



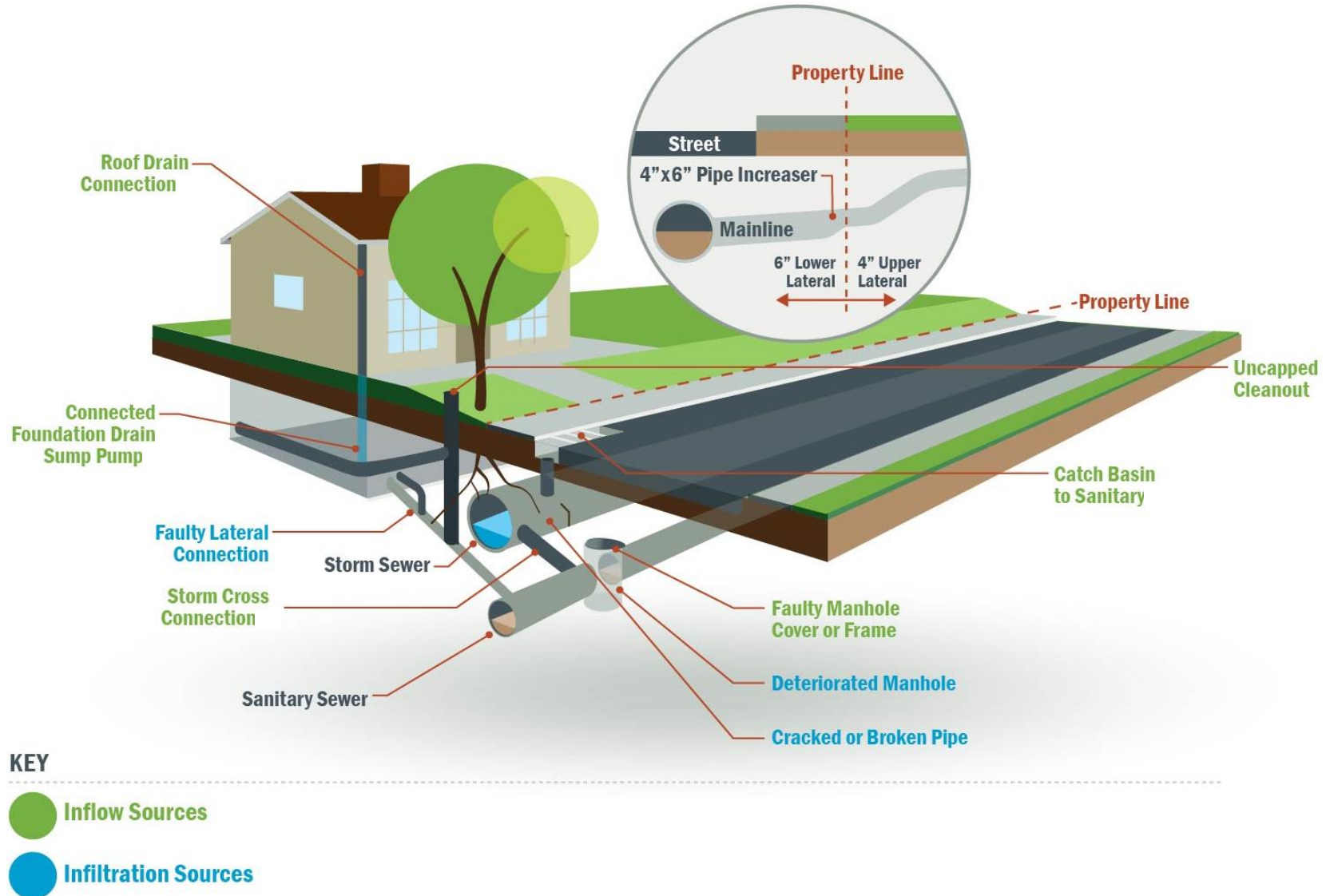
NEW Water Infiltration and Inflow Program Workshop

Workshop Agenda

- Introductions
- I&I Overview
- Tools, Techniques, and Technologies
 - I&I Investigations
 - I&I Removal Techniques
 - I&I Effectiveness Evaluation
- I&I Case Studies
- Next Steps

I&I Overview

Where does I&I come from?



Common Sources of I&I

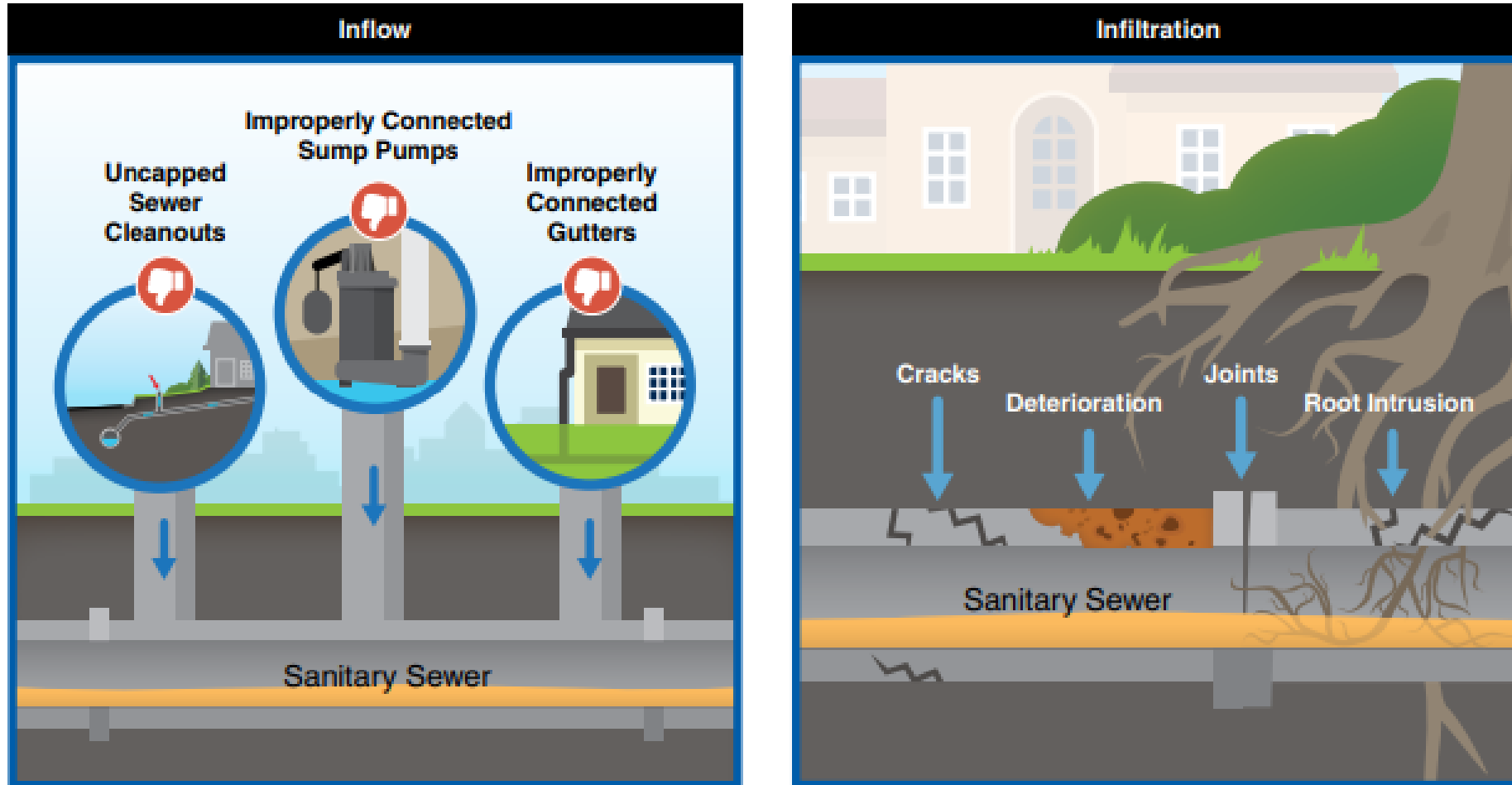
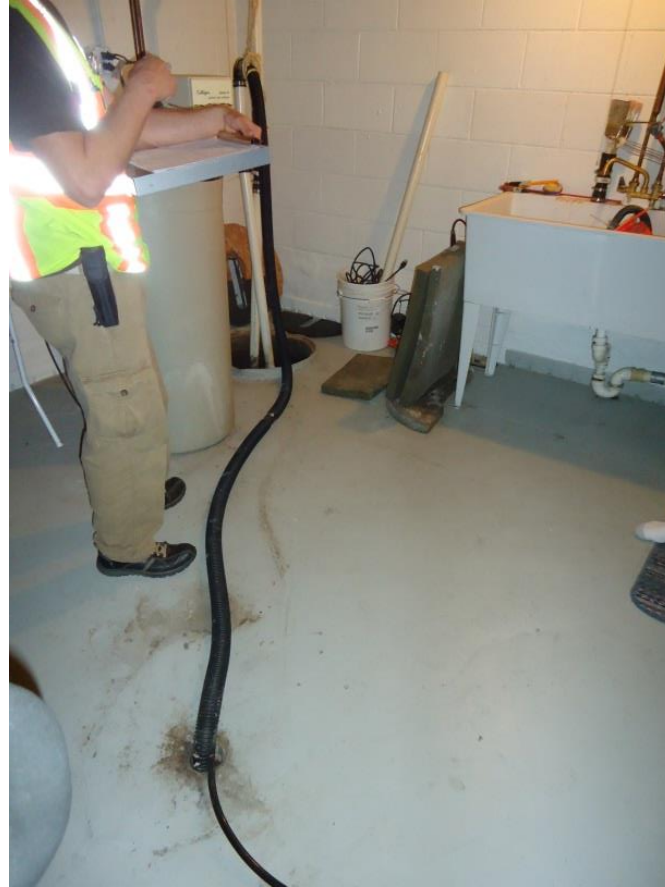


Figure 1. Common sources of I&I
source: Metropolitan Council, St. Paul, MN

Inflow Source Examples



Connected downspout

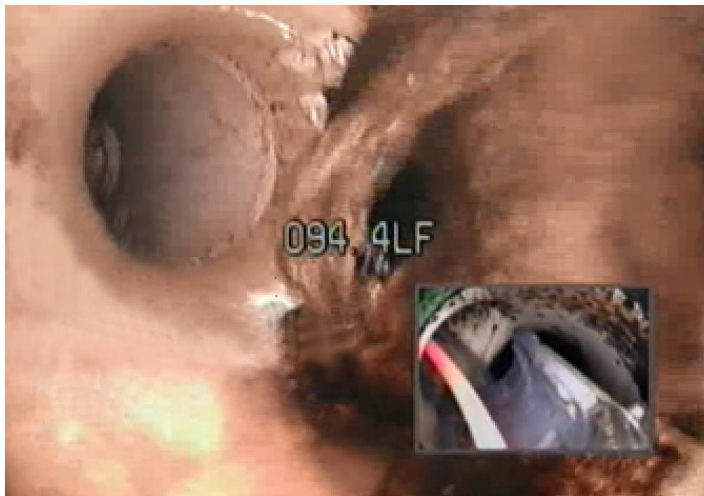
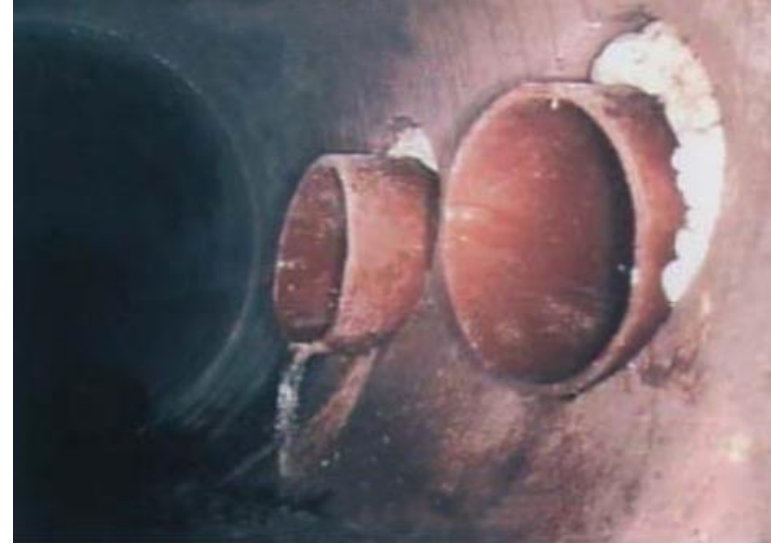


