How to Effectively Reduce Collection System I&I Flows

Presented by
Rich Gushman, PE

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I&I Presentation Topics

- Definition and Sources
- History of Removal
- What is excessive
- Pipe materials and age help identify effective I&I removal opportunities
- The impact of side sewer laterals
- Prioritizing system or basin wide removal
- Effective I&I removal project example

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I & I = Inflow & Infiltration

- **Inflow is storm (surface) water that enters the sewer system** during rainfall events or as snow melt occurs.
  - Inflow may come from sources on both private and public property.
  - Inflow is more directly related to storm events.
  - Specific events last for a short period of time (from hours to a few days).

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I & I = Inflow & Infiltration

- **Infiltration is groundwater that enters the sewer system** through defective manhole joints, deteriorated sewer main lines and side sewer pipelines. Infiltration tends to be slower to enter the collection system and therefore it can last for a prolonged period.
  - **Groundwater sources include:**
    - Precipitation moving through the soil and into shallower pipes as it flows toward the groundwater table.
    - Deep sewer lines (groundwater enters sewer lines from groundwater table)

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Bucket Analogy

- An analogy for how to achieve effective I&I removal is to compare a sewer collection/conveyance system to a bucket.
- What happens with a bucket with thousands of holes if it is partially submerged in water – it quickly fills up.
- If some of the holes are patched, flow into the bucket is slowed but not significantly reduced until nearly all the holes are plugged.
- If you think of a sewer system as the bucket with holes in it, most of the holes in the sewer system also have to plugged before meaningful I&I reduction is achieved.

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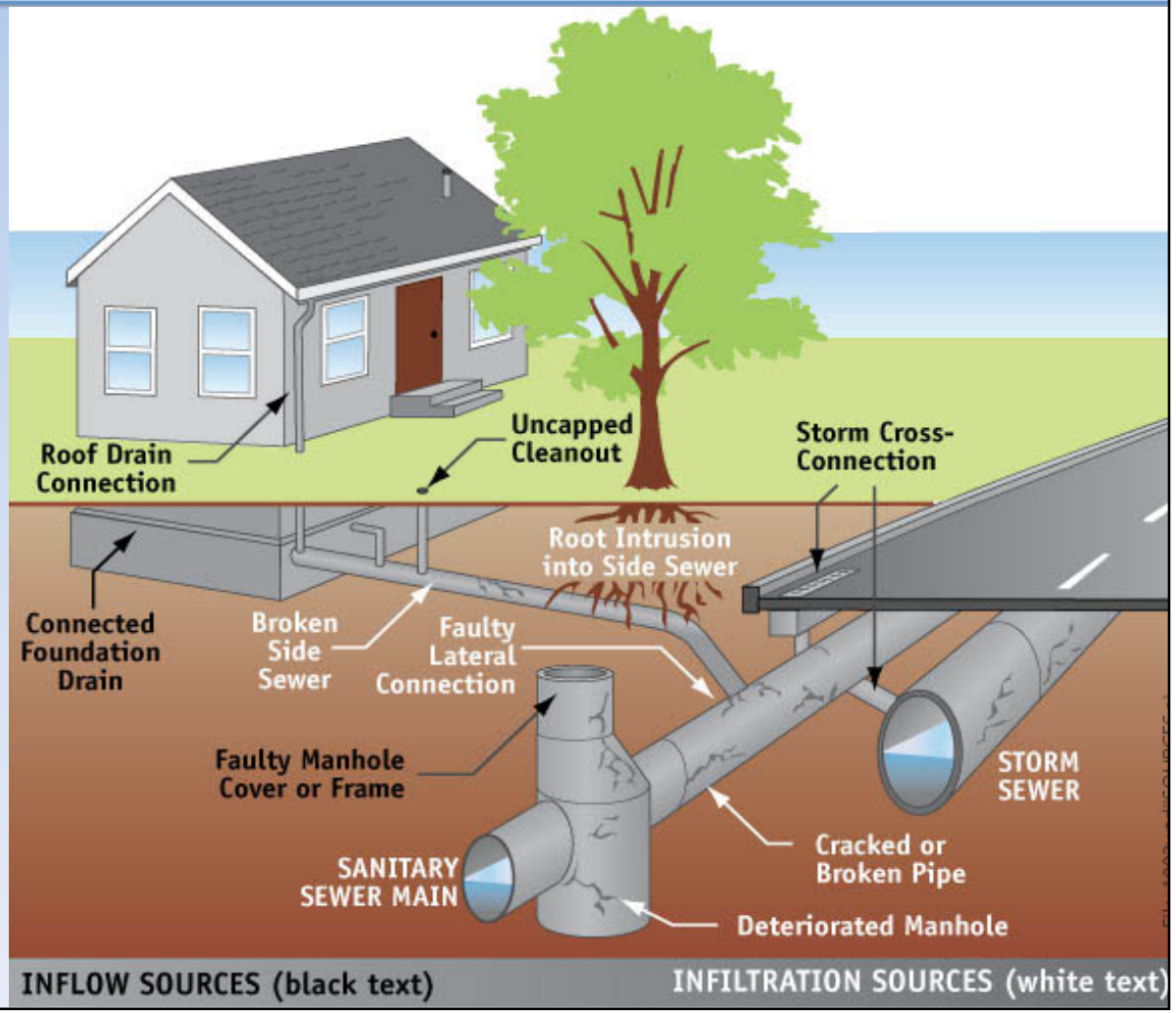
Typical Sources of I & I

- I&I is commonly expressed in gallons per acre per day.
- No collection system is ever completely free of I&I
- No rehabilitation program will ever completely eliminate I&I.

Graphic Source - King County Website
http://www.kingcounty.gov/environment/wastewater/II/What.aspx



History of I&I Removal

- Removing I&I from sewer systems gained momentum in 1972 after Congress passed Public Law 92-500.
- Initial I&I removal goals included removing excess I&I flows to allow smaller WWTP's to be constructed.
- In 1972, I&I removal was a new concept
  - Most I&I removal programs completed in the 1970's and early 1980's were not very successful in obtaining their goal.
- Current I&I removal programs focus on reducing flow to extend the existing WWTP's useful life.

