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Collection Systems

FINAL REPORT

Methods for Cost-Effective Rehabilitation of Private Lateral Sewers

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METHODS FOR COST-EFFECTIVE REHABILITATION OF PRIVATE LATERAL SEWERS

by:

Raymond L. Sterling
Jadranka Simicevic
Trenchless Technology Center, Louisiana Tech University

Ahmad Habibian
Rick Nelson
Black and Veatch, Inc.

Roger L. Tarbutton
Johnson County, KS

Alan Johnson
Wade and Associates, Inc.

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For more information, contact:
Water Environment Research Foundation
635 Slaters Lane, Suite 300
Alexandria, VA 22314-1177
Tel: (703) 684-2470
Fax: (703) 299-0742
www.werf.org
werf@werf.org

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Report Preparation

Principal Investigator:
Raymond L. Sterling, P.E., Ph.D.
Trenchless Technology Center, Louisiana Tech University

Project Manager:
Jadranka Simicevic, M.S.
Trenchless Technology Center, Louisiana Tech University

Project Team:
Ahmad Habibian, P.E., Ph.D., *Black and Veatch, Inc.*
Rick Nelson, P.E., *Black and Veatch, Inc.*
Alan Johnson, P.E., *Wade and Associates, Inc.*
Deidra Hodges, M.S., *Computer Solutions*
Roger L. Tarbutton, J.D, LL.M., *Johnson County, KS, Legal Department*

External Review Committee:
Dan Hegwald, P.E., *Wade and Associates, Inc.*
Mark Wade, P.E., *Wade and Associates, Inc.*
George Riek, P.E., DEE, CVS, *Creativity Enterprises, Inc.*
Gunars Sreibers, P.E., *King County, WA, Wastewater Treatment Division*
Jim Scott, P.E., *Solution Resource*
Erez Allouche, P.E., Ph.D., *University of Western Ontario*, London, Ontario, Canada

Project Subcommittee

Rick Baxter, P.E., *Insituform Technologies, Inc.*
John Chorlog, P.E., *Miami-Dade County*
Tyler Richards-Strawinski, Chair, P.E., *Gwinnett County*
John Sullivan, P.E., *Boston Water and Sewer Commission*
Richard Thomasson, *Parsons Brinckerhoff Quade & Douglass, Inc.*
Charles P. Vanderlyn, *U.S. EPA, Municipal Technology Branch 4204M*

Water Environment Research Foundation Staff

Director of Research:	Daniel M. Woltering, Ph.D.
Project Manager:	Jennifer Simmons

ABSTRACT AND BENEFITS

Abstract:

Millions of sewer laterals exist throughout the U.S. and many allow the entry of a significant amount of inflow and infiltration (I/I) into sewer systems. Sewer laterals are often a significant contributor to sanitary sewer overflows, increased cost of wastewater conveying and treatment, and costly damage to private property through sewer backups. This report is intended to provide a clear understanding of problems and relevant issues, and explain available options for inspection, evaluation and repair of sewer laterals. It also addresses the financing and legal issues that affect the means by which the work can be carried out. The report includes a survey with responses from 58 agencies within the U.S. and three foreign agencies. The information collected illustrates the diversity of administrative and physical arrangements for private sewer laterals—often even within local regions. The cost effectiveness of lateral rehabilitation programs was found to depend on both the circumstances of the municipality (e.g. treatment capacity available and existing overflow problems) and on the way in which the lateral program is approached (e.g. selection of most suitable basins for rehabilitation and level of quality control for rehabilitation work).

Benefits:

- Provides a comprehensive reference document on the physical and administrative circumstances for sewer laterals in the U.S.
- Documents the available techniques for inspection, assessment, and rehabilitation of sewer laterals.
- Documents the results of I/I reduction programs involving sewer lateral rehabilitation that are already underway in the U.S.
- Illustrates how many of the legal and liability issues regarding sewer laterals can be addressed.
- Identifies a variety of approaches for public agency financial support and encouragement of lateral repair programs.
- Provides a road map for the development of an agency program to address private sewer lateral issues.

Keywords:

Infiltration, inflow, laterals, legal, inspection, financing, assessment, planning, sewer

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LIST OF ACRONYMS

”	Inch
’	Foot
AMSA	Association of Metropolitan Sewerage Agencies (now NACWA, National Association of Clean Water Agencies)
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
°C	Degree Centigrade
CCTV	Closed-Circuit Television
CMMS	Computerized Maintenance Management System
CMOM	Capacity, Management, Operations and Maintenance (U.S. EPA program)
CF	Cubic Feet
cfs	Cubic Feet per Second
CI	Cast Iron
CIP	Cured-In-Place
CO	Cleanout
CSO	Combined Sewer Overflow
CWA	Clean Water Act
DWF	Dry Weather Flow
DOJ	U.S. Department of Justice
°F	Degree Fahrenheit
FDA	Food and Drug Administration
FELL™	Focused Electrode Leak Location (see *electro scanning*)
FM	Flow Monitoring
ft/min	Feet per minute
ft	Feet
gal	Gallon
GASB 34	Government Accounting Standards Board Statement No. 34
GIS	Geographic Information System
GPR	Ground Penetrating Radar
GPS	Global Positioning System
gpm	Gallons per Minute
gpad	Gallons/Acre/Day
gpd	Gallons per Day
GW	Groundwater
HDD	Horizontal Directional Drilling
HDPE	High Density Polyethylene
HP	Horsepower
Hr	Hour
I/I	Infiltration and Inflow
in/hr	Inch per Hour
ID	Inside Diameter
IHC	Intralaminar Heat Cure
L	Length

lb	Pound
LS	Lift Station; also Lump Sum in cost tables
mg	Million Gallons
mgd	Millions Gallons per Day
MH	Manhole
MIS	Management Information System
NAGMA	North American Grout Marketing Association[1]
NASSCO	National Association of Sewer Service Companies
NIOSH	National Institute for Occupational Safety and Health
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and Maintenance
OSHA	Occupational Safety and Health Administration
PACP	Pipeline Assessment Certification Program
pH	Hydrogen-Ion Concentration
PL	Property Line
POTW	Publicly Owned Treatment Works
psi	Pounds per Square Inch
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/Quality Control
R/R	Rehabilitation/ Replacement
RDI/I	Rainfall derived inflow and infiltration
ROW	Right-of-way
RPM	Revolutions per Minute
RT	Radar Tomography
SSES	Sewer System Evaluation Study
SSO	Sanitary Sewer Overflow
SF	Square Feet
SY	Square Yard
U.L.	Underwriters Laboratories, Inc.
U.S. EPA	United States Environmental Protection Agency
VCP	Vitrified Clay Pipe
WEF	Water Environment Federation
WW	Wastewater
WWF	Wastewater Flow
WWTP	Wastewater Treatment Plant

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[1] *Reformed as the International Chemical Grout Association within NASSCO.*

EXECUTIVE SUMMARY

ES.1 Introduction

Wastewater collection systems are essential utilities and it is critical that communities preserve and maintain them in a reliable, serviceable, and structurally sound condition. For many communities, their sewer system may be their most valuable asset.

Sewer laterals (the portion of the sewer network connecting individual properties to the public sewer network) are part of these systems but with some features—size of pipes, materials used, construction practices, ownership responsibility, etc. that are different to the rest of the sewer collection system. Laterals are very often found in bad condition, having defects that cause serious problems. Of special interest are problems related to inflow and infiltration (I/I) of surface water and groundwater that have been the subject in recent years of increasingly strict regulation by federal and state permitting authorities. However, in general, the consequences of poor control of I/I involve needlessly high costs of wastewater conveyance and treatment as well as detrimental impacts on public health, the environment and quality of life. Even when the system-wide impact of I/I is not an issue, defective laterals can cause sewer backups and sanitary sewer overflows (SSOs), and can be an important issue of concern in public works agencies.

This report is intended to provide a clear understanding of problems and relevant issues, and explain available options for inspection, evaluation and repair of sewer laterals, as well as addressing the financing and legal issues that affect the means by which the work can be carried out. By doing this, it is hoped that those who formulate policy recommendations (directors of public works agencies, city engineers, general managers, planners, financial managers, etc.) would be able to present, with appropriate justification, to politicians and the general public a sound course of action of how to manage problems with sewer laterals in their community.

ES.2 Survey

A survey aimed at giving a comprehensive insight into the diversity of existing conditions and working practices in dealing with issues related to private sewer laterals was made available for input to agencies in the United States and throughout the world. In a six-month period, a total of 58 agencies filled in a web-based questionnaire with 42 questions covering all aspects of sewer laterals. The majority of responses came from the U.S. and three from other countries. The information collected through the questionnaire process illustrates the diversity of administrative and physical arrangements for private sewer laterals—often even within local regions.

ES.3 Locating, Inspection, and Condition Assessment

A variety of methods for locating, inspecting and collecting data on the performance of sewer laterals exists—providing a wide range of potential approaches to gathering information about sewer laterals. Smoke testing, for example, can cover a large area at relatively low cost and identify a broad range of defects but cannot be expected to find all defects and provide anything but a qualitative indication of severity of defect. Pressure testing of laterals, on the other hand, provides a precise proof of the tightness of a sewer lateral but is much more costly to apply and, in the event of a leak, does not by itself pinpoint the position of the leak. The range of methods available are described and examples described of how particular agencies have used the available methods and collected data to make condition assessments for sewer laterals which can then be used in turn for quality control and to plan an ongoing program for maintenance and rehabilitation.

ES.4 Quantification of I/I from Sewer Laterals

This report describes methods that agencies can use to estimate the I/I in particular basins within their sewer collection system and how they can evaluate the effectiveness of completed lateral rehabilitation. Data collection for I/I analysis can be of different scopes (from smoke testing to long-term flow monitoring) and the analysis of collected data can vary from simple (empirical calculations of I/I, basic comparison of total measured flows on representative days) to elaborate (hydrologic/hydraulic simulation modeling of FM data). The accuracy of results and the confidence in conclusions typically improves with applied complexity.

The cost effectiveness of lateral rehabilitation programs depends on both the circumstances of the municipality (e.g. treatment capacity available, existing overflow problems, etc.) and on the way in which the lateral program is approached (e.g. selection of most suitable basins for rehabilitation, level of quality control, etc.). Monitored data from several agencies that have completed at least pilot studies for lateral rehabilitation indicates that savings in peak flow and annual volume can be significant—ranging from 5% to over 30% of flows prior to any rehabilitation and representing much higher percentages of remaining flows after a mainline rehabilitation program is completed.

Any published numbers providing a calculated contribution of laterals within the total I/I for a system cannot be considered universally applicable as they depend on local conditions (soil, groundwater, rainfall) and pipe condition (existence of I/I sources). The same applies to published numbers about the achieved effectiveness of lateral rehabilitation, which depends mostly on how well the applied repair measures targeted the existing sources of I/I. Any previous experience, even an agency’s experience from its own pilot projects, needs to be used carefully—acknowledging the specific conditions in the basin and/or project. However, despite the difficulties in generalizing the results, pilot projects are essentially the only way for an agency to get reliable data about the contribution of laterals to I/I in its sewer collection system and to build a good program to provide the most effective reduction of I/I problems caused by laterals.

ES.5 Inflow Removal and Rehabilitation Methods

The widespread strong interest in I/I reduction and the resulting growing interest in sewer lateral programs has spurred the development and introduction of a variety of techniques for safe inflow source removal and lateral rehabilitation and replacement. While problems may occur with the any of the rehabilitation and replacement techniques presented, all of the methods can be applied successfully under the right conditions and most municipalities report good overall success rates with their chosen technique(s). One city reported very poor results with its trials of pipe bursting and CIP relining as a result of a poorly qualified contractor whereas the same techniques have been used successfully in many other cities across the country. Proper qualification requirements (of the crew(s) as well as the contractor) and adequate quality control and quality assurance are necessary components of a successful lateral rehabilitation program.

Since most municipalities want to maximize the early results of an I/I reduction program, strong attention should be paid to the removal of inflow sources as a potential first step. Costs for inflow removal are generally quite low and the quantities of inflow removed from the sewer system are usually very significant.

ES.6 Financing Issues

The overall financial resources needed for the repair of sewer laterals in the U.S. are estimated to be very large. According to the U.S. EPA, about 200 million people are served by sewer systems. If it is assumed that there are 2.6 people per lateral, the approximate population of an average single family residence, then there are about 77 million laterals in the U.S. If the average repair cost is assumed to be $2,000 and just 25% of the laterals are defective, the total need would be over $38 billion. Even if only 10% of the laterals are defective, the total need would still be over $15 billion.

A public program designed to fix I/I and other problems in sewer laterals must either find the means to encourage or force private property owners to pay for the necessary improvements or must decide how to use public funds, public financing or public assistance to make the program happen. Depending on the lateral ownership arrangements, it may be necessary to prove that a lateral is defective, determine whether the property owner or the agency is responsible for the defect(s) and to decide whether the agency can legally spend public money on private property improvements. There are also the socio-economic ramifications of many lateral defects being located in older neighborhoods whose residents tend to be elderly residents on fixed incomes.

The responsibility for meeting the cost of rehabilitation often falls primarily on individual home and other property owners but the benefits that accrue to wastewater system operation, the environment and the general public provide a strong incentive for agencies and local and national governments to support cost-effective programs both administratively and with public funds.

A range of possible approaches to such public agency financial support and encouragement of lateral repair programs has been identified in this report along with brief descriptions of specific programs adopted by various agencies across the country. These examples show that successful financing approaches are available and that individual approaches can be tailored to the physical, political and economic structure of a particular community.

ES.7 Legal and Liability Issues

Testing and repair of private lateral sewers involves not only issues concerning access to private property but also potential liability for personal injury or property damage resulting from performance of such work on private property and restrictions on the use of public funds for private property improvements. These and other key legal and liability issues involved in working with the private portion of sewer laterals are explored in this report with examples provided of the legal opinions and administrative arrangements adopted in some cities across North America. In depth reference is made to a few examples for which the authors had strong involvement or familiarity or for which extensive analysis of legal issues had been made in a written report made available to the project.

In order for a public entity to gain access to private property, Fourth Amendment search and seizure issues must be addressed. Regulations requiring inspection of private property must be cognizant of Fourth Amendment prohibitions against unreasonable search and seizures. In this regard, the use of administrative search warrants has the advantage of allowing a large number of inspections within problem areas without the necessity of obtaining the permission of each individual owner in advance. In emergency situations, inspection of private facilities may be conducted without a search warrant. The most obvious example is where immediate access is necessary to protect the public health or safety.

Most states have constitutional provisions that restrict the use of public funds to expenditures for public purposes. These restrictions are commonly referred to as the public purpose doctrine. Although state laws vary considerably in this regard and should be carefully reviewed prior to implementing improvement programs, the courts have generally held that some benefit may be derived by private owners provided it is incidental to the benefit derived by the public at large in the form of improvements to the public health, safety and environment. Further, as such programs generally fall within the legislative or public policy making function of the municipality, courts generally allow great deference to the judgment of the governing officials in making such determinations.

The methods employed to address these issues to date and the legal precedents reported in the literature indicate that where there is the political will and proven benefit to the general public, the legal issues associated with the inspection and repair of private laterals can be managed.

ES.8 Decision Making

After documenting and reviewing existing problems related to I/I, an agency has typically more than one option in addressing these problems. In selecting the “best” alternative, economic analysis of alternatives is very important but other criteria must also be considered that affect public health, the environment and quality of life.

When looking at the cost-effectiveness of lateral rehabilitation, it is important to see it in a broader view. Repair of the laterals in one small basin may not appear cost-effective if the savings are calculated only by multiplying the reduction in total quantity of conveyed sewage annually with the average cost of conveyance/treatment per 1,000 gallons of sewage. However, the same repair may be cost-effective if it prevents the peak flows from exceeding design maximum flows at lift stations and at the wastewater treatment plants (WWTP), and also eliminates the need for upsizing parts of the collection system. Future needs should also be considered and projected community development and any related need for increased capacity of the sewer system assessed. If the extra conveyance/treatment capacity needed in the future can be accommodated with the existing sewer system by just eliminating the I/I, then the value of lateral rehabilitation grows accordingly.

Thus, in developing a plan to deal with sewer laterals, it is important to have a good understanding of the entire sewer system performance and where the efforts for reduction of I/I should be directed. Also, because of the investments required to bring most systems up to standard, rehabilitation and capacity building efforts may take many years to achieve so decisions need to be made on the prioritization of system improvements over time. Of course, individual decisions about specific lateral rehabilitation projects can be based on project specific evaluation. In this case, specific basins or projects would be evaluated for cost-effectiveness or public necessity on their own. This approach allows specific projects to deal with identified major problems or opportunities (e.g. lateral work to accompany mainline renewal) to proceed without waiting for an overall system evaluation that could take years to accomplish. Early projects also can provide useful data for use in the system wide analysis.

The use of pilot projects for lateral rehabilitation has proved a useful technique in many cities that have adopted broad lateral rehabilitation programs. They provide site and system specific data and help identify the rehabilitation techniques to be adopted as well as their effectiveness.

ES.9 Conclusion

The potential range of parameters affecting the cost-effectiveness of lateral rehabilitation and the relatively small number of municipalities that have reported to date on the cost-effectiveness of their lateral rehabilitation programs makes it difficult to answer in a general way the question "When is the rehabilitation of private lateral sewers cost effective?" Some systems have achieved important results in terms of peak flow and annual flow reductions by including lateral rehabilitation in their I/I reduction approaches, other systems have concluded that dealing with laterals and particularly private laterals is not worthwhile—at least at the present time. It is hoped, however, that this report provides a road map as to the assessment, analysis, program development, method selection and legal and financial implementation that will make it an easier task to decide how to implement lateral rehabilitation within an overall wastewater system rehabilitation strategy.

CHAPTER 1.0

INTRODUCTION

1.1 Background

Wastewater collection systems are essential utilities and it is critical that communities preserve and maintain them in a reliable, serviceable, and structurally sound condition.

Sewer laterals (the portion of the sewer network connecting individual properties to the public sewer network) are part of these systems but with some features—size of pipes, materials used, construction practices, ownership responsibility, etc. that are different to the rest of the sewer collection system. Laterals are very often found in bad condition, having defects that cause serious problems. Of special interest are problems related to inflow and infiltration (I/I) of surface water and groundwater that have been the subject in recent years of increasingly strict regulation by the U.S. Environmental Protection Agency. Chapter 4.0 provides a definition of I/I and examines its specific impacts on the operation of wastewater collections systems. However, in general, the consequences of poor control of I/I involve needlessly high costs of wastewater conveyance and treatment as well as detrimental impacts on public health, the environment and quality of life. Even when the system-wide impact of I/I is not an issue, defective laterals can cause sewer backups and sanitary sewer overflows (SSOs), and can be an important issue of concern in public works agencies.

Although awareness of the problems related to sewer laterals is generally present in most communities, this awareness alone often has not provided adequate impetus for addressing and fixing these problems. An “out of sight, out of mind” attitude has often prevailed—meaning that adequate funds have not been spent on preventive maintenance and the provisions of codes and ordinances that regulate the required condition of sewer laterals (typically structurally sound and without leaks) have not been fully enforced.

Bearing in mind the importance and urgency of the need to address the contribution of sewer laterals to wastewater collection system problems, this report and the research that preceded it aspires to change this attitude. The report is intended to provide a clear understanding of problems and relevant issues, and explain available options for inspection, evaluation and repair of sewer laterals, as well as addressing the financing and legal issues that affect the means by which the work can be carried out. By doing this, it is hoped that those who formulate policy recommendations (directors of public works agencies, city engineers, general managers, etc) would be able to present, with appropriate justification, to politicians and the general public a sound course of action of how to manage problems with sewer laterals in their community.

1.2 Problems Promoted by Defective Laterals

Defective laterals promote the occurrence of sanitary sewer overflows (SSOs) and basement sewage backups, and the hydraulic overloading of lift stations and wastewater treatment plants (WWTPs). These problems are most often linked to excessive peak flows in the sewer collection system during wet weather. However, even moderately increased flows during wet weather and/or permanent I/I can generate a significant amount of surplus sewage volume to be conveyed/treated annually. Furthermore, SSOs and basement backups also occur from defective laterals for reasons not related to I/I (as explained below). Whatever the circumstances, the problems involve potentially dangerous consequences from exposing the public to raw sewage and/or serious drawbacks from inefficient operating and maintenance of sewer systems.

In this section, an introduction is given to system wide problems to which a poor condition of sewer laterals is often a contributing factor. These system wide problems are the driving force for most sewer rehabilitation efforts and it is important to understand the magnitude and severity of these issues in order to delve more closely into the connection of poorly performing sewer laterals to these issues in the rest of this report.

1.2.1 Sanitary Sewer Overflows (SSOs) and Basement Backups

A sanitary sewer overflow (SSO) is a wastewater discharge from a sanitary sewer on land or public area before the WWTP. It occurs through manholes (Figure 1-1, Left) and lift stations, and deteriorated pipes throughout the system. Sewer basement backups and flooding of homes with sewage are also SSOs, as is an emergency sewer bypass used at a WWTP.

Occasional SSOs occur in almost every system and the U.S. EPA estimates between 23,000 and 75,000 events occur annually. SSO events can be related to either bringing too much water into the collection system through I/I or to "bottlenecks" in the system (partial or complete pipe blockages caused by tree roots, sediments and debris, grease buildup, foreign objects, pipe structural failure and collapse) that can cause overflows during both dry and wet weather (Figure 1-1, Right).

Figure 1-1. Left: SSO at the Manhole. Right: Partial Pipe Blockage (ADS Services).

In some agencies, sewage backups are a major problem with a large number of complaints of flooded basements reported annually. The backups occur when sewage (or a mixture of sewage and stormwater) flows backwards and out of pipes that normally drain basement washing machines, sinks and toilets—thus flooding the basements of homes. The backups can be caused by a blockage in the lateral or a surcharged mainline (Table 1-1).

Table 1-1. Common Causes of Lateral Blockages and Mainline Surcharging Leading to Basement Backups.

Cause	Explanation
Inflow/infiltration	Rainwater entering the sewer pipe causes surcharging of the system and overflows
Root intrusion	Tree roots block the laterals or lateral-to-mainline connections partially or completely
Solids	Typical solids that buildup in the pipe and cause backups are grease, dirt, bones, tampons, paper towels, diapers, broken dishware, garbage, concrete, and debris
Structural defects in pipes	Cracks and holes in the laterals, protruding laterals, misaligned pipe, offset joints are all possible sources of I/I

Through SSOs and basement backups, defective and poorly maintained sewer laterals are to a degree responsible for creating a public health hazard, pollution of the environment and significant financial consequences to the agency operating the wastewater collection and treatment system.

Public Health Hazards. The health hazards come from exposing the public to contaminants in raw sewage that cause various diseases with some being life threatening (Table 1-2). People or animals get sick either through direct contact with sewage, inhalation, drinking water, skin contact or ingestion during recreation, or eating contaminated shellfish.

Table 1-2. Public Health Hazards from Raw Sewage.

Contaminants in Raw Sewage	Severity of Diseases
Bacteria, viruses, protozoa (parasitic organisms), helminths (intestinal worms), and borroughs (inhaled molds and fungi), etc.	From mild gastroenteritis causing stomach cramps and diarrhea to life threatening diseases such as cholera, dysentery, infections hepatitis, and severe gastroenteritis.

One example of a serious disease outbreak from sewer backups happened in a suburb of Orlando, FL, in 1988-89. After heavy rains, one mobile home park was flooded on several occasions with sewage and these SSOs were linked with the outbreak of hepatitis A[2] (Vonstille et al., 1993). Several infected people[3] were living in the park shedding into the sewer the virus which can survive for weeks in sewage or groundwater. A total of 39 cases of hepatitis were identified among residents. Four infected people were food handlers and continued to work for 7-10 days during the incubation phase, and were linked to a 100 additional cases of hepatitis A in Ft. Lauderdale where they worked.

More about the health hazards from SSOs can be found in various U.S. EPA documents (U.S. EPA, 1996).

Pollution of the Environment. SSOs have an adverse impact on the environment by polluting the waters and harmfully affecting fish and other wildlife species. The U.S. EPA found that 75% of SSO events reach surface waters (U.S. EPA, 2004a).

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[2] *Hepatitis A is a chronic liver disease that can lead to permanent health injury and shorten life expectancy. Using a special health analysis scale, health damages were measured at up to 20 years' lost life expectancy. Diarrhea and other symptoms continued for two years.*

[3] *One adult and five children living in this mobile home park were sick from unknown source. In addition, a student nurse in the second mobile home park serviced by the same sewer system was at home and sick with Hepatitis A.*

One example of how lethal for aquatic life SSO discharges can be is the ongoing documenting of fish kill events by the North Carolina Division of Water Quality (http://h2o.enr.state.nc.us/esb/Fishkill/fishkillmain.htm). The records include the number of fish killed per event and the reasons that caused the kill. Table 1-3 shows the events in 1997 attributed to sewage spills.

Because of pollution of the water, beaches get frequently closed for swimming and, on occasions, SSOs are directly responsible for the closings. In 1997, the U.S. EPA initiated an annual National Health Protection Survey of Beaches ("Beach Survey"). This is a voluntary nationwide survey that collects information related to beach water quality. Among other information, the survey identifies the number of beach closings during the swimming season and the reasons for closings. According to the survey in 2002, 25% of beaches participating in the survey (i.e. 708 beaches out of 2,823) had at least one closing during the 2002 swimming season. Of that number, 3% were attributed to SSOs (U.S. EPA, 2003).

Table 1-3. Fish Kills Attributed to Sewage Spills in North Carolina.

Date	Location	Number of Fish Killed	Cause of Kill
07/01/97	UT to Cokey Swamp	300	Spill of at least 23,000 gal sewage from Sharpsburg WWTP
07/14/97	Elerbee Creek	120	Sewage spill from storm drain at nearby Coca Cola plant; spill originated from sump overflow into floor drain at plant; sewage caused a drop in pH and DO in the creek
07/27/97	Burden Creek/ Northeast Creek	1,375	Sewage spill and mechanical failure at theTriangle WWTP; 1.6 million gal of sewage were discharged to Burden/ Northeast Creeks; spill resulted in high fecal coliform bacteria and low DO
07/29/97	UT to Elerbee Creek	100	Sewage spill of 30,000 gal from Glenn Road Pump Station in Durham Co; the discharge occurred from 7/25 to 7/28
08/13/97	Swift Creek/Mahlers Creek	1,000	Sewage spill from line to the Garner WWTP; the spill was estimated at 0.5-1 mg; sewage spilled into Mahlers Creek initially
08/14/97	UT to Northeast Creek	200	Sewage overflow of 20,000 gal from Durham/Triangle sewerline; low DO observed; all fish observed dead; various sunfish species affected
08/19/97	Coon Creek	3,500	Sewage spill of 1.2 million gal from an Oxford pumping station; low flows in stream resulted in little dilution of waste; low DO and high coliform counts observed up to three miles downstream; distressed fish first observed on 8/18
09/23/97	Little Buffalo Creek	25	Sewage spill of 50,000 gal into unnamed tributary of Little Buffalo Creek from the Sanford WWTP; low DO was observed ATI
10/07/97	Lovills Creek	3,099	Sewage leakage from junction in Town of Mount Airy sewage lines, DO levels reported as acceptable during investigation; investigators suspected other agent in sewage as a cause for the kill
11/9/97	East Beaverdam Creek	40	Sewage spill from broken manhole, 500,000 gal of sewage released
	Total:	9,759	

Financial Consequences. SSOs come with a significant "price tag". First, there is the cost of cleaning and repairing of homes and properties after SSOs. Agencies often are held liable for basement flooding and property damages caused by I/I and often have to pay rather large amounts for damage and clean up. One example is the Washington Suburban Sanitary Commission, MD, where between 500 and 650 backups occurred annually between 1990 and

1994, with an average cost of basement cleanup of $700[4], thus totaling over $2 million in those five years (WSSC, 1995).

SSOs are illegal, unless authorized by an NPDES permit, and subject to regulatory penalties as follows:

- Civil penalties—The CWA requires that WWTPs provide secondary treatment of wastewater before releasing the effluent into the environment and meet any additional water quality standards. An SSO is viewed by EPA as a violation of this requirement, and can qualify for a Class I civil penalty under the CWA. Currently, civil penalties are up to $32,500/day (adjusted regularly for inflation from the statutory level of $25,000/day). Regional EPA offices, however, have the authority to use enforcement discretion and not enforce the payment of penalties if the agency develops and executes a compliance schedule with the permittee (the remedial measures that lead to compliance with the CWA and regulations).
- Administrative penalties—Some states have their own requirement for SSOs. For example, the State of Florida has its own assessment formula to calculate SSO penalties. Also, many cities have signed a consent decree or order[5] on SSOs that detail the response remediation program and stipulate penalties for any non-compliance. For example, the consent order in Mobile, AL, specifies that the agency agrees to pay penalties for unpermitted discharges in the amount that depends on time passed since the specified date (Aug 1, 2003) as follows: $500/day for discharges in first 12 months, $600 in the following 12 months, and $750 thereafter. (U.S. DOJ, 2002)
- Criminal penalties—An SSO qualifies for a criminal case penalty if two elements are involved: a significant environmental harm and a culpable conduct[6] (U.S. EPA, 1994). This legal avenue, however, has rarely been pursued[7].

The U.S. EPA, many states and environmental groups have been focused over the last number of years on Sanitary Sewer Overflows (SSO) in sewer systems. As a result, many enforcement actions have been taken against agencies for SSOs. These enforcement actions included remedial work to be carried out by the agencies as well as penalties. The following are examples of some of these recent orders:

- City of Los Angeles, CA, ordered to pay an $800,000 fine to the United States and $800,000 to the California Regional Water Quality Control Board, the latter directing the

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[4] *The cost included removal and disposal of sewage, removal and cleaning or disposal of carpet, wallpaper, wallboard, insulation, and other materials; disinfection; and drying.*

[5] *A legal agreement, under the jurisdiction of the U.S. court system, entered into by the agency and the federal Environmental Protection Agency (U.S. EPA) and/or the state Environmental Protection Division for violations of the federal Clear Water Act.*

[6] *A significant harm determination considers the presence of actual harm, threat of significant harm, the failure to report and whether the illegal conduct appears to be part of a trend or common attitude in the regulated community. The culpable conduct factor considers the history of repeated violations, whether the conduct was deliberate, concealment or falsification of records, and operation of the business without the required permits.*

[7] *An example of a criminal case is a knowing violation of the CWA by the former superintendent of the WWTP in Bay City, MI. The violation was connected to the discharging of untreated sewage sludge into the Saginaw River in August 1996, and causing the falsification of CWA records in June 1997. He was sentenced to six months imprisonment and six months of home confinement, and was also ordered to pay a $6,000 fine and a $300 special assessment. (U.S. EPA, 2002d). This was not, however, an SSO case.*

funds to local environmental improvement projects that the city would perform. (U.S. EPA, 2004b);

- City of Baltimore, MD, ordered to pay a $600,000 civil penalty (U.S. EPA, 2002a);
- City of Toledo, OH, ordered to pay a $500,000 civil penalty (U.S. EPA, 2002b);
- Knoxville Utilities Board, TN, ordered to pay a $334,000 civil penalty (U.S. EPA, 2004c).

In addition, many states have intiaited efforts to permit sewer systems and require specific program elements targeted at SSO reduction and prevention.

An example of a different kind of expense related to SSOs is the cost of disposing of the sewage from surcharged manholes and/or lift stations during storms, which is performed to avoid imminent SSOs when wet weather flows become very large. This is usually performed with tanker trucks and can be very expensive. In Sarasota, FL, for example, such trucks dispose of about 4,000 gal in about two hours (loading the sewage, driving to another system that is not surcharged, and unloading)—the efficiency depends on the distance that the sewage has to be transported. The cost of operating the trucks in this agency is approximately $100/hr, and several trucks are needed concurrently during heavy storms (Ray, 2005).

1.2.2 Hydraulic Overloading of Lift Stations and WWTPs

Lift Stations. Lift stations are typically designed with two or more main pumps of the same size and one standby pump that operates only when one of other pumps is out of service. The main pumps together should be capable of pumping peak wet weather sewage flows, whereas typically fewer main pumps are needed to pump average daily flows (often one pump only is sufficient). However, with large I/I in the system, the main pumps often cannot pump the extreme wet weather peak flows and the standby pump has to be used to prevent the occurrence of an SSO. In contrast, some lift stations are designed without a specific standby pump, e.g. with two identical pumps that work alternatively for most of the time while pumping average daily flows. Both pumps run together if one cannot handle the extreme wet weather peak flows.

Whichever is the case, when all pumps in the lift station operate simultaneously, the increased cost of pumping shows immediately as a short-term expense. Also, because the pumps operate at or near their full capacity for a longer time, the useful life of the pumps is shortened, as they need to be replaced sooner, and this shows as a long-term cost. In cases where the standby pump is used on a regular basis, such operating practices take away from the Class I reliability required for this pump, which is a legal problem.

An example of hydraulic overloading of a lift station is shown in Figure 1-2. Peak wet weather flows greatly exceed average dry weather daily flows. The lift station in question (Olympia, WA) has two identical pumps with a design capacity of 475 gpm each (actual pump capacities were tested to be 403 and 435 gpm). At wet weather flows of over 1,500 gpm, SSOs occur—there were at least two such events in winter 2001. As discussed above, the expected useful life of the pumps is shortened by the need to deal with excess flows during heavy rain events and there is an additional direct cost of pumping although it is hard to estimate this cost of pumping (Lu, 2005).

Although it is very hard to estimate shortening of the life of standby pumps (because this is so dependent on the amount of I/I and the amount of rain the area receives), a rough guess can be made based on a record of usage of these pumps annually. For example, the worst situation in Virginia Beach, VA, indicates that a standby pump is used about 200 hours per year, which could take away about two years or 10% off the pump life. The real problem is that these pumps operate against very high pressures, which provides high wear on a pump. It is possible under these conditions that pump life could be cut as much as 50% (Schlobohm, 2005).

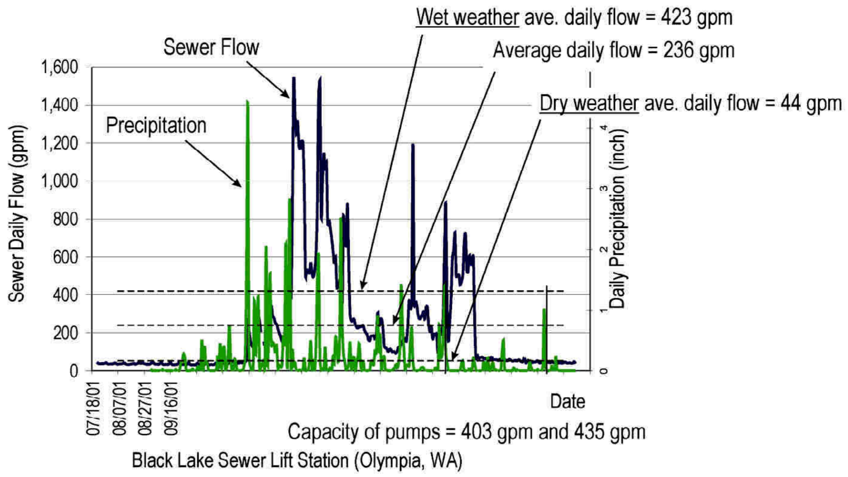

Figure 1-2. Pumping Flows at Black Lake Lift Station (City of Olympia, WA).

Wastewater Treatment Plants (WTTPs). The most obvious problem from excessive I/I at WWTPs is the increased operating costs from treating unnecessarily large volumes of diluted sewage annually. This can be a significant cost, however, the problem is more complex than this. Peak wet weather flows present a huge challenge for the treatment of wastewater and the quality of final effluent is often significantly degraded at some point in time as a result of peak flows. In particular, biological processes are sensitive to the change in quantity/quality of influent and this is exactly what I/I does—bringing much larger flows of sewage to the plant, often diluted several times compared to dry weather conditions. Treating such flows can disrupt the biological processes for a long period of time[8].

An example of hydraulic overloading of a WWTP is shown in Figure 1-3. The plant in question is a regional plant that treats the flow from a collection system that is not fully separated. One portion of the system, the combined sewer in the downtown area, brings excessive inflow during rainfall storms and is accountable for the large spikes in the graph. However, the remainder of the collection system, which is a nominally separated sanitary sewer system, also exhibits significant RDI/I (Lu, 2005).

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[8] *During peak flows, solids within the system tend to move from the aeration basin to the secondary clarifier at a higher rate than they can be returned. This condition results in an increase in the quantity of sludge in the clarifier and negatively affects the facility performance.*

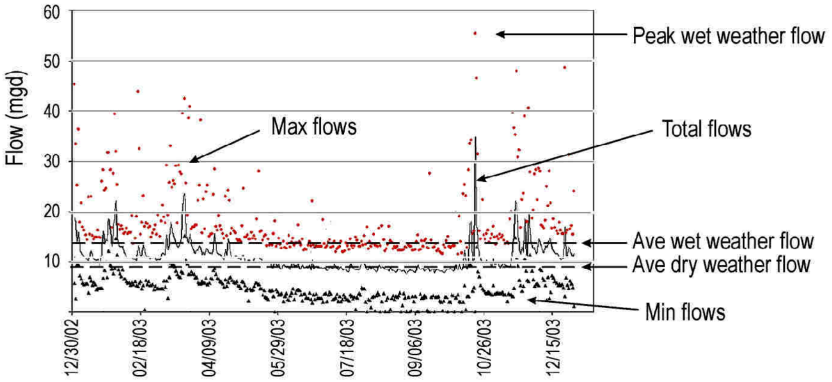

Figure 1-3. Treatment Plant Flow Example.

In practice, peak wet weather flows at WWTPs have been handled in several ways:

- Bypassing the treatment plant—The worst option because an illegal SSO is created. In the Indianapolis metropolitan area, for example, more than one billion gallons of untreated sewage are discharged over a period of around 31 days a year because the WWTPs cannot handle the typical wet weather flows (Dorfman, 2004).
- Applying a blending technique—Following the primary treatment, the flow in excess of the capacity of biological unit is diverted and blended with the flow that had passed through the biological unit. Blending has historically been authorized by the federal government, however, certain EPA regions now declare it to be an illegal bypass or prohibit the technique unless the WWTP has equalization basins (AMSA, 2003).
- Treating peak flows—The biological processes are often disrupted for long periods after the storm event. This also implies having oversized facilities installed, which is expensive, with underutilization of invested capital.
- Storing peak flows off-line and treating them later
- Designing processes to deal with the peak flows only—A parallel process (a satellite WWTP) is constructed to treat only the peak wet weather flows. With less treatment, the construction cost of such a WWTP is rather low (can be less than 50% of the cost of the conventional biological plant per volume of wastewater treated), however the operating cost when in use is higher (about 20% more than the conventional system, per volume of wastewater treated) due to the use of chemicals[9] (Booker, 2000).

An example of the problems caused by treating peak flows is the WWTP in Pittsburgh, PA (Table 1-4). Operating problems due to I/I can be summarized as follows: Peak flows stress the final clarifiers, and effluent quality during peak events depends on the mixed liquor Sludge Volume Index (SVI). If less than 100, the treatment biology is preserved and the effluent quality is degraded but decent. If the SVI is over 100, the mixed liquor biology is lost resulting in poor quality effluent. The wet weather operating problem actually results in more acute treatment problems during "dry weather". While this sounds illogical, during dry weather, all treatment tanks have to be kept in service to be ready for sudden wet weather. That results in excess detention time for adequate biodegradation of wastewater components and a low Food to Microorganism ratio (F/M), which leads to additional operating problems (Miskis, 2005).

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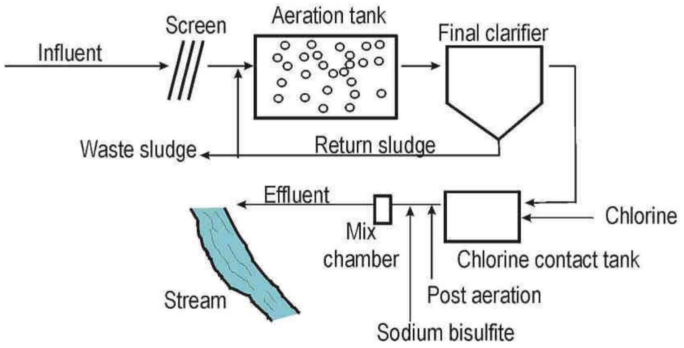
[9] *These plants rely on chemical coagulation, flocculation and rapid separation.*

Table 1-4. Donaldsons Crossroads WWTP (Pittsburgh, PA).

Design flow:	1.2 mgd
Ave DWF:	0.6 mgd
Ave WWF:	1.2 mgd
Peak WWF:	7.0 mgd
SSOs:	None at the WWTP[10]
Cost of treatment:	$2.18/1,000 gal of wastewater processed (includes infiltration) $4.27/1,000 gal of water consumed (excludes infiltration)
Annual quantity treated:	390 mg (2004)

Treatment:

6 Screening
6 Extended aeration
6 Secondary clarification
6 Disinfection/Dechlorination
6 Post Aeration



An example of on-site storage is at the LOTT Alliance's Budd Inlet Treatment Plant in Olympia, WA (Table 1-5). The plant utilizes equalization (EQ) basins with 2.25 mg maximum capacity to eliminate significant impact on the biological treatment by capturing the "slug" loadings of high flows to the plant from diluted wet weather flows (up to four times compared to average dry weather flows) or any discharges that may cause process upset or pass-through to the receiving waters. There is some incidental separation of solids in the EQ basins but their primary function is to act as a shock absorber. All flows entering the facility are fully treated. In addition to the EQ basins, unused treatment basin capacity is used for temporary storage. The number of unused basins available depends on the set up of the plant for the desired season[11]. For instance, out of a total of four 1st anoxic basins at the plant, typically three are online, leaving one, with a capacity of 585,000 gallons, available for storage in the event of a storm (Butti, 2005).

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[10] *SSOs occur only in the collection system: about four to five in wet years, and one or less in dry years*

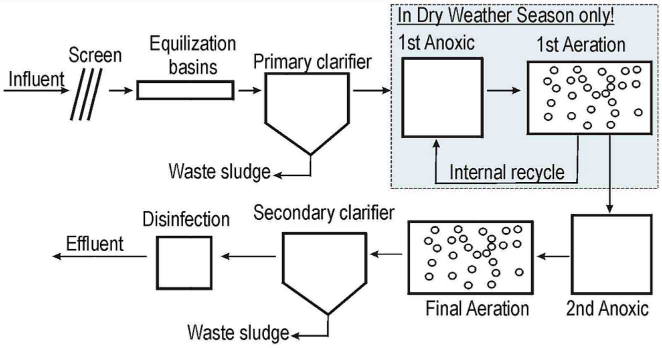
[11] *The NPDES permit allows the LOTT Alliance Budd Inlet Treatment Plant to operate in two different modes dependent upon the season. In the wet weather season (Nov 1- Mar 30), there is no Total Inorganic Nitrogen (TIN) requirement of 3mg/l, so a conventional activated sludge treatment can be utilized (the internal recycle and 1st anoxic basin are not utilized). In the dry weather season (Apr 1- Oct 31), the monthly average TIN requirement of ≤ 3 mg/l has to be met i.e. Biological Nutrient Removal (BNR) is applied using all treatment processes listed in Table 1-5.*

Table 1-5. LOTT Alliance (Olympia, WA).

Design flow:	17 mgd
Ave DWF:	9.43 mgd (ave daily flow in Jun 2004—month with min average)
Peak WWF:	13.20 mgd (ave daily flow in Jan 2004—month with max average)
Peak Hourly Flow (Permitted):	55 mgd
CSOs:	None (Last CSO event was in 1991)
Cost of treatment:	$1.10/1,000 gal (2004)
Annual quantity treated (2004):	3,815 million gal

Treatment:

- Screening
- Primary Clarification
- 1st Anoxic Zone
- 1st aeration zone
- 2nd Anoxic Zone
- Final Aeration
- Secondary clarification
- Disinfection (Ultraviolet)



An example of facility for storing peak flows is a reservoir under construction at the Marigold Pump Station in Victoria, B.C., Canada (Figure 1-4). This below-grade, reinforced concrete storage facility will provide off-line storage during peak wet-weather events. The capacity of the facility is 5,000 m^3 (1.3 mg).

Figure 1-4. Peak Flow Storage Facility (Victoria, B.C., Canada).

A schematic diagram of a separate WWTP constructed to deal only with peak flows is shown in Figure 1-5 (Booker, 2000). This approach has been selected in Salem, OR, where the existing conventional WWTP (Table 1-6) is overloaded during wet weather and a new peak load WWTP (Table 1-7) is being built to serve over the next 30 years while the system-wide I/I control program is taking place. The plant will be completed in 2007. It is expected that the plant will operate six times per year and that the operating time will vary from a few hours to several days.

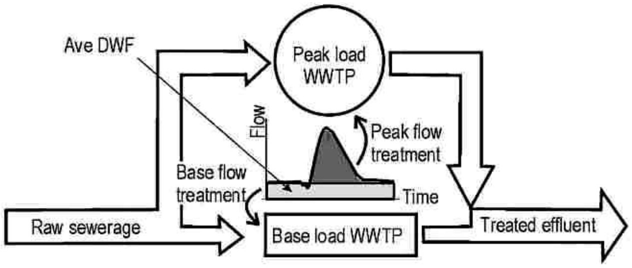


Figure 1-5. Separate WWTP to Treat Peak Flows Only.

Table 1-6. Willow Lake Water Pollution Control FacilityThe Existing Conventional WWTP (City of Salem, OR).

Design flow:	155.0 mgd
Ave DWF:	32.5 mgd
Ave WWF:	53.5 mgd
Peak WWF:	155.0 mgd (315 mgd peak hour flow)
SSOs:	On average six times per year— however, a blending technique is applied
Cost of treatment:	$2.70/1,000 gal
Annual quantity treated:	13,140 mg

Treatment:

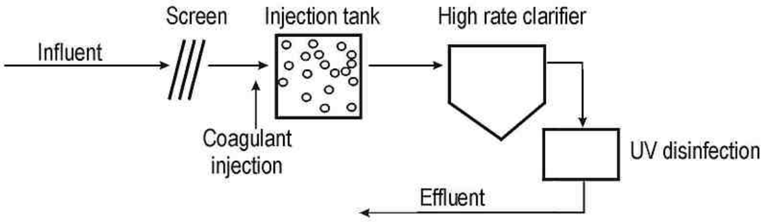
- Screening
- Primary sedimentation
- Extended aeration
- Chemical phosphorus precipitation
- Secondary clarification
- Disinfection

Table 1-7. Peak Excess Flow Treatment Facility (PEFTF)—A Satellite WWTP under Construction (City of Salem, OR).

Design flow:	60 mgd
Peak WWF:	50 mgd (expected to be diverted to this plant)
Cost of treatment:	Unknown at this time, assumed higher than at the conventional WWTP
Annual quantity treated:	300 mg (expected)

Treatment:

- Screening
- Coagulent injection
- Mixing
- High rate clarifier
- UV disinfection



1.2.3 Importance of Addressing Sewer Lateral Issues

The problems described in previous paragraphs and the consequences resulting from them clearly show that dealing with SSOs, additional volumes of sewage, and treatment problems caused by peak flows is an important task. The next question that must be answered by each community is to what extent excess flow due to I/I must be removed from the system instead of merely accommodating it in the treatment process. This, in turn, leads to the subject of this report which is how important laterals are in their contribution to I/I and/or system problems and how to approach an effective program to remove private sources of I/I and to rehabilitate defective sewer laterals. Although the exact extent of the blame placed on laterals for these problems varies from case to case, laterals often play an important role in exacerbating I/I related problems and must be dealt with effectively to reach an acceptably complete solution. For example, a 1999 survey of 316 municipalities nationwide found that 69% had problems with I/I from private property and almost half believed that 5-50% of their I/I originated on private property (WEF, 1999). Chapter 2.0 provides additional data collected as part of the survey conducted for this report.

It is important to understand that while defective laterals in any one neighborhood may generate only a moderate amount of I/I, this amount becomes an integral component of the total I/I in the sewer system. The “minor” I/I from many tiny sub-basins can thus be responsible for increasing downstream flows in sewer pipes over their capacity—causing SSOs and backups, having lift-stations and WWTPs pump and treat unnecessarily large volumes of diluted sewage, and disturbing the treatment of sewage at WWTPs. The defective sewer laterals in sub-basins can be the reason why larger sewer trunks are constructed and WWTPs and lift stations need to be upgraded. Defective sewer laterals can limit the ability of the wastewater collection system and WWTPs in one community to service its growing population and its future needs and thus may be confining for the community growth. For all these reasons, it is important to deal with sewer laterals in proper manner—to have them inspected, to determine how much they really contribute to the problems, and to rehabilitate them as appropriate and necessary. The rationale for such programs may be either because either this is a cost-beneficial alternative to solving systemwide problems or simply because a sound and leak-free sewer lateral is what is required by regulation and by good practice in sewer design and operation.

1.3 Unique Features of Sewer Laterals

Sewer laterals can be connected to the sewer mainline in the street (Figure 1-6) or a sewer easement pipe. Although usually illegal, various drains, downspouts, sump pumps, etc. can be found connected to the laterals letting stormwater and/or groundwater into the sewer system. Lateral pipes are often found cracked or broken, with roots pushing their way into the pipes through joints and thus opening them further. Water often can migrate along the outside of lateral and mainline pipes allowing leaks to migrate from one joint or leaking section to another if only a portion of the system is sealed.

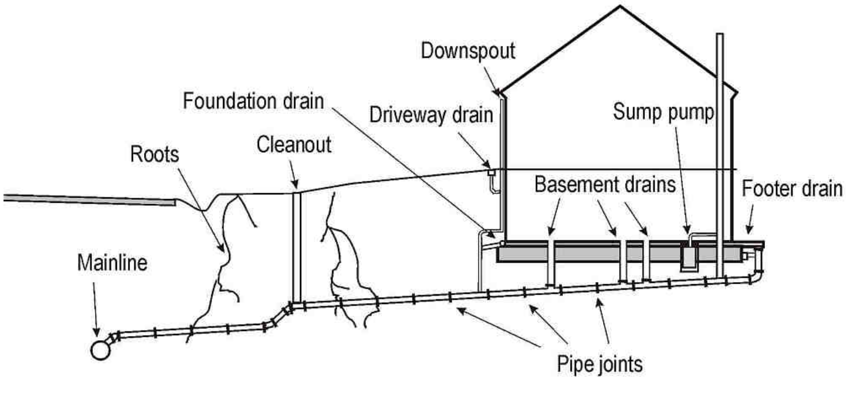


Figure 1-6. Typical Layout of Sewer Laterals.

Sewer laterals have some unique features compared to sewer mainlines, which are important when organizing and performing activities such as pipe inspection or rehabilitation:

- Small diameters—These pipes are most often 4” or 6” in diameter.
- Diameter changes—There is commonly a diameter change at the foundation or property line, for example from 4” to 6”.
- Multiple bends with multiple fittings for cleanouts, etc.
- Flat and shallow pipes—Laterals often have a minimum slope and are laid as shallow as possible in the existing topography until close to the mainline.
- Often constructed by local plumbing contractors with little or no inspection.
- Limited access to pipes—These pipes usually have no access points other than through the mainline connection or a cleanout. Sometimes they can be accessed from inside the house.
- Defective connections with the mainline—Often there is a “break-in” installation (“hammer tap”) or the lateral protrudes into the mainline (Figure 1-7). Also, the connection to the mainline is often broken because of ground settlement over time.
- Misaligned and/or open pipe joints—Mortar used to seal the joints between pipe sections deteriorates or was not fully installed in the first place.
- Many bells at the pipe joints are cracked and/or displaced
- Laterals often pass close to trees either on private property or at the edge of the roadway—roots can follow the outside of the sewer pipe until they find a joint to enter.
- Where repairs have previously been made, they are often of poor quality and “makeshift”.

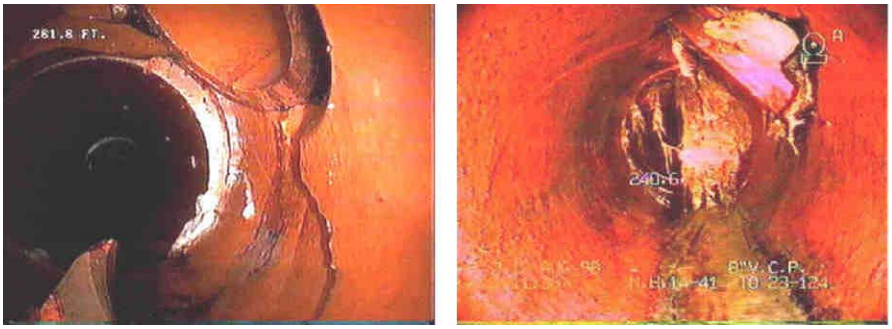


Figure 1-7. Defective Connections with Mainline. Left: “Break-in” Connection. Right: Protruding Tap with Root Intrusion (LMK Enterprises, Inc).

1.4 Summary

To provide a background as to why sewer laterals have come under particular scrutiny in recent years, this chapter has attempted to introduce the environmental imperative and regulatory drive in recent years to solve wastewater system I/I problems. The chapter has also begun the identification of what is different about the physical and administrative nature of sewer laterals. The rest of the report focuses more closely on the lateral problems and rehabilitation practices themselves and includes in the next chapter a good understanding of various features of sewer laterals and existing site conditions, as well as the diverse practices related to sewer laterals throughout the U.S. that has been obtained through a survey of public works agencies.

CHAPTER 2.0

SURVEY OF PUBLIC WORKS AGENCIES

2.1 Introduction

2.1.1 About the Survey

A survey aimed at giving a comprehensive insight into the diversity of existing conditions and working practices in dealing with issues related to private sewer laterals was made available for input to agencies in the United States and throughout the world. In a six-month period, a total of 58 agencies filled in a web-based questionnaire. The majority of responses came from the U.S. (Figure 2-1) and only three from other countries. This chapter presents a compilation of the collected responses.

Figure 2-1. Map Showing Participating Agencies in North America.

2.1.2 How to Read the Graphs in This Chapter

The answers that participating agencies provided in the questionnaire are presented in this chapter using either a pie chart or a two-part graph that is arranged to allow the reader to analyze the answers in summary form or to look for specific relationships among the answers given by a particular agency.

The pie charts illustrate at glance alternative answers to a question and the percentage of participating agencies that selected a particular answer to that question. However, pie charts are not suitable for questions that allow multiple answers because the percentages of the alternative answers do not add to 100%.

The two-part graphs, consisting of a bar chart on the left and a scatter graph on the right were used for questions with multiple answers (Figure 2-2). The order of the agencies on the x-axis was kept consistent in these graphs, however, it does not correspond to the order by which the agencies are listed in Table 2-2 to preserve the anonymity of the agency. The exception to this rule are graphs in Table 2-1, Figure 2-7, Figure 2-9, and Figure 2-11, in which the agencies were ordered in ascending/descending order of the quantity presented.

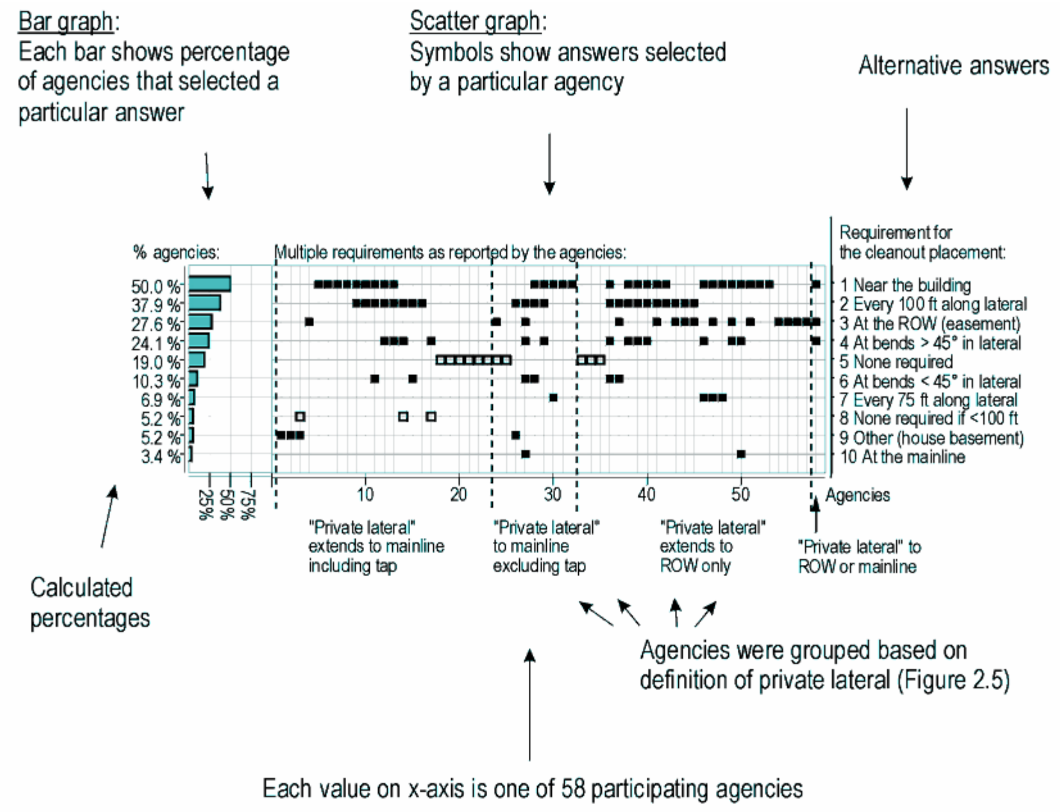


Figure 2-2. Example of a Two-part Graph.

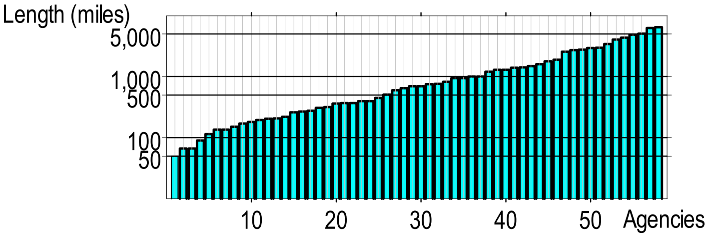
The 58 agencies on the x-axis were grouped (dotted line divides each group) based on their definition of a private lateral. This was one of the questions in the questionnaire and it was felt to have a strong relevance to many of the other questions about how agencies approach private sewer lateral issues. The same grouping was used for consistency throughout the graphs (minus the exceptions noted above) even if the answers to some questions did not necessarily relate to the extent of private ownership on the lateral.

2.2 Background Information

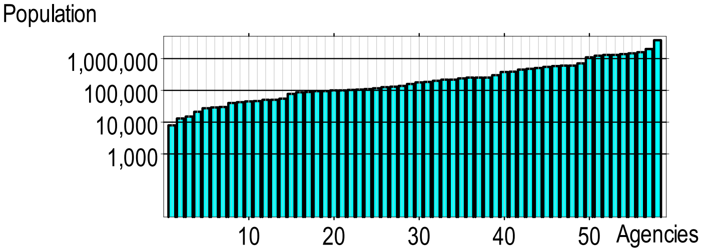
2.2.1 Participating Agencies

Agencies that have participated in the survey are listed in Table 2-2. Although the number of participating agencies is small compared to the number of existing wastewater agencies (estimated at over 17,000 in the U.S.), the survey sampling represents a wide range of wastewater collection systems of different sizes (in terms of total length in miles, population served, and the number of private laterals, as shown in Table 2-1) and with different local conditions (climate, soil and groundwater conditions, age and condition of pipes).

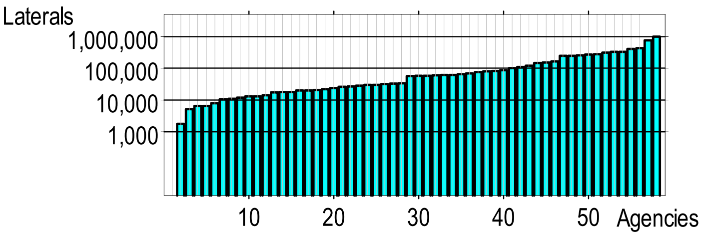
Table 2-1. Size of Wastewater Collection Systems Managed by the Participating Agencies.



Total Length:	Number of agencies:
≥1,000 miles	23 agencies
500-1,000 miles	10 agencies
100-500 miles	21 agencies
50-100 miles	4 agencies
0-50 miles	-



Population Served:	Number of agencies:
≥ 1,000,000	9 agencies
100,000-1,000,000	30 agencies
10,000-100,000	18 agencies
1,000-10,000	1 agency
0-1,000	-



Number of Private Sewer Laterals:	Number of agencies:
≥ 1,000,000	1 agency
100,000-1,000,000	17 agencies
10,000-100,000	34 agencies
1,000-10,000	5 agencies
0-1,000	-
Missing data	1 agency

Note: Ranges shown above include start values and exclude end values. For example: 500-1,000 miles means ≥500 miles and <1,000 miles.

The total number of responses is also comparable to surveys from earlier WERF research projects:

- A survey about innovative methods for inspecting and assessing the condition of sewer pipes was carried out in 2004. The survey had 31 participating agencies (WERF, 2004).
- A survey about practices for operation and maintenance of sanitary sewers was carried out in 2002. The survey had 27 participating agencies (WERF, 2003).

Table 2-2. Public Works Agencies Participating in the Survey and Their Collection Systems.

	Agency		Total Miles	Population Served	Number of Laterals
1.	City and Borough of Sitka	AK	50.00	8,000	1,800
2.	Little Rock Wastewater Utility	AR	1,200.00	183,000	62,500
3.	City of Phoenix, Water Services Dept	AZ	4,400.00	1,480,187	333,000
4.	City of Los Angeles	CA	6,500.00	3,800,000	750,000
5.	City of San Diego	CA	3,000.00	1,224,000	255,000
6.	City of Santa Barbara	CA	277.00	95,000	24,000
7.	South Coast Water District	CA	136.02	42,000	17,957
8.	Stege Sanitary District	CA	150.00	40,000	13,000
9.	Vallejo Sanitation and Flood Control	CA	400.00	117,000	30,000
10.	City and County of Denver WW Mgmt	CO	1,790.00	500,000	145,000

Table 2-2. Public Works Agencies Participating in the Survey and Their Collection Systems.

Agency			Total Miles	Population Served	Number of Laterals
11.	City of Arvada	CO	370.00	100,000	33,000
12.	City of Greeley	CO	317.00	78,000	20,867
13.	City of Thornton	CO	370.00	126,000	32,000
14.	City of Westminster	CO	365.00	110,000	30,000
15.	City of Key West	FL	66.00	29,000	14,266
16.	City of Sarasota	FL	267.00	54,000	17,224
17.	Miami-Dade County	FL	2,760.00	2,000,000	315,000
18.	Orange County Utilities	FL	1,420.00	253,761	110,331
19.	City of Savannah Water& Sewer Bureau	GA	750.00	220,000	70,000
20.	Boise City Public Works	ID	600.00	180,000	60,000
21.	City of Lawrence	KS	450.00	88,000	27,000
22.	City of Wichita	KS	1,900.00	450,000	120,000
23.	City of Shreveport	LA	1,000.00	200,000	58,000
24.	Lafayette Consolidated Government	LA	650.00	95,000	20,000
25.	New Orleans Sewer & Water Board	LA	1,600.00	476,000	Missing
26.	Boston Water and Sewer Commission	MA	1,409.00	589,000	88,190
27.	Washington Suburban Sanitary Comm	MD	5,100.00	1,600,000	425,000
28.	City of Duluth	MN	400.00	86,000	26,000
29.	Minneapolis Public Works	MN	830.00	385,000	250,000
30.	City of Springfield, MO	MO	1,000.00	160,000	65,000
31.	Metropolitan St. Louis Sewer District	MO	6,300.00	1,400,000	1,000,000
32.	City of Greensboro	NC	1,300.00	250,000	80,000
33.	City of Binghamton	NE	170.00	50,000	12,000
34.	City of Las Vegas	NV	1,500.00	600,000	150,000
35.	City of Bellefontaine	OH	66.00	13,100	6,500
36.	City of Columbus	OH	2,567.00	1,100,000	250,000
37.	City of Toledo	OH	950.00	300,000	100,000
38.	City of Eugene Public Works	OR	770.00	137,000	58,000
39.	City of McMinnville	OR	90.00	27,000	6,500
40.	City of Salem	OR	700.00	220,000	56,500
41.	Peters Township Sanitary Authority	PA	115.00	15,000	5,200
42.	Parker Sewer & Fire District	SC	260.00	50,000	18,000
43.	Knoxville Utilities Board (KUB)	TN	1,300.00	380,000	62,000
44.	Nashville and Davidson County Metro	TN	2,800.00	550,000	167,000
45.	City of Grapevine	TX	203.00	46,188	13,100
46.	City of Plano	TX	952.00	240,000	75,410
47.	City of Wichita Falls	TX	506.00	104,000	34,000
48.	Dallas Water Utilities	TX	4,086.00	1,300,000	266,608
49.	City of Everett	WA	310.00	100,000	21,892
50.	City of Olympia	WA	180.00	45,000	11,000
51.	City of Tacoma	WA	700.00	250,000	82,500
52.	King County	WA	4,905.00	1,300,000	400,000
53.	Village Of Menomonee Falls	WI	194.60	21,200	10,600
54.	City of Laramie	WY	135.00	30,000	8,000
55.	City of Edmonton, Alberta	Canada	2,960.00	707,300	273,214
56.	City of Waterloo, Ontario	Canada	207.00	107,200	28,090
57.	City of Göttingen	Germany	220.00	130,000	20,000
58.	City of Tshwane Metro Municipality	S. Africa	3,438.00	600,000	330,000
	Minimum:		50.00	8,000	1,800
	Mean:		1,335.00	428,309	122,110
	Median:		700.00	170,000	58,000
	Max:		6,500.00	3,800,000	1,000,000

2.2.2 Magnitude of Problem—I/I from Private Laterals

All but one participating agency considered I/I into the wastewater collection system a problem[12]. Despite the problem awareness, however, only 44.8% of the participating agencies have attempted to estimate how much private sewer laterals contribute to total I/I into the system (Figure 2-3).

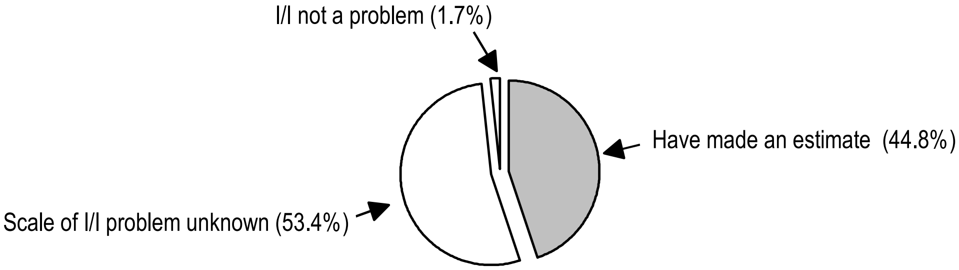


Figure 2-3. Agencies Estimating I/I from Private Sewer Laterals.

The 26 participating agencies that had analyzed the issue estimated the contribution of private sewer laterals to total I/I in the wastewater system at between 7% and 80%. The mean and median of the 26 estimates was 40% (Figure 2-4).

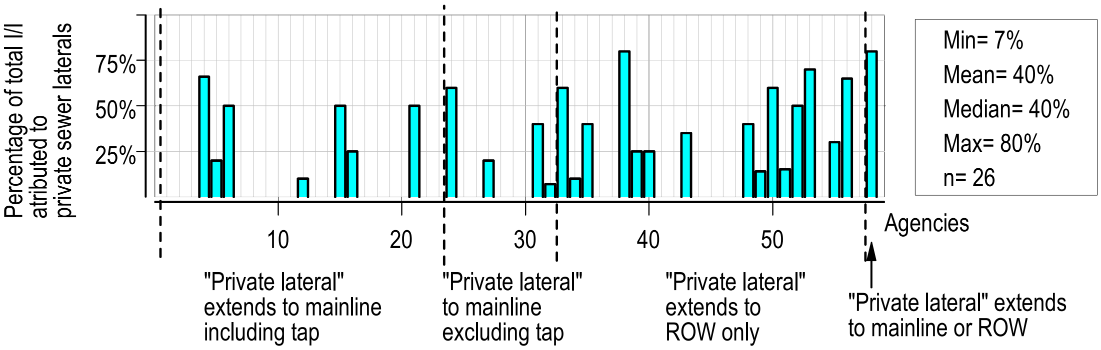


Figure 2-4. Estimated Contribution of Private Laterals to Total I/I into the Wastewater System.

About half of the agencies reported that their estimate was an educated guess, which means that a ballpark figure of lateral contribution in total I/I was assigned rather intuitively by acknowledging known facts about the system, existing defects, and deducing from other rehabilitation projects completed within the same system. For example:

- Total lengths of laterals and mainlines in the collection system were compared and used to allocate a corresponding percentage of total I/I to the laterals (for example 50%). If more defects recognized as sources of significant infiltration were on laterals than mainlines, the percentage was adjusted accordingly (for example 80%). The adjustment may also have been made based on considering the age and type of pipes in the system.
- Completed rehabilitation projects that excluded and included private sewer laterals in I/I reduction were compared for effectiveness. If there was a significant difference (for

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[12] *The single agency that claimed having no I/I problem is in a dry climate, with 296 days of sunshine per year and average annual precipitation of 8.29 inches.*

example, 20% vs. 80%), the difference (60%) was attributed to the laterals contribution in total I/I.

The rest of the agencies reported that their estimate was a more-or-less a firm figure because the contribution from the laterals in total I/I was calculated in a particular way. The following approaches were reported:

- Rehabilitation projects were performed with phased rehabilitation (mainlines/manholes first, sewer laterals next).
- Rehabilitation projects were performed that involved comprehensive mainline/manhole rehabilitation but that excluded private sewer laterals.
- Sewer System Evaluation Studies (SSES) were performed in which individual sources of I/I were identified and quantified throughout the system.
- SSES were performed in which total I/I into the system was divided between manholes, mainlines and laterals based on results of smoke testing.

2.3 General Information about Private Laterals

2.3.1 Definition of "Privately Owned Lateral"

A total of 43.1% of participating agencies reported having a definition of a "privately owned lateral" from the house to the property line, and 55.2% from the house to the mainline (Figure 2-5).

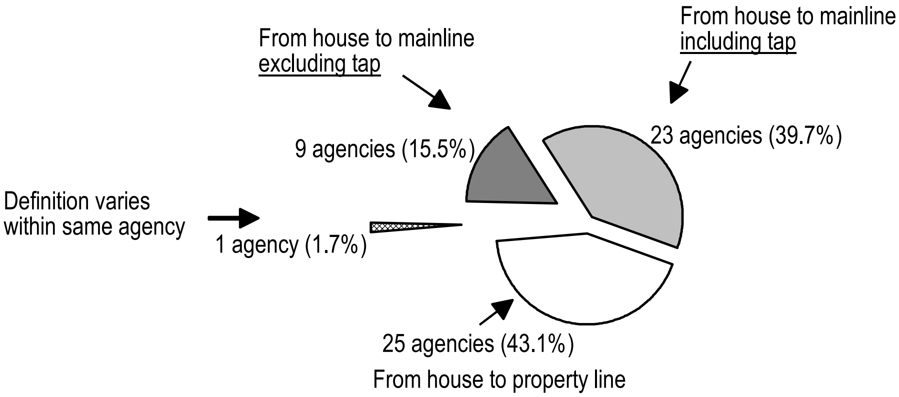


Figure 2-5. Definition of "Privately Owned Lateral".

In the agencies where private ownership extends to the mainline, the homeowner usually also owns the tap to the mainline (23 out of 32 agencies). One participating agency reported that the definition of a "privately owned lateral" was not the same for all laterals in the system. If there was an agency cleanout near the property line, the homeowner owned the lateral from the house to the cleanout, and otherwise from the house to the mainline. None of participating agencies reported owning the entire lateral.

2.3.2 Pipe Types Used for Private Sewer Laterals

The participating agencies reported the pipe types used for sewer laterals in their systems (Figure 2-6 and Figure 2-7). Most private sewer laterals were reported to be VCP pipes (51.8%), but that PVC pipes, being usually the preferred pipe type for new installations and pipe replacements, were already representing a large portion of pipes within their systems (26.6%). "Other" pipe types in the survey responses referred to Orangeburg pipes and asbestos-cement pipes, which are no longer installed in current practice.

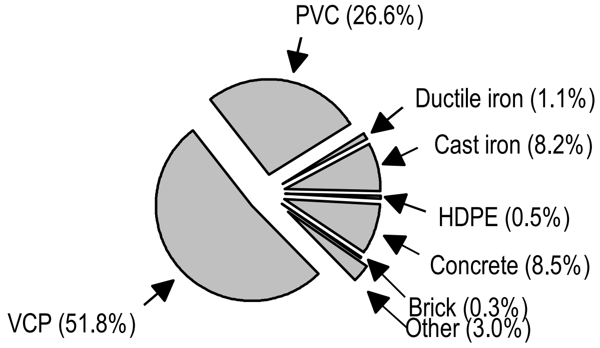
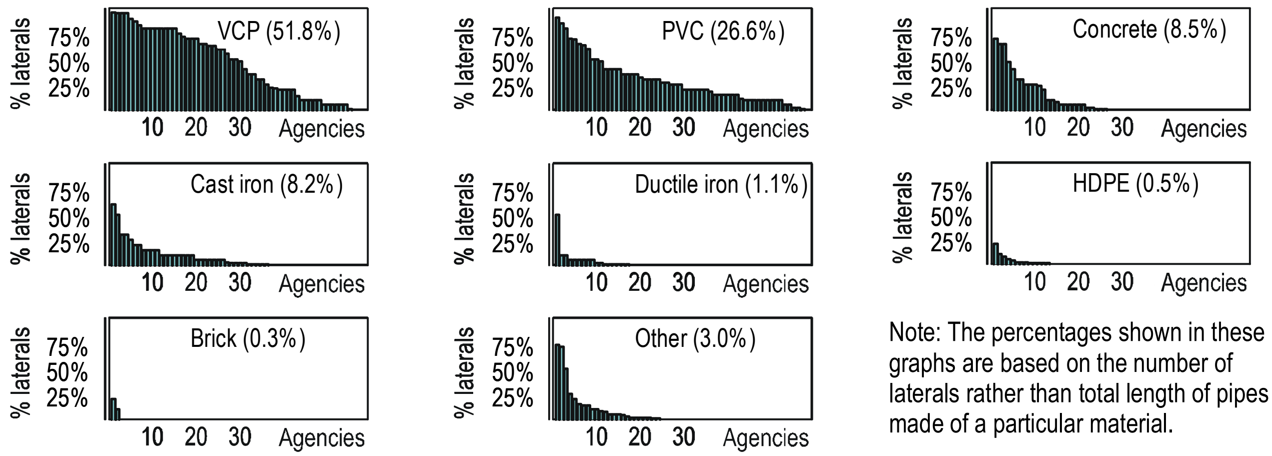


Figure 2-6. Pipe Types Used for Sewer Laterals.



Note: The percentages shown in these graphs are based on the number of laterals rather than total length of pipes made of a particular material.

Figure 2-7. Allocation of Different Pipe Types within the Participating Agencies.

2.3.3 Pipe Sizes Used for Private Sewer Laterals

The participating agencies reported the pipe sizes used for sewer laterals in their systems (Figure 2-8 and Figure 2-9). Most private sewer laterals were reported to be 4" pipes (62.6%) and 6" pipes (29.7%). Smaller diameters (3" or less) and larger diameters (up to 12") were reported in smaller quantities.

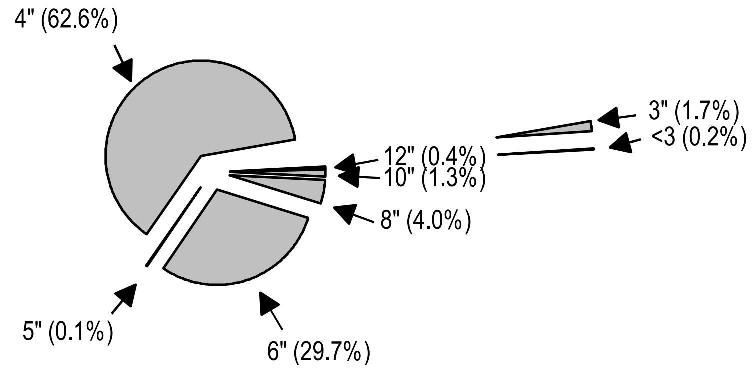
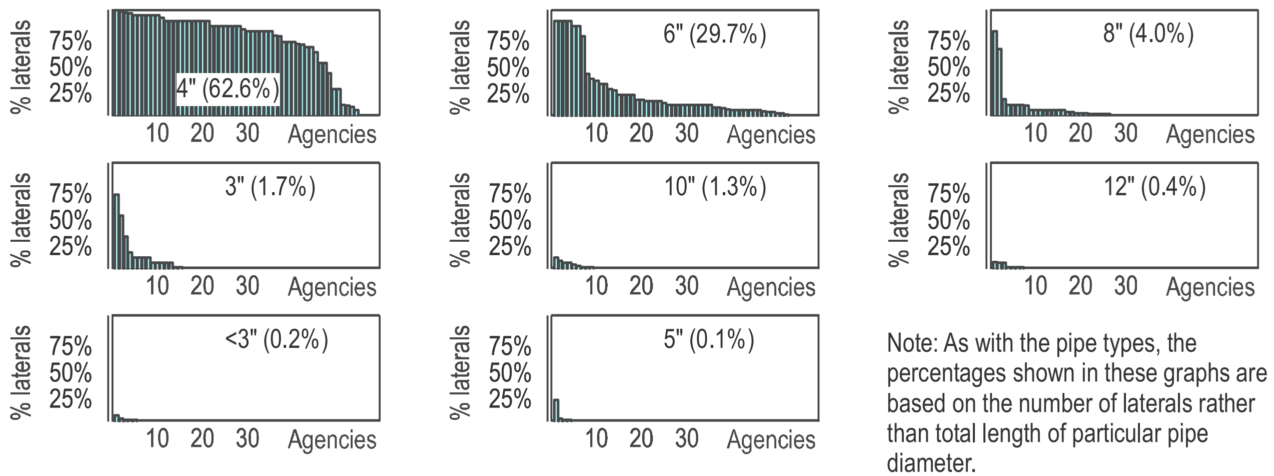


Figure 2-8. Pipe Sizes Used for Sewer Laterals.



Note: As with the pipe types, the percentages shown in these graphs are based on the number of laterals rather than total length of particular pipe diameter.

Figure 2-9. Allocation of Different Pipe Sizes within the Participating Agencies.

2.3.4 Location of Laterals and Cleanouts on Private Property

Laterals. The location of a sewer lateral on private property depends on site conditions (Figure 2-10 and Figure 2-11). Most laterals are in front of the house, but there are agencies that have over 80% of their laterals at the back of the house, as well as agencies with over 50% of their laterals at the side of the house.

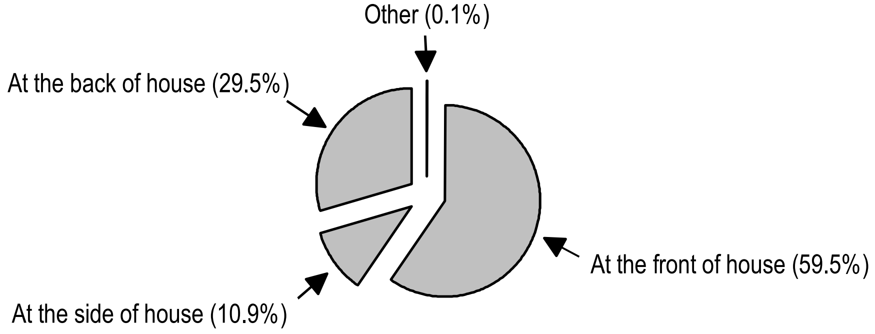


Figure 2-10. Placement of Laterals on Private Property.

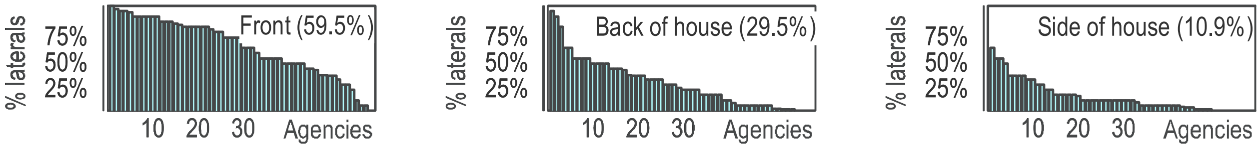


Figure 2-11. Placement of Laterals on Private Property within the Participating Agencies.

Cleanouts. A total of 19.0% of participating agencies reported that cleanouts are still not required and the remaining 81.0% of agencies require at least one cleanout on their laterals (Figure 2-12). The agencies that require cleanouts reported that the requirement for placing the cleanouts is generally controlled by local plumbing codes and that the cleanouts are required at different locations along the laterals (Figure 2-13).

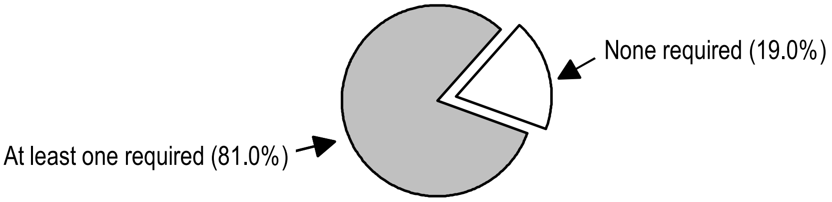


Figure 2-12. Requirement for Cleanouts in the Participating Agencies.

Most agencies require a cleanout near the house (50% of participating agencies), which is followed by the requirement for a cleanout at every 100’ distance (38% of participating agencies), and at the ROW or easement (28% of participating agencies). Cleanouts were not required in 24% of the participating agencies and, in addition, 5% of participating agencies did not require cleanouts if the laterals were less than 100’ long.

Figure 2-13 also shows that cleanouts are typically required at multiple locations along the laterals even within the same participating agency. Also, the figure shows that if the private ownership ends at the ROW, at least one cleanout is usually required (in all but three agencies). The cleanout is typically not required at the ROW if the private ownership extends to the mainline (only three participating agencies have that requirement).

Within the same agency, the required location of cleanouts may be different for different laterals. For example, the agency may require one cleanout (at the ROW or elsewhere) for any new lateral being built but allows old laterals to stay without the cleanouts (depicted as #24 in the graph). Another participating agency reported that cleanouts could be positioned at different locations along the laterals, but that at least one cleanout was required outside the house and one “last cleaning eye” before the mainline (depicted as #27 in the graph).

Additional remarks by the participating agencies were:

- When some work is performed on laterals (for example, rehabilitation), new cleanouts are installed where they are missing (one participating agency).
- If cleanouts are required at a closer spacing (e.g. every 75’), they need not all be visible (one agency).

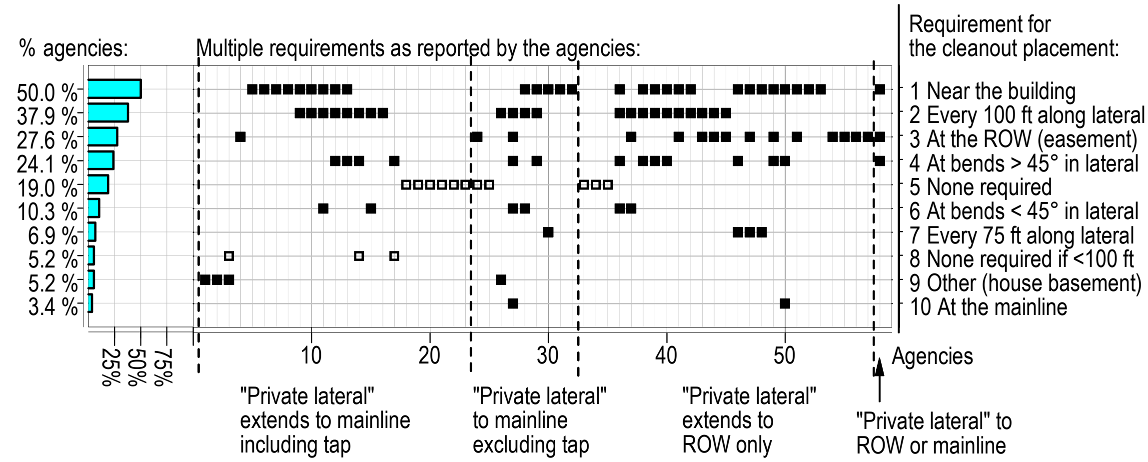


Figure 2-13. Location of Cleanouts along the Laterals.

2.4 Locating Private Sewer Laterals

2.4.1 Keeping the Record of Location of Private Sewer Laterals

A total of 24.1% of participating agencies reported keeping no record about the location of sewer laterals in their systems (Figure 2-14). The rest of participating agencies reported having some kind of record about lateral location even though in some cases it only involved the public part of the lateral (the part between the mainline and the ROW) or only information about the lateral-to-mainline connection.

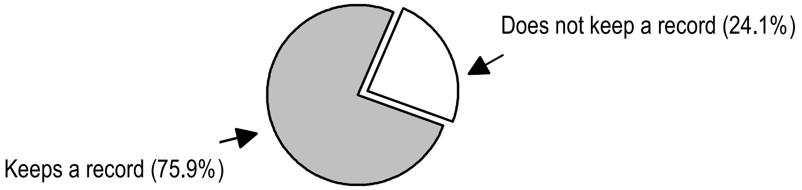


Figure 2-14. Agencies Keeping a Record of Location of Private Laterals.