**Clear water sump discharge
Connected to sanitary sewer**



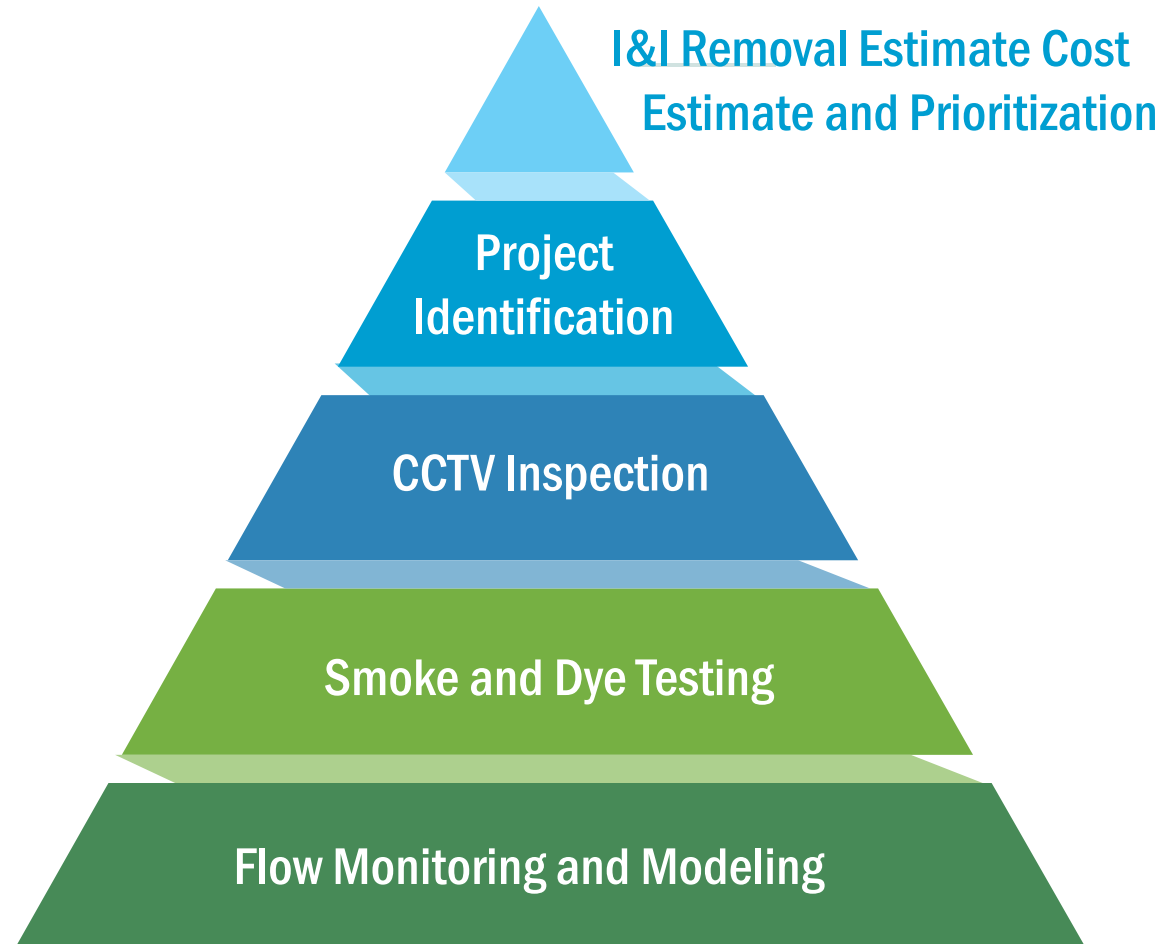
Stairwell with drain

Infiltration Source Examples



Tools, Techniques, Technologies

I&I Program Components



I&I Investigations

- Flow Monitoring
- Smoke Testing
- Manhole Inspections
- Closed Circuit Televising (CCTV)
 - Main line launch (LETS)
 - House or cleanout launch (push)
 - CCTV with Rainfall Simulation
 - Dye Testing of Storm Sewer/Ditch
 - Dye Injection
 - Soaker Hose
 - Wet Weather CCTV
- Focused Electrode Leak Location (FELL)
- Distributed Temperature Sensing (DTS)
- House Inspections



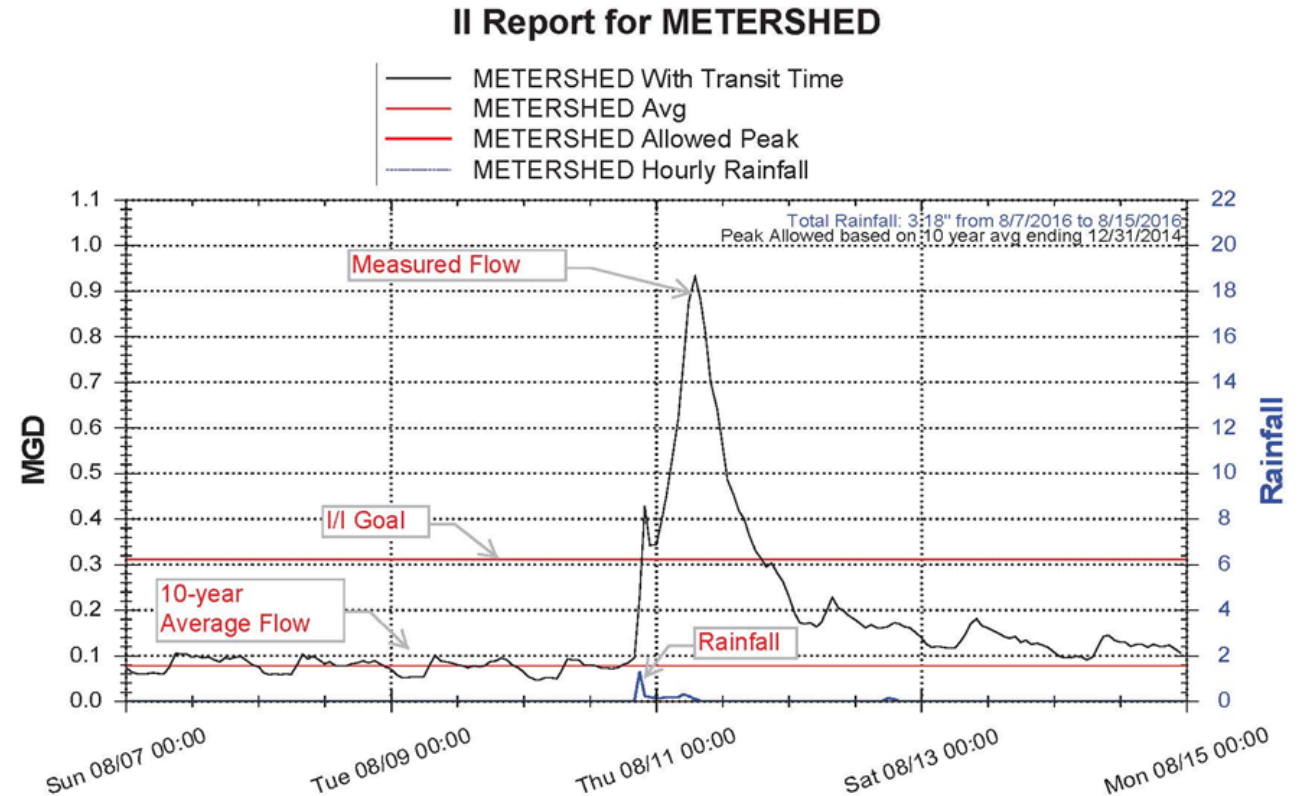
Smoke Testing



Manhole Inspection

Flow Monitoring

- Foundation of an effective I&I program
- Identifies where to investigate further
- Measures compliance with I&I standards
- Measures large areas at one time
- Relatively inexpensive investigation method