History of I&I Removal

- Poor I&I reduction results from the 1970's and early 1980's occurred because:
  - Lack of understanding about the extent and various causes within most collection systems
  - Failure to require property owners to replace side sewers on private property
  - Repairs often involved correcting only isolated leaks or replacing individual lines or small groups of lines, and
  - Often only chemical grouting of "defective" joints and cracks was done rather than sewer line and manhole replacement and/or repair.

What is Excessive I&I

- Risk of public health and safety from collection and treatment system overflows/high flows.

Photo source – City of Portland Bureau of Environmental Services http://www.portlandoregon.gov/bes/article/362812

What is Excessive I&I

Another way to consider if I&I is excessive

- If cost to transport and treat the flow exceeds the cost to reduce.
  - Additional capital costs for larger piping, pumps, and treatment plant units (including higher energy, chemical and maintenance costs) compared to the cost to reduce I&I through collection system rehabilitation or reconstruction.
  - Additional on-going O&M costs – higher energy, chemical and maintenance costs – also need to be considered in this evaluation.
- Compare life cycle or PW costs for transport/treatment versus collection system work to reduce I&I.

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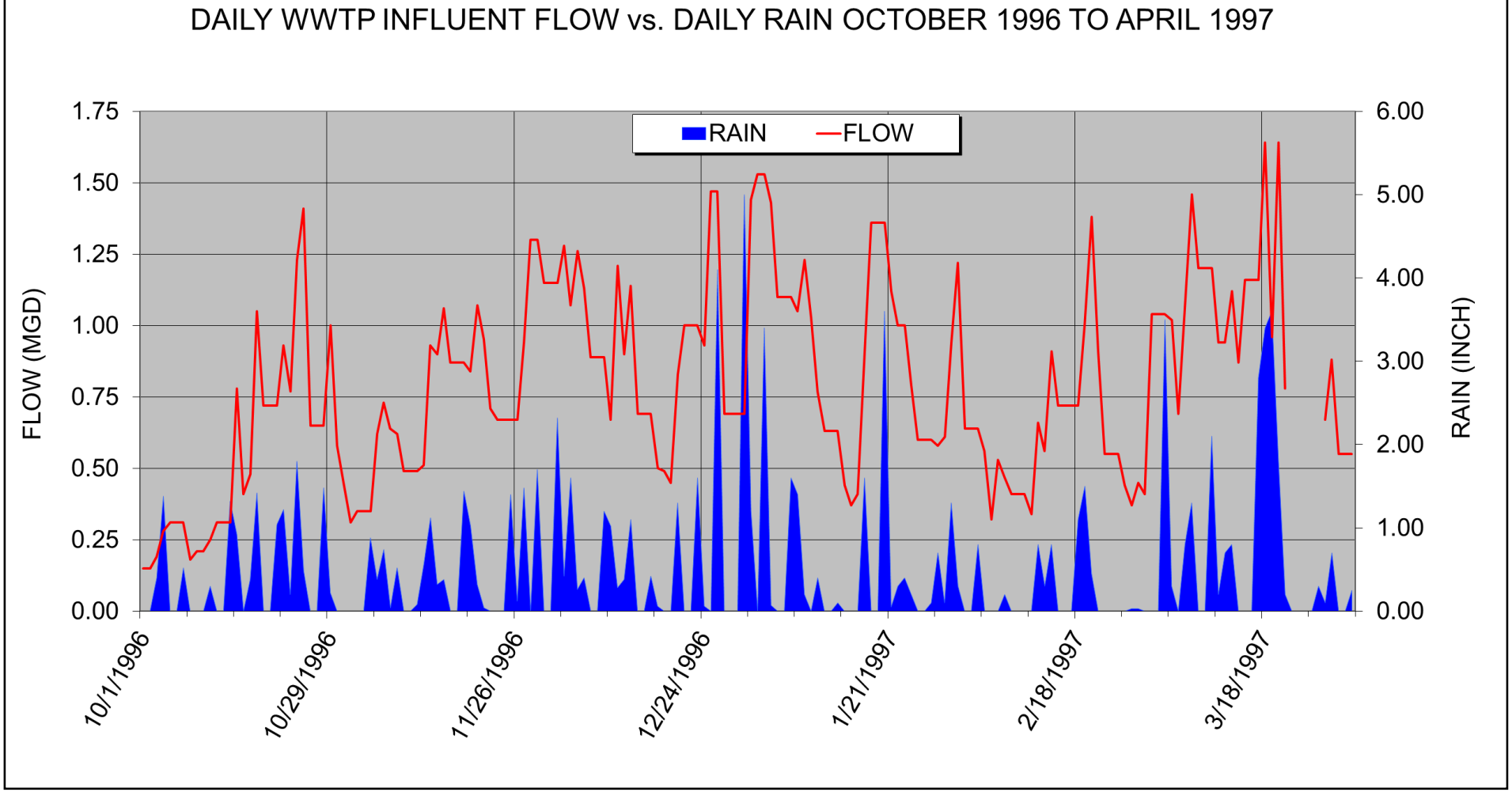
Flow & Rainfall Data | Ryderwood, WA