The participating agencies reported utilizing different ways for keeping records of sewer laterals (Figure 2-15). Most frequently the location of private laterals is stored on maps (55.2% of participating agencies). However, storing the record electronically in databases is getting to be used quite often (32.8% of participating agencies), as well as in GIS systems (27.6% of participating agencies). Additionally, one participating agency reported being in the process of entering the records from CCTV logs into GIS systems, and another one being in the planning stage. “Other” reported ways to keep records of private sewer lateral locations include index cards (seven agencies), permit records (four agencies), and microfilm (two agencies). Several agencies reported using inspection forms when only the record of lateral-to-mainline connection is available (three agencies).

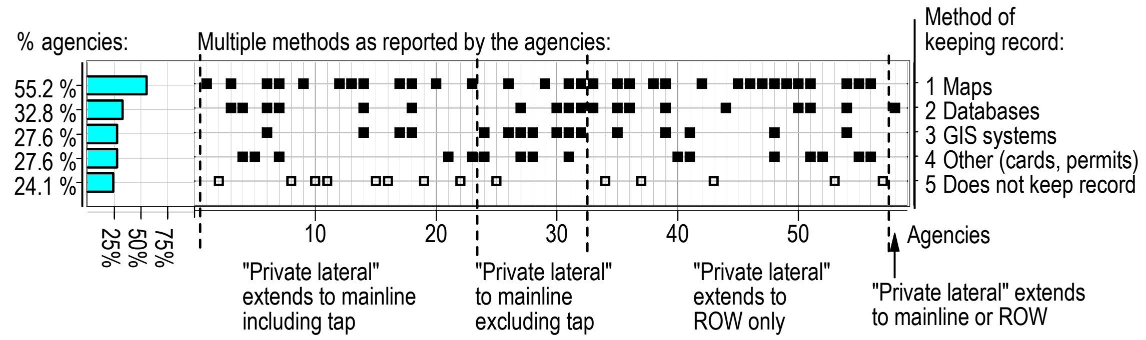


Figure 2-15. Record of Location of Laterals.

2.4.2 Locating Private Sewer Laterals

A total of 60.3% of participating agencies reported engaging in field locating activities to verify the path of known private laterals or discover if any private laterals are missing from the agency's records (Figure 2-16). Other agencies (25.9%) also locate their laterals, however, not as a standard practice but occasionally, as needed. Only eight agencies (13.8%) reported never using any of the methods for lateral locating.

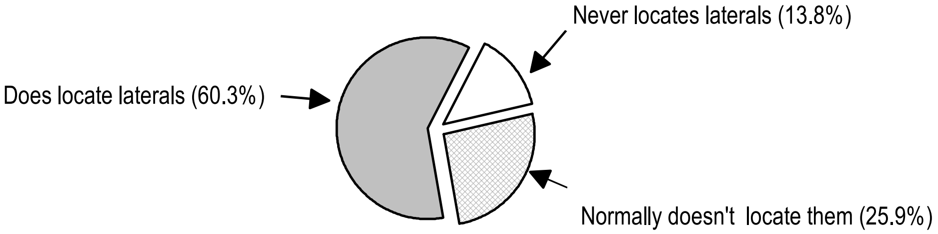


Figure 2-16. Agencies Performing Field Locating of Sewer Laterals.

The laterals are most often located during inspection work (e.g. smoke testing, etc.) or prior to some trenchless work on laterals (e.g. new installations, rehabilitation/replacement of laterals) (Figure 2-17). However, the agency may also engage in locating the laterals at other times as follows:

- When mainlines are inspected or repaired, the lateral-to-mainline connections are also recorded (four agencies).
- When mainlines are relocated, all connecting laterals must also be located and rerouted (one agency).
- Prior to any excavating, the agency may still want to locate all existing laterals in the area following the "One Call" from contractors (two agencies).
- When a new connection to the mainline is requested, the existing connections must be known. A homeowner may request the locating/CCTV inspection of the lateral (two agencies).
- Sale of property may require the locating of laterals (one agency).

Several agencies reported having locating of private laterals as a part of a continuous program of systematic identifying and mapping of the path of mainlines and public laterals (three agencies).

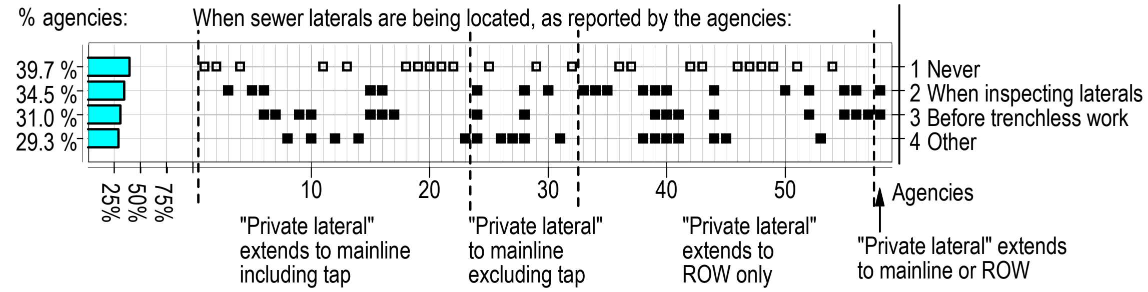


Figure 2-17. When the Agencies Engage in Locating Laterals.

2.4.3 Methods for Locating Private Sewer Laterals

The agencies reported using a variety of methods to locate laterals (Figure 2-18), but most often a mainline CCTV inspection, followed by lateral CCTV inspection, dye water testing and smoke testing, and walk-over sonde detectors. “Other” reported methods include the use of a plumber’s snake, which is passed through the pipe and followed aboveground with a stethoscope-type instrument (one agency), vacuum excavated test pits (one agency), witching (one agency), sewer marker balls installed on new pipes (one agency), as-builts (one agency), or were not clarified (five agencies).

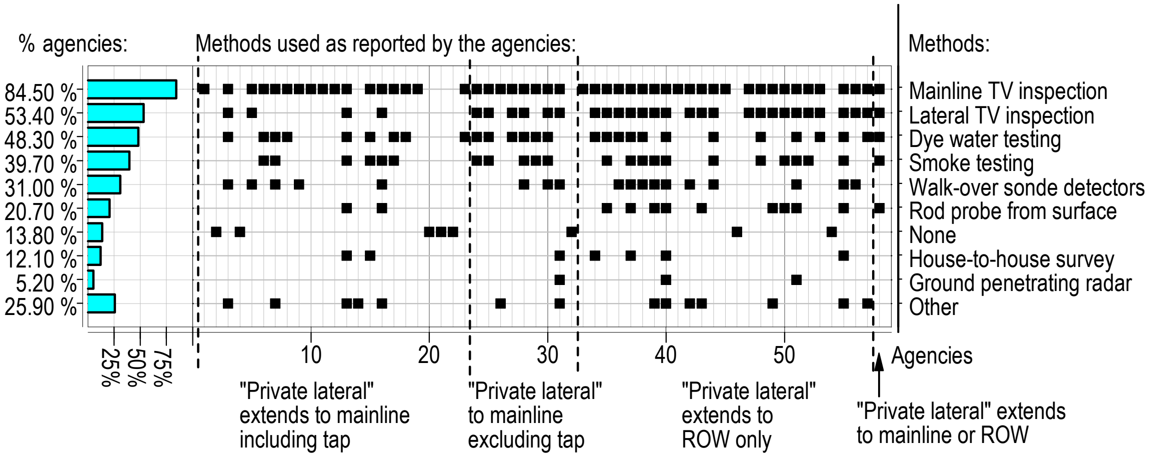


Figure 2-18. Methods Used for Locating Sewer Laterals.

2.5 Infiltration and Inflow (I/I)

2.5.1 Methods to Identify Sources of I/I

The agencies reported using various methods to identify sources of I/I on private property (Figure 2-19). The most popular method is mainline CCTV inspection, which identifies leaking lateral-to-mainline connections (86.2% of agencies), followed by smoke testing and dye water testing (69.0% and 56.9% of participating agencies respectively). “Other” reported methods include visual inspection of the basements on sale of property (one agency) and questionnaires filled in by homeowners (one agency).

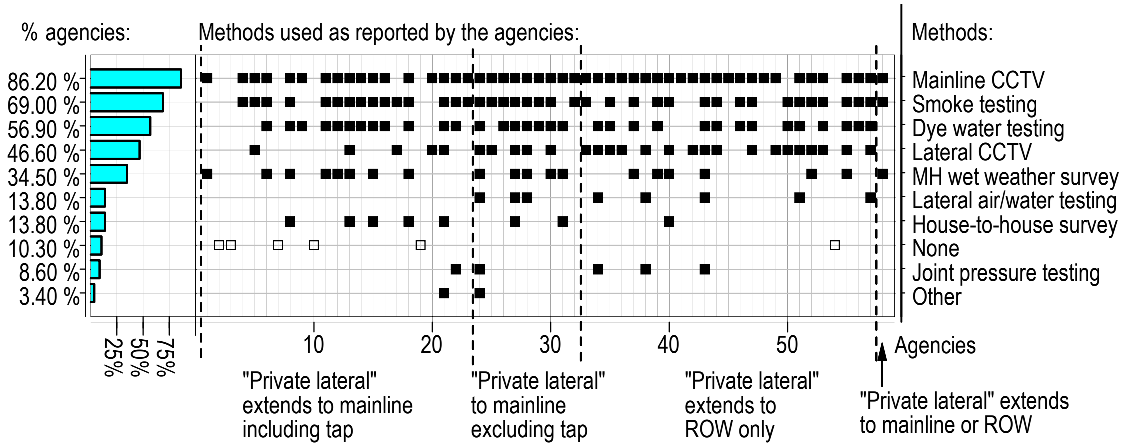


Figure 2-19. Methods for Identification of I/I Sources.

2.5.2 I/I Studies and Quantification of I/I

A total of 78% of participating agencies have performed I/I studies to quantify total I/I into the collection system, however only 38% of them have performed I/I studies that quantify I/I contribution from private sewer laterals (Figure 2-20).

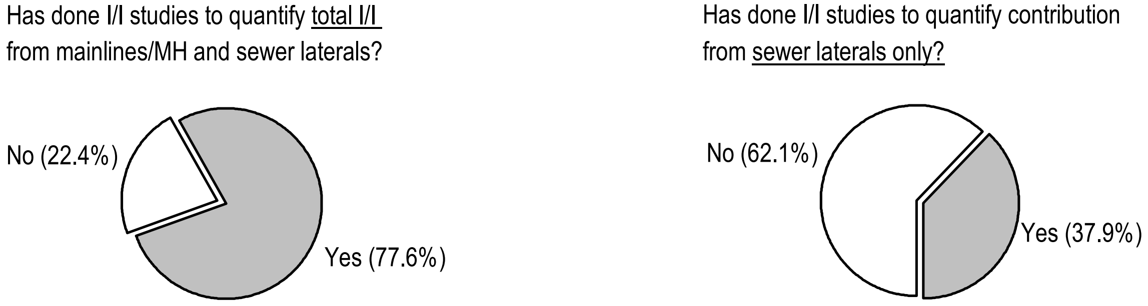


Figure 2-20. Types of I/I Studies.

The 22 agencies that have performed I/I studies quantifying I/I from private sewer laterals reported that these studies were done as follows:

- Total I/I into the system was determined either before any rehabilitation was carried out or after a combined public/private sewer rehabilitation, and was subsequently broken down into I/I from public and private sector based on defect classification of defects throughout the system or specific site conditions (nine agencies).
- Total I/I into the system was determined after completed comprehensive mainline rehabilitation (public sector rehabilitation), and as a whole allocated to private sewer laterals (three agencies).
- Total I/I into the system was determined before and after comprehensive private lateral rehabilitation (e.g. removal of inflow sources or repair of private lateral pipes) and the whole difference allocated to private sewer laterals (four agencies).
- Leaks identified in the private sector throughout the system were quantified and the quantities summarized (three agencies).

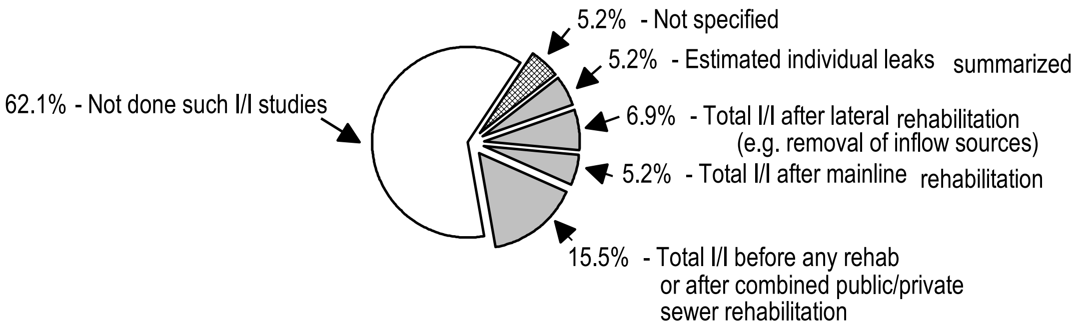


Figure 2-21. How the Completed I/I Studies Estimate I/I from Private Sewer Laterals.

The 22 agencies further reported using the following data in their I/I studies (Figure 2-22):

- Flow monitoring (FM) data collected in sub-basins or controlled study areas (20 agencies)
- Water consumption data (six agencies)
- Flow estimates during CCTV inspection of laterals (eight agencies)
- Defect quantification tests in Sewer System Evaluation Studies (SSES) (six agencies)

None of the participating agencies has attempted remote measuring of lateral flows from the mainline. Also, none of the participating agencies tried to incorporate in any way a rainfall simulation using sprinklers in their I/I study.

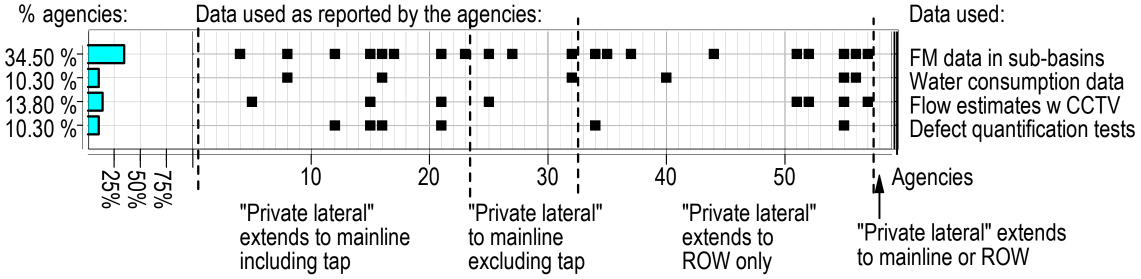


Figure 2-22. Data Used in I/I Studies that Quantify Contribution from Private Sewer Laterals.

2.5.3 Connecting Various Drains to the Sanitary Sewer

A total of 46.6% of participating agencies reported that homeowners were not allowed to connect any sources of inflow to the sanitary system (Figure 2-23). The rest of the participating agencies reported allowing connection of various drains in the past. Only 25.9% of participating agencies reported that they allow connecting various drains to the sanitary sewer in current practice (Figure 2-24). The permitted connections include mostly garage drains (19.0% of participating agencies) and basement drains (15.5% of participating agencies).

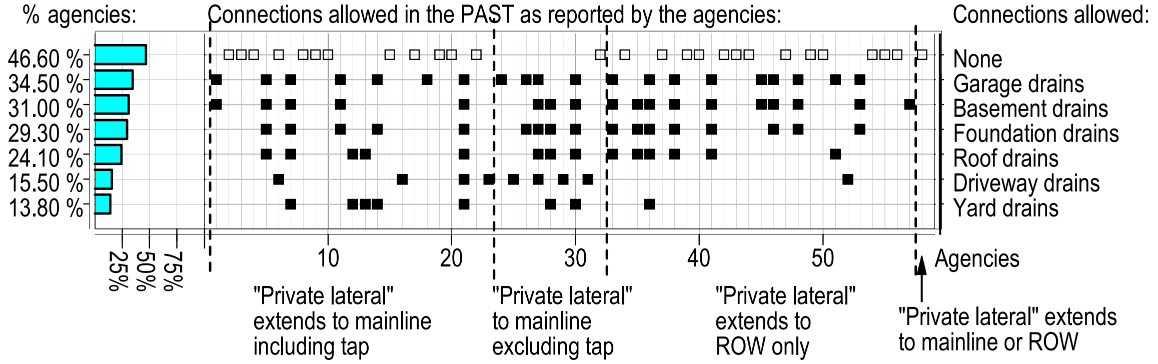


Figure 2-23. Legal Connection of Inflow Sources to the Sanitary Sewer in the Past.

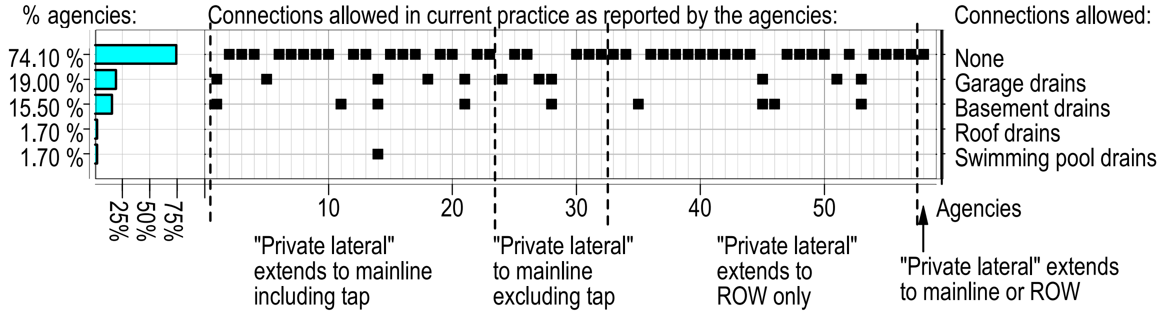


Figure 2-24. Legal Connection of Inflow Sources to the Sanitary Sewer in Current Practice.

2.5.4 Specific Local Conditions

A total of 46.6% of participating agencies reported that they could not specify local conditions that impact sources and/or quantity of I/I. The rest of agencies identified high groundwater elevations, rainfall events, soil conditions and proximity of body of water as principal factors (Figure 2-25).

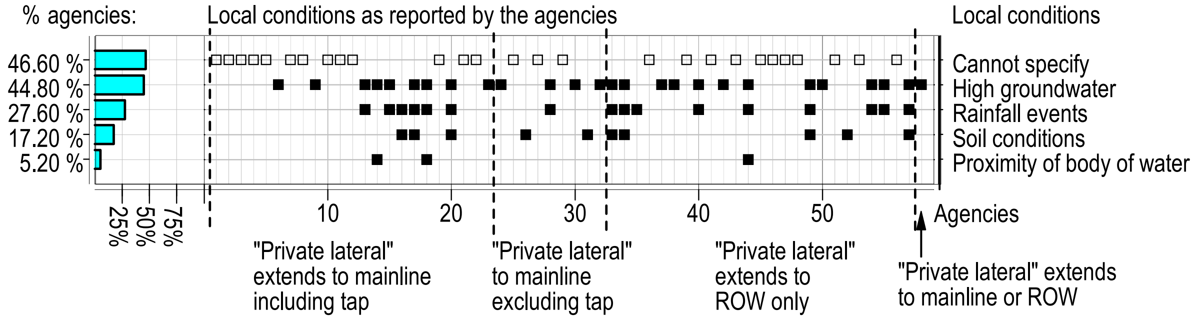


Figure 2-25. Specific Local Conditions that Impact Sources and/or Quantity of I/I.

The agencies explained the impact of rainfall events as follows:

- Several participating agencies have high annual rainfall with averages of 30”, 40-50”, to nearly 100” of rain per year. Excessive rainfall eventually finds its way into the system.

- ♦ One participating agency reported having repetitive smaller storms rather then intensive thunderstorms, which still amounts to a rather large total rainfall in a relatively brief period of time and thus maintains a high groundwater table.

The agencies explained the impact of soil conditions as follows:

- ♦ Three participating agencies reported soil movement and/or weather-based expansion and contraction causing lateral cracks and offset joints.
- ♦ One participating agency reported having rocky soil conditions, in which sewer trenches function as French drains causing the groundwater to flow along the sewer pipe in the trench. Such migration turns inactive leaks into active leaks.
- ♦ One participating agency reported having soil conditions that quickly become saturated with water, even after rainfall events as little as 1.5".

The agencies explained the proximity of a body of water as follows:

- ♦ One participating agency reported experiencing the impact of tides on groundwater elevation.
- ♦ Two agencies reported having natural springs that run year around or a lake in the area, which maintain a high groundwater table.

2.6 Condition Assessment

2.6.1 Defect Coding for Structural/Hydraulic Rating of Defects

A total of 53.4% of participating agencies either reported not to be sure about the system used for structural and hydraulic rating of defects or did not specify the system used (Figure 2-26). A total of 29.3% of participating agencies reported using a system developed or modified in-house. Two agencies provided examples of in-house systems: defects are rated as "excellent, good, fair, poor" or equivalent. The satisfaction with in-house developed systems varies among the agencies from "very pleased" to regarding their use as "a limited success". Several agencies reported moving from in-house systems towards defect rating systems such as NASSCO or PACP.

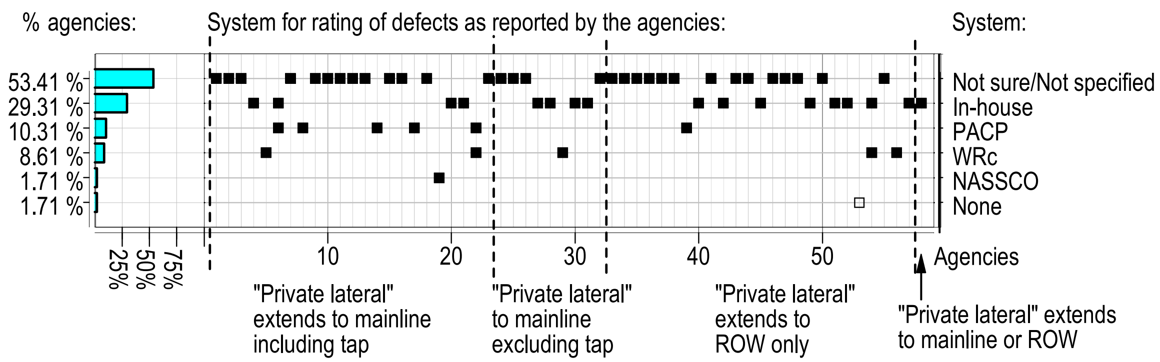


Figure 2-26. Systems for Defect Coding in Use.

2.6.2 Causes of Lateral Problems

The participating agencies have identified reasons for lateral problems in their wastewater systems (Figure 2-27). Most agencies reported the following:

- The quality of initial construction of laterals is held responsible for existing problems on laterals (75.9% of participating agencies).
- The quality of installed products, i.e. materials used, is held responsible (67.2% of participating agencies).
- Soil movement/bedding type/soil movement is held responsible (55.2% of participating agencies).

Later modification to the system (design of rehabilitation/replacement, quality of rehabilitation construction and/or rehabilitation materials) is held responsible for problems in less than 15% of participating agencies. “Other” reported causes involve intrusion of tree roots through pipe joints and other defects (12.1% of participating agencies), age/type/depth of pipes, improper bedding at the lateral-to-mainline connection, lack of maintenance and its unclear jurisdiction, and damage to pipes caused by contractors utilizing both conventional open-cut installations and horizontal directional drilling (HDD).

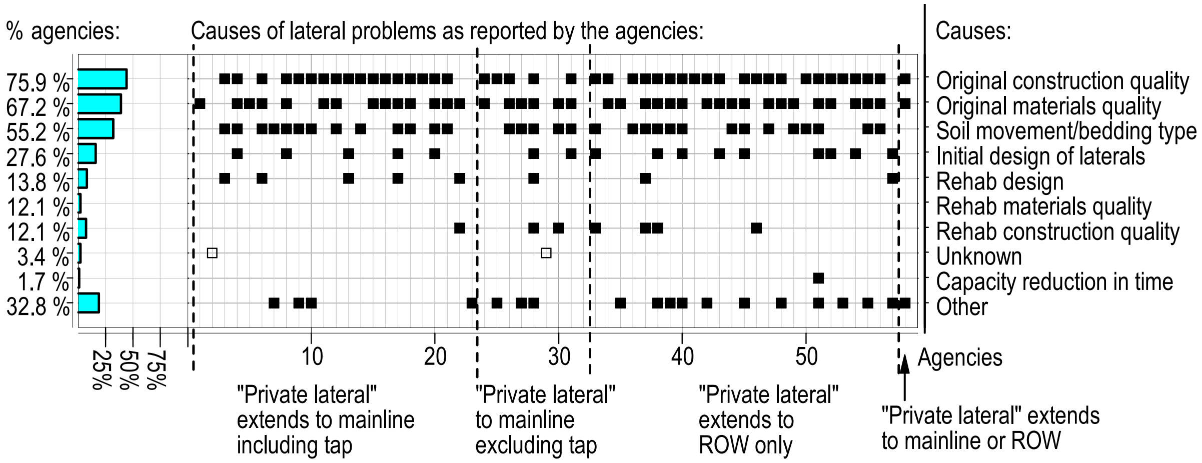


Figure 2-27. Causes of Lateral Problems.

2.7 Rehabilitation of Sewer Laterals

2.7.1 Methods for Rehabilitation/Replacement

The participating agencies reported utilizing various repair methods on sewer laterals aimed at removal of infiltration (Figure 2-28), however, their responses were not completely consistent:

- Most agencies reported methods used only on the private portion of laterals, which may have included methods on upper laterals or entire laterals (depending on the length of the privately owned laterals in agencies). Some agencies reported also on methods utilized on the public portion of laterals.
- Most agencies did not report methods contracted by homeowners but some did.
- Some agencies reported only methods utilized on a regular basis but most agencies reported also those tried in pilot studies even if only on selected laterals.

A total of 82.8% of participating agencies reported using open cut replacement or open cut point repair for repairing the laterals. Pipe bursting and pipe relining were reported as the most frequently used trenchless repair methods by 46.6% and 41.4% of participating agencies respectively. Chemical grouting was reported as used by 10.3% of participating agencies, however, this reflects the fact that this method is usually used on the publicly owned part of laterals (lateral-to-mainline connections and the first few feet up the lateral from the mainline).

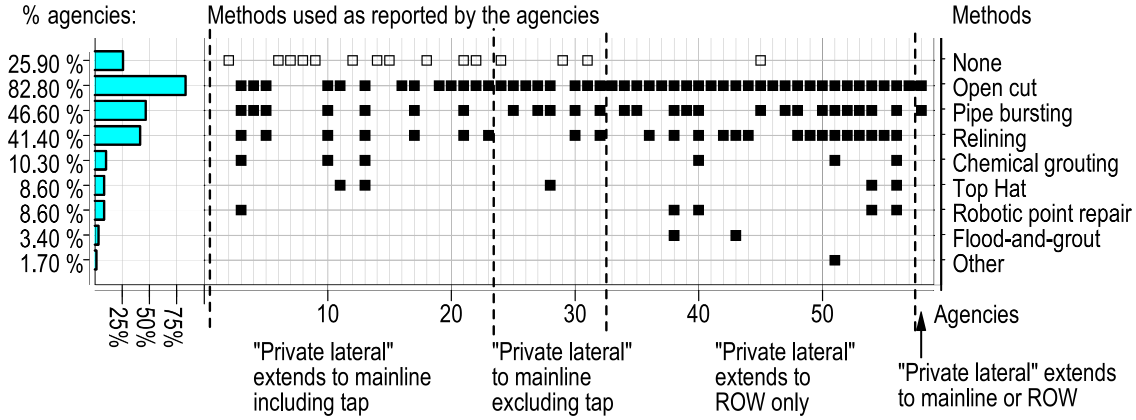


Figure 2-28. Methods for Rehabilitation of (Private/Public) Sewer Laterals.

2.7.2 Methods for Eliminating Sources of Inflow

A total of 24.1% of participating agencies reported that they had not pursued measures for eliminating sources of inflow, while the rest of the agencies reported utilizing various methods (Figure 2-29). Methods most often utilized are disconnecting of downspouts, disconnecting of area drains, and replacement of broken/missing cleanout caps (a total of 56.9%, 51.7% and 48.3% respectively). “Other” methods in the graph referred to disconnecting of pool drains and a requirement for installation of storm drainage in new developments.

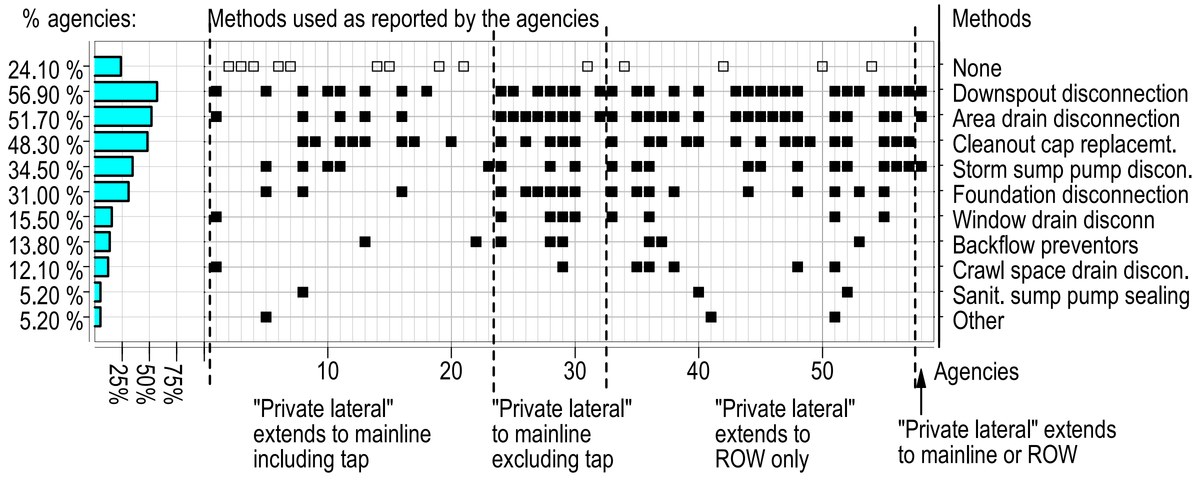


Figure 2-29. Methods for Elimination of Inflow Sources

2.7.3 Effectiveness of Past Measures in I/I Reduction

A total of 37.9% of participating agencies reported that they tried to determine the effectiveness of applied measures for I/I reduction, such as pipe rehabilitation and/or the elimination of inflow sources (Figure 2-30). A total of 29.3% of participating agencies reported having a formal ongoing program for lateral rehabilitation (Figure 2-31). Some of these agencies have not yet tried to determine its effectiveness in I/I reduction, whereas some other agencies have tried such analysis even though not having established a formal rehabilitation program (Figure 2-32).

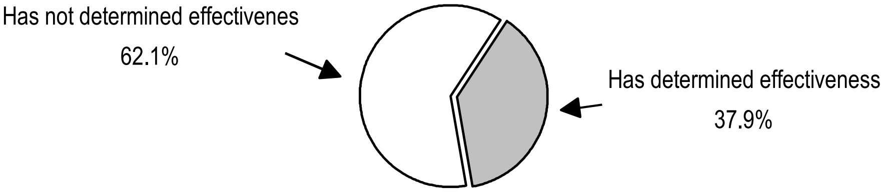


Figure 2-30. Estimating Effectiveness of Applied Measures for I/I Reduction.

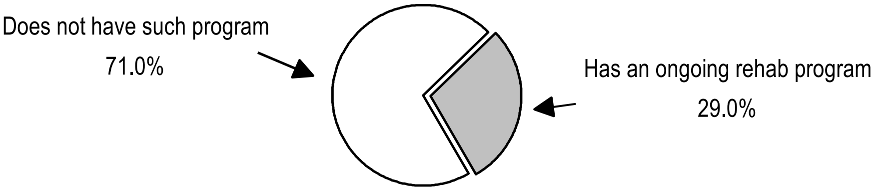


Figure 2-31. Formal Ongoing Rehabilitation Program in Agencies.

Figure 2-32 also shows the number of laterals repaired annually and the budget spent on lateral rehabilitation in the participating agencies. Typically, ongoing rehabilitation programs repair less than 3% of existing laterals annually, and annual spending on lateral rehabilitation is usually under $10 per capita.

Reported numbers of repaired laterals do not reflect the extent of repair on them and therefore total reported annual budgets for lateral rehabilitation are not directly proportional to the numbers of rehabilitated laterals.

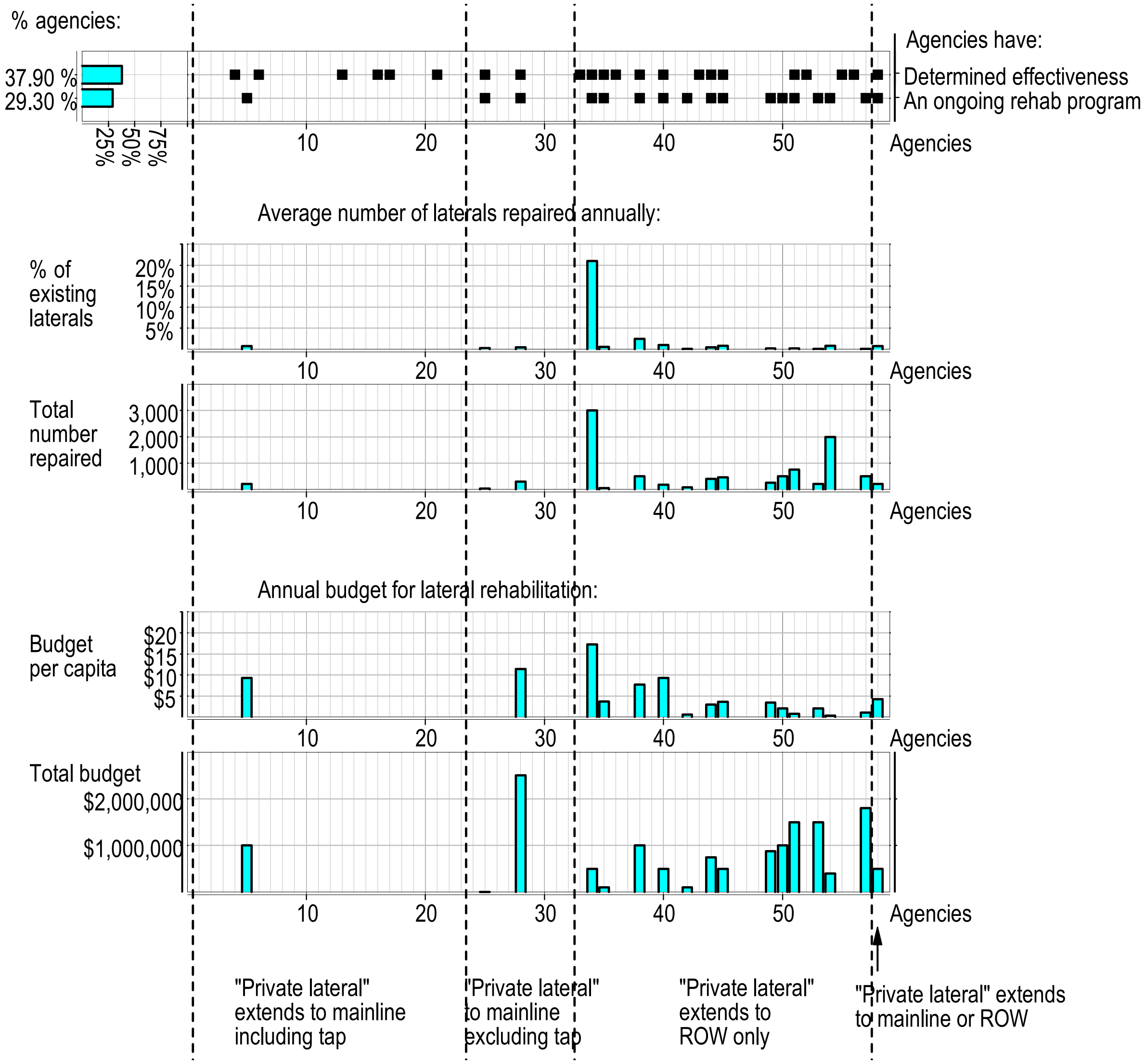


Figure 2-32. Ongoing Formal Lateral Rehabilitation Programs in the Agencies.

2.8 Management

2.8.1 Tracking Activities Related to Private Sewer Laterals

A total of 34.5% of participating agencies reported not having activities related to private laterals tracked, mainly because the private laterals are not in their jurisdiction. The remaining 65.6% of participating agencies keep a record of these activities as follows (Figure 2-33):

- Inspection/locating: 48.8% of participating agencies. Results from the CCTV inspection are kept in CCTV logs/videos, which may be entered into a database. Drawings of lateral layout are made or are updated.
- Rehabilitation: 39.7% of participating agencies. Work performed by homeowners is very often tracked by work permits, which are generally required prior to making any repair or replacement. Performed activities may also be logged in into a database or a computerized maintenance management system (CMMS).

- Basement backups: 39.7% of participating agencies. Calls reporting the backups are recorded in a claims database, a CMMS and/or as a hard copy incident reporting. The CCTV records from the inspection following the backups may also provide a record of the backups.
- Evaluation of I/I: 31.0% of participating agencies. Records of I/I evaluations are usually stored in reports from I/I studies and SSO reduction projects.
- Maintenance: 27.6% of participating agencies. Work orders, plumbing inspections, or removals of a private lateral blockage (reported by a plumber) are recorded on sewer connection cards or in a database.
- Measures for removal of inflow sources: 24.1% of participating agencies. A follow-up inspection is made and disconnected sources entered into a database or the record of their disconnection stored in some other way.
- Evaluation of effectiveness in I/I reduction: 20.7% of participating agencies. Same as evaluation of I/I.

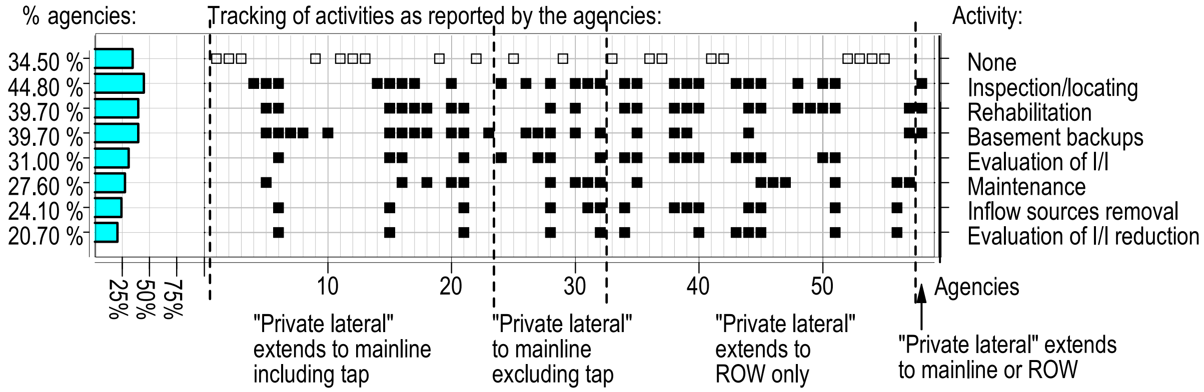


Figure 2-33. Tracking of Activities Related to Private Laterals.

2.9 Legal Issues

2.9.1 Accessing Private Property

A total of 39.7% of participating agencies reported not ever entering private properties for any work on private sewer laterals (i.e. for maintenance, inspection or rehabilitation of sewer laterals, or removal of inflow sources) (Figure 2-34). Agencies contracting private plumbers to do the work on their behalf were counted as agencies that do not enter private properties. The remaining 60.3% of agencies enter private properties regularly or occasionally.

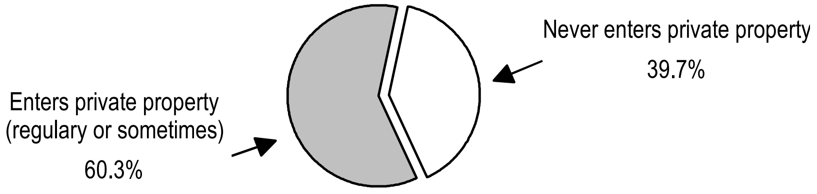


Figure 2-34. Agencies Accessing Private Property.

The agencies that enter private property reported gaining and maintaining authority to do so based on obtaining the following (Figure 2-35):

- Special permits must be signed by homeowners in 25.9% of participating agencies.
- Municipal or other codes provide jurisdiction to enter and no additional documents or actions are required in12.1% of participating agencies.

A total of three agencies reported different requirements:

- One agency had to obtain a court order to enter private property.
- One agency procures only a verbal agreement from the homeowner.
- One agency requires a homeowner physically present on site while its crew performs any work on private property.

The remaining 17.2% of participating agencies did not specify requirements for entering private properties.

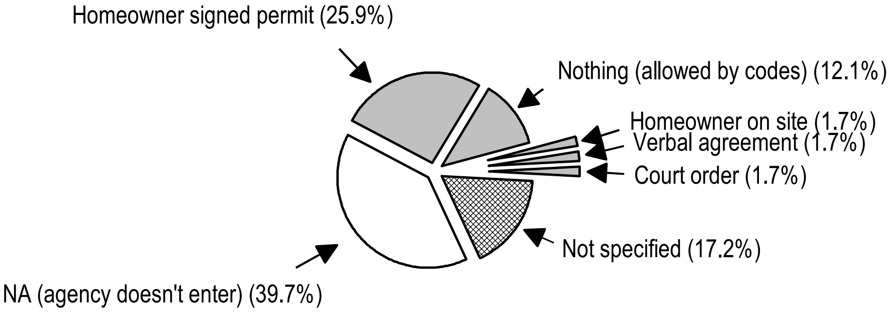


Figure 2-35. Requirements for Agency to Gain Authority to Enter Private Property.

2.9.2 Liability for Damages or Injuries

The agencies that enter private property reported the following policies about accepting the liability and reimbursing the homeowner for repair of damage in case of damage done to the property or injury occurring during work on private property (Figure 2-36):

- A total of 25.9% of participating agencies would accept liability and reimburse the homeowner. Some of these agencies have insurance to cover these costs (8.6% of participating agencies). In order to identify damages that rightfully qualify for reimbursement, some agencies have a legal department with a city lawyer or a risk management department to handle the claims (8.6% of participating agencies).
- A total of 6.9% of participating agencies does not reimburse the homeowner for damages. These agencies avoid legal responsibility for damages or injuries by including a disclaimer of liabilities on the right-of-entry permit and have the homeowner sign it.
- The remaining 27.6% of participating agencies did not specify their policy regarding this issue.

Figure 2-37 indicates how policies for addressing liability relate to policies for entering private property. For example, agencies that obtain a special agreement signed by the homeowner prior to accessing private property (15 agencies) reported addressing liability for damages in two ways: four agencies reported that they would never accept any liability but seven agencies reported not ruling out reimbursing homeowners in some cases. The remaining four agencies did not clarify this issue. Agencies that have ordinances authorizing them to enter private property (seven agencies) reported that they would accept liabilities (three agencies) or did not clearly specify (four agencies).

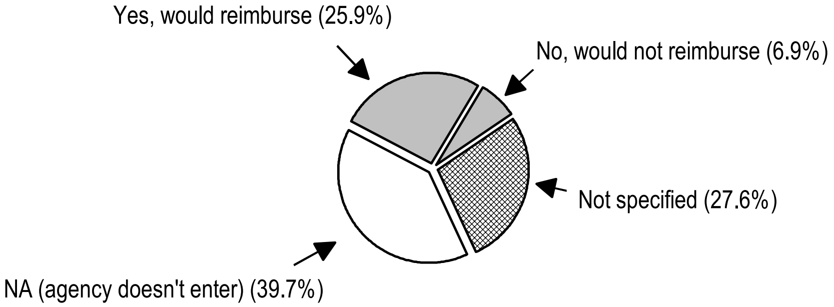


Figure 2-36. Agencies Addressing Liability for Damages or Injuries During Work on Private Property.

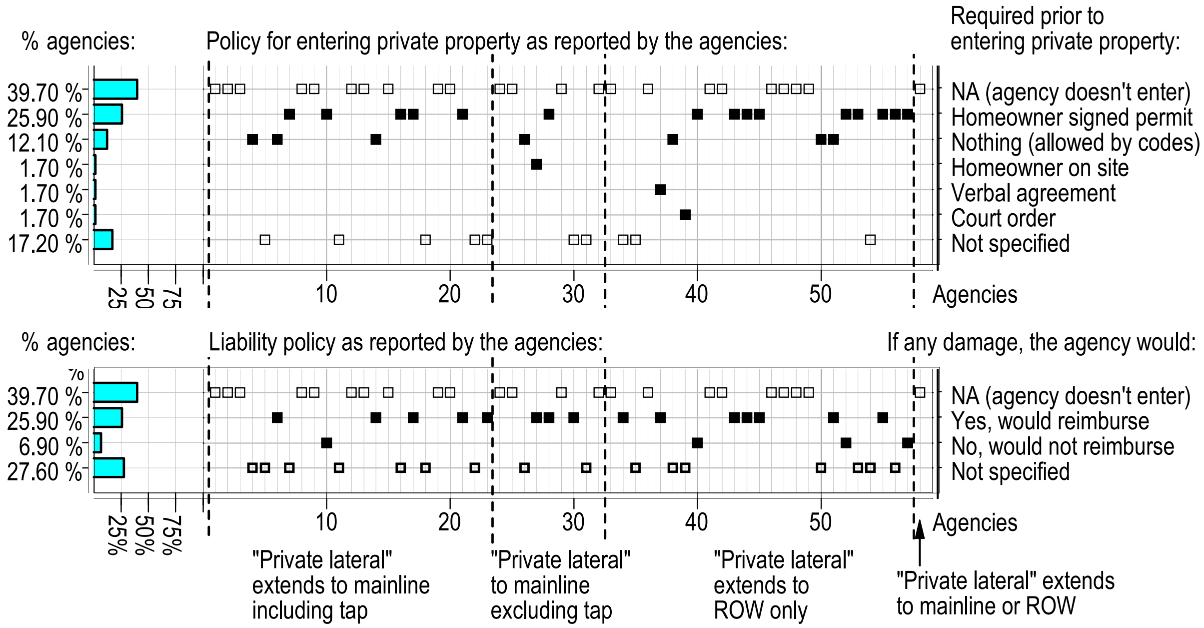


Figure 2-37. Addressing Liability Related to Accessing Private Property.

2.9.3 History of Legal Cases

A total of 24.1% of participating agencies reported having a history of legal cases related to activities on private property (Figure 2-38). (Legal cases might have been related to accessing private property or dealing with liabilities.)

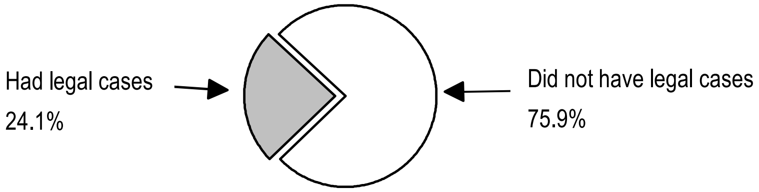


Figure 2-38. History of Legal Cases in Agencies.

2.10 Responsibility for Organizing and Financing Activities on Sewer Laterals

One part of the survey questionnaire focused on clarifying who is responsible to organize and pay for the necessary work on sewer laterals. This is not necessarily the same party—the agency may, for example, bring its own crew or hire a third party contractor to inspect or repair a lateral and have the homeowner pay for the cost. On the other hand, the homeowner may have to repair the lateral and later be fully or partially reimbursed by the agency.

In general, more than one answer to any question in one agency indicates that there is not a firm policy regarding that question in that agency. Agencies may choose to organize/finance activities differently when they are part of a pilot study or when they are done, for example, during inspection/rehabilitation of public sewers (mainlines/lower laterals) in the neighborhood. Some participating agencies were regional sanitation districts and their answers covered policies of local service providers within the district that may have varied.

Based on the responses, separate graphs were made that show responsibility for organizing and financing inspection sewer laterals, removal of inflow sources and rehabilitation of laterals, and their maintenance in the participating agencies (Figure 2-39 through Figure 2-42). The order of agencies on the x-axis in these graphs is the same.

Inspection. Organizing and financing of lateral inspection were reported to be the responsibilities of homeowners in 55.2% and 56.9% of participating agencies respectively. However, some of these agencies reported also having laterals inspected by the agency when:

- Lateral inspection is performed as part of pilot projects (depicted as #27, #40, #56 in the graph)
- Lateral inspection is part of public sewer rehabilitation/replacement (R/R) projects[13] (depicted as #28 in the graph).
- The homeowner bought a warranty from the agency (depicted as #25 in the graph).

Overall, in 29.3% of participating agencies lateral inspection is paid by both agency and homeowner. These are mostly agencies where private ownership ends at the ROW. In an additional 19.0% of agencies the homeowner may be partially reimbursed for the cost of inspection. One agency reported that lateral inspection is still not required at all (depicted as #24 in the graph) and another one that private laterals have not yet been inspected (depicted as #1 in the graph). None of the participating agencies reported that the homeowner is required to provide a yearly inspection report or an inspection report at the time of change of title or ownership.

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[13] *These are projects that are focused on sewer mainline and, if publicly owned, lower laterals.*

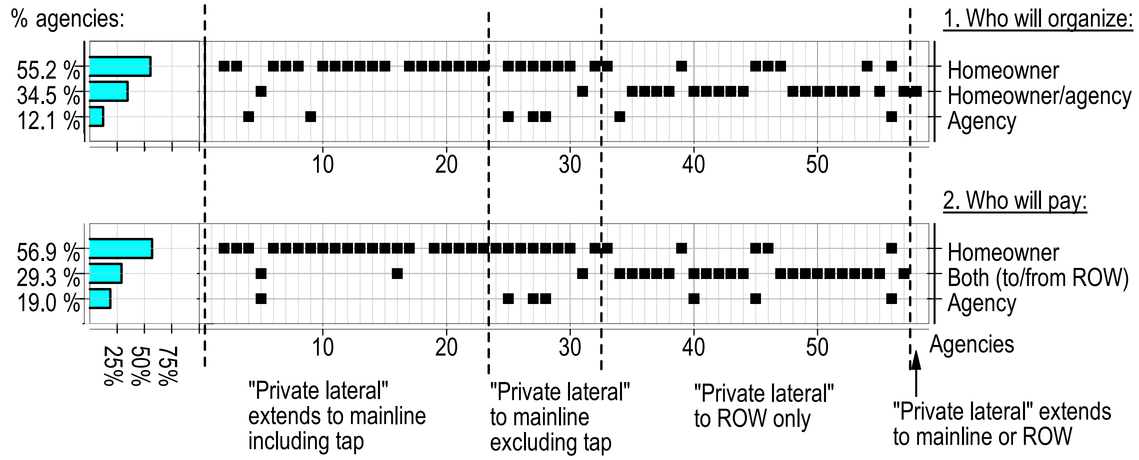

Figure 2-39. Inspection of Sewer Laterals.

Removal of Inflow Sources. Organizing and financing of removal of inflow sources were reported to be responsibilities of homeowners in 62.1% and 58.6% of participating agencies respectively. Some of these agencies reported that they remove inflow sources from selected laterals instead of homeowners when:

- Disconnection of inflow sources (e.g. footing drains) is performed as part of pilot projects (depicted as #27, #40, #56 in the graph)
- Disconnection of inflow sources is part of public sewer rehabilitation/replacement (R/R) projects (depicted as #28 in the graph[14]).
- The agency would replace missing or damaged cleanout caps especially if they get damaged when the agency performs smoke testing (depicted as #43 in the graph).

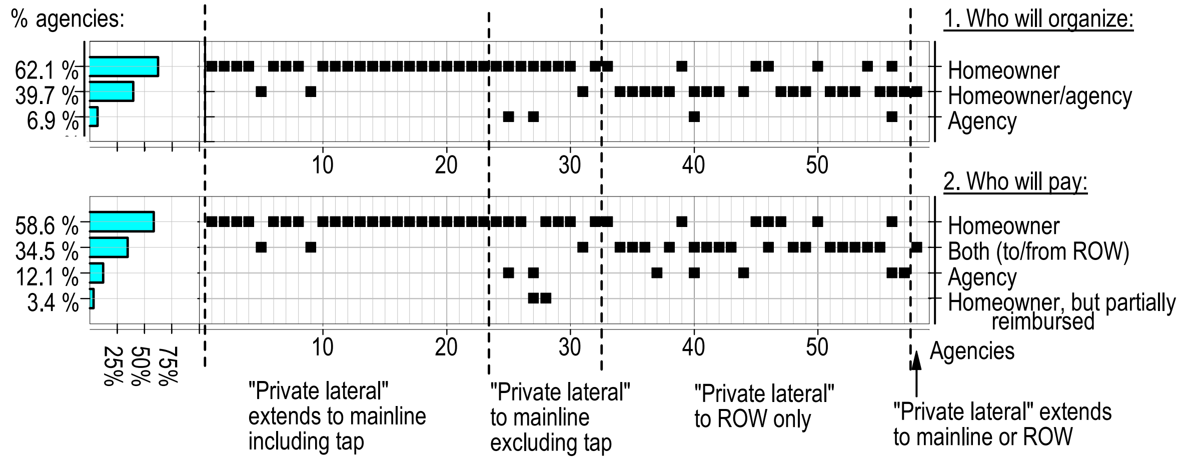

Figure 2-40. Removal of Sources of Inflow.

Rehabilitation/Replacement. Organizing and financing of lateral rehabilitation/replacement were reported to be responsibilities of homeowners in 56.9% and 58.6% of participating agencies respectively. Some of these agencies reported that they repair selected laterals instead of homeowners when:

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[14] *Paid by homeowners but financial assistance provided in the form of loans.*

- Lateral repair is performed as part of pilot projects (depicted as #27, #40, #56 in the graph)
- Lateral repair is part of public sewer rehabilitation/replacement (R/R) projects (depicted as #28, #45 in the graph[15]).
- The agency would repair certain types of laterals, for example, those made of Orangeburg pipe (depicted as #5 in the graph).

Overall, in 43.1% of the participating agencies, repair of lower laterals is paid for by the agency and repair of upper laterals by the homeowner. In addition, 1.7% of participating agencies (one agency only) reported partially reimbursing the homeowner for the cost of private lateral repair.

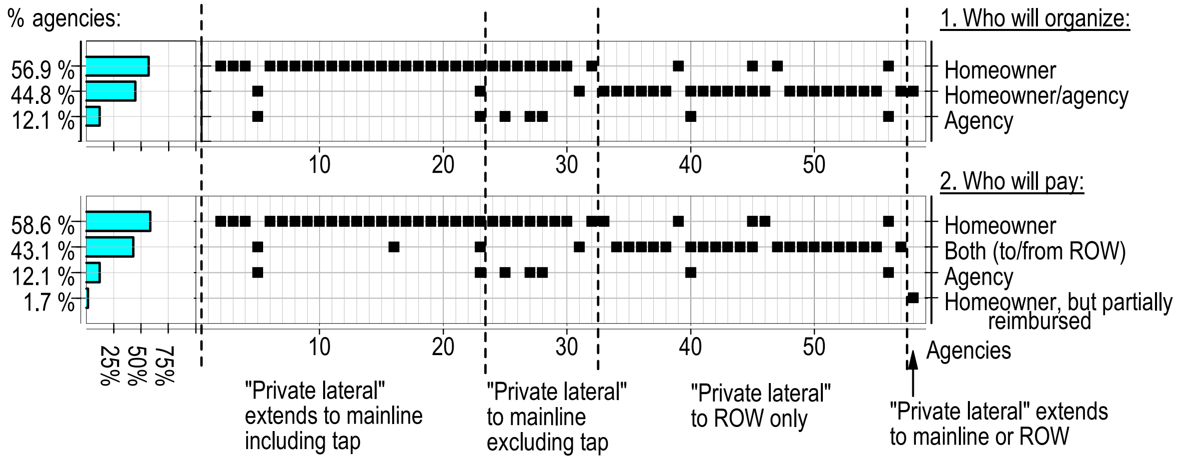

Figure 2-41. Rehabilitation/Replacement of Sewer Laterals.

Maintenance. Organizing and financing of the maintenance of laterals were reported to be responsibilities of homeowners in 65.5% and 60.3% of participating agencies respectively. As would be expected, if a homeowner owns a lateral to the mainline, most agencies (30 out of 32 agencies) reported that the homeowner has to organize and pay for the maintenance of the lateral. If private ownership of the lateral extends only to the ROW, most agencies reported that the homeowner and the agency organize and finance the maintenance of the part of lateral they own (22 out of 25 agencies). However, the remaining three out of 25 agencies (depicted as #33, #39, and #54 in the graph) reported that the homeowner has to organize/pay for maintenance of the entire lateral even though the private ownership ends at the ROW.

In 37.9% of participating agencies, the homeowner pays for lateral maintenance to the ROW and the agency for the remaining part of the lateral. An additional 3.4% of agencies reported that the homeowner could be partially reimbursed for the cost of lateral maintenance.

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[15] *Paid by homeowners but financial assistance provided in the form of loans.*

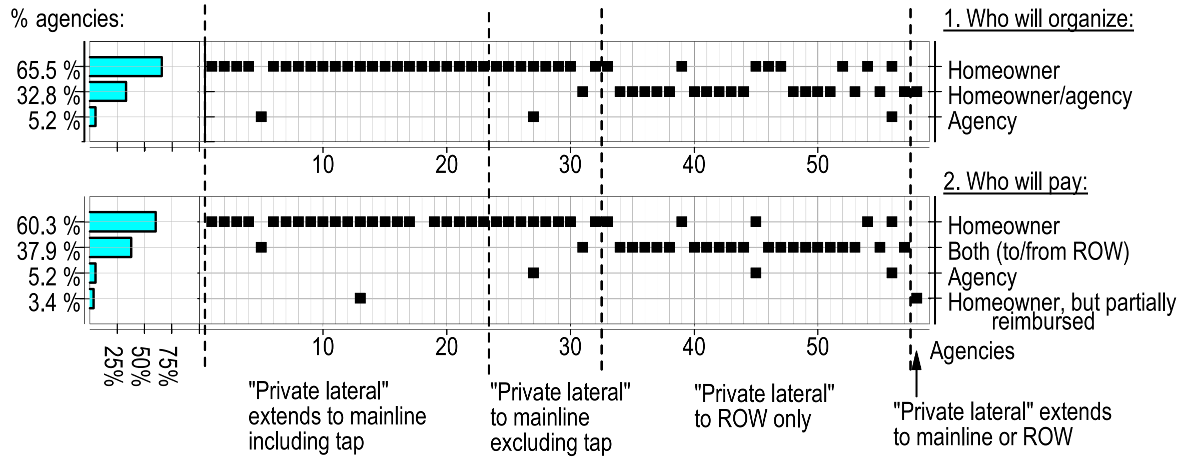


Figure 2-42. Maintenance of Sewer Laterals.

2.10.1 Enforcement Measures for Homeowners

Removal of Sources of Inflow. Although all participating agencies but one require that homeowners remove sources of inflow from the sewer laterals, 34.5% of agencies reported that they do nothing in terms of enforcement to make the homeowners carry out disconnections, repair cleanout caps, etc. (Figure 2-43). The reasons given were as follows:

- The agency has not yet established any program for I/I reduction (four participating agencies).
- The agency obtains satisfactory voluntary compliance only by advising the homeowners about their potential liability for damages from sewer backups (one participating agency).
- The remaining "non-enforcing" agencies did not clarify (15 participating agencies).

A total of 29.3% of participating agencies reported that they apply fines to the homeowners if they do not act on this as required. The measure was reported as successful.

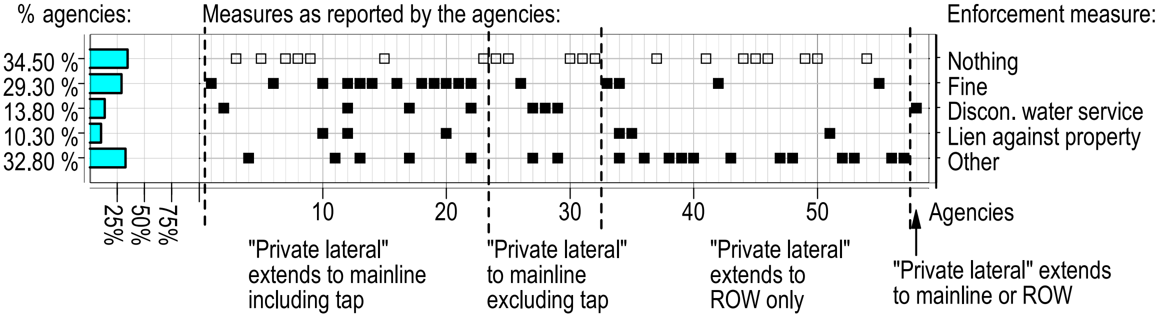


Figure 2-43. Enforcement Measures to Remove Sources of Inflow.

A total of 13.8% participating agencies reported warning the homeowners that their water service would be disconnected and that this measure is very effective with the inflow sources typically removed within 2-3 days. However, one participating agency reported that this measure is ruled out, as their Health Department does not allow it. Fewer agencies reported making liens against property (10.3%). This measure was also reported successful.

The agencies reported several other measures that work well but are poor for customer relations:

- Adding a monthly surcharge on the utility bill (one participating agency)
- Adding an amount to the property tax bill (one participating agency)
- Summoning the homeowner to the court (two participating agencies).

Contrary to enforcement measures are incentive measures such as reimbursement for various disconnections or a small discount on the water/sewer bill. Only two participating agencies reported using such measures.

Repair of Laterals. The agencies tend to use the same enforcement measures to make the homeowners rehabilitate the laterals as to make them remove sources of inflow (Figure 2-44). A slight difference is that more agencies seem ready to disconnect the water service than in case of inflow sources removal (10 participating agencies).

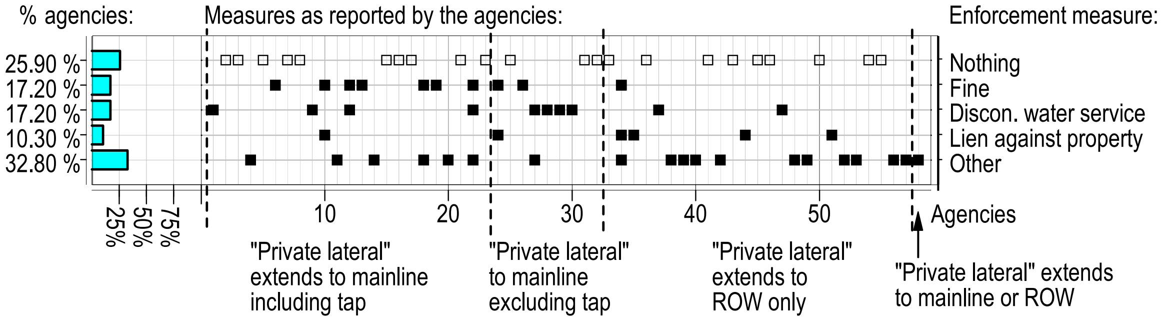


Figure 2-44. Enforcement Measures to Rehabilitate Laterals.

2.10.2 Spending of Public Funds on Private Property

A total of 41.4% of participating agencies reported spending public funds on private property and explained the authorization for such spending as follows (Figure 2-45):

- The agency is authorized by state legislation (one agency).
- The agency is authorized by the sewer ordinance (two agencies).
- The agency is authorized by the approval of the City Council or City Commission (two agencies).
- The agency agrees to such spending because the ownership of the lateral under the ROW is a gray area and the spending of public funds not clearly forbidden (one agency).
- The agency limits such spending to pilot projects only and is prepared to change the existing sewer ordinance if a long-term I/I program would be modeled after the pilot projects (three agencies).

Some agencies reported spending public funds on certain private laterals only, for example:

- When private laterals have been damaged during mainline replacement (one agency).
- When rehabilitation of public sewers extends on private laterals at very little additional cost—for example, applying flood-and-grout rehabilitation method (one agency).
- When new laterals are added to an area that currently has a septic system as part of a county project (one agency).

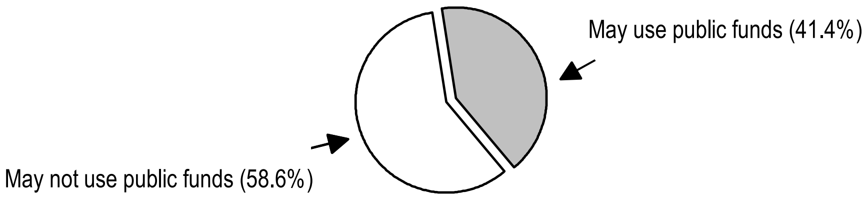


Figure 2-45. Spending Public Funds on Private Sewer Laterals.

The rest of the agencies did not clarify this issue (13 agencies) but some of these agencies commented instead on when such spending is justified:

- When private lateral rehabilitation projects are projected to be cost-effective and are shown that they would benefit the public by eliminating the need for costly sewer system upgrades (four agencies).

The 24 agencies that reported spending public funds on private property identified the source of funds (Figure 2-46). User fees is the source used in 27.6% of agencies. “Other” sources reported by these agencies include property taxes or special charges (one agency) and bond sales (one agency). Two agencies did not specify the source of funds.

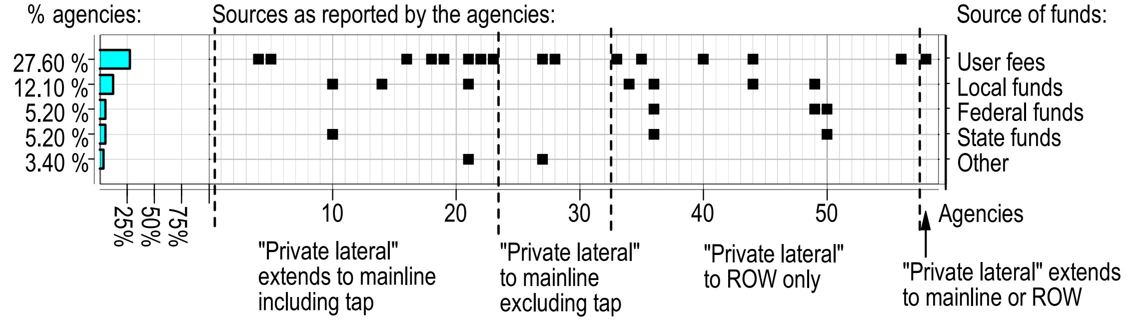


Figure 2-46. Source of Public Funds Spent on Private Property.

2.10.3 Financial Assistance to Homeowners

Types of Financial Assistance Offered to Homeowners. A total of 62.1% of participating agencies reported that they don’t offer any type of financial assistance to homeowners for any work the homeowners are required to do on their laterals (Figure 2-47). The remaining 37.9% of participating agencies specified types of financial assistance they provide (Figure 2-48). Most agencies reported offering low-interest loans. “Partial payments” is the payment plan in which the agency pays a certain percentage of cost or up to a predefined cap (three agencies). “Hardship cases” offered by an agency is the financial assistance for low-income homeowners and is given on a case-by-case basis (six agencies). One agency did not specify type of financial assistance it offers.

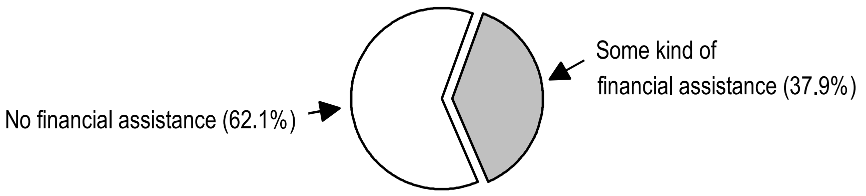


Figure 2-47. Agencies Providing Financial Assistance to Homeowners.

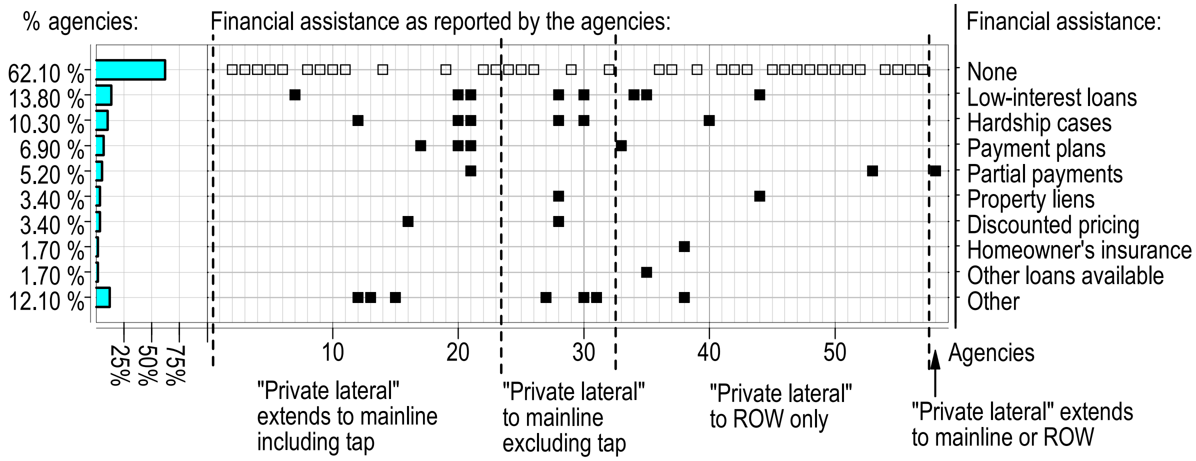


Figure 2-48. Types of Financial Assistance to Homeowners.

Type of Work Qualifying for Financial Assistance. The participating agencies that offer the financial assistance were asked to specify if this assistance is limited to any certain type of work on laterals. Although many agencies did not clarify, most agencies that answered this question reported that the financial assistance is offered for either repair of laterals or removal of sources of inflow (Figure 2-49). Only two agencies reported that the financial assistance is generally not limited by the type of work. One agency offers the financial assistance for construction of new private laterals and clean-outs.

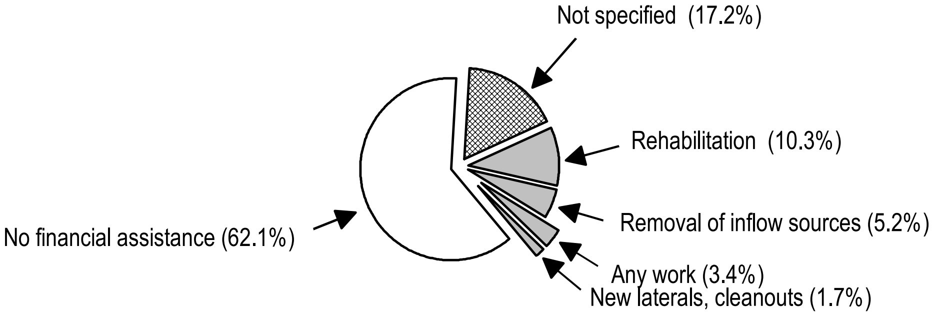


Figure 2-49. Work on Private Sewer Laterals Qualifying for Financial Assistance.

Success of Financial Assistance Programs. All but two agencies offering financial assistance reported that such programs are popular with the homeowners and successful in getting the required work on private laterals done. The two agencies with a poor experience reported the following:

- A large volume of loans to homeowners has been accumulated over time depleting the funds available for other loans (one agency).
- Different types of loans have been offered to homeowners, which no one has applied for in years (one agency).

2.11 Conclusion

The information collected through the questionnaire process illustrates the diversity of administrative and physical arrangements for private sewer laterals among the 58 agencies responding. Readers of this report will be able to check their own circumstances against those of the responding agencies and should find the statistics useful when preparing plans for a private sewer lateral program. It should be noted, however, that the data included in this chapter refers only to the agencies responding to the questionnaire. Thus, in other chapters drawing from a variety of published sources, site visits and personal contacts, approaches may be described that are not reflected in the questionnaire data.

CHAPTER 3.0

LOCATING, INSPECTION AND CONDITION ASSESSMENT OF SEWER LATERALS

3.1 Introduction

Locating laterals and making an assessment of their condition are critical components of a collection system maintenance program in any wastewater utility. Lack of accurate records will hinder efficient maintenance and rehabilitation efforts and may occasionally have tragic outcomes. One example is a case in which, during gas line installation by directional boring, an unlocated sewer lateral was pierced and the gas line was installed through the lateral (Miller and Wallbom, 2000). Blockage of the lateral followed some time later and then cleaning of the lateral by a root cutter ruptured the gas pipeline, releasing the gas into the lateral and causing an explosion.

Decisions regarding the maintenance, repair, relocation, and rehabilitation of laterals will depend on the results of a condition assessment of the system, i.e. visual inspection, testing, data collection, and the subsequent grouping of individual lateral segments into various classifications of condition. Condition assessment may address the structural and/or infiltration/inflow conditions.

The survey of public works agencies in Chapter 2.0 has identified a number of different methods for locating and inspecting of private sewer laterals, as well as condition assessment. This chapter describes these methods and reviews their advantages and limitations. The chapter also reviews some measures for marking the laterals and cleanouts (the latter if the municipal code requires them to be covered with soil) intended to simplify their locating in the future (e.g. using magnetic tape or electromagnetic marker balls).

3.2 Locating of Sewer Laterals

3.2.1 Objectives of Locating

Depending on the site conditions and the purpose for the locating, i.e. the work that will follow, the information that must be obtained varies and so do the objectives of locating.

Locating Lateral-to-mainline Connections Only. Sometimes it is not important to know the exact layout (horizontal and vertical alignment) of the entire lateral on the property. For example, for mainline pipe bursting, pits must be positioned exactly where lateral connections are, so that the laterals can be reopened in the new mainline pipe after the bursting. For that purpose knowing only the location of connections is sufficient. The same applies to lateral rehabilitation with methods that repair only the first 1-2' of the lateral such as chemical grouting or short connection CIP liners (Chapter 5.0). Location of lateral-to-mainline connections is most commonly determined with mainline CCTV.

Locating Cleanouts on Laterals. The location of cleanouts has to be known when laterals would be CCTV inspected or pressure tested, and/or repaired with a method that requires above-the-ground access into the lateral. Sometimes, however, the cleanouts are out of sight (covered with soil, flower beds, etc.) and a crew performing inspection or rehabilitation may have trouble locating them. Existing, soil-covered cleanouts are most commonly located with rod probing and vacuum excavating of test pits. With vacuum excavating, new cleanouts are often installed where they missing but are needed. Over the located cleanout, a flag is positioned or a cross is painted on the surface for marking purpose.

Identifying the Exact Layout of a Whole Lateral. Lateral rehabilitation methods such as CIPP, pipe bursting, etc. require that the horizontal and vertical alignment of the entire lateral is known. This includes length and depth of pipe, bends in the pipe, and any secondary laterals connected to the lateral at some distance from the mainline connection. The exact lateral layout must also be known prior to any excavation or trenchless new installation in the area using, for example, impact moling or directional drilling. The most common method is to use a walkover sonde integrated with a lateral CCTV camera, but the sonde can also be attached to a specially designed assembly such as shown in Figure 3-7. Other methods include the use of a plumber snake with "stethoscope" type instruments at the surface, ground penetrating radar (GPR), etc.

Updating Agency Records During Sanitary Sewer Evaluation Studies. Some inspection methods may not be performed with the objective of locating laterals but do, however, locate them as part of the inspection work. Such work often can locate many laterals but not all of them and, despite the lack of comprehensiveness, may be useful for updating an agency's existing records. For example, during house-to-house surveys, all laterals with visible cleanouts can easily be detected and the records verified. Smoke testing can identify laterals that are missing in the records, but only if they have defects and are fairly shallow. These methods only identify existence of the lateral on the property but are not able to identify the layout of entire lateral.

3.2.2 House-To-House Survey

A house-to-house survey is a simple field investigation focused on finding cleanouts that are missing in the agency's records. However, the laterals may not have visible cleanouts since they can be covered with soil (in some agencies, the code requires a 6" soil cover to protect the cleanout cover from damage) or landscaping plantings, or they can end up below a concrete driveway or a sidewalk. Some laterals may not have cleanouts at all.

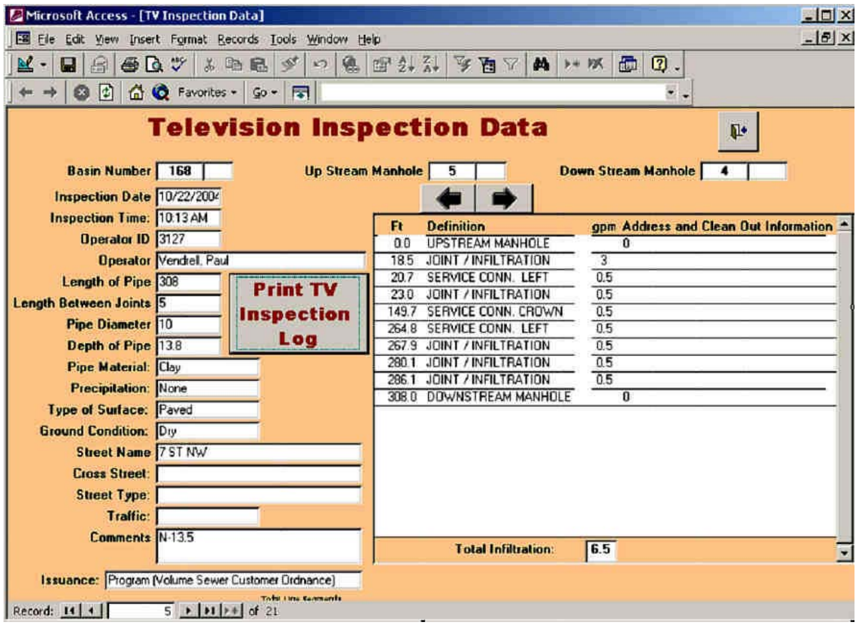
3.2.3 Smoke Testing and Dye Water Testing

In smoke testing, a non-toxic smoke is pumped through a manhole into the sewer pipes. The smoke is observed surfacing through open pipe joints and connections, and pipe defects. Providing the laterals have such defects, the method confirms the existence of known laterals and identifies the existence of unknown laterals in the area. Emergence of the smoke, however, depends on the ground conditions, and can be obstructed if the groundwater level is high or the pipes are flowing full.

In dye water testing, a dye is inserted into the toilet in the house and flushed. This can identify whether the house is connected to the sewer main. Then, the exact location of the lateral may be sought by a different method if needed. Additionally, dye testing is very useful to detect if the house has more than one lateral. For that purpose, for example, the City of Salem, OR has a practice to dye test each fixture in the house (e.g. sink, toilet, etc.). During the test, a CCTV camera is inserted into the lateral close to the house foundation and an operator monitors the appearance of dye in the lateral. (Serres, 2005)

3.2.4 Mainline CCTV

Mainline CCTV identifies existing lateral-to-mainline connections while carrying out the routine pipe inspection of mainlines. This is a very common type of pipe inspection carried out by nearly all agencies. A mainline CCTV inspection log can be entered into a database (Figure 3-1), in which information about lateral-to-mainline connections is readily available. The information stored in the database shown, for example, includes the footage of the lateral connection along the mainline (from the upstream manhole) and the location of the connection in the mainline cross-section (at the crown or on the left, when viewing in direction of the flow).



Basin Number: 168
Up Stream Manhole: 5
Down Stream Manhole: 4
Inspection Date: 10/22/2004
Inspection Time: 10:13 AM
Operator ID: 3127
Operator: Vendrell, Paul
Length of Pipe: 308
Length Between Joints: 5
Pipe Diameter: 10
Depth of Pipe: 13.8
Pipe Material: Clay
Precipitation: None
Type of Surface: Paved
Ground Condition: Dry
Street Name: 7 ST NW
Cross Street:
Street Type:
Traffic:
Comments: N-13.5
Issuance: Program (Volume Sewer Customer Ordnance)

Ft	Definition	gpm	Address and Clean Out Information
0.0	UPSTREAM MANHOLE	0	
18.5	JOINT / INFILTRATION	3	
20.7	SERVICE CONN. LEFT	0.5	
23.0	JOINT / INFILTRATION	0.5	
149.7	SERVICE CONN. CROWN	0.5	
264.8	SERVICE CONN. LEFT	0.5	
267.9	JOINT / INFILTRATION	0.5	
280.1	JOINT / INFILTRATION	0.5	
286.1	JOINT / INFILTRATION	0.5	
308.0	DOWNSTREAM MANHOLE	0	

Total Infiltration: 6.5

Figure 3-1. Mainline CCTV Inspection Log Database (Miami-Dade County, FL).

3.2.5 Walkover Sonde

A walkover sonde like the one used in directional drilling is often used for identifying the layout of laterals. The sonde can be inserted into the lateral and driven through it either attached on a lateral mini-CCTV camera, a flexible rod or a cleaning hose.

While the sonde is moved through the lateral pipe, it emits a radio-wave signal. A hand-held receiver is used above ground to locate the maximum signal strength above the lateral and estimate the depth of the signal source. An operator walks out the path of the lateral “wagging” a handheld receiver left-and-right and receiving the signal and thus identifying the path and depth of pipe, as well as any bends on the pipe (Figure 3-2). Care is required to obtain accurate location information if there is electromagnetic interference in the area.

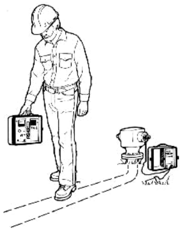


Figure 3-2. Operator "Wagging" a Handheld Receiver above the Walkover Sonde.

For the purpose of recording the location, the procedure may include laying a rope on the ground marking the path of the lateral. The rope is digitally photographed and the exact measurements relative to the property corners, trees and other objects on the property entered into the agency's records (Figure 3-3).

Using a sonde is the most accurate method to locate laterals except for direct observation through excavation or potholing. Occasionally there is a problem in that the camera/sonde cannot pass through the lateral. An obstruction such as rock or debris can be easily cleaned with water jetting, however severely corroded pipes can be so much reduced in diameter that conventional cleaning is not sufficient to enable the camera to pass.

Figure 3-3. Rope Laid over the Lateral (City of Sarasota).

Sonde on a Flexible Rod. A sonde can be attached to a ¼" flexible rod (for example, 100' long) and inserted through a cleanout or a roof vent (if connected to the lateral) (Figure 3-4).

Figure 3-4. Flexible Rod Used with a Walkover Sonde.

This option has been used in the Parker Sanitary Sewer District, SC, where most houses are one-story structures and roof vents are easily accessible (Tarker, 2004). This agency reports that the flexible rod moves easily through the pipe toward the road. The sonde transmits a signal (512Hz frequency), which is traced with the walkover locator and marked along its path. These systems typically cost in the neighborhood of $1,000, which includes a rod, a reel, a sonde, and a flexible head adaptor for going around house plumbing in 2" pipes (MetroTech, ProtoTec & Rigid are some of the manufacturers). Typical units used for this application will locate reliably up to about 8' depth.

Sonde on a Lateral Mini-CCTV Camera. A sonde can be built into a mini-CCTV camera (Figure 3-5), which is an option offered by most manufacturers of this equipment (see Table 3-4 on p.3-19). The camera can either be inserted into the lateral through the cleanout and pushed through the lateral (Figure 3-6), or launched from the mainline if the mini-CCTV camera is designed for such application.

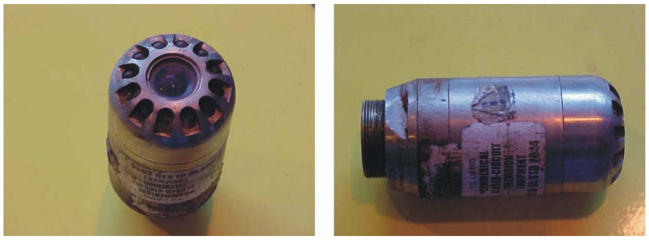


Figure 3-5. Sonde Added to a Lateral CCTV Camera (Miami-Dade County, FL).

Figure 3-6. Cable-pushed Lateral Mini-CCTV Camera (The Ridge Tool Co.).

Sonde on a Cleaning Hose Launched from the Mainline. Another way to launch a sonde from the mainline is to use a special assembly such as one developed by the City of Sarasota, FL (Figure 3-7).

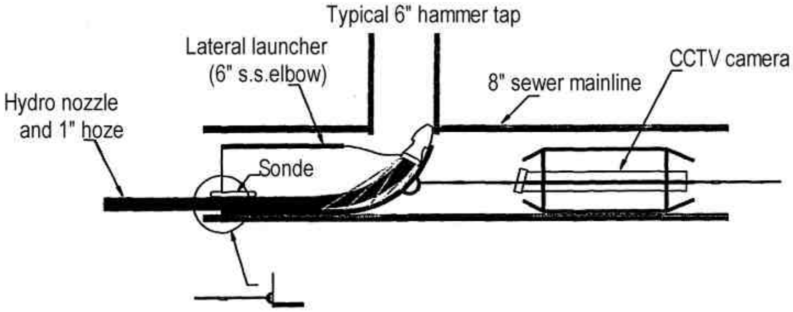


Figure 3-7. Sonde Attached onto a Cleaning Hose (City of Sarasota, FL).

In this assembly, a sonde is attached with a tape onto a regular cleaning hose (1-1½" diameter, 50-60' long) and inserted into the mainline through the nearest manhole. A specially shaped plastic form is positioned in the mainline near the lateral opening (pulled in place with a cable). The CCTV camera is positioned in the mainline just past the lateral opening to monitor the operation. As the water in the hose is turned on, it creates a pressure and the whole assembly moves forward and up the lateral. (Ray, 2005).

A sonde on the lateral CCTV camera is a preferred option in agencies where existence of secondary laterals is not uncommon (i.e. a lateral connected to the mainline has another lateral connected to it at some distance from the mainline). The secondary lateral is likely to be missed during locating with a walkover sonde unless it is noticed with the camera.

3.2.6 Rod Probing from Surface

For locating of cleanouts covered with soil, a rod probe can be used (Figure 3-8). The probe shown is a 4’ fiberglass probe, which is non-conductive and therefore safe for use even if an electrical wire is accidentally hit under ground.