Flow Monitoring and Evaluation Considerations

I&I reduction
spread over too
large an area

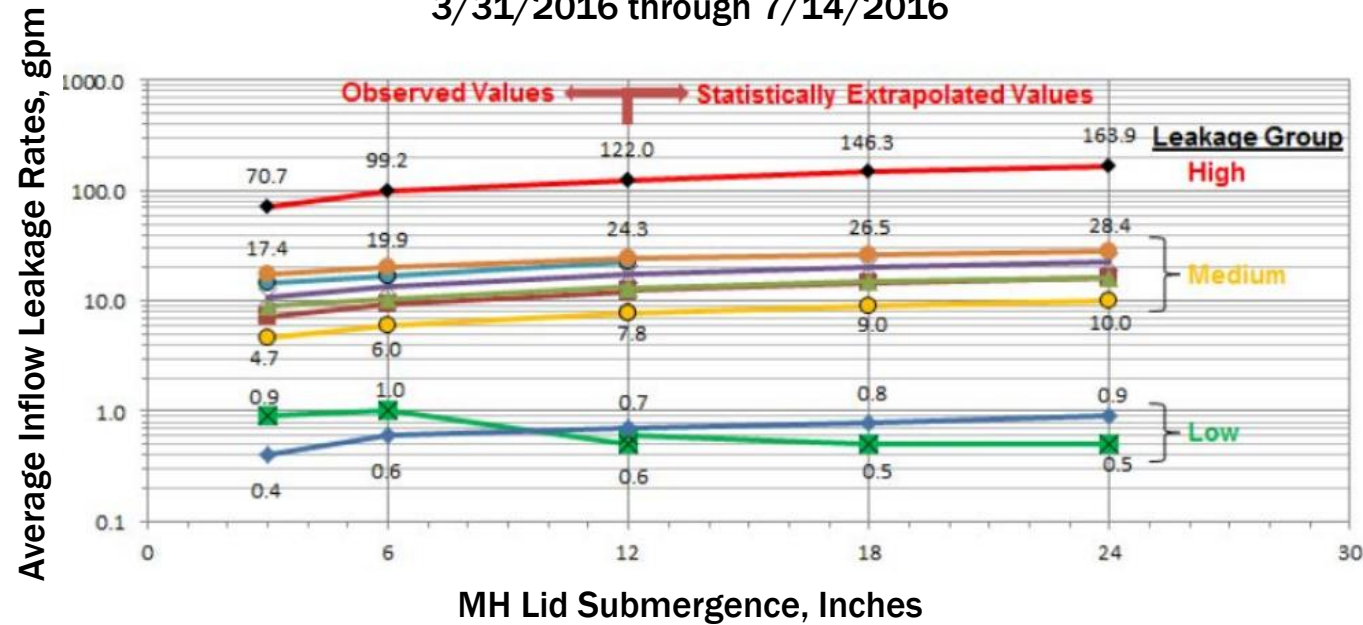


Just right

Area too small
to reliably
measure

Manhole Inspections

Manhole Frame & Lid Leakage Testing Summary
3/31/2016 through 7/14/2016



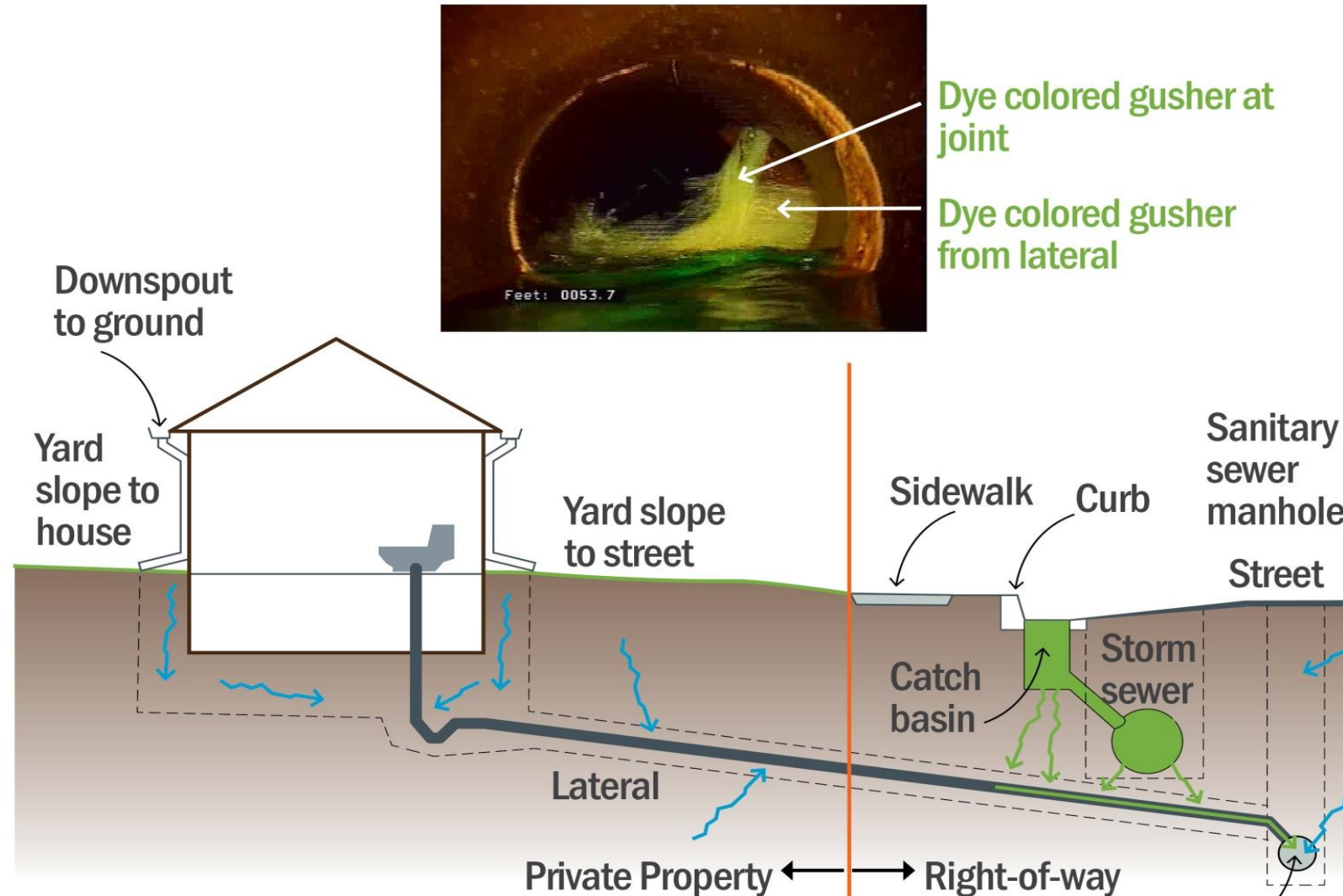
- Water System tested “in service” and new manhole structures
- Test box flooded manhole cover up to 24-inches
- Common issues in large leaks:
 - Corrosion at lid/frame interface
 - Poor/damaged gaskets
 - Lid vent holes and missing cover bolts
 - Hinges lacking no leak protection
 - Cam lock clamp malfunction
 - Structural damage to lids, frames, and riser rings

CCTV

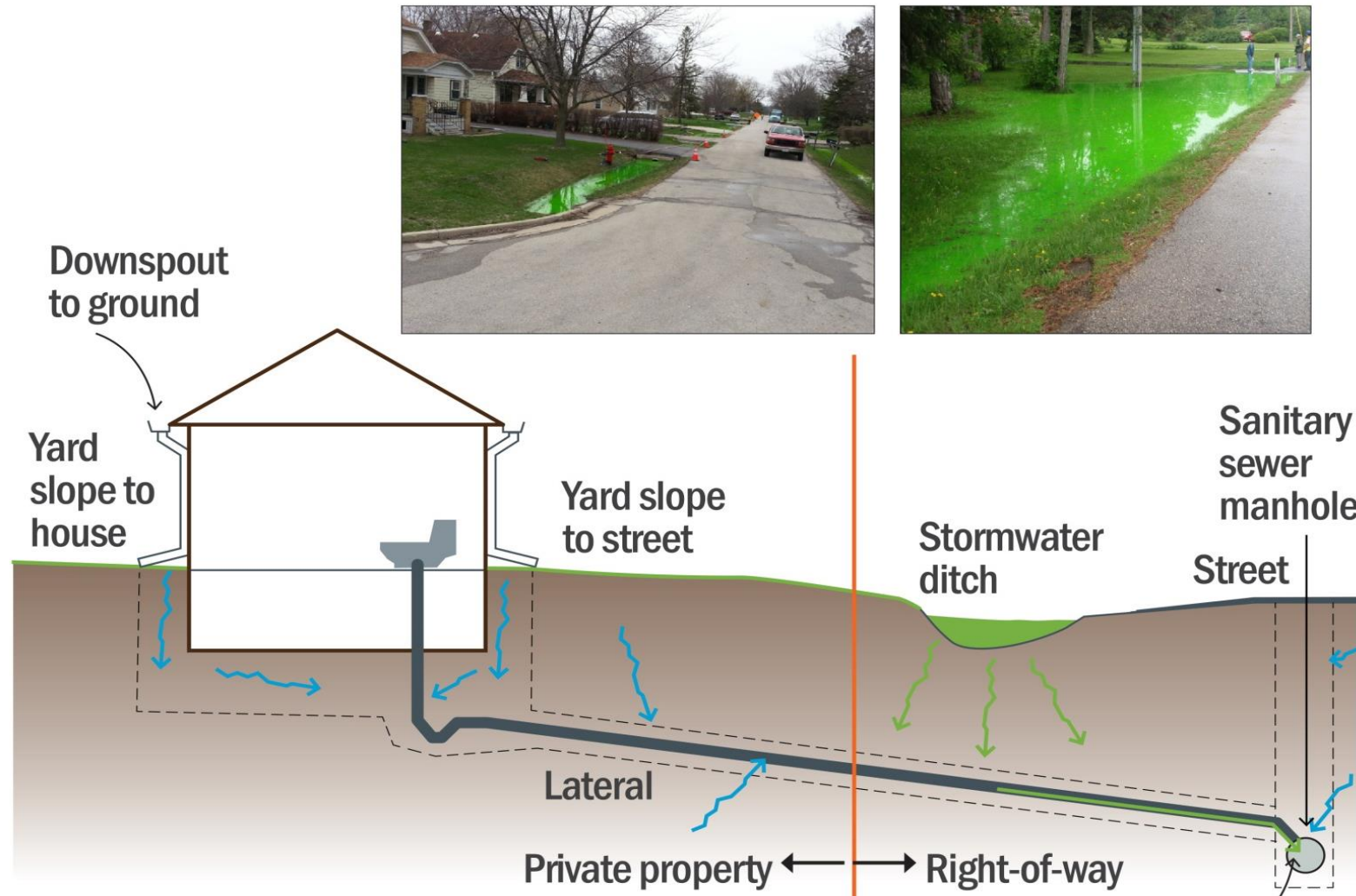
- Closed Circuit Televising (CCTV)
- Can inspect laterals with little interruption
- Can see major flaws in the pipe
- Standardized documentation processes (NASSCO)



