Interactive Decision Tree Automates Sewer Rehabilitation Planning

IWPCA Annual Conference
June 5, 2008

Rodney Moeller, P.E.,
John Schroeder, P.E. BCEE,
C. Timothy Fallara, P.E. & Mel Meng, P.E.
Agenda

• Overview of Livingston/James Sewer System I/I Remediation Project
• Sewer Coding & NASSCO PACP
• Condition Assessment to Prioritized Solutions
• Automated Decision Tree
  – Decision Tree Demo
  – Final Decision Tree Structure
  – Summary
Agenda

• Overview of LJII Project
  • Sewer Coding & NASSCO PACP
  • Condition Assessment to Prioritized Solutions
  • Automated Decision Tree
    – Decision Tree Demo
    – Final Decision Tree Structure
    – Summary
Livingston/James Sewer System I/I Remediation Project

- 7,560-acre study area
- Mostly 1950s residential development
Livingston/James Sewer System I/I Remediation Project

- Over 3,300 sanitary sewers (150 miles)
- 8 to 66 inches in diameter
Livingston/James Sewer System I/I Remediation Project

- 1,825 WIB complaints in last 5 years
- 439 WIB complaints January 2005
LJII Project Tasks

- Clean and record with CCTV all sewers (>700,000 lf)
- Database with PACP Defect Codes & Linked to Video
- Quick-Response Investigations
- Investigate Private & Public I/I Sources with Dye Testing
- Windshield Surveys
- Flow Monitoring & Radar Rainfall
- Hydraulic Modeling & Calibration
- Develop, Evaluate & Prioritize Alternatives
  - Capacity Related Improvements
  - Structural
  - O&M
- Cost Estimating & Developing CIP
- Development of Implementation Plan
LJII Project Tasks

• Clean and CCTV all sewers (>700,000 lf)
• Database with PACP Defect Codes & Linked to Video
• Quick Response Investigations
• Investigate Private & Public I/I sources with Dye Testing
• Windshield Surveys
• Flow Monitoring & Radar Rainfall
• Hydraulic Modeling & Calibration

• Develop, Evaluate & Prioritize Alternatives
  – Capacity Related Improvements
  – Structural
  – O&M

• Cost Estimating & Developing CIP
• Development of Implementation Plan
Agenda

- Overview of LJII Project
- **Sewer Coding & NASSCO PACP**
- Condition Assessment to Prioritized Solutions
- Automated Decision Tree
  - Decision Tree Demo
  - Final Decision Tree Structure
  - Summary
NASSCO PACP

- Structural (Cracks, Fractures, Holes)
- Operation & Maintenance (Roots, Debris, Deposits, Infiltration)
- Construction Features (Taps, Seals)
- Miscellaneous (Pipe Change)
- PACP Condition Grading System
PACP Condition Grading System

- Grade 1 – Excellent (No Defects)
- Grade 2 – Good
- Grade 3 – Fair
- Grade 4 – Poor
- Grade 5 – Severe
Sewer Main Assessment

• Sewer Defects - Structural
  – Cracks
  – Fractures
  – Broken
  – Holes
  – Collapses
  – Sags
Sewer Main Assessment

- Sewer Defects – O&M
  - Roots
  - Deposits
  - Infiltration
  - Sags
High Structural Scores (5s)

- Holes
- Deformed Pipes
- Collapsed Pipes
- Broken Pipes
- Surface Deterioration
High O&M Scores (5s)

- Severe Grease
- Root Balls
- Severe Deposits
- Infiltration Gushers
Agenda

• Overview of LJII Project
• Sewer Coding & NASSCO PACP
• **Condition Assessment to Prioritized Solutions**
• Automated Decision Tree
  – Decision Tree Demo
  – Final Decision Tree Structure
  – Summary
Sanitary Sewer Improvement Alternatives

**Hydraulic Capacity**
- New Larger Pipe or Relief Sewer
- Columbus I/I Reduction Program
- Satellite Communities I/I Reduction Program