Figure 3-8. Rod Probe (Miami-Dade County, FL).

3.2.7 Plumber’s Snake

A plumber’s snake, which is a long flexible steel cable for dislodging stoppages in pipes, can be used to identify the path of the lateral in a similar manner to a walkover sonde. The snake is inserted into the lateral through a cleanout in the yard near the house foundation or a vent in the roof (if connected). As the snake travels through the pipe, a sound is made from the scraping action within the pipe. A person above the ground can hear the sound either with a stethoscope type instrument or sometimes even without any instrument. Following the sound trace, the path of the pipe is determined.

Several “stethoscope” type instruments are available, ranging in price from over $2,000 to as little as $20. Instruments in the range between $20 and $200 work well for laterals where the average depth usually does not exceed 4’. A good source of the instruments available can be found in the USABlueBook Catalog, http://www.usabluebook.com, under Leak Detection Equipment.

The method was used in the past in the Parker Sanitary Sewer District, SC, but it was found that the work became difficult in noisy work areas (traffic, running lawnmowers, etc.) and that pushing the plumber’s snake down a roof vent often did not really work well. This agency has therefore switched to a walkover sonde described earlier in this chapter (Tarker, 2004).

3.2.8 Vacuum Excavation

In vacuum excavating (Figure 3-9), the lateral pipe can be physically exposed and its depth confirmed. If the general location of the lateral is known in advance (for example, the beginning and end point of the lateral are known from the CCTV inspection or the cleanouts are visible and thus known), vacuum excavation can confirm the location of the lateral at some mid-points. However, vacuum excavating is most often used to install new cleanouts when needed.

Figure 3-9. Hydro Excavating of a Cleanout Pit (City of Sarasota, FL).

This method was used, for example, with great success in Sarasota, FL, where 764 cleanouts (4" Inserta Tee) were installed as a part of a lateral pipe bursting project in 2000/01 as described in the case study in Appendix A. The soil was cut with a water jet and vacuumed out with a 6" tube connected to the vacuum truck. The pit size was about 2'×3'. It took on average 60 minutes to complete each pit. (Ray, 2005)

The case study in Sarasota also showed that the cost of the method depends greatly on depth and groundwater level, i.e. the need for dewatering. Without dewatering, the typical cost was \$100/ea and \$588/ea for pits ≤ 4' deep and > 4' deep, respectively. With dewatering, the cost grew to \$750/ea and \$1,000/ea, respectively.

3.2.9 Ground Penetrating Radar (GPR)

Ground penetrating radar uses the transmission and reflection properties of an electromagnetic wave passing through the soil to accurately determine the depth and location of subsurface objects. This principle can be used to locate sewer laterals. For locating a lateral, a GPR device is moved over the surface where the lateral is expected to be located (Figure 3-10). There is no need to access the inside of the lateral and the method is therefore suitable in situations where the CCTV cannot be used because there are no accessible cleanouts or any other points of entry into the lateral.

Figure 3-10. Lightweight and Compact GPR Unit (Sensors & Software Inc.).

One example of locating a sewer pipe with a GPR unit is a field demonstration of this technique in Covington, GA in 2001 (Sensors & Software Inc, 2002; DeSouza, 2005). (Although a storm sewer crossing a road was being located, the same procedure could have been used for locating the sewer lateral pipe.) The GPR unit was run in four lines: the first three perpendicular to what was suspected to be the path of the pipe and the fourth along the path of the pipe as it became evident from the GPR images (Figure 3-11).

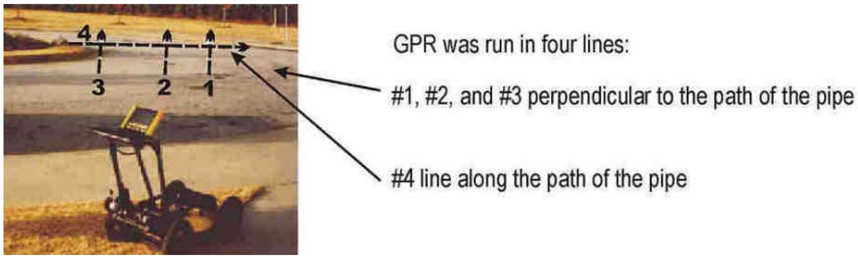


Figure 3-11. Location of GPR Lines During Locating of a Sewer Pipe (Sensors & Software Inc).

The created images of the four GPR lines are shown in Figure 3-12. Images from the first three lines (on the bottom) show the pipe at different depths indicating that the pipe is sloping. The image from the fourth line (on the top) confirms the slope of the pipe. In the example shown, the sewer pipe was simply located from the raw radar data and no plan maps were created.

The GPR systems (such as the Noggin SmartCart by Sensors & Software Inc. shown in Figure 3-10) start around $19,000 for purchase. A Florida based contractor reported using GPR for the past 12 years in several Florida agencies (Orange County, Seminole Lake County, Orlando Utilities Commission, etc.) and that locating of utilities is contracted on an hourly base for approximately $170/hr (DeMarsh, 2005). The locating is typically contracted for all subsurface utilities prior to a design project rather than for locating of sewer laterals exclusively. In one eight-hour working day, roughly 3,500-4,500' of utilities can be located on average[16].

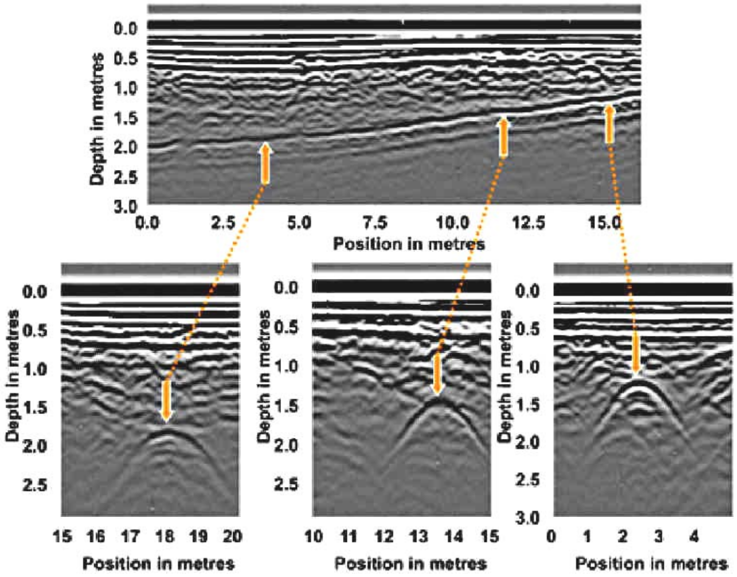


Figure 3-12. GPR Lines over the Sewer Pipe (Sensors & Software Inc.).

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[16] *If an area adjacent to 1,000' of roadway is investigated and, for example, four utilities have been located (one water line, one sewer line, two phone lines, this accounts for 4,000' of located utilities. The length of all connecting laterals is added.*

A limitation of GPR is that its performance depends on the soil condition and its moisture content (in particular, its conductivity). The City of Sarasota, FL, has evaluated GPR as a locating option for the laterals (as described in the case study in Appendix A). Soil conditions were fine sands, however with a relatively high moisture content. The method was proved to be quick but only 80% effective, i.e. it was successful in locating 52 out of 65 laterals (the other 13 laterals were identified with "cleaning hose/sonde with lateral launcher" (described earlier in this chapter). (Ray, 2005)

In summary, GPR can be a very effective method of locating the path and depth of laterals—especially when there is no easy direct access to the lateral for the use of an internal sonde. However, GPR is often not suitable for clay soils and high moisture-content soils, or for deep laterals. Other drawbacks of the method at present are that there is a requirement for skilled operators, interpretation of results can sometimes be difficult, and the cost of the equipment or service is high. The use of GPR for utility locating continues to see technological advances both in performance[17], e.g. the Harris Technologies system as evaluated in a report by Fugro South Inc (Tubb, 2003), and in signal/image processing to permit interpretation of data by construction personnel rather than GPR experts.

3.2.10 Radar Tomography (RT)

Although not designed for locating of sewer laterals, this technology can be used for their location (on a large scale) providing the surveyed area is accessible to a vehicle with a pool-table-size antennae attachment. In the system shown on Figure 3-13, a mobile array of 17 GPR antennae[18] and a robotic laser tracking system is pulled over the area at speed of 2.0 mph. Large quantities of 2-D, multiple-angle imagery are collected and subsequently processed via patented software into 3-D imagery, in the form of computer video files. These "movies" can provide a virtual descent through the earth at 1" increments, showing utility lines and other features appearing at various depths. The utilities are then extracted from the movies and rendered in a CAD environment. (Lund, 2005) Tomographic GPR approaches are being pursued by manufacturers such as Witten Technologies and IDS Ingegneria Dei Sistemi S.p.A. (Italy). Information on a recent European collaborative effort on GPR research can be found at www.giga.com.

Figure 3-13. Scanning with a Mobile Array of GPR Antennae (Witten Technologies Inc).

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[17] *One measure of performance is the diameter of pipe that can be detected versus the depth of the pipe. This is a particularly critical measure in conductive soils that quickly dissipate high frequency signals.*

[18] *Nine transmitters and eight receivers*

Although RT detects both conductive (steel, iron) and non-conductive (clay, plastic) utilities, it's effectiveness is limited by soil conditions, specifically conductivity. While it works very well in non-conductive (sand, limestone, rock) soils, it works poorly in conductive ground conditions (certain mineral-bearing clays, igneous, caliche soils). In good soils, it can "see" up to 20', with an average penetration depth of 6-8'.

3.2.11 Marking of Laterals and Cleanouts for Future Locating

Metallic Tape. When PVC or other non-metallic pipes are being installed with an open cut, a detectable metallic underground tape can also be installed above the pipe at shallow depth (1-2') on the entire length of the pipe. Such tape allows easy locating of pipes in the future. The magnetic tape is detected with any metallic detector (Figure 3-14) and a simple wand type detector, for example, can be used. The drawback to metallic tapes and similar conductive lines laid to mark pipe position is that they can be disturbed by future excavations resulting in loss of continuity and/or a change in position relative to the pipe beneath.

Figure 3-14. Left: Metallic Tape for Marking Laterals (USABlueBook.com). Right: Detecting the Metallic Tape Using a Wand Type Detector (www.3m.com).

Sewer Marker Balls. Sewer marker balls (Figure 3-15—Left) can be buried next to cleanouts or at intervals along the pipe before or during backfilling. The balls have no batteries or active components, and are completely passive in the ground. However, when a signal of certain radio frequency (RF) is aimed in their direction, the balls provide a strong signal reflection. For creating the signal and detecting the signal response, special marker locators are used (Figure 3-15—Right). The peak signal response appears directly over the marker balls.

The radio signal has to be in resonance with the marker balls. For example, there are several kinds of OmniMarker™ balls, which differ (based on intended application) in the marker color and the frequency to which they respond. For marking sewer pipes, marker balls of this brand are green, with a resonant frequency of 121.6 kHz, and a cost of about $8.00 each. The marker locating equipment can be multi-frequency (Metrotech® 760 Dx), or single or dual frequency (Goldal® MLX series, available at a cost of $1,000-1,300).

The method has been used, for example, in Orange County, FL, where a couple of other approaches were previously tried unsuccessfully. The first approach was to make a cement pad with a valve type cover over the plastic lateral cap to make it easy to locate with a metal detector and hard to destroy with a lawnmower. However, this was rejected by the community as unsightly. Next, the cleanouts were brought up to grade and an "S" cut in the curb to indicate a sewer lateral. This resulted in many calls for broken cleanout caps. The latest approach is to mark the curb with an "S" and install a locator ball at the cleanout. Positioning of the balls is shown in Figure 3-16. The balls are positioned next to the cleanouts just below the cap. The top of cleanouts is laid 4” below the grade (Noke, 2004).

Figure 3-15. Left: Sewer Locator Balls. Right: Marker Locators for Detecting Locator Balls (USABlueBook.com).

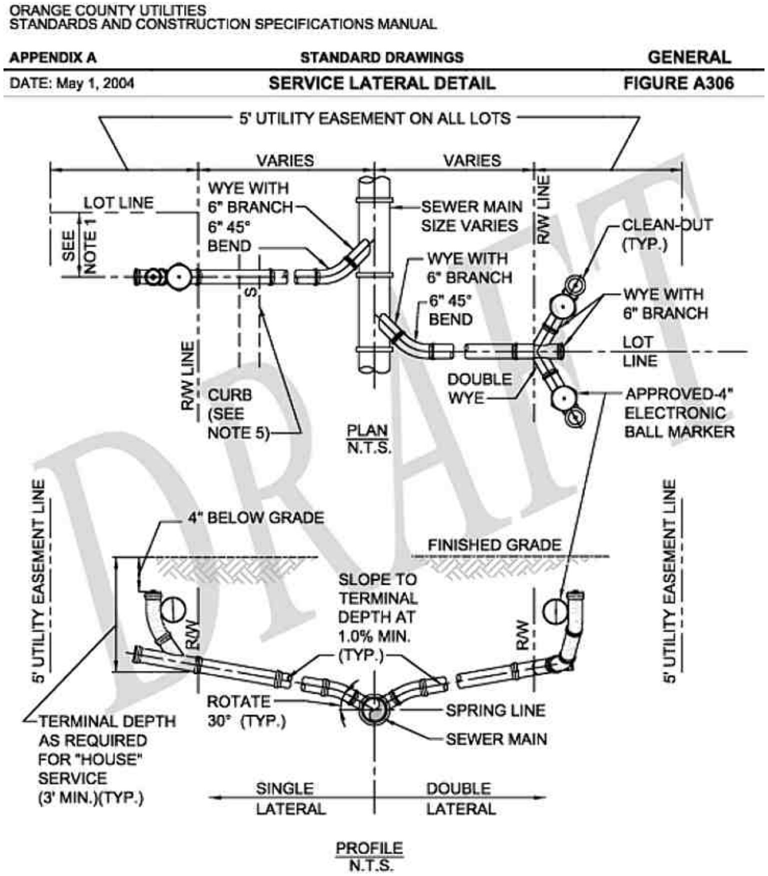

Figure 3-16. Placement of Locator Balls (Orange County, FL).

3.2.12 Summary of Locating Methods

The existing methods for locating of sewer laterals and cleanouts are summarized (Table 3-1) as well as methods for marking of laterals and cleanouts for future locating (Table 3-2).

Table 3-1. Methods for Locating of Sewer Laterals and Cleanouts.

Method	Description
◆ House-to-house survey	Locates cleanouts visible from the surface.
◆ Smoke testing	Locates pipes that are not very deep and have defects. Used often and on a large scale.
◆ Dye water flooding	Checks if the house is connected to the mainline. If so, another method can be utilized to identify the lateral layout if necessary.
◆ Mainline CCTV	Locates lateral-to-mainline connections along the mainline. Used frequently.
◆ Walkover sonde (on lateral CCTV, flexible rod or cleaning hose)	Identifies layout and depth of the pipe on its entire length (where the camera can pass). The most accurate method after open cut excavating.
◆ Rod probe from surface	Locates cleanouts where they are suspected to be. Used occasionally.
◆ Plumber's snake	Identifies layout of the pipe on its entire length, however difficult to work with in noisy conditions. Used less as other methods became available.
◆ Vacuum excavation	May be used to locate and check the depth of the pipe at selected points where it the lateral is believed to be laid, however mostly used for installation of cleanouts and opening of small pits where needed during lateral rehabilitation. Has become very popular for its ease of use and small footprint.
◆ Ground penetrating radar (GPR)	Identifies layout and depth of the pipe where the soil conditions are favorable and access to inside the lateral is difficult. Currently used rather infrequently but use increasing as cost of equipment drops and ease of use improves. Research is improving the resolution of utilities at greater depths in difficult soil conditions.
◆ Radar tomography (RT)	Can be used for locating (on a large scale) of sewer laterals if the surveyed area is accessible to a vehicle pulling a pool-table-size attachment. Creates 3D images showing utility lines and other features appearing at various depths.

Table 3-2. Methods for Marking of Laterals and Cleanouts for Future Locating.

Method	Description
◆ Magnetic tapes	Installed in a trench at shallow depth during open cut pipe installation or replacement. Easily detected with any metallic detector such as a simple wand type detector.
◆ Sewer balls	Installed at shallow depth next to cleanouts or at intervals along the pipe before or during backfilling. Detected with special marker locators that create and detect radio signal in resonance with the marker balls.

3.2.13 Ongoing Efforts to Make Locating of Laterals Mandatory

The survey of agencies in Chapter 2.0 indicated that, in about 40% of the agencies surveyed, the location of sewer laterals is either not a normal practice or else is never carried out.

In most cases, agencies or municipalities that do not accept any responsibility for locating sewer laterals or keeping a record of their location are concerned about taking on additional work, responsibility and legal liability. In contrast to this approach, some municipalities feel that they are in a better position to be able to maintain records of sewer laterals and to be able to locate their position (at least within the public right-of-way) than is a homeowner. With the increased use of trenchless technologies such as horizontal directional drilling for new utility installation, the accurate locating of existing utilities can be critical but usually sewer laterals are not covered under existing provisions of "One Call" services, etc.—thus leading to their potential damage during drilling operations. The test for many public infrastructure services is whether a public agency can provide the service more effectively than individual citizens or property owners. However, being appropriate in theory does not always result in the willingness to raise budgets and taxes to provide the additional service.

The occurrence of a number of fatal accidents across the country caused by the lack of location of sewer laterals (similar to the one described in the introduction to this chapter) and the high number of "cross-bores" that have been discovered in specific studies in some cities is driving an interest in developing recommended practices for lateral locating. In particular, a committee within the Common Ground Alliance (Best Practice Committee, TR 2004-01 Locating Sewer Service Laterals Subcommittee) has been working on guidelines and/or regulatory approaches to the location of sewer laterals. The Common Ground Alliance (www.commongroundalliance.com) is a non-profit organization involving utility owners and utility contractors as well as other parties active in buried utility infrastructure. Their efforts are directed at developing procedures to reduce utility damage that are workable and effective for all the parties involved.

3.2.14 Subsurface Utility Engineering

One difficulty in using various sources of information such as existing plans and previous surveys to predict the plan location and depth of underground utilities is that the quality and accuracy of the prior information often is not known. A more systematic approach to underground utility location is offered by the Subsurface Utility Engineering (SUE) approach (ASCE, 2002). The principal feature of this approach is the classification of utility location information into four quality levels (Table 3-3).

Table 3-3. Subsurface Utility Engineering (SUE) Approach in the Classification of Utility Location Information.

Quality Level	Description
Quality Level "D"	Plotted on plans from records. Sometimes a field visit—to look for utility indications on the site—is made. Sometimes "verbal recollections" are plotted.
Quality Level "C"	Surface Appurtenances are surveyed and accurately plotted on a current site plan. Utility data from records (Quality Level D) are correlated to the appurtenances.
Quality Level "B"	Surface Geophysical Methods used to search for and trace existing utilities. Designated utilities are then surveyed and plotted on site plan.
Quality Level "A"	Utilities exposed via non-destructive air-vacuum means. Exposed utilities are then surveyed and plotted on site plan: Elevations, Size, Condition, Materials, Precise Horizontal Positions are measured and documented.

The SUE approach is usually used in a comprehensive manner in a particular area prior to a project and offers an excellent model for the management of positional information about underground utilities—including sewer laterals.

3.3 Inspecting Private Sewer Laterals

3.3.1 Purpose of Inspection

Private (and pubic) sewer laterals are being inspected for the following reasons:

- To identify the existence of leaks, e.g. cracks, joints, etc. that are either actively leaking at the time of inspection or with stains that indicate leaking at other times, and sometimes to determine severity of these leaks (i.e. to quantify them for certain rainfall or groundwater conditions)

- To identify various connections to the pipe such as area drains, etc. that are likely sources of inflow
- To identify structural defects such as cracks or holes in pipes that have led or could lead to the collapse of pipes
- To identify any defects at connections in the pipes that are often a weak link
- To identify existence of roots in pipes and the extent of their growth in them
- To identify corrosion and mineral buildup that have reduced the hydraulic capacity of pipes in time
- To identify bends in the pipe (location and degree)
- To identify any existing sags or misaligned joints that can promote buildup of material in the pipes
- To identify any change in pipe material along the length of lateral as well as change in pipe diameter

WERF recently has developed a computerized tool to prioritize mainline sewer inspections based on a variety of pipe, system and site conditions as well as prior activities relevant to each section of pipe (Merrill et al., 2004). Although the analysis uses input for mainline pipe sections and is not designed for evaluation of lateral segments, the tool is useful to identify areas of a system at high risk and with high inspection needs. In the absence of other information, it would be a reasonable starting point to also assume that the same areas of the system may have greater needs for lateral inspection.

The various methods for inspecting laterals described in this chapter offer different means of collecting related data that may have different degrees of difficulty, success rate and cost.

3.3.2 Building Inspections

Building inspections identify uncapped cleanouts on the property as well as various connections to the sanitary sewer such as downspouts (roof drains), window well drains, driveway drains, exterior stairwell drains, sump pumps, foundation drains, etc. These connections are sources of inflow and are prohibited in many agencies. The impact of inflow sources on system-wide I/I can be significant (see Chapter 4.0) and their removal through identification (via building inspection) and follow up with the property owner to require removal is usually an important part of a sewer lateral program.

3.3.3 Smoke Testing

Smoke testing can identify defective service laterals, which are sources of infiltration (see Chapter 4.0 for the definition of infiltration versus inflow). The inflow sources listed in 3.3.2 also can be detected via smoke testing and may identify inflow sources that are not obvious from a building inspection.

Procedure. After the pipes are flow-isolated by placing sand bags or plugs where necessary, dual blowers are generally placed over manholes to inject a non-toxic smoke. Typically, three-minute smoke bombs are inserted into the blower intake. Blowers are generally placed on consecutive or alternate manholes as long as the distance between the blowers does not exceed 750’. When smoke testing subsequent lines, the crew may “leap frog” the line to save time and be more productive. The smoke surfaces through open connections and defects (Figure 3-17), and such sources are photographed and documented. An assessment of the quantity of I/I is made based on the area and type of ground cover.

For optimum results, smoke testing is generally performed during periods of dry soil conditions. This is due to the fact that groundwater may restrict the migration of the smoke towards the surface. Therefore, in order to ensure satisfactory ground conditions after a rain event, line segments previously tested during dry soil conditions would be re-tested after a rain. The results of the two tests can then be compared. If the test results after a rain event are comparable to the results of the test performed during dry conditions, smoke-testing activities may be resumed.

When a defect is found to be smoking, a 2”×2” orange plastic square survey flag is used to mark the defect. Each flagged defect must be photographed, whether by Polaroid camera, 35mm camera, digital camera or other device that can capture the location of the defect and the intensity of smoke so that it can be traced back at a later time for follow-up repair or removal (Figure 3-18). Photographs must show smoke coming from the defect as well as a permanent landmark such as a building, tree or power pole for reference.

Figure 3-17. Left: Smoke Testing (City of Savannah, MO).

Figure 3-18. Typical Field Photograph with Notations (Wade & Associates).

Effectiveness in Identifying Defects. Smoke testing typically does not identify all defects that could be sources of I/I since factors such as traps, sags, leaves and deposition, and high water levels may restrict smoke migration to the source in question. This has been the experience in many agencies and is generally acknowledged. In Berkeley, CA, for example, a project was completed in 1980s in which 250 out of 600 laterals in seven sub-basins (three in Berkeley and four in Oakland) were tested with different inspection methods (TEC, 1984). The results were compared with results of smoke testing performed previously on the same laterals. The comparison showed that smoke testing identified only one third or less of lateral leaks (CDM/Jordan/Montgomery, 1985). Another report from the same I/I study indicates that out of 21 laterals with measurable I/I in one particular FM sub-basin, only three had previously been identified as defective by smoke testing (CDM/Jordan/Montgomery, 1985).

With the objective to improve the effectiveness in identifying defects, Miami-Dade County, FL, has recently decided to try a modification of the standard protocol of smoke testing and combine it with air pressurization. After filling the pipe with smoke, the pipe will be plugged on the both ends and put under pressure, which is hoped to further promote appearance of the smoke above the ground. This procedure has not been used at the time of this report preparation and no results are available to verify whether it improves the identification of defects when using smoke testing or not. (Lovett, 2005)

Inspection Rate and Cost. Smoke testing typically is contracted based on footage of mainline (the length of all connected laterals that are smoked as well is not counted). The number of defects greatly affects the inspection rate, as each defect must be documented. The City of Salem, OR, for example, has performed smoke testing with its own crews since the mid 1970s. A four-person crew normally sets up and tests one block of sewer (300-400’) at a time and typically completes about 3,600’ of pipes per day. This agency has been smoke testing on average about 100,000’ of pipes each year and is spending currently $61,187 for the program or $0.61/ft (Roley, 2005; Serres, 2005).

The City of Sarasota, FL, is hiring an outside contractor for smoke testing. One recent contract involved testing of close to 100,000’ of pipe at a cost of $0.15/ft, but an upcoming contract will cost $0.22/ft. The contractor typically completes 5,000-10,000’ per day, depending on pipe condition and traffic control (Ray, 2005).

3.3.4 Dyed Water Testing

Dyed water flooding is done to determine possible sources of infiltration through the soil and lateral cracks, but can also be used to determine various inflow sources as listed in 3.2.2. The testing involves mixing a nontoxic indicator dye with water and flooding the suspect areas (Figure 3-19) or injecting the dyed water in the area of underground suspect sources. For checking suspected drain connections, the dyed water can be poured down the drain. The appearance of dye is monitored either on the CCTV camera positioned in the lateral or looking down into the cleanout. All test results should be appropriately recorded on a dye testing form. All positive dye tests should be quantified by giving consideration to the surrounding area contributing to the problem, and the amount or intensity of dye observed.

Figure 3-19. Dye Water Testing (King County, WA).

3.3.5 Mainline CCTV

During CCTV inspection of mainlines, cameras with a pan-and-tilt option can typically view a short distance into the lateral. Even without this option, some agencies make use of mainline CCTV to evaluate the laterals. In Miami-Dade County, FL, for example, continuous inflow of clear water from the lateral into the mainline indicates a “suspect” lateral. Such laterals are subsequently inspected with a lateral CCTV—in this agency, to the property line. Furthermore, the agency estimates leakage from a lateral using “flow estimate slides” such as the two examples shown in Figure 3-20. Five slides have been prepared to help quantify I/I from the lateral (1.0, 2.0, 4.0, 6.0, and 8.0 gpm) depending on the height of water flow in the mainline pipe (Earth Tech). Each operator of the CCTV camera has these slides in the truck for comparison with the screen view. (Roberts, 2004)

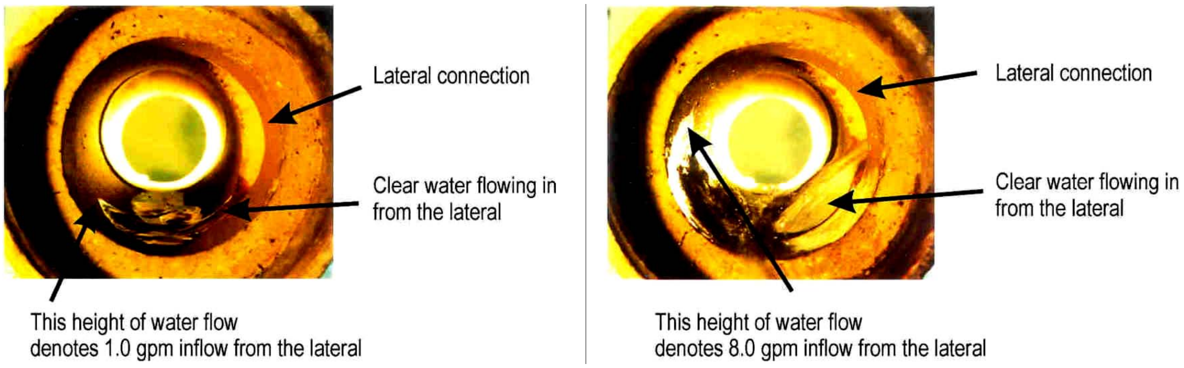

Figure 3-20. Flow Estimate Slides (Miami-Dade County, FL).

3.3.6 Lateral CCTV Inspection

Lateral CCTV-Inspection Systems on the Market. Several manufacturers offer lateral mini-CCTV inspection systems in U.S. (Table 3-4) while other similar systems are available in other countries. Most U.S. manufacturers participated in this study by providing details about their systems (Appendix B). Overall, there are two types of lateral CCTV inspection systems:

- Push-type systems mounted on a push-cable and inserted through a cleanout outside the house or a basement cleanout if the house has one (Figure 3-21). Toilet traps generally make the toilets unsuitable for insertion of the inspection equipment. If there is no suitable access point to the lateral, a small pit can be excavated, especially if rehabilitation of lateral would follow immediately after the inspection. In addition, a new cleanout is usually installed as well.

- Self-propelled systems mounted on a mainline CCTV camera and launched into the lateral from the mainline (Figure 3-22).


Push-type mini-CCTV camera
inserted into the plumbing in
the basement that leads to the lateral

Figure 3-21. Lateral CCTV Inspection from a House Basement (City of Salem, OR).

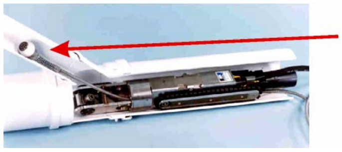
Lateral CCTV camera launched into the lateral

Figure 3-22. Self-propelled System Launched from the Mainline (CUES, Inc).

CCTV lateral systems are predominately used in laterals from 2-6” in diameter, but most systems can be used in larger laterals as well (some in pipes over 12”). The maximum inspected lengths vary. Push-type systems often come with a standard length of a push cable (usually 100’ or 200’) and an optional extended length for inspection of longer laterals (up to 500’). Systems launched from the mainline usually can inspect up to 100’.

Most lateral CCTV systems can negotiate bends in the pipe, even multiple 90º bends. The slope of the pipe is generally not a limitation and is only an issue if a system launched from the mainline has to traverse up a vertical pipe (a “riser”). In this situation, the stiffness of a push cable may be important and systems with sheathed steel cables in place of fiberglass rods are available depending on the severity of the lateral layouts expected.

It is critical that CCTV of the lateral be performed after any existing blockage in the pipe is cleared. If the lateral is infested with roots or has grease or debris, it should be first cleaned before attempting to CCTV.

Nearly all systems allow the use of a sonde for locating.

Table 3-4. Lateral CCTV Systems* [19].

Manufacturer	System	Inspection Distance	Lateral Pipe ID	Resolution (Horizontal)	Camera Self-Leveling	Sonde for Locating	Inspection Speed
<u>Self-Propelled Systems</u> (Launched from the Mainline):							
Aries	LETS®	120’	3-6”	570 lines	Yes	Yes	15 ft/min
CUES	LAMP®	100’	3-8”	460 lines	Optional	Yes	30 ft/min
Hydrovideo	Satel 200	66’		460 lines	No	No	
IBAK	LISY 150M	110’	4-8”	350 lines	Yes	Yes	75 ft/min
RS Tech. Services	Lateral Inspection System	100’	4-8”	480 lines	Yes	Yes	30 ft/min
Sewer Depot	Lateral Navigator	200’	2-10”	470 lines	Optional	Yes	30 ft/min
<u>Push-Type Systems</u> (Cleanout Access):							
Aries	Seeker®	100’ (300’)	2-15”	570 lines	Yes	Yes	-
	Saturn III ®	200’ (400’)					
CUES	MiniPush 20 20	200’ (300’)	2-15”	460 lines	Optional	Yes	-
Hydrovideo	Mini, Evolutis	105’ (165’)	1.5-10”	460 lines	Optional	Yes	-
Pearpoint	P571 Flexicoiler	500’	3-24”	450 lines	Yes	Yes	-
	GatorCam2	200’ (400’)	2-10”	570 lines	Optional	Yes	-
Ratech Electronics	Plumber’s Elite	200’ (300’, 400’)	2-12”	380 or 470 lines	Yes	Yes	-
	Plumber’s Mate						
	Plumber’s Inspector PC						
	Plumber’s Fast Peek						
The Ridge Tool Co.	SeeSnake Plus	325’	2-12”	350 or 400 lines	Yes	Yes	-
	SeeSnake Mini Plus	200’	1.25-6”				
	SeeSnake FlatPack Plus	100’	1.5-4”				
	SeeSnake Compact Plus	100’	1.5-4”				
RS Tech. Services	1300 Series[20]	1,000’	3-16”	480 lines	No	Yes	25 ft/min[21]
	1500 Series	400’	1.75-6”		Optional		-
Scooter Video	Scooter™ Mini	200’	2-12”	420 lines	Yes	Yes	-

** Based on information received from the respective manufacturers.*

Data Collected and Output. All lateral CCTV cameras offer a forward view but some cameras also allow rotation and offer a side view (Figure 3-23).

Figure 3-23. Pearpoint’s P455 Twinview Camera (Pearpoint Inc).

Some systems have an optional self-leveling feature to automatically rotate the image produced to an upright position (as the camera on the cable inevitably rotates somewhat as it

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[19] *All listed systems except Hydrovideo are available in the U.S.*

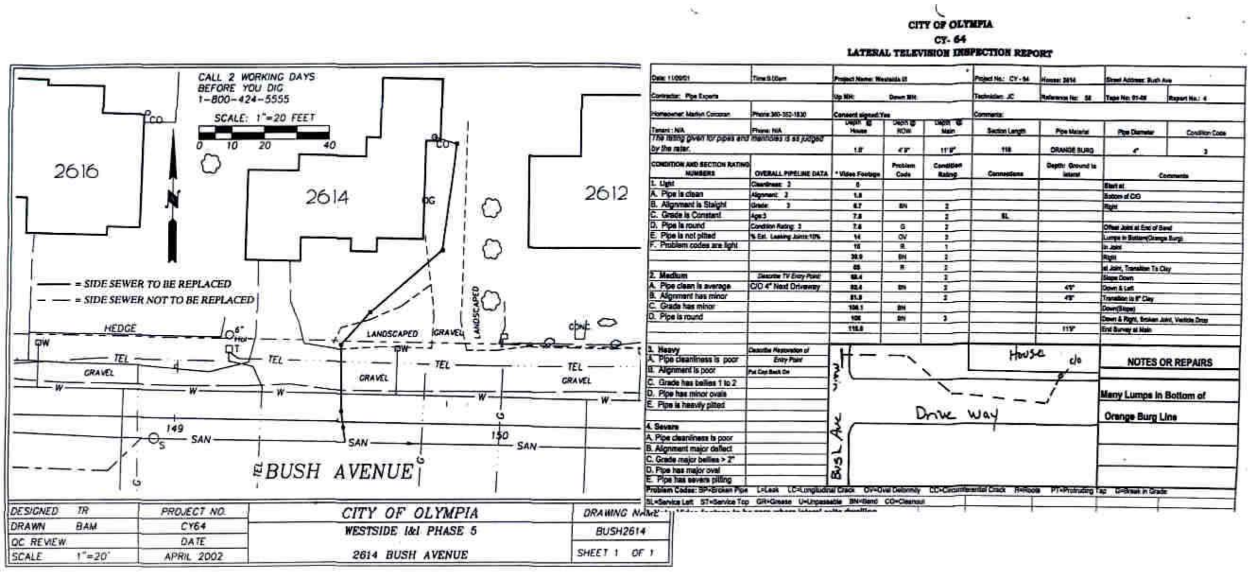
[20] *1300 Series is also used in small diameter mainlines. 1500 Series is a lateral inspection system exclusively.*

[21] *If used on tractor. See in Appendix B for details.*

traverses through the pipe). Self-leveling is favored by many operators, however, the option has additional cost and experienced CCTV operators can usually tell from the image where on the screen the pipe invert is.

As with mainline CCTV inspection, a forward view video of a lateral CCTV inspection is recorded on a videotape or DVD. Some manufacturers also offer optional transfer of recorded images to a CD-ROM.

The results of CCTV inspection are documented in a written log of defects (Figure 3-24), which contains information about defects and their location and clock position, approximate location and quantity of inflow/infiltration, root intrusion, the type and condition of the lateral connection, etc. The log form should also include general information such as the name of the inspector, date of inspection, and name and address of homeowner, and general location of lateral preferably shown on an attached map.



CITY OF OLYMPIA
CY- 64
LATERAL TELEVISION INSPECTION REPORT

Date: 11/09/01	Time 9:00am	Project Name: Westside I/I			Project No.: CY-64	House: 2614	Street Address: Bush Ave
Contractor: Pipe Experts		Up MH:	Down MH:		Technician: JC	Reference No.: 58	Tape No: 01-68 Report No.: 4
Homeowner: Marlyn Corcoran	Phone 360-352-1830	Consent signed: Yes			Comments:		
Tenant: N/A	Phone: N/A	Depth @ House	Depth @ ROW	Depth @ Main	Section Length	Pipe Material	Pipe Diameter Condition Code
The rating given for pipes and manholes is as judged by the rater.		1.8'	4'9"	11'9"	116	ORANGE BURG	4" 3

CONDITION AND SECTION RATING NUMBERS	OVERALL PIPELINE DATA	* Video Footage	Problem Code	Condition Rating	Connections	Depth: Ground to lateral	Comments
1. Light	Cleanliness: 3	0					Start at
A. Pipe is clean	Alignment: 3	1.8					Bottom of C/O
B. Alignment is Staight	Grade: 3	6.7	BN	2			Right
C. Grade is Constant	Age 3	7.8		2	SL		
D. Pipe is round	Condition Rating: 3	7.8	G	2			Offset Joint at End of Bend
E. Pipe is not pitted	% Est. Leaking Joints 10%	14	OV	3			Lumps in Bottom/Orange Burg
F. Problem codes are light		16	R	1			In Joint
		30.9	BN	2			Right
		48	R	2			at Joint, Transition To Clay
2. Medium	Describe TV Entry Point	58.4		2			Slope Down
A. Pipe clean is average	C/O 4" Next Driveway	80.4	BN	2		4'9"	Down & Left
B. Alignment has minor		81.8		2		4'8"	Transition to 6" Clay
C. Grade has minor		100.1	BN				Down(Slope)
D. Pipe is round		106	BN	3			Down & Right, Broken Joint, Vertical Drop
		116.6				11'9"	End Survey at Main
3. Heavy	Describe Restoration of Entry Point						NOTES OR REPAIRS
A. Pipe cleanliness is poor							
B. Alignment is poor	Put Cap Back On						Many Lumps In Bottom of
C. Grade has bellies 1 to 2							Orange Burg Line
D. Pipe has minor ovals							
E. Pipe is heavily pitted							
4. Severe							
A. Pipe cleanliness is poor							
B. Alignment major deflect							
C. Grade major bellies > 2"							
D. Pipe has major oval							
E. Pipe has severe pitting							

Problem Codes: BP=Broken Pipe L=Leak LC=Longitudinal Crack OV=Oval Deformity CC=Circumferential Crack R=Roots PT=Protruding Tap G=Break in Grade SL=Service Left ST=Service Top GR=Grease U=Unpassable BN=Bend CO=Cleanout

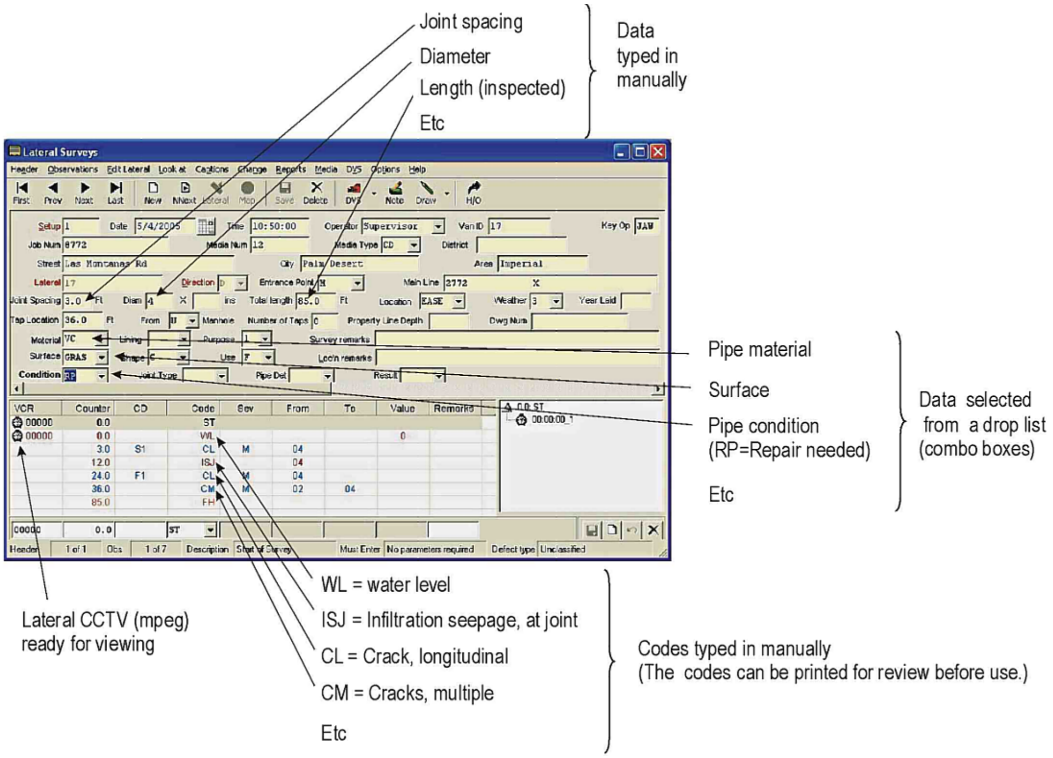
* Video footage to be zero where lateral exits dwelling

Figure 3-24. Sample CCTV Report Log (City of Olympia, WA).

Handling of data recorded during lateral CCTV inspection can be simplified using customized software. In the following discussion the Flexidata software (PipeLogix Inc.) will be used as an example. This software works with all CCTV systems, but it became applicable for lateral inspections only after additional features were added in 2004. Screen forms display information about inspected pipes—length, diameter, pipe type, etc, as well as identified defects—cracks, leaking joints, etc. The forms are easy to enter with key detail by the CCTV inspector. Some data such as pipe type, length, etc. can be auto-filled from the database, the rest is typed in manually. Standard pipe defect and location codes are provided from a drop list but custom descriptions can easily be added.

In 2004, a lateral survey form (Figure 3-25) was added to the software, as well as codes for lateral pipe inspection. The lateral survey form contains detail about a lateral survey and is available for launch from either a mainline survey form or for an individual lateral survey. The lateral codes can be grouped as a subset of the mainline codes (PACP[22] codes contain a total of 199 codes to choose from and there is a total of 52 codes specifically for laterals). The codes can be printed for review before use (Table 3-11 at the end of this chapter).

After CCTV inspections are completed and survey forms filled in, the software automatically creates professional reports in tabular form (Figure 3-26) or graphic form (Figure 3-27). The software is fully PACP Certified, WRc and European Union compliant and is translatable into other languages.



Setup 1 Date 5/4/2005 Time 10:50:00 Operator Supervisor Van ID 17 Key Op JAW
Job Num 8772 Media Num 12 Media Type CD District
Street Las Montanas Rd City Palm Desert Area Imperial
Lateral 17 Direction D Entrance Point H Main Line 2772 X
Joint Spacing 3.0 Ft Diam 4 X ins Total length 85.0 Ft Location EASE Weather 3 Year Laid
Tap Location 36.0 Ft From U Manhole Number of Taps 0 Property Line Depth Dwg Num
Material VC Lining Purpose 1 Survey remarks
Surface GRAS Shape C Use F Loc'n remarks
Condition RP Joint Type Pipe Det Result

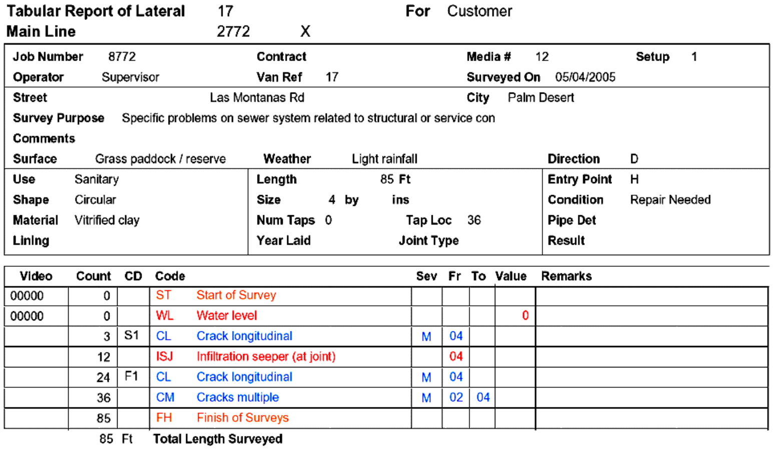
VCR	Counter	CD	Code	Sev	From	To	Value	Remarks
00000	0.0		ST					
00000	0.0		WL				0	
	3.0	S1	CL	M	04			
	12.0		ISJ		04			
	24.0	F1	CL	M	04			
	36.0		CM	M	02	04		
	85.0		FH					

0.0: ST
00:00:00_1

00000 0.0 ST

Header 1 of 1 Obs 1 of 7 Description Start of Survey Must Enter No parameters required Defect type Unclassified

Figure 3-25. Flexidata's Lateral Survey Form (PipeLogix Inc).



Tabular Report of Lateral 17 **For** Customer
Main Line 2772 X

Job Number	8772	**Contract**		**Media #**	12	**Setup**	1
Operator	Supervisor	**Van Ref**	17	**Surveyed On**	05/04/2005		
Street	Las Montanas Rd			**City**	Palm Desert		
Survey Purpose	Specific problems on sewer system related to structural or service con						
Comments							
Surface	Grass paddock / reserve	**Weather**	Light rainfall	**Direction**	D		
Use	Sanitary	**Length**	85 Ft	**Entry Point**	H		
Shape	Circular	**Size**	4 by ins	**Condition**	Repair Needed		
Material	Vitrified clay	**Num Taps**	0 **Tap Loc** 36	**Pipe Det**			
Lining		**Year Laid**	**Joint Type**	**Result**			

Video	Count	CD	Code		Sev	Fr	To	Value	Remarks
00000	0		ST	Start of Survey					
00000	0		WL	Water level				0	
	3	S1	CL	Crack longitudinal	M	04			
	12		ISJ	Infiltration seeper (at joint)		04			
	24	F1	CL	Crack longitudinal	M	04			
	36		CM	Cracks multiple	M	02	04		
	85		FH	Finish of Surveys					

85 Ft **Total Length Surveyed**

Figure 3-26. Flexidata's Report of Lateral CCTV Inspection in Tabular Form (PipeLogix Inc.).

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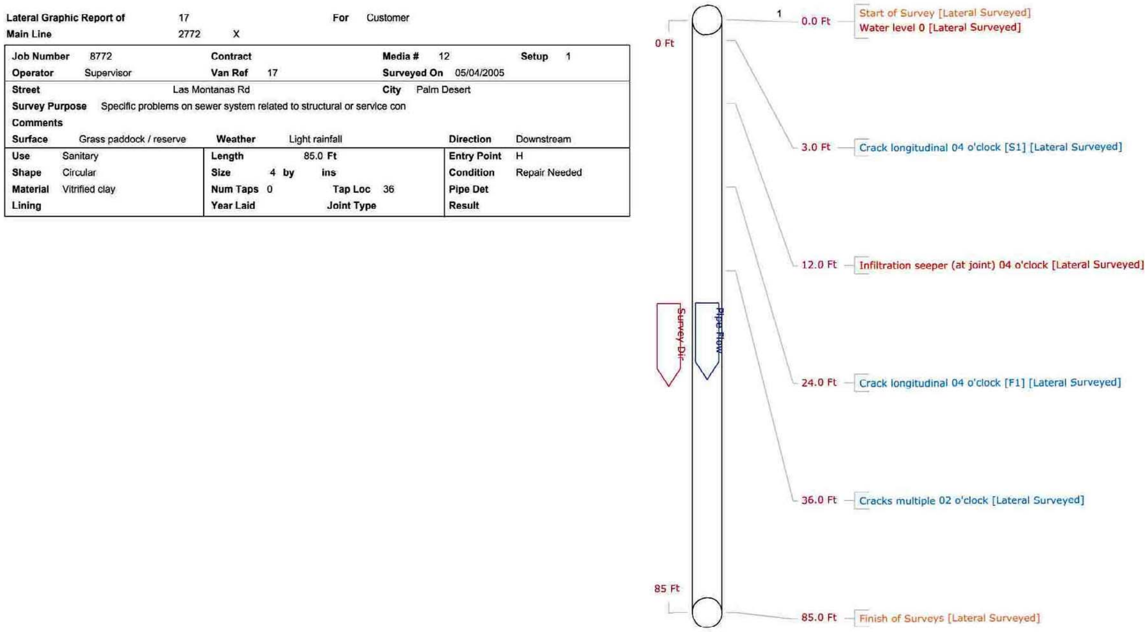
[22] *Pipeline Assessment and Certification Program*



Lateral Graphic Report of 17 **For** Customer
Main Line 2772 X

Job Number	8772	**Contract**		**Media #**	12	**Setup**	1
Operator	Supervisor	**Van Ref**	17	**Surveyed On**	05/04/2005		
Street	Las Montanas Rd			**City**	Palm Desert		
Survey Purpose	Specific problems on sewer system related to structural or service con						
Comments							
Surface	Grass paddock / reserve	**Weather**	Light rainfall	**Direction**	Downstream		
Use	Sanitary	**Length**	85.0 Ft	**Entry Point**	H		
Shape	Circular	**Size**	4 by ins	**Condition**	Repair Needed		
Material	Vitrified clay	**Num Taps**	0 **Tap Loc** 36	**Pipe Det**			
Lining		**Year Laid**	**Joint Type**	**Result**			

Figure 3-27. Flexidata's Report of Lateral CCTV Inspection in Graphic Form (PipeLogix Inc).

Inspection Rate and Cost of Lateral CCTV Inspection. With push type systems, the speed of inspection varies depending on the operator. Mainline launched systems usually inspect at a speed of about 30 ft/min. The daily inspection rate is, according to most manufacturers, about 20-30 laterals, assuming on average 50' long laterals and an eight-hour shift. The number of laterals that can be inspected depends mostly on setup: accessibility of a cleanout if needed as a point of insertion (i.e. whether the location of cleanout is known or it has to be located, and whether any excavation is required) and the distance between the laterals (i.e. whether they are in the same neighborhood or the crew has to drive across town to inspect the laterals).

Generally speaking, lateral CCTV is more expensive per foot of pipe inspected than mainline CCTV because of shorter footage per setup and greater difficulty to access the pipe. According to Miami-Dade County, FL, the cost depends on the type of lateral CCTV used and whether any excavating is required (Lovett, 2005). Compared to the cost of mainline CCTV, which is $1.50/ft in this agency, the cost of lateral CCTV compares as follows:

- Push type lateral CCTV inserted through cleanouts can be 2.5-3 times more expensive.
- Mainline launched lateral CCTV can be 3.5-4 times more expensive.
- If any excavation is required, especially a street asphalt cutting, lateral CCTV can be 6-7 times more expensive.

The City of Salem, OR, pays a contractor $225 per lateral, which is about $3.00-3.25/ft, however, the cost includes also cleaning (this was shown to be necessary in about 90% of laterals before inspection) and dye testing. The inspection procedure starts with the contractor making an appointment with the homeowner. They flush, locate and CCTV the service lateral. This information is sketched on a site map provided to the contractor. The contractor also dye tests each fixture in the home and verifies the discharge location. They identify all footing drains, roof drains, sump pumps, and combined service laterals. The contractor can do about five homes per day. (Roley, 2005)

A California based manufacturer of CCTV inspection equipment reported that the cost of lateral CCTV inspection is at a minimum \$125 per lateral while most inspections cost about \$200-400 per lateral (Stone, 2005).

In Sarasota, FL, the cost is rather low at \$1.40/ft of lateral, which includes both cleaning and CCTV (Ray, 2005).

3.3.7 Pressure Testing

Pressure testing is a widely used testing method in new pipe installations, and is quite often used to evaluate the leak-tightness of existing sewer pipes.

In this process, a selected section of the lateral is plugged and a fluid (air or water) inserted into it under a pressure. The air pressure decrease or the water level drop is monitored over certain period of time. If it remains within established tolerances, the pipe passes the test and the leak-tightness is confirmed. The allowable pressure loss varies between the agencies and is determined in their codes. Some agencies allow a certain small pressure loss, although usually only for the testing of existing pipes. Other agencies do not allow any loss of pressure regardless of the pipe age.

Air Pressure Testing. The procedure for pipe testing using low-pressure air to demonstrate the integrity of an installed pipe is described in two standards developed by the American Society for Testing Materials (ASTM):

ASTM C828-03	Standard Test Method for Low-Pressure Air Test of Vitrified Clay Pipe Lines
ASTM C924-89	Standard Practice for Testing Concrete Pipe Sewer Lines by Low-Pressure Air Test Method

An air pressure testing procedure to verify leak-tightness of laterals developed and used in Miami-Dade County, FL, is described as an example (Lovet, 2005). The test is performed in up to three steps, each testing a different part of the lateral. For plugging the pipes, three different plugs are used (Figure 3-28). One of them, a flow-through test ball, has an airline to insert air under pressure into the isolated section (see its application in the 3rd test configuration below).

In the testing, air pressure must offset the hydrostatic pressure if the groundwater level is above the pipe. If it is below the pipe, the applied air pressure is 3.5 psi, and for each foot of water level above the pipe, it should increase 0.43 psi. However, it should never go above 5 psi to avoid pipe damage. Therefore, if the groundwater is 2' or more above the top of the pipe in its upstream end, the air pressure test should not be used!

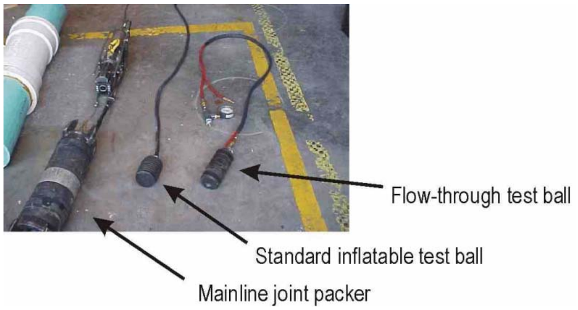


Figure 3-28. Plugs Used in Lateral Air Testing (Miami-Dade County, FL).

The testing is first performed on the entire lateral (Figure 3-29). A plug is inserted at the cleanout near the house using the standard test ball. A mainline joint packer is positioned at the connection to the mainline and inflated. The air is inserted through the mainline packer to reach 3.5 psi plus 0.5 psi per foot depth of groundwater over the pipe. If the pressure holds for one minute, the pipe has passed the test.

Experience in this agency has shown that the pipe either holds the pressure or fails "immediately" with either a rapid drop of pressure or an inability to pressurize the pipe. If the lateral fails the test, the agency's portion of the lateral is tested (Figure 3-30). In this case, the plug is positioned in the cleanout near the property line and the air inserted again through the mainline joint packer. As before, the air pressure is monitored for one minute.

If the lower lateral passes the test, the leaks are on the private side and the homeowner is required to repair the upper lateral. If the lower lateral fails the test, the agency repairs the lateral to the property line, but the upper lateral still needs to be tested. For the upper lateral test, the plugs are placed at the cleanouts as shown in Figure 3-31. At the very top of the cleanout CO 2, the "flow through test ball" is inserted and air pumped through it. The air pressure is again monitored for one minute.

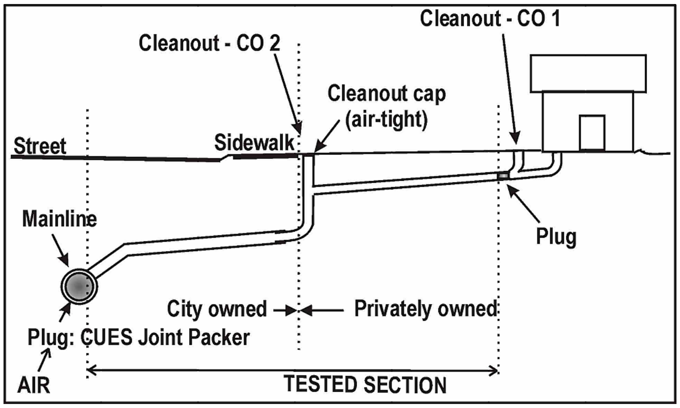


Figure 3-29. Step 1—Air Testing of Entire Lateral in Miami-Dade County, FL.

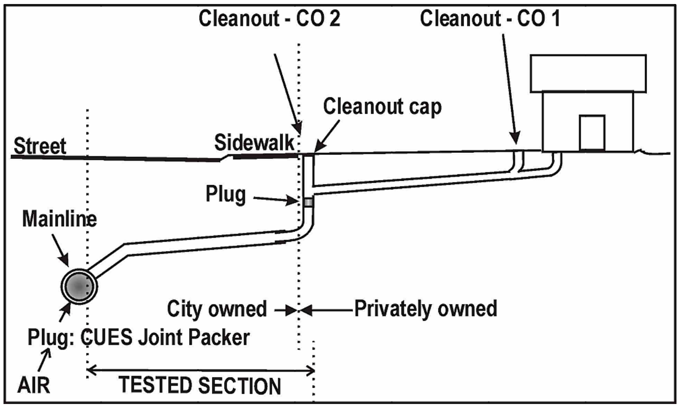


Figure 3-30. Step 2—Air Testing of Lower Lateral in Miami-Dade County, FL.

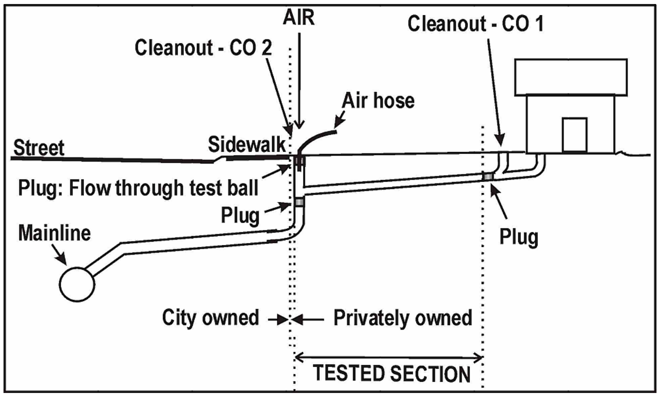


Figure 3-31. Step 3—Air Testing of Upper Lateral in Miami-Dade County, FL.

Another example of an air pressure test is a procedure used in the City of Burlingame, CA. In the test, the air is slowly supplied into the plugged upper lateral[23] until the pressure reaches 4.0 psi over the "groundwater pressure"[24]. After at least two minutes allowed for temperature stabilization, a time interval is measured for internal pressure to drop from 3.5 psi to 2.5 psi (both over the groundwater pressure). If the measured time interval is 10 seconds or more, the lateral has passed the test successfully. (Murtuza, 2005)

Hydrostatic Pressure Testing (Water Exfiltration Testing). The procedure for hydrostatic testing of vitrified clay pipes to demonstrate the structural integrity of an installed pipe is described in one standard prepared by the American Society for Testing and Materials:

ASTM C1091-03a	Standard Test Method for Hydrostatic Infiltration Testing of Vitrified Clay Pipe Lines

A hydrostatic pressure testing procedure to verify the leak-tightness of upper laterals developed and used in the City of Key West, FL, is described as an example. In this agency, there are usually two cleanouts on the lateral: one at the property line, also referred to as a "city cleanout" (CC) and the other, often near the house referred to as a "personal cleanout" (PC). Having both cleanouts at a very close distance apart, as shown in Figure 3-32, is a rather atypical situation. However, this lateral was selected for a demonstration of the testing procedure to avoid entering private property.

Figure 3-32. Cleanouts on the Lateral Selected for Demonstration of Water Exfiltration Testing (City of Key West, FL).

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[23] *Plugs are inserted at a cleanout near the building and a cleanout at the property line.*

[24] *In this test description, the "groundwater pressure" is the average hydrostatic pressure of groundwater on the submerged lateral pipe, which is calculated before the pressure test.*

The testing of each upper lateral is done in two steps. First, the “upper part” of the upper lateral is tested (Figure 3-35). A plug (i.e. a 4” inflatable test ball) is positioned at the cleanout near the house and inflated. This isolates a section of lateral immediately next to the house to be pressure tested.

To fill the plugged section with water and create the required hydrostatic pressure, a stack is mounted over the cleanout (Figure 3-33). For this purpose, a short PVC pipe is used, which is an extension of the cleanout to the required height. It should extend no further than to the house floor level to prevent any damage to the house. A dye is added to the water and, for the duration of filling the section with water, the city cleanout is observed for any trace of dye, which would indicate improper plugging. After the stack is completely filled, the water level in it is monitored for 30 minutes (Figure 3-34).

Figure 3-33. Stack over the Cleanout (City of Key West, FL).

Figure 3-34. Dyed Water in the Stack Monitored for Any Level Drop (City of Key West, FL).

In the second step, the procedure is repeated on the section of the lateral between two cleanouts (Figure 3-36). The stack mounted over the city cleanout needs to extend vertically to anywhere between the level of the personal cleanout and the house floor level.

In both tests, if there is a leak, the dyed water in the stack settles at a level that indicates the location of the leak in the pipe (the section of pipe extending below the dyed water level has no cracks). The agency has a “no tolerance” approach and does not allow even the slightest water level drop. The agency is also very strict in forcing the homeowners to promptly repair any failed lateral.

On some laterals, one more test is carried out. If the water level drops drastically in the second step (i.e. to the cleanout boot), it is likely that a pipe joint fitting (Fernco fitting) has failed and a “city cleanout isolation test” is performed (Figure 3-37). The cleanout is plugged with two plugs and a mini-CCTV camera mounted on a flexible hose pushed towards the upstream plug inspecting the pipe in this area and the Fernco fitting for damage.

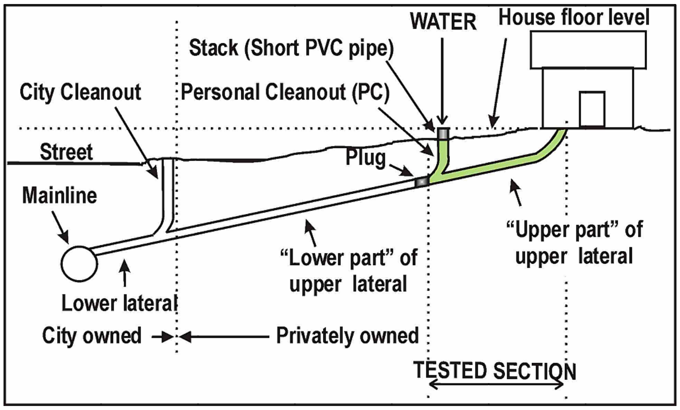

Figure 3-35. Step 1—"Upper Part" of Upper Lateral Test in the City of Key West, FL.

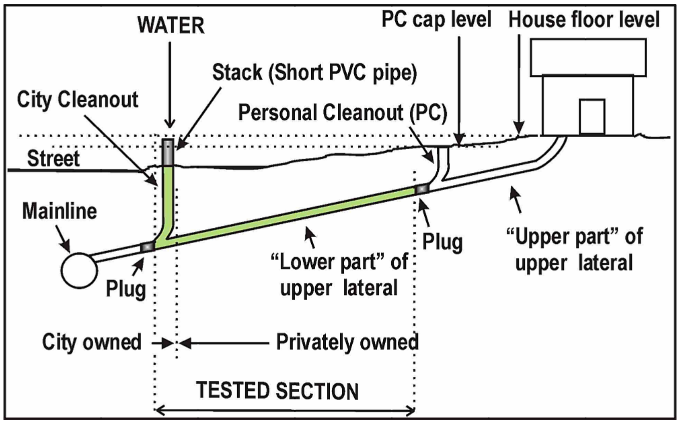

Figure 3-36. Step 2—"Lower Part" of Upper Lateral Test in the City of Key West, FL.

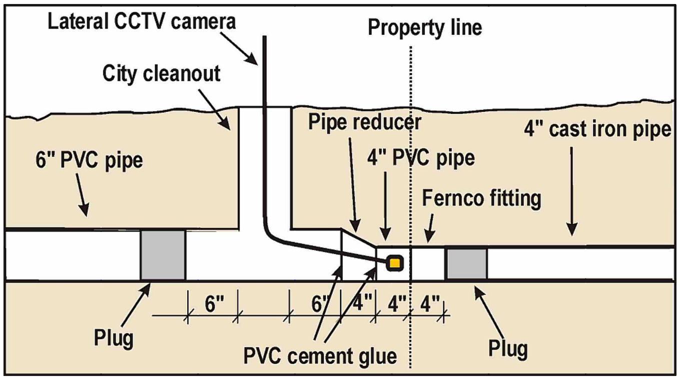

Figure 3-37. Step 3—"City Cleanout" Isolation Test in the City of Key West, FL.

Another example of a water exfiltration test is a similar procedure used in the City of Burlingame, CA (Figure 3-38). After plugging the cleanout at the property line and the lower lateral, either a fixture inside the house or a cleanout near the house is used to surcharge the upper lateral with water. The testing water level must be at a minimum of 2' above the lateral elevation at the city cleanout. If there is any fixture inside the house lower than the testing water level, the contractor has to plug either the fixture or the lateral at the building. A plumbing permit is required for this work. The amount of water lost is measured for 30 minutes and if it is less than four gallons, the lateral is considered acceptable. (Murtuza, 2005)

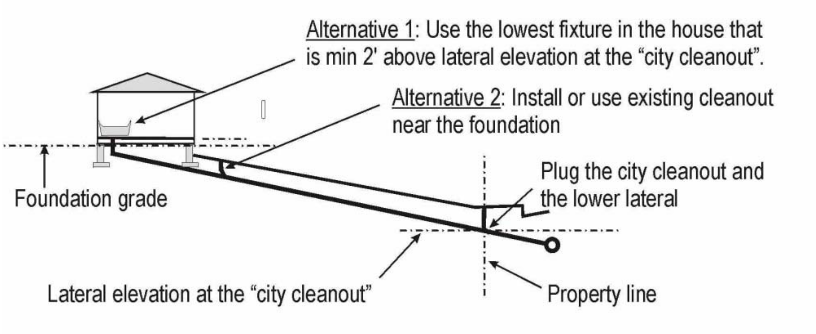

Figure 3-38. Water Exfiltration Test of Upper Laterals in the City of Burlingame, CA.

Pressure Maintenance vs. Purpose of Testing. As mentioned earlier, the requirements about holding the pressure in the pipe can be different even within the same agency depending on the purpose of testing. For example, in the City of Salem, OR, the plugged lateral must hold a pressure (air or water) of 3.5 psi for 15 minutes without any loss when testing new installations. However, the code allows for a loss of half of the pressure (1.75 psi) in 15 minutes when testing the existing pipes.

Cost of Pressure Testing. In Salem, OR, the cost of pressure testing is included in the cost of pipe replacement, but considering a typical test duration of about one hour, could be estimated at approximately $75.00 per lateral, i.e. about $1.00-1.50/ft.

3.3.8 Electro Scanning

The Focused Electrode Leak Location (FELL) technique is relatively new technology and only recently available on the U.S. market. The method measures electrical current flow between a probe that travels in the pipe and a surface electrode. Pipe defects that allow liquids to flow into or out of the pipe cause a spike in the electrical signal due to the increased conductivity at the leaking area compared to the rest of the (non-conducting) pipe. The spike in the electrical signal thereby locates the sources of infiltration or exfiltration. The intensity of the measured current can be correlated to the magnitude of the leaks and the nature of the conductivity change along the pipe can provide information about the type of defect. It should be noted that this method is not applicable on metallic pipes such as, for example, cast iron laterals.

The technology has been used for identifying leaks in sewer mainlines (FELL-41), but a version applicable in sewer laterals has been available since 2004 (FELL-21). For testing, the lateral is plugged with a bladder and filled with water from a cleanout or a house (Figure 3-39). A sonde (in-pipe electrode) is attached on a 150’ push rod and inserted into the lateral through the cleanout, usually at the property line. The sonde is pushed down the lateral towards the mainline and/or up the lateral towards the house.

An example of electro-scans created during testing is shown in Figure 3-40. This lateral was replaced not long before the inspection and was not supposed to have any leaks. The scan indicates, however, a possible faulty joint at about 14’ from the cleanout.

Application issues are that the pipe still needs to be CCTV inspected and that the lateral needs to be fairly straight or with bends that allow passage of the sonde. The sonde is 4” long and 1½” in diameter.

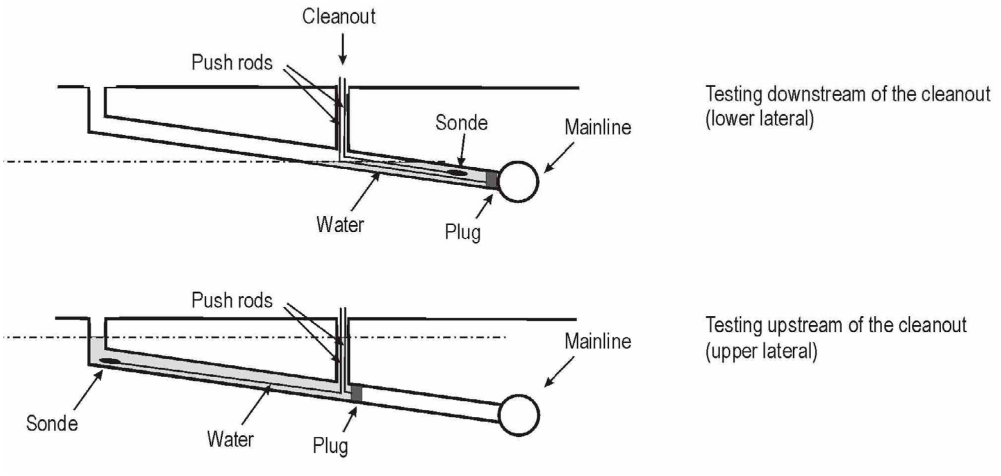

Figure 3-39. FELL-21 Testing. Top: Testing of the Lower Lateral. Bottom: Testing of the Upper Lateral.

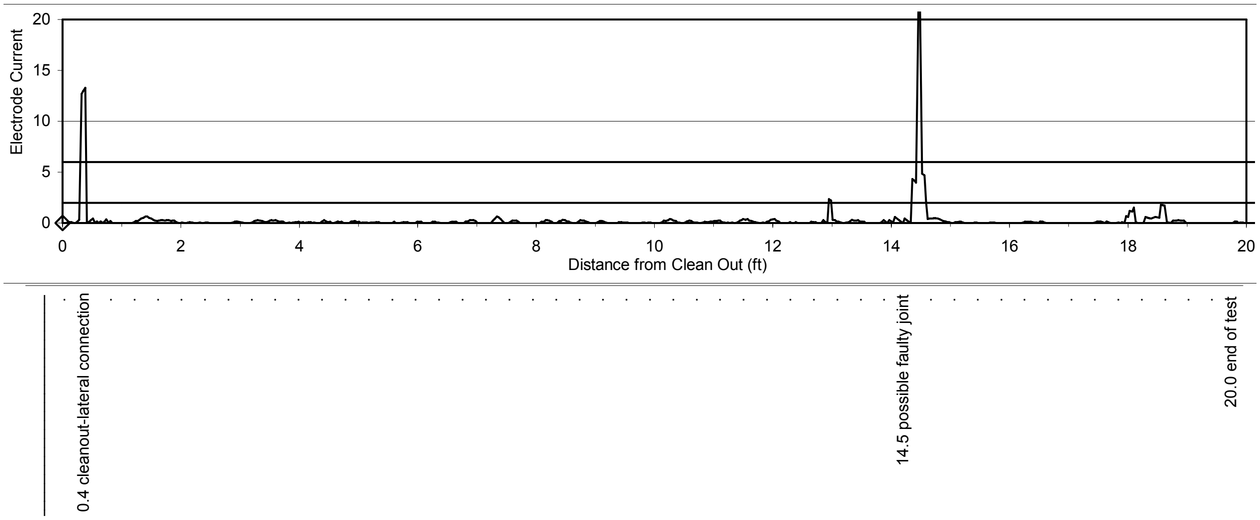

Figure 3-40. Example of Electro-scans Created with FELL-21 in Vallejo Sanitation and Flood District, CA.

Several agencies had a field demonstration of FELL 21 during the last few months of this research:

- In Vallejo, CA, nine laterals were tested in December 2004. The agency's personnel reported that they liked the technology and found the results easy to interpret. (Ohlemutz, 2005)
- Ten laterals were tested in Sarasota, FL, in March 2005. The city engineers were very impressed because the inspection pinpointed leaks that were not visible on the lateral CCTV[25]. The ease of use was also appealing and the agency felt that it would be able to purchase the system and perform in-house inspection with only a short training of the city personnel. (Ray, 2005)

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[25] *Sewer laterals in Sarasota are above groundwater level most of time and there is no base infiltration through them. The leaks become active only during rainfall events (existing groundwater conditions in this agency are explained in 4.2.4). For that reason there are no easily detectable stains on the pipe wall that are characteristic of long-term leaks.*

- In Miami-Dade, FL, the system was tested on 12 laterals in April 2005. The system, however, identified leaks in two laterals that had passed successfully the air pressure test. It is believed that metal clamps used to repair those laterals were interpreted as leaks. (Lovett, 2005)

Productivity and Cost of Lateral Electroscanning. If only sewer laterals are tested, the testing rate is probably around 10-15 laterals per day. The most time consuming part is the setup and the length of the lateral does not affect much the total duration of testing. The cost of testing is around $200 per lateral, which is about $4/ft assuming a 50' long lateral, or between $2-6 per lateral for laterals 35-100' long.

3.3.9 Summary of Inspection Methods

The following two tables summarize methods for laterals inspection and compare their attributes.

Table 3-5. Methods for Inspection of Sewer Laterals.

Method	Description
♦ Building inspections	Identifies uncapped cleanouts and various connections to the laterals
♦ Smoke testing	Identifies various connections and defective service laterals
♦ Dye water flooding	Identifies defective laterals and various connections to the sewer lateral
♦ Mainline CCTV	Identifies "suspect" laterals and may be able to inspect first few feet of the lateral
♦ Lateral CCTV	Identifies location and size of active leaks and some inactive leaks (water stains) Also identifies change in pipe material/diameter along the lateral, sags, bends, etc.
♦ Pressure testing	Identifies existence of both active and passive leaks
♦ Electro scanning	Identifies existence of both active and passive leaks in non-conductive pipes

Table 3-6. Comparison of Methods for Inspection of Sewer Laterals.

Property	Smoke Testing (Mainline & Laterals)	CCTV Inspection (Laterals Only)	Pressure Testing (Laterals Only)	Electro Scanning (Laterals)
Test rate daily	3,500-10,000’	20-30 laterals	8-12 laterals	10-15 laterals
Cost per foot	$0.25-1.00/ft	$1.50-9.00/ft	$1.00-5.00/ft	$2.00-6.00/ft
Pipe type	Any	Any	Any	Non-metallic pipes
Groundwater conditions	Below the pipe important	Above the pipe preferred	Below the pipe preferred	Not important
Water in the pipe before test	Pipe must not be surcharged	Water level as low as possible	Water level as low as possible	Not important
Pipe cleaning	None typically	Recommended: For camera passing, defect identifying.	Localized: Typically required where plugs would be placed.	Depends: If necessary for sonde passing.
Cleanout required	No	Yes (push-type CCTV systems); No (mainline launched)	Yes	Yes
Type of leaks detected	Any leaking defects (but typically not all of them)	Active leaks, possibly non-active leaks	All (active and non-active leaks)	All (active and non-active leaks)
Leak measurement	Descriptive estimate of defects	Descriptive estimate of active leaks	Rate of pressure loss related to size of defect	Aptitude of current trace related to size of defect
Output data	Qualitative	Qualitative (quantitative)	Quantitative	Quantitative
Leak location accuracy	Variable	Within inches	Not definitive usually	Within inches
Data reliability	Low: Highly dependent on surface and soil conditions.	Moderate: Dependent on experience of operator. Leaks in laterals often less obvious than in mainlines.	High: Providing the plugs are properly installed and not leaking.	High: Providing there are nometallic repair clamps in pipes.
Defects other than leaks detected	No	Yes (obstructions, deposits, roots, etc.)	No	No

Combining Inspection Methods. With awareness of limitations of inspection methods both in applicability and data reliability, the agencies usually inspect the laterals with more than one method thus getting more reliable data to make an accurate condition assessment of these pipes. In this way, defects that are missed or misinterpreted with one method are still identified with another method.

An example of one early pilot study in which sewer laterals were inspected with different methods is the Berkeley Pilot Study, Phase I, in Berkeley, CA, performed in 1981-85 (CDM/Jordan/Montgomery, 1985). Within this project, selected laterals were tested using a water exfiltration test, inspected with CCTV, and visually examined after excavation. (Prior to the study, all sewer pipes were also smoke tested.)

A water exfiltration test was performed on 67 lower laterals and 27 upper laterals showing high exfiltration rates (Table 3-7). The measured exfiltration rates were between 2.0 gpm to over 40.0 gpm, whereas the allowable rates were 0.03 gpm. Although every attempt was made to have proper seals during testing, it is possible that minor leaks occurred at plugs. Nevertheless, the test showed that all tested laterals were leaking and that as many as 67% of lower laterals and 10% of upper laterals were leaking extensively (over 40 gpm).

Table 3-7. Exfiltration Test on Laterals in Berkeley Pilot Study, Phase I, 1981-85 (CDM/Jordan/Montgomery, 1985).

Exfiltration Rate (gpm)	Number of Lower Laterals		Number of Upper Laterals		Comment
0- 5.0	2	3%	3	4%	Approx 0.03 gpm allowed!
5.1- 10.0	0	0%	4	6%	
10.1- 15.0	4	6%	2	3%	
15.1- 20.0	3	4%	3	4%	
20.1- 25.0	3	4%	2	3%	
25.1- 30.0	10	15%	3	4%	
30.1- 35.0	0	0%	0	0%	
35.1- 40.0	0	0%	3	4%	
40.1- Up	45	67%	7	10%	
Total tested:	67		27		

CCTV inspection was performed next on 68 laterals showing roots as the most common defect—found in 69% of lower laterals and 75% of upper laterals (Table 3-8). There were also many laterals with offset joints and cracks (radial and longitudinal).

Table 3-8. Lateral CCTV Inspection in Berkeley Pilot Study, Phase I, 1981-85 (CDM/Jordan/Montgomery, 1985).

Defect Identified	Number of Lower Laterals		Number of Upper Laterals	
Structural defects: cracks	16	24%	13	19%
Structural defects: crushed/broken pipe	7	10%	4	6%
Offset joints	31	46%	33	49%
Misalignment, vertical (sags)	4	6%	1	1%
Misalignment, horizontal	9	13%	9	13%
Roots	47	69%	51	75%
Total tested:	68		68	

Excavation and visual examination of pipes was done on 11 lower laterals selected from those already tested with the other two methods. Excavation was performed using "archeological methods": a backhoe was first used to remove the existing pavement and material to the depth of approximately 1' above the pipe and, from that point on, shovels and smaller tools were used to remove the soil until the pipe was exposed. The pipe was further cleaned using a small hand broom. Visual examination confirmed many defects identified with CCTV inspection and further showed that pipes which appeared to have little or no problems with roots on the outside had extensive root growth inside the pipes (Table 3-9).

Table 3-9. Visual Examination after Excavation in Berkeley Pilot Study, Phase I, 1981-85.

Defect Identified	Number of Lower Laterals		Number of Upper Laterals
Structural defects: cracks	7	64%	-
Structural defects: crushed/broken pipe	2	18%	-
Structural defects: mortar deterioration	10	91%	-
Offset joints	8	73%	-
Open joints	6	55%	-
Misalignment, vertical (sags)	4	36%	-
Misalignment, horizontal	4	36%	-
Roots	9	82%	-
Total tested:	11		

In summary, testing with different inspection methods gathered different data, which, when considered together, helped to reach a basic conclusion that the laterals were in poor condition and in need of rehabilitation or replacement. (Yee, 2005)

3.4 Condition Assessment of Lateral Pipes

Most often agencies use inspection data to perform condition assessment of sewer laterals and make decisions whether the rehabilitation/replacement of a particular lateral is necessary. There are exceptions to this as particular agencies may have a policy about the process of selecting laterals for repair and the length/type of repair that does not involve condition assessment of individual laterals. For example:

- Nashville and Davidson County, TN, has a policy of rehabilitating all laterals that are connected to the mainline segment being rehabilitated. This policy is the result of the following reasoning. The laterals may have fine cracks that do not show during the CCTV inspection but leak at higher groundwater levels during wet weather. The mainline rehabilitation prevents groundwater from entering into the sewer system and locally raises its level. Thus, the laterals become submerged longer and may stay submerged even during dry weather. For lateral rehabilitation, CIP relining of lower laterals has been found to be the most cost effective. CCTV inspection of laterals is performed only as a quality control after CIP relining. (Ballard, 2005)
- In Sarasota, FL, inspection of laterals is performed only to determine the pipe type on the entire length of lateral. Namely, the laterals have often been repaired in the past by plumbers, who would make open cut point repairs and install different pipe types during these repairs. The agency has the policy to replace all the laterals in the sub-basin being rehabilitated, unless the lateral is a relatively new PVC pipe, because older pipes in the system have historically performed badly, i.e. the pipes have either failed or would be failing soon. Because pipe bursting is the method of choice, it is preferred to finish the work in the neighborhood all at once rather than return and disrupt the neighborhood every time another single lateral has failed. (Ray, 2004; Castorani, 2004)

In many agencies, however, only laterals that are proven defective qualify for repair, especially if the agency has to force the homeowner to do and/or pay for the repair.

Assessment of I/I Conditions in Laterals. Some agencies with serious I/I problems focus on assessment of I/I conditions in laterals. Pressure testing of laterals is often a preferred method of inspection, which not only allows the agency to simply classify one lateral as “leaking” or “not-leaking”, but also to weigh up the severity of leaking in the lateral by comparing measured exfiltration rates with allowed exfiltration rates[26].

However, the assessment of I/I conditions in sewer laterals can also be based on the CCTV inspection, during which leaking joints in the laterals are observed and documented and their percentage against the total number of joints in the laterals calculated. In the City of Ft. Lauderdale, FL, for example, a lateral CCTV inspection report includes a table showing for each lateral (Reina, 2004; Schwarz, 2004):

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[26] *See case study #8 in Appendix A (Flood Grouting in Lafayette, LA) about calculating allowed exfiltration rates. Table A1.8-7 compares allowed leakage rates with actual leakage rates before and after rehabilitation.*

- Joint infiltration i.e. joints visibly leaking on the CCTV tape
- Evidence of infiltration i.e. joints not leaking visibly on the CCTV tape but with stains that indicate infiltration during rainfall events.

Both the joint infiltration and the evidence of infiltration are calculated as a percentage of total number of joints in all laterals on the mainline section. For example, the evidence of infiltration is calculated using the following formula:

$$\mathrm{EI}(\%) = \frac{\mathrm{N}_{\mathrm{INF}}}{\mathrm{N}_{\mathrm{ALL}}} \quad \text{..........} \quad (3.3.9\text{-}1)$$

Where: EI..............Evidence of infiltration,
$\mathrm{N}_{\mathrm{INF}}$..........Number of joints with evidence of infiltration,
$\mathrm{N}_{\mathrm{ALL}}$..........Number of joints in all laterals on a particular mainline section.

Furthermore, the evidence of infiltration is calculated for three different sections of the laterals (depending on distance from the connection to the mainline): EI <3’, EI 3-15’, EI>15’. This assessment provides the basis to select the laterals for rehabilitation and select the method of rehabilitation (in this case a 15’ long T-Liner vs. a 5’ long Top Hat).

Assessment of Structural Condition of Laterals. Lateral CCTV inspection identifies pipe defects such as cracks, holes, out–of-shape pipes, collapsed pipes or pipes with defective joints (opened or misaligned). Based on the collected data, structural assessment of laterals can be made in two ways:

- Qualitatively, e.g. the lateral condition is described as excellent, good, fair or poor.
- Quantitatively, i.e. the lateral condition is expressed as a score.

The quantitative approach involves assigning a score to each defect based on its type and severity. The scores are summarized for all defects on the lateral into the final score for the lateral. In addition, defects can be given their own weighting factors (Table 3-10) and the weighted score for the lateral calculated (3.3.9-2).

Table 3-10. Sample Defect Scoring and Sample Weighting Factors.

Defect Condition	Score	Defect	Weighting Factor
Defect requiring immediate attention	5	Collapsed	100
Severe defects requiring attention in the near future	4	Broken Pipe	50
Moderate defects that will continue to deteriorate	3	Fracture	25
Defects that have not begun to deteriorate	2	Hole	15
Minor defects	1	Crack	5

$$\mathrm{WS} = \sum(\mathrm{WF} \times \mathrm{RS}) \quad \text{..........} \quad (3.3.9\text{-}2)$$

Where: WS..........Weighted score for lateral,
WF............Weighted factor,
RS.............Raw score.

Assessment of Operating Condition of Laterals. Lateral CCTV inspection also identifies "defects" that prevent reliable service of the pipes such as tree roots protruding into the laterals, debris and obstructions in the pipe, encrustation (dissolved salts deposited on the pipe walls), etc. Active leaks also belong in this group of defects. Assessment of the operating condition of laterals can be done in the same manner as the structural assessment of laterals.

Other Defects in Laterals. Certain defects in sewer laterals are caused by construction practices, for example, wrongly installed cleanouts or improper lateral connections with the mainline (break-in laterals). Construction-caused defects usually affect the serviceability of laterals and can be part of the assessment of operating conditions, however, are often classified as a separate defect category.

Standardization of Defect Codes. The need for standard coding of defects has long been acknowledged. Standardization of defect codes enables benchmarking of sewer pipe conditions within a single agency (if different coding systems were used within one agency, the pipe data would not be comparable and any prioritization for repair impossible) and also comparing sewer pipe conditions among different agencies.