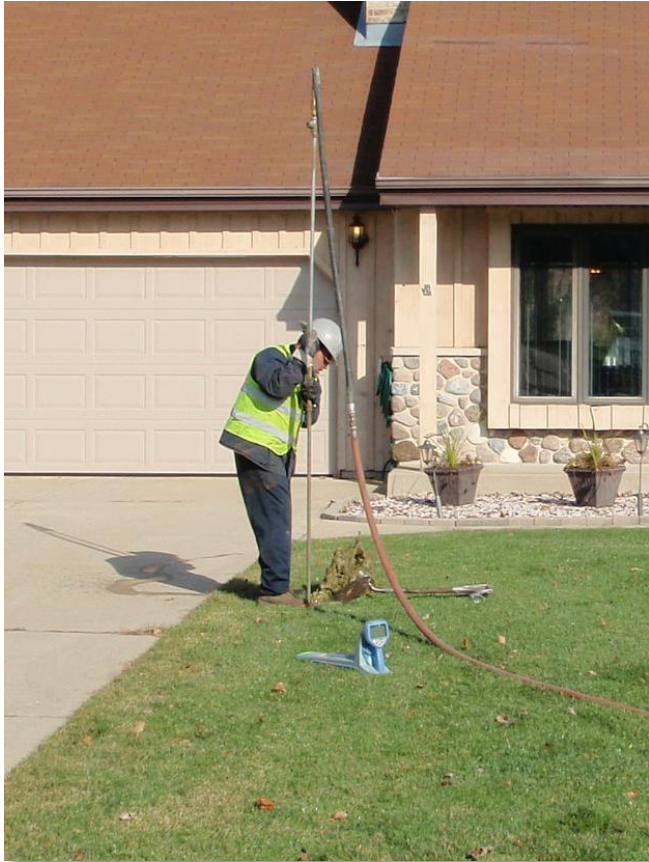
CCTV Plus Storm Sewer Dyed Water Test



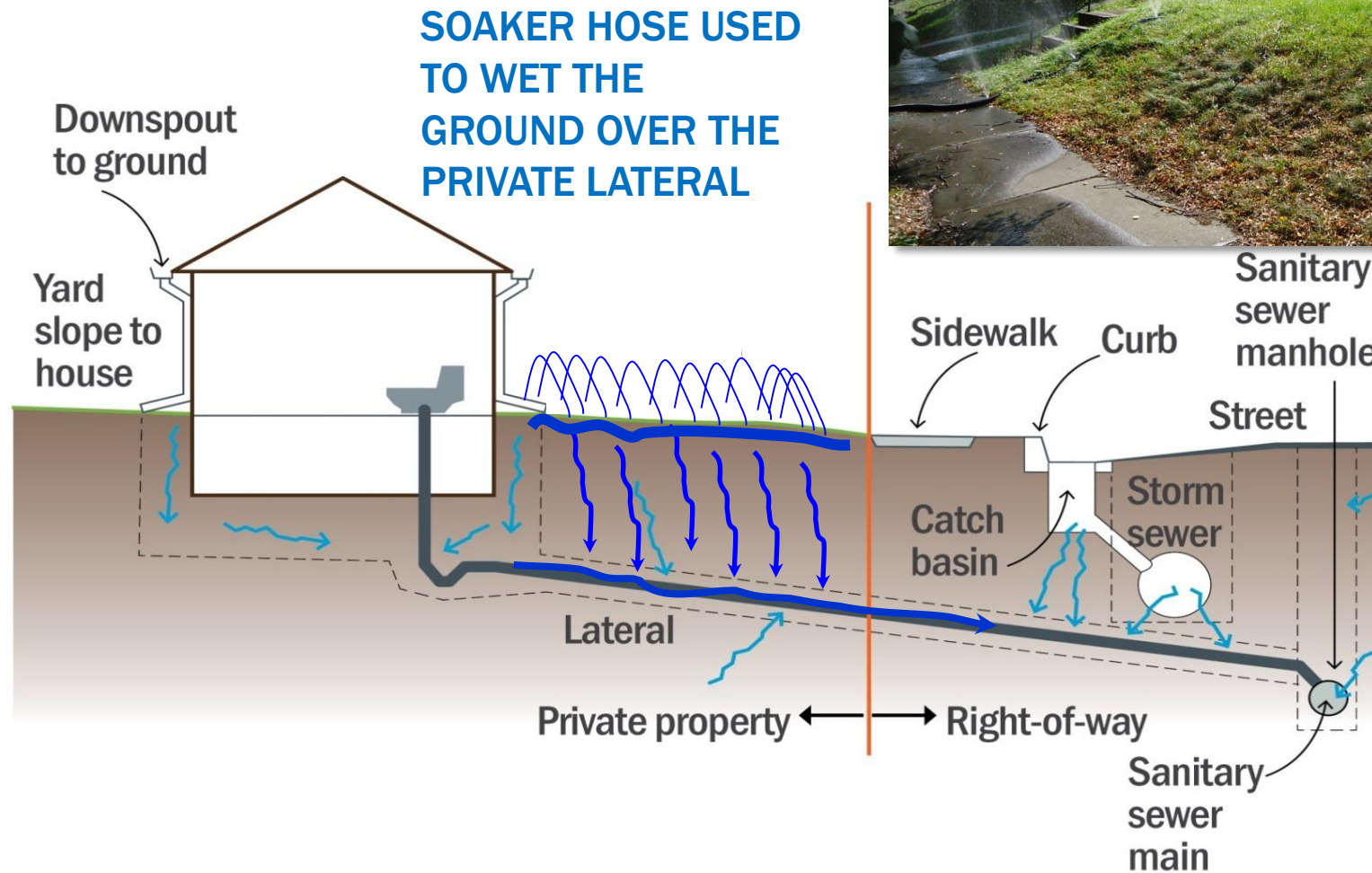
CCTV Plus Storm Ditch Dyed Water Test



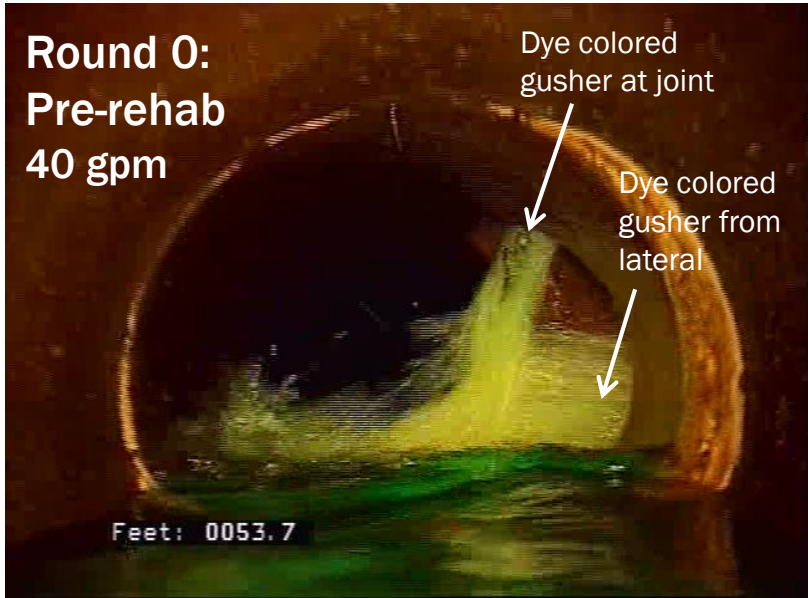
CCTV Plus Dye Injection Above Sewer Lateral



Soaker Hose Testing



Direct Observation



One moment in time

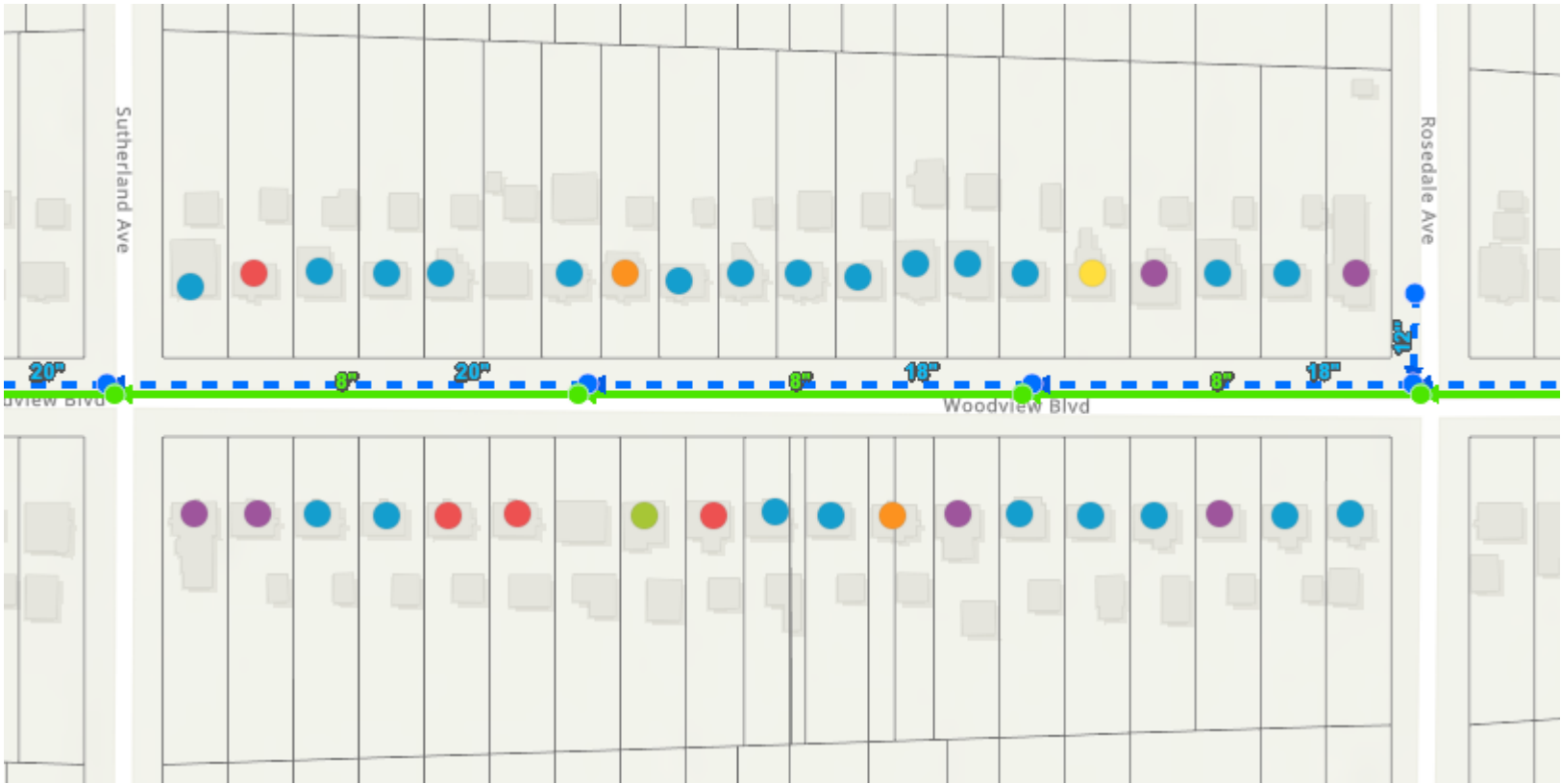


Round 1: New PVC sanitary main
and lateral connector stub

Round 2:
Priority Lateral After Targeted
Rehabilitation



House Downspout Test Results



RESIDENTIAL DYE TEST

- All Positive Rapid
- All Positive Light
- Mixed Positive Rapid or Light
- Mixed Positive and Negative (Rapid)
- Mixed Positive and Negative (Light)
- All Negative
- Sanitary Manhole
- Storm Manhole
- Sanitary Sewer
- Storm Sewer

Distributed Temperature Sensing (DTS)



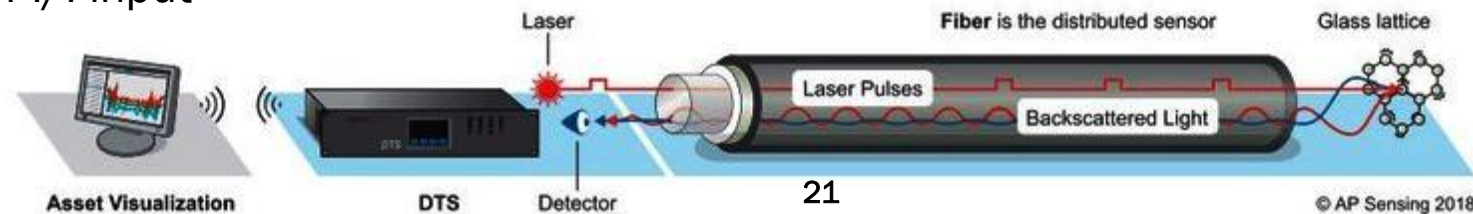
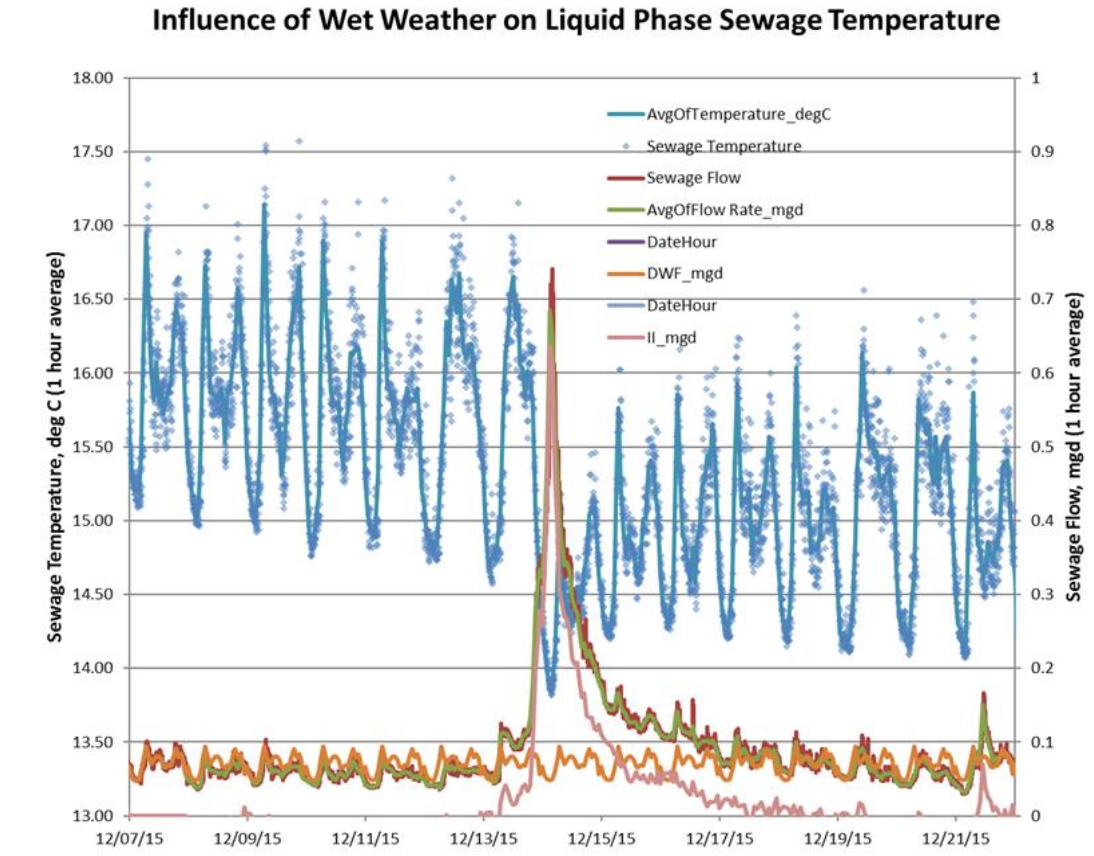
Flow monitoring data shows I/I can change sewage temps



