Shafts

Questions?

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