A standard coding for sewer laterals has not yet been released at the time of writing of this report, however, the NASSCO Lateral Assessment Committee has prepared a preliminary coding system for Lateral Assessment, which is being beta tested (Larsen, 2005). The Pipeline Assessment and Certification Program (PACP) codes developed by NASSCO for sewer mainlines based on the standards originally developed by the Water Research Centre (WRc) in the U.K. have been used as a basis for laterals. For illustration, a list of lateral codes created as a subset of PACP mainline observation codes (using Flexidata software described earlier in 3.3.6) is shown in Table 3-11.

Table 3-11. Lateral Codes from PACP Mainline Codes (PipeLogix Inc.).

	Code	Type	Description	Score O&M	Score Structural
1.	ACOH	Constructional	Cleanout House		
2.	AMH	Constructional	Manhole		
3.	B	Structural	Broken		4
4.	BSV	Structural	Broken Soil Visible		5
5.	BVV	Structural	Broken Void Visible		5
6.	CC	Structural	Crack Circumferential		1
7.	CL	Structural	Crack Longitudinal		2
8.	CM	Structural	Crack Multiple		3
9.	CS	Structural	Crack Spiral		2
10.	D	Structural	Deformed	4	
11.	DAE	O&M	Deposits Attached Encrustation	2	
12.	DAGS	O&M	Deposits Attached Grease	2	
13.	DAR	O&M	Deposits Attached Ragging	2	
14.	DAZ	O&M	Deposits Attached Other	2	
15.	DNF	O&M	Deposits Ingressed Fine	2	
16.	DNGV	O&M	Deposits Ingressed Gravel	2	
17.	DNZ	O&M	Deposits Ingressed Other	2	
18.	FC	Structural	Fracture Circumferential		2
19.	FH	Miscellaneous	End of Survey		
20.	FL	Structural	Fracture Longitudinal		3
21.	FM	Structural	Fracture Multiple		4
22.	FS	Structural	Fracture Spiral		3
23.	H	Structural	Hole		4

Table 3-11. Lateral Codes from PACP Mainline Codes (PipeLogix Inc.).

	Code	Type	Description	Score O&M	Score Structural
24.	HSV	Structural	Hole Soil Visible		5
25.	HVV	Structural	Hole Void Visible		5
26.	ID	O&M	Infiltration Dripper	3	
27.	IR	O&M	Infiltration Runner	4	
28.	IW	O&M	Infiltration Weeper		
29.	JSM	Structural	Joint Separated Medium		1
30.	MGO	Miscellaneous	General Observation		
31.	MGP	Miscellaneous	General Photo		
32.	MSA	Miscellaneous	Abandoned Survey		
33.	OBR	O&M	Obstacle Rocks	2	
34.	OBZ	O&M	Obstacle Other	2	
35.	RBB	O&M	Roots Ball Barrel	5	
36.	RBC	O&M	Roots Ball Connection	4	
37.	RBJ	O&M	Roots Ball Joint	4	
38.	RBL	O&M	Roots Ball Lateral	4	
39.	RFB	O&M	Roots Fine Barrel	2	
40.	RFJ	O&M	Roots Fine Joint	1	
41.	RMB	O&M	Roots Medium Barrel	4	
42.	RMJ	O&M	Roots Medium Joint	3	
43.	RTB	O&M	Roots Tap Barrel	3	
44.	SAM	Structural	Surface Aggregate Missing		4
45.	SAP	Structural	Surface Aggregate Projecting		3
46.	SAV	Structural	Surface Aggregate Visible		3
47.	SMW	Structural	Surface Missing Wall		5
48.	ST	Miscellaneous	Start of Survey		
49.	VC	O&M	Vermin Cockroach	1	
50.	VR	O&M	Vermin Rat	2	
51.	VZ	O&M	Vermin Other	1	
52.	XP	Structural	Collapse Pipe Sewer		5

3.5 Conclusion

A variety of methods for locating, inspecting and collecting data on the performance of sewer laterals exists—providing a wide range of potential approaches to gathering information about sewer laterals. Smoke testing, for example, can cover a large area at relatively low cost and identify a broad range of defects but cannot be expected to find all defects and provide anything but a qualititative indication of severity of defect. Pressure testing of laterals, on the other hand, provides a precise proof of the tightness of a sewer lateral but is much more costly to apply and, in the event of a leak, does not by itself pinpoint the position of the leak. This chapter describes the range of methods available and provides examples of how particular agencies have used the available methods and collected data to make condition assessments for sewer laterals which can then be used in turn for quality control and to plan an ongoing program for maintenance and rehabilitation.

With the increase in interest by municipalities across the country in sewer lateral problems, many companies are developing, improving or adapting techniques for locating, inspecting, and assessing condition for use in sewer laterals. It may be expected that the technology available for these purposes will continue to improve over the next several years.

CHAPTER 4.0

QUANTIFICATION OF INFILTRATION/INFLOW FROM SEWER LATERALS

4.1 Introduction

In sewer collection systems experiencing infiltration/inflow (I/I) problems, sewer laterals are often perceived as the weakest link and potentially the major contributors of both inflow and infiltration. The significance of leaking laterals was first recognized in the early sixties (Van Natta, 1963), and numerous SSES studies conducted by public works agencies thereafter confirmed that laterals are generally in poor condition and are associated with various sources of I/I. The survey of agencies presented in Chapter 2.0 showed that the contribution of private sewer laterals to total I/I is estimated over a wide range between 7% and 80% with both a median and mean value of around 40%. The survey also showed that these estimates are mostly educated guesses or even wild guesses that are not based on substantive hard data. Most agencies, at present, appear to be working to obtain more reliable information about the contribution of laterals to total I/I through pilot projects, even though quantifying their contribution to I/I is still rather challenging even in such projects.

The first part of this chapter explains physical circumstances that result in I/I and the terminology that is used to define it. Next, the different ways of quantifying the total I/I in sewer systems as used in current practice are described. Then, methods for quantifying the I/I from sewer laterals only are presented together with the ways in which these methods can be applied. For each method, the rationale and the assessment are given, as well as one example where it has been used.

The second part of this chapter explains what determines the effectiveness of the rehabilitation and what quantities have been used to express the extent of effectiveness. This sets the stage for Chapter 5.0, in which different methods for the rehabilitation of laterals are described in terms of applicability, capability, and cost. The objective here is to explain how selecting “what and where to repair” affects the achieved reduction in I/I. It is demonstrated that lateral rehabilitation can be evaluated only in projects where it was carried out as a separate phase. As examples, the chapter presents several projects that have evaluated the effectiveness of lateral rehabilitation, and these are either projects that included measures for removal of inflow sources or projects that repaired laterals to remove infiltration.

4.2 Infiltration/Inflow (I/I) through Sewer Laterals

4.2.1 Types of I/I

Although sewer laterals are designed to convey **sanitary wastewater** only (i.e. domestic sewage), they often carry extraneous water that appears in the form of infiltration and/or inflow.

Inflow is any extraneous water that enters the sewer system through various direct connections. Most inflow sources deliver the surface water directly from the ground surface, however, some inflow sources bring in sub-surface water (foundation drains, for example).

Infiltration is extraneous water that enters the pipes through defects in pipes (and manholes), i.e. cracks, missing parts, open joints, defective connections between pipes, etc. Infiltration primarily occurs when the defects are below the groundwater level, although it also includes stormwater seeping through the soil from the surface and finding its way through pipe defects even when the groundwater level in the vicinity is below the pipe. The groundwater level typically fluctuates throughout the year depending on the local climate. Low or "minimum groundwater conditions" occur after prolonged periods of dry weather or minimal rainfall (usually in late summer), whereas high or "peak groundwater conditions" occur after prolonged periods of wet weather, extensive rainfall events, or snow melting (in spring). In coastal areas, however, the groundwater level fluctuates also due to tides.

Further distinction can be made between types of infiltration and inflow related to their permanence and time of occurrence:

- **Base infiltration** (BI) or permanent infiltration is the groundwater infiltration that occurs when the groundwater level is at its minimum. It happens year-round.
- **Stormwater infiltration** occurs when the groundwater level is elevated due to rainfall events. **Direct infiltration** happens during the rainfall event, whereas **delayed infiltration** continues for some time after the rainfall event has ended because the groundwater level remains elevated after the storm. Extraneous water from groundwater level increase due to snow melting can be regarded as a form of delayed infiltration because it occurs much later than the precipitation (snow storms).
- Similarly, **stormwater inflow** can be distinguished as **direct inflow** (roof leaders allow rapid entry of stormwater into the system) and **delayed inflow** (sump pumps, foundation drains, etc.).
- In coastal areas near the sea, **tidal infiltration** happens through pipe defects when the groundwater is temporarily elevated due to high tides. Similarly, **tidal inflow** is the seawater that enters the sewer system through direct connections. Tidal infiltration and inflow can be regarded as a form of variable base infiltration.

Infiltration and inflow are usually quantified together as infiltration and inflow (I/I). Furthermore, I/I studies often disregard base infiltration as small compared to stormwater I/I and hence focus on quantifying the later. In I/I studies, stormwater I/I is commonly referred to as a **rainfall derived I/I** or **rainfall dependent I/I** (**RDI/I**). In sewer collection systems experiencing I/I problems, it is RDI/I that makes the greatest impact on the peak flows in the pipes and on the volume of flow conveyed through the pipes over time.

4.2.2 What Quantifying I/I Means

I/I manifests itself in the sewer systems as increased flow in the pipes and increased volume of flow conveyed through the pipes, both during storm events and annually. When it comes to quantifying I/I, agencies, either by themselves or though consulting companies, calculate various quantities to express the amount and impact of I/I. One or more of the following quantities are usually used as a measure of I/I in a particular agency:

- Increased peak flow calculated in mgd and/or increased volume of flow calculated in mg for a storm of given duration to be expected once in a given time period such as one year or several years (design storm).
- Increased peak flow calculated in mgd and/or increased volume of flow calculated in mg for top ranked storms from a long-term rainfall record (for example, 50 years).
- Increased peak flow calculated in mgd and/or increased volume of flow calculated in mg for one actual storm, usually singled out from recent rainfall record for having exceptional total rainfall depth or peak intensity.
- Increased volume of flow on an average annual basis calculated in mg.
- The ratio between the volume of rainfall and the volume of RDI/I (R-factor).

In addition, calculated I/I peak flows and/or I/I volumes are often compared to total flows and/or volumes, and expressed as a percentage increase of peak flows and/or volumes due to I/I.

Thus, in current practice, there is no one standard way of quantifying I/I and consequently, quantified I/I often is not comparable between agencies. To provide a more detailed background for the I/I data presented, however, some additional discussion of the general approaches to the analysis of wastewater flow is provided.

Figure 4-1 shows typical flow data for sewer pipes in residential areas. Sanitary wastewater flow has a diurnal pattern due to the rhythm of residential life. The difference between total flow in the system and sanitary wastewater flow is the I/I to be quantified.

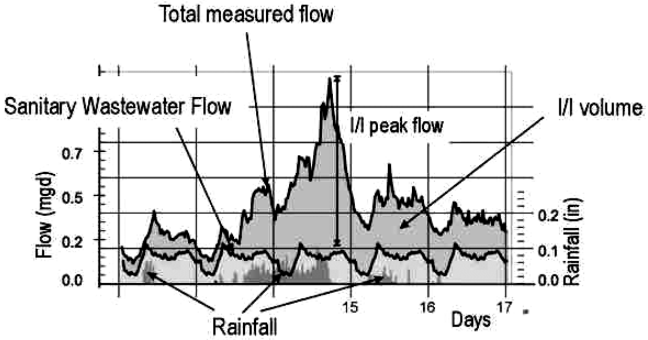

Figure 4-1. Typical Flow Data for Sewer Pipes.

The I/I peak flow shown in the figure is a local peak within the 5-day period shown, but this is not necessarily the worst peak in a longer time period such as one whole year or more. This brings into discussion time as a parameter in I/I quantification. Rainfall events are characterized by their intensity, duration and return period (frequency, recurrence period), and storms of the same duration have greater intensity and depth with the assumption of a greater return period. Thus, quantifying RDI/I can be carried out not only for one particular storm, but also for a selected time period (such as 1, 2, 5 years, etc.) by analyzing design storms. Another option is to analyze top ranked storms from a long-term storm recurrence period.

A **design storm** is a storm of given return interval and duration often used in the quantification of I/I. Such a rainfall event is selected by the agency based on agency's design goals (return interval) and hydrologic principles (duration). The return interval can be selected based on acceptable frequency of surcharging that the agency/community decides to set as a design goal, or even an "acceptable" frequency of overflows as an intermediate design goal although no overflows are actually permitted by NPDES. It should be noted that wet weather overflows may occur as the result of conditions other than design storms such as high groundwater table, snowmelt, consecutive storms, etc. and the agencies have reported such occurrences even after SSO abatement design storm goals were implemented (Table 4-1). The duration of a design storm is selected to reflect a worst-case scenario, i.e. to create maximum flows and surcharging/flooding in the system.

Table 4-1. Wet Weather Overflows after Implementation of SSO Abatement Design Storm Goals (Weiss, 1998).

Agency	Design Storm	Average Annual Wet Weather Overflow (Actual Data over 18 Months or Less)
Covington, LA	10-yr, 24-hr	<1
Crowley, LA	5-yr, 1-hr	1
Buena Vista, MI	25-yr, 24-hr	2
Downriver Communities, MI	100-yr, 24-hr	0.2 (i.e. 1 overflow in 5 years, based on model estimates)
Jackson, MI	25-yr, 24-hr	3
Midland, MI	25-yr, 24-hr	3
Fairfield, OH	10-yr, 24-hr	<1
Enid, OK	25-yr, 24-hr	2
Norman, OK	2-yr, 24-hr	3
Kerrvile,TX	10-yr, 24-hr	<1

I/I studies usually are designed to quantify RDI/I based on the analysis of flow data collected during continuous flow monitoring (FM). In some cases, however, the calculation is based only on data of pumped flows at lift stations.

4.2.3 Quantifying Total I/I in the Sewer System

The vast majority of I/I studies are based on continuous flow monitoring (FM) at the downstream end points of delineated sewer basins[27]. (Pilot projects with FM on individual sewer laterals have been attempted in the past, and this method is described in 4.2.4). Thus, the monitored flows comprise the I/I through both mainlines and laterals. The separation of how much the mainlines/manholes contribute to the I/I vs. how much the laterals contribute is possible only to some extent or in special circumstances as will be described later in this chapter.

It is beyond the scope of this report to discuss the procedures of FM data collecting or even the methods of analysis of FM data, as the primary focus of this report is on the use of results of such analysis for drawing conclusions regarding contribution from the laterals. For a discussion of how bias (a measure of systematic error) and precision (agreement between multiple readings) affect the quality of FM data or how the size of an FM basin can affect the

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[27] *In this study, sub-basins are referred to as basins for short*

accuracy and conclusions of data analysis, the reader is referred to references such as (Stevens, 2001) and (Stevens, 1993), respectively.

Keeping in mind groundwater level fluctuation, continuous FM preferably includes flow data for both minimum and peak groundwater conditions and is carried out for one entire year or longer. For practical reasons, FM data are often collected for a period of three months or less, when peak groundwater conditions are expected and when the soil is sufficiently moist. During that period, a certain number of significant rainfall events is usually anticipated, although annual fluctuation in I/I is not always directly related to the annual rainfall variation (Kurz, 2002). If the season happens to have less rainfall than expected (the groundwater was not at its peak level), FM data collection may have to be repeated the following year.

Significant rainfall is a rainfall event sufficient to cause a detectable increase in the monitored hydrograph over the expected dry weather flow (for a similar day without rain). The definition of significant rainfall varies. Sometimes, it is defined as a rainfall event of some total amount (rainfall depth) during given time period. East of the Mississippi, 0.2” of rain in 24 hours may be sufficient to cause measurable I/I during the wet season (Kurz, 2004). One agency in California defines it as 0.5” of rain in 24 hours (Santa Clara Valley Water District, 2002), another agency as 1” or more of rain from the start of precipitation to the end of precipitation, followed by three consecutive dry days (San Diego Regional Water Quality Control Board, 2005). Sometimes, however, significant rainfall is defined as a rainfall event of certain duration and continuity (for example, a continuous rainfall for a minimum of one hour or an intermittent rainfall for a minimum of three hours during a 12-hour period).

Multiple significant rainfalls during the FM data collection period are usually preferred because they ensure that groundwater level has been affected. When the soil is dry, one heavy rainfall may run off and not replenish the soil wetness more than superficially.

Another requirement for the FM data collection period is that it should comprise both “dry weather periods” and “wet weather periods”. A dry weather period is usually a period of at least five to seven days without a rainfall event. A typical dry weather hydrograph from a residential neighborhood shows a diurnal pattern (Figure 4-2), and is slightly different on the weekdays and weekends/holidays reflecting different living lifestyles and daily routines of people on those days.

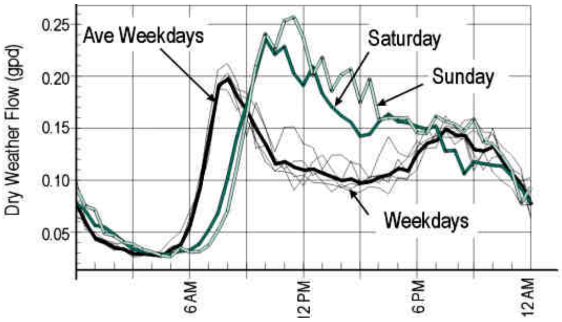

Figure 4-2. Dry Weather Diurnal Hydrographs.

In a dry weather period, the flow typically comprises sanitary wastewater flow and base infiltration, but it can also include some delayed rainfall dependent infiltration and/or delayed rainfall dependent inflow. Dry weather infiltration (DWI) is often referred to as “antecedent I/I” (Figure 4-3).

In a wet weather period, the hydrograph shows increased flow following the significant rainfall event. Overlapping a dry weather hydrograph (for a similar day) over a wet weather hydrograph creates an area that denotes RDI/I (Figure 4-4). It consists of direct RDI/I and delayed RDI/I. The largest rate difference over a one-hour period between the WWF and DWF represents “RDI/I peak flow”. The area between two hydrographs represents “RDI/I volume”. The ratio between the volume of rainfall and the volume of RDI/I is called the R-factor.

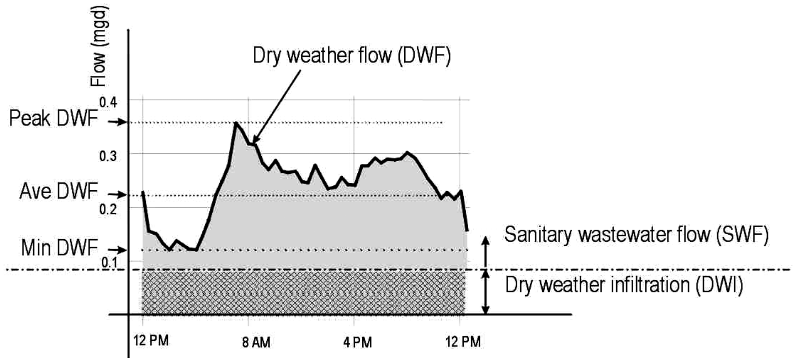

Figure 4-3. Components of Dry Weather Flow.

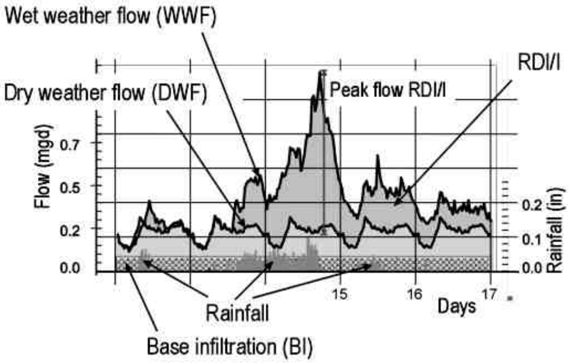

Figure 4-4. Wet Weather Period Hydrograph.

Table 4-2 shows the flow components in dry and wet weather periods.

Table 4-2. Flow Components in Measured FM Data.

Dry Weather Period:		Wet Weather Period:		
Sanitary wastewater flow		Sanitary wastewater flow		
Base infiltration	Antecedent I/I	Base infiltration	Antecedent I/I	
Delayed RDI/I		Delayed RDI/I		RDI/I
		Direct RDI/I		

Different methods are being used to determine the flow components in measured FM data, and there is no general consensus as to one method being the best.

Some analyses, for example, estimate the sanitary wastewater flow based on electric power industry estimates. This method assumes that the overnight activity of residents creates water usage similar to electric power usage, while the electric power usage during night hours is usually estimated as 12% of electric power usage during daily hours. Some other analysts believe that the Stevens/Schutzbach equation is a refinement of this calculation that is more suitable for traditional residential flow patterns (King County, 2002). However, many other analysts strongly disapprove of any such calculations and, as mentioned earlier, focus on quantifying only RDI/I.

One earlier WERF research report presented and evaluated several methods for quantification of RDI/I, as shown in Table 4-3 (Merrill et al., 2003).

Table 4-3. Methods for Generating RDI/I Hydrographs (Merrill et al., 2003).

Method	Description
◆ Constant unit rate	Constant unit rate (gall per inch rainfall, gallons per acre per land use, gallons per inch rainfall per capita) are determined based on sewershed characteristics
◆ Percentage of rainfall volume (R-value)	Relationship is established between volume of RDI/I at the monitoring location and rainfall volume falling on the area served by the monitor.
◆ Percentage of streamflow	Relationship is established between FM data and streamflow data.
◆ Synthetic unit hydrograph	Based on assumption that RDI/I responds to rainfall volume and duration in the same manner as stormwater runoff, an RDI/I hydrograph is shaped as a function of basin characteristics
◆ Probabilistic	Relationship is established between peak RDI/I flow and recurrence interval based on frequency analysis of peak RDI/I flows
◆ Predictive equations based on rainfall/flow regression	Relationship is established between hourly rainfall and RDI/I using multiple linear regression methods
◆ Predictive equations based on synthetic streamflow and basin characteristics	A continuous hydrological model of a watershed is created and correlated to flow components (daily BI and RDI/I)
◆ RDI/I computed by hydraulic analysis software	Various hydrology/hydraulic packages include methods for generating RDI/I quantities

Similar to the sixth method from Table 4-3 is a rainfall-flow regression method developed and used in Nashville, TN, and some other agencies (Kurz et al., 2003). With this method, all qualifying (significant) rainfall events in the FM period are analyzed and linear regression applied to correlate rainfall depth and RDI/I volume (Figure 4-5), as well as rainfall depth and RDI/I peak flow.

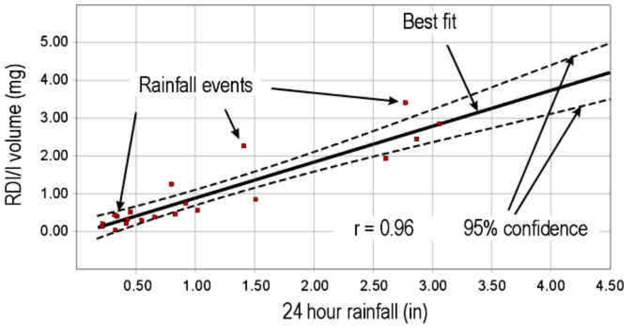

Figure 4-5. Regression Analysis in Rainfall-flow Regression Method (Consoer Townsend Envirodyne—CTE).

Once the relationship has been established between rainfall and RDI/I, flow projections are made for selected rainfall events which are usually either design storms or actual rainfall events recorded before, during or after the FM data collection period. The result of calculation is RDI/I peak flow and/or RDI/I volume or R-factor for the selected storm. Flow projections for single storms, however, do not account for antecedent conditions (i.e. the peak flow from a small event preceded by a prolonged wet period may exceed that from a larger event in a dry period).

An alternative to the use of a single storm is the use of a storm period from the long-term actual rainfall record. Although more accurate, the use of a storm period is workable only with developed and calibrated simulation models. The result of the calculation is RDI/I peak flows and/or RDI/I volume or R-factor for the time period that corresponds to the duration of storm period.

Other than using continuous FM data, RDI/I can be quantified using the record of pumped volumes in lift stations that are located in downstream points of basins. Overall, different types of data used, flow projections, and quantities calculated for quantifying RDI/I are summarized in Table 4-4.

Table 4-4. Quantifying RDI/I.

Data used:	Continuous FM data Pumped volumes at lift stations
Flow projections for:	Design storms Selected rainfall events Storm periods from long-term actual rainfall records
Quantities calculated:	RDI/I peak flow RDI/I volume R-factor

4.2.4 Quantifying I/I from Laterals

Quantifying I/I from laterals is more challenging than quantifying total I/I from the entire sewer basin. The preferred method based on FM data analysis has limited applicability (see discussion below), and less accurate methods based on empirical quantification of I/I sources are often used instead.

4.2.4.1 Method Based on FM Data Analysis

This method can be applied under the following conditions:

- FM data collection follows comprehensive mainline/manhole rehabilitation
- Specific site conditions allow calculated total RDI/I be attributed to laterals directly
- FM data are collected on individual sewer laterals

FM Data Collection Follows Comprehensive Mainline/Manhole Rehabilitation. Rationale: If the FM data are collected after a comprehensive rehabilitation on mainlines/manholes in the basin, the determined RDI/I comes only from sewer laterals. Further more, if the FM data were also collected before any rehabilitation, the results can be compared and the percentage of the contribution of laterals in total RDI/I estimated.

Assessment: The application of this method is based on the assumption that the completed mainline/manhole rehabilitation has indeed removed all I/I sources on these segments of the system. The limitation is that such comprehensive rehabilitation of mainlines/manholes has to be completed first and the agency does not know in advance (prior to any rehabilitation in the basin) what the contribution from laterals will be, which is important when planning lateral rehabilitation in the area. The agency may prefer to perform rehabilitation of both mainlines and laterals simultaneously to minimize the disturbance to public in the neighborhood (especially when phased rehabilitation involves repeated excavation of pits such as, for example, with pipe bursting). However, the agency does not know whether the rehabilitation of laterals is needed or what kind of lateral rehabilitation would be effective (i.e. what laterals to repair and what parts of laterals to repair).

Example: Oak Valley is a small basin within the wastewater collection system in Nashville, TN, where a pilot project was carried out to evaluate the contribution of laterals in total I/I and the effectiveness of lateral rehabilitation in the reduction of I/I. The basin was located in a residential area (Figure 4-6), and was comprised of 10,800’ of mainlines (8” VCP or 8” PVC pipes) and approximately 200 laterals (6” VCP pipes).

The pilot project consisted of phased rehabilitation: 1) comprehensive mainline rehabilitation in the first phase (CIP relining of 41% of mainlines), and 2) comprehensive lateral rehabilitation in the second phase (CIP relining of all lower laterals connected to the rehabilitated mainlines). FM data collection and analysis were done before and after each rehabilitation phase. The second phase of FM data collection was conducted after mainline rehabilitation for a period of 89 days (02/23/91-05/31/91).

Figure 4-6. Oak Valley Subdivision in Nashville, TN (Nashville and Davidson County).

A total of 12 storms were analyzed. For each storm, RDI/I peak flow was calculated for a period of 24-hours from the storm beginning. Linear regression was applied, resulting in a coefficient of regression r = 0.85 (Figure 4-7). RDI/I volume was also calculated for each storm and linear regression applied, resulting in a coefficient of regression r = 0.88 (Figure 4-8). Regression lines were then used for projections of peak flows and average volumes of RDI/I (Table 4-5).

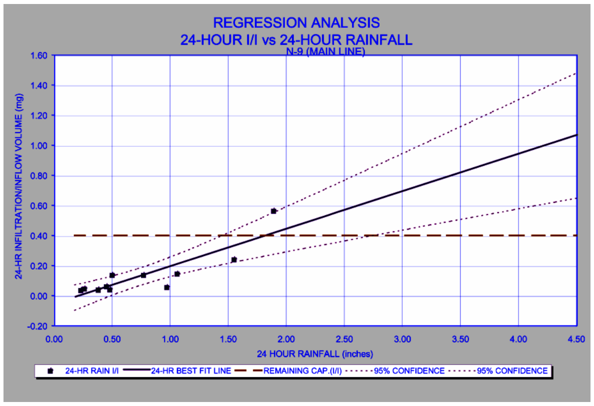

Figure 4-7. Regression Analysis for RDI/I Peak Flow vs. Rainfall in Oak Valley, 1991 (Nashville, TN).

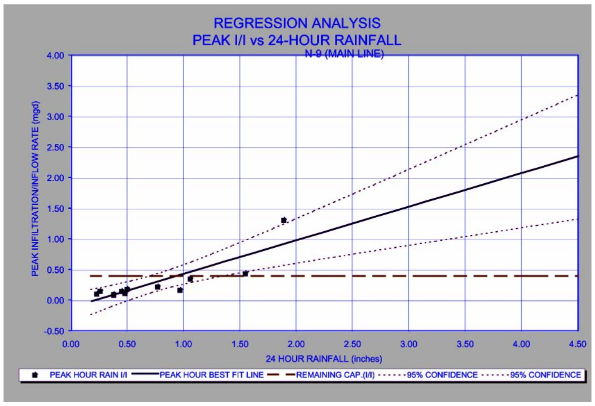

Figure 4-8. Regression Analysis for RDI/I Volume vs. Rainfall in Oak Valley, 1991 (Nashville, TN).

Table 4-5. Flow Projections in Oak Valley, 1991 (Nashville, TN).

Strom	Rainfall Depth	After Mainline Rehab	Before Mainline Rehab	Contribution from Laterals
RDI/I Peak Flows				
2-yr 24-hour storm	3.39”	1.738 mgd	3.906 mgd	44%
5-yr 24-hour storm	4.50”	2.346 mgd	5.472 mgd	43%
5-yr 1-hour storm	1.97”	2.501 mgd	16.534 mgd	15%
RDI/I Volumes				
2-yr 24-hour storm	3.39”	0.792 mg	3.211 mg	25%
5-yr 24-hour storm	4.50”	1.069 mg	4.299 mg	25%
Average annual	48.1”	48.1 mg	117.6 mg	41%

In the table, the projected values for volumes and peak flows after mainline rehabilitation are compared with the corresponding values from the first FM phase (before mainline rehabilitation). During this first phase, FM data were collected over 30 days (03/13/89-04/11/89) and a total of six rainfall periods were analyzed.

Assuming that all the remaining RDI/I flow was due to the laterals, the FM data analysis showed that the laterals in this basin contributed originally around 43% in peak flows when the rainfall lasted for 24 hours, but only 15% during short one-hour storms. The laterals were also estimated to have contributed around 41% of total RDI/I volume annually.

Specific Site Conditions Allow Calculated Total RDI/I to be Attributed to Laterals Directly. Rationale: If the groundwater level is just above mainlines throughout the year on dry weather days and is raised up only during rainfall events, the measured RDI/I is said to come from the sewer laterals (Figure 4-9). In the same way, if the groundwater level is just below upper laterals during dry weather, the determined RDI/I is said to come from the upper sewer laterals only.

Assessment: Applying this logic, the breakdown of RDI/I into portions contributed from mainlines and laterals, and further from upper and lower laterals, is only an approximation for two reasons. First, the depth of mainline is not constant but increases in the downstream direction. The condition, for example, that “mainlines are just below given groundwater level” refers to the sections where they are at shallowest depth. Mainlines further downstream are laid deeper and consequently some laterals are likely to be below the groundwater level contributing inflow. Second, the infiltration through given source (crack in the pipe) is not a constant but increases as the groundwater level rises and hydrostatic pressure on the pipe increases. When this is not taken in consideration, the contribution from mainlines in RDI/I is underestimated and from the laterals overestimated.

This method application is not often applicable because described specific site conditions are a requisite. This research identified only one agency that was able to utilize this approach. The example that follows demonstrates how this agency took advantage of the specific site conditions in determining the RDI/I directly, as well as how RDI/I was quantified using the record of pumped volumes in lift stations on days that represented typical or extreme wet weather conditions.

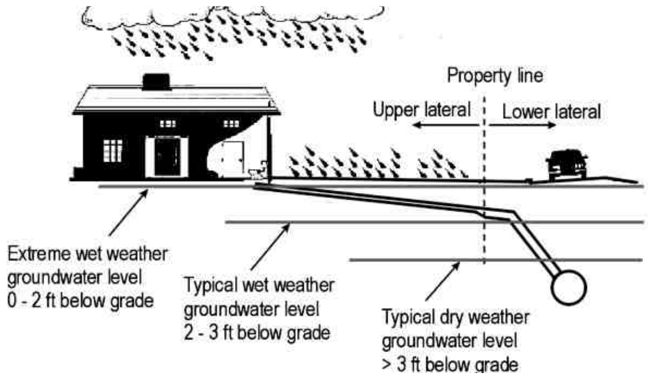

Figure 4-9. Site Conditions of Special Advantage for I/I Quantification from the Laterals (City of Sarasota, FL).

Example: Two small basins LS-1and LS-5[28] in the Southwest Wastewater Collection System in Sarasota, FL, were evaluated for RDI/I from laterals (Table 4-6, Figure 4-10) and later rehabilitated.

Table 4-6. Size of Basins in Sarasota Pilot Project.

	Lift Stations	Mainlines	Manholes	Laterals
LS-1	#1, #28, #41	26,800' (8")	105	417 (4", 6")
LS-5	#5	6,402' (8-12")	29	99 (4")

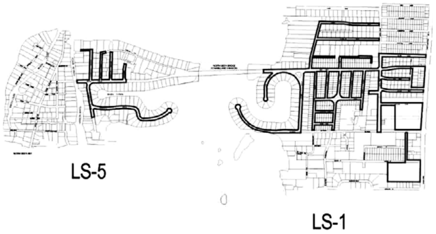

Figure 4-10. Two Basins—Service Areas of Lift Stations LS-1 and LS-5 in Sarasota, FL.

Data collection included daily recording of the pumped volumes in the lift stations in the downstream ends of the basins, as well as recording of the groundwater level and the rainfall depth during storms. On dry weather days, the groundwater level was below the pipes in both basins and it was assumed that no infiltration was part of pumped volumes. Therefore, an

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[28] *Full name of the basin LS-1 is Service area LS-1 & 85.*

increase in pumped volumes on wet weather days was observed as RDI/I generated though pipes that are below the groundwater level on those days (Table 4-7). In these basins, inflow sources had already been removed in the past and observed RDI/I implied infiltration only

Table 4-7. Quantification of RDI/I—Before Rehabilitation in Sarasota, FL.

	Date	Groundwater Level	Pumped Volume (Gal)	RDI/I (Gal)	Location of RDI/I Sources	% of Pumped Volume:
Basin LS-1:						
Water consumption (average)		–	96,567			
Wastewater (average)		–	114,657			
Typical Dry Weather	09/15/97	**-6.47’**	**121,351**		–	
Typical Wet Weather	12/11/97	-2.90’	235,144			100%
				113,793	Mainlines only	48%
Extreme Wet Weather	11/14/97	-0.70’	770,000			100%
				648,649	Mainlines and entire laterals	84%
				534,856	**Entire laterals**	**69%**
				113,793	Mainlines only	15%
Basin LS-5:						
Water consumption (average)		–	24,618			
Wastewater (average)		–	27,225			
Typical Dry Weather	05/26/97	-3.40’	**65,262**		–	
Wet Weather—Day 1	05/05/99	-2.92’	78,352			100%
				13,090	Mainlines only	17%
Wet Weather—Day 2	01/03/99	-2.14’	178,117			100%
				112,855	Mainlines and lower laterals	63%
				99,765	**Lower laterals**	**56%**
Extreme Wet Weather	11/14/97	-0.70’	264,781			100%
				199,519	Mainlines and entire laterals	75%
				186,429	**Entire laterals**	**70%**
				86,664	**Upper laterals**	**33%**
				13,090	Mainlines only	5%

Table 4-7 shows that entire laterals contributed 0.535 mg and 0.186 mg of RDI/I, which was determined on extreme wet weather days when the groundwater level was close to the grade (0.70’ depth). The RDI/I generated from the laterals contributed around 70% of total pumped volumes. Mainlines contributed only 15% and 5% of the total pumped flow.

RDI/I could be further evaluated from lower laterals and upper laterals in the basin LS-5. RDI/I generated from lower laterals only was determined on “wet weather day 2”, when the groundwater level was near 2’ below grade, and was about 56% of total pumped flow. RDI/I generated from upper laterals only was determined on “wet weather day 1”, when the groundwater level was near 3’ below grade, and was about 33% of total pumped flow.

FM Data Are Collected on Individual Sewer Laterals. Rationale: For each sewer lateral, FM equipment is installed in the mainline where the lateral connects with the mainline. If the mainline is plugged upstream of the equipment, and flow coming from the lateral is measured at time when the sanitary wastewater flow is not generated, it denotes the I/I from the lateral.

Assessment: The method requires plugging the mainline during the flow monitoring and is therefore workable only when performed for a short time (up to several hours). It is best combined with rainfall simulation, in which the water is sprayed over the lateral thus simulating the rainfall of selected return interval and duration. Considering the labor involved, the method is applicable on a small scale as a part of pilot projects, however, the systematic FM of individual laterals on a representative scale is impossible considering the large number of laterals in municipal systems.

Example: One pilot study carried out in the East Bay area in 1984 (Berkeley and Oakland, CA, shown in Figure 4-11), involved FM of 50 individual laterals applying the rainfall simulation approach (Hamid, 1995).

Figure 4-11. Basins in East Bay Pilot Project, CA (Hamid, 1995).

For the rainfall simulation, soaker hoses were connected to garden faucets with water meters, and placed over the laterals. The ground was first saturated with sprinkling for four to eight hours, and then water was sprayed over the laterals to simulate design rainstorm conditions. The flow rates in laterals were measured with a specially modified packer device strategically placed in the mainline (Figure 4-12).

The packer was modified such to block the upstream flow, and a calibrated V-notch was installed at its downstream end to allow measurement of the flow from the lateral. Depth of the flow from the calibrated weir was observed with a CCTV camera. The water was sprayed over the laterals to simulate storms of varied return interval and duration: 1-yr, 4-hrs (0.19 in/hr); 2-yr, 4-hrs (0.23 in/hr); 2-yr, 6-hrs (0.21in/hr); 5-yr, 4-hrs (0.35 in/hr); 5-yr, 6-hrs (0.32 in/hr); 5-yr, 8-hrs (0.26 in/hr); and 20-yr, 1-hr (0.85 in/hr).

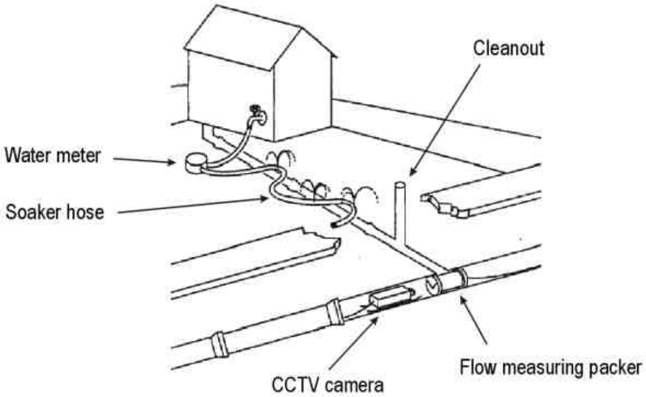

Figure 4-12. Rainfall Simulation (Hamid, 1995).

The laterals included in this FM were of different age (i.e. built before or after 1960), in different soil conditions (with low or high permeability), and with different groundwater table conditions before the FM (below or above the lateral).

Typical hydrographs showing measured flows from the laterals is depicted in Figure 4-13. Even before the water was sprayed from the hose, a base infiltration of 0.125 gpm was observed. After the rainfall simulation started, the flow in the lateral grew over a 90-minute period until it reached the peak value of 0.5 gpm. When a plug was inserted at the cleanout near the sidewalk, the flow in the pipe immediately dropped indicating that the upper lateral was contributing the infiltration. The I/I from the laterals was quantified for a 10-yr, 8-hr design storm, with total rainfall depth of 1.56" (Table 4-8).

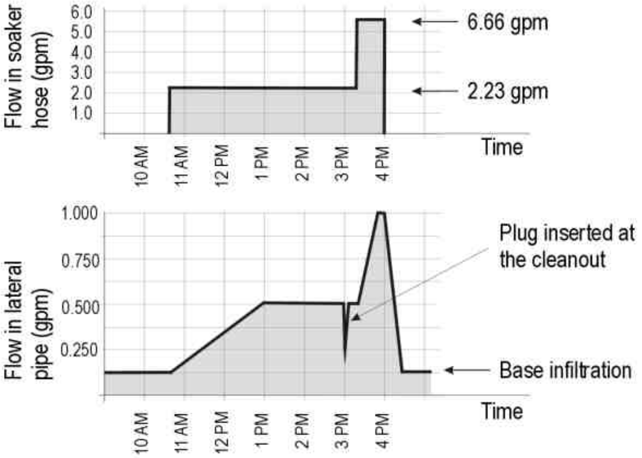

Figure 4-13. Typical Hydrograph Measured During Rainfall Simulation (Hamid, 1995).

Table 4-8. Projected Average Flow Based on FM from Individual Laterals (Hamid, 1995).

Age	Soil Type	Groundwater Level	Projected Average Flow—10-yr, 8-hr Storm
Pre-1960 construction	Permeable	Above lateral	0.32 gpm
Pre-1960 construction	Permeable	Below lateral	0.48 gpm
Pre-1960 construction	Impermeable	Below lateral	Not computed (negative flow occurred)
Post-1960 construction	Permeable	Below lateral	0.10 gpm
Post-1960 construction	Impermeable	Below lateral	0.25 gpm

The pilot project enabled the following conclusions to be reached:

- Laterals regardless of age were generating a significant quantity of RDI/I.
- Older laterals on average contributed more infiltration than newer construction.
- Being in a seismic area, some newer laterals were also rather cracked and contributing infiltration.
- The infiltration from the laterals was rapid (i.e. similar to inflow in terms of response time).
- R-factor for the laterals was similar to R-factor for the entire basin or higher.

4.2.4.2 Method Based on Empirical Quantification of I/I Sources

This method can be applied in two ways:

- Empirical estimating of individual I/I sources
- Empirical estimating of I/I source types

Empirical Estimating of Individual I/I Sources. Rationale: Sources of I/I are identified in the SSES study using smoke testing and dye water testing, and I/I from identified sources quantified one by one using calculations based on empirical estimates. Calculated I/I quantities are summarized separately for I/I sources on mainlines and manholes, and on laterals. (The summarizing can also be done for I/I sources in the public sector and in the private sector.)

Assessment: When compared with flow projections based on FM data, this method usually calculates a lower total I/I from defects in the system (analysts generally estimate about 40-65%). Compared to the I/I quantity determined from FM data which is considered accurate, the I/I quantity determined with this method is acknowledged to be approximate and also an underestimate since 1) smoke testing does not identify all sources of I/I in the system, and 2) the parameters and coefficients used in calculations are empirical estimates. As one parameter in the formulae used in calculations is the rainfall intensity (in/hr), the I/I sources are quantified for the storm of return period and duration with matching rainfall intensity.

Example: The wastewater collection system in Joe's Creek Drainage Area (Dallas Water Utilities, TX) has been evaluated for RDI/I in 2003. The system has 500,000' of 6-30" mainlines and an additional 6, 650' of typically 4" laterals (Figure 4-14).

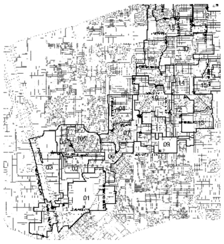

Figure 4-14. Joe's Creek Drainage Area in Dallas, TX (Dallas Water Utilities, TX).

FM was conducted in 22 basins for a period of 68 days (04/04/02-06/11/02). Peak flow was calculated for individual storms and plotted against rainfall intensity on a log/log graph. Flow projection for a 1-yr/60 minute storm (1.60 in/hr) determined a peak flow of 12.631 mgd. Smoke testing and dyed water flooding were utilized to identify I/I sources and provide the necessary data to make estimates of I/I from individual sources throughout the system for the same design storm.

Table 4-9 shows nine types of I/I sources on manholes and mainlines, and two on public laterals, whereas four others are on private laterals. For cleanouts with missing caps, for example, the quantity of I/I was calculated using the rational formula for runoff from the estimated surface area draining to the cleanout, type of surface (paved or unpaved), and intensity of storm (1.60 in/hr). Depending on the intensity of smoke observed from the cleanout (light, medium or heavy), the result was corrected for up to ±30% (based on experience and guidelines from the consulting company doing the work). This value was reduced, if necessary, so that it did not exceed the flow calculated with the formula for flow through an orifice. The latter formula uses the cross sectional area of the hole, head (vertical distance from water surface to cleanout top), and coefficient of discharge. The quantity of I/I through area drains was calculated in the same manner. The flow from down spouts was calculated substituting the roof area for the surface area.

For defective laterals, the quantity of I/I was estimated based on the intensity of smoke appearing on the surface and the surface area draining towards the defect, using guidelines from the consulting company doing the work. Typical lateral defects were estimated between 0.4-1.0 gpm.

Private and public laterals in this basin were estimated to contribute 23% and 10% of total I/I, respectively, or 33% together, and the rest was estimated to come from the sources on mainlines and manholes. However, total I/I through all identified sources thus calculated makes only 43% of the total I/I projected from FM data, which indicates that there are other sources of I/I mised with the smoke testing.

Table 4-9. Distribution of Inflow Sources—Joe's Creek Drainage Area (Dallas Water Utilities, TX).

Source	Quantity	Projected Peak Inflow for 1-yr/60-min Storm (gpd)		
Public sector inflow				
Pick Holes (on Manhole Covers)	723	1,421,993		
Manhole Rim Leaks	77	6,350		
Defective Frame Seals	687	1,002,888		
Broken Frames	12	6,912		
Cover—Missing Bolts (on Manholes)	9	14,406		
Manhole Corbel Defects	443	502,992		
Manhole Wall Defects	26	54,288		
Main Sewer Defects	53	354,010		
Cross Connections	14	275,774		
Subtotal—Mainline/manhole:			3,639,613	67 %
Defective Building Laterals	68	136,289		
Defective Service Cleanouts	291	380,715		
Subtotal—Public laterals:			517,004	10 %
Subtotal—Public sector:	2,403	4,156,617		77 %
Private sector inflow				
Defective Building Laterals	122	244,519		
Defective Service Cleanouts	676	884,411		
Area Drains	12	116,237		
Downspouts	2	28,800		
Subtotal—Private laterals:			1,273,967	23 %
Subtotal—Private sector:	812	1,273,967		23 %
Total	3,215	5,430,584	5,430,584	100 %

Empirical Estimating of I/I Source Types. Rationale: Sources of I/I are identified in the SSES study using smoke testing and dye water testing, and source types itemized (downspouts, foundation drains, etc.). The I/I is quantified for each source type using empirical estimates, and the amount multiplied with the number of sources of particular type in the basin. These values can be adjusted in relative amounts to equal the total RDI/I calculated from FM data for a particular rainfall event. Also, some of these values can be estimated based on total RDI/I calculated from FM data for a particular rainfall event.

Assessment: The method is relatively quick and easy to apply. The distribution of total RDI/I between the source types is only approximate because 1) I/I sources may not be exactly counted within the source type (some sources of I/I may be overlooked), and 2) the parameters and coefficients used in calculations are empirical estimates.

Example: Two small basins, Basin AS09 and Basin AS20, in Columbus, OH, are currently being evaluated for RDI/I from laterals, in particular inflow from private laterals (Table 4-10). Data and results presented here are still in draft form. RDI/I from inflow sources that had been positively identified as connected to the sanitary system by dye testing was estimated for each different type of source as shown in Table 4-11.

Table 4-10. Size and Age of Basins in the Pilot Project (City of Columbus, OH).

	Age	Mainlines	Laterals	Terrain	Area
Basin AS09	~ 60 yrs	4,600’ (8” VCP)	130 (6”)	Relatively flat	41 acres
Basin AS20	~ 70 yrs	3,600’ (8” VCP)	86 (6”)	Moderately steep	30 acres

Table 4-11. Estimating the RDI/I from Different Source Types (City of Columbus, OH).

Source Type	Number Identified	Average Area per Source	Runoff Coefficient	Flow per Source Type	Total Flow per Source Type			
Basin AS09								
Downspouts	21	535 SF	0.70		0.29 cfs	0.187 mgd	39%	
Driveway drains	0	0 SF	1.00		0.00 cfs	0.000 mgd	0%	
Area drains	8	100 SF	0.30		0.01 cfs	0.006 mgd	1%	
Sump pumps	0	-		25 gpm	0.00 cfs	0.000 mgd	0%	
Foundation drains	66	-		3 gpm	0.44 cfs	0.284 mgd	59%	
Subtotal					0.74 cfs	0.478 mgd	100%	75%
Defective Laterals		0.800 gpd · 20% =		0.160 gpd	0.25 cfs	0.160 mgd		25%
Total					0.99 cfs	**0.638** mgd		**100%**
Basin AS20								
Downspouts	18	290 SF	0.70		0.13 cfs	0.084 mgd	27%	
Driveway drains	1	600 SF	1.00		0.02 cfs	0.013 mgd	4%	
Area drains	1	120 SF	0.30		0.00 cfs	0.000 mgd	0%	
Sump pumps	1	-		25 gpm	0.06 cfs	0.039 mgd	13%	
Foundation drains	41	-		3 gpm	0.27 cfs	0.174 mgd	56%	
Subtotal					0.48 cfs	0.310 mgd	100%	59%
Defective Laterals		1.080 gpd · 20% =		0.216 gpd	0.33 cfs	0.216 mgd		41%
Total					0.81 cfs	**0.526** mgd		**100%**

Estimating was done as follows:

- The estimating for downspouts and driveway/area drains was done using a 5-yr, 1-hr design storm (1.59 in/hr, based on records from the Columbus Station of the U.S. Weather Bureau). The Rational Method was used to calculate flows based on average area per source type for that particular basin.
- For foundation drains and sump pumps, the number of identified sources was multiplied by a conservative estimate of flow per source type, which was determined as follows: For foundation drains, a contribution of 3.0 gpm was assumed based on some earlier projects in different agencies where this quantity had been reported from 1-10 gpm (Ann Arbor, Michigan). Similarly, a contribution of 25.0 gpm was assumed for sump pumps.
- For leaking laterals, a contribution was assumed as 20% of total RDI/I peak flow calculated from the FM data, based on various sources (the published experience from Nashville, TN was considered the most appropriate).

In each basin, the I/I quantity calculated from FM data (using the storm event of 01/03/04 that represented a 5-yr, 48-hr storm) was compared with the I/I estimated in Table 4-11, and the difference between the two values was allocated to public sources (Table 4-12). Based on this method of estimating the peak flows from the source types, public and private sector jointly contribute 88% of peak flows during a 5-yr, 48-hr storm in both basins. Private sources contribute 80% in one basin and 49% in the other.

Furthermore, two basins were compared for I/I (Table 4-13). It is interesting to observe that Basin AS20, which is much smaller than the other basin, generates a larger total RDI/I peak flow. The table shows that the RDI/I peak flow from private laterals is in proportion with the basin size (especially with the basin surface area), however, the portion of RDI/I peak flow generated from public sources is much larger in Basin AS20. This can be explained by the different terrains in the two basins. Basin AS20 is moderately steep, the streets have curb and gutter; and the storm sewers that service the area are sufficiently sized. In contrast, Basin AS09 is relatively flat with very limited conveyance of stormwater on the surface and underground, and thus the stormwater does not reach the public sewer as easily as in the other basin.

Table 4-12. Linking I/I Calculated from FM Data and I/I Estimated from Individual Sources (Columbus, OH).

	Basin AS09			Basin AS20		
Calculated from FM data[a]						
Total peak flow	0.910 mgd		100%	1.230 mgd		100%
Dry weather peak flow	0.140 mgd			0.200 mgd		
Dry weather average flow (ave DWF)	0.110 mgd			0.150 mgd		
Total RDI/I peak flow	**0.800** mgd	100%	88%	**1.080** mgd	100%	88%
Estimated from individual sources						
RDI/I estimated from private sources	0.638 mgd	80%		0.526 mgd	49%	
RDI/I estimated from public sources	0.162 mgd	20%		0.554 mgd	51%	
Additional quantities from FM data						
Total flow volume during rainfall event	3.50 mg			2.62 mg		
Total RDI/I volume during rainfall event	1.27 mg			1.45 mg		

[a] Storm of 01/03/04 represented a 5-yr 48-hr storm. Total rainfall depth: 3.69”; peak intensity: 0.43 in/hr

Table 4-13. Comparison of Two Basins for I/I (Columbus, OH).

	AS09	AS20	AS20/AS09
Basin surface area	41 acres	30 acres	73%
Mainline length	4,600’	3,600’	78%
Number of laterals	130	86	66%
RDI/I peak flow estimated from private sources	0.638 mgd	0.526 mgd	82%
RDI/I peak flow estimated from public sources	0.162 mgd	0.554 mgd	342%
RDI/I peak flow estimated from all sources	**0.800 mgd**	**1.080 mgd**	135%

The FM that generated the data used in the calculation of flows shown in Table 4-2 has been conducted continuously since November 2003. RDI/I peak flow and RDI/I volume were determined by making flow projections for one actual storm (01/03/04), which accumulated a total of 3.69” of rainfall over a 42-hour period. This rainfall depth is roughly an equivalent of a 5-yr, 48-hour storm (Huff and Angel, 1992).

The city plans to phase the improvements (disconnection of inflow sources and sump pumps in summer 2005, mainline relining in winter 2005, and lateral relining in summer 2006), and continue the FM in these basins during and between the phases to see the effect of the applied measures. This will also be an opportunity to compare the empirically estimated RDI/I flows with measured RDI/I flows that will be removed with the improvements.

4.3 Effectiveness of Lateral Rehabilitation in Reducing I/I

While conducting this research study, the project team was on different occasions asked: "What methods of lateral rehabilitation has the research identified as cost-effective?" The idea that the selection of the rehabilitation method is the principal determinant of the effectiveness of lateral rehabilitation is wrong—as explained below.

Regardless of the rehabilitation method applied, the rehabilitated parts of the sewer (pipes, joints, lateral-to-mainline connections) should be watertight and thus completely effective in I/I reduction. For quality assurance, CCTV inspection, air-pressure testing and/or water exfiltration testing (described in Chapter 3.0) are performed after the completed rehabilitation. If a lateral with an installed CIP liner or a grouted joint, for example, does not pass the test, the repair has to be redone. Nevertheless, in practice, even with excellent quality control on the work done, rehabilitation projects do not achieve complete removal of I/I because some sources of I/I remain in the sewer system. Either, the removal of these sources was not included in the rehabilitation project deliberately (their removal was not assessed as cost-effective) or they were omitted by mistake (this refers to a failure to identify some sources of I/I during the inspection or a failure to predict that some sources of I/I will "appear" upon project completion). This reasoning applies to lateral rehabilitation projects focused on inflow reduction and on infiltration reduction. Different projects that apply the same rehabilitation method can achieve rather different effectiveness in I/I reduction, and therefore the effectiveness in I/I reduction should be viewed as something related to the overall methodology of the rehabilitation project and not just the rehabilitation method.

Of course, there may be inherent differences in some of the rehabilitation techniques in terms of their ability to completely seal the lateral and the connection between the lateral and the mainline. For example, grouting the connection or installing a "Top Hat" type connection will not seal the remainder of the lateral even if the rehabilitation works 100% as intended. Likewise, a lateral relining technique may fully seal the length of the lateral but not seal the connection with the mainline unless this ability is built into the system or the connection seal is provided separately. In these examples, as in others, the choice of which rehabilitation system to choose is based on many factors including site conditions, sequencing of mainline and lateral rehabilitation, etc. Chapter 5.0 discusses available rehabilitation methods and their selection.

4.3.1 What Determines the Effectiveness of Lateral Rehabilitation

Two major aspects of a lateral rehabilitation project define how effective the project is:

- Design—For the projects focused on infiltration reduction, this refers to selecting 1) laterals to repair and 2) length/portion of laterals to repair. For projects focused on inflow reduction, this refers to selecting types of inflow sources to disconnect.
- Quality of material and labor—As already said, they should be on the level to satisfy quality assurance tests, and it is in the best interest of the agencies to enforce the appropriate tests as the last step in rehabilitation projects.

In addition, the longevity of installed materials may affect the long-term effectiveness of I/I reduction. For example, if grout pumped into the soil shrinks over the years or the installed liner gets damaged, the I/I may reappear. Unfortunately, there is very little hard data on longevity of rehabilitation methods (discussed in Chapter 5.0), and hence the focus of this chapter is necessarily on short-term, immediately evident achieved effectiveness in I/I reduction.

With respect to what laterals exactly to repair within the lateral rehabilitation project, (this is usually referred to as intensity of repair), there are three possible options:

- Comprehensive rehabilitation—means repairing all the laterals in the basin.
- Targeted comprehensive rehabilitation—means repairing the existing laterals on a large scale based on some accepted lateral rehabilitation strategy. For example, all laterals connected to the repaired mainline segments are routinely selected for repair (Nashville, TN), or all laterals excluding new pipes (newly installed PVC pipes known to be in good condition) are routinely selected for replacement (Sarasota, FL).
- Source-by-source rehabilitation—means repairing only the laterals that were identified as being in poor condition and prioritized for repair.

Then, with respect to the length/location of repair, the following can be repaired on the selected laterals:

- Lateral-to-mainline connection, and/or
- First few feet into the lateral
- Lower lateral (between the mainline and the property line)
- Upper lateral (between the property line and the house)
- Entire length (between the mainline and the house).
- Any part of the lateral where defects are identified.

The decision as to what and where exactly to repair is very often affected by the projected cost-effectiveness, however, there are also other issues involved that are described in Chapter 8.0 (court orders and regulations regarding elimination of SSOs, funding issues, and legal issues). It is also important to draw attention to the phenomenon of groundwater migration after rehabilitation because understanding this concept is important for decision making from a technical perspective.

If the sewer is leaking badly before rehabilitation and the pipes are basically functioning as a French drain, the groundwater level will be depressed below the natural level in the area. CCTV inspection of laterals is less likely to detect cracks that do not leak during inspection or characteristic stains that indicate leaking at other times, unless these cracks are rather large. Thus, inactive leaks easily pass undetected. (Some other inspection methods detect cracks regardless of being active or not—see Chapter 3.0). Sealing some leaks during a rehabilitation project may significantly affect the groundwater level in the area and even restore close to the original groundwater conditions from before the sewer was constructed (Figure 4-15). With a raised groundwater level, inactive leaks may become submerged and start actively leaking. This phenomenon may cause the project effectiveness in I/I reduction to be lower than anticipated.

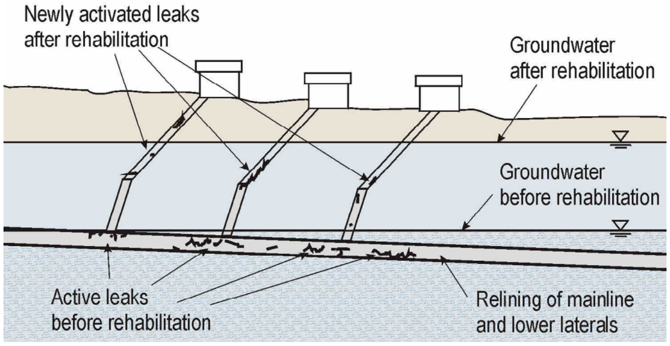

Figure 4-15. Migration of Groundwater after Pipe Rehabilitation.

When selecting the length/location of repair, it is therefore important to consider how much the groundwater level could rise with the planned rehabilitation and how far up the lateral this increase would be felt (i.e. how deep the lateral is laid and whether the lateral connects with the mainline with a vertical drop).

4.3.2 Which Lateral Rehabilitation Projects Can Be Evaluated for Effectiveness

Municipalities evaluate the effectiveness of completed lateral rehabilitation projects for several reasons:

- To demonstrate that the funds were spent on the rehabilitation wisely.
- To show that the requirements of the rehabilitation have been achieved (the applied rehabilitation eliminates SSOs, reduces volumes pumped at lift stations and/or volumes to be treated at the wastewater treatment plant, etc.).
- To learn how a particular lateral rehabilitation design (intensity of repair, location/length) is successful in reducing the I/I in the existing local conditions.

In the normal practice of mixed mainline and lateral work across a system, it is difficult or impossible to attribute with any degree of accuracy the reduction of I/I volumes to specific lateral rehabilitation approaches. Only a small number of projects with the right sequencing and characteristics are suitable for evaluation of the effectiveness of lateral rehabilitation. The approaches that have been used for evaluation of specific projects are discussed below together with the limitations on the generalization of the results to guide other projects in the system.

Lateral Rehabilitation Pilot Projects. For gaining knowledge and experience, small pilot projects with lateral rehabilitation carried out as a separate phase are of special value. It should be pointed out, though, that conclusions from pilot projects should be taken and applied with caution. Namely, extrapolating the conclusions from a small pilot project in one basin into other basins is appropriate as long as the basins are alike in terms of pipe age (similar materials, installation practice and pipe condition) and local conditions (topography, soil and groundwater level conditions). However, wastewater collection systems typically show no overall consistency in pipe age and/or local conditions—as the growth of one system typically follows the community's development over many years. Therefore, the municipality should be ready to carry out diverse pilot projects, as many as necessary, to get good and reliable input for decision making.

Projects with Mixed Mainline/Manhole/Laterals Rehabilitation. It is practically impossible to assess the effectiveness of lateral rehabilitation in projects that also include mainline and/or manhole rehabilitation. Some conclusions about the effectiveness of lateral rehabilitation could be made if several basins are rehabilitated with varied intensity of lateral rehabilitation but comparable mainline rehabilitation in all basins. However, such conclusions are difficult and tentative because the basins must be similar enough to respond to rainfall events in a similar manner.

For example, a pilot project in Vallejo, CA (2001/02) involved rehabilitation in four[29] basins (Table 4-4). The basins had a different percentage of rehabilitated laterals (between 54% and 98%). Furthermore, the percentage of laterals rehabilitated over their entire length or only in the lower part of the lateral varied within the basins as well. FM data were collected before and after the rehabilitation and analyzed, and the effectiveness in RDI/I reduction determined in each basin. However, it was not possible to draw conclusions as to how the percentage of lateral repair and the length of lateral repair affected the achieved effectiveness in RDI/I reduction. (Ohlemutz, 2005)

Table 4-14. Rehabilitation in Four Basins within One Pilot Project in Vallejo, CA (Dent, 2003).

Basin	Mainline Rehabilitated	Number of Laterals Rehabilitated	Number of Entire Laterals Rehabilitated	Number of Rehabilitated "Lower" Laterals Only
I	16,416' 0%	417 54%	358 46%	59 8%
II	23,158' 71%	243 59%	186 45%	57 14%
II	12,458' 97%	256 98%	185 71%	71 27%
V	14,758' 80%	171 79%	40 18%	131 60%

Sewer Rehabilitation Effectiveness Databases. Even when the rehabilitation projects involve mixed mainline and lateral rehabilitation, and the effectiveness of lateral rehabilitation can't be determined per se, it is valuable for the agency to determine the achieved effectiveness in the projects completed over time and maintain its own sewer rehabilitation effectiveness database. Such a database exposes whether the applied lateral rehabilitation design strategy works or not. For illustration, a database of completed projects created in Nashville, TN, stores the record of rehabilitated mainline length and rehabilitated number of laterals per project, and the annual reduction in RDI/I in mg (Table 4-5, Figure 4-16). The linear regression line in Figure 4-16 indicates the trend in annual I/I reduction from rehabilitation projects which is very useful for planning and decision making.

Table 4-15. Excerpt from Sewer Rehabilitation Effectiveness Database (Nashville and Davidson County).

Project	Project Number	Mainline Rehabilitated	Laterals Rehabilitated	Annual Reduction in RDI/I	Rate of RDI/I Reduction
Berwick Trail	Annual	2,290'		15.0 mg	6.55 mg/1,000'
Brookwood	Annual	2,550' 18%		4.0 mg	1.57 mg/1,000'
Cleeces Ferry	90-SC-60B&c	2,143' 3%		26.0 mg	12.13 mg/1,000'
Clifton Park	90-SC-1A&2	38,744' 46%	588	228.0 mg	5.88 mg/1,000'
Foster Ave.		10,445'		189.0 mg	18.11 mg/1,000'
Gibson Cr.	90-SC-88D	38,006'	447	0.0 mg	0 mg/1,000'
Hermitage Hills	90-SG-9A1&2	34,100'	637	116.0 mg	3.40 mg/1,000'
Hopedale	90-SC-74	16,084' 21%	245	289.0 mg	17.97 mg/1,000'
Etc.					

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[29] *The project started with six basins, but was reduced to four with a completed effectiveness assessment.*

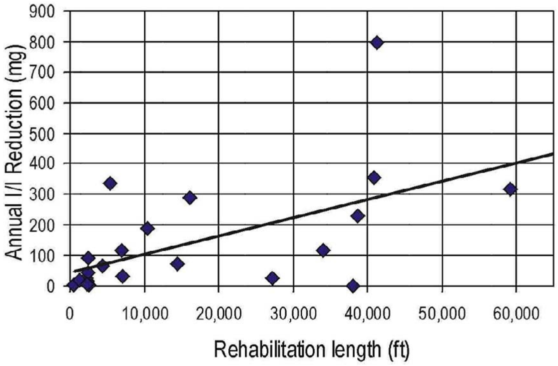


Figure 4-16. Sewer Rehabilitation Effectiveness Data and Regression Line (Nashville and Davidson County).

4.3.3 Quantifying the Effectiveness of Lateral Rehabilitation

Different quantities have been used to express the effectiveness of lateral rehabilitation in I/I reduction. The quantities are usually:

- Reduction in RDI/I quantities (RDI/I volume, RDI/I peak flow, R-factor)
- Reduction in total volumes pumped at lift stations and/or treated at wastewater treatment plants, and/or reduction in peak total flows in the sewer system
- Reduction in the number of SSOs or the frequency of flow surcharging
- Reduction in RDI/I quantities determined as a percentage reduction of "before rehabilitation" quantities.

In general, the annual reduction in RDI/I volume from the laterals is important because it helps reduce the cost of conveying/treating the sewage. However, agencies are often more often concerned about the peak flows, which are important when the existing flow capacity of pipes is insufficient. Both the capacity at the present time and in the future (with the projected growth of population and consequently of sewage flows in the community) are important to consider. Effective lateral rehabilitation in this regard helps by eliminating or at least reducing the frequency of the surcharging of pipes, and eliminating overflows and sewer backups. An alternative to rehabilitation is upsizing of sections of the sewer system with insufficient hydraulic capacity (typically larger mainlines further downstream in the collection system) but this also can be a costly solution.

Several examples of quantifying the effectiveness of lateral rehabilitation are presented to illustrate how the reduction in different RDI/I quantities was determined. They are:

- Oak Valley (Nashville, TN)—Determined percentage reduction in RDI/I volume and RDI/I peak flow using a rainfall-flow regression method, together with quantity and percentage reduction in RDI/I volume annually, and decrease in frequency of surcharging.
- Basin ML030 (Tacoma, WA)—Determined percentage reduction in RDI/I volume and RDI/I peak flow using hydrologic modeling of a rehabilitated basin and a neighboring basin.
- Basins LS-1 and LS-5 (Sarasota, FL)—Determined percentage reduction of peak day volumes pumped at lift stations.

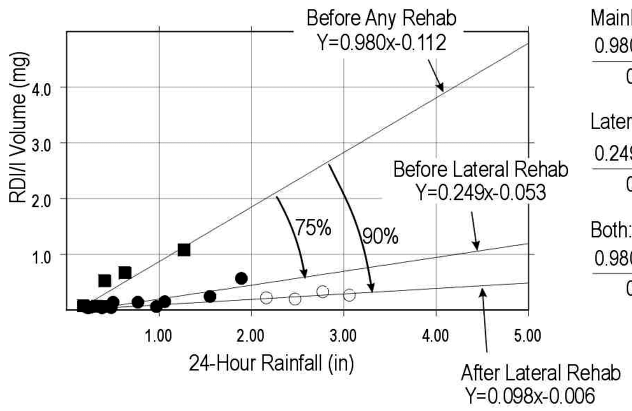
Example No. 1: Oak Valley (Nashville, TN). The project in this example was described earlier in Section 4.2.4, and is briefly summarized in Table 4-16.

Table 4-16. Basin Size and Project Phases in Oak Valley Project.

Basin size	Mainlines 10,800’ of 8∀ pipe (50% VCP, 50% concrete and PVC), laterals 200 of 6” pipe (VCP pipes)	
Phase 1	Flow monitoring	Mar/Apr 1989
	Rehabilitation	CIP relined 4,400’ mainlines (41%)
Phase 2	Flow monitoring	Feb-May 1991
	Rehabilitation	CIP relined 67 lower laterals (34%)
Phase 3	Flow monitoring	Jul 1991-Jul 1992

The RDI/I volume was calculated for each significant storm in each FM phase, and linear regression applied. The change in the slope between regression lines denotes the percentage reduction of RDI/I volume between the phases, which applies to any storm (Figure 4-17). In the same fashion, the reduction in RDI/I peak flows was analyzed (Figure 4-18).

The regression indicates that lateral rehabilitation removed 61% of RDI/I volume that would for any storm enter the system after mainline rehabilitation, or 15% of RDI/I volume that would for any storm enter the system before any rehabilitation took place. Similarly, lateral rehabilitation removed 67% of RDI/I peak flow that would for any storm appear in the system after mainline rehabilitation, or 32% of RDI/I peak flow that would for any storm enter the system without any rehabilitation.



Mainline rehabilitation:

$$\frac{0.980-0.249}{0.980}=75\%$$

Lateral rehabilitation:

$$\frac{0.249-0.098}{0.249}=61\%$$

Both:

$$\frac{0.980-0.098}{0.980}=90\%$$

Figure 4-17. RDI/I Volume Reduction in Oak Valley (Nashville and Davidson County).

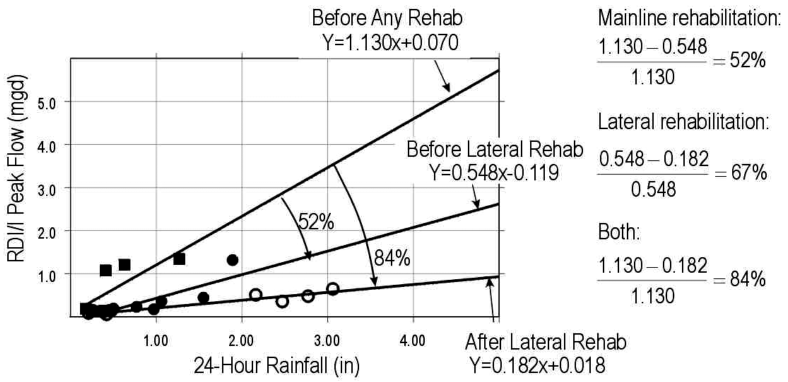


Figure 4-18. RDI/I Peak Flow Reduction in Oak Valley (Nashville and Davidson County).

Annual RDI/I volume was calculated by first summarizing RDI/I volume during the FM period (mg), then dividing this value with the total rainfall during the FM period (mg/in), and multiplying by the average annual rainfall in the area (mg). In the final step, base infiltration (nighttime dry weather flow) for 365 days was added (Table 4-17).

Table 4-17. Annual RDI/I Volume in Oak Valley (Nashville and Davidson County).

	Phase 1	Phase 2	Phase 3		
During FM period					
Number of days	30	89	356		
Total flow	13.001 mg	17.118 mg	46.5 mg		
ADF (average dry weather flow)	0.188 mg	0.139 mg	0.097 mg		
RDI/I	7.361 mg	4.747 mg	11.97 mg		
Total rainfall	4.33"	10.78"	41.28"		
Normalized RDII	1.700 mg/in	0.440 mg/in	0.290 mg/in		
Average annual rainfall (47.3")					
a.m. DWF	0.102 mgd	0.075 mgd	0.041 mgd		
Annual RDII	**117.6** mg	**48.1** mg	**28.8** mg		
Annual RDII removed:		69.5 mg	19.3 mg	(40% of 48.1 mg)	(16% of 117.6 mg)

Lateral rehabilitation removed 19.3 mg of RDI/I volume from the basin annually. This makes 40% of the total RDI/I volume in this basin after mainline rehabilitation annually, and 16% of total RDI/I volume in the basin before any rehabilitation annually.

To calculate the frequency of surcharging, the "remaining flow capacity" was determined first in each FM phase. This was a capacity of the pipe not used for the base flow and therefore available to take RDI/I. It was calculated by subtracting the peak dry weather flow (DWF) measured in the FM period from the pipe capacity (for given pipe diameter, slope and surface roughness). The intersection between the RDI/I peak flow regression line and the remaining flow capacity line in the graph indicates the rainfall depth at which the surcharging occurs (Figure 4-19), which is related to the return interval of storms with analyzed duration (24-hours). This indicates the time period over which the pipe is surcharged once or, if pipe is surcharged more than one a year, the number of occurrences in one year.

Additional hydrologic analysis of historical rainfall records were needed because the surcharging was occurring more frequently than once a year, and standard rainfall intensity/duration/frequency curves can be obtained only for return intervals of one year or longer. The analysis determined maximum rainfall events that on average happen four times a year, eight times a year, etc. as shown in Figure 4-20 (Dillard et al., 1993).

Lateral rehabilitation was successful in reducing the occurrence of surcharging to less than once in two years, whereas the system was still surcharging about 15 times a year after the mainline rehabilitation only. Occurrence of surcharging does not necessarily imply an SSO but is a condition that precedes it. The calculated frequency of surcharging is in agreement with the observed frequency over the years after completion of the project.

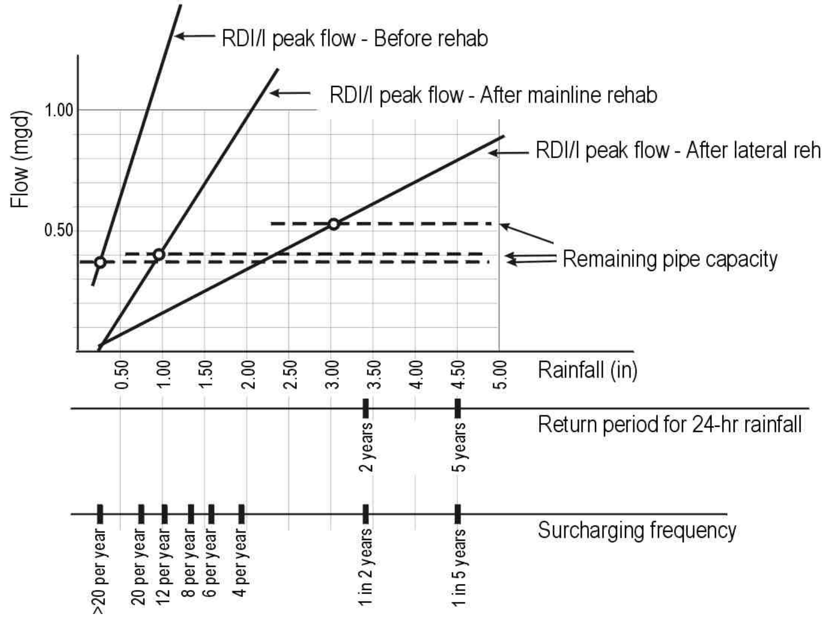


Figure 4-19. Frequency of Surcharging in Oak Valley (Nashville and Davidson County).

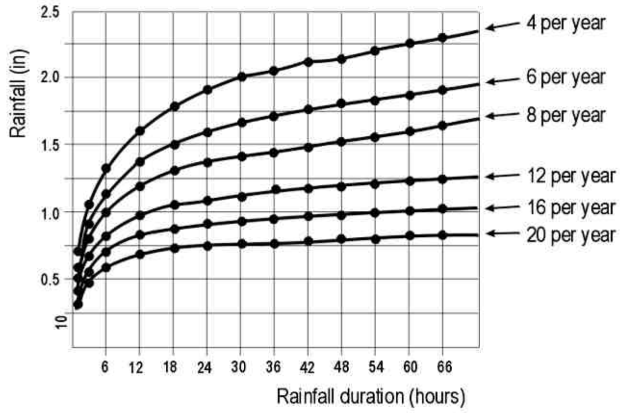


Figure 4-20. Rainfall Depth/Duration for Return Frequencies of Less Than One Year (Dillard et al., 1993).

Example No. 2: Basin ML030 (Tacoma, WA). A rehabilitation project focused on removal of inflow sources was carried out in one basin (referred to as ML030) in Tacoma, WA, in 2002. The project involved disconnection of sump pumps and foundation drains from sewer laterals. The effectiveness in RDI/I reduction was estimated as a percent reduction of RDI/I volume and as a percent reduction of RDI/I peak flows for any rainfall. RDI/I quantities were determined with hydrologic modeling in two basins: one that was rehabilitated and another neighboring basin that was not (basin ML031, referred to as a control basin).

FM was carried out before the rehabilitation in winter 2001/02, and after the rehabilitation in winter 2002/03. A simulation model (MOUSE flow model) was calibrated with the measured flows. A 56-yr rainfall record was run through the model. For the top 28 storms, RDI/I volume and RDI/I peak flow were calculated in both basins. Then, calculated RDI/I volume was normalized by dividing it with the area of the corresponding basin, and the result was the normalized RDI/I volume.

The basic assumption was that the two neighboring basins respond similarly to storm events. Thus, comparison of RDI/I quantities calculated in these two basins before and after the rehabilitation indicates the effectiveness of rehabilitation in RDI/I reduction.

For each storm in the pre-rehabilitation phase, RDI/I volume in the rehabilitated basin was plotted as a function of RDI/I volume in the control basin, and linear regression was applied. The same was repeated for the post-rehabilitation phase. The difference in the slope of the regression lines denoted the percentage in RDI/I volume reduction, which applies to any storm (Figure 4-21). The same analysis was repeated for RDI/I peak flows thus determining the percentage in RDI/I peak flow reduction, which again applies to any storm (Figure 4-22).

The rehabilitation successfully eliminated 35% of RDI/I volume and reduced RDI/I peak flows by 15%.

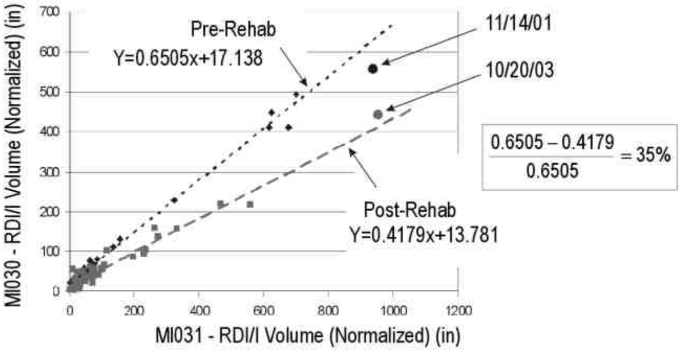


Figure 4-21. RDI/I Volume Reduction from Removal of Inflow Sources (City of Tacoma, WA).

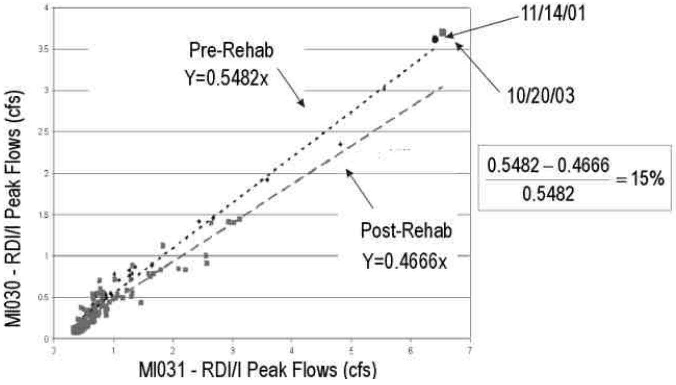


Figure 4-22. RDI/I Peak Flow Reduction from Removal of Inflow Sources (City of Tacoma, WA).

Example No. 3: Basins LS-1 and LS-5 (Sarasota, FL). The project in this example was described earlier in 4.2.4, and is briefly summarized in Table 4-18. The rehabilitation involved the replacement of 58% of upper laterals with pipe bursting. The effectiveness in RDI/I reduction was estimated as a percent reduction of pumped volumes.

RDI/I quantities after the rehabilitation were determined first (Table 4-19), and the reduction in pumped volumes and estimated RDI/I quantities calculated next (Table 4-20).

Table 4-18. Basin Size and Project Phases in Sarasota, FL.

Size of basins:	LS-1: 26,800’ (8”) mainline and 417 (4”, 6”) laterals; LS-5: 6,402’ (8-12”) mainline and 99 (4”) laterals	
Project phases:	Recording at lift stations:	Pumped volumes, groundwater level, rainfall depth
	Rehabilitation 2001/02:	Pipe bursting of upper laterals (58%)
	Recording at lift stations:	Pumped volumes, groundwater level, rainfall depth

Table 4-19. Quantification of RDI/I—After Rehabilitation (City of Sarasota, FL).

	Date	Groundwater Level	Pumped Volume (gal)	RDI/I (gal)	Location of RDI/I Sources	RDI/I as % of Pumped Volume:
Basin LS-1						
Water consumption (ave)		-	96,567			
Wastewater (average)		-	114,657			
Typical Dry Weather	01/31/02	**-6.00’**	**105,404**		NA	
Typical Wet Weather	10/07/04	-2.88’	187,000			100%
				81,596	Mainlines only	44%
Extreme Wet Weather	09/07/03	-0.50’	543,900			100%
				438,496	Mainlines and entire laterals	81%
				356,900	**Entire laterals**	**66%**
				81,596	Mainlines only	15%
Basin LS-5						
Water consumption (ave)			24,618			
Wastewater (average)		-	27,225			
Typical Dry Weather	01/30/02	**-3.40’**	**45,719**		NA	
Wet Weather—Day 1	01/15/02	-2.76’	66,671			100%
				20,952	Mainlines only	31%
Wet Weather—Day 2	08/27/02	-2.15’	98,138			100%
				52,419	Mainlines and lower laterals	53%
				31,467	**Lower laterals**	**32%**
Extreme Wet Weather	08/28/02	-0.74’	121,342			100%
				75,623	Mainlines and entire laterals	62%
				54,671	**Entire laterals**	**45%**
				23,204	**Upper laterals**	**19%**
				20,952	Mainlines only	17%

Table 4-20. Comparison of Quantities “Before” and “After” (City of Sarasota, FL).

	Groundwater Level		Decrease In Pumped Volume (gal)		Decrease in RDI/I (gal)		Location of RDI/I Sources
	“Before”	“After”					
Basin LS-1							
Typical Dry Weather	-6.47’	-6.00’	15,947	13%			NA
Typical Wet Weather	-2.90’	-2.88’	48,144	**20%**	32,197	28%	Mainlines
Extreme Wet Weather	-0.70’	-0.50’	**226,100**	**29%**	210,153	32%	Mainlines and entire laterals
					177,956	33%	**Entire laterals**
Basin LS-5							
Typical Dry Weather	-3.40’	-3.40’	19,543	30%			NA
Wet Weather—Day 1	-2.92’	-2.76’	11,681	**15%**	-7,862	-60%	Mainlines only
Wet Weather—Day 2	-2.14’	-2.15’	79,979	45%	60,436	54%	Mainlines and lower laterals
					68,298	68%	**Lower laterals**
Extreme Wet Weather	-0.70’	-0.74’	**143,439**	**54%**	123,896	62%	Mainlines and entire laterals
					131,758	71%	**Entire laterals**
					63,460	73%	**Upper laterals**

Rehabilitation of upper laterals reduced total pumped volumes in these two basins around 15-20% when the groundwater level is about 3’ below the grade. On extreme wet weather days when the groundwater level is less than 1’ below the grade, the reduction of total pumped flows is 29% and 54% in LS-1 and LS-5 respectively. These values are firm data and trustworthy.

Comparison of RDI/I volumes “before” and “after”, however, indicates that application of the method for calculating RDI/I from the laterals was not accurate (it was understood as an approximation from the start). Table 4-20 shows the change in RDI/I attributed to mainlines and lower laterals that that cannot be explained because no repairs were done on deep pipes or the lift station within the time period in question. There are two reasons for the inaccuracy:

- Wastewater flow is variable. In LS-1, the pumped volumes are 13% lower after the rehabilitation during dry weather and it is believed that this difference is entirely caused by a variation of daily water consumption and wastewater flow. The values used in the analysis are monthly average values (representative for many predominantly dry months) and acknowledging them as variable means that RDI/I on wet weather days was calculated as a very rough approximation only. In LS-1, during extreme wet days, for example, the calculated 648,649 mg before rehabilitation and 438,496 after are not reliable RDI/I quantities.
- Dry weather flow may include base infiltration. In LS-5, there is an even larger difference percent-wise between pumped volumes on dry days before and after than in LS-1. In this basin, there is also base infiltration involved that happens through mainlines and lower laterals. The groundwater level of -3.40’, which is as low as it gets in this basin, is still above the mainlines and many lower laterals. Therefore, the assumed location of RDI/I sources (the rightmost column in the Table 4-20) is inaccurate in this basin.

Taking this into consideration, the analysis of pumped flows in LS-5 basin can be corrected as shown in Table 4-21. With the new interpretation of sources of infiltration, only the contribution from the upper laterals is estimated. The rehabilitation has removed 63,460 gal of infiltration from upper laterals, or 73% compared to “before rehabilitation” infiltration. This estimate is still only approximate because it is again based on uncertain wastewater flows.

Table 4-21. Corrected Analysis of Pumped Flows in LS-5 (Sarasota, FL).