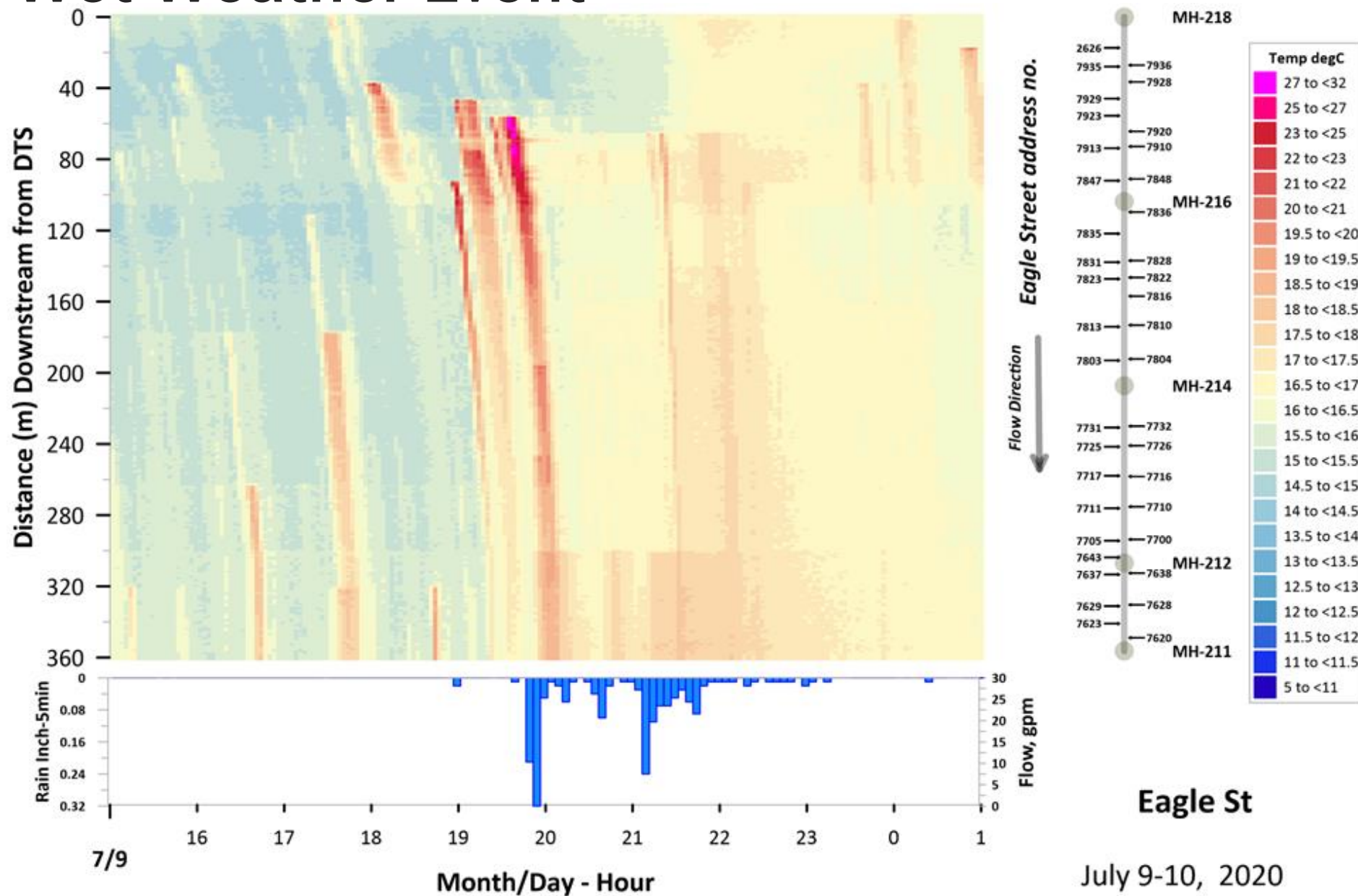
DTS studies in sewers:

Changes in temperature along the cable indicate location of I/I input

Magnitude of temperature change will indicate quantity of I/I input



July 9 Wet Weather Event

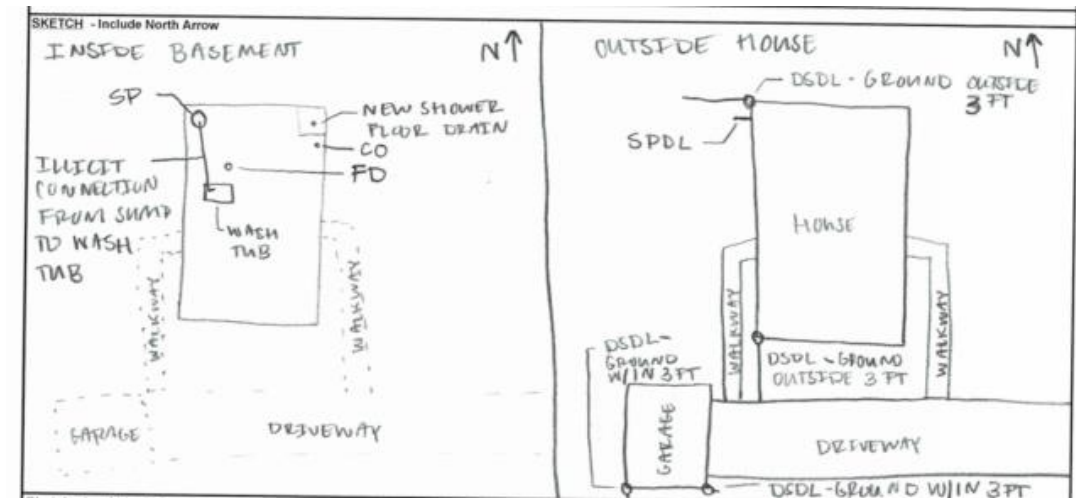


Internal/External Home Inspections

- Identify improper connections to the sanitary sewer system
- Review existing grading around property
- Identify points where clear water is entering the house
- Identify discharge location of downspouts



YEAR BUILT		1960
BUILDING USE		1F, 2F, 3F, 4F, COMMERCIAL, INDUSTRIAL, OTHER (CHURCH, SCHOOL), # OF APTS
1	PREVIOUS BASEMENT FLOODING	YES NO
2	SOURCE OF PREVIOUS BASEMENT FLOODING	FLOOR DRAIN SUMP PUMP FOUNDATION FLOOR WALLS WINDOW WELLS OTHER UNKNOWN X-NONE
3	FLOOR DRAINS	2 NUMBER OF FLOOR DRAINS X-NONE
4	PIPES ENTERING FLOOR DRAIN	0 NUMBER OF PIPES ENTERING FLOOR DRAIN X-NONE
5	PALMER VALVE IN FLOOR DRAIN	N YES NO X-NONE
6	CLEAR WATER (CW) SUMP CROCK CONDITION	W DRY WET PREVIOUSLY WET X-NONE
7	CW SUMP PUMP OPERABLE	Y YES NO OTHER X-NONE
8	PIPES INTO CW SUMP CROCK	2-T FLOOR DRAIN FOOTING TILE BOTH OTHER X-NONE
9	CW SUMP PUMP DISCHARGE LOCATION	B (A) TO SANITARY SEWER (B) GROUND W/IN 3' (FEET) (C) GROUND OUTSIDE 3' (FEET) (D) TO CURB (E) TO STORM SEWER (F) TO AREA DRAIN (G) UNKNOWN X-NONE
10	WASTEWATER (WW) SUMP CROCK CONDITION	X DRY WET PREVIOUSLY WET UNKNOWN X-NONE
11	WW SUMP PUMP OPERABLE	X YES NO OTHER X-NONE
12	WW SUMP PUMP DISCHARGE LOCATION	X GRAVITY TO SANITARY SEWER HUNG PIPE WITH PUMP X-NONE
13	INTERNAL CLEANOUT	Y YES NO UNKNOWN
14	DOWNSPOUTS	A TOTAL NUMBER OF DOWNSPOUTS X-NONE
15	DOWNSPOUTS ENTERING GROUND	0 NUMBER OF DOWNSPOUTS ENTERING THE GROUND X-NONE
16	DOWNSPOUT DISCHARGE LOCATION	2-C 2-B (A) TO SANITARY SEWER (B) GROUND W/IN 3' (FEET) (C) GROUND OUTSIDE 3' (FEET) (D) TO CURB (E) TO STORM SEWER (F) TO AREA DRAIN (G) UNKNOWN
17	ABANDONED DOWNSPOUT DISCHARGE	X SEALED UNSEALED OPEN X-NONE
18	YARD OR AREA DRAINS	X LAWN DRIVEWAY PARKING AREA STAIRWELL WINDOW WELL PATIO OTHER X-NONE
19	OBSERVABLE OUTDOOR CLEANOUTS	X NUMBER OF CLEANOUTS X-NONE
20	CONDITION OF CLEANOUTS	X SEALED UNSEALED CAP MISSING OTHER X-NONE



Questions on I&I Investigations?

I&I Removal Techniques

- Sanitary Sewer Mainline Replacement/Rehabilitation
- Manhole Replacement/Rehabilitation, including filling in pick holes
- Storm System Cross-Connection Removal
- Storm System Replacement/Rehabilitation
- Foundation Drain Disconnection
- Lateral Replacement/Rehabilitation
 - Open Cut Excavation
 - Lining
 - Pipe Bursting
 - Chemical Grouting
- Flood Grouting
- Improper Connections Removal
- Basement Window Replacement
- Downspout Disconnection