**Structural**
- Point Repair
- Pipeline Rehabilitation (CIPP)
- Replace Pipe

**O&M**
- Perform Periodic Maintenance & CCTV Insp.
- Chemical Root Control Program
- Grease Control Program
DRAFT Decision Chart for Livingston James Sanitary Sewer Remediation Plan

CCTV Data & Model Results

1. Does Pipe Have Sufficient Capacity?
   - Y: Structural Score
     - 3, 4, 5
   - N

2. Structural Score
   - Y: Does Pipe Have Major Structural Defect?
     - Y: Open Cut Point Repair & Relining Possible?
       - Y: Long Term > 5 yrs
         - Y: Pipe Rehab CIPP
         - N: Point Repair
       - N: Y
       - N: N
     - N: Y
     - N: N
   - N

3. Does Pipe Have Major Structural Defect?
   - Y: Does Pipe Have Roots?
     - Y: Does Pipe Have I/I
       - Y: Implement I/I Reduction Program
     - N: New Larger Pipe or Parallel Pipe
   - N: Y
   - N: Y

4. Does Pipe Have Roots?
   - Y: Are I/I Reductions Feasible?
     - Y: Is I/I in City Limits?
       - Y: Can I/I Reductions Meet Needs?
         - Y: Implement I/I Reduction Program
         - N: Get Satellite Community to Implement I/I Red. Program
       - N: OR
     - N: Y
     - N: N
   - N: Y
   - N: N

5. Are I/I Reductions Feasible?
   - Y: New Larger Pipe or Parallel Pipe?
     - Y: N
     - N: Y
     - N: Y
     - N: N

6. Is I/I in City Limits?
   - Y: Can I/I Reductions Meet Needs?
     - Y: Implement I/I Reduction Program
     - N: Get Satellite Community to Implement I/I Red. Program
   - N: OR

7. Can I/I Reductions Meet Needs?
   - Y: N
   - N: Y

8. New Larger Pipe or Parallel Pipe?
   - N: Y
   - Y: N

   - Y

10. Get Satellite Community to Implement I/I Red. Program
    - Y

11. Implement I/I Reduction Program
    - Y

12. Pipeline Rehabilitation (CIPP)
    - Y

13. Chem. Root Control Program
    - Y
Stakeholders Developed Condition & Criticality Factors to Set Priorities

- Stakeholders
  - Condition
    - Capacity
      - Modeling
      - Growth Needs
      - I/I Issues
    - Structural
      - PACP Grade
      - Age
      - Corrosion
    - Maintenance
      - PACP Grade
      - Work Orders
      - Preventative Maintenance
  - Criticality
    - Environmental Impact
    - Size
    - Transportation Impact
    - Reliability
      - Public Health Impact
Priority is a Function of Both Condition and Criticality

<table>
<thead>
<tr>
<th>Priority</th>
<th>Condition (Probability of Failure)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Long-Term Rehab/Replace</td>
<td>Mid-Term Replace/Rehab</td>
<td>Short-Term Replace/Rehab</td>
<td>Immediate Replace</td>
<td>Immediate Replace</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Long-Term Rehab</td>
<td>Mid-Term Rehab</td>
<td>Mid-Term Rehab</td>
<td>Immediate Rehab</td>
<td>Immediate Rehab</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Long-Term Rehab</td>
<td>Long-Term Rehab</td>
<td>Mid-Term Rehab</td>
<td>Mid-Term Rehab</td>
<td>Short-Term Rehab</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Infrequent Monitoring</td>
<td>Infrequent Monitoring</td>
<td>Regular Monitoring</td>
<td>Frequent Cleaning/Monitoring</td>
<td>Frequent Cleaning/Monitoring</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Infrequent Monitoring</td>
<td>Infrequent Monitoring</td>
<td>Regular Monitoring</td>
<td>Regular Monitoring</td>
<td>Frequent Monitoring</td>
<td></td>
</tr>
</tbody>
</table>
Sewer Improvement Priority Timeframes