	Before Rehabilitation				After Rehabilitation				Infiltr.	
	Date	GW	Pumped (gal)	Infiltr. (gal)	Date	GW	Pumped (gal)	Infiltr. (gal)	Reduction	Location of RDI/I Sources
Wastewater			27,225							
Dry day flow	05/26/97	**-3.40’**	**65,262**	**0**	01/30/02	**-3.40’**	**45,719**	**0**		Mains, lower laterals—min
Wet day #1 flow	05/05/99	-2.92’	78,352	13,090	01/15/02	-2.76’	66,671	20,952		Mains, lower laterals—ave
Wet day #2 flow	01/03/99	-2.14’	178,117	112,855	08/27/02	-2.15’	98,138	52,419	54%	Mains, lower laterals—max
Ext wet day flow	11/14/97	-0.70’	264,781	199,519	08/28/02	-0.74’	121,342	75,623	62%	Mains and entire laterals
				86,664				23,204	73%	Upper laterals

4.4 Conclusion

This chapter has described methods that agencies can use to estimate the I/I in particular basins within their sewer collection system and how they can evaluate the effectiveness of completed lateral rehabilitation. Data collection for I/I analysis can be of different scopes (from smoke testing to long-term flow monitoring) and the analysis of collected data can vary from simple (empirical calculations of I/I, basic comparison of total measured flows on representative days) to elaborate (hydrologic/hydraulic simulation modeling of FM data). The accuracy of results and the confidence in conclusions typically improves with applied complexity.

Any published numbers providing a calculated contribution of laterals within the total I/I for a system cannot be considered universally applicable as they depend on local conditions (soil, groundwater, rainfall) and pipe condition (existence of I/I sources). The same applies to published numbers about the achieved effectiveness of lateral rehabilitation, which depends mostly on how well the applied repair measures targeted the existing sources of I/I. Any previous experience, even an agency’s experience from its own pilot projects, needs to be used carefully—acknowledging the specific conditions in the basin and/or project. However, despite the difficulties in generalizing the results, pilot projects are essentially the only way for an agency to get reliable data about the contribution of laterals to I/I in its sewer collection system and to build a good program to provide the most effective reduction of I/I problems caused by laterals.

There was no mention of cost in this chapter as the effectiveness in I/I reduction was assessed only from a technical point of view (what determines it and how it is quantified). The technical effectiveness is tied with cost considerations in the last chapter of this report dealing with decision making. In this chapter, the cost-effectiveness of inflow source removal and lateral rehabilitation strategies becomes an important factor in policy development and planning.

CHAPTER 5.0

METHODS FOR INFLOW REMOVAL AND REHABILITATION OF SEWER LATERALS

5.1 Background

Inflow removal addresses illegal and undesirable sources of I/I entering laterals and often represents the first step in addressing private sources of I/I. Rehabilitation of defective sewer laterals restores impaired structural integrity and reduced hydraulic capacity of these pipes, as well as improving the leak-tightness of pipes and connections and hence eliminating or minimizing groundwater infiltration into the sewer system. Rehabilitation also prevents root intrusion through defects into the pipes, which is a serious problem for many agencies. Sewer laterals can be repaired or replaced either over their entire length or only in selected parts. In addition to traditional open cut repair, a number of trenchless rehabilitation methods have been developed for the purpose of lateral repair—the principal methods in use today being cured-in-place (CIP) relining of pipes, replacement by pipe bursting, chemical grouting, and flood grouting. Sliplining of sewer laterals is possible but no longer really used in practice since the other repair options became available. Robotic repair currently is not used significantly in the U.S but has been made a late addition to the report due to the recent interest of European manufacturers in the U.S. market. This chapter explains where and how different methods can be applied, as well as the main advantages and limitations. The relevant issues for each method are discussed considering the small pipe diameters of laterals and the other specific application conditions pertaining to sewer laterals and their connections to the mainline. Duration of repair work, longevity and cost of methods are also discussed.

The effectiveness of the various methods in terms of their ability to reduce I/I in a sewer basin is not estimated in this chapter. Such effectiveness is related to project design and quality control in addition to the choice of method. However, the detailed information provided about the application parameters for each method can be combined with regional information about the experience of the available construction crews and the prior application of the methods in the region to assist in the selection of the preferred techniques.

Detailed descriptions of how particular rehabilitation systems have been selected and applied in several selected projects is given in several case studies, which are included in Appendix A. These case studies have been written based on input from agencies and engineering firms, and from contractors that have carried out the construction work in the field. They provided the necessary data, photos and in-depth explanations. Appendix C provides a comprehensive review of existing systems for lateral rehabilitation. It provides summaries of the features of different rehabilitation systems/technologies for sewer lateral repair that are currently available on the U.S. market and for which the technology provider responded to the requests for detailed information for this study. The technical information and application parameters are provided by the manufacturers/owners of the rehabilitation systems, however, there is also input from public works agencies in form of comments/testimonials about their experiences with particular rehabilitation systems. Such comments are not intended to represent a judgment on the suitability of the system but rather how a particular agency dealt with the application of the method(s) it had chosen to use. An attempt was also made to identify innovative methods for rehabilitation that currently are being developed for application to sewer laterals. One such method, slug grouting, is presented and a case study describing the first field test of this method is included in Appendix A.

Efforts to minimize extraneous water coming through sewer laterals into the sewer system would not be well presented without describing measures for removal of inflow sources, which include repair of cleanouts (e.g. replacing missing caps) and disconnection of various drains from the laterals. These measures are often very effective in removing thousands of gallons of rainwater from the sewer system, and yet less expensive than rehabilitation of pipes, and are typically the first step any agency will try in reducing the I/I. Two measures, disconnection of roof leader downspouts and disconnection of footing drains, are therefore presented at the beginning of this chapter.

Acknowledging that many agencies have a huge problem related to tree roots protruding into sewer laterals that further promotes structural deterioration of these pipes and causes a loss of hydraulic capacity and even blockages of pipes, this chapter also summarizes methods for root control that are applicable in sewer laterals.

5.2 Removal/Reduction of Inflow

5.2.1 Disconnection of Roof Leader Downspouts

Disconnecting roof leader downspouts from the sewer system is usually a straightforward and inexpensive procedure in which a downspout is simply cut near the ground surface, the sewer pipe capped, and the rainwater from the downspout discharged on the ground surface, stored in rain barrels, or redirected to rain gardens. In some cases, however, the disconnection requires additional construction work (e.g. a downspout has to be moved to another part of the house), which complicates the procedure and raises the cost of disconnecting.

Basic Disconnecting Procedure. A distance of 9” is measured from where the downspout enters the sewer connection and the downspout is cut with a hacksaw. The sewer standpipe is capped—a simple rubber cap secured by hose clamp can be used in most cases or a wing-nut test plug if available cap sizes don’t fit. (Figure 5-1). The downspout is next inserted into an elbow and a downspout pipe extension is attached to carry water away from the house and foundation. A splash block can be placed at the end of the downspout to prevent erosion where the water exits the pipe extension.

Figure 5-1. Downspout Disconnection (Milwaukee Metropolitan Sewerage District, WI).

Surface Discharge of Rainwater. The water discharged on the surface should drain away from the house foundations. Optionally, a bubbler pot can be installed to discharge the rainwater further away from the foundation. The bubbler pot is made of PVC and about 8" in diameter, and is buried in the lawn approximately 8-10' from the foundation (Figure 5-2). As the water fills up in the pot, the lid rises up to let the water evenly overflow onto the lawn. Drainage slots in the pot let standing water filter down into the ground. The cost of a bubbler pot kit (excluding a PVC pipe and an elbow) is about $20.

Figure 5-2. Bubbler Pot (City of Toronto, Canada).

In general, lot size and existing site conditions determine if the flow from disconnected downspouts should be discharged on the ground surface. For example, Table 5-1 is listing the preferred site conditions as outlined by the City of Toronto, Canada, which has had a program for disconnecting downspouts since the early 1990s[30] worth approximately CAN $2.0 million annually, and approximately 25,000 properties have been disconnected to date (Longo, 2005). During this program, the agency made inspections of all properties of residents willing to participate and was able to summarize reasons why some private properties may be unsuitable for this type of disconnecting (Table 5-2). Overall, about 18% of inspected properties were found unsuitable. This percentage also includes properties where the downspout was shared with an adjacent property owner (semi-detached or multiple unit dwelling) who objected to the disconnection.

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[30] *The first pilot project was in 1992, the citywide project since 1999.*

Table 5-1. Preferred Site Conditions for Rainwater Surface Discharge Near the House (City of Toronto, Canada).

Lawn to lot area ratio	> 0.5
Lot grading slope	Gentle
Area type	Low density residential areas
Soil type	Sandy soil (although not essential to success)
Ground water table	> 8' below grade

Table 5-2. Private Properties Unsuitable for Rainwater Surface Discharge Near the House (City of Toronto, Canada).

There is no suitable discharge area.
The property is graded towards the house.
There are physical obstructions on the property.
There is a risk of flooding of neighboring property.
The property is close to a ravine.
There is contaminated sub-soil.
Soil conditions are unsuitable (limited infiltration capacity).

Total cost depends on whether the homeowner does the work or a contractor is hired. A "do-it-yourself" disconnection by the homeowner can cost as little as $15.00 per downspout.

The City of Portland, OR, has had an ongoing downspout disconnection program since 1995. To date downspouts on over 44,000 properties have been disconnected at cost of $53 per downspout. The program in this agency is voluntary and the city actually reimburses the homeowners this amount for each disconnection. The amount of rainwater removed annually from the sewer system is estimated at 22,000 gal per house totaling to about one billion gallons for all the disconnections made. (Dobson, 2005)

In the City of Toronto, Canada, the average cost for disconnecting a private property is between $320 and $480 (CAN $400-600) depending on the area where the property is located and the number of downspouts on the property (usually three to five downspouts, on average four). The cost of simple disconnection as described in this chapter is about $40-50 (CAN $50-60) if a contractor is hired, but can be significantly higher if additional work is needed. The city installs about 100 bubbler pots per year as part of the Downspout Disconnection Program. The cost of disconnection of one downspout when installing a bubbler pot is close to $80 (CAN $100) on average. (Longo, 2005)

Rain Barrels. The use of rain barrels makes downspout disconnections possible in some areas where it would otherwise be difficult to disconnect. This approach also provides a means of water conservation as the collected water can be used for watering lawns and gardens. Some residents use their water for washing hair, laundry and cars. Rain barrels are attractive to many homeowners and can be used as an incentive to disconnect downspouts.

One rain barrel is placed under each disconnected downspout (Figure 5-3). Optionally, a hose is attached to the spigot and/or to the overflow hole near the top of barrel, and the overflow is directed into the yard. The method is best suited for downspouts close to the plants and garden watered, where any overflow from the barrel would soak into the yard, and not a neighbor's property. The surface on which to place the barrel would preferably be pervious (e.g. landscaped) to allow the overflow to soak into the ground. If placed on an impervious surface (e.g. a paved area), a hose is typically used to direct water to a garden area.

The most effective barrels are those that have a continuous slow discharge to a garden area. However, the performance of rain barrels in reducing runoff from a storm depends on the attention from the homeowners—who need to make sure that the barrel is drained and empty when the rain starts. For illustration purposes, a 60-gallon barrel (about 230 liters) will be filled with rainwater from 1” (2.5 mm) of rainfall on a 1,000 SF roof area. It will water about 240 SF of garden space (10’×24’).

Figure 5-3. Rain Barrel Set-up for a Residential Property (City of Toronto, Canada).

The use of rain barrels can be a problem in the winter in cold climates. The barrels should be drained before temperatures drop below freezing. In some agencies, the barrels are bypassed (a downspout bypass valve may be necessary at the connection point to the rain barrel), which can lead to hazardous situations to the residents (the snow on the roof melts on warmer days and the walkways or driveways on the property develop an ice buildup). Some agencies recommend keeping the rain barrel connected but with the spigot open so that water does not accumulate in the rain barrel and freeze. It is also possible to allow downspouts to be seasonally reconnected to the sewer system. In warm weather, a mosquito-proof screen should be placed over all openings to keep mosquitoes and other insects out. During the rainy season, a homeowner is recommended to splash off by hand any water that may collect on the top of the barrel every three to four days. (Mosquitoes need at least four days of standing water to develop as larva.) If there is a concern that mosquitoes are breeding in the barrel, it should be emptied completely. This would kill all mosquito larvae in the barrel. Rain barrels are typically low maintenance but require a routine inspection of all components.

The use of rain barrels in urban and suburban areas along with downspout disconnection has been encouraged by a number of agencies in North America. The City of Toronto, Canada, initiated a citywide Rain Barrel Program in 1996, in which the residents have access to free downspout disconnection by a city contractor. Barrels in Toronto range from 60-150 gal (225-565 liters). (Longo, 2005)

The City of Chicago, IL, completed a Rain Barrel pilot project in 2004. A total of 440 rain barrels were offered at cost of $15.00 to homeowners across the city, targeting five areas within the city with most basement flooding incidents. (The city bought and retrofitted recycled barrels for the pilot project, and sold them at a subsidized rate.) Gardening centers in the city were informed about the high demand for the rain barrels so that they could increase their stock of rain barrels in the future. The purpose of the project was to promote the proper method of downspout disconnecting and conserving water with rain barrels. The agency estimates that between 170,000 and 400,000 gallons of water could be conserved per year from installed barrels[31], which depends on whether the barrels are emptied only after rain events of 1” or more (semi-active rain barrels) or after every rain event (fully-active rain barrels). The agency also estimates that this pilot project could divert over 760,000 gallons of water from entering the city’s sewer system over the course of a year if all rain barrel purchasers disconnected their downspouts as a result of buying a rain barrel. (Beazley, 2005)

The City of Portland, OR, has had a downspout disconnection program incorporating the use of rain barrels since 1996. To date, over 325 rain barrels (55 gal each) have been installed.[32] (Dobson, 2005).

The cost of rain barrels depends on the manufacturer and is roughly between $100-200 (excluding a downspout and other accessories). For example, the price for a single 55-gallon barrel installed in the Portland area is $170 (the barrel comes with a filter) and, for a self-installed barrel without delivery the cost is $140.

Rain Gardens. A flow from a downspout can also be directed to a rain garden[33], which is a shallow, man-made depression planted with deep-rooted native flowers and grasses and positioned in the vicinity of the downspout (Figure 5-4). Rain gardens hold the water for a short period of time and then allow the water to naturally infiltrate back into the ground.

A separate rain garden is preferably made for each downspout if there is available space on the property. The recommended size of the garden is roughly 20% of the area drained (roof area drained by the downspout) for sandy soils and 40-60% of the area drained for clays. Typically the size is between 150 SF and 400 SF. The cost of rain gardens ranges from about $3-4/SF for “do-it-yourself” projects to about $10-12/SF for projects completed by qualified landscapers (see, for example, Rain Garden Network, www.raingardennetwork.com). (Cubberly, 2005)

Figure 5-4. Rain Garden (Wisconsin Department of Natural Resources).

5.2.2 Disconnection of Footing Drains (Foundation Drains)

Footing drains (foundation drains) can be disconnected from sewer laterals in two ways (Figure 5-5):

- Partially
- Completely

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[31] *Based on rainfall data in 2004, and assuming that during a 1 ∀ rainfall, at a typical Chicago house with four downspouts, one disconnected downspout accepts 55 gallons of water.*

[32] *Also several larger tanks have been installed (four 1,000-gallon tanks).*

[33] *Rain gardens can be used to catch runoff water from other impervious surfaces such as sidewalks, driveways, etc.*

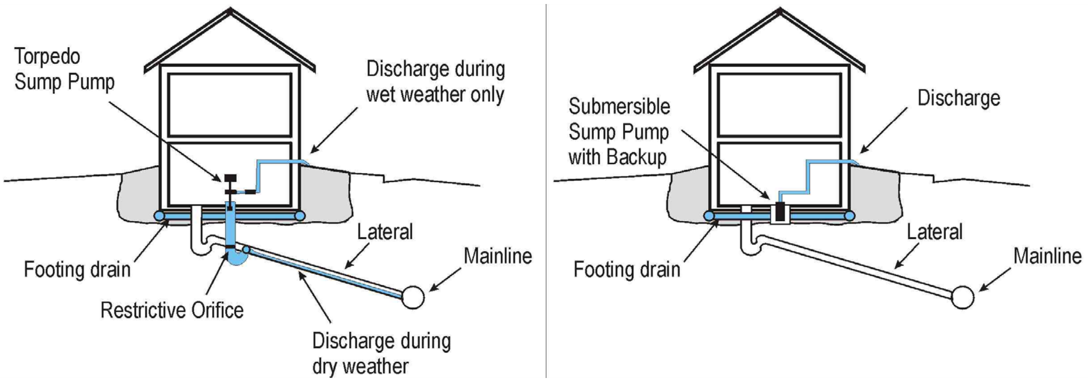


Figure 5-5. Disconnection of Footing Drains. Left: Partial. Right: Complete.

Partial Disconnection of Footing Drains. With this type of disconnection, the flow from footing drains is allowed to discharge to the sewer lateral as long as the flow is small (during dry weather), but the installed sump pump(s) discharge a portion of water out of the house onto the residential lawn when the flow increases during wet weather events. This eliminates nuisance discharges to the yard during dry weather and during the winter when it could cause icing. Torpedo or submersible sump pumps can be used.

Torpedo sump pump are small pumps that can be placed inside a 4" cleanout in the basement (Figure 5-6). The motor extends above the floor. Plug has an opening to allow low flows into the sanitary system.

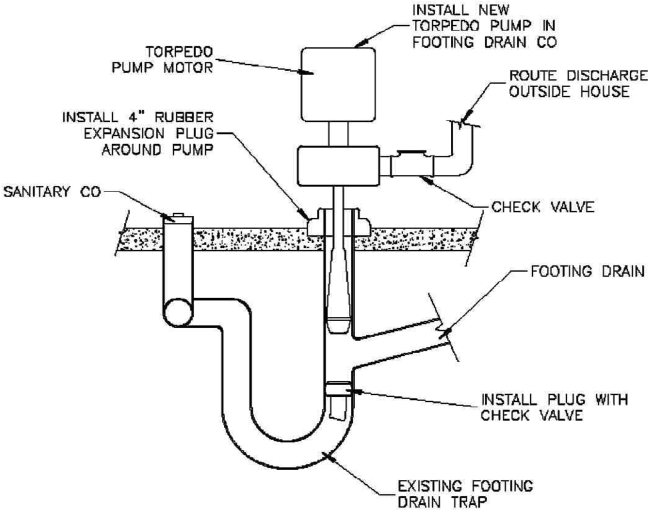


Figure 5-6. Installation of Torpedo Sump Pumps (City of Ann Arbor, MI).

Canton Township, MI, has installed 2,164 torpedo pumps to date (August 2005) at an average cost of $500. Approximately 5% of the torpedo pumps have failed, primarily because they only run under wet weather conditions and may be inactive for months. Failures are mostly attributable to lack of maintenance by the homeowner (Casari, 2005).

The City of Ann Arbor, MI, considered this type of disconnection but decided to do complete disconnection with submersible sump pumps instead because of the maintenance issues with torpedo sump pumps reported by some other agencies and the desire to remove all the footing drain water from treatment processes (Perala, 2005).

Complete Disconnection of Footing Drains. With this type of disconnection, the flow is completely disconnected from the sanitary sewer and discharged on the surface near the house or redirected to a new drainage system installed by the agency.

Disconnection Setups. A basic setup for disconnecting foundation drains used in Duluth, MN, is shown in Figure 5-7. A footing drain originally connected to the plumbing in the basement is disconnected and connected to a sump pump pit (the floor drain and the sump pump pit are separated), from where the collected water is pumped out of the house to the lawn and to the storm sewers. The backwater valve is a simple "flapper" type device that allows water to flow through the valve towards the mainline but does not allow the flow in the opposite direction.

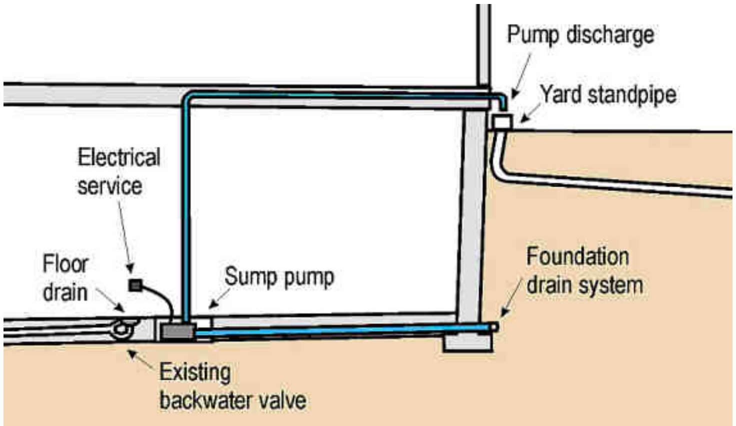
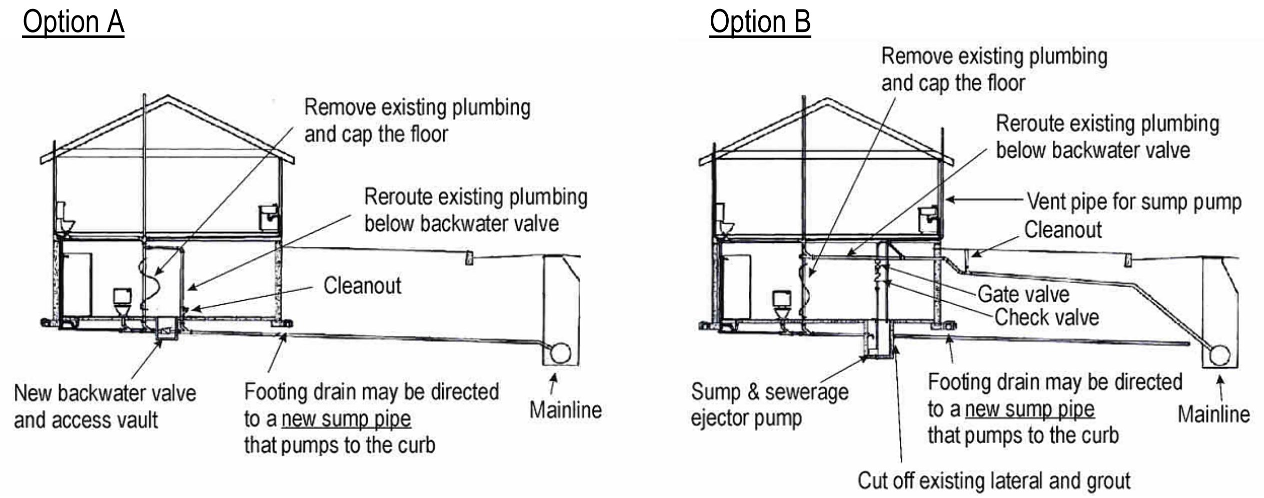


Figure 5-7. Foundation Drain Disconnection Setup in Duluth, MN.

In Salem, OR, two different setups have been utilized (Figure 5-8). Option A is very similar to the setup in Duluth, MN, as it involves installation of a new backwater valve and an optional sump pump. Interior plumbing is also modified to reroute the existing plumbing on upper floors to connect downstream of the backwater valve. This allows the plumbing on upper floors to be used during the storm when the backwater valve is activated. The footing drain is disconnected and the water can optionally be pumped to the curb with a sump pump. The backwater valves have been installed in Salem for years and have proven to be fairly reliable (in some rare cases, basement flooding occurred after the valve was installed because the valve either failed or was not properly installed) and require minimal maintenance. The cost of this option depends on the characteristics of the house that needs to be worked on (houses with a fully finished living area in the basement are more expensive). The cost is approximately $6,000 per home, which includes $3,000 for a new sump pump.

Option B involves building of a new lateral and installation of a new ejector pump to pump sewage from the basement area into the new lateral (Figure 5-9). The interior plumbing is accordingly modified. Under this option, footing drains must be re-directed to a sump pump unless they can be drained by gravity to the storm drain system. If not, there is the possibility that groundwater may enter the basement. This option is more expensive than the previous one (approximately $10,000–12,000 per home) but allows the basement to be used under any surcharging conditions and is more appropriate for homes that have a bathroom in the basement or plan to construct one in the future. The experience in Salem over the years has shown that this alternative provides a lower risk of failure. Ejector pumps have been used in thousands of installations and have proven reliability. Once the sump and ejector pump systems are installed, the homeowner is responsible for all maintenance.


Option A

Option B

Figure 5-8. Two Setups for Foundation Drain Disconnection in Salem, OR.

Figure 5-9. Left: Ejector Pumps Installed in the Basement. Right: A Closer View (City of Salem, OR).

Backup Sump Pumps. One problem with sump pumps is that in the event of a power failure they do not function, which can result in groundwater collecting around the outside of basement walls and seeping though cracks in the concrete or through the sump lid into the basement. A solution to this problem is to install either battery-powered or water-powered backup sump pumps. Based on experience with power failures during storm events, homeowners are often advised to install a backup system.

Discharge of Water from Footing Drains. The disconnected flow can be discharged outside the house in a similar way as the flow from disconnected downspouts. Most often, surface discharge near or further away from the house is selected, but underground drain pipes that convey the flow into a catch basin or a storm sewer are preferred especially in cold climates with icing problems.

For surface discharge near the house, a black drainpipe can be used. The main disadvantage is that the water can recycle into footing drains again if the pipe is short. If it is long, however, the pipe can be an obstruction to homeowners (while mowing the lawn, for example) and can freeze during winter months in cold climates. Shortening the length and installing an airgap (a vertical distance between the pipe end and the ground) will enable the uninterrupted pumping but will not eliminate the icing issue for homes that have a lot of water to dispose of during the winter months (Figure 5-10). A bubbler pot is an alternative that allows discharge a little further away from the foundation.

A discharge pipe from the sump pump can also connect to an underground drainpipe laid from a basement wall to a catch basin in a ditch or to a curb where a hole is drilled to allow discharging the sump pump water into the drainage channel of the curb (Figure 5-11). An underground drainpipe is especially helpful in cold climates as it prevents the possible collecting and icing of water on the property (Figure 5-12).

Figure 5-10. Surface Discharge of Disconnected Flow. Left: Black Drainpipe. Right: Bubbler Pot (City of Duluth, MN).

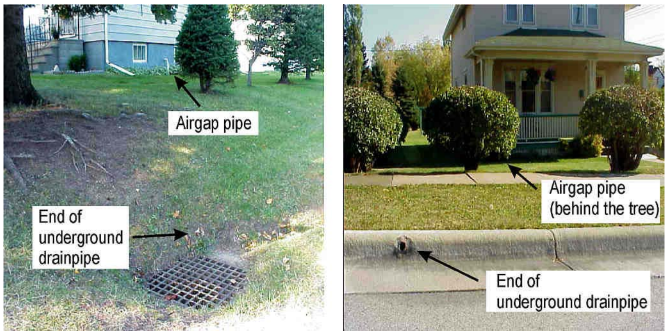


Figure 5-11. Discharge through Underground Drainpipe. Left: Ending in the Ditch. Right: Ending in a Curb (City of Duluth, MN).

Figure 5-12. Icing behind Curb Drains (City of Duluth, MN).

5.3 Methods for Repair of Defective Sewer Laterals

5.3.1 Open-Cut Replacement

Before trenchless methods became available, open-cut replacement was the only option to repair defective laterals. Although trenchless methods have become established over the years and are being increasingly used for repair of laterals, some agencies continue to have reservations about them and favor open-cut repair even if the local conditions seem more appropriate for a trenchless approach. Some agencies have indicated that they had a bad experience with trenchless methods in the past—the City of Norfolk, VA is one example where disastrous results were reported to be related to the contractor's incompetence and aptitude and is presented here.

Experience in the City of Norfolk, VA. This agency tried trenchless methods in 1996 (Fortin, 2005). The project involved rehabilitation of 325 laterals in one sub-basin (beside mainline/manhole rehabilitation). Open cut replacement and trenchless methods were utilized (Table 5-3). The same contractor was used for both pipe bursting and CIP. Unfortunately, the contractor was exceptionally sloppy, using the project as means to instruct the crews on trenchless work. As soon as one crew would start to understand the process, a new crew would arrive to site.

Table 5-3. Experience with Lateral Rehabilitation/Replacement in Norfolk, VA.

Method	Total Laterals Rehabilitated	Laterals Rehabilitated Successfully	Failures (Laterals Repaired Open Cut)
Pipe bursting	110	34	76 (69%)
CIP relining	85	0	85 (100%)
Open cut replacement	130	130	N/A

The contractor first tried hydraulic pipe bursting but could not manage to pull replacement piping through without pipe coming off the head. Next he tried static pull but the pulling cable could not withstand the pull and was breaking, or the pipe would pull off the head. Eventually, 49 laterals were replaced with pipe bursting. However, 15 laterals had to be replaced after bursting with an open-cut due to sags or collapsed piping, totaling 76 failures in lateral pipe bursting. Experience with CIP relining was even worse. The contractor was not sure how to prepare the resin and was trying different ratios, none successful (in some cases, resin set too fast, some too slow, and some not at all). All 85 attempts of CIP relining failed.

Cost. The cost to replace a lateral with open cut excavation depends on the length, depth, and needs for surface restoration. The cost is lower if the lateral is on the same side of the street as the connection to the mainline, and is much higher if the lateral has to cross the street. Lateral open-cut replacement is less expensive if the street pavement is asphalt rather than concrete.

The cost also very much depends on the part of country where the job is performed. In Louisiana, the replacement cost can range from $250-1,500 per lateral (Aillet, 2005), whereas in California the range reported is from $5,000-10,000 per lateral.

Advantages. The open-cut method is most suitable for very damaged pipes that are shallow and in open areas without obstacles. Open-cut allows installation of a new pipe of any diameter and material, and furthermore, the layout or depth of the lateral can be changed.

Limitations/Disadvantages. Mature landscaping and driveways, retaining walls, etc., reduce the suitability of this method. The method causes disturbance to the homeowner's property causing public relations difficulties and replacing high quality landscaping and major sections of road pavement can be expensive.

5.3.2 Sliplining

Sliplining is a method in which a slipliner pipe (for laterals, typically an HDPE pipe) is pushed into the existing lateral pipe (Figure 5-13). This is a well-established rehabilitation option in mainline rehabilitation, but is essentially no longer used for repair of typical sewer laterals. Agencies are reluctant to slipline small diameter pipes such as 4" or 6" pipes because of the risk of pipe blockages due to pipe diameter reduction. The method could however be used in larger diameter sewer laterals and is therefore described in this chapter.

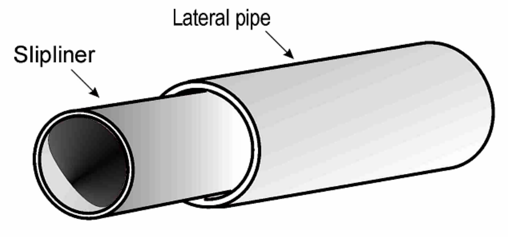


Figure 5-13. Sliplining.

A case study in Stege, CA, included in Appendix A provides details of how this method was performed on laterals 4" in diameter. The project was effective in I/I reduction, showing good results even after 18 years. However, the agency does not utilize this method any longer.

Sliplining was also used in a pilot project in Berkeley, CA, in 1985. Out of 68 lower laterals rehabilitated in the pilot project (Parker Street Project), only six were sliplined (a total of 150' in length with a diameter reduction from 4" to 3.5"), although 25 laterals were scheduled for sliplining before the construction began. Excavation of insertion pits for sliplining the lower laterals removed roughly 12-15' of the lateral, which left only a short length of about 10-12' to be actually sliplined. (Pits were excavated at cleanouts where the laterals were shallow. They could have been excavated on the side of the mainline opposite the sewer lateral, however, that would have required much more excavation—a trench roughly 15' long and 7-8' deep, and this would have damaged the curb, gutter or sidewalk.) (CDM/Jordan/Montgomery, 1985)

The Napa Sanitation District, CA, is another agency where this method was used quite extensively in the 1970s. Laterals are now being repaired open cut or with pipe bursting[34]. (Merryweather, 2005)

Duration. Sliplining of laterals is time consuming. According to the case study in Stege, about one lateral could be completed per day. The Berkeley pilot project also confirmed that the method was slow. A lot of "piecing together" was necessary for connections at the mainline,

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[34] *The homeowners finance the repair and therefore have the freedom to select the method based on their preferences. The District however requires a $35.00 inspection permit, which the District inspector looks at all connections to see if they are water tight, and the pipe is installed properly.*

cleanout, existing upper lateral and to the liner in the mainline. This meant frequent interruptions to any development of an assembly line type operation.

Cost. Sliplining is rather expensive when used in sewer laterals. In the Stege project (1987), the cost to slipline one 65’ lateral was about $16/ft or $1,050/lateral, which is equivalent of $27/ft or $1,765 in 2005 USD.

In the 1985 Berkeley project, sliplining of lower laterals was done at cost of $1,572/lateral, which is the equivalent of $2,790/lateral in 2005 dollars. For illustration, sliplining is compared with open-cut replacement within the same project showing that sliplining was cost-competitive in mainlines but not in the laterals (Table 5-4). The city acknowledged that these costs were probably not a true representation of the method cost due to the research nature of the pilot study and that the cost-effectiveness of sliplining over open-cut replacement would increase with an increased rehabilitated length of laterals.

Table 5-4. Cost of Rehabilitation in the Berkeley Pilot Project, 1985 (CDM/Jordan/Montgomery, 1985).

	Method:	Quantity:		1985 USD	2005 USD	1985 USD	2005 USD
Lower laterals:	Sliplining	150’	6 laterals	$63/ft	$112/ft	$1,572/lateral	$2,790/lateral
	Open cut	1,612’	62 laterals	$50/ft	$89/ft	$1,300/lateral	$2,307/lateral
Mainlines:	Sliplining	1,025’		$26/ft	$46/ft	-	-
	Open cut replacement	1,726’		$44/ft	$78/ft	-	-

Advantages/Disadvantages. The advantage of this method is that no special equipment or chemicals are needed, however, the disadvantages generally outweigh the advantages: the pipe diameter is unacceptably reduced, the method is time-consuming and it is not cost competitive with other rehabilitation methods.

5.3.3 Cured-in-Place (CIP) Relining

Cured-in-place (CIP) relining is a method in which a resin-saturated tube is inserted into the pipe and the resin subsequently cured creating a “pipe within a pipe”. The main components of a CIP relining system are a fabric tube and a resin, and often a plastic protective coating (Figure 5-14). The coating allows the resin impregnated tube to be handled, holds the vacuum if used during resin impregnation, protects the resin from water during installation/curing, and takes abrasion from sewage over the years when the lateral is in service. In some CIP systems, a second coating is used to encapsulate the resin and fabric so that the liner can be pulled into place rather than being inverted into place.

The method eliminates infiltration and restores or enhances the structural integrity of pipes lost over time. Hydraulic capacity of aged, deteriorated pipes is also generally improved.

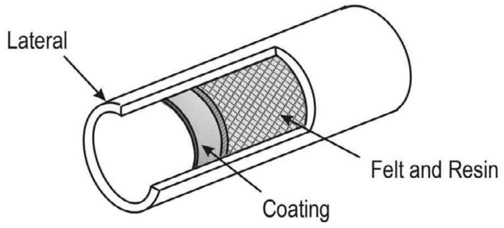

Figure 5-14. Components of the CIP Relining System.

Types of Lateral CIP Liners. There are four types of CIP relining systems installed in sewer laterals (Figure 5-15):

- Standard liners—These liners are shaped as simple tubes without any special end pieces. They are typically installed through cleanouts or small pits either in the direction towards the house or the mainline (one system from the mainline) may extend all the way to the mainline but do not cover the connection. Most systems on the market are standard liners.
- Short connection liners—These liners are shaped to cover the connection of the lateral with the mainline. They create a brim (about 3") around the lateral connection in the mainline and extend for a short distance (usually about 6") into the lateral. These liners are installed through the mainline. A short connection liner is often referred to as a "TOP HAT" after one brand name.
- Long connection liners—These liners combine standard liners with short connection liners, i.e. cover the lateral connection creating a brim in the mainline and extend into the lateral up to 25-30'. They are inverted remotely from the mainline.
- T-Liners—These liners add a full circle mainline seal (12-16") to standard CIP liners. They are also installed through the mainline.

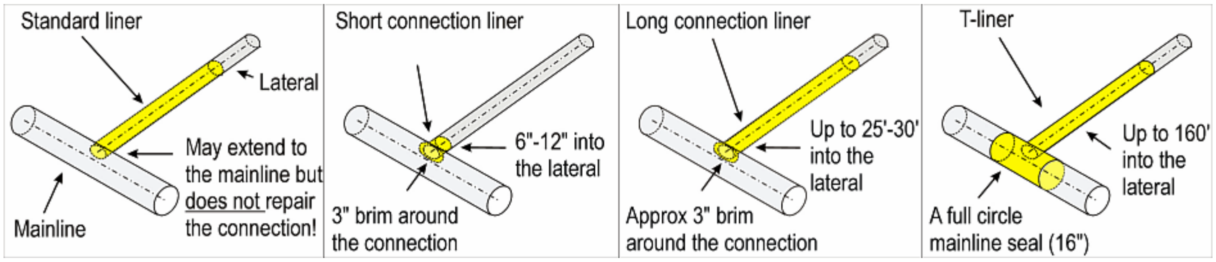

Figure 5-16. Types of Lateral CIP Relining Systems.

Lateral CIP Relining Systems on the Market. A number of systems are available on the U.S. market (Table 5-5). The authors of this report have attempted to include information on as many available lateral rehabilitation and replacement systems as possible but it is possible that some commercially available systems have been overlooked. Readers should supplement the information provided with their own search of available systems—not least because new products and systems are being continually developed to meet the growing interest and market in lateral rehabilitation and replacement. For example, a new lateral connection seal INSTA "T"™ developed by Masterliner was undergoing final testing prior to market release as this report was being finalized.

Features of CIP systems presented in this report are summarized in Table 5-5 through Table 5-7 and Table 5- 9 (based on information and data provided by the manufacturers), as well as in Appendix C. The CIP systems differ not only in type, but also in materials used for making the liners, as well as procedures in creating the final product:

- Tube material—can be one or more layers of needled felt or equivalent woven or non-woven material.
- Shape forming—the material can be made flat and stitched into tube (creating a seam), or can be manufactured as a cylinder (seamless tube). One system is inserting a sheet wrapped around a bladder with an overlap.
- Protective coating type—can be polyurethane, polyethylene (PE), or PVC.
- Position of protective coating—can be on the inside or outside of the tube, or both.

Table 5-5. CIP Relining Systems on the U.S. Market.

	Developed in	Available/Used in	Estimated Installed*	Manufacturer (in U.S.)
<u>Standard Liners</u>				
DrainLiner™	Canada, 1999	U.S., Canada		Link Pipe, Inc.
Easy Liner Cleanout; House	U.K., 1989	U.S., Europe	8,500,000’ (10,000’ U.S.)	Easy Liner, Inc
Easy Liner Junction	U.K., 2002	U.S., Europe	100,000’ (2,000’ U.S.)	Easy Liner, Inc
Formadrain®	Canada, 1994	North America		Formadrain
INFlex Liner™	Germany, 1993	Europe, Japan, U.S.		Reline America
Inserv™	U.S., 2003	U.S., Canada	>100,000’	Reynolds Inliner
Insituform® Lateral	U.K./U.S., 1986	U.S., Europe		
MasterFlex	U.S, 1996	U.S.	100s of laterals	MasterLiner Inc
MaxLiner™	Switzerland, 1995	U.S., worldwide	5,000 laterals (U.S.)	MaxLiner, LCC
PermaLateral™	U.S., 1999	U.S., worldwide		Perma Liner Indust
Primeliner™	U.S., 1999	U.S.	>100,000’	Primeline Products
Verline Lateral	U.S., 1999	U.S.	10,000’	Verline, Inc.
<u>Short Connection Liners</u>				
TOP HAT®	Austria, 1995	U.S., Europe, Australia	5,000 laterals (U.S.)	Amerik Supplies
PrimeLiner LC™	U.S., 2004	U.S.	>1,000	Primeline Products
<u>Long Connection Liners</u>				
Insituform® Lateral	U.K./U.S., 1986	U.S., Europe		Insituform Tech.
Insta T	U.S, 2004	U.S.	100s of laterals	MasterLiner Inc
<u>T-Liners</u>				
Easy Liner Saddle	U.K., 2000	U.S., Europe	4,000 laterals (500 U.S.)	Easy Liner, Inc
LMK T-Liner®	U.S., 2004	U.S., Canada, S. America		LMK Enterprises
PrimeLiner LC™		U.S.		Primeline Products

Table 5-6. CIP Relining Systems—Final Product after Installation*.

Brand	Liner Type	Length in Lateral	Length in Mainline	Flexural Modulus
DrainLiner™	Standard	≤150’	-	297,000 psi
Formadrain®	Standard	≤100’	-	1,305,000 psi
EL Cleanout, House	Standard	≤300’	-	250,000 psi
EL Junction	Standard (from mainline)	≤50’	-	250,000 psi
INFlex Liner™	Standard	≤165’	-	417,000 psi
Inserv™	Standard	≤60’	-	300,000-350,000 psi
Insituform® Lateral	Standard		-	250,000 psi
MasterFlex	Standard	≤50’	-	250,000 psi
MaxLiner™	Standard	≤200’	-	250,000 psi
PermaLateral™	Standard	≤150’	-	416,000 psi
Primeliner™	Standard	≤200’	-	1,400,000 psi
Verline Lateral	Standard	≤120’	-	750,000 psi
TOP HAT®	Short connection	6”	3” brim	800,000-1,500,000 psi
PrimeLiner LC™	Short connection	12”	3” brim	
Insituform® Lateral	Long connection	1-25’	3” brim	250,000 psi
Insta T	Long connection	5’	1.5×3” brim	250,000 psi
Easy Liner Saddle	T-liner	4-8”	12”	250,000 psi
LMK T-Liner®	T-liner	≤160’	16”	443,642 psi
PrimeLiner LC™	T-liner	12”	12”	

** Based on information received from the respective manufacturers.*

- Resin type—can be unsaturated polyester, epoxy vinyl ester, or epoxy with catalysts.
- Time of resin impregnation—can be on-site impregnated or factory pre-impregnated.
- Method of resin impregnation—can be vacuum impregnated or impregnated by hand.
- Installation—can be inverted into a lateral (under air or water pressure) or winched in.
- Resin curing—can use ambient temperature, hot water, steam, UV-light, or electricity.

The final product after installation for each system is shown in Table 5-6. With the exception of short connection liners, all other systems are typically installed over the length of the lower lateral at a minimum, or they may extend further into the upper lateral. A decision can also be made to install the liner in the upper laterals only if there is need for such repair.

The "length in lateral" shown in Table 5-6 is the maximum length of a single run for each system. If the lateral is longer, additional liner can be inserted through a different cleanout or small pit towards the end of the already installed liner slightly overlapping with the first liner. Liners other than standard also have a piece in the mainline, either a brim around the lateral connection opening in the mainline or a short mainline CIP liner.

Applicability. Existing conditions that can potentially limit the applicability of CIP liners are shown in Table 5-7. Mainline diameter is only a factor in systems installed from the mainline. Diameter transition, which is often one pipe size and at the property line, is not a problem and can be even greater. (The systems do not all handle the transition in the same way though, which is explained further later in this chapter). CIP liners can be installed though multiple bends although there is a limit in their number, especially if they are 90º bends. A large number of bends can make liner inversion difficult. Offset joints can be relined, however large offset joints will remain a pipe defect even after relining. Although the infiltration at this point is stopped, a potential for blockage remains. All systems reline cracks in the laterals that are reasonably structurally sound but some systems are also full structural liners and can bridge large missing sections in the pipe (Figure 5-16).

Figure 5-16. Liner Installed in Broken VCP Pipe Sample (Perma-Liner Industries, Inc.).

The following does not represent problem in applicability for any of the CIP systems or limits their applicability only slightly:

- Slope of pipe—all systems can be installed at any slope, even in vertical pipes,
- Type of lateral connection with the mainline—all systems can be installed if the connection is either Tee or Wye, although Tee is often easier for the systems installed from the mainline,
- Type of flow—all systems are designed for gravity flow, but only two can also be installed in force lines (PermaLateral™ and Verline Lateral),
- Sewage pH and maximum temperature of the sewage—the systems can generally handled the typical pH range and temperatures in domestic sewage. Applicable ranges provided by the manufacturers are shown in Appendix C, however, test results were not reviewed.

Table 5-7. CIP Relining Systems—Applicability*.

	Mainline Diameter	Lateral Diameter	Diameter Transition	Max Bends in Lateral	Max Offset Joint in Lateral	Cracks in Lateral	If Heavy Leaks in Lateral
DrainLiner™	N/A	4-8”	¼”	Multiple 45º	Any (sleeve)	Any (sleeve)	Preliner or ch. grout
EL Cleanout, House	N/A	2-6”	4” to 6”	Multiple 45º	10%	Yes	
Easy Liner Junction	8-15”	4-6”	4” to 6”	Multiple 45º	10%	Yes	
Formadrain®	N/A	2”-up	4” to 6”, 6” to 8”	Several 90º	2”	Any	
INFlex Liner™	N/A	3-12”		Several 90º	40%	Some	Preliner or ch. grout
Inserv™	N/A	4-6”	4” to 6”	Two 90º	5%	Any	Preliner or ch. grout
Insituform	N/A	4-6”					
Masterflex	N/A	4-6”	No			Any	
MaxLiner™	N/A	2-10”	4” to 6”, 6” to 8”, 8” to 10”	Multiple 90º	15%	Some	Preliner or ch. grout
PermaLateral ™	N/A	2-8”	4” to 6”, 6” to 8”	Several 90°	2”	Any	No action needed
Primeliner™	N/A	2-8”	4” to 6”	Several 90°	2”	Any	No action needed
Verline Lateral	N/A	4-8”	4” to 6”, 6” to 8”	N/A	20%	Any	Point repair
TOP HAT®	4-20”	4-8”	N/A		25%	Some	Chemical grout
PrimeLiner LC™	6-15”	3-6”		N/A		Any	
Insituform® Lateral	6-18”	4-6”		Multiple 90º	40%	Some	
Insta T	8-12”	4-6”	No	Multiple	25%	Any	
Easy Liner Saddle	8-15”	4-6”	N/A	N/A	10%	Some	
LMK T-Liner®	6-24”	3-6”	3” to 6”	Six 90º (soft)	25%	Some	Chemical grout

Explanations: Offset joint expressed as % means a % of lateral pipe diameter. “Any cracks” means that the liner provides full structural repair. “Some cracks” means that pipe must be reasonably structurally sound. “Any (sleeve)” means that a repair sleeve is used prior to relining to repair the defect.

** Based on information received from the respective manufacturers.*

Requirement for Excavation. The only time excavation is required is if a cleanout needs to be installed. Cleanouts on the laterals are basically always required even if the liner is installed remotely from the mainline, if not for insertion of liners then to prepare the pipe for relining i.e. for cleaning the pipe. The cleanouts used prior to or during CIP relining are most often located outside the house although sometimes cleanouts in basements can be used as well (Figure 5-17).

Figure 5-17. Cleanout in the Basement (City of Weymouth, MA).

If cleanouts are missing, small pits can be opened and cleanouts installed at the time of relining. As already mentioned, sometimes an extra cleanout may be necessary if the length to be relined is longer than the distance that can be spanned with the liner. This is probably more of an issue with long connection liners installed from the mainline, as they have a limited length. Standard CIP liners can be installed over quite long lengths.

Rehabilitation Procedure. Several case studies included in Appendix A provide details of how this method can be carried out with different systems. The repair typically involves the following steps:

- Pipe inspection and cleaning (preparatory work),
- Resin mixing and in-situ liner impregnation,
- Inversion/winching of the liner,
- Resin cure,
- Reconnection of the cured liner,
- Post-CCTV inspection.

Pipe preparation is essential for proper installation of liners. The lateral must be free of roots and debris that could hinder the inversion or winching of the liner in place. Liners that are inverted typically end up with the protective coating on the inside and the resin-impregnated surface on the outside, which allows the possibility of bonding of the liner with the host pipe during the resin cure. It is desired to eliminate the annular space between the liner and the host pipe, which is otherwise an open path for groundwater migration and can lead to new leaks after rehabilitation if defects exist anywhere along the lateral or its connection to the mainline. However, the possibility of bonding depends on the cleanliness of the pipe and the amount of shrinkage of the liner after curing. Standard cleaning techniques (most often water jetting) have a limited ability to clean the lateral from grease thoroughly and hence the annular space is rarely completely eliminated and bonding is rarely achieved.

If there are active leaks in the lateral before the liner inversion, many lining systems overcome them by using a preliner, which is a fiber-reinforced plastic tube that acts as a water barrier between the liner and the host pipe. The preliner is inverted into the pipe first, and the CIP liner is inverted inside the preliner next using the same inversion equipment (Figure 5-18). Thus, the preliner becomes an integral part of the CIP liner after the rehabilitation is complete. The liner is inverted into the preliner preventing water from diluting the resin in the liner material. There are other alternatives for dealing with heavy leaks as well. If the leak is under significant head pressure, it can be grouted using a packer and a chemical grout. One system recommends the use of a drain repair sleeve if the pipe is structurally damaged or infiltrating (Figure 5-19). The sleeve can be passed through three or more 90° elbows and is very easily passed through cleanouts.

Figure 5-18. Inversion of Preliner (Link Pipe, Inc.).

Figure 5-19. Drain Repair Sleeve Next to and Passing through 90° Elbows (Link Pipe Inc.).

For installing the CIP liner, the lateral pipe must be first flow isolated. Flow bypassing is generally not necessary because the homeowners are out of service for only a few hours (duration of relining depends mostly on the type of resin cure). The steps in the installation procedure described below can be performed slightly differently in different CIP relining systems.

Resin mixing and impregnating—Most CIP systems have a liner that is vacuum impregnated with the resin on the site (Figure 5-20). The liner tube is cut to fit the length of the lateral and all air from the liner tube is removed with the vacuum pump. The resin is prepared by thoroughly mixing the components (a drill with a mixer attachment can be used) and the mixture poured into the liner tube. The vacuum pump is used to spread the resin along the liner tube. For even distribution of the resin in the liner tube, calibration rollers set to match the liner wall thickness are usually used. An alternative is to roll a pipe or other roller along the liner to disperse the resin as evenly as possible. During hot weather, if thermo-setting resin is used, the liner may need to be placed in cold water with ice after the wet-out is complete to slow the curing of the resin and allow the installation crew extra time before the inversion.

Figure 5-20. Resin Impregnating. Left to Right: Pouring the Resin into the Tube; Manual Resin Spreading Inside the Tube (MaxLiner LCC). Vacuum Impregnation (Easy Liner, Inc.); Calibration Rollers (MaxLiner LCC).

Inversion/winching of the resin-impregnated liner into the lateral pipe—For inverting the resin-saturated liner through a cleanout or a small pit, an inversion drum is usually used. The liner is loaded into the drum and from it inverted into the lateral pipe (Figure 5-21—Left). The inversion drum may have a bladder that extends out of the drum and “swallows” the liner inside the bladder, which is followed by inverting both the liner and the bladder into the pipe (Figure 5-22). However, if the liner is installed by winching, a bladder is inserted into the resin-saturated liner and the liner fixed onto the bladder firmly with tape (Figure 5-21-Middle). This creates an integral bladder/liner assembly, which is carried to the entry pit and from there pulled inside the pipe.

Figure 5-21. Left: Inversion Drum (Easy Liner Inc). Middle: Preparation for Insertion by Winching (Mar-Tech Underground Services Ltd). Right: Device for Inversion of Long Connection Liner (MasterLiner Inc).

Figure 5-22. Loading of Inversion Drum with Bladder. Left: Extending the Bladder Out from the Drum. Middle Two: Feeding the Liner into the Bladder and Retrieving the Bladder inside the Drum. Right: Liner End Clamped to Invert "Inside-out" (Verline, Inc).

For inverting the resin-saturated liner remotely from a mainline, a special inversion device is used (Figure 5-21—Right). Generally speaking, the liner is loaded into the device above the ground, the device winched through the mainline and positioned at the lateral connection, and the liner is inverted from the device into the lateral. The procedure is performed in two phases, each phase involving four steps as follows (Figure 5-23):

- Step 1-1: The inversion device is laid out on the ground.
- Step 1-2: The inversion bladder is inflated and inverted through the lateral liner.
- Step 1-3: The bladder is retracted tucking in the liner into the inversion device.
- Step 1-4: The liner and bladder are completely inverted (only the liner brim is exposed).
- Step 2-1: The assembly is winched through trough the mainline.
- Step 2-2: The assembly is rotated to align its opening with the lateral.
- Step 2-3: Mainline and inversion bladders are inflated, the liner inverted and cured.
- Step 2-4: Inversion bladder is retracted, and the device pulled out of the mainline.

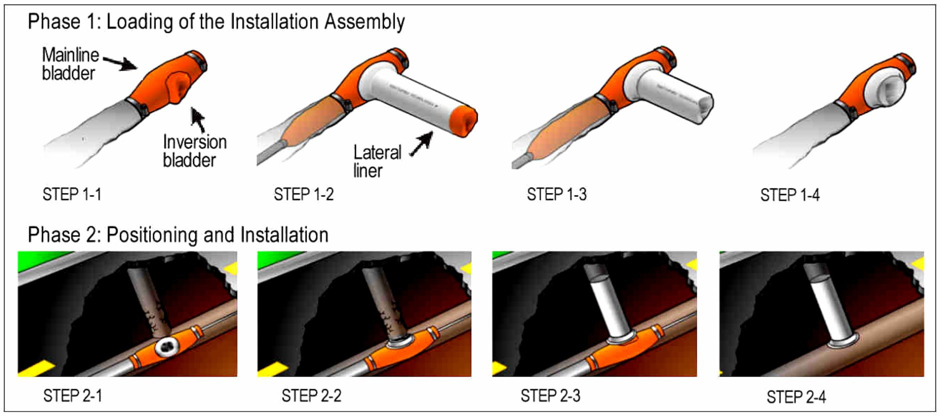

Figure 5-23. Installation of the Liner from the Mainline (Insituform Technologies, Inc).

Resin curing—The resins usually cure at ambient temperature or heat is applied to accelerate the curing process (steam or hot water). Some systems use a UV light cure. Special light initiators in the resin react to UV light at specific wavelengths. The UV-light cure liners can be resin impregnated on site or come factory pre-impregnated (packed in UV-light-proof external foil, they can be stored for a long periods of time, e.g. months). A mobile light source contains several UV lamps (Figure 5-24), which must operate at steady radiation intensity during the service life (wavelength range of 360-420 nm) and be optimally placed in the liner during the curing process so that the liner is evenly lit even with varying channel diameters and line profiles. The advantage of these liners is that the curing process is very fast, e.g. curing speeds of up to 150 cm/min (5 ft/min) are possible.

One system uses electricity to cure the resin, i.e. electrically heated bladders or heating elements in the lining material. The cure typically takes one to two hours.

Figure 5-24. Mobile Light Source for UV-light Curing (Reline America).

Duration of Repair and Productivity. Duration of repair depends mostly on the type of resin cure and the number of laterals being repaired in the area. Another important factor is the extent of preparatory work required (e.g. cleaning, root cutting, any spot repairs, cutting off protruding laterals within the mainline, etc.).

Assuming a "typical" 50' long lateral with moderate root intrusion, it usually takes two to five hours per lateral for a single lateral to be relined with heat-accelerated resin cure (ambient cure extends it for an additional several hours), or two to three hours per lateral if multiple laterals are being relined. On average, three to four laterals can be completed in one working day. This assumes that the laterals are close by, cleanouts are accessible, and the crew is experienced and well organized. Table 5-9 shows the approximate duration of lateral relining for different CIP systems including pipe cleaning.

Cost. Lateral lining cost is based upon site specific and project specific factors. The laterals are unique in their construction and access requirements and, because of the small diameter, are more difficult to prepare for lining than mainlines. The density of laterals on the mainline (between two manholes) determines the frequency of setting up the lateral equipment. Low service density inflates the average unit price because the longer setup times decrease production rates and limit the crew efficiency. The length of laterals usually does not affect the cost significantly.

On average, the cost of CIP relining is approximately $3,500-5,000 per lateral, which includes the preparatory work (cleaning of moderate roots in the pipe) and CCTV inspection, but this can go up and down quite significantly as explained in the previous paragraph. Table 5-9 shows the cost of repairing one lateral for different CIP systems, assuming a "typical" 50' long lateral with moderate root intrusion. For illustration, Table 5-8 summarizes the average cost per lateral from the case studies included in Appendix A.

Table 5-8. Cost of CIP Relining of Laterals (Source: Case Studies in Appendix A).

Location	Laterals Relined	CIP (Material and Labor)	Total Project Cost	System Used
Tacoma, WA (2003)	69	$900/lateral	$1,110/lateral (w CCTV)	PermaLateral ™
Nashville, TN (1991)	67	$1,925/lateral		Insituform® Later
Weymouth, MA (2003)	2	$6,500/lateral	$7,500/lateral (w cleaning, CCTV)	MaxLiner™
W. Vancouver, Canada (2003)	16	CAN $2,260/lateral	CAN $4,900/lateral (mobili, cleaning, CCTV)	Custom built

Installation Features of CIP Relining Systems on the Market. Table 5-9 summarizes some features of these systems related to installation.

Table 5-9. CIP Relining Systems—Installation Features*.

	Impregnation with Resin	Access into Lateral	Liner Inversion	Resin Cure	Approx Duration (Single Lateral)	Productivity (8-Hr Day)	Approx Cost (50' lateral)
DrainLiner™	On site	CO	Air	Ambient, hot water	1-2 hr	3-4 laterals	Confidential
INFlex Liner™	On site	CO	Air, water	Ambient, hot water, UV light		≤8 laterals	$750-2,500
Formadrain®	On site	CO	Winching	Steam	3-4 hr	1-2 laterals	$3,500- 6,250
Inserv™	Factory	CO	Air	Steam, hot water	4 hr	3-4 laterals	$3,000-3,200
MaxLiner™	On site	CO	Air	Ambient, hot water	3-4 hr	≤4 laterals	$3,500-5,000
PermaLateral ™	On site	CO	Air	Ambient	3 hr	3-7 laterals	$3,750-7,500
Primeliner™	On site	CO	Air	Ambient, hot water	2-3 hr	5-6 laterals	$750-2,500
Verline Lateral	Factory	CO	Air	Electricity	2 hr	5-6 laterals	$2,000-3,750
TOP HAT®	Factory	Main	N/A	UV light	45 min	≤10 connections	$800-1,200
PrimeLiner LC™	On site	Main	N/A	Ambient	1.5-5 hr	4-5 connections	$500-1,000
Insituform® Lateral	On site	Main, CO	Air	Ambient, hot water, steam	3-5 hr	3+ laterals	$1,500-4,000
LMK T-Liner ®	On site	Main	Air	Ambient, steam	3-4 hr	10 laterals	$3,500

Explanations: "Approximate Cost" range is given assuming a 50' long lateral in different site conditions.
"CO" indicates access through a cleanout or a small pit.

** Based on information received from the respective manufacturers.*

Wrinkling and Thickness of Installed Liner. Lateral CIP liners are typically installed through multiple vertical and horizontal bends, and some liners negotiate even 90° bends. In sharp 90° bends, the length of liner on the inside radius (R1) and the outside radius (R2) of the bend can be notably different[35] (Figure 5-25). The CIP liners typically wrinkle in such sharp bends in small diameter pipes, although with flexible and stretchable liners, these wrinkles are minimized (not exceeding $^{1}/_{8}$∀).

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[35] *For instance, a 90° bend with short bending radius R=5.75" in a 4" pipe is an example of a severe sharp bend used sometimes where the sewer lateral changes from horizontal to vertical direction. The liner length in such bend is about 6"on the inside radius and 12" on the outside radius.*

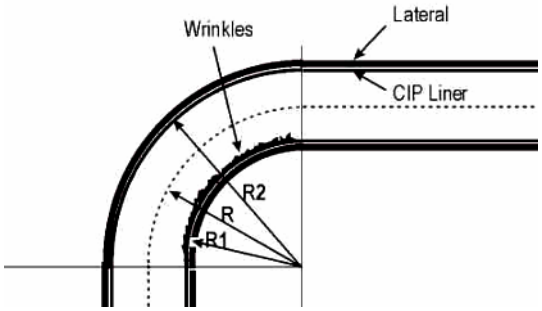

Figure 5-25. Wrinkles in the Lateral CIP Liner Installed through a 90° Bend.

Another "problem" location in the pipe for CIP laterals is a point of diameter transition[36] (Figure 5-26). The liner can be made from two pieces (matching each diameter exactly) that are stitched or butt-fused together, or can be made as a one-piece liner that will typically both stretch (and thin out) a little in the larger diameter, and compact (and thicken) in the smaller diameter. Thinning out of the liner happens in the lower lateral, which is also the deepest part of the lateral, where the hydrostatic pressure from the groundwater is the largest. If the mainline is very deep, it may be necessary to calculate if the liner still provides the structural repair as designed. In the smaller diameter, liner wrinkling can be an issue. The appearance of the wrinkles depends on the ability of the liner to be compressed.

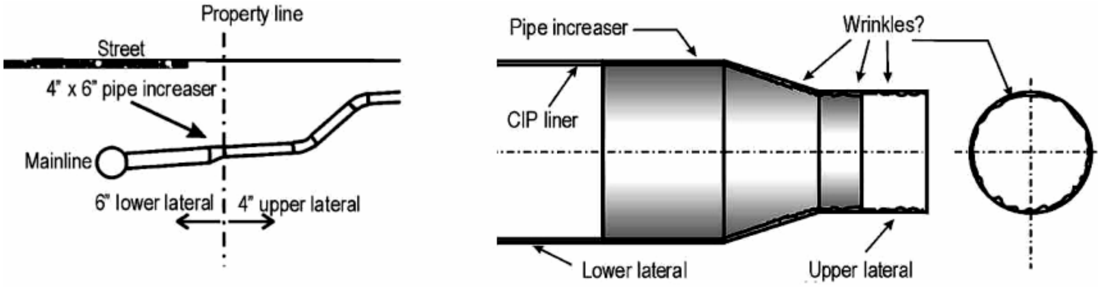

Figure 5-26. Lateral CIP Liner Installed through Diameter Transition. Left: Location of Diameter Transition Is Usually at the Property Line. Right: Wrinkles at Diameter Transition.

Overall, knitted or woven type liner tubes are more stretchable than non-woven needled polyester felt materials, and they tend to better conform to the bends in pipe and the diameter changes. However, the downside to this stretchiness is not only the change in liner thickness but also the shrinking of the void space that holds the resin. It is hard for the resin to stay in the tube where the void space is severely reduced and "dry" spots may appear. The "dry" spots manifest as splotchy areas with noticeably lighter color and indicate areas where the resin may have been lost during the installation and where the liner would not remain watertight for a very long time nor it would be able to carry significant groundwater pressure.

Longitudinal wrinkles or "dry" spots can be created if the inversion is performed under pressure below a certain minimum installation pressure or in significant excess of the recommended installation pressure (these values are given by the manufacturers).

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[36] *If the diameter of the lateral changes along the lateral, the transition point is typically located near the building foundation or at the property line. Diameter change is usually of one pipe size i.e. 4" to 6", 6" to 8", or 8" to 10".*

When the lateral being lined is below the groundwater table, the recommended installation pressure must be adjusted accordingly[37] (Kampbell, 2004). The pressure can come from either pressurized steam or heated water. Namely, ambient cure resin systems typically do not generate enough heat to fuel the resin to a complete cure when there is water present in the ground, and, in these installations, re-circulated hot water or steam is necessary to continue the curing past the energy provided in the exothermic reaction of the resin itself. One cautionary note on laterals is that they can be on a very steep grade and the weight of the water itself can add significantly to the head at the remote end of the lateral. This can cause the liner to give up an unacceptable amount of resin at the end.

Owing to the lack of access to installed liners, the finished thickness of the liner can only be estimated from the applied installation pressures and the manufacturer's data on installation pressures/finished thickness relationship. Post-relining CCTV inspection can only establish if the new lateral liner has been properly fit to the host lateral and can identify any dry spots, lifts, or spots where the hydrostatic forces caused the liner to reverse curvature.

Lateral-to-Mainline Connection. This connection is often the "weak link" allowing infiltration of groundwater into the sewer systems. Short connection liners (TOP HAT™) can be applied after mainline CIP relining or after lateral relining with a standard CIP liner to connect the two liners. They extend for a short distance into the lateral and create a brim in the mainline (Figure 5-27). TOP HAT™ liners bond with the pipe surface or any CIP liner already in the pipe, and rely on the adhesion of this bond. Therefore surface preparation is extremely important for the quality of installation.

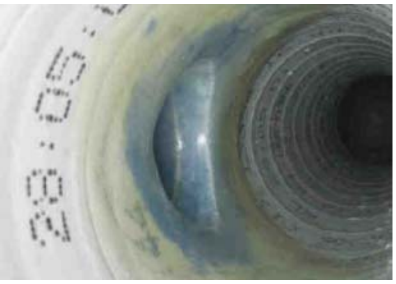

Figure 5-27. TOP HAT™ Installed (Amerik Supplies).

T-liners are intended to further protect against the infiltration at this location. They have a full-circle mainline seal factory welded to a lateral liner to become a one-piece liner. They may bond with the host pipe and/or mainline CIP liner, however they do not rely on the bonding, as the liner can stand by itself in the pipe. For sealing in the absence of a complete bond, hydrophilic rubber bands that fit between the mainline liner and the short mainline portion of the T-liner can be used (Figure 5-28). Two bands are installed on each side of the connection. These hydrophilic bands are designed to swell in the presence of water up to eight times their original thickness. This swelling action provides equal force around the entire circumference of the mainline liner. The key to water-tightness is the fact that adhesion is not a factor—the bands will make a seal to any type of material including polyethylene as well as greasy surfaces typically found in any collection system.

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[37] *For every one foot of groundwater over the flowline of the lateral, the internal pressure of the uncured liner must be increased by that same amount.*

Figure 5-28. T-Liner® Installed—Cut Away Showing the 16" Mainline Seal and Hydrophilic Bands (LMK Enterprises Inc).

Structural Integrity. For calculating the required wall thickness of the liner, two standards are used in the U.S.: ASTM F1216 (Appendix X1.2) and AWWA C-950, and the minimum wall thickness has to exceed the requirements of the selected standard. For relining of sewer laterals, design formulae are usually applied for selected laterals only to either calculate the required thickness for those laterals or verify the thickness recommended by the manufacturers.

The manufacturers recommend the nominal wall thickness (one or several thickesses) based on design calculations for "typical" site conditions and experience from practice. This recommendation may be based on the pipe diameter, for example, 3.0 mm for 3-4" pipe diameters, and 4.5 mm for 5–6" pipe diameters (LMK Performance T-Liner).

Some manufacturers have developed proprietary software for liner wall thickness design that can be used for design of both mainline and lateral liners and this software may be available for use on the manufacturer's website.

Hydraulic Capacity. Although the original pipe diameter is reduced after relining due to the liner thickness, the hydraulic capacity of a relined pipe is generally improved due to reduced surface roughness. A Manning coefficient of n = 0.010 has been determined in hydraulic laboratory testing of some liners[38] and generally is quoted by manufacturers for all CIP liners. For illustration, Table 5-10 shows the improvement in flow capacity when a VCP host pipe with initial Manning coefficient n=0.013 is relined with CIP liners (various liner thicknesses) having n=0.010.

Table 5-10. Lateral CIP Liner: Change in Flow Capacity (Host Pipe: VCP, n = 0.013).

Host Pipe ID	Host Pipe n	Liner Thickness	ID After Relining	CIP Liner n	Change in Flow Capacity After Relining
3"	0.013	3.0 mm	2.76"	0.010	104.5 %
4"	0.013	3.0 mm	3.76"	0.010	110.5 %
4"	0.013	4.5 mm	3.65"	0.010	101.5 %
6"	0.013	3.0 mm	5.76"	0.010	116.8 %
6"	0.013	4.5 mm	5.65"	0.010	110.5 %
6"	0.013	5.0 mm	5.61"	0.010	108.5 %
8"	0.013	3.0 mm	7.76"	0.010	120.0 %

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[38] *One testing of flow capacity of CIP liners that determined Manning coefficient, for example, was carried out for Insituform CIP liners by Sverdrup Corp and Southeast Environmental Service in 1990. (http://www.insituform.com/resourceroom.)*

The 0.010 value, however, does not consider the long-term effect of the liner exposure to flowing sewage, which can alter the surface roughness of the material in time. Different materials in different relining systems also may suffer surface wear. Typically, the liner protective coating ends up as the inside layer after the liner installation and that can be, depending on the lining system, a layer of polyurethane, polyethylene, PVC, or a special blend developed to improve the coating's performance.

In the absence of any published long-term data on the n value for installed liners, some agencies accept n=0.012 to be on the safe side[39]. Some agencies are not concerned about the Manning coefficient in sewer laterals because the flow through these pipes is typically small and the hydraulic capacity is rarely an issue.

Longevity of Repair. The design life for CIP liners is typically estimated to be 50 years or more (based on extrapolation from 10,000-hour testing and the approximately 30 years of CIP liner field installations), and many believe that the useful life of relined laterals will exceed the calculated design life. At this time, published data specific to the diameters, thicknesses and liner configurations for lateral systems is not known to be available, nor have the liners been installed in the laterals long enough to verify the 50-yr life expectation. On the positive side, however, the majority of the length of laterals are often at a shallow depth and above the water table except during wet periods. Also, the small liner radii provide a good resistance against liner buckling failures unless the liner is designed with too small a thickness.

In Nashville and Davidson County, TN, the oldest lateral CIP liners have been in the ground since December 1992 (almost 13 years). Over the years, several different CIP relining systems were used and they all have shown some long-term warranty/construction issues with time. Some of the laterals installed in early and mid 1990s have a small percentage of defects in incidental reviews (<5%). The agency expects that, overall, the liners will meet their 50-year life expectation but it is not sure about any extended expectation of liner lifetime. (Ballard, 2005; Stonecipher, 2005)

Evaluation of Lateral CIP Relining in King County, WA. An in-depth evaluation of selected CIP liners was done by King County, WA (King County, 2005), where short connection liners and T-liners were tested in several pilot projects (Table 5-11).

Table 5-11. Evaluation of CIP Liners in Pilot Projects in King County, WA.

System	Project	Year	Laterals Repaired	Location/Length Repaired
TOP HAT®	Lake Forest Park I/I Pilot Project	2003	2	Connection extending 4" up the lateral
	Mercer Island I/I Pilot Project	2003	225	
	Redmond I/I Pilot Project	2003	20	
	Brier I/I Pilot Project	2003	19	
		Total:	226	
LMK T-Liner®	Kent I/I Pilot Project	2003	20	Lower laterals/lateral up to 35' in length

Evaluation of TOP HATS™—Installation of TOP HATS™ was generally shown to be a smooth process with good production rates. The quality of preparation work was critical. Because the general contractor did the preparation work, there were a few conflicts when the TOP HAT™ installer started work. However, the TOP HAT™ crew was well prepared to clean up

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[39] *E.g. City of Santa Monica, CA (Chusid, 2005)*

any problem openings (although this was apparently not in their contract with the general contractor).

Most of the TOP HATS™ appeared to adhere well to the host pipe. Failures did occur when the TOP HAT™ did not seal the connection or did not adhere to the host pipe (which usually contained a liner). Surface preparation of the inverted liner to facilitate adhesion of the TOP HAT™ was discussed with the manufacturer. In addition, the TOP HAT™ extended only 4” up the lateral, which was not far enough to cover the first joint in the lateral. The designers thought that a TOP HAT™ would cover the first joint up the lateral, though this was rarely the case.

For mainlines larger than 12” in diameter, use of a TOP HAT™ robot was required. Equipment for installation was located at the manholes. One truck contained all the following equipment: TOP HAT ™ robot with internal camera and UV-lighting system, external CCTV camera, air compressor, lateral cutter/grinder unit for root cutting and lateral cleaning, small generator, and two-way radios. The process also required the use of a jet cleaner truck.

The crew installed 10-16 TOP HATS™ per day. This did not include cutting and brushing the CIPP, which was done by the sewer main CIPP crew. Installation time for TOP HATS™ depended on the quality of the lateral cutting and brushing work. Any additional work needed to prepare the connection could cut production roughly in half. For example, in Lake Forest Park, crews needed to remove resin slugs in the side lateral before the TOP HATS™ could be installed. In Mercer Island and Lake Forest Park, TOP HAT™ production was on the high end because almost every connection received a TOP HAT™. In Redmond and Brier, fewer TOP HATS™ were installed and they were spread out over a greater area—necessitating more setups.

Field QA/QC involved timing the UV-light exposure, watching the bladder pressure, and visual inspection via attached cameras. No other in-place testing was possible.

The agency identified pros/cons for TOP HAT™ as shown in Table 5-12.

Table 5-12. Pros/Cons for TOP HAT® in King County, WA.

Pros	◆ The product seals the void between the sewer main CIPP and the host pipe. ◆ A fairly high production rate can be achieved with an experienced crew. ◆ There is minimal impact to customers. The lateral is plugged for less than 15 minutes.
Cons	◆ This is a relatively new product so there is a limited pool of qualified contractors. There were no local qualified contractors, so a single contractor was mobilized from out of state for all projects. ◆ The TOP HATS™ were not likely to seal the first joint up the lateral. Failure to adequately seal against the lateral or the joint may allow future leaks. ◆ The TOP HAT™ relies mainly on adhesion and secondarily on a mechanical “lock” into the defective connection. Adhesion between the TOP HAT™ and the CIPP has not been tested. To date, it appears that testing has been done only for adhesion to the host pipe. ◆ There is no way to test a TOP HAT™ after installation. Leaks are visible only when I/I is present and a CCTV catches it on film. ◆ The costs ranged from $1,200-2,000 per connection.

Evaluation of T-Liners®—Installation of T-liners required a surface preparation that involved pulling a high-pressure spray head through the pipe to remove debris attached to the walls and solids in the bottom of the pipe. In Kent, root removal became a large part of the work.

Root removal was necessary to allow a camera to examine the pipe and to install a liner through the pipe. Excavation and replacement of a bad section of pipe was sometimes needed.

The laterals were relined remotely from within the sewer mainline. The contractor needed access to the manholes at each end of the sewer mainline and at a cleanout located near the building. Cleanouts were installed if they did not exist. The required trucks and equipment were located at the manholes. A CCTV push camera was located at the cleanout. The image from the push camera was visible on a TV screen at each manhole. The trailer contained the wet-out materials and most of the equipment. Equipment included: a fifth-wheel trailer for wet-out of the liner and storage of materials and tools, steam generator equipment mounted in a pickup truck, T-Liner® launch tube with lay-flat hose, remote reel for winching launch tube in place, CCTV camera truck, CCTV push camera, wheelbarrow air compressor, small generators, and two-way radios. The process also required the use of a jet cleaner truck.

The rate of production of T-Liners® depended upon the number of liners installed in each manhole-to-manhole setup. A set up for T-Liner® installation required a truck with a winch located at one manhole and another truck with liner inflation and curing equipment at the other manhole in a segment of sewer. A cable needed to be installed from one manhole to the other to winch the T-Liner® installation equipment into place. There was a setup time required each time the trucks had to move to a new location, which reduced the overall production rate in terms of T-Liners® installed per day.

T-Liner® installation time also depends on the skill level of the operators and whether or not steam was used for curing. Heat accelerates the rate of cure. In Kent, the crew installed about two T-Liners® per day using an ambient temperature cure. Ambient temperature curing took about three hours per T-Liner®. In Redmond, the manufacturer's crew typically installed four T-Liners® per night. This crew used steam for the curing process, which meant the cure took only half an hour. Overall production might have been higher except for the fact that the work was done at night and installation locations were spread out over a large area, necessitating more setups.

The length of a T-Liner® installed in any of the pilot projects was between 5' and 35', although the manufacturer stated that T-Liners® are designed to extend as far as 80'.

Field QA/QC involved timing the wet-out and curing processes, watching the bladder pressure, monitoring steam temperature, and visual inspection using both the CCTV cameras. Based on the post-construction CCTV video, the liners in Redmond and Kent were installed properly with a minimal amount of wrinkling. The only problem noted was that on one T-Liner®, the portion of the liner inside the sewer mainline did not seal. It flapped loose and partially blocked flow in the mainline. The repair involved placing two spot repair liners on the ends of the T-Liner® while avoiding covering the connection opening.

Overall, the CIPP lateral relining with T-Liner® was of good quality. However, after approximately 20 houses received a liner in the Kent project, King County and the general contractor determined that the low production rate, root problems, and the complexity of the piping made CIPP an inefficient method of completing this work. The remaining side sewers were rehabilitated by pipe bursting.

The agency identified pros/cons for LMK T-Liners® as shown in Table 5-13, however, most apply to other CIP liners as well.

Table 5-13. Pros/Cons for LMK T-Liner® in King County, WA.

Pros	◆ The only time excavation is required is if a cleanout needs to be installed. ◆ Steam curing takes less time than ambient curing. Impact on the property owner is usually limited to one or two partial days of work. ◆ There is very limited potential conflict with other buried utilities, caving soils, dewatering, etc. ◆ Long lengths of pipe, up to 80', may be lined. It may be possible to line longer lengths of pipe as the technology improves.
Cons	◆ The pool of qualified contractors is limited. For the pilot projects, there were no local (Washington State) qualified contractors, so a contractor mobilized from out of state. ◆ A T-Liner® slightly reduces the inside pipe diameter. In a 4" diameter pipe, this may be a significant decrease, especially if the liner becomes wrinkled during installation. ◆ A T-Liner® does not allow upsizing of the pipe, as is possible with pipe bursting and with open excavation and pipe replacement. ◆ When the current technology is used for pipes longer than 80', the section of pipe beyond 80' requires some other type of rehabilitation work. ◆ Roots need to be removed. Roots could be a future problem if they migrate into a void between the liner and host pipe. ◆ The CIPP will not remove sags or curves in the existing pipe. Larger defects such as offset joints and out-of-round pipes are apparent through the finished liner. ◆ Installation of liners in branched laterals is complex ◆ T-Liners® may go smoothly through a 45° bend, but 90° bends and Wye fittings make installation more difficult. Reducers may also present installation issues. ◆ CIPP is fairly thin in comparison to an HDPE pipe; therefore, CIPP may be more susceptible to holes and there may be more wear and tear by maintenance equipment. ◆ Chemicals used (resins and solvents) may be hazardous if spilled or splashed on the skin or in the eyes. The crews used disposable overalls, gloves, and safety glasses when working with these chemicals. No hazard remains once the material cures.

Experience with Lateral CIP Relining in Nashville, TN. The Nashville and Davidson County, TN, has been using three systems for CIP relining of lower laterals: Insituform® Lateral since 1994, Inserv™ since 1996, and LMK T-Liner® since 1997 (Stonecipher, 2005; Ballard, 2005). All three systems have refined the installation over time with many upgrades and "improved versions" and are significantly improved from the time of introduction in terms of quality, production rate, cost, seal effectiveness and appearance. The experience with all three systems showed that pipe configuration and condition, e.g. size transitions, severe bends, massive roots, collapsed pipe, etc. limit the applicability of trenchless lateral relining, and although trenchless lateral relining is not always possible, most often it can be done with a special crew effort. The insertion through the mainline or cleanout has advantages over the plain end installation (pit excavation), and the placement of a cleanout is imperative.

Each system has issues occasionally with wrinkles in bends (inside curve) and size transitions. Wrinkle size may be from barely visible to 0.5". Most have been tolerated but the agency hopes for an industry improvement in this regard.

All systems are CCTV viewed after installation and included in the full segment air testing for final acceptance. Generally three to five liners are the normal daily production rate.

The costs now typically fall into a relatively narrow range of $3,500-4,500 per lateral, with LMK T-Liner® at the upper end of the range due to the 360° mainline wrap.

The agency reports that while they feel that LMK T-Liner® may theoretically offer a better seal than other systems, it does have some drawbacks in their application environment. The fact that the specialist installer of this system is a subcontractor to the prime contractor means that scheduling/scope often provides issues to progress. It is also a little more costly. The agency prefers to let market conditions govern the selection of system especially because most of time they feel that other lateral liners have demonstrated success and they do not have the justification to specify a single system limiting competitive pricing.

In summary, the agency is very pleased with all three systems. They are an important "tool" in achieving I/I reduction and without them the I/I reduction effectiveness in Nashville would be significantly lower.

Experience with Lateral CIP Relining in Some Other Agencies. The Prince William Service Authority, VA has relined 20 laterals with LMK T-Liner® in 2004. The project is described in detail in Appendix A. Overall, it took three hours on average to reline each lateral, and the crew could replace two laterals per day. The project went generally smoothly and despite some challenges was very beneficial. The major challenges were the poor condition of the Orangeburg laterals, obtaining permission from all homeowners prior to beginning work, and conforming Vac-a-Tee saddles properly to cast iron pipes (this issue has since been addressed by the manufacturer) (French, 2005).

Boston Water & Sewer Commission, MA has rehabilitated 21 sewer laterals in 1999 as part of a Charlestown Navy Yard Project using LMK T-Liner® (McSweeney Woodfall and Oliveira, 2000; McSweeney Woodfall, 2005). This project was unique and complex because of the issues associated with the tide. In most laterals, the liner was installed up to 20' into the lateral (they were generally 6" in diameter), but at a few locations the liner length had to be extended because the lateral depth at 20' from the mainline was still tidally influenced. In several other laterals that were selected for relining, however, the liners could not be installed. Some of these laterals had extensive bends. One example is a very deep, 40' long lateral laid parallel with the mainline at its lower end and then turning 90° towards the building. Other laterals that were not relined did not rise above the high tide mark until they entered the building, which exceeded the maximum length of the liner installation. The laterals that were not relined were excavated and replaced, however, some were also challenging to excavate. Overall, the LMK T-Liner® was a comprehensive repair to the lateral problems with the tidal infiltration. The system provided a watertight seal and reduced the volume of water introduced twice a day during the high tide cycle.

The City of Tacoma, WA has relined 69 upper laterals in 2003 and an additional 229 laterals in 2004 with PermaLateral™. The 2003 project is described in detail in Appendix A. The system was easy to use and a crew of three was able to reline two sites a day. The resins were found to be quite temperature sensitive—so in hot or cold weather the correct accelerator was needed to allow for adequate time to install the liner. Overall, the city is very happy with the completed rehabilitation work (Rossi, 2005).

Louisville and Jefferson County, KY, has relined 405 laterals in 2004/05 with PermaLateral™. The CIPP method is in general considered a great option compared to the old open cut replacement because it saves money and time, and streets, driveways and sidewalks are cut less. The county has found the process quite basic, but with each step needing to be watched carefully. Weather is of the biggest hurdles to work through. One big issue has been changing in-house mentalities, at a city run, union company. Some people are still afraid of the process, as well as being put out of work. Overall, the city reports that it is now hard to imagine life without the CIP lining process (Vessels, 2005).

The City of Dunedin, FL, has been using PermaLateral™ since June 2004, completing 24 laterals in 2004 and 29 laterals in 2005. The initial training was very good and the entire crew felt very comfortable at the end of the third day. The crew had, and still has, a few questions/concerns at times, but support by phone has been very good. A few problems/concerns were related to the prolonged cure times—first when the weather got a little cold, and another time when the crew forgot to pre-mix the "B" component before adding it to the "A" component (although the instruction was written right on the bucket). The city reports that this lateral lining system allows effective and efficient repair of a sewer lateral through one small access hole (approx. 3'×3'×3') with virtually no other visible or physical change to the surrounding area. In the past, there was no other choice but to close roads, detour traffic and use conventional "dig and replace" techniques with trenches often 5-12' deep. The city would like to install more of these liners but currently has only a seven-man crew that handles residential blockages, manhole repairs, field locates, lateral mini-scouting, and mainline repairs/installations. (Parris, 2005)

The Village of Brown Deer, WI, a suburb of Milwaukee, WI, relined 55 laterals in 2002 using PermaLateral™. Three liners have failed since, which is not considered a big failure rate (5%) according to the agency. The first failure was discovered a year later while a plumber was cleaning the lateral due to a backup, and two other in 2005 during CCTV inspection by the agency's crew. In all three cases, the liner had collapsed remaining loosely installed in the pipe. Two homes did not observe any problems in the functioning of the lateral. The cause of the failures was the fact that the liners did not cure properly. Ambient temperature cure was used and it is thought that the cure time while maintaining pressure was not long enough. The laterals in this project were fairly deep, on average about 10-12' at the mainline connection and close to 9' near the house (because of basements), and the ground temperature at that depth was in the low 50°s. The installer was before that time used to installing liners in warmer climates and ground temperatures and did not estimate the required time for cure correctly. Such curing time/curing condition problems are possible for any CIP system and show that ambient cured CIP liners in general are susceptible to ground temperature variation with depth and that their success very much depends on experience of installers. (Neitzel, 2005)

The City of San Diego, CA, has relined 850 laterals between 2002 and 2004 using MaxLiner™. The relining was successful in the majority of laterals. In laterals with many bends, the liner would have some wrinkles, especially at 45° bends. This agency has installed a total of 2,613 TOP HATS™ (extending 4-6" into the lateral) and a total of 900 Insituform® Laterals (extending 6" into the lateral) in the same period. The city reports that both were found to be very good products. Post installation photographs show a very good condition of these short connection liners, and a warranty video inspection conducted a year after installation showed no defects or deterioration. (Sherry, 2005)

Two agencies have used the Verline Lateral system in the past several years (this system cures the resin with electrically produced heat). Rice University in Houston, TX, used this system to reline downspouts in one building (Lovett Hall, a 1912 vintage building has downspouts built into the 2' thick exterior brick walls). The University was looking for a technology that could reline these pipes with minimal disturbance to the occupants and the structure. In 2001, a total of 12 vertical pipes, which were 5" in diameter and on average 50-60' long, were relined with Verline Lateral. The liner reduced the cross-section by ½-¾". The project was done in a relatively short duration. The system was used again in 2003 to reline 200' of 6" storm drainpipe. In both projects, accessibility to both ends of relined pipe was required. There were difficulties in cutting a hole for the Y elbow in the pipe, and the agency recommends that all elbows should be exposed so that either a new elbow can be installed or to enable the installer to cut out the resulting blockage across the second leg of the Y elbow. In addition, the system application in this case did not include any pipe smoothing out prior to relining. All protrusions or blockages in the original pipe remain as obstructions in the relined—buried under the installed liner. The cost was of these projects was equal to pipe removal and replacement. (Amery, 2005)

The Federal Reserve Bank of New York also used the Verline Lateral system in a small pilot project in 2004 to reline four downspout pipes, which were 4" in diameter and approx 50' long. The installation was easy and quick and the installed product has been performing so far in accordance with the specifications. (Oszacki, 2005)

Method Advantages. Main advantages of CIP relining are:

- The method stops infiltration through defects in the lateral pipe (cracks, offset joints, etc.).
- With all liner types other than standard liners, the method stops infiltration through defective connections with the mainline, and can seal the void between the mainline CIPP liner and the host pipe.
- The method restores or enhances the structural integrity of lateral pipes that may have been lost over time.
- The hydraulic capacity of aged, deteriorated pipes is usually improved despite a reduced cross-section.
- The method applicability is not limited by soil conditions and can be used even with high groundwater level and active leaks (applying adequate measures). There is very limited potential conflict with other buried utilities, caving soils, dewatering, etc.
- The only time excavation is required is if a cleanout needs to be installed.
- The method is suitable for repair of deeper laterals.
- Duration of relining is relatively short, especially with accelerated resin cure (heat, UV light, electricity). Impact on the property owner is usually limited to one or two partial days of work. With TOP HATS™, the lateral is plugged for less than 15 minutes.
- The method provides a long-term repair (50 years design life time).