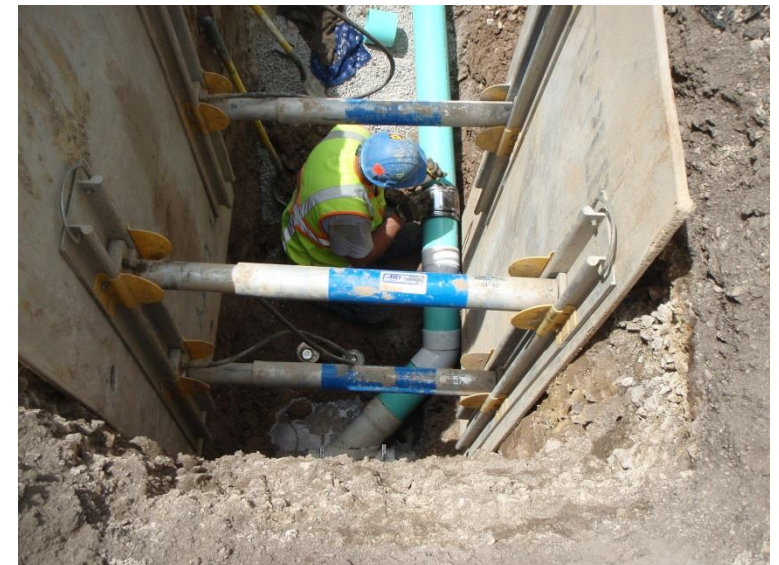
Manhole Rehabilitation

Foundation Drain Disconnection

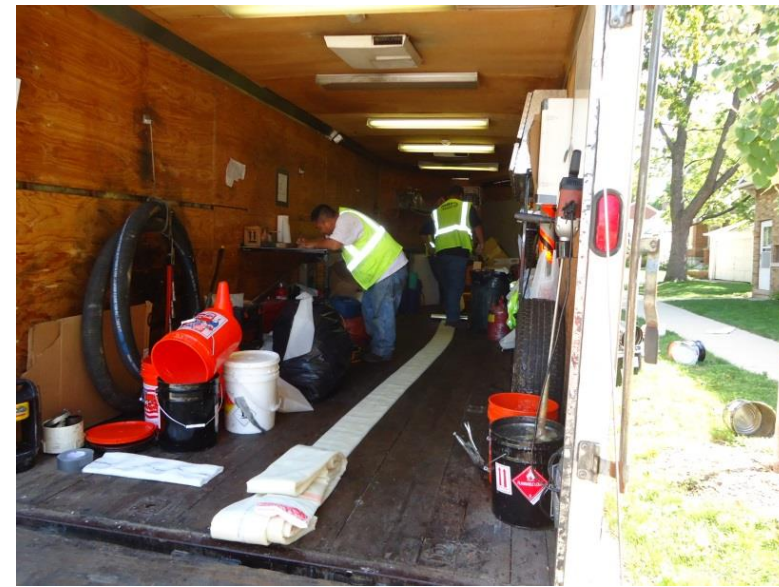
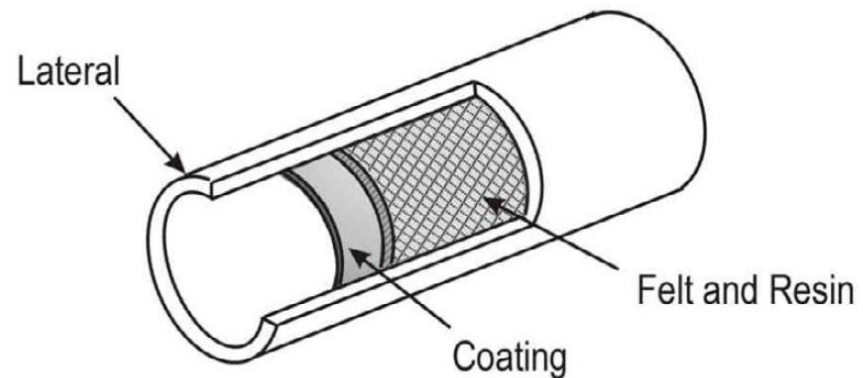
- Install a sump pump to collect water from around the house foundation
- Replace Palmer Valve
- Sump pump discharge
 - To a storm pipe (lateral)
 - Over the yard
 - To a rain garden