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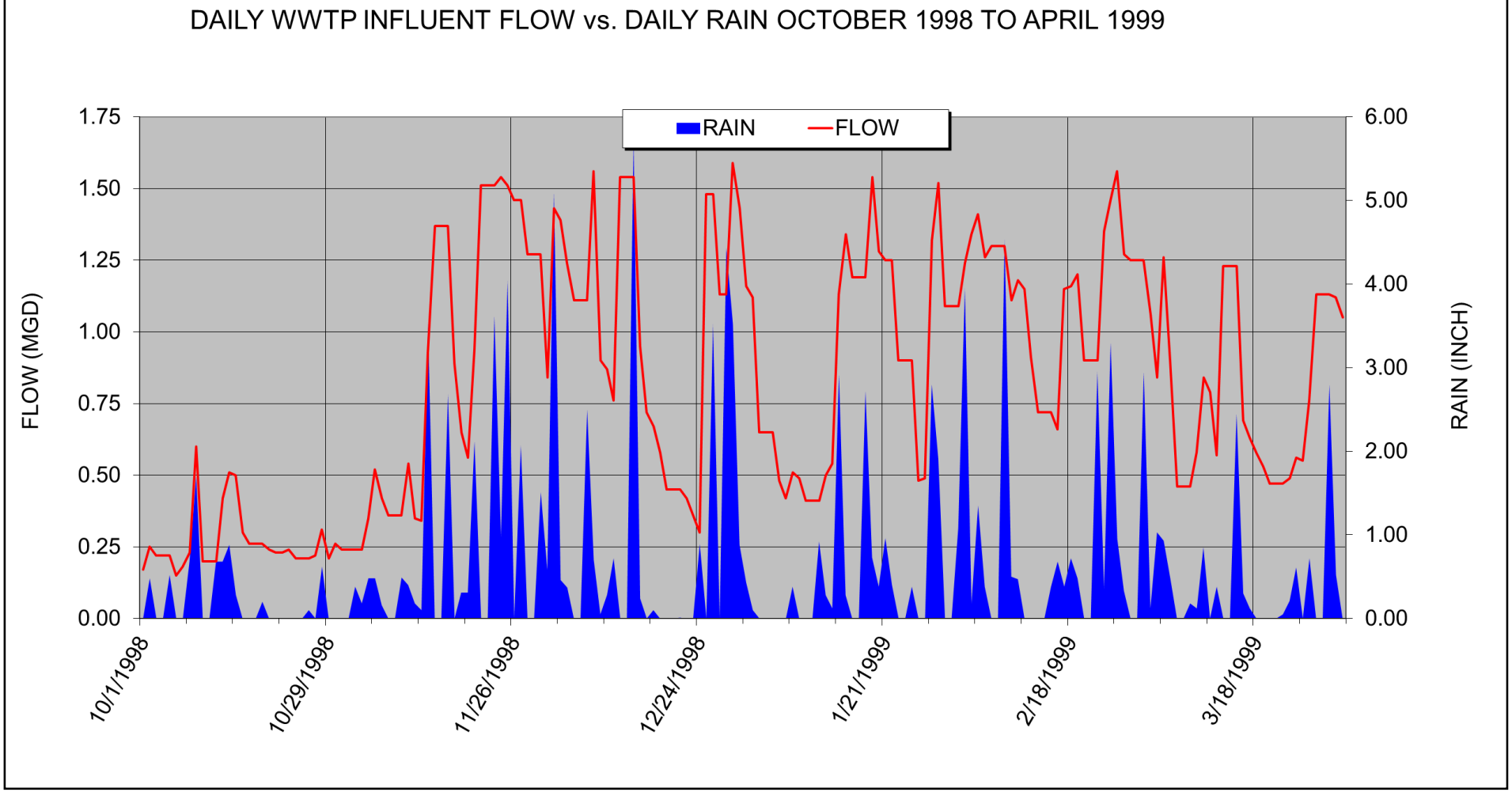
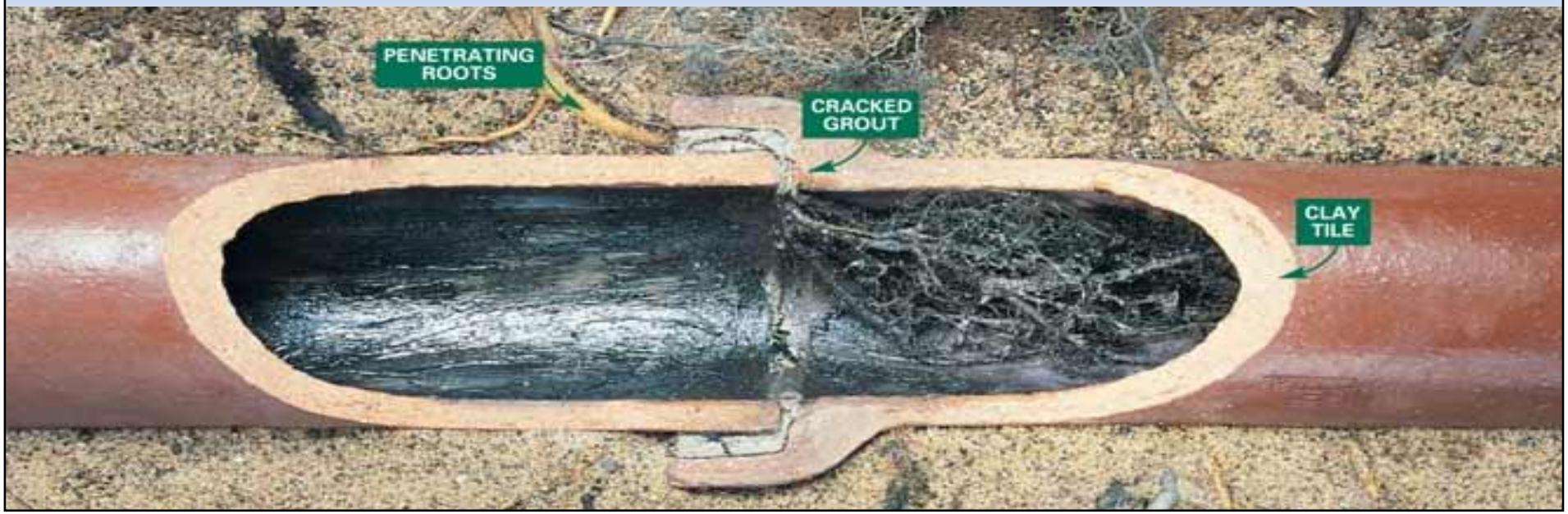


Pipe Material & Age

- Prior to the 1960's most sewer mainline pipe was constructed of concrete, clay, or asbestos cement (AC) pipe
- Pipe lengths were as short as 3-feet = LOTS OF JOINTS (bucket holes)!
- Joints were commonly "sealed" with cement grout or tar.