Method Limitations/Disadvantages. The limitations/disadvantages of CIP relining are:

- The method does not allow upsizing of the pipe, as is possible with pipe bursting and with open excavation and pipe replacement.
- The method is not suitable for laterals with severe offset pipe joints.
- The method is not suitable for severely corroded laterals with a mineral buildup that has badly reduced their hydraulic capacity.
- The method cannot remove sags or any protrusions in the pipe.
- The liners slightly reduce the inside pipe diameter, but this may be a significant if the liner becomes wrinkled during installation.
- For some new systems, the pool of qualified contractors is limited and out-of-state contractors need to be mobilized.

- The relining usually goes smoothly through a 45º bend, but 90º bends and Wye fittings make installation more difficult. Numerous bends in the pipe make the inversion difficult or impossible. Reducers may also present installation issues.
- Roots could be a future problem if they migrate into the annular space between the liner and host pipe or if the liner gets punctured at some time.
- Chemicals used (resins and solvents) are hazardous if spilled or splashed on the skin or in the eyes. The crews need to use overalls, gloves, and safety glasses when working with these chemicals. No hazard remains once the material cures.

5.3.4 Pipe Bursting

Pipe bursting is a method in which (in its basic form) a cone-shaped tool (bursting head) is forced through an existing pipe fracturing the pipe into small pieces (Figure 5-29). These pipe fragments are forced into the surrounding soil and the existing pipe cavity expanded to allow the simultaneous pulling in of a new replacement pipe. The replacement pipe is usually an HDPE pipe, although other pipe types can also be pulled used.

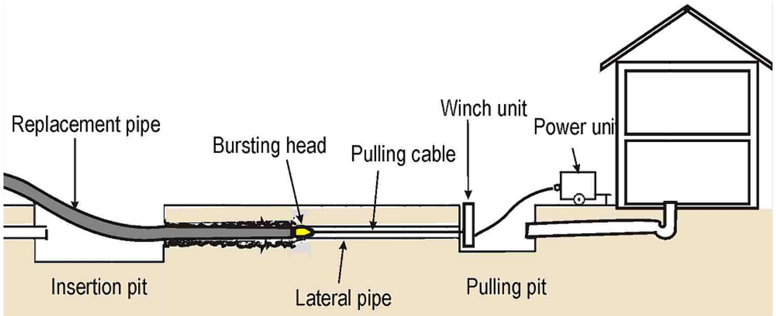

Figure 5-29. Schematic of Lateral Pipe Bursting.

The method eliminates infiltration and provides a “permanent” structural and hydraulic solution (a brand new pipe is installed) with the possibility of diameter upsizing (typically one pipe size in these applications).

Types of Pipe Bursting. Two types of pipe bursting are being used for the replacement of sewer laterals:

- Static pull—This type of bursting uses a bursting head that has no moving internal parts. The head is simply pulled through the old pipe by a heavy-duty pulling device. For replacing ductile pipes (lead, galvanized iron, cast iron, etc.), a pipe splitting head is used (Figure 5-30). This is a variation of the static pull head, with blades that slice through the pipe and split the pipe open rather than burst it into fragments as the head is pulled through the pipe.
- Pneumatic bursting—This type of bursting uses repeated impacts of the bursting head which are driven by compressed air. The bursting head is a cone-shaped soil displacement hammer guided by a small pulling device to keep the hammer in contact with the existing pipe. The percussive action of the bursting head is similar to hammering a nail into a wall, where each impact pushes the nail a small distance farther into the wall.

Figure 5-30. Pipe Splitting Head with Band Cutting Blade, and Clevis Head with PE End Cap (Tric Technologies Inc).

The majority of pipe bursting jobs in sewer laterals is performed with a static pull. The main advantages of static pull over pneumatic bursting are simple setup and ability to get through 22½° and 45° bends in the pipe (even a 90° bend can be pulled through). Pneumatic bursting can get through the most difficult ground conditions (very hard soils), although is not suitable for sandy soils with high groundwater level because the vibrations can liquefy the soil to the point where the borehole stability is lost and the bursting head gets stuck in the soil.

Regardless of type, pipe bursting is performed either on the entire length of a lateral or only on a part (lower or upper lateral) depending on project requirements.

Pipe Bursting Systems on the Market. Several pipe bursting systems intended for use in laterals are available on the U.S. market (Table 5-14). Features of these systems are summarized in Table 5-15 and Table 5-16, and in Appendix C. The systems are very similar—following the same concepts for either static pull or pneumatic approach.

Table 5-14. Pipe Bursting Systems on the U.S. Market.

	Developed	Available	Estimated Replaced*	Manufacturer (in U.S.)
Grundotugger®, Grundocrack®	U.S., 2000	Worldwide	300,000’	TT Technologies, www.tttechnologies.com
Buno B-100	U.S., 1995	Northwest U.S.	43,500’	Buno Construction
PortaBurst™	U.S., 2000	Worldwide	600,000’	Hammerhead/Vermeer, www.Hammerheadmole.com
TRIC™ Trenchless	U.S., 1996	U.S.	10,000,000’	TRIC Tools, Inc, http://www.trictrenchless.com
Undertaker™	U.S., 2004	U.S.	N/A	Spartan Tools, www.spartantool.com

Explanations: N/A … Undertaker™ is on the market since June 2005.

** Based on information received from the respective manufacturers.*

Applicability. As shown in Table 5-15, lateral pipe bursting is not limited by pipe size or type (bursting heads are adapted to slice through the pipe if it is not brittle), however the number of bends in the pipe is typically limited to two. Bends should preferably be only up to 45º although all systems claim to be able to pull through at least one 90º bend. The most difficult soil conditions are hard clay.

Typical lengths in lateral replacement are between 20’ and 200’, although longer lengths can be carried out. In that sense, the length is not a limitation in applicability. However, pipe bursting is often considered unsuitable for short replacements, e.g. replacement of lower laterals only, because the pits are required at close distances (the neighborhood may look like a Swiss cheese) and it is easier to simply open-cut replace the pipe. In some situations, even a relatively short trench would produce a lot of dirt and is suitable for pipe bursting (Figure 5-31).

Table 5-15. Pipe Bursting Systems—Applicability*.

	Lateral Diameter	Limit of Bends in Lateral	Pipe Type	Soil Conditions—Preferred	Soil Conditions—Worst
Buno B-100	2-8"	Two 90º or three 45º	Any		
Grundotugger®	4-6"	Two 90º	Any	Soft clay	Hard, dry clay
Grundocrack®	4-6"	Several 90°	Any	Soft clay	Hard, dry clay
PortaBurst™	2-8"	Two 45º	Any	Loam	Hard, dry clay
TRIC™ Trenchless	4-8"	Three 45º and one 90º	Any	Wet sand	Hard, dry clay
Undertaker™	2-8"	Two 45º	Any	Loam	Hard, dry clay

** Based on information received from the respective manufacturers.*

Figure 5-31. Roughly 40' under the Sloping Front Lawn—Suitable for Pipe Bursting (Tric Trenchless Inc).

Requirement for Excavation. Each replacement setup requires excavation of two small pits, for example 4'×4', however the pits can be smaller or larger (Figure 5-32). The pit sizes depend mostly on depth of lateral. Depth of pits should be about 1' below the invert of the lateral. The pits are usually located outside the house but the pulling pit can also be inside the house, which allows replacement of the pipe under the foundation as well.

Figure 5-32. Excavating for Lateral Pipe Bursting. Left: Pits Can Be Deep (Roughly 8' Near the House). Right: Shallow Pulling Pit—Approx 2'×4' (Tric Trenchless Inc).

Replacement Pipes. The typical pipe for pipe bursting is an HDPE pipe. This pipe is chemically inert, can flex and bend, keeps its circular shape and has a memory to return to its initial shape when kinked. The estimated life of HDPE pipe is over 100 years. For pipe replacement, HDPE SDR 17 typically is used.

Because trenchless replacement is a relatively new method in the plumbing industry, there are still building and plumbing codes in the U.S. that haven't provided approval of this type of pipe even when HDPE is routinely used for mainline sewers. This situation is progressively changing as manufacturers of trenchless replacement systems promote the acceptance of this pipe to plumbing and building code authorities on a local and state level. Tric Trenchless, Inc. has been very active in this area.

In states where HDPE pipe has not yet been approved, other pipe types can be used for trenchless replacement, for example, cast iron or PVC. The work with these pipes is much more difficult in lateral projects. These pipes are not as flexible and entry pits need to be much longer. (They need to be long enough to accommodate the entire length of each pipe joint, which is 10' for cast iron pipes.)

Procedure. The replacement typically involves the following steps:

- Pit excavation (fusing together of the replacement pipe sections can occur at the same time)
- Pipe bursting with simultaneous pulling in of the replacement pipe
- Reconnection of the new pipe
- Surface restoration and demobilization.

The pulling pit must have the pulling wall (the wall facing the lateral to be replaced) as vertical as possible and all protruding pipe from the wall removed (Figure 5-33). The downstream pipe can be plugged if necessary. The insertion (entry) pit must enable unobstructed entry for the replacement pipe and as even a grade as possible. Note: Most figures in this paragraph are Tric Trenchless, Inc. A case study from West Vancouver in Appendix A provides additional details of how this method can be applied using the equipment from TT Technologies.

Figure 5-33. Pulling Pit Preparation. Left: Breaking Old Pipe. Middle: Clearing the Way. Right: Remove All Protruding Pipe from the Pulling Wall (Tric Trenchless Inc).

While the pits are being excavated, the HDPE pipe that comes in 20' and 40' lengths is butt fused to the required length (Figure 5-34). The fusion at about 500°F takes only a short time. First the pipe ends are cut and heated until melting, then the heater is removed and pipe ends pressed together applying steady and even force until the pipe ends are fused together and the melted material rolls back to form a complete rounded "bead" on either side of the joint. The pipe is left undisturbed until just warm, or about 8–10 minutes. Bead reaming is used to clear out the pipe interior bead where the section was fused together (Figure 5-35) although not all agencies require this step.

A winch (pulley) is placed inside the exit pit and braced with a vertical bearing plate behind it to spread the load on the soil (Figure 5-36). The pulling cable is strung through the lateral pipe and attached to the bursting head near the entry pit. In the case of pneumatic bursting, the head is attached to an air compressor. The head is next pulled through the lateral, pulling the replacement pipe with it (Figure 5-37. A little extra length of pipe is left to extend beyond the pit on both ends. The bursting tool is next detached and the pipe cut to the correct length. If a significant force is exerted on the pipe or the pipe temperature is high when inserted, then time for relaxation (shortening) of the pipe should be allowed before cutting to length.

Figure 5-34. Pipe Fusing. Left: Cutting Pipe in the Jig. Right: Heated Pipe Ends Pressed Together (Tric Trenchless Inc).

Figure 5-35. Bead Reaming. Left: Bead Reamer Aligned with the Pipe. Right: Shaved Bead Removed by Reamer Blade (Tric Trenchless Inc).

Figure 5-36. Pulling Pit. Left: Placing the Bearing Plate. Right: Pulley and Ram (Tric Trenchless Inc).

Figure 5-37. Left: Ready for the Pull. Middle: Pipe Moves Quickly. Right: Old Tire As a Container for the Cable (Tric Trenchless Inc).

Once the replacement pipe is in place, the pipe is cut and the connections made—first at the pulling pit and then at the entry pit. This sequence allows the option of “bumping” the PE pipe with a sledge hammer in the entrance pit (where excess pipe is protruding) up to connections (Figure 5-38). The bumping is a very useful technique with the smaller pipe diameters and helps relieve any pipe stretching that may have occurred during the pull, and also assists in coupling connections (it can eliminate extra couplings). Flexible rubber couplings are usually used in combination with stainless steel shear bands (Figure 5-39). Finally, the pits are closed and the surface brought to its original state (Figure 5-40).

Figure 5-38. Left: Ready to Connect in the Pulling Pit. Middle: “Bumping” in the Entry Pit.

Figure 5-39. Reconnecting New Pipe with Existing Pipes. Left: Fittings, Rubber Couplings and Stainless Steel Shear Bands. Right: Connection Completed (Tric Trenchless Inc).

Figure 5-40. Surface Restoration (Tric Trenchless Inc).

Duration of Repair. Duration of lateral replacement is usually more affected by the necessary preparatory work than the pipe bursting technology. It makes a huge difference if the pits are excavated by hand or using a backhoe. However, the equipment (for example, the capacity of hydraulic power pack that powers the static pipe bursting operation) also plays a role by affecting the pulling speed. Plumbers who replace one or two laterals per week do not usually invest in as powerful equipment as contractors that perform large number of replacements continuously. For illustration, Bono Construction reported an average pulling speed of 15 ft/min.

Overall, replacement of one lateral (including reconnections and surface restoration) can take only a few hours, or one to two days. In the West Vancouver case study (Appendix A), it took on average four hours to replace one lateral.

Cost. The cost of lateral replacement depends on site conditions (mostly depth of pipe, but not very much on the length), region of the country (California, Northeast, Chicago area, etc. are more expensive than some other parts of country), and the contractor that performs the work. For example, a plumber can charge between $2,000 and $10,000 to replace a single lateral, and a utility contractor can charge between $1,000 and $2,000 (more or less depending on the conditions) when doing large-scale replacement projects.

Installation Features of Pipe Bursting Systems on the Market. Table 5-16 summarizes some features of pipe bursting systems on the market related to installation.

Table 5-16. Pipe Bursting Systems—Replacement Process*.

	Pipe Upsizing		Max Length	Type	Max Pull	Duration	Productivity (8-Hr Day)	Approx Cost
Buno B-100	One pipe size	4” to 6”, 6” to 8”	280’	Static	100,000 lbs	2 hrs	6-7 laterals	$30-40/ft
Grundotugger®	One pipe size	4” to 6”	150’	Static	60,000 lbs	3-4 hrs	2-3 laterals	
Grundocrack®	One pipe size	4” to 6”	150’	Pneumatic		3-4 hrs	2-3 laterals	
PortaBurst™	One pipe size	2” to 4”,⌡, 6” to 8”	200’	Static	60,000 lbs	3 hrs	8 laterals	
TRIC™ Trenchless	Several sizes	4” to 8”	1,400’	Static	60,000 lbs	3-5 hrs	3 laterals	$60-120/ft
Undertaker™	One pipe size	2” to 4”, ⌡, 6” to 8”	200’	Static	60,000 lbs	3-5 hrs	8 laterals	$60-120/ft

Explanation: Max length is given for one continuous pull.
Duration is approx time given for a replacement of a single lateral and includes pit excavation. In most cases, assumes a 2-person crew for replacement only, and additional crew members for excavation.

** Based on information received from the respective manufacturers.*

Ground Vibrations and Surface Displacement. Pipe bursting operations (especially pneumatic methods) create vibrations in the ground. An extensive study of the velocity of vibrational ground movement was done by the TTC (Atalah, 1998, Atalah et al., 1998). Overall, the effect of ground vibrations caused by the size of equipment used in lateral pipe bursting will rarely be damaging to nearby objects (even if a person standing close by can feel them). Ground movement caused by the expansion from the bursting can cause surface heaving (if the lateral is very shallow) or potential damage to closely adjacent utilities (within one or two feet).

The most critical conditions for the occurrence of surface heave is shallow pipe depth and soil conditions that direct the ground movements upward (firm soil below the pipe). Pipe upsizing also promotes the soil expansion. The heave can be damaging to the existing objects on the property in the close proximity, especially concrete driveways directly above the pipe. In Sarasota, FL (case study in Appendix A), this problem occurred with shallow pipes (some burst pipes had soil cover of only 6”) but was not evident at greater depths (bursting with soil cover of 18-24” was usually fine). Out of almost 300 burst laterals, less than half a dozen had a damaged concrete driveway, which was financially quite acceptable considering the total project savings compared to open cut repair. (Ray, 2005)

Pipe bursting may reduce sags in the existing pipe if the soil conditions around the existing pipe are uniform. However, if there is a soft zone beneath the existing pipe in the sag area, the new pipe may be driven towards the soft zone and the sag deepened. Longer-than-normal bursting heads can help to maintain a straighter replacement pipe. If the existing pipe is clean and the bursting head properly designed, bursting should not normally increase the sag, especially when the static pull system is used.

Significant sediment in the invert of the existing pipe may drive the bursting head upward relative to the existing pipe. A hard soil or rock base beneath the existing pipe may even inhibit the breakage of the underside of the pipe and cause the bursting head to break out at the top of the pipe, moving the replacement pipe substantially outside the envelope of the existing pipe. This problem has been solved in practice by redesigning the bursting head, and adapting it to promote splitting of the base of the existing pipe.

Evaluation of Pipe Bursting in King County, WA. An in-depth evaluation of pipe bursting was done by King County, WA (King County, 2005), where the method was used in several pilot projects (Table 5-17). The system used was Bono B-100, which is used slightly differently than other lateral replacement systems (because of equipment size and position during bursting).

Table 5-17. Evaluation of Pipe Bursting in Pilot Projects in King County, WA.

System Used	Project	Year	Laterals Replaced	Part Replaced
Bono B-100	Ronald I/I Pilot Project	2003	209	Entire length
	Kent I/I Pilot Project	2003	172	Entire length
	Skyway I/I Pilot Project	2003	163	Entire length
	Auburn I/I Pilot Project	2003	19	Entire length
		Total:	563	

Pipe bursting of laterals was found to perform similarly to pipe bursting of sewer mains with the following differences:

- Laterals were typically 4-6” in diameter, which made the pull of new pipe easier than in 8” and larger mainline pipes. The 4” replacement pipe came in rolls and was easier to drag into position than the 6” diameter pipe.
- Pits (at cleanouts, side connections, and fittings) needed to be excavated on private property. Pits were usually no more than 6’×6’ and were shallower on private property than at the sewer mainline.
- Laterals were usually not straight pipes. The pipes typically consisted of a variety of bends, tees, wyes, reducers, etc. In some cases, multiple legal or illegal connections needed to be reconnected or disconnected. The upper laterals sometimes consisted of more than one pipe. The connection points needed to be excavated but the crew could usually pull through most fittings.

The HDPE replacement pipe used during pipe bursting was either 4” or 6” in diameter. The 4” pipe was much more flexible than the 6” pipe, which reduced the size of the launching pit and required less layout room. It was also possible to get 4” diameter pipe in longer, coiled rolls, thereby reducing the number of welds. The 6” pipe was much stiffer, came in lengths that need to be welded, and required more layout room. The 6” pipe could be stored in the homeowner’s yard in one or two pieces until needed.

The 4” pipe was used most often for laterals to a single-family residence. The 6” pipe was used for some single-family residences if required by the local agency or if the service was already 6” in diameter. The 6” pipe was also used if multiple houses were connected to one lateral for those portions of the lateral where the flows were in common. The contractor preferred using 4” pipe wherever possible. In some instances where there was a shared lateral, the contractor pulled in two 4” pipes in place of an existing 6” pipe. Large tracked backhoes were rarely used in backyards or very far off the asphalt. In backyards, excavations were mainly performed using a Bobcat®-sized track hoe (a compact hydraulic excavator, www.bobcat.com) or by hand. The replacement pipes were fed into the ground at these locations. The equipment pulling the pipe into the ground stayed in the street.

Crews could typically prepare for two or three pulls in one day and complete the pulls the next day, assuming the setups were fairly simple. Installation time also depended on the number of bursting operations on the property. For example, a sewer pipe might run across the front yard, turn at a 60° angle along the side yard, and turn again at a 90° angle along the back of the house. This combination required three pulls. A third day was usually necessary for restoration work.

The minimum length of a single pull for pipe bursting laterals was selected at approximately 40’. For shorter lengths, it was usually easier to open-cut the trench and lay new pipe. (Open-cut replacement was usually done with PVC pipe instead of HDPE pipe). In Kirkland, pipe bursting was performed for a few short lateral runs because the number of buried utilities would have made open excavation difficult. The maximum length of a single pull for pipe bursting side sewers was 300’. The limiting factors on private property were access for the equipment and bends in the pipe. For example, neither the contractor’s medium nor large track hoe could get into most backyards. Typically the insertion (entry) pit was in the backyard and the pulling pit was wherever it was most convenient, usually in the front yard or street.

The work for pipe bursting of a whole lateral was a combination of a deeper excavation at the mainline and a shallower excavation on private property. Excavations for reconnection of laterals to the sewer mainline were less than 12’ deep. Upper lateral excavations on private property ranged from 3’ deep for houses with slab-on-grade construction to about 9’ deep for houses with basements.

The agency identified the pros/cons for pipe bursting as shown in Table 5-18.

Table 5-18. Pros/Cons for Pipe Bursting in King County, WA.

Pros	♦ Minimal excavation is required when compared to open trench installation of sewers. ♦ Roots need only be removed well enough to get the pulling cable through the pipe. ♦ Roots should not be an issue in the future because there are no joints in the HDPE pipe. ♦ Where necessary, the pipes can be upsized. In situations where two neighbors share part of a lateral, some contractors can pull two independent 4” diameter lines or upsize to a 6” diameter service line.
Cons	♦ HDPE pipe follows the old pipe alignment, whether or not that alignment is straight. Pipe bursting does not remove sags or curves in the existing pipe, although it may smooth them out if they are abrupt. The typically steeper pipes on private property may make sags less of an issue than for flatter sewer mains. ♦ HDPE pipe may not be absolutely round after installation (although there were no cases during construction of the pilot projects where pipes were out-of-round to the point of being unacceptable). ♦ Excavation and associated restoration work is required. Some private property owners might assume that further backups or other problems are associated with the work performed.

Experience with Pipe Bursting in Sarasota, FL. The City of Sarasota has replaced 297 upper laterals with pipe bursting in 2001/02 using the TRIC™ Trenchless system (Ray, 2005, Castorani, 2005). The project is described as a case study in Appendix A. Most laterals were 4" (294 laterals) and several were 6" (three laterals only).

Before the project, the agency tested pneumatic bursting on one lateral, which was 4" in diameter and 150' long, and went under a driveway, sidewalks and huge tropical trees, and was filled with roots. The bursting went for 4' and then stopped. Due to vibrations, the groundwater level that was just below the lateral was raised to submerge the lateral. The soil became liquefied and the borehole lost stability. The bursting tool got stuck. Static pull was attempted next on the same lateral and it pulled through successfully, so static pull was used on all other laterals.

Damage to driveways during bursting of shallow laterals in this project was already mentioned in the Ground Vibrations and Surface Displacement paragraph. The extent of damage was little (in almost 300 bursts less than half a dozen concrete driveways were damaged and several paved driveways had bricks lifted) and the method was still very cost competitive to open cut replacement considering overall savings.

The crew could replace one lateral per day on average. Overall, the agency is very pleased with the method and considers it a good option because it restores lost hydraulic capacity of pipes and provides a long lasting solution.

Method Advantages. The advantages of lateral pipe bursting are:

- New lateral pipe is installed ("permanent" repair).
- Pipe can be upsized by one pipe size if necessary.
- Little excavation is required, significantly less then with open-cut replacement.
- The method is applicable in all pipe types and in pipes that have lost structural stability (about to collapse).
- Works in most different soil conditions.
- Pipe cleaning/roots removal is not needed or is required only to a minimal extent. Roots need only be removed well enough to get the pulling cable through the pipe.
- Roots should not be an issue in the future because there are no joints in the HDPE pipe.
- Minor sags can be eliminated during the process.
- Short disruption of service to homeowners (up to one day).
- No chemicals are used.
- Systems have been developed specially for lateral pipe replacement, that are easy for handling without special equipment (components weighting no more than 75 lbs, i.e. lightweight and portable).

Method Limitations/Disadvantages. The limitations/disadvantages of lateral pipe bursting are:

- Excavation (to larger extent than with other trenchless methods) and associated surface restoration work is required.
- Access to private property is required and may be an issue.
- Difficult in hard clays.
- Difficult in pipes repaired with metal clamps in the past.
- Not suitable for pipes with many sharp bends. Pipes with several sharp bends have to be replaced in separate bursts with a pit excavated wherever such bend is located ("divide

and conquer" approach). With more than three sharp bends in the pipe, CIP relining is usually better suited.

- Significant sags cannot be removed. This is more of an issue in flatter than steeper pipes.
- Risk of damaging nearby objects and surface objects when bursting at shallow depths.

5.3.5 Chemical Grouting

Chemical grouting creates a sealing collar of material around the pipe by injecting a self-setting grout into an opening in a pipe wall, which is followed by the grout passing through the pipe wall into the surrounding soil and bonding of the grout with the soil (Figure 5-41). Chemical grouting is usually done as a "test-and-seal" procedure, in which an isolated segment of the pipe is pressure-tested for leak-tightness and, if the test fails, the segment is sealed by injecting the grout.

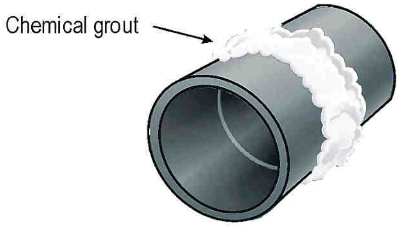

Figure 5-41. Chemical Grouting.

The method eliminates infiltration but does not provide any structural enhancement and is intended for rehabilitation of structurally sound pipes only. Hydraulic capacity remains generally unchanged.

Types of Chemical Grouting in Sewer Laterals. There are two types of chemical grouting when repairing sewer laterals (Figure 5-42):

- Grouting from mainlines—This type of grouting is performed on a lateral-to-mainline connection and first several feet (1-6') of the lateral. It is often done after relining of mainlines (to seal the exposed annular space after reopening of the lateral connections), but is also done as a standalone repair of defective connections. The equipment used for grouting is inserted through the manhole and is driven through the mainline until it reaches the lateral connection, where the test-and-seal procedure is carried out. It is also possible to grout longer lengths from the mainline.
- Grouting from cleanouts—This type of grouting is performed along entire lateral or any selected length. Special push type packers are inserted through cleanouts and moved along the lateral while performing test-and-seal in 3' or 5' increments.

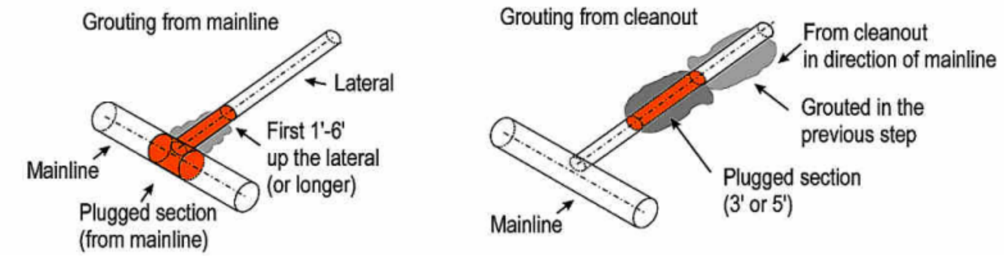

Figure 5-42. Types of Chemical Grouting in Sewer Laterals.

Technologies for Application of Grouts on the Market. Only one company in the U.S. is known to be manufacturing the packers for chemical grouting (Table 5-19).

Table 5-19. Technologies for Application of Chemical Grouts on the U.S. Market.

	Developed	Used	Estimated Laterals Grouted Worldwide*	Manufacturer
Grouting from mainlines				
Connection Test & Seal Packers	Canada, early 1980s	U.S., worldwide	100,000-150,000	American Logiball, Inc. www.logiball.com
Grouting from cleanouts				
Push Type Test & Seal Packers	Canada, mid 1980s	U.S., worldwide	5,000	American Logiball, Inc. www.logiball.com

** Based on information received from the manufacturer.*

Applicability. Table 5-20 shows existing conditions in which the test-and-seal packers can be used. The method requires structurally stable pipes. The most serious limitation comes from soil conditions. If there are large voids in the ground behind cracks or open joints in the pipe, the plugged section simply cannot be pressurized.

Table 5-20. Packers for Chemical Grouting—Applicability*.

American Logiball Packers	Mainline Diameter	Lateral Diameter	Diameter Transition	Max Bends in Lateral	Max Offset Joint in Lateral	Cracks in Lateral	If Heavy Leaks in Lateral
Connection Test & Seal	6”-24”	4”, 5”, 6”	4” to 6”	Multiple 90º	20%	Some	No problem
Push Type Test & Seal	N/A	4”, 5”, 6”	4” to 6”	Multiple 90º	20%	Some	No problem
Explanation	“Some cracks” means that pipe must be reasonably structurally sound.						

** Based on information received from the manufacturer.*

Requirement for Excavation. This method requires no excavation. In some cases, however, limited excavation may be engaged to install missing cleanouts if needed for pipe cleaning (if performing extended grouting from the mainline or grouting of whole laterals with push-type packers).

Grouts Used for Sewer Laterals. Chemical grouts used to seal sewer laterals fall into four main categories: acrylamide grouts, acrylate grouts, acrylic grouts, and urethane gels (NAGMA, 1998). In the U.S. and Canada, the most frequently used grouts are Acrylamide and Acrylate. Acrylic grouts are used less frequently, and only a small portion of grouts are urethane gels. Properties of different types of chemical grouts are shown in Table 5-21.

Table 5-21. Types of Chemical Grout and Properties.

Grout	Example brand name	Description	Catalyst	Water to Resin	Gel Time	Viscosity
Acrylamide	Avanti AV-100	Powder, liquid	Chemical	1:1	5 seconds to few hours	1-2 cps (very low)
Acrylate	De Neef AC-400[40]	Liquid	Chemical	1:1	5 seconds to few hours	1-3 cps (very low)
Acrylic	Avanti AV-118	Liquid	Chemical	1:1	5 seconds to few hours	1-2 cps (very low)
Urethane	Prime-Flex Hydro Gel SX[41]	Liquid	Water	8:1	~ 1 min	10-20 cps (low)

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[40] *AC-400 contains no Acrylamide monomer.*

[41] *$50/gal diluted in water-to-gel ratio 8:1*

One important parameter in chemical grouting is the "gel time", which is the time it takes the grout to gel (cure). If the grout pumped through pipe defects cures too quickly, it does not reach the outside of the pipe, and that is where the effective grout must be placed. The gel time begins with the addition of catalysts (except for urethane gels), which are usually chemicals dissolved in water and added through a separate pump. If the grout cures too slowly, the amount of used grout may be unnecessarily large.

Additives are additional chemicals mixed with the grout for protection against freezing temperatures or to extend the gel time. Special additives are root inhibitors (used often) and buffers (used rather rarely to control pH in grout solutions[42]). Type and concentration of catalysts and additives are selected based on manufacturers' recommendations, and the selection confirmed by checking the performance of prepared grout mixture on-site with a gel-time test[43].

The following may affect the gel time of the grouts:

- Changes in concentration of one or all of the catalysts of the mixture may have a very significant effect on the gel time.
- The temperature under the ground, if different from the temperature above the ground, can also affect the get time. Generally, gel time increases when temperature falls and decreases when temperature rises. As a rough rule of thumb, the gel time is reduced by half if the temperature goes up 10°F. When a short gel time at low temperatures is needed, warming the grout solution may be more economical than large amounts of catalyst, but the solutions must be stirred while the heater is in use.
- Metals and chemicals in the soil can also affect the gel time.

The viscosity of grouts used for pipe grouting must be low enough (similar to water) to allow the grout to pass through the cracks and defects in the pipe easily.

The required amount of grout to seal the leaks in lateral pipes depends on the volume of voids in the soil and therefore cannot be calculated in advance, but is determined during the sealing based on readouts of grout pressure. For illustration, the required amount of grout can be estimated as a rule of thumb as:

- About 3 gal to seal a lateral-to-mainline connection that failed an air-test (8" mainline and 6" lateral)
- About 1 gal/ft to seal the lateral along its length (6" lateral).

Repair Procedure. Rehabilitation with chemical grouting typically involves the following steps:

- Pipe inspection and cleaning (preparatory work)
- Test-and-seal procedure
- Post-CCTV inspection.

Pipe inspection with a pan-and-tilt camera from the mainline is normally sufficient if the length of the lateral to be repaired does not exceed 4'. For longer distances, the lateral is inspected with either a push type lateral CCTV camera (for above the ground access) or a

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[42] *In some cases, when long gel time is needed, especially in acid groundwater conditions, buffers are added to the water to bring the pH above 7.*

[43] *Each time a new batch of grout is mixed, the gel time is checked with a gel-time test, which is done on a small quantity of the chemicals taken from the packer hose and mixed in a paper cup.*

"satellite" camera (mainline access). The inspected length is typically the distance to be repaired plus 1'.

The mainline and the section of lateral to be test-and-sealed must be free of roots, debris, grease and dirt that would prevent the complete inversion of the lateral bladder or proper seating of the rubber bladder in the host pipe. Mineral buildup must be removed and protruding taps protruding more than 5/8" into the mainline must be cut back to avoid interference with the test-and-seal equipment (Figure 5-43). However, hammer taps or light root intrusion do not hinder the test-and-seal procedure and not need be fixed (Figure 5-44). Flow bypass is typically not required because the packer in the mainline is only inflated for a few minutes at a time and then deflated. However, the flow must be controlled so that the camera can monitor the progress of work.

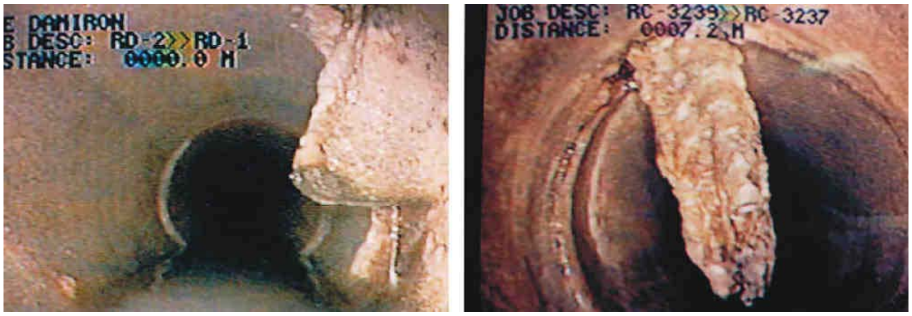

Figure 5-43. Obstructions to Be Removed. Left: Protruding Tap. Right: Mineral Buildup (American Logiball Inc).

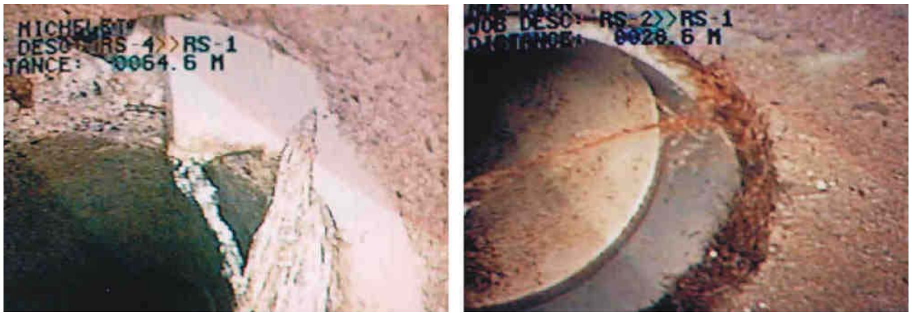

Figure 5-44. Obstructions That Can Stay. Left: Hammer Tap. Right: Light Root Intrusion (American Logiball Inc).

<u>The test-and-seal procedure</u> involves the following steps:

- Positioning of the test-and-seal equipment in place
- Pressure isolating of the sewer segment
- Pressure test
- Grout injection
- Pressure test
- Removal of the test-and-seal equipment.

For test-and-seal from the mainline, special packers for this application are used (Figure 5-45). The packer is connected to a pan-and-tilt camera and a winch, and inserted into the mainline through the manhole, positioned at the lateral connection and rotated to align the lateral grouting plug with the lateral. Using air pressure, the lateral grouting plug is inverted into the lateral. Next, a mainline sleeve is inflated and the end of lateral grouting plug expanded creating an isolated T-section of the connection and the first several feet of the lateral. The air test is performed. If the test fails, the packer remains in position and chemical grout is pressure-injected into the voids and out into the soil through the pipe or joint defects. When a satisfactory grouting pressure is obtained, the leak is sealed. After sealing, the lateral grouting plug is vacuumed back within the packer and the procedure repeated at all lateral connections along the mainline.

Bladders up to 20' long are available for grouting from the mainline, however it usually becomes rather difficult to grout lengths over 12' and this is typically the practical limit.

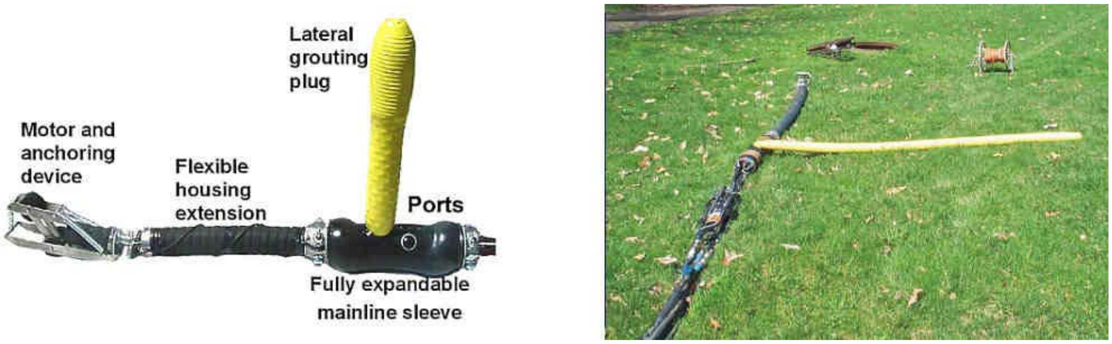

Figure 5-45. Packers Used from the Mainline. Left: Short Bladder. Right: Long Bladder—Shown Is 8' Long (American Logiball).

For test-and-seal from a cleanout, a flexible push type packer that performs the procedure in 3-5' long increments is used (Figure 5-46). The packer is attached to a semi-rigid hose assembly and inserted into the lateral through the cleanout or other above ground access, then pushed to the furthest lateral joint. The packer is inflated and a portion of the lateral tested-and-sealed. The packer is then pulled back for the length of the sealed portion and the process repeated. The test-and-seal procedure may leave some residual grout in the pipe, especially at points of diameter transition in the lateral. For example, if the lateral changes from 4" to 6", the packer would be selected to fit 4" pipe and it would not be pressing tightly against the host pipe through the transition area. The residual grout washes away by itself and need not be cleaned using jetting.

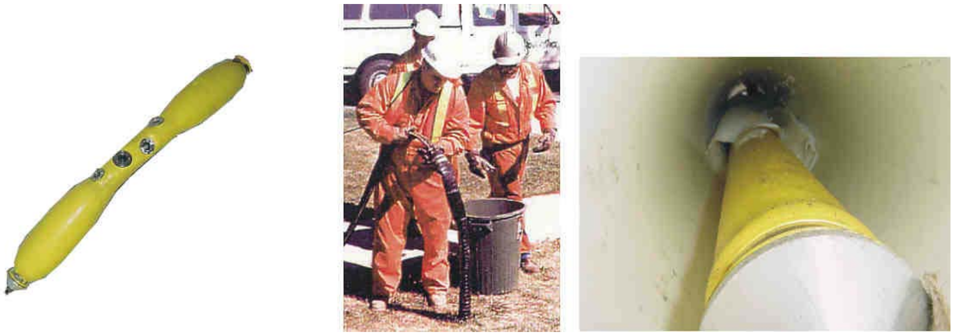

Figure 5-46. Test-and-seal from Cleanouts. Left: Flexible Push Type Packer. Middle: Inserting through a Cleanout. Right: Push Packer in the 6" Lateral Pipe and Residual Grout in The Back (American Logiball).

Duration. The time required to test-and-seal lateral-to-mainline connections depends on the number of lateral connections on the mainline between the manholes. The setup and preparation time including test-and-seal of the first connection takes about 2-2½ hours, and each additional connection on that mainline adds approximately 15 min.

Grouting of a lateral through a cleanout takes about the same time (2-2½ hours). The length of lateral makes little difference and the total time is mostly affected by the setup and preparation for grouting.

Longevity of Repair. The performance of grouts depends on soil conditions and the moisture content. In areas where the groundwater table varies and drops below the grouted sections, the grout in the soil can dry out, shrink and crack. The most favorable circumstance is that the grouted sections (usually lateral-to-mainline connections) are often deep enough (at least 3-4', or else open cut repairs may be preferred) that, in many parts of the country, that they will stay below the groundwater level even during dry weather. In addition, sewage flowing through the laterals also provides some moisture to the grout.

Before discussing the issue of longevity, it is worth pointing out that, because chemical grouting of scattered defects or problem joints is relatively inexpensive compared to a full rehabilitation or replacement, some cities do not assess whether to use chemical grouting based on an extended life expectancy. They may use it as a short- to medium-term fix for problem areas thus allowing them to delay a full rehabilitation.

Limited testing has been completed on selected chemical grouts with respect to their durability. One research project has shown that properly cured Acrylamide grout has a half-life of approximately 115 years (Keller, 2001[44]).

Another research project has shown less satisfactory performance of the Acrylamide and Acrylate grouts, however these tests were simulating conditions in mining operations rather than the soil/groundwater conditions around sewer laterals. The grouts were exposed to nearly saturated NaCl brine solution and different pressures for a duration of six years. Still Acrylamide showed very little deterioration under atmospheric pressure and only under increased pressures (500 psi and 1,000 psi) developed cracks and significant weight loss between the third and fifth year (Haug et al., 1998).

Responses from agencies for this study provide some indication of the performance of grouting in their network, soil and groundwater conditions.

Two agencies in Florida reported a short life of chemical grouting, which made them decide not to utilize this method. The City of Hollywood, FL, tried chemical grouting on mainlines in early 1990s. It was an in-house testing of the method effectiveness in stopping infiltration: between 1,000э and 3,000э of VCP mainline was rehabilitated applying Acrylamide grout on joints and longitudinal cracks. The installed product was effective initially, however, the longevity of repair was rather short-lived and the infiltration was again visible on CCTV two years later. The repaired pipes were rather shallow (up to 6э depth) with groundwater fluctuating notably during the year (between 6э and 2э), which is believed accountable for the failure of installed product (Bolton, 2005).

The City of Bradenton, FL used chemical grouting in mainlines during a citywide sewer rehabilitation project in 1985-87 for internal joint sealing of VCP pipes[45]. The grout was

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[44] *Referencing (Farmer et al, 1986).*

[45] *The bid (Sep 1984) specified 18,396 joints on mainline pipe 8-10"; 1,310 joints on 12-15"; 1,080 joints on 18-21"; and 346 joints on 23" mainline pipe. The grouting material specified was a choice of the following: AC-400 as made by Geochemical Corp.; CR-250 as made by 3M; or Q-Seal as made by Cues, Inc. At present, the agency is not quite sure what was actually used.*

installed successfully, however, the repair held approx four to five years only. The leaking recurred and the pipes were subsequently repaired with an open cut point repair (Cumming, 2005; Bridges, 2005).

Two other agencies reported good experience with longevity of repairs. In the Village of Genoa, WI, chemical grouting was used in two projects (1993, 1996) after relining mainlines (U-Liner) to seal the annual space at the lateral connections and the first 1-10' into the lateral. In the second project, the soil conditions include quicksand and the area is under groundwater six to seven months a year. At this time (approx 10 years later) there have been no failures of installed U liner or grouted laterals (Wrzeszcz, 2005).

The City of Battleground, WA, used grouting for repair of over 400 lateral-to-mainline connections in late 1990s and the grout still holds well after over six years (Newton, 2004).

Cost. The cost of chemical grouting depends on the type and quantity of grout used, and on the number of laterals per setup (the number of laterals between two manholes). The cost is also dependent on the region of the country (Table 5-22).

Table 5-22. Cost of Chemical Grouting (Ballpark Estimate)*.

Region in U.S.	Location/Length of Test-and-Seal	Grout Used	Price Per Lateral
Northeast U.S. (New England, NY, PA, MD, etc)	From mainline, up to 6' into the lateral	Acrylamide	$325-500
West coast U.S. (CA)	From mainline, up to 6' into the lateral	Acrylamide	$300-400
	From cleanout		$300-500
Southeast U.S. (Miami-Dade, FL)	From mainline, annular space after mainline CIP only		$300

** Based on information received from selected contractors.*

Installation Features of Technologies for Chemical Grouting on the Market. Table 5-23 summarizes some installation features of packers for the test-and-seal process.

Table 5-23. Packers for Chemical Grouting—Installation Features*.

	Length of Bladders:	Length Grouted	Access into Lateral	Approximate Duration	Average Productivity	Approx Cost
American Logiball—Connection Test & Seal	1. Standard 2. Long	1-5' 5-30'	Mainline	2 hrs setup; 15 min/ lateral	7-12 laterals 7 laterals or more	$350-1,200
American Logiball—Push Type Test & Seal		150'	Cleanout	30-60 min/lateral	7-10 laterals	$350-700

Explanation: "Approx duration" is given for a replacement of a single lateral and includes pit excavation. In most cases, assumes a 2-person crew for replacement only, and additional crew members for excavation. "Average productivity" assumes an 8-hour day.

** Based on information received from the manufacturer.*

Toxicity of Chemical Grouts. Polyurethane grouts, which are more expensive than Acrylamide and Acrylic based grouts (as much as three to four times), are environmentally friendly and safe to use with drinking water[46]. In some countries where pollution control has been a major issue (e.g. Germany), polyurethane gels are more in demand than other types of grout.

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[46] *Prime-Flex Hydro Gel SX (Prime Resins, Inc, Conyers, GA) is U.L. certified to conform to ANSI/NSF Standard 61 Drinking Water Systems Components—Health Effects.*

Acrylamide has long been known as an occupational hazard that can cause numbness and other neurotoxic symptoms in exposed workers (airborne exposure and dermal contact during chemical grouting operations), and OSHA recommends proper engineering controls, work practices (ventilation), decontamination procedures, protective clothing and respirators (NIOSH/OSHA, 1981).

Pollution of groundwater with Acrylic-based grouts is another issue that has raised concerns over the years. A case of extreme groundwater pollution with Acrylamide happened in Sweden, in the 1990s, during building of a nine-kilometer tunnel beneath the Hallandsas. Acrylamide grout used on the tunnel walls did not set properly and was mixed with the groundwater still seeping inside the tunnel, and the mixture was pumped back into a stream killing cows on the nearby farms and fish in the stream. (Craig, 2001)

At present, however, it is believed that typical sewer grouting with Acrylamide grouts does not cause environmental contamination. The U.S. EPA has withdrawn a proposed ban on these grouts in 2002 based on findings of several government agencies[47], which showed that Acrylamide could be found in certain fried and baked foods, but not in raw foods (U.S. EPA, 2002c). In addition, a recent epidemiological study has not shown a correlation between Acrylamide at levels found in foods and an increased cancer rate in people (Mucci et al., 2003).

Evaluation of Chemical Grouting in King County, WA. A limited evaluation of chemical grouting was done by King County, WA (King County, 2005), where the method was used in one pilot project (Table 5-24). Lateral connections were selected for grouting if:

- The mainline was CIP relined and the lateral connections were reopened in the CIP liner.
- The connections were in old concrete pipes where no other rehabilitation was performed.

Table 5-24. Evaluation of Chemical Grouting in Pilot Projects in King County, WA.

Grout Used	Project	Year	Laterals Grouted	Part Grouted
Avanti AV-100 Grout	Brier I/I Pilot Project	2003	20	Connections and 16" into the lateral

The grout used was Avanti AV-100 Grout. The equipment, surface preparation, access issues, limitations, root issues, and field QC issues were the same as for chemical grouting of sewer mains. The grout packer extended up the lateral about 16" and in the mainline it was about 3' long. Basically this method was used to grout only the joint between the lateral pipe and the mainline.

It was hard to get the packer in place when the lateral connected with the mainline at a 45° angle, but there was no problem with pressurizing plugged sections. All connections were successfully grouted. This does not, however, necessarily represent a reliable evaluation of the success of this method because not many laterals were rehabilitated.

All connections that were selected for the trial failed the initial air test and hence were grouted. That was not surprising because the connections were selected for grouting based on defects observed in a visual inspection.

A well-trained crew could complete the chemical grouting work on approx 10-15 connections per day. In the pilot project, the productivity was less than 10 connections per day because the connections were spread over a large area.

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[47] *Sweden, Great Britain, Norway, and Switzerland, as well as U.S. Food and Drug Administration (FDA)*

Because the method was used in only a few instances, only a limited assessment of its pros and cons could be made (Table 5-25). The agency will further evaluate this product during the warranty inspection.

Table 5-25. Pros/Cons for Chemical Grouting in King County, WA.

Pros	6	Grouting did stop some visible leakage from pipes
	6	Fairly inexpensive compared to other rehabilitation products.
Cons	6	Open questions about the product's service life as well as its ability to stop root intrusion.

Experience in the City of Santa Monica, CA. The city tested chemical grouting in 1997 on 183 lateral connections (Chusid, 2005). The plugged sections were 2' long in the lateral and 3' in the mainline. The mainline was previously lined with PVC. Only 75 connections (41%) were successfully pressurized in order to enable the grouting work. The connections that could be pressurized were successfully grouted. These grouted connections seem to have held well over time and continue to be a root barrier. However, regardless of success in completed lateral connections, the high installation failure rate (59%) and the price of $750/connection made the agency stop chemical grouting.

The ground conditions involved clay and the groundwater level is normally below the pipes. These conditions are not in themselves a problem for the grouting work. However, the majority of lateral connections were break-ins with big cavities around them, and that was found to be the reason for failure of the test-and-seal plugs. It was difficult or impossible to pressurize and grout all the cracks with such large cavities behind. Also, roots in the laterals presented a big problem for the installation process. The connections were perhaps better suited for a structural repair.

Experience in South Fayette Township Municipal Authority, PA. The agency first tried chemical grouting in a small pilot project in 1997 and then in a large project in 2000 (Brown, 2002; Brown, 2005) (Table 5-26). In both projects, acrylamide grout was used. The lateral connections with the mainline were typically Wye connections. In both projects, plugging of connections extended 8' into the lateral and there were few problems with the ability to pressurize the plugged sections. The soil conditions in the Hunting Ridge project are primarily clay-based soils. The quantities of grout used and the cost of the rehabilitation are shown in Table 5-27.

Table 5-26. Chemical Grouting Projects in South Fayette Township Municipal Authority, PA.

Project	Year	Tested	Sealed	Grout	Location/Length Sealed
Pilot project	1997	59 laterals	52 laterals (88%)	Avanti AV-100	Connections and 8' into the lateral
Hunting Ridge Grouting Project	2000	499 laterals	452 laterals (91%)		

Table 5-27. Cost of Chemical Grouting in South Fayette Township Municipal Authority, PA.

Project	Total Quantity of Grout Used	Quantity per Connection	Total Cost of Project	Cost per Tested Connection	Cost per Grouted Connection
Pilot project	303 gal	5.8 gal	$29,830	$505	$574
Hunting Ridge Grouting Project	2,209 gal	4.9 gal	$203,725	$408	$450

The grouting effectively eliminated leaks, some quite extensive. Approximately six to nine months after the pilot project completion, the agency went back to check on the condition of grouted connections. The timing for re-inspection was chosen when groundwater level should have been as high or higher than at the time of grouting. There was no evidence of renewed leakage or of migration of the groundwater in either the sealed lateral or mainline joints. The success of pilot project led to undertaking of the larger project. The agency has not yet inspected the grouted connections in the Hunting Ridge Grouting Project to observe if roots have reentered the grout zone joints (only a small percentage of the wyes sealed had any type of visible root intrusion, and an effort was made to remove significant root growth prior to sealing, but the roots were not chemically treated). Based on good experience with acrylamide grout in this area, the agency is confident that chemical grouting does provide a long-term seal of joints if applied properly.

Installation Performance of Test-and-Seal Packers. The experience in Santa Monica and South Fayette Township Municipal Authority shows that the performance of packers may range from unacceptable to excellent depending on existing conditions. Additional skepticism has been detected in some agencies regarding the applicability of test-and-seal packers with long bladders. For that reason selected contractors utilizing this equipment have been contacted and asked about their experience with this equipment.

Lake County Sewer Company is a contracting company in New Jersey involved in chemical grouting since the mid 1990s. They have been using American Logiball packers with both short bladders usually grouting 18”-5’ into the lateral, and long bladders typically grouting 10’ into the lateral. These bladders have been used weekly, depending on the job. Problems occur only in structurally damaged or dirty laterals. They have also been using push type packers, but less frequently, typically only a few times a year. The clients have been cities throughout Ohio and Michigan, e.g. Columbus, Youngstown, Mansfield, Lexington, Detroit, Lansing, Grand Rapid, etc. Acrylamide based gel or acrylic based gel are the grouts used. (Marruci, 2005)

Video Pipe Services is another contracting company in New Jersey that has also been using American Logiball packers for over 10 years. The grouted length in the lateral is typically 4’ with short bladders and up to 20’ with long bladders. Experience has shown that the longer the bladder, the harder it is to use it. The company rehabilitates on average 500-1,000 laterals per year. (Costandino, 2005)

The Village of Brown Deer, WI, a suburb of Milwaukee, WI, used chemical grouting in a recent project in 2005, which involved grouting of 22 laterals from the mainline. (The test-and-seal procedure was performed on 24 laterals but two passed the test and were not grouted.) Special American Logiball packers were constructed 38’ long to test-and-grout 30’ into each lateral (to the property line). The soil conditions were comprised of clay with sand seams. The mainline was 8” in diameter and rehabilitated previously using chemical grouting, and the laterals were 8” in diameter. The project went well. The challenge was to pump the grout through the length of 30’ and have it gel when it reached the soil cavities and not before. Avanti AV-100 grout was used with a gel time from two to three minutes, which was pumped at 6gpm. It took, on average, about 28 gallons of grout per lateral (20 gallons on the low end and 75 gallons on the high end). About 14 gallons of grout was used in each section to fill in the space between the bladder and the pipe, and only the remaining quantity was pumped into the soil. The grout in the pipe would gel by the time the bladder was vacuumed back from the pipe—some of it was removed together with the bladder and some was left in the pipe to wash out afterwards. The production rate was three to four laterals a day at the beginning, but later it was seven or more laterals per day. The actual cost of rehabilitation was not yet determined at the time of this report preparation. The agency plans to continue to use this method for another 350 laterals that need repair. (Neitzel, 2005)

Method Advantages. The main advantages of chemical grouting are:

- No excavation is generally required.
- Performs pipe testing and repairs only where the repair is needed.
- The method eliminates infiltration.
- The method is fast and disturbance to homeowners minimal.
- The method is inexpensive.

Method Limitations/Disadvantages. The limitations/disadvantages of chemical grouting are:

- No structural repair is possible.
- No pipe diameter upsizing.
- Sometimes can’t be completed (the section can’t be pressurized), i.e. in soils with many holes and voids or in pipes that are too damaged.
- The longer the bladder, the more difficult the installation when performed from mainline.
- The grout may dry out and crack under some (dry or variable) groundwater conditions.
- Chemicals used are hazardous if spilled or splashed on the skin or in the eyes (overalls, gloves, and safety glasses required). No hazard remains once the material cures.

5.3.6 Flood Grouting

Flood grouting seals manholes, mainlines and laterals simultaneously in one setup utilizing an exfiltration sealing process. Two proprietary chemical solutions are consecutively applied to “flood” an isolated section of sewer, where they exfiltrate through defects in pipes and manholes into the soil and chemically react with each other (Figure 5-47). The cured grout in the soil is a watertight sandstone-like silicate.

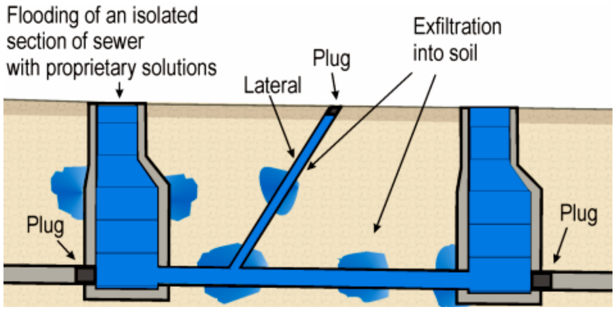

Figure 5-47. Flood Grouting.

The method eliminates infiltration but does not provide any structural enhancement and is intended for rehabilitation of structurally sound pipes only. Hydraulic capacity remains generally unchanged.

Flood Grouting Systems on the Market. Only one company, Sanipor®, offers flood grouting system on the U.S. market (Table 5-28). A similar system Tubogel® is offered in Europe since 2002 by another German company (Geochemie Sanierungssysteme GmbH, www.tubogel.de) but the only information received for this project was from Sanipor®.

Table 5-28. Flood Grouting Systems on the U.S. Market.

	Developed	Available/Used in	Estimated Grouted Worldwide *	Manufacturer (in U.S.)
Sanipor®	Hungary, 1987	U.S., Europe, Australia, New Zealand	300 miles of mainlines/laterals	Sanipor, Ltd. www.sanipor.com

** Based on information received from the manufacturer.*

Applicability. Table 5-29 shows existing conditions in which the test-and-seal packers can be used. The method requires structurally stable pipes. The most serious limitation comes from soil conditions. If there are large voids in the ground behind cracks or open joints in the pipe, the solutions continue to drain out of the plugged section without stabilizing.

Table 5-29. Flood Grouting—Applicability*.

	Mainline Diameter	Lateral Diameter	Diameter Transition	Max Bends in Lateral	Max Offset Joint in Lateral	Cracks in Lateral	If Heavy Leaks in Lateral
Sanipor®	Any	Any	Any	Any	Any	Some	No problem

Explanation: "Some cracks" means that pipe must be reasonably structurally sound. Typically are allowed radial cracks around 3" and axial around 2", but this depends on the diameter of pipes and structural stability decides.

** Based on information received from the manufacturer.*

Requirement for Excavation. This method requires no excavation. In some cases, however, limited excavation may be used to install missing cleanouts if needed for pipe cleaning (if performing extended grouting from the mainline or grouting of whole laterals with push-type packers) and plugging of laterals.

Chemicals Used in the Process. There is only one system on the market in the U.S. that utilizes the flood grouting method (SANIPOR®). Chemicals used in this system are silicate based and are non-toxic to the surrounding soil and the groundwater after cure, as has been confirmed by several German authorities and institutions that tested this technology and gave their approval of it (Institute for Water Hazardous Materials of the Berlin University of Technology; Institut of Hygiene, Gelsenkirchen; Federal Office of Public Health, Berlin; German Institute for Construction Technology; Senate Council for City Development and Environment, Berlin). The system has also been approved by the Water Research Centre (United Kingdom). The chemicals present, however, a potential health hazard to workers (dermal and respiratory problems) before they cure and must be handled with care by operators in the field. OSHA Safety and Health recommendations must be followed.

Procedure. One case study included in Appendix A provides details of how this method can be applied. The procedure generally involves:

- Pipe preparation, i.e. cleaning of pipes and installation of cleanouts if necessary
- Plugging of the selected sections
- Flood grouting

- Removal of plugs.

Sections selected for rehabilitation consist of manholes and/or mainline and/or laterals (the number of components depend on the volume to be filled and the rate of infiltration). The plugs are inserted in mainlines where they connect to manholes and in laterals at cleanouts near houses as needed. After plugging the sections, the flood grouting is performed in four steps (Figure 5-48):

- Step 1—The section is completely filled with the solution S-1 though one manhole (the liquid level is brought up to the street level). This creates the necessary hydrostatic head for the injection of S-1 through the defects into the soil. While the level of S-1 is gradually sinking, the liquid is being refilled (once or several times) up to street level in order to maintain the hydrostatic head required for exfiltration.
- Step 2—After a certain time, S-1 is pumped out completely and all pipes are flushed with water (the laterals with the help of buckets and the mainline with a quick interim flush of water with the jetting truck).
- Step 3—Next, the section is completely filled with the solution S-2 from its tanker in the same manner as previously with the solution S-1. In the soil, the two components react with each other and the soil particles, and an isolating watertight layer is created around the leaks. Thus, a soil stabilisation takes place.
- Step 4—After certain time, S-2 is pumped out and all pipes are flushed with water.

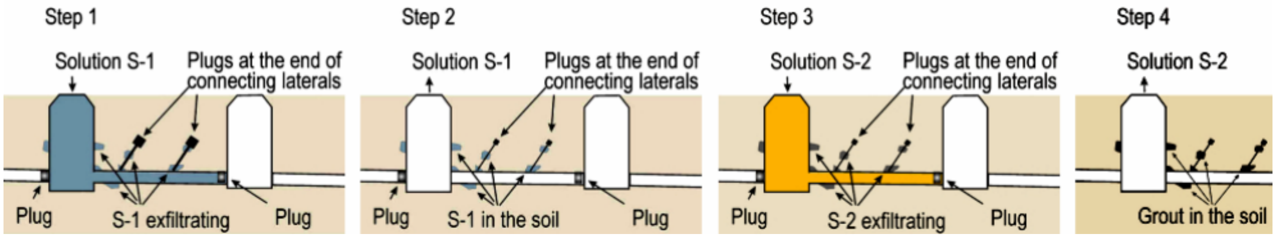

Figure 5-48. Four Steps in the Flood Grouting Procedure.

Duration of Repair. The duration of flood grouting depends on the number of refilling cycles performed, which depends on the severity of defects and volume of voids in the soil behind the pipe defects that are filled with the solutions. It can take on average about eight hours per section with interruptions. Overall, productivity of one crew is one or two sections per day.

Longevity of Repair. In practice, no shrinkage or aging is observed over time, and the microstructure and the chemical condition of the cured sealant within the soil are stable (see section *Experience with Flood Grouting* below).

Cost. The cost of rehabilitation includes the cost of chemicals plus the cost of labor and equipment. The quantity of chemicals used depends on pipe diameter, length and leakage rate of manholes and pipes. Ballpark values for cost of chemicals are from $7.60/ft in 4” pipes to $92/ft in 48” pipes. Daily fixed cost (labor, equipment) depends on who does the work, whether the equipment rented or owned, etc. and the ballpark is $3,000/daily. This means that the cost to repair single laterals (assuming two laterals sealed daily, 6” in diameter) could be about $2,100/lateral. If applied in typical sections with mainlines and laterals, the average cost could be estimated at about $1,200/lateral.

Installation Features of Flood Grouting System on the Market. Table 5-30 summarizes some features of the SANIPOR® system related to installation.

Table 5-30. CIP Relining Systems—Installation Features*.

	Plugged Section	Insertion of Chemicals	Approx Duration	Productivity (8-Hr Day)	Approximate Cost (Chemicals Only)
SANIPOR®	Mainline with connecting laterals or mainline only	Through manhole	8 hr per section (with interruptions)	1-2 sections	$7.60/ft (4")-$92.09/ft (48")
Explanations	"Productivity" assumes one mainline and several laterals connected to it. "Approximate cost" shows the cost of chemicals only and the cost of labor and equipment must be added.				
** Based on information received from the manufacturer.*					

Experience with Flood Grouting. Thames Water, U.K., tried the SANIPOR® system in 1989, sealing approximately 11,677' (3,559 m) of mainline 6-12" (150-300mm) in diameter and 5,840' (1,780 m) of lateral pipes 4" (100 mm) in diameter (Reynolds, 2005; Reynolds, 2005(2)). The project was in Lambourne, Berkshire, U.K. and sealed only the worst leaking lengths in the valley catchment The rehabilitation was very effective in reducing the infiltration-about 80% of annual infiltration due to groundwater leakage was removed in a year with average groundwater levels. Individual rainfall events had very little effect on flows as almost all houses used soakaways[48]. The rehabilitated sections were retested eight years after the contract by carrying out a standard water exfiltration test. The average leakage was 3% of that allowed for new sewers, with a maximum leakage of 9.5% of the allowed leakage for new sewers. Afterwards, the SANIPOR® system was used a couple of times more by Thames Water, as well as some other agencies in the U.K. e.g. Wessex Water, Southern Water, etc.

The City of Berlin, Germany, has used the SANIPOR® system on stormwater sewers and laterals in several projects in 1994 and 1997 repairing approximately a total of 6,600' (2,000 m) of mainlines 12-27" (300-700 mm) in diameter and about 3,300' (1,000 m) of laterals. Although not used on sanitary sewers, the experience with effectiveness in providing the leak-tightness is valuable for sanitary sewers as well. All repaired sections were tested for leak-tightness with CCTV inspection and in accordance to DIN/EN 1610[49] two years after the repair and again five years after, showing very good results. (Sedehizade, 2005). In particular, the pipes rehabilitated in 1994, which included approximately 1,500' (460 m) of pipes 14-20" (350-500 mm) in diameter, had a total of 88 leaks before rehabilitation and only four minor leaks were identified with CCTV in 2004. (Downey, 2004)

The City of Göttingen, Germany, tried the SANIPOR® system in a small pilot project involving five laterals in 2002 (Eisener, 2005). The project was so successful at reducing I/I that the groundwater table rose after the application causing two basements to become very wet. Despite this experience and many little problems with private owners and their special wishes, the city continues rehabilitation using the flood-and-grout method-considering it to be the most suitable rehabilitation method in a very branched sewer system with many laterals under basement floors that are inaccessible. The groundwater table is high and there are many damaged VCP pipes, leaky manholes and cleanouts. The city is currently starting tests with another flood grouting system TUBOGEL® that is available in Germany.

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[48] *A soakaway is a hole in the ground filled with gravel and coarse stone with a drainage pipe laid to it removing surface (rain) water from other areas.*

[49] *EN 1610: Construction and Testing of Drains and Sewers is a European Standard (1997), which requires the leak-tightness be tested with either air or water pressure test.*

Method Advantages. The main advantages of flood grouting are:

- No excavation is generally required.
- The method eliminates infiltration in an entire section, i.e. both in mainlines and all connecting laterals at the same time.
- There is no limit in applicability with respect to the pipe material, shape or size, or depth.
- Applicable in pipes with many sharp bends.
- The disturbance to homeowners is minimal.
- The chemicals used are environmentally friendly.

Method Limitations/Disadvantages. The limitations/disadvantages of flood grouting are:

- No structural repair is possible.
- No pipe diameter upsizing.
- Sometimes cannot be completed, i.e. in soils with many holes and voids.
- Chemicals used are hazardous if spilled or splashed on the skin or in the eyes. The crews need to use overalls, gloves, and safety glasses when working with these chemicals. No hazard remains once the material cures.

5.3.7 Slug Grouting

Slug grouting seals a mainline and the laterals connected to it in one setup utilizing an exfiltration sealing process. However, the grout does not flood the entire section but only a limited volume (roughly 100 gal), which travels from the downstream manhole towards the upstream manhole and through each connecting lateral along the way (Figure 5-49). In the course of the sealing action, two mainline bladders and one bladder in each lateral are used. Bladders are thin reinforced polyethylene type tubes. The method utilizes ultra fine cement grout which exfiltrates under low pressure through defects into the soil.

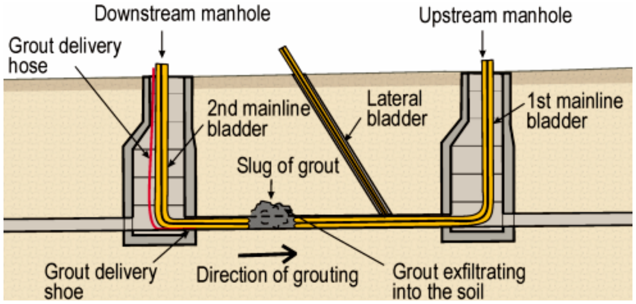

Figure 5-49. Slug Grouting.

The method eliminates infiltration but does not provide any structural enhancement and is intended for rehabilitation of structurally sound pipes only. Hydraulic capacity remains generally unchanged.

Slug Grouting System on the Market. One company offers the slug grouting system in the U.S.

Table 5-31. Slug Grouting System on the U.S. Market*.

	Developed	Available/Used	Grouted*	Manufacturer (in U.S.)
End-I™	U.S., 2004	U.S.	380' mainlines and 60' laterals (field tests only)	EBD/End-I, www.sewersealing.com

** Based on information received from the manufacturer.*

Applicability. Table 5-32 shows the existing conditions in which slug grouting can be used. The method requires structurally stable pipes. The ability to enhance structural stability has not been tested yet.

Table 5-32. Slug Grouting—Applicability*.

	Mainline Length	Mainline Diameter	Lateral Length	Lateral Diameter	Diameter Transition	Bends in Lateral	Offset Joint in Lateral	Cracks in Lateral	If Heavy Leaks
End-I™	600’	6-12”	50’	3-12”	3” to 6”	One 90°, multiple 45°	Up to 50%	Some	No problem

** Based on information received from the manufacturer.*

Requirement for Excavation. This method requires no excavation. In some cases however limited excavation may be used to install missing cleanouts if needed for pipe cleaning (if performing extended grouting from the mainline or grouting of whole laterals with push-type packers) and plugging of laterals.

Procedure. One case study included in Appendix A provides details of how this method can be applied. The procedure involves:

- Flow isolating of the selected section
- Inversion of bladders in all laterals and the mainline
- Insertion of grout
- Grout curing
- Removal of all bladders
- Removal of residual grout on the pipe surface.

After the section is plugged, each lateral bladder is inverted from the cleanout into the lateral and slightly into the mainline i.e. protruding into the mainline for about half the mainline ID, i.e. about 4” (Figure 5-50). The first mainline bladder is then inverted (Figure 5-51) through the upstream manhole and stopped about 18” before the downstream manhole. A special grout shoe is inserted through the downstream manhole against the bladder, which is followed with inversion of the second mainline bladder through the same manhole to meet the grout shoe.

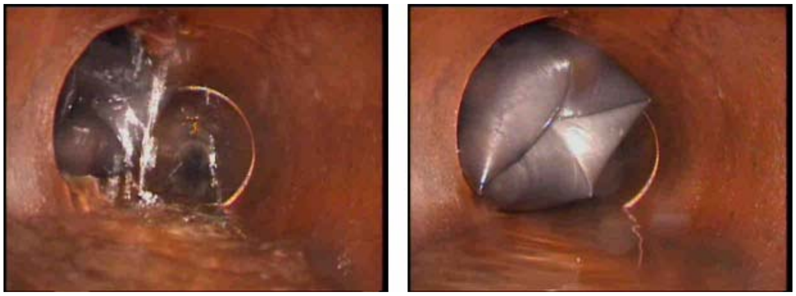

Figure 5-50. Lateral Bladder Insertion. Left: Just Reaching the Mainline. Right: Protruding in the Mainline (EBD/End-I).

Next the grouting starts through the grout shoe in direction of upstream manhole (Figure 5-52). The second mainline bladder is being inverted while the first bladder is simultaneously retracted[50]. As the bladders are simultaneously inverted and retracted, the slug of cement grout moves along the pipe in direction of the upstream manhole. For grouting the laterals, the path of the slug of cement grout is diverted into the lateral by retracting the lateral bladder instead of the mainline bladder.

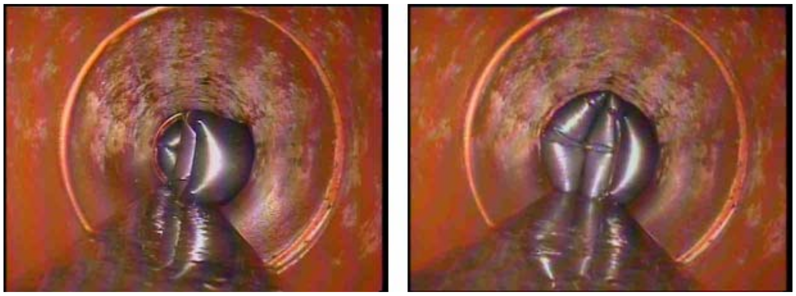

Figure 5-51. Mainline Bladder Insertion. Left: Moving Towards the Lateral Bladder. Right: Going Past the Lateral Bladder (EBD/End-I).

After the slug of cement grout has passed the entire length of the lateral, the mainline bladder that has been held in place to that point is now retracted back along the mainline. Simultaneously, the lateral bladder is now re-inverted until it reaches the mainline forcing any excess cement grout into the mainline. Thus the grouting of the mainline resumes.

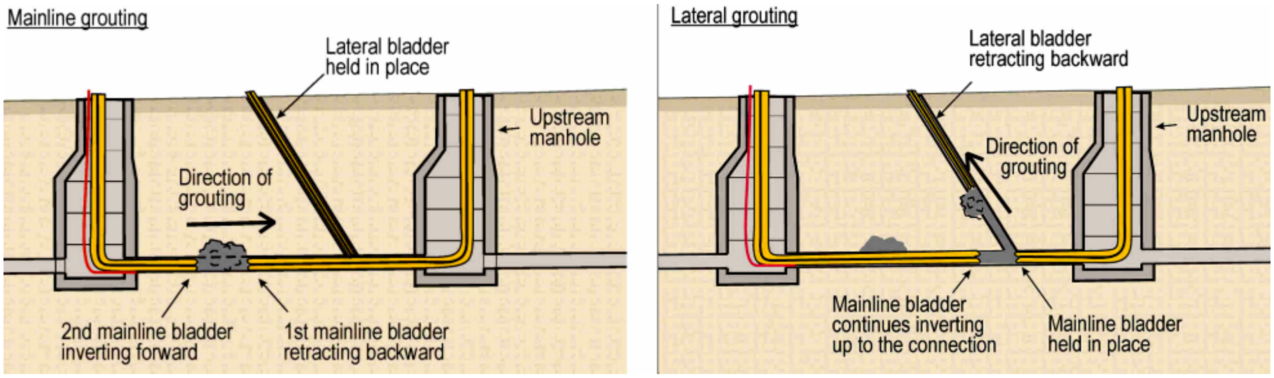

Figure 5-52. Slug of Cement Grout Moving through the Pipes. Left: Mainline Grouting. Right: Lateral Grouting.

Once the first bladder is completely retrieved from the mainline, the second bladder is left in place for three hours to let the grout cure. The bladder is then removed, and the residual green grout in the pipe (Figure 5-53) is cleaned with water jetting and a root cutter. This can be done immediately or after a couple of days. The short distance near the downstream manhole that is covered by the grout shoe at the beginning of grouting does not get grouted, and, if any defect is at that location, it is point repaired by reaching from the manhole.

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[50] *Bladders actually "evert" as they advance and "invert" as they are retracted. This report, however, uses "invert" for the tube advancement because this term has been commonly accepted as such in the CIP relining.*

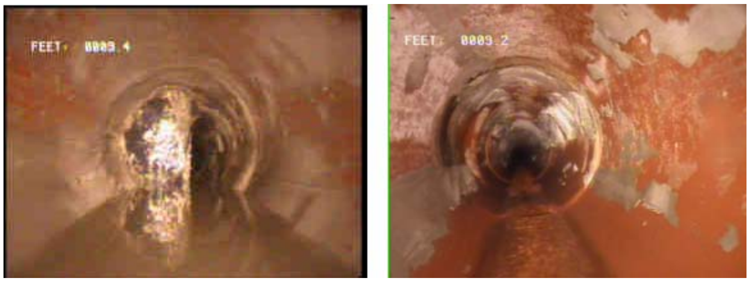

Figure 5-53. Left: Residual Grout on the Pipe Wall. Right: Pipe After Cleaning. (EBD/End-I).

Depth of Grouting. The depth of grout penetration into the soil depends on the viscosity of the grout, porosity of the soil and speed of grouting (i.e. passing of the slug of grout through the pipe, which determines how long the defect is exposed to the grout exfiltration). This is a method in its infancy and additional testing would be needed to answer this question.

Duration of Repair. Duration of rehabilitation with this method depends largely on the duration of setup, which is most affected by the number of laterals. Grout cure takes three hours. Assuming one mainline and three laterals, it takes about eight hours to complete one section and hence one section can be completed in a day. The quoted duration includes approximately one hour required for setting up the flow bypass before grouting and removing it afterwards. Removal of the residual green cement grout requires an extra several hours (about six hours in the case study in Appendix A), and it may be done on the day of grouting or a few days later.

Cost. With this system, the cost is more dependent on the number of setups than on the linear footage of pipes in each setup. Extent of preparatory work (cleaning, cleanout installation if needed) is also affecting the cost. Ballpark cost is about $500-1,500 for an individual lateral, and about $8,000-10,000 per section (assuming one mainline and three connecting laterals).

Longevity of Repair. At this time it is not possible to say how long the repair will last and whether repeated treatments of same sections would be necessary. An open question is whether the grout will have a reduced lifetime when exposed to domestic sewage. However, corrosion is not expected to be a serious problem because only a small area of installed grout is actually exposed to the corrosive pipe interior (grout fills in the gaps and voids in the pipe and the soil behind) and additives may be added to the grout to reduce the susceptibility to corrosion if needed.

Installation Features of Slug Grouting System on the Market. Table 5-33 summarizes some features of the End-I™ system related to installation.

Table 5-33. CIP Relining Systems—Installation Features*.

	Plugged Section	Insertion of Grout	Approx Duration	Productivity (8-Hr Day)	Approximate Cost (Mainline Plus Laterals)
End-I ®	Mainline with connecting laterals or mainline only	Through manhole	8 hr per section (with interruptions)	1 section	$8,000-10,000

** Based on information received from the manufacturer. Productivity assumes one mainline and several laterals connected to it.*

Experience in the City and County of Honolulu, HI. In this agency, the system has been tried in two field tests since May 2004, rehabilitating a total of two sections—two mainlines and three laterals. The process appears to be working and shows a promise as an economical fix. Challenges that need to be overcome are tooling issues and the longevity of the repair. Regarding the latter, not only is there a stigma regarding “grouting” as being a temporary fix. The use of a cement-based grout may result in a problem that the rehabilitation needs to be repeated after some time. On the other hand, the grout resides outside the pipe, so it is not quite clear if that would be necessary. The city considers that the system needs to be further proven in practice before being fully endorsed but that the process seems to be a success story in the making. They have observed that the inventor of the technology is an individual who understands the problems and is willing to accept the challenges of innovation. (Nishimura, 2005)

Method Advantages. The main advantages of slug grouting are:

- The only time excavation is required is if a cleanout (near house) needs to be installed.
- The method eliminates infiltration both in mainlines and all connecting laterals at the same time.
- There is no limit in applicability with respect to the pipe material or depth.
- There is little limit in applicability with respect to cavernous soils (which is an issue with chemical grouting or flood grouting).
- The disturbance to homeowners is minimal.
- No chemicals are used.
- The method is cost competitive to other trenchless methods.

Method Limitations/Disadvantages. The limitations/disadvantages of slug grouting are:

- No structural repair provided (or at least proven at this time).
- No pipe diameter upsizing.
- This is a new method that needs to be tested and proved in practice.

5.3.8 Robotic Repairs

Information about robotic repairs was obtained after the report had been completed and the method description can be found in 5.6.1 at the end of this chapter.

5.3.9 Summary of Rehabilitation Methods

The following tables list the repair options for sewer laterals and show the main advantages and limitations of each method, as well as the most suitable conditions for its application.

Table 5-34. Summary of Repair Options for Sewer Laterals.

Method	Description
Open cut repair	Pipe is excavated and replaced with a new pipe.
CIP relining	Material shaped to fit inside the pipe or connection and saturated with resin is installed in the pipe, followed by resin cure.
Pipe bursting	Pipe is burst with a bursting tool and a new pipe pulled in simultaneously.
Chemical grouting	Soil surrounding a pipe joint or section is impregnated with a curable chemical grout.
Flood grouting	Soil surrounding mainline/manholes/laterals is impregnated with a silicate-based grout.
Slug grouting	Soil surrounding mainline/laterals and voids in the pipe are impregnated with a cement-based grout.
Robotic repairs	Curable resin (or mortar) is injected into defective pipe wall and the soil surrounding the pipe, followed by resin cure.
Sliplining	New pipe is pulled/pushed through the old pipe.

Table 5-35. Comparison of Repair Options for Sewer Laterals.

Main Advantages	Main Disadvantages/Limitations	Most Suitable Conditions for Application
Open Cut Repair		
◆ Permanent repair ◆ Unlimited upsizing ◆ No chemicals used ◆ Commonly used and well-understood	◆ Extensive surface disruption and disturbance of homeowners ◆ Access to private property required ◆ Time consuming ◆ Often expensive	◆ Open area without obstacles ◆ Shallow pipe ◆ Pipes with severe offset joints ◆ Completely damaged pipe ◆ Large upsize needed
CIP Standard Liners		
◆ No excavation (cleanouts required) ◆ Structural repair possible ◆ Long term repair	◆ Repair up to 100-200' from cleanout ◆ Connection w mainline not repaired ◆ Can't upsize pipes, remove sags ◆ Not for pipes with large offset joints, many bends, baddly corroded ◆ Root problems in future possible ◆ Access to private property usually required ◆ Chemicals used toxic before cure (safety requirements)	◆ Long lengths of laterals need to be repaired and cleanouts exist ◆ Pits required for bursting are to be avoided ◆ Deep laterals that are difficult to repair with some other methods
CIP Short Connection Liners		
◆ No excavation (cleanouts required) ◆ Min disturbance to homeowners ◆ Access to private property not required ◆ Structural repair possible ◆ Long term repair	◆ Repair limited to first 1' of the lateral from the mainline ◆ Adhesion with existing CIP liners not fully proven (for some liners) ◆ Chemicals used are toxic before cure (safety requirements)	◆ Only lateral-to-mainline connections need to be repaired ◆ Mainline and/or lateral have been CIP relined but the annular space at lateral connection is not sealed
CIP Long Connection Liners		
◆ Connection with mainline repaired ◆ No excavation (cleanouts required) ◆ Short disruption to homeowners ◆ Structural repair possible ◆ Long term repair	◆ Repair limited to about 25' from mainline ◆ No upsizing ◆ Root problems in future possible ◆ Chemicals use (safety requirements)	◆ Longer lengths of lower lateral need rehalitation ◆ Mainline already CIP relined (if necessary)
CIP T-Liners		
◆ No excavation (cleanouts required) ◆ Connection with mainline repaired ◆ Repair extends into mainline ◆ Root problems in future even less likely ◆ Short disturbance to homeowners ◆ Structural repair possible ◆ Long term repair	◆ Repair limited to 80-160' of the lateral from the mainline ◆ No upsizing ◆ Chemicals used (safety requirements) ◆ Access to private property typically still required	◆ Extra protection against infiltration wanted near lateral-to-mainline connection ◆ Mainline already CIP relined (if necessary)

Pipe Bursting	◆ New pipe is installed ◆ No pipe cleaning/root removal needed (or minimal) ◆ Upsizing (one size) possible ◆ Eliminates minor sags ◆ Eliminates root problems in future ◆ Short disruption to homeowners (up to one day). ◆ No chemicals used	◆ Pits required ◆ Access to private property required ◆ Difficult in hard clays, high groundwater table ◆ Difficult in pipes repaired with metal clamps in the past ◆ Not for pipes with many sharp bends ◆ Risk of damaging objects when bursting at shallow depths	◆ Not very deep laterals ◆ Length to replace at least 20' ◆ Badly damaged pipe, few bends ◆ Roots are persistent problem
Chemical Grouting	◆ No excavation required ◆ Repairs only where needed (pressure test performed first) ◆ Removes infiltration, root problems ◆ Min disturbance to homeowners ◆ Access to private property usually not required ◆ Inexpensive	◆ No structural repair ◆ No upsizing ◆ Sometimes can't be completed (the section can't be pressurized) ◆ The longer the bladder, the more difficult the installation when performed from the mainline ◆ Grout may crack in some groundwater conditions ◆ Chemicals used (safety requirements)	◆ Many leaking defects in structurally sound pipes ◆ Groudwater table stable around the pipe defects throught the year ◆ Inexpensive and quick repair is desired ◆ Cleanouts exist already
Flood Grouting	◆ No excavation (cleanouts required) ◆ Removes infiltration, root problems ◆ Repairs both mainlines and laterals ◆ Min disturbance to homeowners	◆ No structural repair, no upsizing ◆ Access to private property required ◆ Chemicals used (safety requirements)	◆ Many leaking defects in still structuraly sound pipes ◆ Deep pipes, many sharp bends ◆ Cleanouts exist already
Slug Grouting	◆ No excavation (cleanouts required) ◆ Removes infiltration, root problems ◆ Repairs both mainline and laterals in one setup ◆ No chemicals are used	◆ No structural repair (evaluated yet) ◆ No upsizing ◆ Access to private property required ◆ New system and must be tested and proven in practice	◆ Many leaking defects in structurally sound pipes ◆ Deep or shallow laterals ◆ Cleanouts exist already ◆ Difficult soils (e.g. cavernous soils)
Robotic repairs	◆ Provides structural repair ◆ Removes infiltration, root problems ◆ No excavation needed ◆ Access to private property not required ◆ Min disturbance to homeowners	◆ Repair limited to first 2' from the mainline ◆ Chemicals used (safety requirements)	◆ Only lateral connection and short distance into lateral need repair ◆ Break-in protruding laterals

Sliplining		
◆ No special equipment needed ◆ No chemicals are used	◆ Reduction in pipe diameter ◆ Pits required ◆ Time consuming ◆ Expensive	◆ Large lateral pipes

5.4 Root Control

5.4.1 Importance of Root Control

Tree roots are a very common and serious problem in sewer collection systems causing sewer blockages and overflows even in locations that do not have significant I/I problems. By supplying water and nutrients, sewer pipes provide an ideal environment for growth of roots. A pipe crack as narrow as a thickness of a human hair is generally sufficient for roots to find their way into the pipe. For a long time it was believed that trees grow roots to the width of their drip line and that the sewer pipe was safe from root intrusion if it was laid outside of that area. Now it is believed that roots can grow four to seven times the size of the drip line area (Figure 5-54) (Conroy, 2005). Roots grow differently in sewer laterals than in mainlines. The flow in mainline pipes is generally continuous and the roots form a curtain reaching from the top into the pipe. In laterals, however, the flow is intermittent and the roots try to fill up the pipe completely (Figure 5-55).