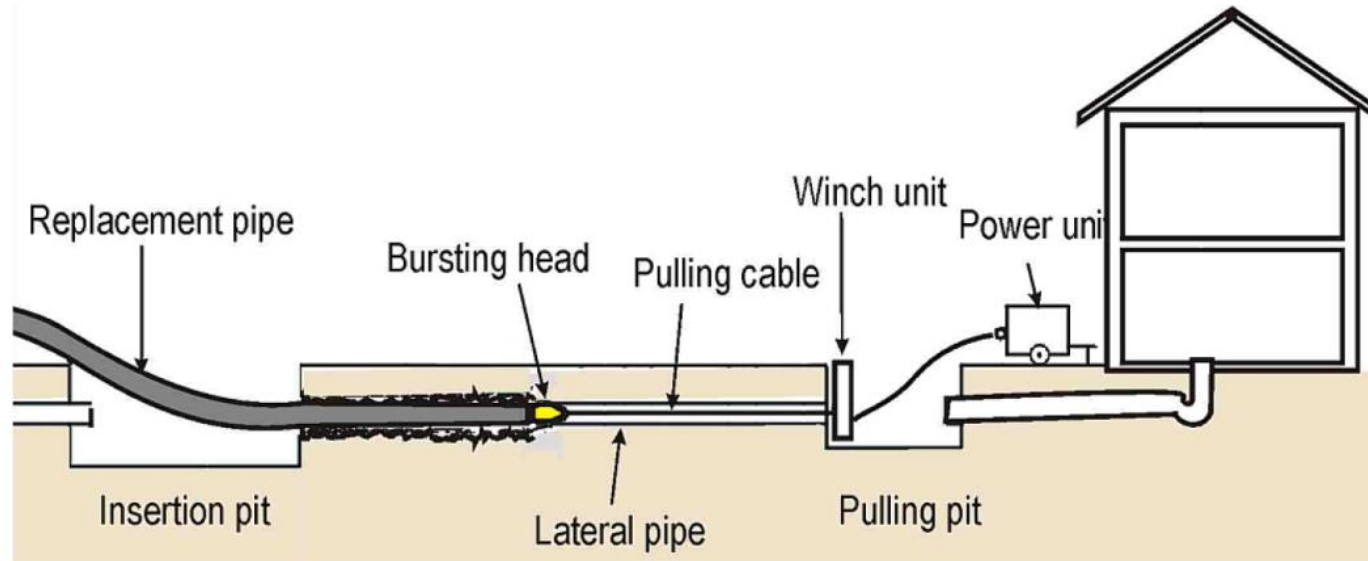
Lateral Open Cut Excavation



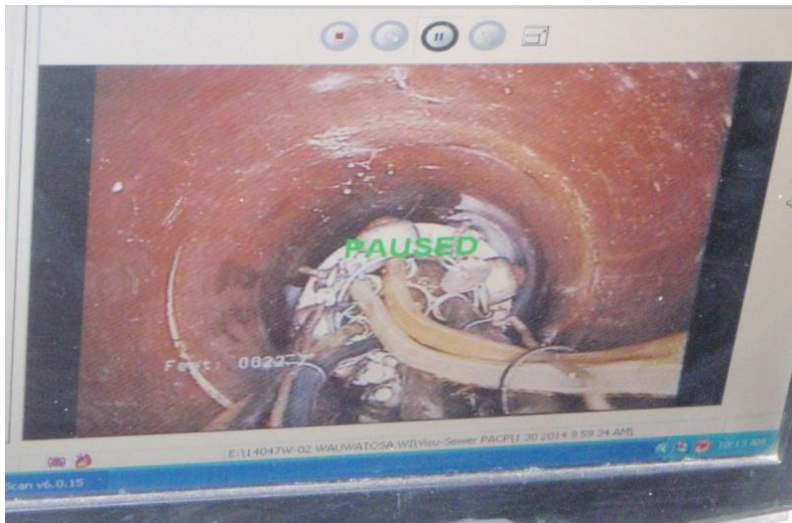
Lateral CIPP Lining



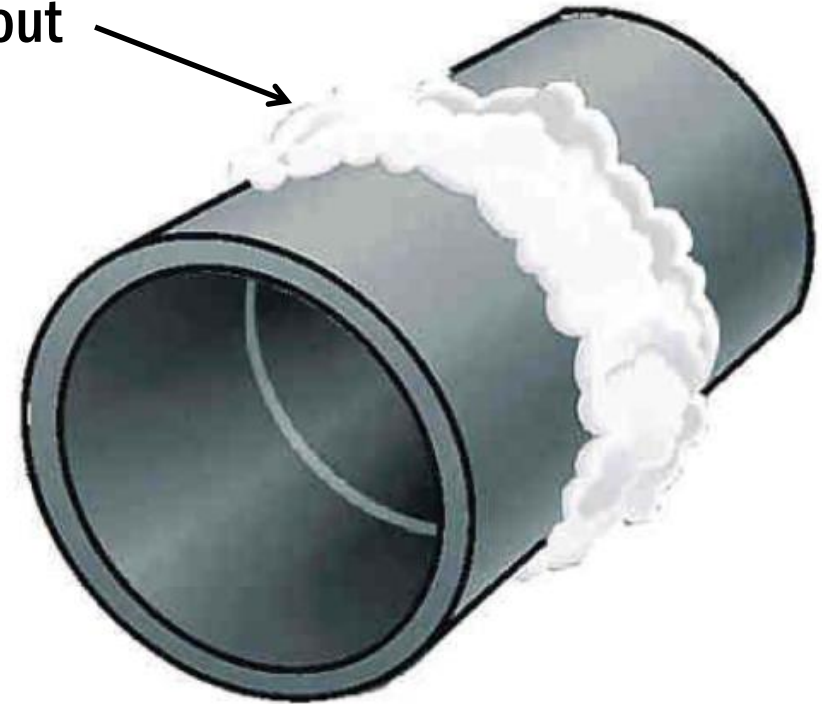
Lateral Pipe Bursting



Lateral Chemical Grouting



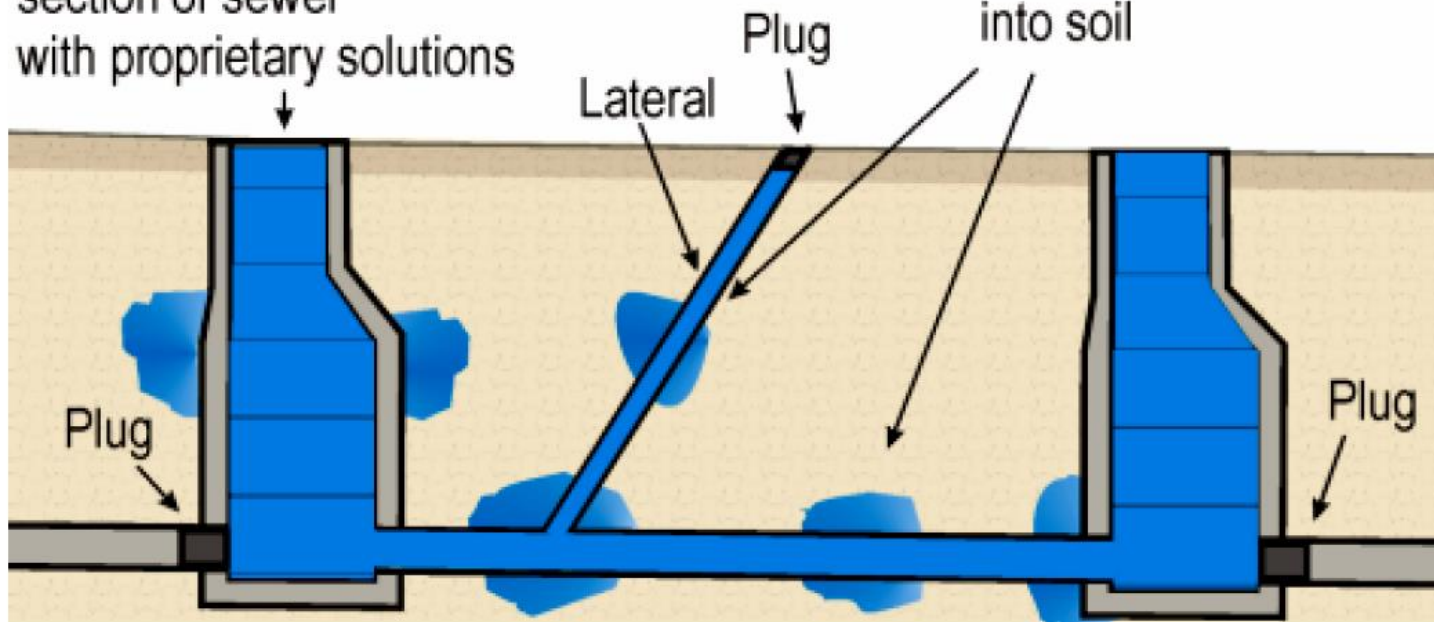
Chemical Grout



Flood Grouting

Flooding of an isolated section of sewer with proprietary solutions

Exfiltration into soil



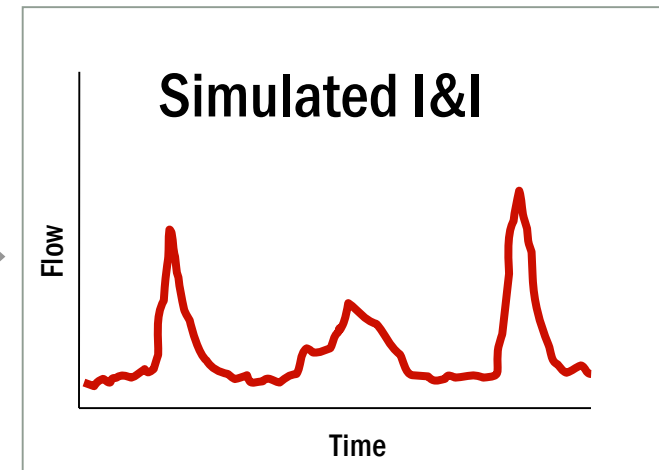
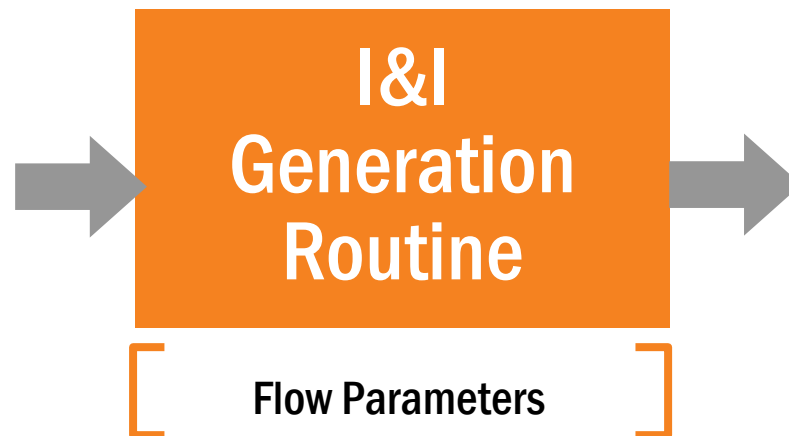
Questions on I&I Removal Techniques?

I&I Reduction Effectiveness Evaluation

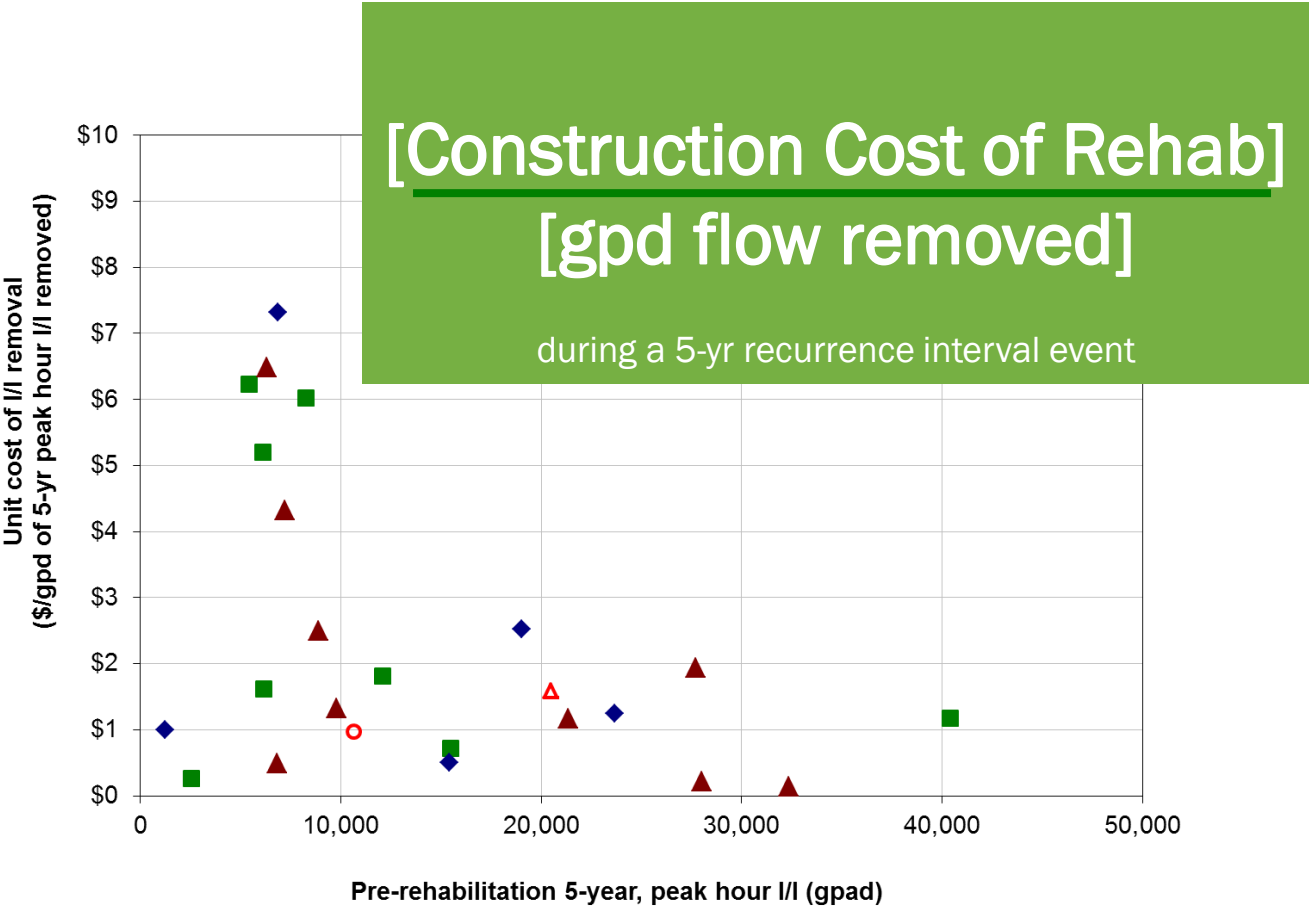
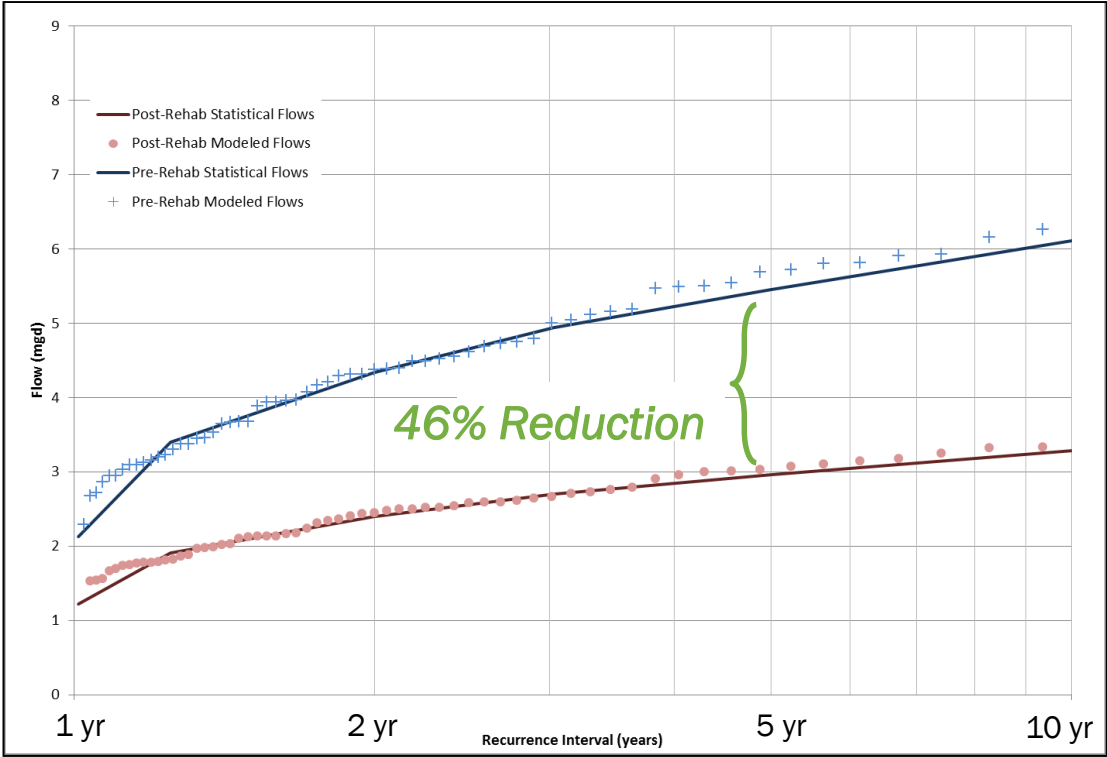
1. Determine if I&I reduction is happening
2. Identify the cost per unit of I&I reduction
3. Identify the residual I&I
4. Identify I&I reduction by phase, for construction projects with multiple phases
5. Distinguish between infiltration and inflow removed
6. Identify whether the flows are in compliance



Rainfall Record



I&I Reduction Effectiveness Evaluation



Questions on I&I Effectiveness Evaluations?

I&I Case Studies

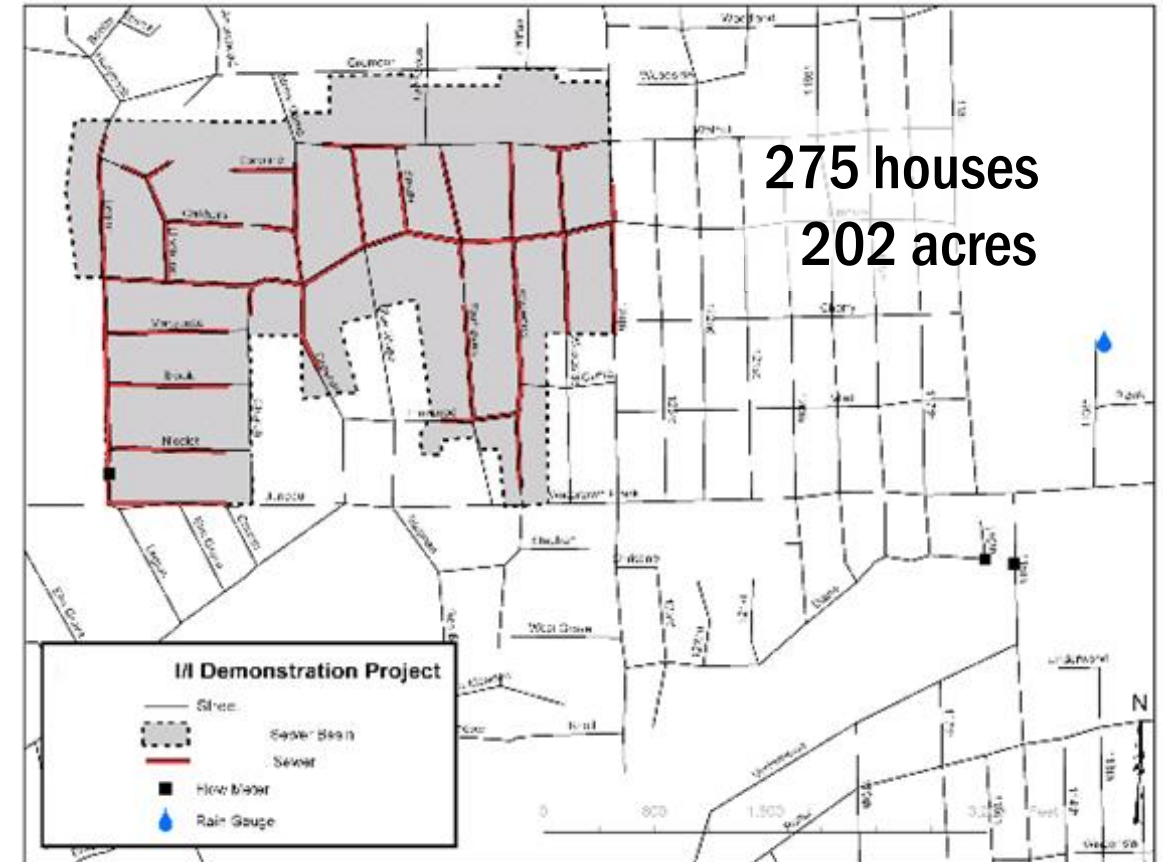
Case Study A



- Investigations
 - Flow monitoring
 - Lateral televising with dye injection
 - Internal and external house inspections
 - Cost of \$17,000
- Construction
 - 24 lateral CIPP (at least 50 feet)
 - 2 lateral excavated spot repairs
 - 6 lateral replacements
 - Removed sump pump connections to sanitary sewer
- \$240,000 total construction cost