Pipe Material & Age

- These pipe materials have a high joint failure rate (90%-100%)
- Continued deterioration of pipe joints creates an under drain system for the overlying soil profile. These pipelines are certain to be significant sources of infiltration.
- Concrete and AC pipe w/ rubber gasketed joints began being installed in the 1960's. PVC started being used in the 1970's.
- Rubber gasketed joints and longer PVC pipe lengths (less joints – less bucket holes) – are significantly better at keeping infiltration from entering the system.

Sample of Fiber or “Orangeburg” Pipe

- Majority of private property side sewer pipes constructed between 1948-1972 were installed using fiber or “Orangeburg” pipe.

Sample of Orangeburg Pipe, 4" Diameter (AZ Water Collection System History Exhibit),
Source: Department of Public Works, City of Orangeburg, SC. Courtesy of William Zorn. Photograph by Jan McDonald.

Fiber Pipe

- Made from bituminous fiber of asphalt impregnated layers of wood pulp and pitch, rolled and pressed under high pressure into a pipe, essentially a pipe made of tar paper.
- Deforms over time, water exposure weakens pipe.
- As pipe deteriorates; clogging, tree root intrusion, and total pipe collapse can occur.
- Significant source of infiltration with a failure rate between 70%-100%
  - If you have any remaining side sewers in your system with this type of pipe replacement should be a high priority.

PVC Pipe

- Most main lines and side sewers installed since the 1970's are PVC with rubber gasketed joints (side sewers often use glued joints).
- An occasional joint failure can occur if a gasket is improperly seated during construction. Generally found when pipelines are air tested.
- Most common sources of infiltration in systems with this type of pipe and joints are:
  - Connections at manholes
  - Connections of side sewers at the property line
- Although sewer lines, even new lines, cannot be made 100% "water-tight", rubber gasketed PVC pipe has demonstrated extremely low infiltration rates over the past 40 years.

Lessons Learned | Pipe & Joint Type

- 1988 West Longview Pilot Study performed by Gibbs & Olson for the City of Longview, Washington
- Study goal was to determine which types of main line sewer pipes were most likely to experience infiltration.
- Joints were air tested on main lines and private property side sewers
  - Concrete pipe w/ tar filled joints installed in the 1950's – 92% failure rate
  - Concrete pipe w/ rubber gasketed joints installed in 1960's – 4% failure rate
  - AC pipe w/ rubber gasketed joints – 3% failure rate
  - PVC pipe w/ rubber gasketed joints – 0% failure rate
  - Side sewers w/ fiber pipe – 72% failure rate

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Lessons Learned | Side Sewer Impacts

- 1994 LOTT I&I Removal Study performed by Gibbs & Olson
  - Identified three types of infiltration: Immediate, Near term, and Long-term
    - Immediate – causes the sewer system to experience a rapid increase in flows in response to a storm event.
    - Near term – infiltration that enters the system over a period of days after a specific storm event
    - Long-term – infiltration that enters the system slowly and is influenced by high groundwater levels and rainfall for several previous months
  - Study also indicated that if private property side sewers are not addressed as part of the I&I removal effort, the amount of I&I removed will be significantly lower.

Lessons Learned | Side Sewer Impacts

- 1997 City of Olympia I&I Removal Project – 2 Phase Project
  - Goal to determine effectiveness of replacing main line and side sewers from the main to property line vs. replacing private property side sewers
  - Extensive flow monitoring was conducted before, during and after the sewer rehabilitation work was completed.
  - Phase 1 replaced only main line and side sewers from the main to the property line. This resulted in:
    - Reduced peak hourly flow by 17%
    - Reduced peak day flow by 32%
    - Reduced peak month flow by 64%

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Lessons Learned | Side Sewer Impacts

- 1997 City of Olympia Removal Project – 2 Phase Project
- Phase 2 replaced only private property side sewers. This resulted in:
  - Reduced peak hourly flow from 17% to 67%
  - Reduced peak day flow from 32% to 58%
  - Reduced peak month flow remained at 64%
- Results of the Olympia project demonstrated
  - Peak hour and peak day I&I enters sewers through shallow sewer lines and that private side sewers are a significant source of I&I
  - Peak month I&I is from elevated groundwater table and dewatering the soil profile above the mainline pipe

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Lessons Learned | Side Sewer Impacts

- King County Regional I&I Control Program Pilot Project
  - 6 Year Study from 1999-2004 – goals were to:
    - Identify sources of I&I
    - Identify methods of reduce I&I
    - Identify the most cost-effective I&I reduction strategies
- Included pre and post flow monitoring to document effectiveness of implemented I&I reduction measures

Source: http://www.kingcounty.gov/environment/wastewater/II/Resources/Reports/AlternativeOptions.aspx

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Lessons Learned | Side Sewer Impacts

King County Regional I&I Control Program Pilot Project

Component	Origin	Ownership
Fast Response Inflow	Direct connection of stormwater sources	Private/Public
Rapid Infiltration	Leaking side sewers & shallow sewer mains, sump pumps, foundation drains, manhole chimneys, and connected storm drains	Private/Public
Slow Infiltration	Leaking deeper sewer mains, manholes & deep laterals	Public
Base Infiltration	Deep sewer mains & MH bases	Public

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Lessons Learned | Side Sewer Impacts

- King County Regional I&I Control Program Pilot Project
  - Modeling completed in 2003 & 2004 for approx. 800 mini-basins
    - 85% of total 20-year peak I&I is either fast response inflow (52%) or rapid infiltration (33%) – strong indication that private property sources account for significant portion of I&I.