- IMMEDIATE (0 to 6 months)
- Short Term (1 to 3 years)
- Intermediate Term (3 to 5 years)
- Long Term (5 to 10 years)
<table>
<thead>
<tr>
<th>Prioritization of Recommended Improvement</th>
<th>Structural Recommendations</th>
<th>Operations and Maintenance Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code 6</td>
<td>Sewer Replacement</td>
<td>11</td>
</tr>
<tr>
<td>7</td>
<td>Point Repair</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Cured-In-Place-Pipe (CIPP)</td>
<td>13</td>
</tr>
<tr>
<td>9</td>
<td>Point Repair and CIPP</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Spot Liner</td>
<td></td>
</tr>
</tbody>
</table>

| | Immediate | Short Term | Intermediate Term | Long Term | |
| | Number of Pipes | Number of Pipes | Number of Pipes | Number of Pipes | |
| Immediate | | | | | |
| A | 14 | 45 | 0 | 31 | 0 |
| | 0 | 0 | 0 | 0 | 0 |
| Short Term | | | | | |
| B | 22 | 277 | 658 | 168 | 20 |
| | 138 | 22 | 175 | | |
| Intermediate Term | | | | | |
| C | 0 | 69 | 422 | 20 | 0 |
| | 203 | 30 | 152 | | |
| Long Term | | | | | |
| D | 0 | 72 | 627 | 12 | 0 |
| | 215 | 162 | 975 | | |

Number of Pipes | 36 | 463 | 1,707 | 231 | 20 | 556 | 214 | 1,302 |

Total Pipes in GIS/Recommendations = 3,389
Agenda

• Overview of LJII Project
• Sewer Coding & NASSCO PACP
• Condition Assessment to Prioritized Solutions

• Automated Decision Tree
  – Decision Tree Demo
  – Final Decision Tree Structure
  – Summary
Custom GIS Decision Toolset

- **Solution Matrix**
- **ArcMap**
- **Decision Tree Editor**
- **CCTV Video**
- **Pipe Info.**
- **Edit Node**
- **Open Tree**
- **Save Tree**
- **New Tree**
- **Map**
- **Select Layer/Field**
- **Test Selected Query**
- **Update Features**
- **Apply Legend**
- **Export Details**
- **Export Outcomes**
- **Report**
Custom Decision Tree Editor

Tree
- Open Tree
- Save Tree
- New Tree

Node
- Add Node
- Delete Node
- Edit Node

Map
- Select Layer/Field
- Test Selected Query
- Update Features
- Apply Legend
- Export CCTV Details
- Export Outcomes
- Report

Decision Tree - TreeView: ObjectData.Tree_2007-05-25\Node10.knit.txt

- Significant Deposit Definition
- Significant Sediment Definition
- Significant Root Definition
- Significant Damage Definition
- FOG Program
- Decision Tree
  - Is pipe to be replaced due to hydraulic model results?
    - Yes: pipe is scheduled to be replaced
    - No: pipe is not scheduled to be replaced
    - Structural Score
      - Low
      - Medium
      - High
  - Rehabilitation Cost Effective or Feasible?
    - Yes (or never less than 4 structural defects)
    - Seg = 200%?
      - Yes
      - No
  - Long Term Pipe Rehabilitation CPP and Field Repair Likelihood?
    - No
    - More than 5 cases
    - Long Term Pipe Replacement CPP-Medium Score
  - Long Term Replacement Pipe
  - Structural Analysis
    - See Engineer's Level C Table

- Prioritization Node - Structural
- Prioritization Node - Operations and Maintenance
- Prioritization Code Assignment
- Engineer's Recommendation Overrides
- Review of Final Recommendations - Query Only

Opened T:\J\J\Source\ObjectData.Tree_2007-05-25\Node10.knit.txt
Building a Decision Tree

Decision Model
- Is Pipe to be Replaced due to Hydraulic Model Results?
  - Yes - the pipe is scheduled to be replaced
    - Structural Score
      - No structural defects
        - Short Term New Replacement Pipe - No Structural Defects
      - Low Structural Score
        - Short Term New Replacement Pipe - Low Structural Score
      - Medium Structural Score
        - Short Term New Replacement Pipe - Medium Structural Score
      - High Structural Score (See Engineers Level 5 Table)
        - Short Term New Replacement Pipe - High Structural Score