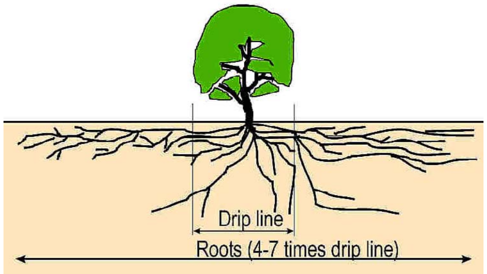

Figure 5-54. Root Structure (Duke's Root Control).

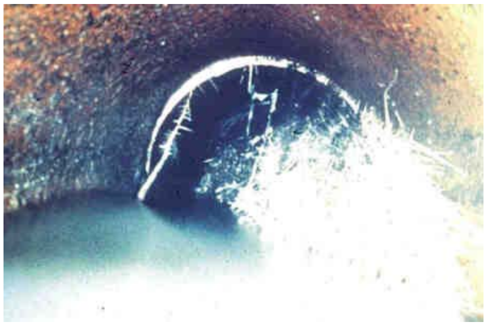

Figure 5-55. Roots in the Lateral Pipe (Duke's Root Control).

Roots in laterals not only block the flow in the pipe but also contribute to further cracking of the pipe and the separation of joints over time. They also endanger the pipe's structural stability by transferring external forces from the tree onto the pipe. For example, if a strong wind is swaying a tree, a pipe imbedded firmly into its roots can dislocate and break, especially if it is shallow and aged. Safe and cost-effective root control is therefore of great importance to many municipalities.

All lateral rehabilitation methods described earlier in this chapter have as one objective the prevention of root intrusion into laterals. Pipe bursting is very effective because it installs a new, continuous HDPE. With CIP liners, as outlined in the presentation of the technique, there is typically some annular space left between the pipe and the liner and roots can enter this space and continue to grow there, pressing on the liner and potentially causing a structural problem with the liner over time. However, if the access to inside of the lateral is sealed by the liner, the roots will be less likely to enter the annular space. Grouts can also potentially give way to strong roots in time, although there are many examples of effective root prevention with this type of repair. Agencies, however, sometimes wish to address root problems without rehabilitating the laterals and seek methods available simply for root control. They also typically need to remove existing roots from laterals prior to any lateral inspection and rehabilitation. This chapter briefly presents available mechanical and chemical methods for root removal and control in sewer laterals.

5.4.2 Mechanical Methods

Mechanical root cutting provides immediate, but temporary relief from protruding roots. Mechanical root cutters poke a hole through the root mass but do not leave a clean-shaven pipe. For example, an 8” root cutter can clean only a 4-6” pathway and the roots are typically not completely removed. Root cutting also stimulates vigorous re-growth and municipalities are forced to cut roots more frequently to avoid blockage.

Rodding. For rodding sewer laterals, small units are very suitable. For illustration, a unit by Electric Eel is described (Figure 5-56). This model runs up to 200’ of 1.25” self-feeding dual cable in 8’ or 10’ sections. The machine spins cable at 500 RPM for maximum cleaning power in 3-10” diameter pipes. A heavy duty 0.5 HP motor motor is standard, but 0.75 HP and 1.0 HP motors are also available. Similar units are available for slightly different pipe ranges and cleaning distances. Model C kit with 200’ of cable would cost approximately $2,200. (Speranza, 2005)

Figure 5-56. Small Rodding Unit (Model C by Electric Eel).

Hydraulic Cleaning (Jetting). Small units for hydraulic jetting of pipes are also available. Another unit by Electric Eel is presented for illustration (Figure 5-57). This model has a heavy-duty 1.5 HP electric motor and a 1,500 psi pump with pulsation. The pump puts out a flow of 1.7

gpm and cleans pipes between 1” and 4” in diameter, up to 150’. Model EJ 1500 would also cost approximately $2,200. (Speranza, 2005)

Figure 5-57. Small Jetting Unit (Model EJ 1500 by Electric Eel).

Additional equipment for mechanical root control from several manufacturers, most of which is more suitable for mainlines than laterals though, can be found on web pages of Weco Industries (http://wecoind.com).

5.4.3 Chemical Methods

Chemical treatment is another approach in root control in which herbicides are used to kill existing roots and/or retard their future growth. The herbicides may be a contact herbicide that kills only the plant parts contacted by the chemical, or a systemic herbicide that is absorbed by the roots and is carried throughout the plant. The following are some of the main chemicals that have been used for root control in sewers:

- Acids and solvents—Typically represented by “pour down” products. These acids and solvents are inefficient because the agents are unable to get above the flow line where most of the root growth resides. Also, varying flow conditions will inhibit these products from being applied successfully and consistently.
- Copper sulfate—A very popular chemical used in 1940s through the 1970s and typically applied in a blue crystal form by pouring into a manhole. The copper sulfate would settle to the bottom of the pipe and help to keep the roots from completely filling the sewer. Copper Sulfate based products are ineffective in killing roots consistently and are unable to kill roots that lie directly outside the pipe. Also, copper sulphate is not easily removed from sewage at WWTP’s and can accumulate in the sludge—requiring special sludge disposal arrangements.
- Dicholbenil—A non-soluble aquatic herbicide typically used more for preventing plant growth rather than killing existing plant growth.
- Metam sodium/dichlobenil—A powerful combination of herbicides commonly used in foaming processes from the 1970s through the mid 1990s. These herbicides are still used, but their use is reported to be declining due to environmental restrictions. Recently, the EPA reclassified metam as a restricted use herbicide; it can only be applied by state licensed pesticide applicators.
- Diquat dibromide—Diquat is a general-use aquatic herbicide (classified by U.S. EPA), which is reported to have an extremely low toxicity to treatment plant processes, including nitrification and denitrification, but is effective at killing tree roots at low concentrations.

> The chemical has received a classification of “evidence of non-carcinogenicity for humans” (U.S. EPA, 1995).

In lateral root control, the chemical is usually applied through cleanouts. Applications of the chemical should only be applied by licensed professionals and the chemicals should only be applied to laterals through a cleanout located outside of the house. Typically, a flow through plug hose is used to apply the foaming root killer. The hose is inserted into the cleanout with the discharge opening pointed downstream towards the main line sewer. The flow thru hose has a bladder, that when filled with air, prevents the foam from discharging upstream toward the building/home and from spilling over onto the ground. A 50’ section of 4” pipe takes about 5-10 minutes for the actual treatment. The most difficult part of applying a foaming root killer to a sewer lateral is usually related to finding the cleanout, if one exists at all. The use of a small sewer video camera can be of great value in helping to locate the sewer lateral and any outside cleanout. Once found, a professional root control applicator can apply the chemicals in minutes. The treatment kills the roots on contact, and within two to four months the roots are typically decomposed and may begin to slough off. Due to low flow conditions in sewer laterals, the dead roots may continue to cause blockages, unlike sewer mains where normal flow conditions can easily wash the dead roots away. Therefore, the most common practice is to have the sewer lateral mechanically cleaned several months after the chemical treatment to help prevent the dead roots from continuing to be a nuisance. The real benefit of following this practice is years of relief from backups and protection of the structural integrity of the pipe. Periodic retreatment of the pipe is recommended as preventative maintenance.

Foam is the best carrying agent to deliver the root killing chemicals because foam consists of millions of small, densely compacted bubbles which trap the active ingredients in between the bubbles and hold it against the roots to provide the contact time needed for the ingredients to work effectively. The chemical with thick, shaving cream consistency (Figure 5-58) travels up the lateral completely filling the dead air space in the pipe (Figure 5-59). The sewer service is not interrupted during the treatment, and the flow will not wash the foam away for several hours. The foam will cling to the top and the sides of the pipe while the flow passes safely underneath. A minimum of one hour is needed for most successful applications, though some foams may last up to 12-15 hours. It is not always necessary to completely fill the pipe with foam to have a successful treatment. Coating the sewer with foam is reported to be enough to do the job.

Figure 5-58. Foam Consistency (Duke’s Root Control).

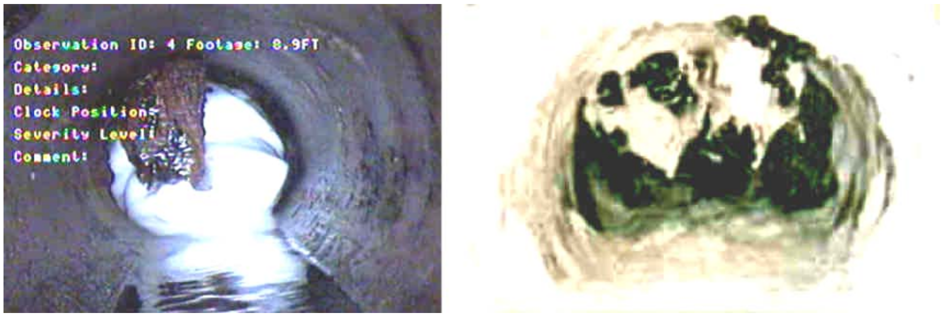

Figure 5-59. Foam in the Pipe. Left: Foam-filled Pipe. Right: Foam-coated Pipe (Duke's Root Control).

A typical treatment takes about 5-10 minutes. On average, 20-30 laterals can be treated in an eight-hour period. However, driving time between locations, finding the cleanouts, getting the cleanout cap off, and dealing with a plugged up lateral can all affect the number of laterals treated in one day.

Treatments in laterals should be repeated about every three to five years as preventive maintenance. Treatments have been known to last 10 years or more. The time duration between treatments is usually related to the initial severity of the root intrusion. The more severe the root intrusion, the more frequently the application should be repeated.

Root Control Program in Norman, OK. The Norman Utilities Authority oversees approximately 430.8 miles of collection system piping, 14 lift stations and one wastewater treatment plant[51]. It inspects about 200,000' of the system each year and this serves as one of the tools to identify root-infested lines that need to be treated. Input is also received from crews in the field that are cleaning the sewer lines with flush trucks. The city previously used mechanical root control but moved away from reliance on mechanical cutting because of the regrowth of roots in problem areas. For the past 10 years, the city has contracted for chemical root control to Duke's Root Control. The root control program treats about 100,000' of sewer main per year and this augments a $3 million per year rehabilitation and replacement program, which renews 25,000-30,000' of pipe per year. The city reported that from fiscal year 2000 through fiscal year 2005, mainline stoppages in authority-owned lines fell by 54% (due to combined cleaning, replacement and root control). The city has indicated that it plans to continue the chemical root control program indefinitely. (Davis, 2005; Rush, 2004)

5.5 Conclusion

The widespread strong interest in I/I reduction and the resulting growing interest in sewer lateral programs has spurred the development and introduction of a variety of techniques for safe inflow source removal and lateral rehabilitation and replacement. While problems may occur with any of the rehabilitation and replacement techniques presented, all of the methods can be applied successfully under the right conditions and most municipalities report good overall success rates with their chosen technique(s). One city reported very poor results with its trials of pipe bursting and CIP relining as a result of a poorly qualified contractor whereas the same techniques have been used successfully in many other cities across the country. Proper

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[51] *The City of Norman does not maintain private sewer laterals.*

qualification requirements (of the crew(s) as well as the contractor) and adequate quality control and quality assurance are necessary components of a successful lateral rehabilitation program. Since most municipalities want to maximize the early results of an I/I reduction program, strong attention should be paid to the removal of inflow sources as a potential first step. Costs for inflow removal are generally quite low (e.g., when compared to the cost of expanded wastewater treatment capacity and associated costs) and the quantities of inflow removed from the sewer system are usually very significant.

5.6 Addendum

5.6.1 Robotic Repair

Robotic repairs renovate lateral-to-mainline connections by applying a resin (or mortar[52]) to the damaged piece of pipe, which cures into a material compatible with the host pipe and which becomes an integral part of the pipe. The damaged area to which the resin is applied is first ground either partially (to the depth required to expose the virgin material of the host pipe) or completely (to remove broken pieces of pipe). Holes also may be drilled through the pipe (Figure 5-60). Depending on the system, the resin can be applied with or without pressure. If pressure is applied, the injected resin penetrates into the soil behind the pipe where it mixes with the soil creating a sealing collar of material around the pipe in a similar manner as in chemical grouting.

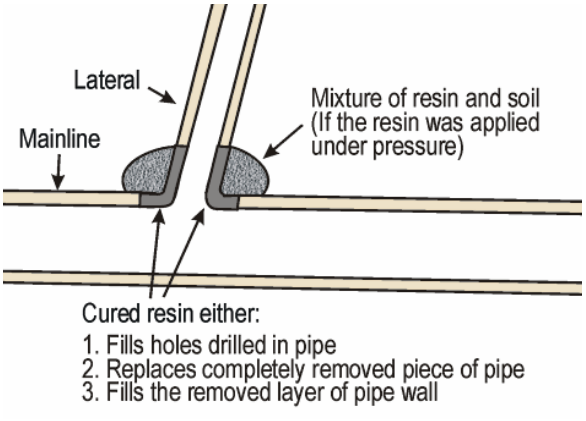

Figure 5-60. Robotic Repair.

The method eliminates infiltration (Figure 5-61) and restores or enhances the structural integrity of pipes lost over time. Hydraulic capacity of pipes is generally not changed.

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[52] *One system only briefly mentioned in this report (Hächler) uses mortar. Two systems presented with more detail use resins.*

Figure 5-61. Robotic Repair Stops Infiltration. Left: Infiltration Before Repair. Right: Repaired Connection. (The Janssen Process LLC).

Systems on the Market. Robotic repair systems have been used from mid 1980s, but mostly in Europe, Australia and the Far East. Two systems are currently available in U.S. (Table 5-36). The KA-TE system was not significantly pursued in the U.S. market over the past several years but interest has been expressed for it to become more active in the U.S. market again. The Janssen system is being introduced to the U.S. market for the first time in 2006.

Table 5-36. Robotic Repair Systems on the U.S. Market*.

	Developed	Used	Estimated Laterals Grouted*	Manufacturer
Janssen Lateral Rehab System	Germany, 1999	Europe, now in U.S.	10,000 laterals in Europe	Janssen Process LLC www.janssen-umwelttechnik.de
KA-TE	Switzerland, 1986	Worldwide and U.S.	500,000 laterals worldwide, 4,000 laterals in USA since 1992	SAF-r-DIG Utility Surveys, Inc. http://safrdig.com

** Based on information received from the manufacturer.*

One other system used in Europe is Hächler EL 300/600 by the Swiss manufacturer Hächler AG Umwelttechnik (www.haechlerumwelttechnik.ch). Unfortunately, the information from this manufacturer has not been received in time to be included in this report.

Applicability. Table 5-37 shows existing conditions in which robotic repairs can be applied.

Table 5-37. Robotic Repair Systems—Applicability*.

System	Mainline Diameter	Lateral Diameter	Max Bend (Angle at Connection)	Max Offset Joint in Lateral	Cracks in Lateral	If Heavy Leaks at the Location That Needs Repair
Janssen	8-24”	4-12”	90°	Any	Any	No problem
KA-TE	8-30”	4-6”	90°	4-6”	Any	No problem

** Based on information received from the manufacturer.*

Resins Used with Robotic Repair Systems. Different resins are used depending on the system:

- The KA-TE system uses a two-component epoxy resin. It cures in about four hours.
- The Janssen Lateral Rehab System uses silica-based resin. JaGoSil is a two-component silicate-isocyanate resin, which is mixed at the nozzle. It cures in 20-30 minutes.
- In contrast to these resins, Hächler EL 300/600 applies a fiber-reinforced dry mortar.

Both epoxy and silica-based resins must be handled with care by operators in the field, as they presents a potential health hazard to workers (dermal and respiratory problems) before they cure. This is the same as with CIP relining. OSHA Safety and Health recommendations must be followed. Once cured, the resins present no hazard and are non-toxic to the surrounding soil and the groundwater.

Repair Procedure. The repair procedure typically involves the following steps:

- Pipe cleaning and inspection
- Preparation of damaged area for repair
- Resin application
- Post CCTV inspection

Initially, cleaning of mainline and lateral connection is performed, if necessary, to the extent to allow positioning of the equipment in the mainline at the lateral connection as well as inverting of the bladder into the lateral pipe later in the procedure. The lateral is cleaned of all obstructions and roots over the length to be repaired (up to 2') plus an additional distance (usually another 1' at minimum). Pipe inspection is performed with a mainline CCTV camera. Final cleaning is completed after the cutting/grinding action in the next step.

Preparation of a damaged area for resin injection may involve:

- Cutting off or grinding away any protruding lateral (Figure 5-62.Left)
- Grinding damaged area of pipe to cut the pipe wall thickness to a depth required to expose the virgin material of the host pipe (KA-TE grinding robot)
- Drilling holes in the pipe if the integrity of lateral-to-mainline connection is good or else grinding to completely remove the damaged piece of pipe (Janssen) (Figure 5-62.Middle)
- After completed cutting/grinding, the area is flushed with water.

Grinding/drilling is important for two reasons. With both systems, it provides a clean surface with which the subsequently applied resin can bond. Additionally, with a pressure resin injection system (e.g. Janssen), it also provides a pathway for the resin to reach the soil behind the pipe wall.

Figure 5-62. Lateral Connection Before, During and After Robotic Repair. Left: Protruding Laterals Before. Middle: The Connections After Grinding. Right: The Connection After the Resin Has Been Applied. (The Janssen Process LLC).

The resin is applied next. With the KA-TE system, a special filling robot in conjunction with a spatula tool can be used to apply the epoxy resin onto the pipe wall. Since the mid 1990s, however, this system has been offered with a lateral shoe (Figure 5-63). The shoe is a flexible plastic plate positioned in the mainline at the lateral opening, from which an inflatable bladder is expanded into the lateral. The bladder fits the lateral closely creating a temporary mold. The resin is injected under pressure through two injection holes into the cavity ("annulus" in the figure) until it is filled. During resin cure (approximately 2-4 hours), the bladder and the lateral shoe holds the resin in place. After curing, the lateral is removed by robot.

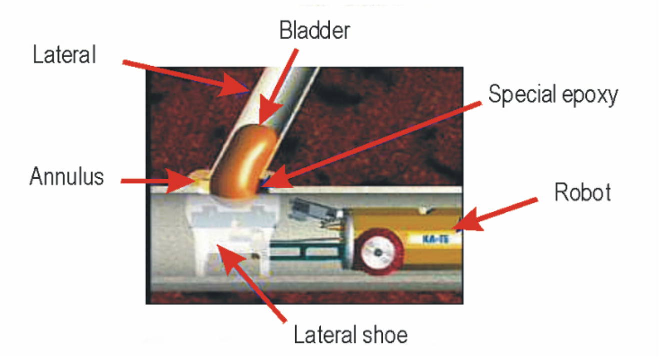

Figure 5-63. The KA-TE System: Repair with Lateral Shoe (SAF-r-DIG Utility Surveys, Inc).

The Janssen system uses a packer with an inflatable bladder (Figure 5-64). Guided by CCTV cameras, the packer is positioned at the lateral opening and the bladder is extended into the lateral connection. The packer and the bladder are then inflated to match the diameter of the mainline and lateral pipe respectively. (The side bladder extends up to 24” into the lateral and forms a homogenous T with the packer in the mainline).

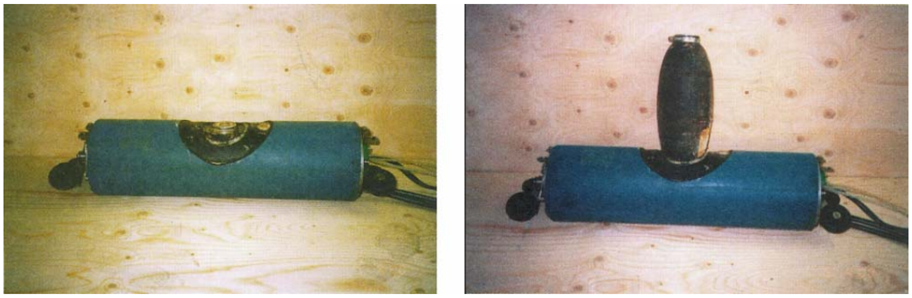

Figure 5-64. Packer Used in the Janssen System. Left: With Deflated Bladder. Right: With Inflated Bladder (The Janssen Process LLC).

The silica-based resin then is injected filling voids in the pipe and reaching further behind the pipe, where it continues filling any voids in the soil and mixing with the soil (Figure 5-65). This solidifies the soil and secures the structural integrity of the lateral and mainline pipe junction. The resin cures in about 20-30 minutes.

Figure 5-65. Janssen System. Left: Inflating of Bladder. Right: Resin Injection into Pipe and Surrounding Soil (The Janssen Process LLC).

After the completed repair, CCTV inspection is typically performed, but the agency can perform any other testing (e.g. pressure testing) if desired.

Duration. The duration of repair depends mostly on the time required for setup (traffic control, pipe cleaning and inspection) and resin cure (from 30 min to four hours, depending on the type of resin used). Overall, up to five lateral connections can be repaired in one day.

Longevity of Repair. The life expectancy of repairs with this method is assumed to be 50 years or more.

Cost. The cost depends on the preparation work required, quantity and type of resin used, and the number of connections repaired in the area. On average, the cost is about $1,000-1,500 per connection with KA-TE and about $2,000 per connection with the Janssen system.

Experience with Robotic Repairs. Limited testimonials were obtained for this report due to time constraints.

The City of Berlin, Germany, has used both the KA-TE and the Janssen system over the years (Sedehizade, 2005). The KA-TE system used in this city does not inject the resin under pressure but rather applies it with spatula, and therefore cannot be used with active infiltration. It is also found to be rather complicated in application, as different robots have to be changed in every step of the process. The agency finds the Janssen system much simpler and "user friendly", and, because it injects the resin under pressure (1.5-2 bar), prefers to use this system to repair broken connections, especially when groundwater infiltration is present. The agency uses the KA-TE robots mostly after mainline relining when reopening lateral connections. The Janssen system was tested by the City and the results verified that it was performing properly. The City wanted to purchase the system about two years ago but did not manage this due to administrative reasons. Nevertheless, the Janssen system has now been in use for about four years and has become a part of the city’s rehabilitation program.

Method Advantages. The main advantages are:

- No excavation is required.
- The method provides structural repair.
- The method eliminates infiltration.
- The method is very suitable for repair of break-in protruding laterals (which would have to be cut off with a robot even if other repair method would be used).
- The method eliminates root problems.
- Relatively easy to use in field applications (with late development of robotic systems).
- The cost is reasonable considering it provides a structural repair of often the most vulnerable spot in the sewer system.
- The method is fast and disturbance to homeowners minimal.

Method Limitations/Disadvantages. The limitations/disadvantages are:

- The method repairs only the lateral-to-mainline connection and a relatively short distance into the lateral (if entire lateral is in bad condition, other methods should be selected or used in conjunction with this method).
- Chemicals used (resins) are hazardous if spilled or splashed on the skin or in the eyes. The crews need to use overalls, gloves, and safety glasses when working with these chemicals. No hazard remains once the material cures.

5.6.2 Testing of Rehabilitation Systems in Germany

The Institute for Underground Infrastructure GmbH (IKT) has been testing performance of systems for sewer rehabilitation aiming to asses the quality of the products available on the market and to illustrate the potential for improvement. Their reports in German (some in English) can be found on http://www.ikt.de/. The tests are ordered and paid by German public works agencies.

One report describes testing of lateral CIP systems offered in Europe (Kaltenhäuser, 2005) and another testing performed on systems for repair of lateral-to-mainline connections (Bosseler and Kaltenhäuser, 2004), where for standard damages, KA-TE was the only robotic repair system to achieve an IKT score of "good". For the extreme damage represented in the IKT tests, KA-TE scored less well than some of its competitors, but none of the robotic systems proved very suitable for the repair of this extreme level of damage.

5.6.3 Updated Product Information

Information about the systems and technologies for lateral rehabilitation/replacement in the market will continue to be updated by the TTC as product information becomes available. For updated product information about these systems please refer to the TTC web page www.ttc.latech.edu.

CHAPTER 6.0

FINANCING ISSUES

6.1 Introduction

In addition to the technical difficulties posed by programs for the rehabilitation of sewer laterals, there are financial issues that can be even more challenging. As discussed in the survey data presented in Chapter 2.0, none of the agencies responding to the survey owned the entire lateral with the distinctions in ownership being whether the agency owned the lateral as far as the property line, owned only the sewer tap, or had no ownership of the lateral connection and piping at all. Thus, a public program designed to fix I/I and other problems in sewer laterals must either find the means to encourage or force private property owners to pay for the necessary improvements or must decide how to use public funds, public financing or public assistance to make the program happen.

Depending on the lateral ownership arrangements, it may be necessary to prove that a lateral is defective, determine whether the property owner or the agency is responsible for the defect(s) and to decide whether the agency can legally spend public money on private property improvements (see Chapter 7.0 for the discussion of this and other legal issues). There is also the socio-economic ramifications of many lateral defects being located in older neighborhoods whose residents tend to be elderly residents on fixed incomes. This chapter of the report discusses the issues related to financing for sewer lateral improvements and presents a variety of programs that have been used by agencies to provide financial assistance or encouragement for property owner participation in the rehabilitation program.

6.1.1 Issues

Even though it has been shown in many cases that repair or replacement of sewer laterals is cost-effective in overall terms (see Chapter 4.0 and Chapter 8.0 for related discussions), the repair or replacement of laterals and the proper disconnection of inflow and other lateral related I/I sources can be expensive and usually requires skills and equipment that most homeowners do not possess. Since most homeowners do not posses the equipment or skills to carry out the repairs, the options available to them for implementing repairs at a low cost are limited. The high cost of repair usually involved (except for some simple measures such an cleanout cap replacement or downspout disconnect) can raise the resistance of the property owner to voluntary participation in a rehabilitation program unless the purpose and public benefits of the program can be clearly explained, the property owner's responsibility clarified, and measures to ease the involvement of the property owner developed.

Where building lateral repairs are cost-effective, there is a strong incentive for agencies to aggressively pursue inflow source disconnect and sewer lateral rehabilitation programs and hence to find ways to tackle the financial issues inherent in this work. And since rehabilitation of service laterals can benefit the system as a whole and is not just a benefit to the individual homeowner, there is some justification for using public money to repair privately owned building sewers. Nevertheless, some states make it illegal for public bodies to spend money on improvements to private property without recovering such expenditures by assessment of the owners. Although restrictive legislation may exist, it should be noted that legislative relief can be pursued and has been successfully accomplished in some states. A more complete discussion of the legal and liability issues related to public work on private sewer laterals is provided in Chapter 7.0.

Once the legal issues have been considered, the remaining key issues are the choice of methods of public financing and methods of encouraging or requiring private payment for the work on the private portions of laterals.

6.2 Methods of Public Financing of Lateral Improvement Programs

The setup and operation of a lateral improvement program requires the allocation of funds (formal or informal) for this purpose irrespective of whether public funds are actually used to pay for physical improvements of private sewer laterals. Programs will likely involve data gathering, site inspection, flow monitoring, cost-benefit analyses, public education, property owner liaison and enforcement in addition to the direct costs of any work done. If a program to finance or pay for all or a portion of the cost of the physical work, is developed, this can involve considerable expenditures. To meet the cost of the program at the planned level of effort and expenditure, there is the normal array of public sector funding alternatives including the following:

- Allocation of existing public resources to create the new program
- Raising funds through the issuance of general obligation bonds
- Increasing property taxes
- Levying special assessments
- Assessing service charges
- Assessing user charges

6.2.1 General Obligation Bonds

General obligation bonds are the most common form of debt issued by state and local governments. Agencies may borrow money to finance any project undertaken for a public purpose. The amount of indebtedness that agencies may incur is limited by law and, in addition, high levels of debt may affect the bond rating for the public agency or municipality and increase the cost of future borrowing. The issue of public purpose in projects involving work on private property is dealt with in Chapter 7.0.

6.2.2 Property Taxes

Agencies may levy property taxes to raise revenue to fund projects. The amount of taxes that can be raised may depend on the size of the agency. A property tax increase may be a contentious local issue unless the public benefit can be clearly explained and communicated to those who would pay the increased property taxes.

6.2.3 Special Assessments

Special assessments on property may also be used to fund a private lateral program. Special assessments can be used for a limited and defined area. The assessments may not exceed the value of the benefits accruing to the property. Special assessments already are used in many communities to fund such projects as sidewalk installation or repair. When making the assessment, it is necessary to determine whether the property owner needs to pay the assessment immediately, for example, whether the payment can be spread over several years, or deferred until the sale of the property at a future date. Either of the latter options will require the financing costs of the deferred payment to be considered.

6.2.4 Service Charges

Agencies may collect service charges for service provided to any user. In the case of private sewer lateral projects, such services may include work done by the agency in inspection, removal of inflow sources, cleaning and root control and rehabilitation/replacement of private portion of the laterals. Decisions to allow deferred payments or exceptions based on income level will require additional resources to provide for the financing costs and any revenue waived. It may not be possible to pass these charges directly to others paying for the service.

6.2.5 User Charges

User charges may also be imposed on users to raise revenue to pay operating costs. The fees imposed must be proportional to other users based on measurable factors. In the case of private sewer lateral projects, the most likely user charge to consider is that levied for water supply and/or wastewater collection and treatment. Since these user charges are typically based on user flow volumes, or some other user characteristic, it will be necessary to consider whether a simple proportional increase in the existing rate structure is appropriate or whether basing increased charges on a different set of criteria to provide a more equitable cost distribution would be appropriate. For example, major industrial contributors to wastewater flow may represent a major portion of wastewater conveyance and treatment cost but represent very little of the needed expenditure on private lateral rehabilitation because of the small number of laterals involved.

6.3 Examples of Current Practices

A high proportion of sewer laterals belong to residential properties and homeowners provide more challenging issues relating to administrative and financial aspects of the rehabilitation work. For this reason, the following discussion will emphasize the issues from a homeowner’s perspective. Homeowner payment for correction of their private lateral sewer may include:

- Full homeowner payment
- Partial homeowner payment
- No homeowner payment

In most communities, repair of the private portion of the sewer lateral is the sole responsibility of the homeowner. Yet, some utilities have developed approaches to provide homeowner assistance in an effort to improve the overall performance of their wastewater systems for all customers. Some examples of these efforts follow.

Montgomery, AL. The Water Works and Sanitary Sewer Board for the City of Montgomery, AL, has had one of the longest and most known lateral repair programs in the country. Montgomery's program provides partial funding to the homeowner for lateral repairs and has developed a proven approach to find, fix and fund lateral repairs. Montgomery has used its Automated Service Lateral Repair Program (ASLRP) since the fall of 1994 with a favorable level of participation from the public and minimal customer resistance, according to their information. Montgomery has successfully accomplished 97% of the lateral defect repairs (2,197) using the lateral program process. The remaining 3% are defects located on abandoned or unoccupied property. In Montgomery, the property owner is responsible for the lateral from the house to the main sewer and the lower lateral is the segment from the right-of-way to the main sewer. As part of their program, Montgomery provides a financial assistance program to property owners with a lower lateral problem so that lower lateral repairs exceeding $1,200 would be financed by Montgomery. If the repair needed is at the Wye connection at the mainline, Montgomery pays for it. The property owner is responsible and must pay for repairs to the upper lateral portion (Holmberg, 2003).

Phoenix, AZ. A survey conducted by the City of Phoenix, AZ, found that out of 10 cities surveyed in 1994, four cities required property owners to maintain and repair the entire lateral, six cities paid for lateral repairs only within the right-of-way and then only for single family residential homes. The City of Phoenix currently pays for repairs from the property line to the main sewer while the property owner pays for any repairs needed from the property line to the house. In 1994, the city allocated $250,000 to the lateral repair program. Since 1996 they have allocated about $200,000 per year to the program (Kaleta, 1999).

Mobile, AL. In Mobile, AL, the homeowner pays for defective laterals minus the cost for one cleanout, one pre-construction video and one post-construction video (Sullivan, 2001).

San Luis Obispo, CA. The City of San Luis Obispo, CA, reimburses homeowners for 50% of repair costs up to $1,000 with video inspection costs included. The funding is only available for single-family homes; no commercial or apartments are eligible for the program and funding will only be provided once per property. Their program is called the Voluntary Service Lateral Rehabilitation Program (VSLRP). The city has current funding of about $50,000 per year for lateral repair (Hix, 2001).

Albany, CA. The City of Albany, CA, has adopted an Upper Lateral Compliance Program which requires homeowners to test, and, if necessary, replace the upper lateral. The tests are administered prior to the property being sold or a building renovation worth more than 5% of the value of the home. The homeowner pays for any lateral improvement needed. The city issues a Certificate of Compliance for those laterals passing the test or that are rehabilitated. The certificate is effective for 20 years. The city pays for any lower lateral repairs needed (Rush, 2003).

WEF Survey. In a Water Environment Federation survey of 316 agencies conducted as part of a cooperative agreement with EPA conducted in 1998, it was found that 50% of the respondents indicated that they rehabilitate private sewer laterals. With regard to the cost of the rehabilitation performed, the customer paid for the work in 72% of the responding utilities while 27% of the respondents had user fees and 15% of the respondents used local funds. For utilities that require the homeowner to pay the full cost of lateral repairs, only 20% provide any payment plans. It was also found during this survey that older neighborhoods with fixed income homeowners were more likely to need lateral repairs. Other information reported in this survey found that a gravity sewer connection repair cost was about $500-600 in 1984 with a lateral repair and replacement cost of $3,000-3,600. In 1986 it was reported that the repair cost for service laterals was about $1,200-4,000 in Johnson County, KS (WEF, 1999).

Castro Valley, CA. The Castro Valley Sanitary District, CA has a lateral repair program that offers financial assistance of up to 50% of approved costs up to a maximum of $2,000. This financial benefit is only available for complete lateral replacements where the lateral replacement cost is in excess of $2,000. An application is required to obtain the financial assistance. (www.cvsan.org)

Brentwood, CA. Brentwood, CA, reports that the average lateral repair cost is $1,700 however some repairs cost as much as $10,000. The Lateral Maintenance Program instituted by the city is paid for by a $1 per month charge to each homeowner that is placed in a Water Enterprise Fund. This fund is used to repair laterals from the cleanout to the main; the homeowner is still responsible for repairs from the cleanout to the house. (www.ci.brentwood.ca.us)

Mishawaka, IN. Mishawaka Utilities, IN, reports that they fund lateral repairs through a $0.50 per month charge to each residential user as part of a sewer insurance program. The money collected is used for repair or replacement of failing private sewer connections. The city pays for costs which exceed $250 including all street repairs, curb repairs and sidewalk repairs. (www.mishawakautilities.com)

Vallejo, CA. Vallejo Sanitation and Flood District has a private sewer lateral program where the agency pays for the first lateral repair and the homeowner is responsible thereafter. A user fee distributed equally among all users is used to pay for the program. This is a reimbursement program (owners hire their own plumbers). Reimbursements are made according to a fixed schedule i.e. $X/ft of pipe, $Y for cleanout, etc. (Ohlemutz, 2005)

Kirkwood, MO. In Kirkwood, MO, a $740 deposit and application will provide homeowner insurance for lateral repair. If repairs are needed, the city will pay for the lateral repair up to 80% of the repair cost plus the deposit. The homeowner is responsible for obtaining the lateral insurance. (www.ci.kirkwood.mo.us)

Salem, OR. The City of Salem has utilized four specific programs over the past eight years to address rehabilitation issues for private laterals (Roley, 1998; Roley, 2005). These are:

- *Positive Protection Program* for homes with a history of basement flooding. This is an $880,000 per year (including $80,000 for management) community development program intended to fund 70 homes per year. It was initiated in 1997 and uses a zero interest deferred payment loan (see description below).
- *Extraneous Water Program* carried out as part of mainline rehabilitation/replacement work since 1999. This is a community development program aimed at removing inflow sources. It is funded at $400,000 per year and is intended to fund 60 homes per year. It also uses a zero interest deferred payment loan.
- *Lateral Retrofit of Previous Projects* carried out by the city since 2001. This project addresses upper laterals and complete laterals left out during mainline rehabilitation

between 1989 and 1999. It is funded at $250,000 per year and is intended to fund approximately 100 repair/replacements per year.

- *Miscellaneous Lateral Replacement Program* carried out by the city since 2001. This is funded at $250,000 per year and is intended to fund 50 replacements per year. It includes assistance for low-income homeowners.

The zero interest, deferred payment loan program has been used since 1997. The city has made over $4.0 million in loans to its customers since the program went into effect. The loans were originally initiated to help homeowners make repairs to prevent basement flooding from sanitary sewer backups in the Positive Protection Program. Project costs range from $4,000-8,000, or more, and homeowners often did not have adequate funds to complete the work, but wanted their basements protected. The Positive Protection Program allowed the work to move forward and eliminated a serious health and sewer system overflow problem for the utility. The city provides technical assistance to the homeowner who hires the contractor to perform the work. After approving the work, the city pays the contractor and files a lien (with the homeowner's permission) against the property. The lien becomes due at the time the home is sold or traded.

In 2001 a similar program was initiated for the City of Salem's rehabilitation/ replacement (R/R) program to fund the removal of extraneous water entering the sanitary sewer from private property. Sources of extraneous water are discovered during the R/R design process when a TV and visual inspection is provided for each home. The homeowner is provided a list of repairs and improvements that must be made and is provided the option of funding the cost "out-of-pocket" or utilizing the zero interest, deferred payment loan program. In Salem, the homeowner is responsible for maintaining the sewer lateral from the home to the connection with the city's main. However, since the late 1980s, the city has replaced the sewer lateral at no cost to the homeowner during an R/R project. Loans are typically made for diverting footing drains from homes with basements to the storm drain system.

The city has found the zero interest deferred payment loan program has been very effective in helping the homeowner make the necessary repairs to remove infiltration and inflow from private property. Without this program, the city staff would be spending much more time working with property owners to make the necessary corrections, greatly reducing their ability to complete R/R projects in a timely manner. The loans create a "win-win" for the city and the property owner, keeping responsibility for the repairs consistent with code requirements while relieving the property owner of a significant financial burden.

Johnson County, KS. Johnson County Kansas Wastewater Districts (JCW) has had a very long and successful program for removing of private sector sources primarily focused on sump pumps and other illegal connections. The most common sources of inflow were foundation drains, basement drains, sump pumps, cleanouts and downspouts, and outdoor drains. JCW's service area is a 20-square mile section of eastern Kansas that shares a border with Kansas City, MO. The region is dominated by single-family homes, commercial businesses, and some light industry. The service area encompasses 22 communities with a population of about 500,000; 1,650 miles of sewer line; nine wastewater treatment plants processing 38 mgd of dry weather flow; and 32,000 manholes.

In Johnson County, KS, a successful private lateral disconnection program was shown to account for almost 40% of the total the I/I reduction achieved. This program, together with collection system rehabilitation, reduced the I/I peak rate by as much as 280 mgd during the 10-

yr storm and has led to significant reductions in the number and severity of sanitary sewer overflows (SSOs).

For the disconnection program, JCW developed a phased investigation/implementation plan that divided the northeast sector into 11 zones, prioritized according to flooding frequency and severity. The Johnson County Board of Commissioners set the groundwork for the program by passing a county ordinance making it illegal for residents to have connections from surface or ground water sources to the sanitary sewer system. This ordinance gave JCW the legal authority to require removal of unpermitted sources and to prohibit any new ones (see Chapter 7.0).

Funds were set aside to reimburse owners for direct costs associated with removal of foundation drains, storm sump pumps or pits, area drains (driveway, patio, yard, window well, and basement entry), downspouts, and defective service line cleanouts. Payments schedules were published for each type of connection.

JCW also established informal fixed-price contracts with local contractors. These contracts were based on standard specifications and set costs for different types of disconnections. Property owners could either have JCW assign the contractor, or be provided with a list of pre-approved contractors and make their selection through a two-bid process. The standard contracts worked extremely well and relieved a serious project backlog in the first year of the program, tripling the disconnection rate to 4,000 per year. The standard agreements allowed contractors to schedule disconnections in clusters, relieved homeowners of the responsibility of scoping and negotiating the contracts, and ensured consistent construction performance.

JCW's I/I reduction program cost a total of about $47 million. Of that total, the private lateral program was the least expensive component, at just under $11.2 million. Another $30 million went to collection system improvements, and the remaining $19.7 million was used to cover program-specific engineering and administrative expenses. JCW was able to obtain $12 million in grant funds and $18 million in low-interest state revolving loans, but the private lateral work was not eligible for public funds. JCW covered the costs with obligation bonds that are being paid for through a tax increase (WEF, 1999).

6.4 Information on Financing from Current Survey

The data collected during this project provided additional information on the current status of funding for private sewer laterals.

Most agencies responding to the survey require the homeowner to pay for maintenance of sewer laterals (56%). A total of 5% of the agencies reported paying for sewer lateral maintenance while the responsibility is split between the upper and lower lateral for 36% of the agencies. About 3% of the agencies reported that the agency pays for all costs above a certain predetermined amount.

Similarly, over half the agencies (53%) reported that they require the homeowner to pay for inspections of the sewer laterals with the agency conducting inspection for 17% of the reporting agencies and both the homeowner and agency paying for inspections 30% of the time.

Rehabilitation of building laterals is also reported to be paid for by the homeowner in most cases (52%) while together the agency and homeowner share costs for 37% of the responses.

Payment for inflow removal is paid for by the homeowner in about 53% of the agencies responding to the survey. In about 12% of the agencies, costs are paid for by the agency and shared costs were reported by about 35% of the agencies.

Since the private portion of lateral sewers is owned by the homeowner, the use of public funds for inspection or repair of these systems is an important issue. Of the agencies reporting, public funds have been used in 42% of the agencies. The sources of public funds for the agencies reporting have been user fees (49%), revenue from penalties (3%), local funds (18%), state funds (8%), and other (22%). It was noted by one agency that Washington State does not allow gifting or lending of public funds to private entities. If a pilot program justifies using public funds for private repair, this agency indicated that they would seek a judgment from the state courts to determine the legality of those expenditures given that the public benefit outweighs the expenditure and benefits to private property (see Chapter 7.0 for a discussion of this issue). Another agency noted that in some cases it is not totally clear who is responsible for the suspected lateral problem and, if the work needs to be done, public funds are used for these cases. Several agencies noted the use of public funds for lateral repairs under paved areas including streets and sidewalks. Another agency noted that public funds have been used for private lateral repair if it can be shown that these private repairs are more cost-effective than a public project.

6.5 Summary of Current Practices

A summary of current financial practices from the homeowner's and agency's perspective is shown in Table 6-1

Table 6-1. Summary of Basic Financing Options.

Perspective	Financing Option
Homeowners perspective:	No funding Partial funding Full funding Loan
Agency perspective:	General Obligation Bond Property Taxes Special Assessments Service Charge User Charge

The practices shown in Table 6-1 have a number of variations for administering the program and payment of the lateral costs, and require legal research, policy decisions, and development of the procedures to implement the program by the utility. Administratively, variations for payment include no funding by the agency, partial funding, full funding or a loan. Some financing options include a fixed funding level by repair or type of repair. Some financing options consider a maximum cost to the homeowner or a maximum funding level by the agency. Payment by the homeowner may include direct payment for repairs, a homeowner loan, or payment by the agency with recovery later in the form of property taxes or at the time of the sale of the property. A summary of reported private lateral payment options is given in Table 6-2

Table 6-2. Reported Private Lateral Payment Options.

No.	Option	Description
1	No Funding	Homeowner responsible for maintenance and repair of entire lateral
2	Lower Lateral Funding Only	Financial assistance provided for lower lateral repairs and Wye connections. Homeowner responsible for upper lateral and part of lower lateral repair up to a maximum cost.
3	Funding for Testing Only	Agency provides funding for testing of lateral and homeowner is responsible for lateral repair
4	Voluntary Test and Repair	Homeowners of a single family home can volunteer to have their lateral tested and receive a specified funding level for any repair costs and inspection costs.
5	Mandatory Test and Repair Upon Sale of Home	Prior to sale of home, mandatory testing and any needed repairs are all paid for by the homeowner. A Certificate of Compliance can be issued after repairs that is effective for a specific length of time.
6	First Time Funding Only	City funds the first time that a lateral is repaired with the homeowner responsible thereafter.
7	Deductible Funding	Agency provides funding for repairs beyond a set maximum cost and, in some cases, all street, curb and sidewalk repairs.
8	Insurance Funding	Agency makes available insurance to homeowners that covers all or part of the cost for lateral repair.
9	Zero Interest Loan With Deferred Payback Funding	Agency funds lateral repairs through a zero interest loan which is paid back at the time of house sale.
10	Funding Limit by Defect	Agency provides full or partial funding for removal or repair of private section, I/I sources and defects based on type of defect.
11	Full Funding	All O&M responsibility is held by the Agency.
12	Warranty	Homeowner purchases an annual warranty and thereby transfers responsibility for all O&M to the Agency.
13	Split Funding	Dual responsibility where Agency conducts all O&M activities and shares the costs equally between the Agency and the homeowner.
14	No Funding/Agency Acts As Agent	Homeowner pays but the Agency acts as the agent for the homeowner in coordination of services and hiring of contractors. Responsibility for O&M and all costs are held by the homeowner.
15	Hardship Cases	Hardship cases where the Agency provides support on a case-by-case basis only. O&M responsibility is held by the homeowner.
16	Agency Inspection/Mandated Repair	Agency assesses lateral condition through inspection or I/I study and identifies lateral defects. Agency instructs the homeowner to make appropriate changes with consideration for penalties. O&M responsibility held by the homeowner.
17	Agency Inspection/Incentive Rebate	Agency inspects laterals as part of sewer reconstruction contracts. Homeowner is advised of defects and fined a set fine per month if the repairs are not completed within a specified time. Homeowners that comply within specified time can participate in an incentive rebate program. O&M responsibility is held by the homeowner.
18	Homeowner Required to Inspect and Provide Annual Report	Homeowner is advised of O&M responsibility and mandated to a provide periodic inspection report. Agency has the right to conduct inspections on the homeowner's behalf and charge costs back to the homeowner. O&M responsibility is held by the homeowner.
19	Joint Inspection/Homeowner Mandated to Repair	Homeowner and the Agency inspect assets and the Agency provides the landowner with a report identifying any necessary repairs. The Agency provides a list of authorized contractors and grants the homeowner a set period (e.g. 30 days) to complete the repairs. Non-compliance results in the Agency completing the work and charging the homeowner. O&M responsibility is held by the homeowner.

6.6 Conclusions

The overall financial resources needed for the repair of sewer laterals in the U.S. are estimated to be large. According to the U.S. EPA, about 200 million people are served by sewer systems. If it is assumed that there are 2.6 people per lateral, the approximate population of an average single family residence, then there are about 77 million laterals in the U.S. If the average repair cost is assumed to be $2,000 and just 25% of the laterals are defective, the total need would be over $38 billion. Even if only 10% of the laterals are defective, the total need would be over $15 billion.

The responsibility for meeting the cost falls primarily on individual home and other property owners but the benefits that accrue to wastewater system operation, the environment and the general public provide a strong incentive for agencies and local and national governments to support cost-effective programs both administratively and with public funds.

A range of possible approaches to such public agency financial support and encouragement of lateral repair programs has been identified in this chapter along with brief descriptions of specific programs adopted by various agencies across the country. These examples show that successful financing approaches are available and that individual approaches can be tailored to the physical, political and economic structure of a particular community.

CHAPTER 7.0

LEGAL ISSUES

7.1 Introduction

As has been demonstrated in previous chapters, private sewer laterals can be an important determinant of the performance of the entire sewer collection network in terms of achieving manageable levels of inflow and infiltration. However, the need to conduct a rehabilitation program that includes privately owned and maintained portions of the sewer collection network raises many legal, liability and administrative issues that need to be resolved in order to have a successful and publicly accepted program.

The survey data presented in Chapter 2.0 confirms that there is a wide variance in the ownership and responsibility for maintenance of sewer laterals throughout the country. In a few communities, the municipality maintains the laterals. In most communities, however, the homeowner is responsible for maintenance of sewer laterals; especially the portion of the lateral that is within private property. There has also been a tendency in many communities to avoid actions or programs that would involve the difficulties of private property work or the possible creation of future liability from city actions on the private portion of the system. Because of this reluctance and the absence of regular private property activities, many communities remain unsure regarding the legal authority to test, maintain, and implement repairs to sewer laterals. In fact, laterals have been characterized as "a city without an NPDES[53] permit since they make up a large part of our collection systems without effective legal control of their condition.

To successfully deal with these issues, policies related to the public health and safety issues involving work on laterals, policies regarding the manner of inspection, and policies setting out the enforcement of municipal codes related to private lateral sewers must be addressed. Establishing effective building codes and ordinances as well as inspection programs for their enforcement are necessary to ensure that private lateral sewers remain in good working condition. The constitutional issues involving private rights cannot be ignored and public education about the importance of lateral inspections and repair is necessary to build public support for inspection and rehabilitation requirements.

Testing and repair of private lateral sewers involves not only issues concerning access to private property but also potential liability for personal injury or property damage resulting from performance of such work on private property and restrictions on the use of public funds for private property improvements. These and other key legal and liability issues involved in

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[53] *National Pollutant Discharge Elimination System*

working with the private portion of sewer laterals are explored in this chapter with examples provided of the legal opinions and administrative arrangements adopted in some cities across North America. In depth reference is made to a few examples for which the authors had strong involvement or familiarity or for which extensive analysis of legal issues had been made in a written report made available to the project. A summary of legal issues and their particular applicability and resolution in the State of Wisconsin also can be found in (Simpson, 2005).

7.2 Legal Precedents Derived from Prior Private I/I Removal Programs: The Johnson County Wastewater District Example

Access, financing and liability issues arise in the context of the inspection and repair of private sewer laterals located on private property. As analogous issues have been addressed through the implementation of private infiltration and inflow (I/I) disconnect programs implemented throughout the country, a brief discussion of the legal precedent established through these programs may be of benefit in the lateral rehabilitation context. As indicated in Section 6.3, one of the earlier I/I disconnect programs that received national recognition[54] was conducted by the Johnson County Wastewater Districts (JCW) in the late 1980s and early 1990s. The program commenced with public hearings addressing the problems associated with the entry of extraneous sources of I/I into the sanitary sewer system and culminated with the adoption of resolutions prohibiting the connection of foundation drains, storm sump pumps, sump pits, downspouts, area drains and defective service line cleanouts to the sanitary sewer system and authorizing the expenditure of public funds for the inspection and remediation of such sources. Inspection of over 50,000 private buildings was completed within three problem watersheds. Approximately 25% of the buildings were determined to have one or more prohibited connections. Nearly 15,000 private sources were removed representing a reduction of approximately 57 mgd of water based upon a 1-yr rain event. Most of the inspections (99%) were completed on a voluntary basis, however, administrative search warrants were required to gain entry to approximately 35 private residences.

7.2.1 Fourth Amendment Considerations/Administrative Search Warrants

In order for a public entity to gain access to private property, Fourth Amendment search and seizure issues must be addressed. Regulations requiring inspection of private property must be cognizant of Fourth Amendment prohibitions against unreasonable search and seizures. The use of administrative search warrants has the advantage of allowing a large number of inspections within problem areas without the necessity of obtaining the permission of each individual owner in advance. As illustrated by the JCW private disconnect program, once the

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[54] U.S. EPA Region 7 Administrator's Award, 1991; Technology Achievement Award, Public Technology, Inc, 1986; State and Local Exemplary Awards Program, Rutgers University National Center for Public Productivity, 1989; Certificate of Environmental Achievement, Renew America/National Awards Council for Environmental Sustainability, 1992, 1994, 1996, 1998; City and County Communications and Marketing Association, "Backup Prevention Program Brochure", 1999; Case Study on SSO Abatement in Kansas, Johnson County Wastewater, for LimnoTech, a consultant for the U.S. EPA concerning I/I reduction and the use of wet weather treatment facilities to reduce SSO's; WEF Publication/Monograph,"Control of Infiltration and Inflow in Private Building Sewer Connections", prepared by the WEF Sanitary Sewer Overflow Cooperative Agreement Workgroup.

requisite regulatory authority is in place, the vast majority of property owners voluntarily comply. In order to meet Fourth Amendment requirements, the search must be based upon reasonable legislative or administrative standards derived from neutral factors such as the age of the structure, the passage of time, or the general condition of the area to be searched. Johnson County's private disconnect program was based upon engineering studies that confirmed excessive amounts of infiltration and inflow contributed to back-up and bypass problems within the watersheds to be searched. A basic understanding of Fourth Amendment legal precedent is useful in understanding the use of administrative search warrants in an inspection program.

The requirement that regulatory agencies must obtain a warrant prior to conducting an administrative search was adopted by the United States Supreme Court in the companion cases of Camara v. Municipal Court,[55] and See v. City of Seattle,[56] pertaining to the search of residential and commercial properties respectively. Prior to Camara and See, the Supreme Court had held in Frank v. Maryland[57] that it was unnecessary to obtain a warrant prior to conducting an administrative search and that criminal sanctions could be imposed upon unwilling participants. The majority in Frank reasoned that because the primary goal of an administrative search is to verify regulatory compliance rather than to seize criminal evidence, historic issues of self preservation guaranteed under the Fourth and Fifth Amendments are not involved, but only the less intense right to be secure from intrusion into ones personal privacy.[58]

In Camara, however, the majority concluded that because administrative codes generally include criminal sanctions, searches intended to ascertain compliance with administrative codes can constitute sufficient intrusion upon historically protected interests under the Fourth Amendment to justify requiring the prior issuance of a search warrant in order to safeguard the privacy and security of individuals against arbitrary invasions by governmental officials.[59] However, the court did not require evidence of a code violation as a prerequisite to the issuance of an administrative search warrant as is required in the context of a criminal search warrant. Instead, it established a more flexible standard in which the need for the inspection is weighed against the intrusiveness of the search. In so doing, the court recognized the historic necessity of permitting administrative searches without requiring prior evidence of code violations which generally cannot be obtained without first gaining access. The court concluded that reasonable legislative or administrative standards derived from neutral factors such as the age of the structure, the passage of time, or the general condition of the area to be searched can constitute sufficient probable cause to issue a warrant:

> Such standards, which will vary with the municipal program being enforced, may be based upon the passage of time, the nature of the building (e.g., a multi-family apartment house), or the condition of the entire area, but they will not necessarily depend upon specific knowledge of the condition of the particular dwelling.[60]

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[55] Camara v. Municipal Court, 387 U.S. 523, 87 S.Ct. 1727, 18 L.Ed.2d 930 (1967)

[56] See v. City of Seattle, 387 U.S. 541, 87 S.Ct. 1737, 18 L.Ed.2d 943 (1967)

[57] Frank v. Maryland, 359 U.S. 360, 79 S.Ct. 804, 3 L.Ed. 2d 877 (1959), reh. denied, 360 U.S. 914, 79 S.Ct. 1292, 3 L Ed. 2d 1263

[58] Frank, 359 U.S. at 365

[59] Camara, 387 U.S. at 528

[60] Camara, 387 U.S. at 538

The court emphasized that the purpose of requiring prior review by a neutral magistrate is to prevent the conduct of searches in an arbitrary or capricious manner, not to second guess the basic policy decision to canvass an area.[61]

During the course of JCW's private disconnect program, 35 owners refused access to code enforcement officers and a motion for the issuance of an administrative search warrant was filed. The motion was contested by the recalcitrant owners at the trial court level and an order approving the issuance of an administrative search warrant was appealed to the Kansas Supreme Court. The Kansas Supreme Court affirmed issuance of the administrative search warrant in Board of County Commissioners v. Grant,[62] thereby extending the principles set forth in Camara and See to the inspection of residential properties for prohibited sources of infiltration and inflow. The Court reasoned that the inconvenience caused by the intrusion upon the rights of the owners under the Fourth Amendment was overridden by the interest of the public in the safe and efficient operation of the sanitary sewer system. The Court concluded that the inspections of private properties under the private disconnect program were reasonable and complied with the requirements set forth in Camara as they were based upon neutral factors, i.e., engineering studies of the watersheds in which the properties were located that indicated sewer back-ups and by-passes were the result of excessive volumes of infiltration and inflow entering the sanitary sewer system from private as well as public sources:

> Reasonableness is the ultimate standard for determining if probable cause exists to issue an administrative search warrant for a code enforcement inspection of a particular private dwelling. If a valid public interest justifies the contemplated intrusion, then there is probable cause to issue an appropriately restricted administrative search warrant.[63]

7.2.2 The Emergency Exception

In emergency situations, inspection of private facilities may be conducted without a search warrant. In Camara, the Supreme Court acknowledged that, under limited circumstances, inspectors may legally demand access to residential or commercial property without first obtaining a search warrant. The most obvious example is where immediate access is necessary to protect the public health or safety. In such situations, immediate entry by police, firefighters, and other emergency personnel for the purpose of rendering aid is deemed reasonable under the Fourth Amendment.[64] In People v. Mitchell,[65] the New York Court of Appeals devised a three pronged test that is useful in evaluating applicability of the emergency exception. The test incorporates the following requirements:

- The police (or code official) must have reasonable grounds to believe that there is an emergency at hand and an immediate need for their assistance for the protection of life or property.
- The search must not be primarily motivated by intent to arrest and seize evidence.

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[61] Camara, 387 U.S. at 532

[62] Board of County Commissioners v. Grant, 264 Kan.58, 954 P.2d 695 (1998)

[63] Grant, 264 Kan. at 58, Syl.& 1,2

[64] Camara, 387 U.S. at 539

[65] People v. Mitchell, 347 N.E.2d 607(1976)

- There must be some reasonable basis, approximating probable cause, to associate the emergency with the area or place to be searched.[66]

Although the three pronged analysis is a useful tool in analyzing applicability of the emergency exception, an analysis of the overall reasonableness of the search in light of Fourth Amendment requirements remains the ultimate test.

7.2.3 Financing of Improvements—The Public Purpose Doctrine

In the JCW program, public hearings were held to receive comment and authorize the raising and expenditure of public funds. Assessments were initially levied against each tract within the three problem watersheds to provide funds for the administration of the program and to reimburse private owners for their reasonable expenses of disconnection. Beginning in 1992, these assessments were converted to system-wide user charges assessed against all tracts within the JCW service area.

Most states have constitutional provisions that restrict the use of public funds to expenditures for public purposes. These restrictions are commonly referred to as the public purpose doctrine. Although state laws vary considerably in this regard and should be carefully reviewed prior to implementing improvement programs, the courts have generally held that some benefit may be derived by private owners provided it is incidental to the benefit derived by the public at large in the form of improvements to the public health, safety and environment. Further, as such programs generally fall within the legislative or public policy making function of the municipality, courts generally allow great deference to the judgment of the governing officials in making such determinations:

> The question to be formulated from the leading cases which establish the legal principles and authoritative precedents is what is a public purpose? This cannot be answered by any precise definition further than to state that if the object is beneficial to the inhabitants and directly connected with the local government it will be considered with favor as a corporate or public purpose. It is not possible to lay down any hard-and-fast rule by which to determine which purposes are public and which private. Hardly any project of public benefit is without some element of peculiar personal profit to individuals, hardly any private attempt to use the taxing power is without some colorable pretext of public good. Each case must be judged on its own facts, and any attempt at fixed definition must result in confusion and contradictions.
>
> The legislature makes the first determination as to what the public purpose is. The legislature is vested with broad discretion in the determination of the question. Although the exercise of such discretion is subject to judicial review, to justify a court in declaring a tax invalid on the ground that is was not imposed for a public purpose, the absence of a public interest must be clear and palpable.[67]

Any benefit derived by private owners under the JCW private disconnect program was clearly incidental to the public benefit derived from reduction in the number and severity of sewer back-ups and by-passes into homes and the environment and property damage associated therewith. Reimbursement under the program ranged from $100 for the disconnection of a

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[66] Mitchell, 347 N.E. 2d at 609

[67] *McQuillin, Mun Corp §44.35 (3d Ed 1994)*

downspout to $2,200 for disconnection of an area drain. Although the private disconnect project cost nearly $11.2 million, engineering studies indicated that approximately $50 million dollars in additional public expenditures would have been required to provide equivalent back-up and bypass protection to the sanitary system through expansion of main sewer lines and treatment plant capacity.

7.2.4 Liability Issues

JCW structured its private disconnection program in an effort to minimize liability issues. When prohibited connections were identified through the inspection process, written notice was provided informing the owner that disconnection was required under the resolution. The notice described the reimbursement program and included a list of private contractors who had attended informational meetings conducted by JCW regarding the program and who had expressed an interest in participating in the program. Owners were instructed to obtain three bids from contractors of their choice (including contractors not on the list) and to submit the bids to JCW. JCW approved the lowest reasonable bid and notified the owner of the selected bidder. Owners were also permitted to complete the necessary disconnection themselves and receive reimbursement of their documented (in kind) expenses. After completion of the work, a follow-up inspection by code enforcement officers was required to verify disconnection in order to qualify for reimbursement. If the disconnection passed inspection, the owner was required to submit an application for reimbursement with copies of any bills or invoices verifying the expenses incurred. Included in the application was an acknowledgment that the owner was responsible for selection of the contractor and a disclaimer of any liability or warranty, expressed or implied, arising from the design, materials, or workmanship used for completion of the work. Few claims have been submitted to JCW under the private disconnect program to date.

7.2.5 Private Property Right Issues

A related issue that arises in the regulatory context concerns the impact that the adoption of new regulations may have on existing property rights. In the wastewater context, new regulations often require considerable expense to property owners for the repair, replacement or upgrading of existing plumbing facilities. In addition to the political ramifications of such requirements, the extent to which the regulations may constitute a compensable taking under the Fifth and Fourteenth Amendments to the United States Constitution must be considered. Many municipalities attempt to minimize the political and legal ramifications of such regulations by incorporating grandfather provisions that exempt specific user classes from its application. However, this is not always desirable especially where the threat to be eliminated requires universal compliance to be effective. In the JCW I/I disconnection program, these issues were ameliorated somewhat by reimbursing private owners for their reasonable expenses of disconnection. However, as funds are not always available for such purposes, the potential impact new regulations may have on private property rights under the federal and state constitutions must be considered.

The Fifth Amendment to the United States Constitution and similar provisions of many state constitutions prohibit governmental entities from taking private property for public use without just compensation. However, a distinction is drawn where private property is depreciated or even destroyed when the government is acting within the scope of its police powers to eliminate a public nuisance or to prevent a threat to the public health or safety. It is uniformly recognized that the establishment and maintenance of a system of public sewers is a legitimate governmental function that is essential for the protection of the public health, safety and environment and that proper maintenance and operation of a sewer system is one of the most important governmental purposes under which the police power can be exercised.

The due process clause of the Fourteenth Amendment also prohibits state action that negatively impacts property rights in an arbitrary or capricious manner. However, Fourteenth Amendment due process requirements are generally considered met provided some rational relationship exists between the regulation and a legitimate governmental purpose or objective. The adoption of regulations negatively impacting the value of private property should pass constitutional muster under the Fifth and Fourteenth Amendments provided such regulations are reasonably related to a legitimate governmental interest such as the establishment and proper maintenance of a system of public sewers and are not exercised in an arbitrary or capricious manner:

> A reasonable police power regulation imposed to protect the public is not a taking in the constitutional sense because the public use is paramount and public use is the desideratum. It follows, moreover, that accretion or depreciation in property or in property value to any person is not determinative of the power of a state or municipal corporation to exercise its police power. Thus, in meeting changed conditions in municipal, social or economic development, a city may impose new and burdensome restrictions on private property. However, an unreasonable regulation under the police power is a taking and is therefore compensable.[68]

Assuming private sewer lateral regulations bear a rational relationship to the prevention or reduction of conditions that would otherwise threaten the public health and environment, they should meet the requirements of the Fifth and Fourteenth Amendments regardless of their impact on private property rights. Furthermore, as reflected by cases that uphold the constitutionality of sanitary sewer regulations requiring the destruction of septic tanks at private expense and connection to public sewers as they become available,[69] the law is flexible and allows for the evolution of more restrictive regulations over time as new technologies emerge.

7.3 Other Approaches and Practices Applicable to the Legal and Liability Issues for Lateral Rehabilitation and Repair

The previous section provided a detailed background on the legal basis for the JCW private lateral program that sets out the key legal arguments that cover most of the legal and liability issues for private lateral rehabilitation projects. This section will complement and amplify these issues using other examples of lateral rehabilitation programs and determinations made in the preparation for those programs. The data sources used to document these issues and to discuss specific approaches include the survey from this project as well as information collected from the literature and from discussions with individuals responsible for the development of lateral sewer rehabilitation programs.

City of Baton Rouge, LA. The City of Baton Rouge has had a private lateral repair program in place for several years and has developed enforcement ordinances and procedures for the repair

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[68] *McQuillin, Mun Corp at §24.22*

[69] Hutchinson v. City of Valdosta, 227 U.S. 303, 33 S. Ct 290, 57 L.Ed. 520 (1917)

of private laterals. An ordinance passed in 1995 requires homeowners to repair private laterals and provides for the initiation of enforcement actions by the city. The ordinance includes the following requirements relative to private lateral repairs:

- The Director of Public works is required to notify the homeowner by certified mail of violations and efforts to remedy violations must begin within ten days. Once commenced, the homeowner must steadily and without delay continue such efforts to remedy such violation under the monitoring of the Director of Public Works.
- If the certified letter is unclaimed or if no effort is made to remedy the violation, suit may be filed to remedy the violation and fines of up to $500/day may be assessed. The suit may also recover reasonable attorney's fees, court costs, court reporter's fees, and other expenses of litigation.
- If in the perception of the Director of Public Works, delay in correcting the violation threatens the public health, injunctive relief is permitted.
- If immediate action is required to avoid a threat to public health, the city may act to remedy the violation and seek damages of $500/day.
- If the owner is absent or has no known mailing address, the city may complete the necessary repairs and file with the recorder of mortgages, a certificate of the cost of the work plus penalty as a tax lien.

It should be noted that legal action is used as a last resort and voluntary compliance with Baton Rouge's private sector program has been excellent.

City of Montgomery, AL. The Waterworks and Sanitary Sewer Board of Montgomery, Alabama, adopted an aggressive lateral repair program in the mid-1990s. The program provides funding for lower lateral repairs and interest free financing is available for owner-incurred lower lateral repair expenses up to a maximum of $1,200. Property owners failing to respond within 60 days from receipt of notice that lateral repairs are required are provided a second 10-day notice. If the property owner again fails to respond, water service may be terminated (Holmberg et al., 1999).

City of Phoenix, AR. The City of Phoenix modified its lateral repair policy in the 1990s to provide funding for lateral repair/replacement of the damaged or broken section of the lateral in the public right-of-way. An ordinance was adopted in 1994 to establish a lateral repair/replacement policy for the city (Kaleta, 1999).

City of Austin, TX. The City of Austin has adopted an ordinance allowing the relocation or reconnection of private laterals with public funds under circumstances when the City Water Director determines that reconnection of customer laterals by the city will promote efficient operation of the utility or otherwise enhance provision of utility service.

7.4 The City of Fort Worth, TX, Study

One of the most comprehensive programs initiated to date for the repair of private laterals, was undertaken by the City of Fort Worth, Texas. In 1995, the city studied the legal issues associated with the completion of work on private property during the course of a project for the reconstruction of public utility lines that required the relocation and reconnection of private service laterals. The following is a brief description of the issues studied and the conclusions drawn from the project.

7.4.1 Fort Worth Project Funding Issues

Prior to initiation of the Fort Worth Project in 1995, the cost of relocation or replacement of private sewer laterals due to the construction of new, renovated or rebuilt sewer mains was assessed to the owner and payment was secured by the attachment of a lien against the property. The city contracted for performance of the work only after obtaining the property owner's written consent, and the property owner was allowed up to five years to repay the city for its actual costs plus interest, not to exceed 10%. However, the owner was not required to agree to the proposed lateral relocation or replacement and the city was not allowed to pay for any part of the relocation or replacement on private property with public funds.

This approach was changed in 1995 and, through the Fort Worth Project, the city furnished labor and material to rehabilitate private laterals in a four to six block area in exchange for the receipt of access agreements by private owners. The city concluded that failure to complete necessary repairs to the old laterals due to their location on private property would result in increased maintenance costs, adverse health considerations (due to leaking lines), and additional conveyance and treatment costs associated with the conveyance and treatment of I/I entering the sewer system. These considerations, coupled with regulatory prohibitions against wet weather overflows (SSOs and/or CSOs), led the city to conclude that the expenditure of public funds for the expense of relocation of service laterals on private property was legally justified and, as a first step, adopted an ordinance requiring the repair or replacement of old or defective laterals thereby encouraging the participation of private owners. Fort Worth concluded that in the event of legal challenge, it needed to be able to provide evidence through engineering studies that the project was in best interests of the public, was within its proper authority for completion, and that any benefit derived by private individuals was purely incidental in nature. A summary of the conclusions drawn by Fort Worth to justify the completion of such project work is as follows:

- The adopted ordinance should allow utility funds to be spent on private laterals under specified term projects.
- The adopted ordinance should require property owners to correct, reconnect or reconstruct service lateral problems whether or not the work is included in a city funded project.
- The public utility must be able to verify through engineering studies or other means that completion of the work will promote efficient operation of the utility or otherwise enhance the provision of utility service and is in the best interest of the general public.
- The adopted ordinance should identify the individual or committee authorized to determine on a case-by-case basis if specific work is in the best interest of the general public and to consider any appeals.
- The proposal to expend public funds for work on private property should be identified up front in the approval process for the proposed project and should be included in the project as approved.
- An agreement between the public utility and property owner should be obtained prior to initiation of any work on laterals located on private property unless court action is pursued.

During its study of the issues, Forth Worth conducted a survey of how other municipalities were handling these issues. The following are a few observations noted by Fort Worth based upon its research as to the practices of other municipalities:

- Most of the municipalities surveyed do not have a specific policy/ordinance addressing the financing of work on private property.
- Most municipalities do not spend public funds for private work.
- Most municipalities do not work on private property without the homeowner's prior permission or a written easement.
- In most municipalities, the homeowner is responsible for all lateral repair/replacement expenses incurred for service lines located on the homeowner's property.
- In most municipalities, the homeowner is responsible for all repair/replacement work done on service lines all the way to the connection with the public sewer main.

Fort Worth noted these additional general/political concerns that a municipality should identify and consider prior to initiating a project to relocate and reconnect private laterals using public funds:

- The likelihood that property owners will object to the project and not allow construction on their property.
- Are the benefits to the general public and the municipality clearly established?
- Some customers may object that property taxes or utility fees are being illegally used to benefit private parties.
- News stories, investigative reporting, etc., may claim public funds are being used for private benefit—it must be possible to document through studies or otherwise that the public benefit is paramount and any private benefit is incidental.

7.4.2 Fort Worth Project Access Issues

Numerous access issues had to be addressed during completion of the Forth Worth project. One issue involved the extent to which maintenance and reconstruction activities are authorized under recorded easements. Although Texas law recognizes that every easement carries with it the right to do whatever is reasonably necessary for full enjoyment of the rights granted, the holder of the easement may not unreasonably interfere with the property rights of the servient (burdened) estate. In addition, an easement cannot be burdened by additional uses for which the easement was not granted.

As the project also required operation and maintenance activities outside the confines of recorded easements, another issue concerned the extent to which Texas law allows such activities. Although the city lacked a specific ordinance authorizing it to conduct operation and maintenance activities on private property beyond the bounds of an existing easement, Texas law recognizes limited factual situations where an "unwritten easement" may be established. Common examples are easements acquired by implication (implied easements), prescriptive easements, easements by necessity, and easements acquired by common law dedication (easement by estoppel).

- An implied easement is acquired when the owner of adjoining properties sells part but not all of his land, and apparent and visible easements required for fair use of the tract sold are being utilized at the time of the transaction. It is implied by law that such easements were intended to pass to the new owner. As such, implied easements can only be established by examining the circumstances of the transaction and the actions of the parties involved.
- A prescriptive easement is acquired by engaging in activities (i.e., conducting activities as if a recorded easement existed) on the property of another in a manner that is inconsistent with the owner's rights. The use must be open, notorious, adverse, and continue for a

period of time established by state law in order for a prescriptive easement to be legally recognized.

- An easement by necessity is acquired when a parent tract is severed in some manner (not necessarily by sale) and it is reasonably necessary that an easement be established for access to the subdivided property. It is generally an easement in favor of land locked parcels or an easement that is otherwise indispensable to the dominant (benefited) estate.
- An easement may also acquired by a public entity without consideration or the necessity of a written grant or by common law dedication (easement by estoppel).

Based on the foregoing legal precedent, Fort Worth concluded that it could make a strong argument that an "unwritten easement" existed in its favor at all locations where utility lines were operated and maintained by the city. However, the city must confine its activities within a reasonable width in the same manner as under written utility easements. Otherwise, the city would be responsible for any damages sustained by the owner of the servient estate regardless of whether the work was conducted under authority of a recorded or unwritten easement. The study also concluded that it was advisable for the city to adopt a policy regarding the use of such "unwritten utility easements" in order to limit the risk of liability. It was recommended that the policy establish specific procedures and standards for the utilization of unwritten easements and that a specific officer or committee be designated to authorize access to private property for such repairs whether of a routine or emergency nature. It was also recommended that policy contain guidelines concerning the level of care required in making such repairs in order to protect existing improvements and to restore the property. The following is a summary of Forth Worth's recommendations for inclusion in such policy:

- Limit work on private property to emergency situations only and obtain utility easements for routine maintenance activities.
- Authorize work on private property on a case by case basis making the decision to enter as the need arises.
- Develop a general policy for work on private property that provides standards for the conditions under which private property may be entered.
- Develop a specific policy for working on private property using unwritten easements that includes:
    - Recognition that unwritten utility easements exist for utilities that are operated and maintained by the city.
    - Identify the staff position or committee that has responsibility to authorize use of unwritten easements.
    - Include guidelines for the protection and restoration of existing improvements and grounds.
    - Provide notification of property owner.
    - Define what constitutes an emergency condition as opposed to routine maintenance activities.
    - Provide a procedure for recording unwritten easements.

Fort Worth concluded that although unwritten utility easement rights may be utilized, the formal acquisition or condemnation of written easements is preferable. Therefore, the city generally utilizes written utility easements to conduct maintenance or repairs. When additional temporary construction easements and/or access easements are necessary, the city attempts to obtain written easements. In situations where utilities exist, but no recorded utility easement can be documented, the city generally obtains written easements before maintenance activities begin. In emergency situations, the city recognizes that the protection of the pubic health, safety, and property, is paramount to private property rights and permits the completion of necessary maintenance or repair activities and ingress or egress necessary for its completion regardless of the existence or nonexistence of recorded easements. The city evaluates emergency situations on a case-by-case basis for protection of the public health, safety, and environment, and to protect city facilities and/or infrastructure from damage.

7.5 Practices Reported in the Survey Conducted for this Project

The data collected from the survey conducted for this project also provided information on additional legal issues related to the repair and/or replacement of private sewer laterals. Of the 58 agencies responding to this survey, a total of 33 agencies (57%) reported they have jurisdiction to enter private property.

Agencies were also requested to comment on how they address liability issues related to entering onto private property to conduct inspections and/or rehabilitate private sewer laterals. The responses received were categorized into the eight groups as indicated in Table 7-1. The data indicates that 33% of the respondents use right of entry permit forms and there are a variety of other options being used.

Table 7-1. Reported Methods to Address Liability Related to Entering Private Property.

Method Group	Percent Responding
Does not enter	12%
Insurance	12%
Right of entry agreement	33%
Contract with private plumber	9%
Reason on permit/contact homeowner	12%
Training of inspectors	3%
Covered in municipal code	12%
No formal policy	6%

Agencies were also asked to comment on how they address liability issues related to property damage or injuries sustained during the inspection and/or rehabilitation of private sewer laterals. The responses received are categorized into the six groups indicated in Table 7-2. The data indicates that 23% of the responding agencies reimburse homeowners for damages and 27% have an internal claims review process.

A total of 24% of the agencies reported that they have experienced at least one legal case related to the maintenance, inspection or rehabilitation of private laterals or the removal of private sources of infiltration and inflow.

Table 7-2. Reported Methods During Inspection or Rehabilitation on Private Property to Address Liability Related to Damages or Injuries.

Method Group	Percent Responding
Reimburse for damages	23%
Contractors are responsible	12%
Disclaimer on right of entry form	12%
Internal claims review process	27%
Not liable	15%
No formal policy	12%

7.6 Conclusions

Numerous potential legal issues related to access, financing and liability must be dealt with prior to the adoption of regulations requiring the inspection and repair of private sewer laterals. Prior to adopting such regulations, the following guidelines for the preparatory studies and policy development may be useful:

- Document the existence of the threat to the public health, safety, or environment that provides the basis for exercising the police power of the municipality.
- Identify the source of the threat and alternative methods of minimizing it through appropriate engineering and financial studies.
- Prior to adopting regulations, conduct public hearings to provide the public with notice of the threat and to receive public input concerning the most reasonable alternative to deal with it.
- Adopt cost effective regulations clearly within the scope of the police power of the municipality that bear a reasonable relationship to prevention or reduction of the conditions threatening the public health and environment.
- If public financing is utilized, document through financial studies if possible that any benefit to be derived by private parties is incidental to the overall benefit to the public health, safety and environment.
- If access to and/or inspection of private property will be required, Fourth Amendment search and seizure issues must be addressed. Confine activities within the area of established written easements except in emergency situations. If area searches are a required component of the program, document that they are based on reasonable legislative or administrative standards derived from neutral factors such as the age of the structure, the passage of time, or the general condition of the area to be searched. Incorporate safeguards into the regulations to prevent arbitrary or capricious searches.
- Structure the program in a manner to minimize the risk of liability associated with working on private property through disclaimers, hold harmless agreements and use of private contractors.

The methods employed to address these issues to date and the legal precedents reported in the literature indicate that where there is the political will and proven benefit to the general public, the legal issues associated with the inspection and repair of private laterals can be managed. However, in order to analyze and address these risks adequately, local counsel should share a prominent role in the drafting and review of proposed regulations in light of existing statutory authority. It should be noted that the information provided in this discussion is intended for informational use only and is not intended as legal advice.

CHAPTER 8.0

DECISION MAKING

8.1 Introduction

The last chapter in this report aims at providing a perspective of how the rehabilitation of private sewer laterals can fit into the overall efforts of agencies to eliminate problems related to I/I and a decision framework by which an agency can decide how to approach the development of a lateral rehabilitation program.

After documenting and reviewing existing problems related to I/I, an agency has typically more than one option in addressing these problems. In selecting the “best” alternative, economic analysis of alternatives is very important, but decision making does not end there. There are other criteria that also need to be considered that affect public health, the environment and quality of life. Alternatives that involve private sewer laterals need to be considered together with potential limitations on effective action that arise from legal and financing issues related to the private ownership of all or a portion of each sewer lateral. The removal of downspout connections from homes, for example, may be very cost-effective per se, but the agency may not currently have, or perceive that they have, the authority to perform this measure or even request the homeowner to do it. Likewise, the repair of upper laterals may be cost-effective but the agency may not have the necessary funds and may be concerned about their authority to spend public funds on private property.

When looking at the cost-effectiveness of lateral rehabilitation, it is important to see it in a broader view. Repair of the laterals in one small basin may not appear cost-effective if the savings are calculated only by multiplying the reduction in total quantity of conveyed sewage annually with the average cost of conveyance/treatment per 1,000 gallons of sewage. However, the same repair may be cost-effective if it prevents the peak flows from exceeding design maximum flows at lift stations and at the wastewater treatment plants (WWTP), and also eliminates the need for upsizing parts of the collection system. Future needs should also be considered and projected community development and any related need for increased capacity of the sewer system assessed. If the extra conveyance/treatment capacity needed in the future can be accommodated with the existing sewer system by just eliminating the I/I, then the value of lateral rehabilitation grows accordingly.

Thus, in developing a plan to deal with sewer laterals, it is important to have a good understanding of the entire sewer system performance and where the efforts for reduction of I/I should be directed. Also, because of the investments required to bring most systems up to standard, rehabilitation and capacity building efforts may take many years to achieve so decisions need to be made on the prioritization of system improvements over time. System needs and prioritization will then guide the development of a strategy in dealing with sewer laterals, i.e. deciding whether the rehabilitation of private sewer laterals is necessary, deciding how lateral rehabilitation will fit within an overall rehabilitation program, selecting the general approach of what laterals to repair and what part of selected laterals to repair, selecting the methods of financing the lateral rehabilitation that will be effective and acceptable for a particular agency, and deciding on how to deal with accessing private properties and related legal liabilities. If existing ordinances will limit the development of a desired strategy, the agency will need either to search for alternate solutions or for ways to change the ordinances accordingly.

8.2 Integrating Lateral Rehabilitation into a System-wide Sanitary Sewer Management Plan

Rehabilitation of sewer laterals is most likely justified and necessary if laterals are responsible for significant I/I into the sewer collection systems. The agency, however, needs to make sure that the lateral rehabilitation projects are cost-beneficial and less costly than other alternatives for I/I control, and that they fit into a system-wide sanitary sewer management plan. This chapter explains the steps in a decision making procedure for developing long-term policies for reducing the I/I (Figure 8-1), in the course of which it is determined if and how the rehabilitation of sewer laterals should be carried out.

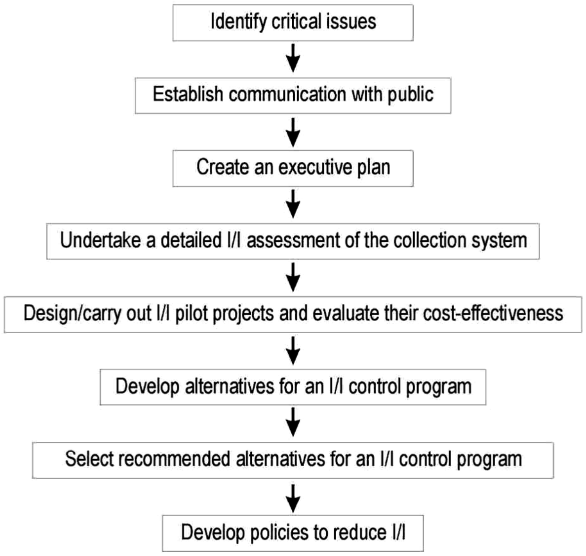

Figure 8-1. Decision Making Procedure for Developing a Long-term I/I Reduction Plan.

Identify Critical Issues. The agency should first distinguish which of the following problems have been occurring in their sewer collection system: SSOs, basement sewage backups, hydraulic overloading of lift stations and WWTPs during wet weather periods.

The agency should also identify related planning, financial and regulatory issues that may be critical to such decisions. The principal examples are:

- The spending of extra dollars on inefficient conveyance/treatment of sewage,
- Regulatory penalties and lawsuits relating to SSOs and backups
- Satisfying future regulations and directives about system management such as CMOM and GASB34

- Upsizing of the portions of the collection system to accommodate present or future capacity needs,
- Pollution of the environment
- Impairment of public health.

At this time, the historical data of past SSOs and basement backups, hydraulic loading of lift stations and WWTPs, and related hydrological data are acquired and reviewed. Also, total annual volumes of sewage being conveyed/treated are compared with water consumption records and estimates of generated wastewater flows.

The agency should audit previous sanitary sewer master plans and engineering studies to establish an assessment of the current infrastructure, and evaluate the cost/benefit of past actions.

From a system-wide perspective, there is usually sufficient data to draw general conclusions on potentially applicable measures for I/I control. However, there is generally insufficient data to identify specific I/I projects or set threshold levels of I/I that would indicate when measures for I/I reduction would be cost-effective.

Establish Communication with Public. Strong communication with the public should be established immediately. Public opinion should be sought though public forums, surveys, and direct interviews. Prompt communication is especially necessary with neighborhoods affected with SSOs and basement backups. A customer service program to deal with complaints related to SSOs and basement backups can be implemented quickly and can provide an improved public opinion of the agency, additional justification for the funding required to implement an I/I reduction plan and additional information about the response of the system to wet weather events.

Create An Executive Plan for the Development of I/I Control. The agency should formulate an executive plan for developing I/I control, which would produce a timetable and recommendations as to how to undertake a detailed I/I assessment of the collection system, design I/I pilot projects and demonstrate their cost effectiveness, develop and evaluate alternatives for an I/I control program, and develop policies to reduce I/I.