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Lessons Learned | Side Sewer Impacts

- King County Regional I&I Control Program Pilot Project
  - Private Property I&I Reduction Effectiveness
    - Nearly 100% of private property side sewers replaced in the Kent pilot basin with a 78% reduction in basin's total 20 year peak I&I flow
    - Approx. 72% of private property side sewers replaced in the Ronald pilot basin with a 74% reduction in basin's total 20 year peak I&I flow.

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Attorney General Ruling | Side Sewers

- Washington Attorney General's Office issued an opinion on August 27, 2009 indicating municipal sewer districts have statutory authority to use public fund to repair/replace side sewers located on private property if doing so will increase sewer capacity by reducing infiltration and inflow.

http:www.atg.wa.gov/AGOOpinions/Opinion.aspx?section=archieve&id=23724

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Working with Private Property Owners

- Inform owners of expected failure rates and costs to test their side sewer.
- Determine type of side sewer through age of residence, building permit or by potholing.
- An approach that has worked well in on past projects in Kelso & Chehalis once side sewer determined, then property owner decides if they want tested
- If side sewer passes test, utility pays for testing.
- If side sewer doesn't pass, owner pays for testing and replacement of the side sewer.

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Working with Private Property Owners

- Replacement costs for private property side sewers are variable.
  - Length and depth of pipe (generally 2-5 feet deep).
  - Type and extent of landscaping or other improvements over the line.
  - Topography of the site
  - If the property owner does the work or hires a contractor.
    - If property owner replaces cost can be less than $1,000.
    - If contractor is hired costs typically range between $1,500-$3,000
      - Other projects have indicated side sewer replacement costs of $5,000-6,000

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Preliminary Screening Hierarchy

- Mainlines, manholes and side sewers installed prior to 1960
- Side sewers – both public and private portions - installed prior to 1972
- Concrete pipe and AC pipe installed in the 1960s and 1970s
- Mainlines and side sewers constructed of PVC will typically not be considered for I&I removal.

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Prioritizing I&I Removal

- Approach to I&I Removal in Large Collection Systems
  - Divide into smaller basins and conduct flow monitoring to determine the I&I from each basin.
  - Opinions of cost are prepared for each basin and basin are then prioritized (least to most expensive).
  - Cost of removal is then compared with cost of treatment.
  - If I&I removal is shown to be cost effective then work is started in the most cost effective basin. All work is done within this basin before moving to the next basin.
  - If I&I is widespread then may want to focus on first replacing side sewers, then replacing the more expensive main lines.

Prioritizing I&I Removal

- Recommended that initial flow monitoring and opinions of cost be performed to establish a systematic approach to I&I removal.
  - This data can help demonstrate to governing bodies, funding sources, and the general public that the “biggest bang for the buck” is achieved.
  - This data can also be utilized after project completion to document the amount of I&I removed.

Prioritizing I&I Removal

- Once a decision is made to move forward with rehabilitation or replacement of the sewer system in a basin additional investigation may be necessary:
  - Review of the basin's pipe system inventory
  - Smoke testing & dye testing to locate defective MH's, storm drain connections, and defective side sewers.
  - TV inspection of pipelines to identify/verify active side sewers, joints with root intrusion, sections of mainline with structural damage & storm connections

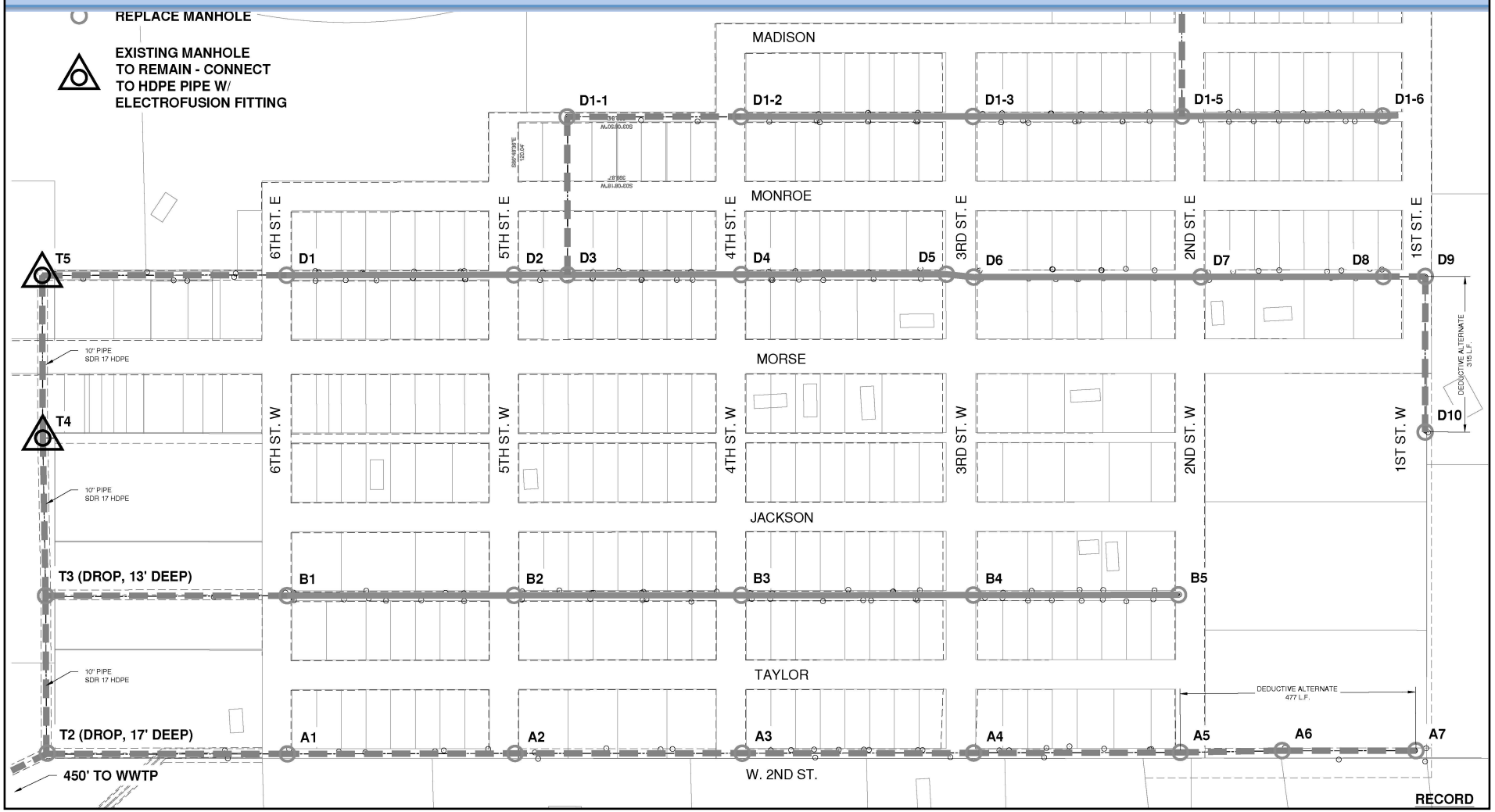
Source: http://www.portlandoregon.gov/bes/article/362812