Node Edit Node
Node Type: Attribute
Display Name: Is Pipe to Be Replaced due to Hyd
Field: Sol_Code_M

Node Edit Node
Node Type: Condition
Display Name: Yes - the pipe is scheduled to be re
Expression: (e.g. ="2")

Node Edit Node
Node Type: Condition
Display Name: No structural defects
Expression: (e.g. ="Y")
Field: Structural Score
Expression: < 1
Field: Score_str
Agenda

• Overview of LJII Project
• Sewer Coding & NASSCO PACP
• Condition Assessment to Prioritized Solutions
• Automated Decision Tree

– Decision Tree Demo
  – Final Decision Tree Structure
  – Summary
Open an Existing SQLTree File
Select GIS Layer To Process by Pressing This Button
Select Layer And Field to Update and Press “Apply”
Select an Attribute Node

Node Information on Status Line
Select a Condition Node

Node Information on Status Line

Condition Expression: HydCapOK="N"
Alternate Condition Node

Node Information on Status Line

Condition Expression: HydCapOK="Y"
A Condition Node Follows

Node Information on Status Line

Condition Expression: STRUCTSCORE=0 or =1 or =2
To Edit a Node
Press This Button

Node Information on Status Line

Condition Expression: $\text{STRUCTSCORE}=0$ or $=1$ or $=2$
Change Node Attributes and Press “Apply”
An Outcome Node

SQL Statement on Status Line

Outcome: SET [RACION] = "Long Term Pipe Rehab CIPP or Chemical Root Control" WHERE ((HydCapOK = "Y")) AND ((STRUCTSCORE = 0) OR (STRUCTSCORE = 1) OR (STRUCTSCORE = 2)) AND ((Signif_Roos = "Y"))
Another Outcome Node

SQL Statement on Status Line

Outcome: SET [RACION] = "Long Term Pipe Rehab CIPP" WHERE ((HydCapOK = "Y") AND ((STRUCTSCORE = 0) OR (STRUCTSCORE = 1) OR (STRUCTSCORE = 2)) AND ((Signif_Roots = "N") AND ((Signif_Score = "Y") AND ((Signif_Dep = "Y")) AND ((Signif_Score = "Y") AND ((Signif_Dep = "Y")))
To Test a Query
Press This Button

SQL Statement on Status Line

Outcome: SET [RACTION] = "Long Term Pipe Rehab CIPP" WHERE ((HydCapOK = "Y") AND ((STRUCTSCORE = 0) OR (STRUCTSCORE = 1) OR (STRUCTSCORE = 2)) AND ((Signif_Roots = "N") AND ((Signif_I = "Y") AND ((Signif_Dep = "Y"))))
The Select Query is run on the GIS layer.

The number of records in the selection set is reported as 36.
Outcome Node is updated with number of records affected.

SQL statement on status line:

```
((HydCapOK = "Y") AND ((STRUCTSCORE = 0) OR (STRUCTSCORE = 1) OR (STRUCTSCORE = 2)) AND ((Signif_Roots = "N") AND ((Signif_II = "Y") AND ((Signif_Dep = "Y"))))
Number Selected = 36
```
To Update the GIS Layer with All of the Queries, Press This Button
Press Yes To Proceed
The Number of Queries Run
The Number of Records Updated By Each Query

RACTION = "Implement II Reduction Program" (0)
RACTION = "Short Term New Replacement or Parallel Pipe" (0)
RACTION = "Long Term Pipe Rehab CIPP or Chemical Root Control" (423)
RACTION = "Long Term Pipe Rehab CIPP" (36)
RACTION = "Periodic Maintenance and Inspection" (151)
RACTION = "Long Term Pipe Rehab CIPP" (100)
RACTION = "Periodic Maintenance and Inspection" (1433)
RACTION = "Long Term Pipe Rehab CIPP" (609)
RACTION = "Long Term New Replacement or Parallel Pipe" (0)
RACTION = "Short Term Pipe Rehab CIPP" (347)
RACTION = "Short Term New Replacement or Parallel Pipe" (0)