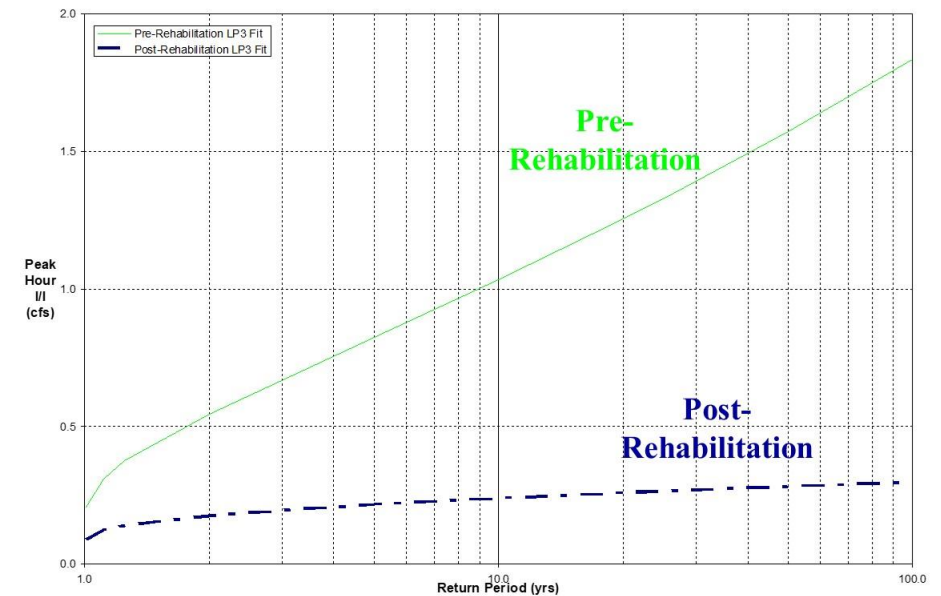
Case Study B

- Construction:
 - Phase 1: Relayed/lined over 1,500 LF of 8- to 12-inch sanitary sewer, tested and sealed nearly 1,300 joints, and sealed lateral connections
 - Phase 2: Added polyurea coating to 38 manholes and epoxy coating to 43 manholes (81% total)
 - Phase 3: Lined 17 laterals (6%) of the laterals in the basin
- \$359,000 total construction cost
- No I&I Reduction



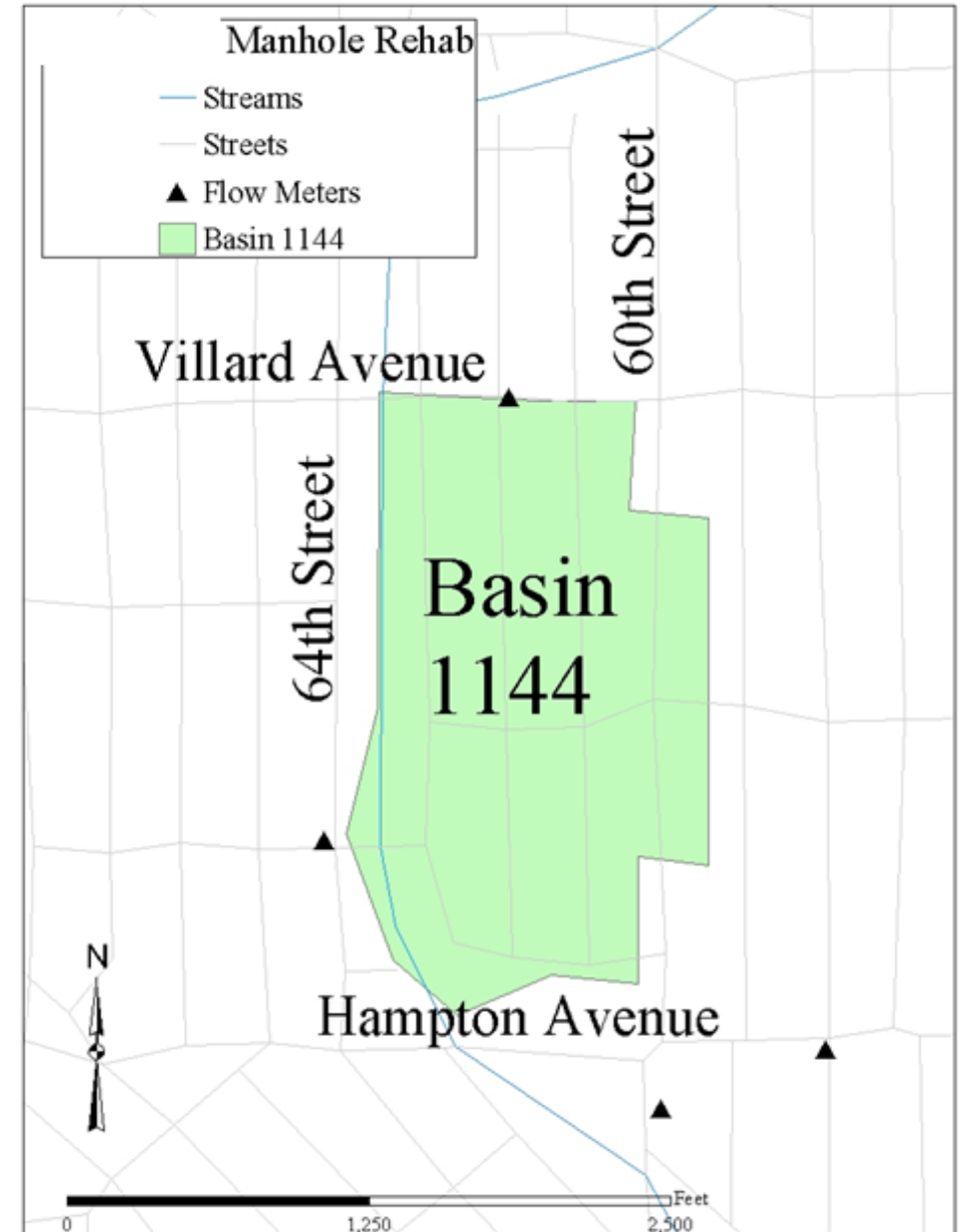
Case Study C

- Investigations
 - Flow monitoring
 - Televising with dye injection
- Construction
 - Lined 1,350 feet of 12-inch storm sewer
 - 231 LF of catch basins
 - 100% of the storm sewers and manholes in the basin
- \$59,000 total construction cost
- 74% reduction in 5-year peak hour I&I



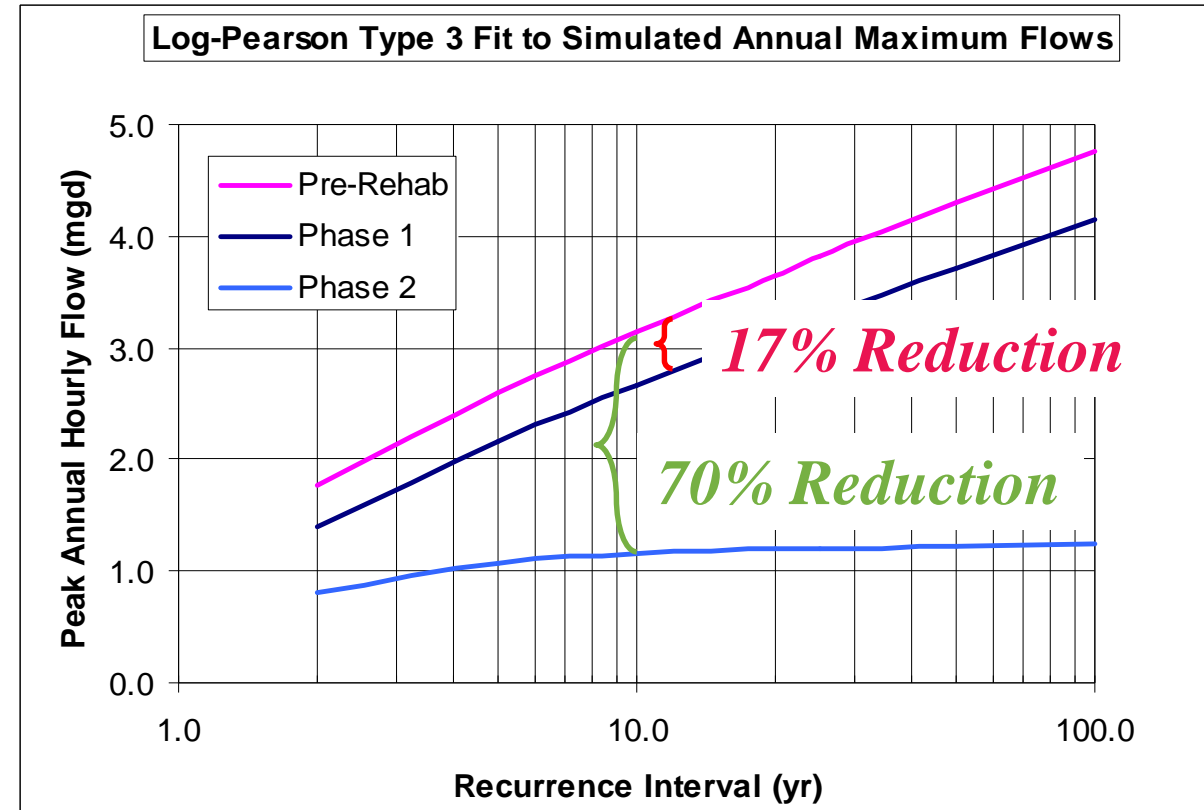
Case Study D

- Investigations
 - Manhole inspections
 - Smoke testing
 - Sewer CCTV
 - Building inspections
- Construction
 - Manhole rehab (solid manhole lids, plugging lids, repairing internal seals, and repairing brickwork, installing internal seals)
- Manholes adjacent to a stream, which would flood manholes
- \$11,000 total construction cost
- 60% reduction in 5-year peak hour I&I



Case Study E

- Investigation
 - Flow monitoring and analysis before and after each phase of work
- Construction
 - Phase 1 – public system rehab plus lateral in right-of-way
 - Phase 2 – private system rehab of laterals and a few roof drains
- \$2.8 million total construction cost (2002)
- Public system rehab accomplished 17% peak flow reduction
- Private system rehab improved peak flow reduction to 70% from original



268 houses
130 acres

Lessons Learned

- Private property has a substantial amount of I&I
- More area rehabilitated typically results in more I&I reduction
- It is more cost-effective to rehabilitate areas with higher I&I to begin with
- Flow monitoring is important for isolating the problem area and quantifying the effectiveness of I&I reduction efforts

Questions on Case Studies?

Next Steps



Thank you.
Questions?