Prioritizing I&I Removal

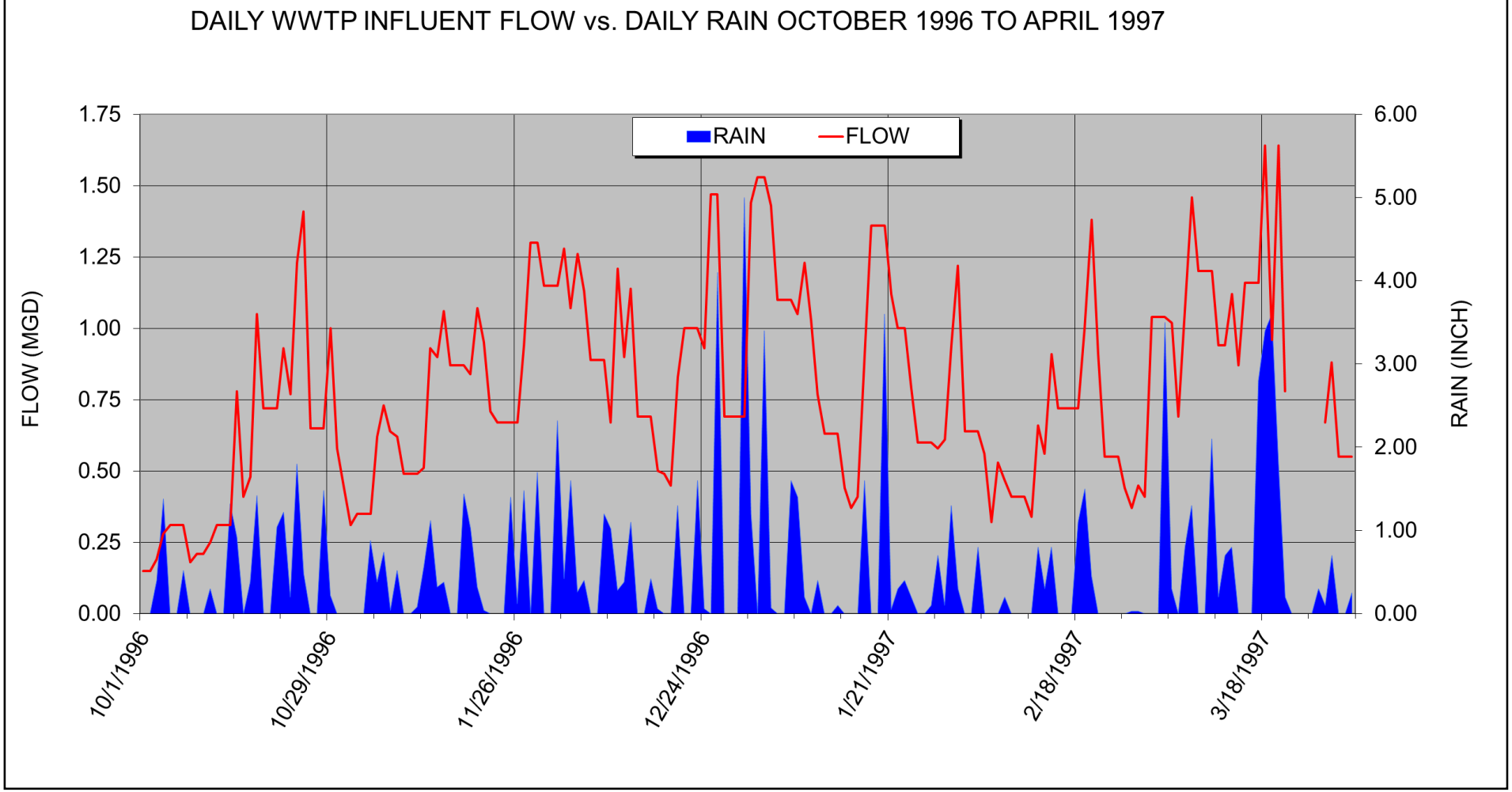
- During the preliminary design of each rehabilitation project, other construction methods of sewer system construction, in addition to dig and replace, should be considered.
- These include pipe bursting, and cured in place pipe liners.
- For the most part, these technologies are more expensive when large quantities of pipe are scheduled to be replaced.
- These technologies are generally more applicable where difficult site conditions either prevent the use of dig and replace construction, or cause the replacement cost to be excessive.
  - Pipe bursting with HDPE pipe can also be cost effective for smaller diameter and shallower private property side sewers