OK
All Outcome Nodes Are Updated with Number
Of Records Affected

To Apply a Legend
To the GIS Layer,
Press This Button
Change Legend Attributes and Press “OK”
End Result:
Updated GIS Layer With Color-Coded Legend
Agenda

• Overview of LJII Project
• Sewer Coding & NASSCO PACP
• Condition Assessment to Prioritized Solutions
• Automated Decision Tree
  – Decision Tree Demo
  – Final Decision Tree Structure
  – Summary
Definition Module
Decision Module

Decision Tree - C:\Documents and Settings\schroederjp\My Documents\projects\columbus\Livingston James\CCTV\Decision Tree...

Node Type: Condition
Display Name: Yes
Expression: (e.g. = 'Y')

Condition Expression: (Select Count(*) from [Details] as [Runs] as b on a.RunId = b.RunId WHERE (a.[ConditionCode] in ('RBB', 'RBJ', 'RMB', 'RMJ') and [MainId] = b.([Owner])) > 0 OR (Select Count(*) from [Details] as [Runs] as b on a.RunId = b.RunID WHERE (a.[ConditionCode] in ('RFJ', 'RMC', 'RBC')) and
Prioritization Module

Decision Tree - C:\Documents and Settings\schroederjp\My Documents\projects\columbus\Livingston James\CCTV\Decision Tree

Tree
- Open Tree
- Save Tree
- New Tree

Node
- Add Node
- Delete Node
- Edit Node

Map
- Select Layer / Field
- Test Selected Query
- Update Features
- Apply Legend
- Export CCTV Details
- Export Outcomes

Prioritization Module - Structural
- Pipe Size
- Water In Basement Complaints - VMBs per Acre
- Total Infiltration
- Public Infiltration
- Structural and O&M PACP Scores
- Sags
- Overall Structural Criticality Score (3389)
  - Sum All
    - [PPts_PS] + [PPts_VWB] + [PPts_TI] + [PPts_PL] + [PPts_Sc] + [PPts_Sg]

Prioritization Module - Operations and Maintenance
- Dry Weather Velocities
- Heavy Cleaning
- Pipe Size
- Water In Basement Complaints - VMBs per Acre
- Roots
- Overall Operations and Maintenance Criticality Score

Prioritization Code Assignment
- Structural Priority
  - High Priority Sewers (810)
    - B
  - Medium Priority Sewers (859)
    - C
  - Low Priority Sewers (1720)
    - D
- O & M Priority
  - High Priority Sewers (461)
    - B
  - Medium Priority Sewers (499)
    - C
  - Low Priority Sewers (2429)
    - D

Engineer's Recommendation Overrides
- First, Initialize the Sol_Code_S field with the RACTION from the Decision Model
- Next, Initialize the Sol_Code_O field with the RACTION from the Decision Model where appropriate
- Structural Solution Code
  - 6 - Sewer Replacement (34)
  - 7 - Point Repair (24)
  - 8 - CIPP (153)

((PPts_Tot_O <= 40))
Number Selected = 2429
Engineer Override Module

- **Engineer's Recommendation Overrides**
  - First, Initialize the Sol_Code_S field with the RACTION from the Decision Model
  - All Structural Decision Model Recommendations - Initialize the Sol_Code_S [RACTION]
  - Next, Initialize the Sol_Code_O field with the RACTION from the Decision Model where appropriate
  - All O & M Decision Model Recommendations - Initialize the Sol_Code_O [RACTION]

- **Structural Solution Code**
  - 6 - Sewer Replacement
  - 7 - Point Repair
  - 8 - CIPP
  - 9 - Point Repair and CIPP
  - 10 - Spot Liner
  - All Structural Engineer Recommendation Overrides - Update Sol_Code_S [Engr5Recom]