Effective I&I Removal Project Example

Effective I&I Removal Project Example



Effective I&I Removal Project Example



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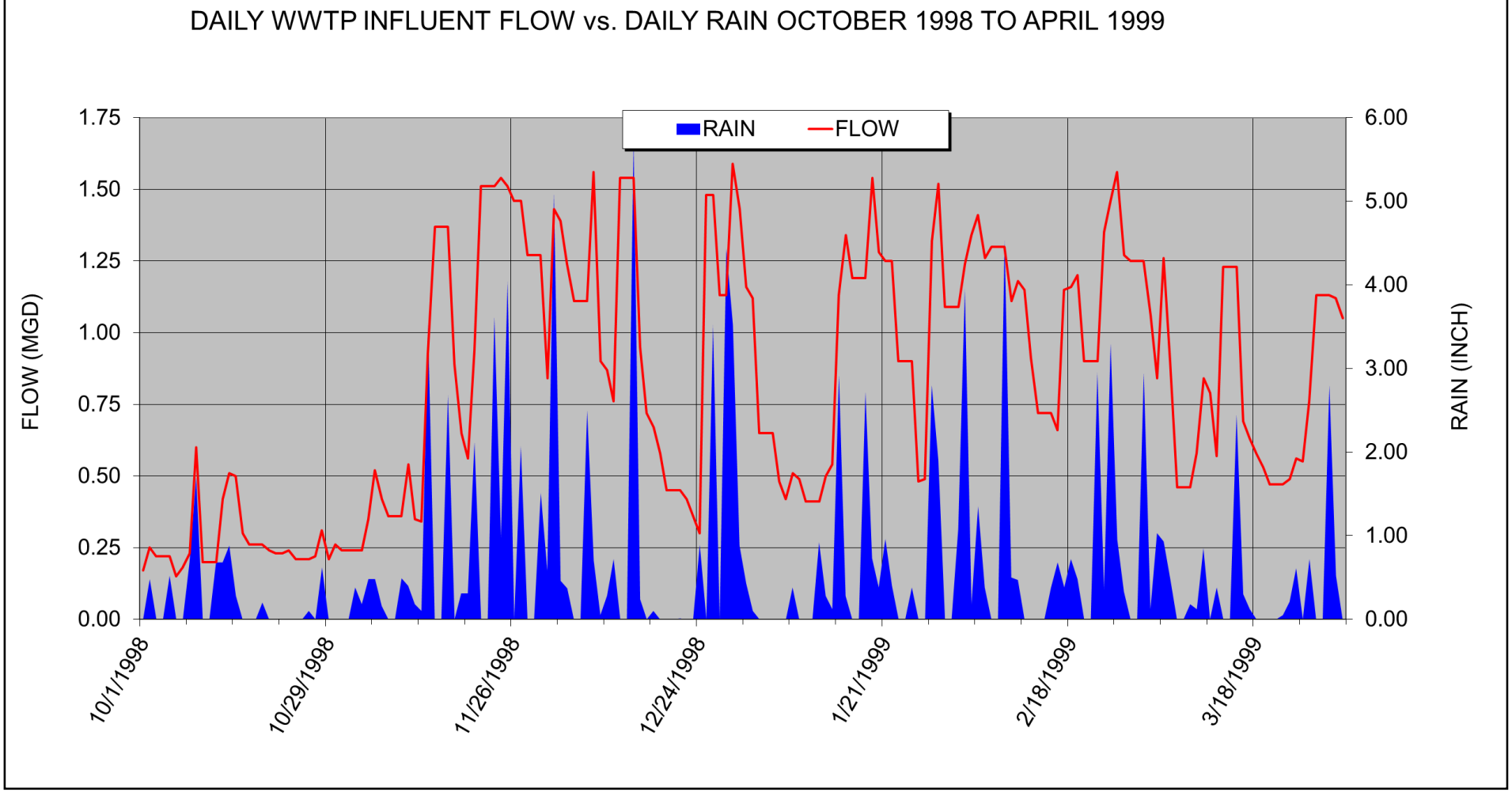

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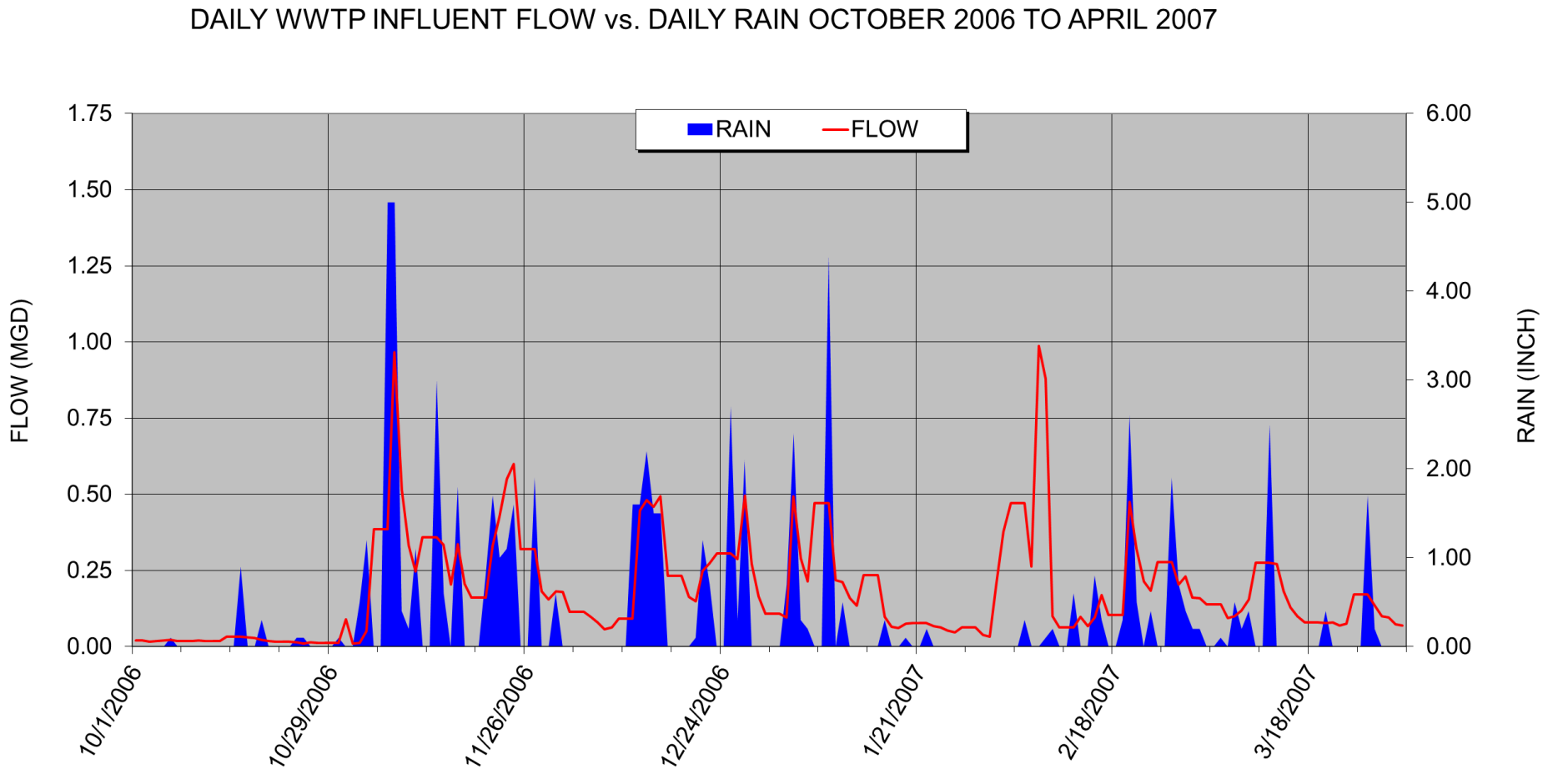

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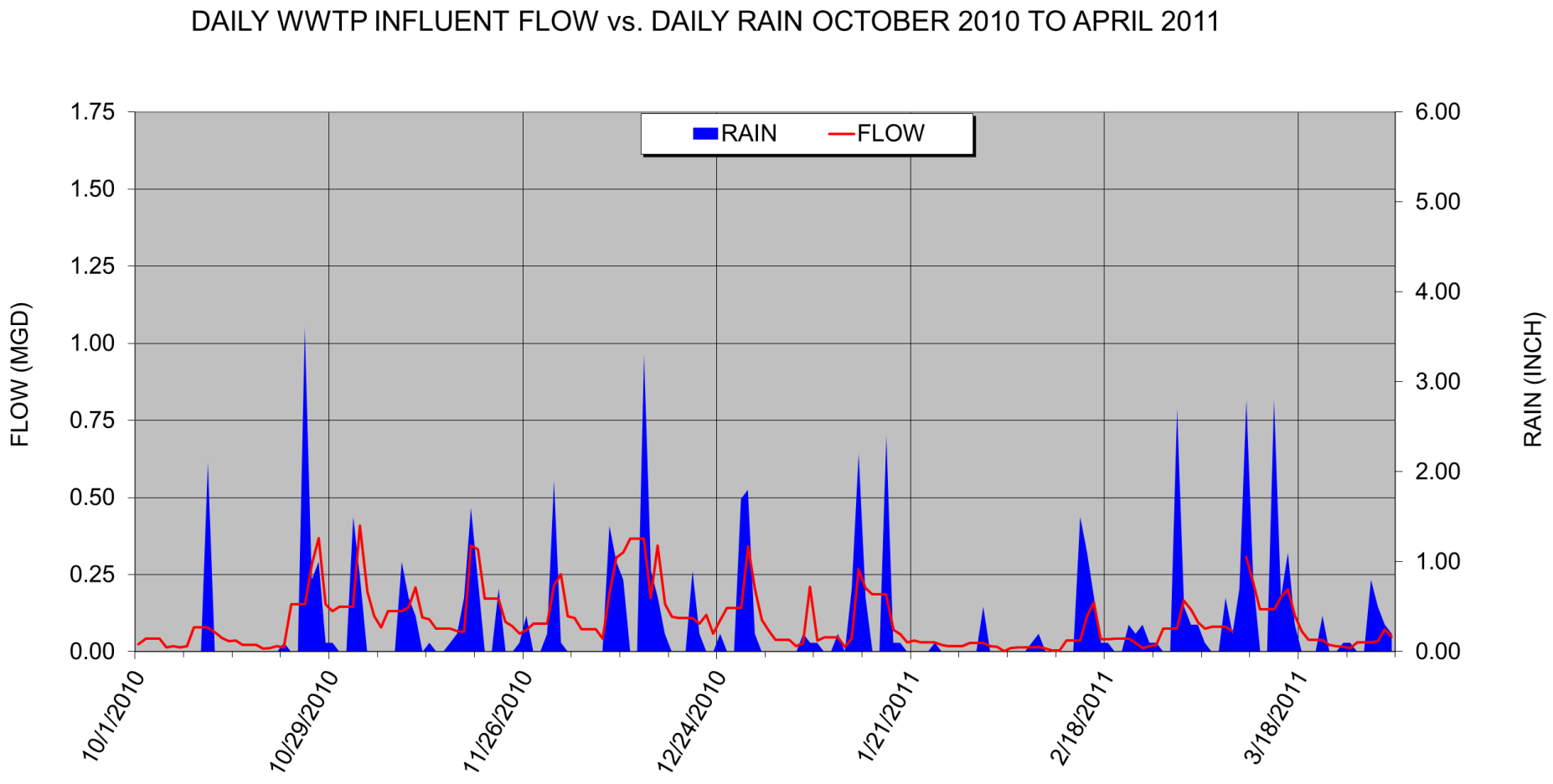

Conclusion

- When considering I&I removal, remember the bucket.
  - With thousands of holes water flows in rapidly when the bucket is partially submerged
  - If some holes are plugged, flow into the bucket is slowed but not significantly reduced until nearly all the holes are plugged.
- 40 years of experience is now available to show how where to focus to achieve effective I&I removal.
- Effective I&I removal requires commitment and that older private property side sewers be replaced.

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Thank you!

Questions?

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