- **Operations and Maintenance Solution Code**
  - 11 - Short Term Chemical Root Treatment
  - 12 - Grease Program (FOG)
  - 13 - Periodic Cleaning and Televising
  - All O & M Engineer Recommendation Overrides - Update Sol_Code_O [Engr5Recom]

- **Priority Codes**
  - A - Immediate
  - B - Short Term
  - C - Intermediate Term
  - D - Long Term
  - All Engineer Structural Recommendations [Engr5Prior]
  - All Engineer O & M Recommendations [Engr5Prior]

- **Review of Final Recommendations - Query Only**
  - Model Solution Codes:
    - 1 - Relief Sewer
    - 2 - Sewer Replacement
    - 3 - Private and Public Inflow & Infiltration Reduction Program
    - 4 - Backflow Prevention &/or Sump Pump
    - 5 - Storage
  - Structural Solution Codes:
    - 6 - Sewer Replacement

((PPts_Tot_O <= 40))
Number Selected = 2429
Review Module
James Livingston VI Phase II

- Structural Score Calculations
- Significant VI Definition
- Significant Deposits Definition
- Significant Sag Definition
- Significant Roots Definition
- Significant Grease Definition
- FOG Program

Decision Model

- Prioritization Model - Structural
- Prioritization Model - Operations and Maintenance
- Prioritization Code Assignment

- Engineer's Recommendation Overrides

- Review of Final Recommendations - Query Only
# LJII Structural & O&M Draft Recommendation Summary

<table>
<thead>
<tr>
<th>Prioritization of Recommended Improvement</th>
<th>Structural Recommendations</th>
<th>Operations and Maintenance Recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sewer Replacement</td>
<td>Point Repair</td>
</tr>
<tr>
<td>Code</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Immediate</td>
<td>14</td>
<td>45</td>
</tr>
<tr>
<td>Short Term</td>
<td>22</td>
<td>277</td>
</tr>
<tr>
<td>Intermediate Term</td>
<td>0</td>
<td>69</td>
</tr>
<tr>
<td>Long Term</td>
<td>0</td>
<td>72</td>
</tr>
<tr>
<td>Number of Pipes</td>
<td>36</td>
<td>463</td>
</tr>
</tbody>
</table>

Total Pipes in GIS/Recommendations = 3,389
# Summary of LJII Costs for Recommendations

<table>
<thead>
<tr>
<th>Prioritization of Recommended Improvement</th>
<th>Hydraulic Capacity Recommendations</th>
<th>Structural Recommendations</th>
<th>Operations and Maintenance Recommendations</th>
<th>Short, Mid, Long-Term Totals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>Relief Sewer</td>
<td>Sewer Replacement</td>
<td>Private and Public Inflow &amp; Infiltration Reduction Program</td>
<td>Backflow Prevention &amp; Sump Pump</td>
</tr>
<tr>
<td>A</td>
<td>$837,138</td>
<td>$568,477</td>
<td>$0</td>
<td>NA</td>
</tr>
<tr>
<td>B</td>
<td>$1,330,000</td>
<td>$5,800,000</td>
<td>$4,100,000</td>
<td>$1,315,502</td>
</tr>
<tr>
<td>C</td>
<td>$2,670,000</td>
<td>$2,900,000</td>
<td>$0</td>
<td>$871,665</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$12,000,000</td>
<td>$8,700,000</td>
<td>$8,200,000</td>
<td>TBD</td>
</tr>
</tbody>
</table>

**Total Hydraulic Capacity Construction Costs = $28,900,000**  
**Total Structural Construction Costs = $27,293,756**  
**Total Annual O&M Costs = $577,399**
Agenda

• Overview of LJII Project
• Sewer Coding & NASSCO PACP
• Condition Assessment to Prioritized Solutions
• Automated Decision Tree
  – Decision Tree Demo
  – Final Decision Tree Structure

Summary
Summary

The Decision Tree process is:

• Efficient
• User Friendly
• Consistent
• Automated with User Overrides
• Transferable
Questions?