In this phase, it is important to review federal and EPA regulations as well as state regulations that govern SSOs. The agency may perform a peer review of other communities and their approaches with problems, and obtain advice or perspectives from identified communities and agencies that have dealt with these problems. Advice also can be sought from federal/state regulatory authorities, consultants and academics that are involved in regulation, planning and design, or research related to the problems faced.

Draft recommendations can be presented to the public for review and input. Public input and any new suggestions and concerns should be considered and, if necessary, alternatives made to the proposed recommendations.

Undertake a Detailed I/I Assessment of the Collection System. The objective is to divide the collection system into basins and determine wet weather performance of the system and geographic distribution of I/I within the collection system. The basins would preferably be flow monitored during one or more rainy seasons, and the amount of RDI/I resulting from the storms determined. Projections of RDI/I for design storms or long-term real rainfall series would be made. The basins would also be smoke tested and dye water tested to identify most inflow sources and some of the various infiltration sources.

At this time, basins with high peaking factors and the worst I/I problems are identified. It is still not clear at this stage how much sewer laterals contribute to the I/I and whether they need rehabilitation.

Design and Carry out I/I Pilot Projects, and Evaluate Their Cost-effectiveness. The objective of this effort is to select small mini-basins where pilot projects would quantify I/I from the laterals, and test the effectiveness of various inspection and rehabilitation techniques, thus demonstrating whether I/I was effectively located and removed.

The agency may opt for one pilot project at a time or several pilot projects simultaneously that represent different local conditions (pipe age/condition, topography, and soils and groundwater conditions). The pilot projects would preferably have phased rehabilitation (lateral rehabilitation separated from mainline/manhole rehabilitation) and flow monitoring data collected before, between and after the phases. It will provide a test of forecasting ability if the cost-effectiveness of rehabilitation is estimated twice: initially in a planning phase to decide whether a rehabilitation would be cost-effective based on an estimate of removed I/I (different rehabilitation options can be evaluated), and for a second time after the pilot project to demonstrate how cost-effective the selected rehabilitation really was and to compare initial expectations with results.

Develop Alternatives for an I/I Control Program. Different alternatives for dealing with wet weather flows would be considered on a system-wide level. The alternatives would cover different approaches, for example: increasing the conveyance capacity of the sewer collection system and the treatment capacity of the WWTPs, temporarily storing the peak wet weather flows off-line, or major removal of I/I with or without lateral rehabilitation. Further, the alternatives could include permutations of existing and new treatment plants in a variety of sizes, locations, and capabilities, and options to transfer wastewater flow to WWTPs in adjacent communities.

Select Recommended Alternatives for an I/I Control Program. The evaluation of alternatives would be a two-step process. First, initial recommendations would be made based on evaluating the alternatives for cost-effectiveness and cost-benefit. This would be followed by consideration of additional decision influences such as stakeholder input, regulatory framework and project delivery methods, which could modify the initial ranking of alternatives.

At this time, funding options for alternatives should also be considered. Of particular interest are alternatives that involve private sewer laterals, as the funding theoretically can be public or private or both and can use a variety of public funding mechanisms such as increased local taxation, user fees, bonds, etc. Incentive programs to maximize compliance of homeowners should be considered when needed.

In the end, recommended alternatives should be integrated with plans of the stormwater management department within the agency or community, to ensure a consistent plan in water management.

Develop Policies to Reduce I/I. Based on the evaluation of alternatives, the agency would create policies to reduce I/I, i.e. create or adjust model standards regarding construction materials and labor, construction inspection, and maintenance and periodic inspection of the system.

One parameter that the agency might develop is a future acceptable I/I threshold (expressed, for example, in gal/acre/day or gal/unit length of sewer). Using such an approach and based on ongoing rehabilitation projects, the agency can develop a good understanding of the minimum threshold I/I levels that can realistically be achieved with cost-effective rehabilitation. In the future, such threshold I/I levels can help decide when some mini-basin within the collection system needs rehabilitation.

8.3 Cost-effectiveness of Pilot Projects

8.3.1 Methods of Life-cycle Cost Analysis

Cost-effectiveness evaluation is often carried out applying methods of life-cycle cost (LCC) analysis, which consider not only the initial cost of the rehabilitation but regard the rehabilitation as a long-term investment. Such analysis takes into consideration costs and savings over the life of rehabilitated sewer system or during the analyzed period. Two methods are used most often in the economic evaluation of sewer rehabilitation projects: payback period and present worth value. The main difference between these two methods is that the payback period method usually does not consider the time value of money, i.e. inflation and interest rates, whereas the present worth value does.

Payback Period. With this method, the rehabilitation is evaluated in terms of how long it takes for an investment in rehabilitation to pay for itself from savings. The payback period is expressed in years, and is calculated as a ratio of the required investment to the estimated cost savings:

$$\text{Payback Period} = \frac{\text{Investment}}{\text{Savings per year}} \quad \text{(8.3.1-1)}$$

This equation is applicable when the investment produces equal annual savings. If the savings change over time, the payback is calculated by deducting the savings of one year after another and establishing the year the investment is paid off.

Discounted payback period is a modification of the original payback equation that incorporates the time value of money concept by discounting annual savings. This improves the original calculation but it is often argued that the trouble of discounting savings to introduce the time value of money may as well be replaced with a more robust methodology such as present worth value.

The payback period method is a simple and widely used financial tool to evaluate the value of investments over relatively short time periods. If the payback period is much less than the economic lifetime of the project, then the project should be considered financially acceptable. If the payback period is equal to or greater than the economic lifetime of the project, then the proposal cannot be justified on a financial basis alone.

Present Worth Value. With this method, the rehabilitation is evaluated in terms of the present worth value of annual savings that grow at a given interest rate and depreciate at a given inflation rate over a number of years. The method involves three simple yet consequential steps. First, the duration of a life cycle is identified, which is the expected life of the rehabilitation or a shorter time period selected for the financial analysis. Next, the inflation percent rate and the interest percent rate expected to be representative over the selected life cycle period are chosen. The last step is to calculate the present value of annual savings. The following formulae can be found in many text books on financial analysis and life cycle costing (e.g. Auxier and Wachowicz, 1995) together with more detailed explanation of their application:

$$P = A \cdot \frac{1-\left(\frac{1+g}{1+i}\right)^n}{i - g} \quad \text{in case } I \neq g \quad \text{(8.3.1-2)}$$

$$P = A \cdot \frac{n}{1+i} \quad \text{in case } I = g \quad \text{(8.3.1-3)}$$

Where: P… Present value of annual savings
A… Growing annuity[70]
n… Duration of a life cycle in years
g, I… Inflation and interest percent rate, respectively

Net present value (NPV) is determined by deducting the initial investment from the present worth value. If the NPV is greater or equal to zero, the rehabilitation is economically sound. Otherwise, the project does not provide enough benefits to financially justify the investment.

For economical comparison of different projects (rehabilitation options), an NPV index can be used. The NPV index is calculated by dividing the NPV of the project by the initial investment. The higher the NPV index the greater the investment opportunity. Thus, NPV index can be used for prioritizing the projects according to the investment opportunity.

This concept provides a good representation of the value of the investment by incorporating the time value of money of the investment. The difficulty is the uncertainty in predicting key elements of the equation, i.e. the interest and inflation rate, and especially in selecting the duration of the life cycle. These estimates can be based on trends from the past (Table 8-1), predicted economic conditions and/or professional judgment. The accuracy of the cost estimates is also uncertain. Uncertainties can easily lead to making wrong decisions, especially when evaluating closely ranked competing projects.

Table 8-1. Inflation[71] and Interest[72] Rate in the U.S. in the Last 40 Years.

Year	Inflation	Interest	Year	Inflation	Interest	Year	Inflation	Interest	Year	Inflation	Interest	Year	Inflation	Interest
1965	1.6%	4.07%	1973	6.2%	8.74%	1981	10.3%	16.39%	1989	4.8%	9.21%	1997	2.3%	5.46%
1966	2.9%	5.11%	1974	11.0%	10.51%	1982	6.2%	12.24%	1990	5.4%	8.10%	1998	1.6%	5.35%
1967	3.1%	4.22%	1975	9.1%	5.82%	1983	3.2%	9.09%	1991	4.2%	5.69%	1999	2.2%	4.97%
1968	4.2%	5.66%	1976	5.8%	5.05%	1984	4.3%	10.23%	1992	3.0%	3.52%	2000	3.4%	6.24%
1969	5.5%	8.21%	1977	6.5%	5.54%	1985	3.6%	8.10%	1993	3.0%	3.02%	2001	2.8%	3.88%
1970	5.7%	7.17%	1978	7.6%	7.94%	1986	1.9%	6.80%	1994	2.6%	4.21%	2002	1.6%	1.67%
1971	4.4%	4.67%	1979	11.3%	11.20%	1987	3.6%	6.66%	1995	2.8%	5.83%	2003	2.3%	1.13%
1972	3.2%	4.44%	1980	13.5%	13.35%	1988	4.1%	7.57%	1996	3.0%	5.30%	2004	2.7%	1.35%

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[70] *In finance, an* ***annuity*** *denotes a series of equal payments over specified number of periods, and a* ***growing annuity*** *a series of payments that change at each period.*

[71] *Source: Consumer Price Index—All Urban Consumers, U.S. city average, U.S. Department Of Labor, Bureau of Labor Statistics, Washington, D.C. ftp://ftp.bls.gov/pub/special.requests/cpi/cpiai.txt*

[72] *Source: Federal Reserve Statistical Board, Annual Interest Rates (annualized using a 360-day year or bank interest) http://www.federalreserve.gov/releases/h15/data/a/fedfund.txt*

Cost-utility Analysis. Cost-effectiveness of rehabilitation projects can also be evaluated using the cost-utility analysis where the project benefit is measured not as savings but as a natural unit—in this case, the quantity of removed I/I. The following formula can be used:

$$\text{Cost per removed I/I} = \frac{\text{Investment}}{\text{Reduction in I/I}} \quad \text{.......................} \quad (8.3.1\text{-}4)$$

The reduction in I/I from the formula can be the annual removal of I/I in millions of gallons (a calculated value or an observed reduction in sewage volumes treated at the WWTPs after rehabilitation). However, this concept of cost-effectiveness evaluation is especially useful when reduction in I/I is a reduction in peak wet weather flows in millions of gallons per day (calculated values for design storms, return time intervals, etc. as explained in Chapter 4.0). There are two primary reasons for the suitability of this measure: 1) the goal of rehabilitation is usually related to the reduction in peak flows, and 2) the money savings from reduced peak flows are not clear[73].

8.3.2 Implementation of Economic Analysis in Sewer Rehabilitation Projects

Planning Lateral Rehabilitation. As mentioned in the previous sections, the cost-effectiveness of prospective lateral rehabilitation may be first estimated in a planning phase involving pilot projects. This cost-effectiveness calculation is based on an estimated quantity of removed I/I, which for some rehabilitation projects is straightforward but for most is not.

Table 8-2 gives an example how the cost-effectiveness of disconnecting downspouts can be calculated. With known and assumed parameters as shown in the table, the rehabilitation would be cost-effective because the savings from reduced conveyance/treatment would by far exceed the cost of disconnecting.

Table 8-2. Cost-effectiveness of Disconnecting Downspouts—Present Worth Value.

Known:	Area of the roof (average)		1,500	SF	
Known:	Annual rainfall (average)		40	“	
Calculated:	Inflow through one downspout connection	5,000 CF/yr)=	37,406	gal/yr	= 102 gal/day
Known:	Annual cost of conveyance/treatment		$2.50	/1,000 gal	
Calculated:	Savings from conveyance/treatment: Annual amount (A)		$0.26	/day	= $93.51/yr
Assumed:	Interest rate		8	%	
Assumed:	Inflation rate		5	%	
Assumed:	Life-cycle		20	years	
Calculated:	Savings from conveyance/treatment: Present equivalent amount (P)		$1,422.03		
Known:	Cost of rehabilitation: Investment		$400.00		
Conclusion	**Disconnection of downspouts is cost-effective!**				

The calculation depends on the selected rate and inflation rate, but, when the interest/inflation rates are within a fairly narrow range, the selected duration of life cycle bears the greatest influence on the results (Table 8-3).

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[73] *Namely, the cost of conveyance/treatment is normally determined per volume of sewerage (USD per 1,000 gallons) and not for the peak wet weather flows (USD per 1.0 gpd)*

Table 8-3. Impact of Inflation Rate, Interest Rate and Life Cycle on Calculated Cost-effectiveness.

		Average last 40 years:	Average last 20 years:	Average last 10 years:
	Inflation rate:	4.7%	3.0%	2.5%
Life-cycle:	Interest rate:	6.6%	5.2%	4.1%
20 years	Savings from conveyance/treatment:	$1,568.23	$1,526.46	$1,611.50
10 years	Savings from conveyance/treatment:	$859.09	$844.04	$870.59

In the same manner, other measures for removal of inflow sources can be evaluated for cost-effectiveness, providing that the removed quantity of I/I annually can be estimated. Some estimates can be made, for example, using empirical estimates for I/I quantification of I/I source types as described in Section 4.2.4, and projecting these “one rainfall event values” to annual average values. The savings from conveyance/treatment are then compared with the cost of these measures (Table 8-4). Some agencies have been measuring for several years the flow from sump pumps after disconnecting and transferring the flow from foundation drains to establish the contribution of these sources to the I/I (City of Salem, OR).

Table 8-4. Cost of Selected Measures for Removal of Inflow Sources.

	Cost (2004USD)	Source
Downspout disconnection	$300	Dallas, TX
Downspout disconnection	$600-700	Denver, CO
Area drain disconnection	$1,200-1,500	Dallas, TX
Area drain disconnection	$750-1,500	Johnson County, KS
Basement drain disconnection	$2,500	Weymouth, MA
Foundation drain disconnection	$2,000	Duluth, MN
Foundation drain disconnection—including sump pump	$6,000	Salem, OR
Foundation drain disconnection—including sump pump, new lateral	$10,000	Salem, OR
New cleanout cap where missing	$10-20	
Repair of cleanout	$200	Dallas, TX
Repair of cleanout	$150	Johnson County, KS

With respect to removal of infiltration from the laterals, an important question is whether the rehabilitation of upper laterals would be cost-effective. One pilot project in Nashville, TN was focused on answering this question (CTE, 1994). During one significant rainfall, the agency representatives checked a number of selected cleanouts at the property line for a visible sign of I/I from upper laterals (i.e. visually estimated the flow of clear water during night hours) and projected the annual I/I from all upper laterals assuming an annual frequency of rainfall events compared to the analyzed event. The analysis (Table 8-5) indicated that the rehabilitations would not be cost-effective.

In conclusion, based on an economic analysis approach, the agency can eliminate the options that are obviously not cost-effective and proceed with testing of only those that seem promising. It should cautioned, however, that using any small sample for prediction purposes provides a risk that the sample chosen is not representative of the basin or of the system. In this regard, an open mind should be kept to revisit initial assumptions as more data from the system and its rehabilitation become available.

Table 8-5. Projecting the Cost-effectiveness of Relining the Upper Laterals (Nashville and Davidson County, TN).

Pilot study:	Smith Springs (1993)		
Time:	December 1993		
Rainfall:	1.17" in the previous 24-hr period		
Soil:	Saturated groundwater and surface runoff conditions		
Objective:	To check cleanouts at the property line for visible signs of I/I from upper laterals		
Scope:	1.36% of all existing laterals in the basin (68 of 5,000)		
Quantity of I/I during investigated rainfall:		Observed number:	Extrapolated I/I from upper laterals in the whole basin:
	Major leaks (≤3 GPM)	4 (6%)	450 gpm (5,000 · 0.06 · 1.5 gpm)
	Slight leaks/Trace flow (<0.5 GPM)	12 (17%)	425 gpm (5,000 · 0.17 · 0.5 gpm)
	"Dry"	52 (76%)	0 gpm
	Total:		875 gpm = 1.26 mgd
Quantity of I/I projected annually:			
	5 days/yr @100%	6.3 mg	
	10 days/yr @ 50%	6.3 mg	
	20 days/yr @ 25%	6.3 mg	
	20 days/yr @ 10%	2.5 mg	
	20 days/yr @ 5%	1.2 mg	
	Total:	22.7 mg	
Investment:	Rehabilitation:	$2,500,000	5,000 at $500/lateral
	Project development 20%	$500,000	
	Contingency 10%	$250,000	
Total:		$3,250,000	
Savings:	Annually:	$12,000	0.53/1,000 gal for conveyance/treatment of removed I/I
Payback period:		270 years	
Conclusion:	**Relining of upper laterals is not cost-effective!**		

After Completion of the Pilot Project. After completing the rehabilitation project, the agency can measure the flows and determine the actually achieved reduction in I/I. This demonstrates how effectively the I/I sources were located and how valuable were the applied reduction measures.

An example as to how a cost-utility analysis was applied in Salem, OR is shown for illustration (Roley and Lough, 2004). The example evaluates one of four basins that underwent sewer rehabilitation[74] in 2000-02 (Figure 8-2). FM data collection started before the rehabilitation and ended after the rehabilitation was completed. Hydrologic modeling was used to develop a pre-rehabilitation model and a post-rehabilitation model, which were applied to the long-term hourly rainfall data (53 years). Peak wet weather flows were calculated on an hourly, daily, and monthly basis and fit to the Log Pearson Type III distribution (Figure 8-3).

With the total cost of rehabilitation of $3,152,753, the cost of reducing I/I peak flows as a function of the recurrence interval was determined (Table 8-6).

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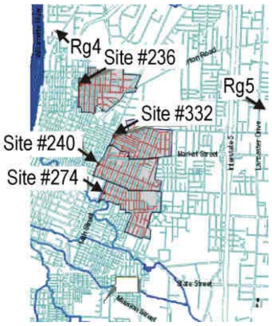
[74] *The rehabilitation was done on both mainlines and laterals, and the calculated effectiveness in I/I removal, as well as cost effectiveness, is attributed to both mainline and lateral rehabilitation.*



Meter:	#236
Basin:	North Central
Pipe Diameter:	14”
Upstream pipe length:	26,420’
Basin Area:	190 acres
Scope of rehab:	Approx 60% of collection system replaced in all four basins

Figure 8-2. North Central Basin (City of Salem, OR).

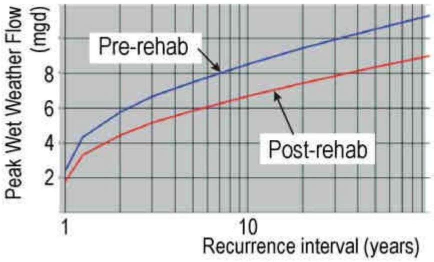


Figure 8-3. Peak Wet Weather Flows Before and After Rehabilitation in the North Central Basin (City of Salem, OR).

Table 8-6. Cost-effectiveness of Sewer Rehabilitation in the North Central Basin (City of Salem, OR).

Recurrence Interval	Pre-Rehab I/I Peak Flow	Post-Rehab I/I Peak Flow	Reduction in I/I Peak Flow		Cost (2002 USD)
5 years	7.49 mgd	5.83 mgd	22%	1,660,000 gpd	$1.90/gpd
10 years	8.52 mgd	6.68 mgd	22%	1,840,000 gpd	$1.71/gpd
20 years	9.44 mgd	7.44 mgd	21%	2,000,000 gpd	$1.58/gpd
50 years	10.53 mgd	8.35 mgd	21%	2,180,000 gpd	$1.45/gpd
100 years	11.30 mgd	9.00 mgd	20%	2,300,000 gpd	$1.37/gpd

8.4 Alternatives for an I/I Control Program

Different alternatives can usually be developed for addressing the existing I/I problems in any wastewater collection system. An illustrative example of some typical alternatives that can be developed is found in one Sewer System Evaluation Study (SSES) from Little Rock, AR, (Figure 8-4) (LRWU, 1997):

- Reduce I/I through rehabilitation—This alternative would involve significant pipe rehabilitation in one part of collection system (upstream of Flow Meter #3) i.e. rehabilitation of mainlines/manholes and laterals, both on the private property and in the right-of-way. Hydraulic modeling predicted 35% reduction of RDI/I, which would reduce peak flows enough to eliminate the SSOs.
- Upgrade the main sewer trunk—The alternative would involve either replacing the existing pipe with a larger diameter pipe or laying a new pipe parallel with the existing pipe, but also an upgrade of the pump station. The alternative would eliminate the SSOs but would pass forward peak wet weather flows. Evaluation of downstream pipes and WWTP capacity would be required.

- Off-line storage—The alternative would build a storage tank to temporarily store peak flows. The alternative would eliminate the SSOs for a design storm but consecutive storms could still create SSOs.

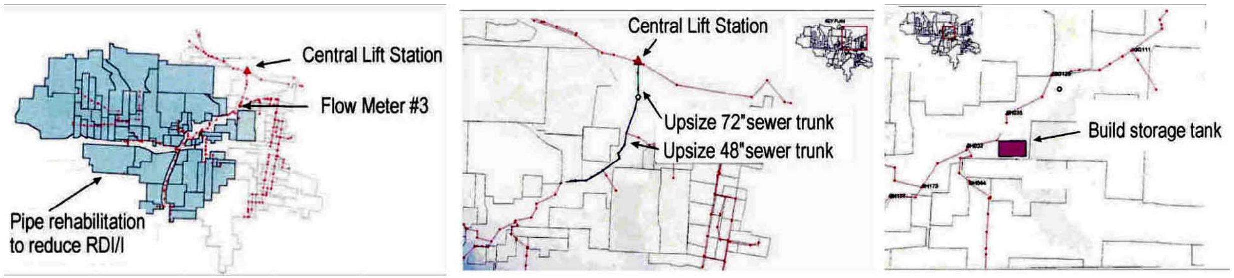


Figure 8-4. Alternatives for an I/I Control Program (Little Rock Wastewater Utility, AR).

Other typical alternatives include upgrading of existing lift stations and/or WWTPs or building new ones.

In large wastewater collection systems, a number of capital improvement projects can sometimes be identified as necessary to address excessive I/I. These projects need not be mutually exclusive (i.e. each project targets a different part of the wastewater collection system) or they can be mutually exclusive to a degree (i.e. a couple of projects are alternatives for the same part of the collection system). Whatever the case, a counterbalance for capital improvement projects in each part of the collection system is sewer rehabilitation—often as an assortment of alternatives that involve different mini-basins, as well as different rehabilitation strategies within the considered mini-basins (what to rehabilitate and what method to apply).

After the alternatives have been developed, they need to be evaluated in order to make recommendations as to which to include in the I/I control program.

8.5 Initial Selection of Alternatives

The process of initial selection of the recommended alternatives starts with a full assessment of alternatives based on a consideration of monetary factors and sometimes non-monetary factors as well. The most appropriate decision making techniques for these applications are:

- Cost-benefit analysis—This is a relatively simple technique that simply adds up the value of the benefits of applying the alternative and subtracts the costs associated with it.
- Grid analysis—This is an effective technique when there is a number of alternatives and many factors to take into account.

Each of these techniques is described and an illustrative example provided. The example for cost-benefit analysis is found in King County, WA, where the evaluation of alternatives is still ongoing at the time of preparing this report. The example for grid analysis is found in Ann Arbor, MI, where the evaluation of alternatives was completed in 2001, as well as the first series of recommended rehabilitation projects, which concluded in 2004.

8.5.1 Cost-benefit Analysis

In its simple form, cost/benefit analysis is carried out using financial costs and direct financial benefits of projects (lower cost of wastewater conveyance/treatment, for example). There are, however, additional financial benefits from removing I/I that are rather intangible and thus difficult to take into consideration.

For example, in Chapter 1.0 of this report, various costs associated with I/I were described such as fines/penalties, economic losses (from repair of flooded properties and related lawsuits), reduced life of pumps in the lift stations, ineffective operating of WWTPs, etc., all of which are the financial benefits of rehabilitation if they are eliminated in the process. It is even harder to put a monetary value on various adverse impacts of I/I (on public health, water pollution, damage to recreation facilities, disruption from construction activities, etc.). Methods used for quantification of social costs associated with construction projects could be used (Gilchrist and Allouche, 2004), however, the development and application of these methods is still poorly defined. The research for this project has not identified any agency that has applied this level of cost-benefit analysis for the evaluation of sewer rehabilitation alternatives.

A practical way of applying cost-benefit analyses for the selection of alternatives is to simply determine a benefit/cost ratio (B/C) of sewer rehabilitation alternatives. The B/C ratio is a fraction representing the return (benefit) on the investment (cost of sewer rehabilitation). The benefit is the elimination of new conveyance and/or storage facilities, delay and downsizing of new conveyance facilities, and/or lower pump station costs and lower treatment costs. Projects with B/C > 1 and the least total costs are expected to be the initially recommended alternatives.

Example: King County, WA. One example of a cost-benefit analysis is a currently ongoing evaluation of rehabilitation alternatives in King County, WA (Lopez, 2004; Herrin, 2004). This example represents one uncommonly comprehensive approach to the problem, in which a large number of alternatives are evaluated applying computer modeling and the cost of alternatives is calculated on a rather sophisticated level. The wastewater collection system in question has total of 758 mini-basins[75].

Before the evaluation started, prospective improvements in the system were identified—a total of 84 different "facilities" of different types as shown in Table 8-7 has been identified as "needed" and sized utilizing the same modeling parameters as those used in developing the I/I flows from each "model" and "mini" basin. For each facility, approximate costs for construction, schedule and operation/maintenance were determined.

Also, a list of prospective I/I rehabilitation projects was created. Each project signifies rehabilitation of one or a series of mini-basins. Mini-basins with less that 3,500 gpad were excluded as candidates for I/I reduction. This criterion was based on the experience from ten pilot rehabilitation projects completed before this evaluation, which was approved by the 34 local agencies and King County. Out of the 758 mini-basins in the whole system, a total of 450 mini-basins were identified to qualify as projects for rehabilitation. For each qualifying mini-basin, four rehabilitation strategies (Table 8-8) would be analyzed for cost-effectiveness once the evaluation of alternatives started.

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[75] *King County is a wholesale sewer service provider to 32 local cities and sewer districts in the Seattle-Metropolitan area. The system has 4,905 miles and 400,000 sewer laterals.*

Table 8-7. Types of Facilities in I/I Control (King County, WA).

Construction of new or expansion existing pump station and/or force main
Modification to existing WWTP
Construction of new parallel line for interceptor
Construction of new conveyance storage facility
Upsizing of existing interceptor (for example from 36" to 40"

Table 8-8. Rehabilitation Strategies in I/I Rehabilitation Projects (King County, WA).

Rehabilitation Strategy	Effectiveness in I/I reduction [76]
Disconnect direct connections to the sewer pipes	10%
Replace mainlines, manholes, "side sewers" and "laterals" [77]	80%
Reline mainlines/manholes	40%
Replace side sewers and only leaky laterals	60%

The process of selecting the alternatives has a number of iterative steps (Figure 8-5). The basic concept is that for each capital improvement project ("facility"), an alternative for I/I rehabilitation of one or more mini-basins ("I/I rehabilitation project") is selected that provides a comparable amount of needed capacity via removal of I/I. The alternative that is the most cost effective is considered for program recommendation.

- Step 1—Beginning at the top of each WWTP basin, facilities are targeted for reduction and the I/I reduction downstream calculated to identify downstream "benefits".
- Step 2— Assuming one rehabilitation strategy at a time, one or more mini-basins qualifying for rehabilitation are selected to achieve removal of I/I equal to the capacity exceedance of the targeted facility.
- Step 3—A hydrologic simulation model is run (based on a long-term rainfall, i.e. a 60-yr record) to estimate peak flows in the mini-basins before and after the rehabilitation alternatives, and predict I/I reduction in the mini-basins.
- Step 4—Cost of construction is calculated for the analyzed mini-basins, based on rehabilitation strategy and quantity of pipe rehabilitated. This cost is compared with the projected cost of the facility that would otherwise be needed. The lower cost determines the alternative to be recommended. If the facility is less costly, however, before dropping the rehabilitation alternative, other rehabilitation strategies are also tested for cost-effectiveness.
- Step 5—This step takes into consideration the different quality of flow monitoring data in various mini-basins and consequentially the different level of confidence in determined I/I reduction. Confidence levels are based on an established set of criteria that guides the reviewer to determine whether the confidence in the mini-basin qualifies as poor, moderate or high.

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[76] *A consensus reached by the King County/Local Agency representatives based on the results of the pilot projects*

[77] *In this analysis, "side laterals" are the portion of laterals between the ROW and the mainline (publicly owned) and "laterals" are the remaining portion of laterals between the ROW and the house (privately owned). The distinction in the analysis is not driven by the ownership but rather different cost of rehabilitation— rehabilitation of side laterals in King County typically involves some excavation in the street and is more expensive.*

- Step 6—If the level of confidence of a mini-basin is poor and additional mini-basins are available, other mini-basins may be considered. If this is not possible, the rehabilitation alternative for the analyzed facility is dropped.
- Step 7—If the level of confidence is moderate, but additional study (SSES, site inspection, etc.) is recommended prior to committing construction funding, a specific notation to this recommendation is called out in the final recommendation.
- Step 8—Once the best I/I rehabilitation alternative is selected, a hydraulic simulation model is run to identify conveyance system attenuation impacts and estimate ultimate I/I reduction at the location of the targeted facilities.
- Step 9—Final I/I reduction quantities and associated costs are determined and compared against the revised (post-I/I reduction) cost of the target facilities. Any additional upstream and downstream "benefits" resulting from the I/I rehabilitation are identified and quantified at this time as well.
- Step 10—Final decision concerning the recommendation of an I/I rehabilitation project is made.

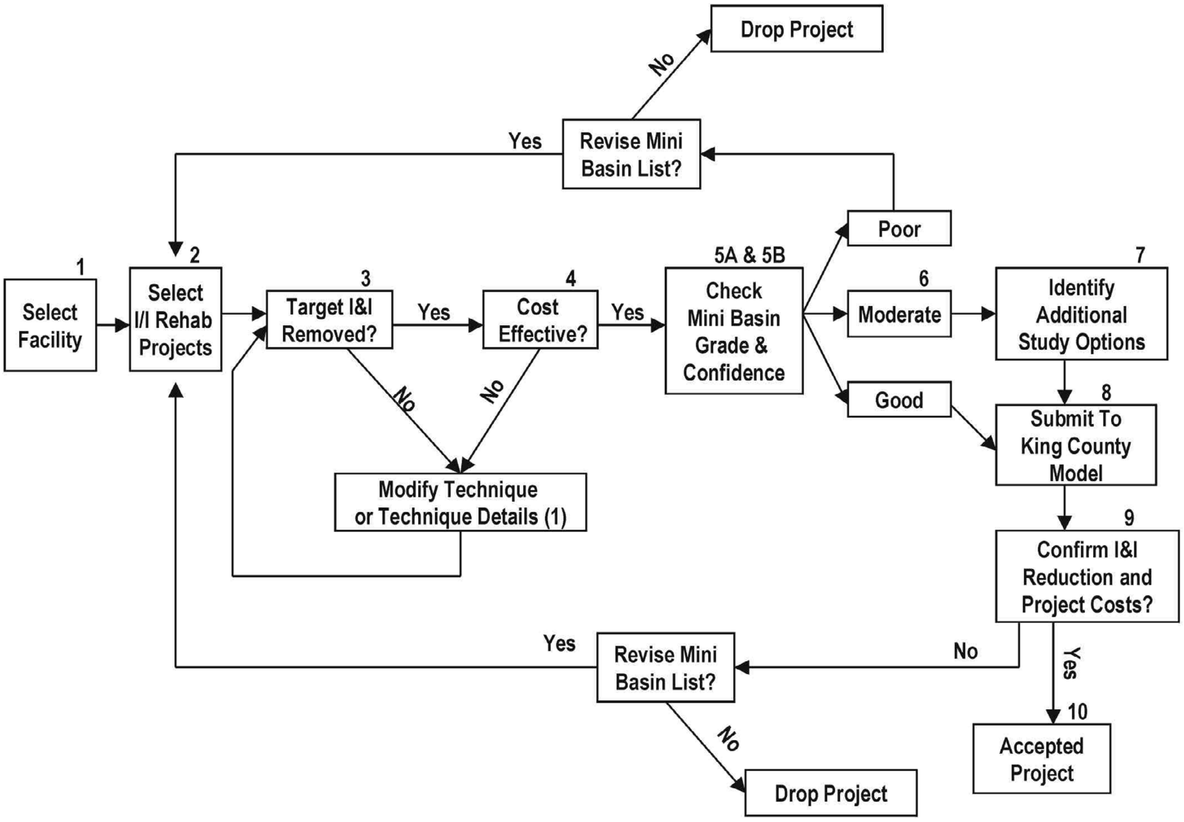

Figure 8-5. Alternatives Selection Process (King County, WA).

8.5.2 Grid Analysis

Grid analysis is performed using the following steps:

- Alternatives and factors important for decision making are listed—These are laid out in a table, with options as row labels, and factors as column headings.
- The relative importance of factors in decision making is established—They are shown as numbers, i.e. the weights that indicate the preferences of the factor by the importance.

Weight factors can range, for example, between 1 (lowest importance) and 4 (highest importance).

- Each alternative in the table is rated for each factor in decision making—Each alternative is rated, for example, from 0 (poor or lowest benefit) to 5 (very good or highest benefit). It is not necessary to have a different score for each option—if none of them are good for a particular factor, then all options should score 0.
- The rates are multiplied by the weight factors and added up as weighted scores—This gives the alternatives the overall weighted score. The alternative with the highest score is recommended.

Example: Ann Arbor, MI. Grid analysis was applied in Ann Arbor, MI to make initial recommendations for I/I control in five basins experiencing serious problems with basement backups and flooding (CDM, 2001; Kotlyar, 2005). The selected basins, referred to as study areas (Figure 8-6), represent 5% of the area served with the city's sewer system but account for 50% of reported backups.

For each study area, four or five alternatives were identified (Table 8-9). The alternatives included 1) relief—a parallel pipe constructed at selected locations to accommodate high flows, 2) upsize—existing pipe upsized with pipe bursting, 3) storage—a storage facility built in the vicinity of flooding areas, and 4) footing drain disconnection. Numerous factors important for evaluation of alternatives were identified (Table 8-10).

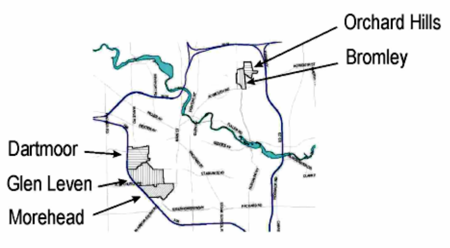

Figure 8-6. Study Areas (City of Ann Arbor, MI).

Table 8-9. Alternatives in Study Areas (City of Ann Arbor, MI).

Alternative	Orchard Hills	Bromley	Dartmoor	Glen Leven	Morehead
Relief	Yes	Yes	Yes	Yes	Yes
Upsize/relief	Yes	Yes	Yes	Yes	Yes
Upsize/storage 1	Yes	Yes	Yes	Yes	Yes
Upsize/storage 2	-	-	-	Yes	Yes
Footing drain disconnection	Yes	Yes	Yes	Yes	Yes

Table 8-10. Factors in Evaluation of Alternatives (City of Ann Arbor, MI).

Factor	Explanation
Quality of life	
Impact on open areas, park or school area	Impact during construction (temporary) or after construction (permanent) on parks, schools etc
Impact on natural features	Impact during construction (temporary) or after construction (permanent) on wetlands, forested areas, natural watercourses, wildlife
Impact on receiving waters	Impact on amount and type of discharge harmful to people and wildlife (SSOs)
Customer disruption outside study area	Amount of construction disruption on residents and businesses
Customer disruption inside study area	Amount of construction disruption on residents and businesses
Odor issues	Potential of the alternative to generate odors
Maintenance access	Some alternatives (storage facilities) need maintenance and the homeowners would be impacted by the noise and traffic
Time for implementation	Duration of time required to complete necessary construction
Certainty by solution	Potential that alternative would not solve flooding problems
Cost issues	
Construction cost	Cost of engineering, design and construction
Maintenance cost	Cost of periodic maintenance to be done by the city
Operational cost	Cost of pumping at lift stations and treating the flow at the WWTP
Future SSO cost	Cost of treating the flows in the future
Construction issues	
Construction constraints	Some alternatives have facilities that add complexity to construction
Contractor availability	Some alternatives may require special equipment and selected contractors
Traffic control during construction	Some alternatives may require traffic control
Construction on private property	Some alternatives may require coordination of activities with homeowners
Easement availability	Some alternatives may require access to the easement
Construction season constraints	With some alternatives, the construction may be delayed due to season

Weight factors and rates were assigned to the alternatives (Table 8-11). In all but one study area, disconnection of footing drains was the highest ranked alternative. The last column in the table shows the total construction cost of the alternatives.

Table 8-11. Grid Analysis of Alternatives in Five Study Areas (City of Ann Arbor, MI).

	Open Areas, Parks	Natural Features	Receiving Waters	Customer Disrupt Outside	Customer Disrupt Inside	Odor Issues	Maintenance Access	Time For Implementation	Certainty By Solution	Construction Cost	Maintenance Cost	Operational Cost	Future SSO Cost	Construction Constraints	Contractor Availability	Traffic Control During Cons	Constr. On Private Prop	Easement Availability	Constr. Season Constraints	Total Weighted	Alternative Ranking	Total Cost (Million USD)
Weight	3	4	2	2	2	1	1	2	4	4	2	3	2	2	2	1	3	1	1			
Orchard Hills																						
Relief	3	3	0	0	2	4	5	4	5	1	1	0	0	4	5	1	5	5	2	109	4	2.2
Upsize/relief	3	3	0	0	3	5	5	4	5	1	5	0	0	5	2	2	5	5	2	117	3	2.3
Upsize/storage	3	4	3	4	2	2	2	3	4	5	4	1	3	3	4	2	4	3	0	137	1	3.2
Footing drain disc	5	2	5	5	0	4	2	2	2	4	4	5	5	3	4	4	0	4	4	136	2	3.3
Bromley																						
Relief	3	3	0	0	2	4	5	4	5	1	1	0	0	4	5	1	5	5	2	109	4	1.6
Upsize/relief	3	3	0	0	3	5	5	4	5	2	5	0	0	5	2	2	5	5	2	121	3	2.0
Upsize/storage	3	4	3	4	2	2	2	3	4	4	4	1	3	3	4	2	4	3	0	133	2	2.4
Footing drain disc	5	2	5	5	0	4	2	2	2	5	4	5	5	3	4	4	0	4	4	140	1	2.5
Dartmoor																						
Relief	1	1	0	0	2	4	5	4	5	0	1	0	0	3	5	1	5	5	2	89	4	1.9
Upsize/relief	3	3	0	0	3	5	5	4	5	0	5	0	0	5	2	2	5	5	2	113	2	4.9
Upsize/storage	1	0	3	2	4	2	2	3	4	3	4	1	3	1	4	2	4	1	0	101	3	2.8
Footing drain disc	5	2	5	5	0	4	2	2	2	5	4	5	5	3	4	4	0	4	4	140	1	4.9
Glen Leven																						
Relief	3	3	0	0	2	4	5	4	5	0	1	0	0	4	5	1	5	5	2	105	5	4.1
Upsize/relief	3	3	0	0	3	5	5	4	5	0	5	0	0	5	2	2	5	5	2	113	4	4.0
Upsize/storage 1	2	3	3	4	2	2	2	3	4	3	4	1	3	3	4	2	4	2	0	121	3	4.3
Upsize/storage 2	3	3	3	4	2	2	2	3	4	5	4	1	3	3	4	2	4	2	0	132	2	7.0
Footing drain disc	5	2	5	5	0	4	2	2	2	4	4	5	5	3	4	4	0	4	4	136	1	7.0
Morehead																						
Relief	3	3	0	0	2	4	5	4	5	0	1	0	0	4	5	1	5	5	2	105	5	2.9
Upsize/relief	3	3	0	0	3	5	5	4	5	0	5	0	0	5	2	2	5	5	2	113	4	3.4
Upsize/storage 1	3	3	3	4	2	2	2	3	4	4	4	1	3	3	4	2	4	3	0	129	3	3.2
Upsize/storage 2	4	3	3	4	2	2	2	3	4	5	4	1	3	3	4	2	4	2	0	135	2	5.7
Footing drain disc	5	2	5	5	0	4	2	2	2	3	4	5	5	3	4	4	0	4	4	132	1	5.5

8.6 Final Selection of Alternatives

The initially recommended alternatives need to be weighed with various factors (legislative, political, environmental) to make the final selection of alternatives for the I/I control. The projects that did not score as top ranked initially may be reconsidered and accepted. Even projects that were not cost-effective in a financial analysis may be accepted if they are promoted by stakeholders, are impelled by regulatory considerations, or include important considerations that could not be included in the financial analysis. In this case, the agency has to be willing and able to provide the additional needed funds over the lowest calculated cost alternative.

The case study in Ann Arbor, MI is an illustrative example of additional decision influences that could modify the initial selection of alternatives. They included 1) stakeholder input, i.e. customers/homeowners and the City Council, 2) regulatory framework, 3) project delivery methods, and 4) funding issues.

Stakeholder Input. Neighborhood meetings were held to present the alternatives that had been evaluated, and to explain their advantages/disadvantages (Figure 8-7). The input from the homeowners was received (Table 8-12). Additional input came from the meeting with the City Council when different issues were discussed (Table 8-13).

Figure 8-7. Neighborhood Meeting (City of Ann Arbor, MI)

Table 8-12. Input from Homeowners (City of Ann Arbor, MI).

Points Made	Explanation
Quick action needed	Homeowners affected by repeated basement flooding should be relieved from these incidents ASAP.
Protection to all homeowners	Homeowners outside of selected five study areas that are also affected by sewage flooding should also get a solution to their problem.
Resistance from some homeowners feared	Some homeowners not affected by sewage flooding might resist the work on their property.
Agency should pay	The cost of the program should be paid by the city. This is basically a statement that all the users of the sewer system should participate in the cost.
Uniform solution desired	All homes should be included in the program because all are contributing the inflow through their footing drains.
Don't move the problem downsteram	The applied measures must not simply transfer the problem somewhere else and have new homes flooding with sewage.
Natural features are important	Construction in areas that impact natural features was regarded with significant resistance.
Environmentaly sensitive solutions supported	Homeowners wanted the alternatives that would deal with basement flooding in an environmentally sensitive manner.

Table 8-13. Input from the City Council (Ann Arbor, MI).

Items Discussed	Explanation
Effectiveness of alternatives in other cities	The City Council wanted to know how different alternatives performed in other communities.
Accessing private propetries in other cities	The City Council wanted to know how this issue could be handled and was handled in other communities in the past.
City paying for rehabilitation	The City Council discussed an issue of the city paying for the work on private properties and the appropriateness of it.
Future SSO requirements	The City Council wanted to know how different alternatives would help complying with pending SSO requirements in the future.
Quick action needed	The City Council was aware that the solution for sewage backup in basements needed to be implemented ASAP.

Regulatory Framework. Impact of the official draft regulations on the selected preferred alternative was considered (Table 8-14). The regulations under scrutiny included the U.S. EPA's draft rule on SSOs (01/05/01) and several bills being developed by the State of Michigan.

Table 8-14. Regulatory Framework Investigated Related to Decision Making (City of Ann Arbor, MI).

Federal (EPA's draft rule)	
Municipal satellite collection systems	The owners of satellite collection systems would have to obtain a no discharge NPDES permit, or issue a permit amendment to the WWTP that receives the wastewater from the satellite collection system.
Municipal satellite collection systems—CMOM projects	All NPDES permittees would have to develop and implement a comprehensive C-MOM program.
Municipal satellite collection systems—prohibition of SSOs	All SSO discharges are prohibited but the enforcement discretion would be used for SSOs caused by severe natural conditions and factors beyond reasonable control of the utility.
Municipal satellite collection systems—reporting SSOs, public notification and recordkeeping	Definition was provided as to what is considered an SSO and a procedure detailed as to how the agency needs to report SSOs, make a public notification and keep the record of these incidents.
State regulations	
Several bills under development[78]	Communities having an approved SSO plan would have limited liabilities. Also, funding would be provided for SSO programs.

Project Delivery Methods. Several alternative methods were distinguished for project delivery, which would affect the construction schedule and ultimate cost (Table 8-15).

Table 8-15. Alternative Methods for Project Delivery (City of Ann Arbor, MI).

Alternative	Explanation
Design/bid/construct	The city would own a separate contract and prepare a project for bidding. A contractor or several contractors would be selected through the bidding (using a low-bid format). The city would have all the contracts and manage the construction work.
Design with construction manager	Same as design/bid/construct except the city would enter into a contract with a construction manager, which would coordinate the construction work between the contractors and homeowners.
Construction manager at risk	The city would have the contract with the designer and the construction manager. The construction manager would hold the contracts with the contractors. This way, many subcontractors could be used and the bidding could be performed throughout the project.
Design/build	The construction management team also includes the designer. The design/build contractor holds all contracts with sub-contractors. The main advantage is that not all designs must be completed before the construction starts, which is an important advantage with disconnection of footing drains because homeowners may have ideas of what is important to them.

Funding Issues. Two funding alternatives were considered (Table 8-16). The decision was made to have the city paying for the costs because the applied measures would benefit the whole system and all customers, not only those that were unfortunate already for being subject to basement flooding. Any additional work that the homeowners might want to have performed during the project construction (resolving the drainage of the yards or additional construction in the basements) would be paid by the homeowners.

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[78] *State Of Michigan Public Act 202—Senate Bill No. 109 (passed on 01/02/02) http://www.legislature.mi.gov/documents/2001-2002/publicact/pdf/2001-PA-0222.pdf*

Table 8-16. Funding Alternatives (City of Ann Arbor, MI).

Alternative	Explanation
Agency pays	The city operates as an enterprise fund, i.e. uses water and wastewater charges to fund operation/maintenance of the system and the capital improvement projects. To fund these projects, the city would sell the bonds and repay these loans out of the fees collected from the customers. The city would have to increase the fees.
Homowners pay	Because the preferred alternative is disconnection of footing drains, an alternative source of funding would be the homeowners.

Final Selection of Preferred Alternatives. The feedback from the homeowners and the City Council resulted in modifying the decision matrix and having the disconnection of footing drains be selected as the preferred alternative in all mini-basins. This alternative would also be compatible with the regulatory trend toward disconnection of footing drains from sanitary sewer systems.

For the preferred project delivery method, the alternative using a contracted construction manager was selected. The city would pre-qualify potential plumbing contractors and the homeowners would select the contractor of their choice from among them. The homeowners would schedule the work and notify the construction manager when the work was completed.

An alternative for homeowners not wanting to manage the construction work on their properties was to have the homeowners select the contractors and allow the construction manager to coordinate the work with the contractor.

8.7 Develop Policies for I/I Reduction

Once the preferred alternatives for I/I reduction are selected, the agency can proceed with the design and construction of individual projects. It is important to continue with flow monitoring and evaluate the achieved reduction in I/I after completed projects. If the rehabilitation projects in particular do not achieve the anticipated results, some modification to the utilized rehabilitation strategy should be carried out—for example, change the length/location of repair and/or number of pipes selected for repair. This would, however, change the cost of the future project and at some point the reevaluation of alternatives might be necessary.

Regular flow monitoring should also be established in parts of the wastewater collection system not included in I/I reduction projects. The emergence of I/I is an ongoing process and can start or develop beyond tolerable levels in those parts of the system over time. It is therefore important to monitor for new sources of I/I and eliminate them in a timely fashion.

The long-term I/I reduction plan should also incorporate necessary changes in an agency’s standard specifications that would impose quality control over construction materials and workmanship, and provide for regular inspection practices and maintenance of the system.

8.8 Conclusion

The selection of the approaches to rehabilitation of private sewer laterals should be based on an evaluation of system-wide problems, needs and opportunities and, in addition to direct cost-benefit studies, should include consideration of non-financial or hard-to-quantify financial impacts as well as the legal, financial and regulatory framework under which the program will exist. Such an approach provides the best opportunity for overall benefit to the community as it takes into consideration operating and construction costs of both the wastewater collection system and WWTPs, community expectations and regulatory input concerning SSOs and sewer backups and planning issues such as the future expansion capacity within the system. It also allows an effective sequencing of projects to provide the quickest return on investment either in terms of financial savings or in terms of reductions of SSOs and property damage.

Of course individual decisions about specific lateral rehabilitation projects can be based on project specific evaluation. In this case, specific basins or projects would be evaluated for cost-effectiveness or public necessity on their own. This approach allows specific projects to deal with identified major problems or opportunities (e.g. lateral work to accompany mainline renewal) to proceed without waiting for an overall system evaluation that could take years to accomplish. Early projects also can provide useful data for use in the system wide analysis.

In this regard, the disconnection of inflow sources on private property is often a relatively inexpensive option with significant payback in financial savings and system performance. Such an option, once examined as to its applicability in a particular community, can proceed while more expensive options that may involve more coordination and planning are in the study and pilot program phase.

The use of pilot projects for lateral rehabilitation has proved a useful technique in many cities that have adopted broad lateral rehabilitation programs. They provide site and system specific data and help identify the rehabilitation techniques to be adopted as well as their effectiveness.

The potential range of parameters affecting the cost-effectiveness of lateral rehabilitation and the relatively small number of municipalities that have reported to date on the cost-effectiveness of their lateral rehabilitation programs makes it difficult to answer in a general way the question “When is the rehabilitation of private lateral sewers cost effective.” Some systems have achieved important results in terms of peak flow and annual flow reductions by including lateral rehabilitation in their I/I reduction approaches, other systems have concluded that dealing with laterals and particularly private laterals is not worthwhile—at least at the present time. Site variables of groundwater levels, soil conditions, rainfall patterns and quality of prior construction must be merged with the extent of private ownership of the lateral, depth of the lateral, existing system capacity and system wide goals to make the determination as to whether such a program is worthwhile. It is hoped, however, that this report provides a road map as to the assessment, analysis, program development, method selection and legal and financial implementation that will make it an easier task to decide how to implement lateral rehabilitation within an overall wastewater system rehabilitation strategy.

APPENDIX A

CASE STUDIES IN LATERAL REHABILITATION

This appendix presents selected case studies that provide explanations as to how public works agencies have made decisions regarding inspection and rehabilitation of their laterals, and detailed information on how the projects were carried out. Some case studies also cover how the agencies quantified I/I and the effectiveness of its removal; costs and financing issues; and how the agencies handled public relations and legal issues. The information and data shown have been provided by the agencies together with their consultants and the contractors who were involved in the construction.

Although the intent is to give a comprehensive summary of each project, the case studies may lack detail in some areas. This is mainly due to difficulty in obtaining the information and data on past projects. It is common that some detailed project documentation gets misplaced over time or that the people involved in the projects retire or leave the agency or company. Providing the data requested for these summaries was very time consuming to the agencies and their effort to track down and obtain the relevant information that would improve understanding of the issues discussed in this research is much appreciated.

A.1 Case Study: CIP Standard Lining in Tacoma, WA (2003)

This case study details how standard CIP relining can be used to rehabilitate sewer laterals.

Table A-1. Project Summary.

Objective	Rehabilitation of the private portion of sewer laterals and quantification of achieved I/I reduction
System used	**Perma-Lateral Lining System™** (CIP standard lateral relining)
Time	Jul 07-Sep 30, 2003
Location	Tacoma, WA
Agency	City of Tacoma, WA Rod Rossi, (253) 502-2127, rrossi@ci.tacoma.wa.us
Contractor	City's in-house crew
Soil conditions	Varied from house to house. Approximately 30% clay, 10% sand, 60% glacial till overall in the pilot area.
Scope	Relined 69 upper laterals (between the property line and the home)[1]
Procedure	a) Preliminary inspection of all laterals (2-3 months prior to rehabilitation) ◆ Locating and CCTV inspection of laterals b) Rehabilitation ◆ Mobilization (site setup) ◆ Pit excavation at the property line ◆ Lateral cleaning and re-inspection (Pre-CCTV) ◆ In-situ liner preparation ◆ Liner inversion and curing ◆ Cleanout installation and lateral reconnection ◆ Post-inspection (Post-CCTV), surface restoration and demobilization
QC after rehabilitation	Only CCTV inspection. No air-pressure testing or water exfiltration testing.
Financing	Paid in full by the city[2].
Public relations	◆ Informational letter to homeowners and renters ◆ Meeting with property owners or renters for investigation ◆ Phone conversations with property owners and renters to discuss the project objectives and benefits to both the property owner and the City of Tacoma ◆ Release form allowing work on private properties ◆ Crew contact with residents the day of the lining to communicate progress
Rehab effectiveness	Continuous flow monitoring before and after lateral replacement/rehabilitation with modeling of the basin before and after to show the effectiveness of lateral relining[3] Tim Sparling, City of Tacoma, P. (253) 502-2128, tsparlin@ci.tacoma.wa.us John Holland, Brown & Caldwell, P. (503) 977-6609 Steve Merrill, Brown & Caldwell, P. (206) 624-0100, smerrill@brwncald.com

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[1] *There were 159 laterals in the pilot area, but 90 were PVC laterals and not candidates for rehabilitation.*

[2] *The city decided to cover all costs to facilitate the participation of homeowners. This pilot study and some other studies planned in near future will help determine the most cost-effective method of removing the peak I/I from the sanitary sewer system.*

[3] *Mainline rehab in this area will follow as a next phase. The mainline rehab will also include the section of pipe from the property line to the main.*

A.1.1 Background

In Tacoma, the lower lateral (distance between the property line and the mainline) is typically 10-20’. Before the pilot project, there was at best only one cleanout at the house. This cleanout was more often than not inside or under the house in cast iron that had not been opened for many years and would need to have the cap broken out to gain access. There were no cleanouts at the property line.

The records about sewer laterals that were more than 40 years old were often missing or were incomplete with little information. The average age of homes in this basin was 60 years. As an offshoot of the investigation, it was found out that only about 25% of homes with sewers replaced in the past 30 years had the replacement done under a permit and had a drawing. Thus, the laterals were first inspected to identify their location, horizontal and vertical bends, pipe size and type, and condition (offset joints, broken pipes, roots, etc.). In all homes with incomplete documentation, a drawing was made for future homeowner’s use.

A.1.2 Steps Preceding Lateral Rehabilitation

Preliminary Inspection. The preliminary inspection of all 159 laterals in the area was performed about two to three months before the rehabilitation. CCTV cameras (Ridgid See Snake cameras) and locating equipment (Ridgid Navitrak locators) were used.

The CCTV camera and the locators were introduced into the lateral either through the existing cleanout near the house or through a roof vent. The inspection revealed a change in pipe diameter from 4” to 6” at the property line (“the transition point”). At the transition point, a stake was put in the ground and the length of lateral measured. Most of the runs were straight and, on average, there was one bend per site (a 22° or 45° bend). All encountered bends were horizontal. The vertical bends usually occur in the lower lateral (in the 6” section before it connects to the sewer main).

The pipe material varied, but most laterals were concrete (67 laterals), some laterals were VCP (two laterals), and the rest were PVC (90 laterals). In most pipes, the joints were leaking badly, and some pipes were cracked and broken.

Selection of Rehabilitation Method. The city considered several rehabilitation options to repair the laterals:

- Open cut—This method was rejected because of the rather lengthy disruption to the homeowners during the rehabilitation.
- Pipe bursting—This method was rejected because it required excavation at two points (one of them on private property, next to the house), and thus more preparation and longer rehabilitation time. Nevertheless, the city obtained a bid from a local contractor for pipe bursting and would use this method if pipe inspection showed the laterals were in too poor a condition for CIP relining. Fortunately, this was not the case and the city was able to avoid scheduling problems that could arise when coordinating the work with this separate contractor.
- CIP relining—Because of time constraints, the method selected was CIP relining with an air-inversion. This method required only one access point to the host lateral. Digging one small hole (3э×3э) at the property line would not only give access for relining the pipe but

also allow installation of a new inspection chamber (cleanout). By using this method, the construction work was held within the city's right of way. In addition, this method was also user-friendly and the in-house crew, which was going to do the work, was fully trained in only a few days. Cost of material was much higher than in other two methods, however cost of labor was much lower, and the method was ultimately the least expensive. The decision was made to reline all laterals in the pilot study, unless they were from PVC[4].

A.1.3 Construction

Mobilization (Site Setup). To each job site, the field crew brought a trailer which contained the air-inversion machine, the two-part resin, liner material, two inversion heads, air compressors, generators, hand tools, sod cutter, power tamper (compactor), inspection chamber (cleanout), roller (to impregnate liner with resin), various fittings (Fernco & PVC) and a backhoe.

Pit Excavation at the Property Line. The only excavation was the digging of one small pit (3эx 3э), in most cases, on the property line where the lateral changed from 4" to 6" (the transition point). Once the lateral was exposed, it was cut open for access.

The excavation was done in the planting strip (City of Tacoma's right of way). Thus, lateral relining and subsequent cleanout installation was accomplished without working on the private property. Only a few laterals (six) had the transition point under the street and not on the property line. In those cases, the pit was excavated near the house and the cleanout installed as usual after relining in that same pit.

Lateral Cleaning and Re-Inspection (Pre-CCTV). After pit excavation, each lateral was cleaned. Duration of cleaning depended on the condition of the pipe. If there were significant amounts of roots, grease, etc, the cleaning might have taken up to an hour. In other cases, it might have taken only two to three minutes. The main cleaning equipment was a jetter (cleaning by water velocity). This was found to be the best way to remove debris and roots. Occasionally, a root-cutting machine was also used.

After cleaning, the lateral was re-inspected with CCTV to make sure that all obstructions had been removed and the line was clean (Figure A-1). Laterals in the condition shown on Figure A-2 were often shallow.

Figure A-1. Inspecting a Lateral with a CCTV Camera Prior to Lining.

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[4] *Out of 159 laterals in the pilot area, 90 were PVC due to the relatively young age of this sub-division.*

Figure A-2. Example of the Condition of Laterals that Were Relined.

In-Situ Liner Preparation. The two-part resin was first mixed together according to company specifications (Figure A-3). It was then poured into the precut length of liner (Figure A-4, Figure A-5) and rolled out with a 50-lb roller. (The required length had been determined during the inspection using a digital foot counter on the CCTV camera.) The liner was completely saturated with the resin and then rolled up into the air-inversion machine (Figure A-6).

Figure A-3. Measuring the Pre-determined Amounts of Resins (Parts A and B). A Digital Scale Was Used for Accuracy.

Figure A-4. Measuring the Length of Liner to Be Installed.

Figure A-5. Pouring the Pre-determined Amount of Resin into the Liner.

Figure A-6. The Crew Reeling the Resin-saturated Liner into the Air-inversion Machine.

Liner Inversion and Curing. The liner was inserted by air-inversion from the property line back towards the house. The air-inversion machine was lined up with the existing lateral, the air-pressure raised to 10 psi and the liner released thus unfurling into the lateral. Figure A-7 shows an "atypical" direction of relining from the house towards the property line. It was used only on a few laterals (six of 69) where the conversion point (4" to 6") was in the street.

Figure A-7. The Crew Shooting the Liner into the Lateral.

Once the liner was in the lateral, the resin curing was performed under continued air-pressure. A calibration tube (Figure A-8) was reeled into the air-inversion machine for this purpose. The air-inversion machine was again lined up with the lateral and the calibration tube shot into the lateral. Then, the calibration tube was clamped off and the air-inversion machine removed. A cap was placed on the end of the calibration tube. Next, an air-compressor was hooked up and the pressure was raised to 6 psi. Then, the clamp was released while making sure the calibration tube was holding pressure (Figure A-9). Once the pressure was holding, the crew moved to the next site. After two to three hours, the crew would return to check the liner and remove the calibration tube and reconnect the service lateral after curing.

With the end cap hooked up to a compressor, the pressure was kept at 6 psi for two to three hours. Once the pressure was steady, the crew would move to the next site.

Figure A-8. Field Crew Member Preparing the Calibration Tube.

Figure A-9. Calibration Tube Being Checked for Holding the Pressure.

A check sheet was used to keep track of construction progress (Figure A-10). Data entered on the sheet included the liner length, the amount of resin used, and the time of installation (so that cure time could be determined).

Figure A-10. Field-crew Member Keeping Record of Construction.

Cleanout Installation and Lateral Reconnection. After the liner had cured, a new inspection chamber was installed. For connecting the new cleanout with the relined upper lateral and the lower lateral, a PVC pipe and bends were used along with a Fernco fitting to connect the different pipe materials.

Post-Inspection (Post-CCTV), Surface Restoration and Demobilization. Once the lateral was reconnected, the lateral was inspected with the CCTV camera to make sure the liner had set up properly and adhered to the host pipe. Special attention was paid to find any potential creases in the liner, especially around bends.

No problems were observed in the installed liners. If there were a problem, the lateral would have been open cut and replaced with a PVC pipe. However, it was evident that as long as the calibration tube was installed correctly, there was little chance of anything going wrong. The calibration tube forced the liner against the host pipe and it was formed in place.

The site was next backfilled and the backfill soil power tamped (with a soil compactor), the sod replaced and a casting set over the cleanout for access. The grounds were restored to the original condition. The crew left the site.

A.1.4 Overview of Performed Work

Table A-2 shows relined lengths and pipe types that were relined.

Table A-2. Tacoma, WA, CIP, 2003: Overview of Performed Work.

	Length	Pipe Type	Length	Pipe Type	Length	Pipe Type	Length	Pipe Type	Length	Pipe Type
1	45’	Concrete	30’	Concrete	45’	Concrete	61’	Concrete	58’	Concrete
2	75’	Concrete	36’	Concrete	40’	Concrete	26’	Concrete	52’	Concrete
3	9’	Concrete	56’	Concrete	11’	Concrete	25’	Concrete	29’	Concrete
4	36’	VCP	21’	VCP	38’	Concrete	25’	Concrete	14’	Concrete
5	28’	Concrete	8’	Concrete	16’	Concrete	22’	Concrete	14’	Concrete
6	112’	Concrete	54’	Concrete	22’	Concrete	30’	Concrete	11’	Concrete
7	37’	Concrete	71’	Concrete	9’	Concrete	48’	Concrete	21’	Concrete
8	54’	Concrete	10’	Concrete	26’	Concrete	14’	Concrete	43’	Concrete
9	52’	Concrete	12’	Concrete	73’	Concrete	53’	Concrete	21’	Concrete
10	47’	Concrete	30’	Concrete	45’	Concrete	55’	Concrete	2,642’	**TOTAL**
11	34’	Concrete	30’	Concrete	80’	Concrete	44’	Concrete	8э	Min
12	39’	Concrete	22’	Concrete	82’	Concrete	41’	Concrete	112’	Max
13	11’	Concrete	59’	Concrete	55’	Concrete	54’	Concrete	38’	Average
14	73’	Concrete	30’	Concrete	30’	Concrete	13’	Concrete		
15	45’	Concrete	31’	Concrete	44’	Concrete	55’	Concrete		

Explanations: The length shown in the table is the relined length from the cleanout to the house.
All laterals were 4” in diameter.

A.1.5 Cost Analysis

The summary of project costs is shown in Table A-3. The City of Tacoma paid for the total cost of the pilot program and the homeowners were not responsible for any payments.

Table A-3. Tacoma, WA, CIP, 2003: Summary of Costs.

Activity	Unit Price	Quantity	Amount	Average
Locating and CCTV inspection	$37.50/lateral	158 laterals	$5,925.00	
Cleaning and CIP relining ($225 labor, $675 material)	$900.00/lateral	69 laterals	$62,100.00	
Post-CCTV inspection	$25.00/lateral	69 laterals	$1,725.00	
TOTAL—Rehabilitation only		69 laterals	$70,725.00	$1,025/lateral
TOTAL—Including preliminary inspection			$76,650.00	$1,110/lateral

A.1.6 Project Duration

The duration of construction work related to CIP relining is shown in Table A-4.

Table A-4. Tacoma, WA, CIP, 2003: Duration of Construction Work on Each Lateral.

Activity	Average Duration
Preliminary inspection	
Locating and CCTV inspection (two people crew)	45 min
Rehabilitation	
Mobilization and pit excavation	15 min
Lateral cleaning and pre-CCTV. Simultaneously: In-situ liner preparation	45 min
Liner inversion and curing	2 hrs 30 min
Cleanout installation and lateral reconnection	15 min
Post-CCTV, surface restoration and demobilization	15 min
TOTAL—Rehabilitation only	4 hrs

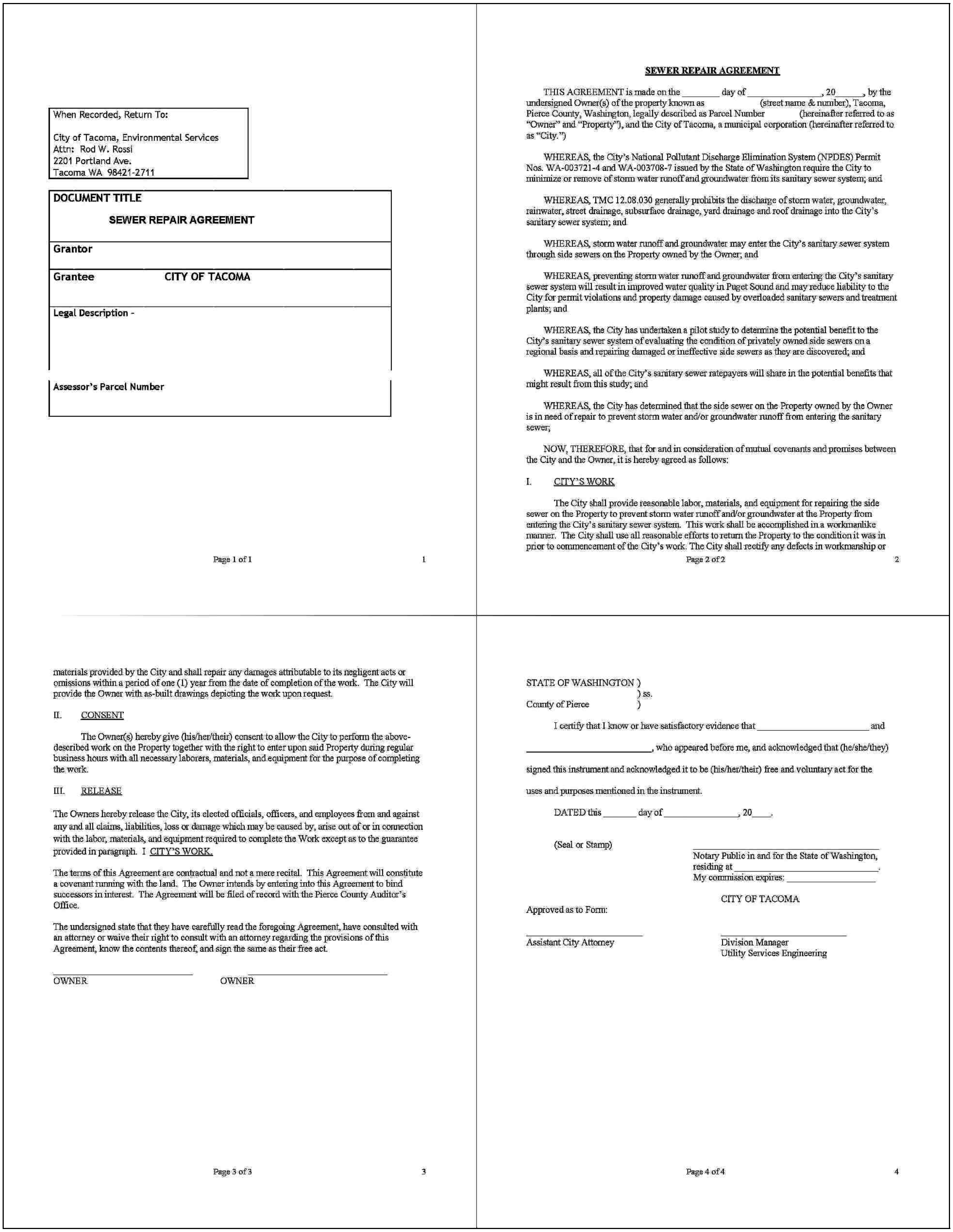
Overall, the project took 45 working days. It took four hours on average to reline each lateral, and the crew could easily reline two laterals per day. The project went generally smoothly and, despite some challenges, was still only one day late in completion.

The following were the challenges encountered in the course of the project:

- Scheduling was somewhat of an issue. About 20 % of the parcels in the basin would not respond to the multiple letters, flyers and door-to-door canvassing of the basin. These were never inspected to determine the condition of the side sewer. About 2% of the homeowners would not return calls or the release agreement after the inspection to schedule the lining of the side sewer. There were occasionally conflicts with the homeowners in scheduling the work and inspection because of their desire to watch the work or just be on site when any work was done.
- Resin cure time was shown to be influenced as much by direct sunlight and compression of the liner in the launching chamber as it was by air temperature for which the resin was rated. In the warmer weather with direct sunlight and longer liners, the curing time became quicker. This created some very short time periods for the wet out and installation. A lesson learned quickly was to use a resin mix designed for warmer days on long laterals or if the wet out was to be done in the direct sunlight. On very hot days, the resin was even put on ice to slow down the cure time and give more working time for the installation. A couple of times on long runs during warm weather, the liner started to cure before it was completely installed. On those instances, the partially cured liner had to be forcibly pulled out of the lateral and a new liner had to be prepared and installed. One time, the line had to be abandoned and a new pipe was placed in another alignment when the liner set up before being completely installed and could not be removed. Luckily, this was a shallow line but it still delayed the work for two days.
- Multiple houses sharing a common lateral or a single home with multiple connections to the lateral required larger pits to work from or multiple pits for lining. When two houses shared the same lateral, three separate liners were inverted from the same hole or, if this location was too deep, three holes were dug and lined. The pit was excavated where they connected together (either a Tee or Wye), and the separate liner was inverted towards each house and the mainline. After relining, the inspection chamber was installed at that point and all laterals reconnected.

A.1.7 Public Relations

Public relations involved sending the homeowners a letter (Figure A-12) explaining the project and the benefits to them (a new sewer line at no cost), as well as to the City of Tacoma (invaluable I/I data). The homeowners were then contacted to set up the initial investigation. Before the lining work started, the homeowners had to sign and have notarized a standard release form allowing the city crews to work on private property (Figure A-11). The release agreement states that the city was also responsible for workmanship for one year.



When Recorded, Return To:

City of Tacoma, Environmental Services
Attn: Rod W. Rossi
2201 Portland Ave.
Tacoma WA 98421-2711

DOCUMENT TITLE **SEWER REPAIR AGREEMENT**	
Grantor	
Grantee	**CITY OF TACOMA**
Legal Description -	
Assessor's Parcel Number	

Page 1 of 1 1

SEWER REPAIR AGREEMENT

THIS AGREEMENT is made on the ________ day of ________________, 20______, by the undersigned Owner(s) of the property known as (street name & number), Tacoma, Pierce County, Washington, legally described as Parcel Number (hereinafter referred to as "Owner" and "Property"), and the City of Tacoma, a municipal corporation (hereinafter referred to as "City.")

WHEREAS, the City's National Pollutant Discharge Elimination System (NPDES) Permit Nos. WA-003721-4 and WA-003708-7 issued by the State of Washington require the City to minimize or remove of storm water runoff and groundwater from its sanitary sewer system; and

WHEREAS, TMC 12.08.030 generally prohibits the discharge of storm water, groundwater, rainwater, street drainage, subsurface drainage, yard drainage and roof drainage into the City's sanitary sewer system; and

WHEREAS, storm water runoff and groundwater may enter the City's sanitary sewer system through side sewers on the Property owned by the Owner; and

WHEREAS, preventing storm water runoff and groundwater from entering the City's sanitary sewer system will result in improved water quality in Puget Sound and may reduce liability to the City for permit violations and property damage caused by overloaded sanitary sewers and treatment plants; and

WHEREAS, the City has undertaken a pilot study to determine the potential benefit to the City's sanitary sewer system of evaluating the condition of privately owned side sewers on a regional basis and repairing damaged or ineffective side sewers as they are discovered; and

WHEREAS, all of the City's sanitary sewer ratepayers will share in the potential benefits that might result from this study; and

WHEREAS, the City has determined that the side sewer on the Property owned by the Owner is in need of repair to prevent storm water and/or groundwater runoff from entering the sanitary sewer;

NOW, THEREFORE, that for and in consideration of mutual covenants and promises between the City and the Owner, it is hereby agreed as follows:

I. CITY'S WORK

The City shall provide reasonable labor, materials, and equipment for repairing the side sewer on the Property to prevent storm water runoff and/or groundwater at the Property from entering the City's sanitary sewer system. This work shall be accomplished in a workmanlike manner. The City shall use all reasonable efforts to return the Property to the condition it was in prior to commencement of the City's work. The City shall rectify any defects in workmanship or materials provided by the City and shall repair any damages attributable to its negligent acts or omissions within a period of one (1) year from the date of completion of the work. The City will provide the Owner with as-built drawings depicting the work upon request.

Page 2 of 2 2

II. CONSENT

The Owner(s) hereby give (his/her/their) consent to allow the City to perform the above-described work on the Property together with the right to enter upon said Property during regular business hours with all necessary laborers, materials, and equipment for the purpose of completing the work.

III. RELEASE

The Owners hereby release the City, its elected officials, officers, and employees from and against any and all claims, liabilities, loss or damage which may be caused by, arise out of or in connection with the labor, materials, and equipment required to complete the Work except as to the guarantee provided in paragraph. I CITY'S WORK.

The terms of this Agreement are contractual and not a mere recital. This Agreement will constitute a covenant running with the land. The Owner intends by entering into this Agreement to bind successors in interest. The Agreement will be filed of record with the Pierce County Auditor's Office.

The undersigned state that they have carefully read the foregoing Agreement, have consulted with an attorney or waive their right to consult with an attorney regarding the provisions of this Agreement, know the contents thereof, and sign the same as their free act.

________________________ ________________________
OWNER OWNER

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STATE OF WASHINGTON)
) ss.
County of Pierce)

I certify that I know or have satisfactory evidence that ______________________ and

______________________, who appeared before me, and acknowledged that (he/she/they)

signed this instrument and acknowledged it to be (his/her/their) free and voluntary act for the

uses and purposes mentioned in the instrument.

DATED this _______ day of ______________, 20____.

(Seal or Stamp)

____
Notary Public in and for the State of Washington,
residing at ____________________________.
My commission expires: __________________

CITY OF TACOMA

Approved as to Form:

______________________ ______________________
Assistant City Attorney
Division Manager
Utility Services Engineering

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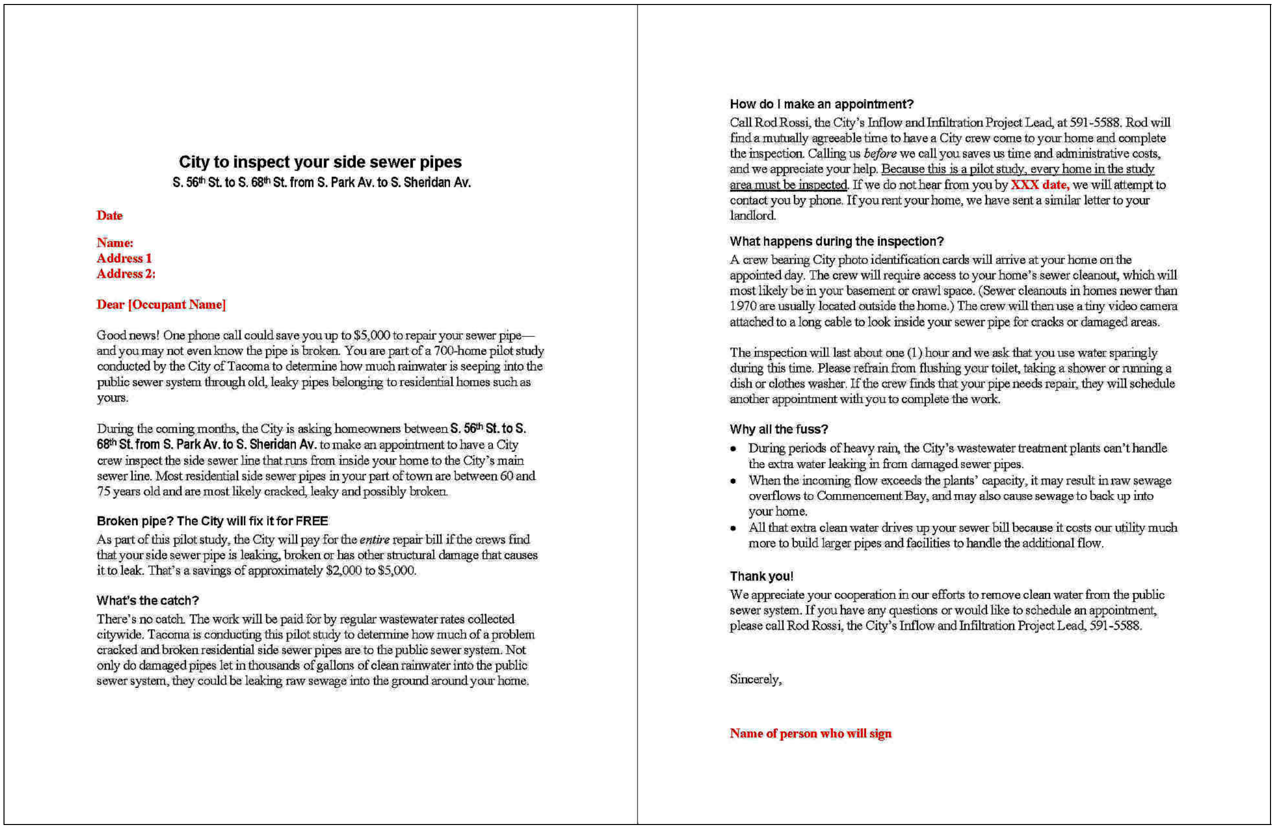
Figure A-11. Access Agreement Allowing the City's Crew to Enter the Private Property.



City to inspect your side sewer pipes

S. 56th St. to S. 68th St. from S. Park Av. to S. Sheridan Av.

Date

Name:
Address 1
Address 2:

Dear [Occupant Name]

Good news! One phone call could save you up to $5,000 to repair your sewer pipe—and you may not even know the pipe is broken. You are part of a 700-home pilot study conducted by the City of Tacoma to determine how much rainwater is seeping into the public sewer system through old, leaky pipes belonging to residential homes such as yours.

During the coming months, the City is asking homeowners between **S. 56th St. to S. 68th St. from S. Park Av. to S. Sheridan Av.** to make an appointment to have a City crew inspect the side sewer line that runs from inside your home to the City's main sewer line. Most residential side sewer pipes in your part of town are between 60 and 75 years old and are most likely cracked, leaky and possibly broken.

Broken pipe? The City will fix it for FREE

As part of this pilot study, the City will pay for the *entire* repair bill if the crews find that your side sewer pipe is leaking, broken or has other structural damage that causes it to leak. That's a savings of approximately $2,000 to $5,000.

What's the catch?

There's no catch. The work will be paid for by regular wastewater rates collected citywide. Tacoma is conducting this pilot study to determine how much of a problem cracked and broken residential side sewer pipes are to the public sewer system. Not only do damaged pipes let in thousands of gallons of clean rainwater into the public sewer system, they could be leaking raw sewage into the ground around your home.

How do I make an appointment?

Call Rod Rossi, the City's Inflow and Infiltration Project Lead, at 591-5588. Rod will find a mutually agreeable time to have a City crew come to your home and complete the inspection. Calling us *before* we call you saves us time and administrative costs, and we appreciate your help. Because this is a pilot study, every home in the study area must be inspected. If we do not hear from you by **XXX date,** we will attempt to contact you by phone. If you rent your home, we have sent a similar letter to your landlord.

What happens during the inspection?

A crew bearing City photo identification cards will arrive at your home on the appointed day. The crew will require access to your home's sewer cleanout, which will most likely be in your basement or crawl space. (Sewer cleanouts in homes newer than 1970 are usually located outside the home.) The crew will then use a tiny video camera attached to a long cable to look inside your sewer pipe for cracks or damaged areas.

The inspection will last about one (1) hour and we ask that you use water sparingly during this time. Please refrain from flushing your toilet, taking a shower or running a dish or clothes washer. If the crew finds that your pipe needs repair, they will schedule another appointment with you to complete the work.

Why all the fuss?

- During periods of heavy rain, the City's wastewater treatment plants can't handle the extra water leaking in from damaged sewer pipes.
- When the incoming flow exceeds the plants' capacity, it may result in raw sewage overflows to Commencement Bay, and may also cause sewage to back up into your home.
- All that extra clean water drives up your sewer bill because it costs our utility much more to build larger pipes and facilities to handle the additional flow.

Thank you!

We appreciate your cooperation in our efforts to remove clean water from the public sewer system. If you have any questions or would like to schedule an appointment, please call Rod Rossi, the City's Inflow and Infiltration Project Lead, 591-5588.

Sincerely,

Name of person who will sign

Figure A-12. Letter to Homeowners.

A.1.8 Effectiveness of Rehabilitation

Rehabilitation of laterals was carried out in a small flow monitoring basin consisting of 6,271' of mainlines (8" pipe), 22 manholes, 159 laterals (approximately 9,200'). Total relined length of the laterals was 2,642' (Figure A-13).

Figure A-13. Sub-basin Where the Rehabilitation of Laterals Was Carried Out.

The basin has one flow monitor (ML-030) in its downstream end. Flow monitoring data were also collected in a control basin next to this basin. This is a basin with similar characteristics, in which no rehabilitation was carried out. The flow monitoring in the control basin is done to eliminate any unaccounted for anomalies in modeling. (Figure A-14).

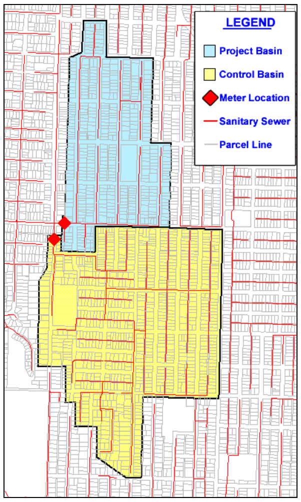


Figure A-14. Sub-basin Where the Rehabilitation of Laterals Was Carried Out (Blue) and Control Sub-basin (Yellow).

The monitor used was DataGator, which combines a modified venturi flow tube design with pressure transducers to measure flow under various conditions (open channel, full pipe, surcharged, submerged, and reverse). Flow monitoring data collection started 9/26/2002. Flow in gpm was continuously recorded every 15 min. Over the same period, rainfall data were collected at seven locations through out the city (0.01” resolution every five minutes). The nearest location was 0.5 miles away from this small basin.

Figure A-15. Flow Monitoring.

Collected flow and rainfall data were used to develop a hydraulic model with the aid of the consulting engineering firm Brown and Caldwell. Using MOUSE software, two models were developed: a “pre-rehab” model based on data collected in the period from 9/26/02-6/30/03, and a “post-rehab” model based on data collected in the period from 10/1/03-6/30/04.

Once the models were calibrated, storms that produce high recurrence interval peak hour flows (2-yr, 24-hr; 5-yr, 24-hr; 10-yr, 24-hr etc.) in the pre-rehab model were run through the post-rehab model. The flow (gpm) from these storms was determined in the 15-min intervals over the 24-hour period. The difference in the peak hour flows was the basis for determining the effectiveness of rehabilitation. While reduction of normal wet-weather flows has some benefit, reduction of peak wet-weather flows was the primary objective of the project in recognition of the importance of reducing SSOs and of reclaiming capacity in both the collection/transmission system and the treatment plant.[5]

The model results have shown the peak I/I reduction ranging from 18% to 39%, depending on the size of the storm. The modeler felt the lower numbers on the projected 100-year storms were due to the fact that prior to the lateral rehabilitation, the whole system had been overwhelmed and no water could get into the system. After the rehabilitation, the additional space in the system was filled with water that in the past had either left the system through the manholes or was unable to enter because of the surcharged condition.

The flow monitoring in this basin will continue for years to track the post-model changes and thus show the long-term effectiveness of rehabilitation.

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[5] *The city regards transmission capacity of the sewer system, treatment plant peak capacity and the SSOs the most significant problems and the real motivation for removal of I/I.*

A.2 Case Study: CIP T-lining in Prince William Service Authority, VA (2004)

This case study details how CIP T-liners can be used to rehabilitate sewer laterals, as well as mainline in the area near the lateral connection.

Table A-5. Project Summary.

Objective	Testing of a T-liner for sealing of laterals and lateral-to-mainline connections in a small pilot project
System used	**LMK T-Liner®** (CIP lateral T-lining)
Time	Mar/Apr 2004
Location	Manassas, VA
Agency	Prince William County Service Authority (PWCSA)—Wayne French, (703) 335-8981, french@pwcsa.org
Contractor	Performance Pipe—Shawn Flannery, 815-433-0080, sflanery@ppi-liner.com
Soil conditions	Predominantly clay and shale (rocky conditions)
Scope	Relined 20 laterals in one neighborhood (2 isolated cul-de-sacs) on their entire length[6] with CIP T-Liner
Procedure	a) Initial steps preceding lateral relining: ♦ CCTV inspection of mainlines and laterals with existing cleanouts (Aug/Sep 2003) ♦ CIP relining of mainlines[7] (Fall 2003) ♦ CCTV inspection of remaining laterals and open cut point repair of several collapsed laterals (Aug/Sep 2003) b) Lateral relining: ♦ Mobilization ♦ Installation of cleanouts (4" Vac-A-Tee) on laterals without any of them (March 2004) ♦ Plugging of laterals, mainlines (Not required, however water meter was turned off during process) ♦ Resin mixing and vacuum impregnation of liner with the resin ♦ Liner inversion and curing ♦ Removal of plugs and demobilization
QC after rehabilitation	Only CCTV inspection. No air-pressure testing or water exfiltration testing.
Financing	Fully funded by the agency (through the fees collected from homeowners for water and sewerage usage)
Public relations	Letter to homeowners, door hangers, agreement form for entering private properties
Project effectiveness	Comparison of measured flows in downstream manholes on selected days for drawing preliminary conclusions (the report with FM data analysis is due in June 2005)

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[6] *Laterals were 4" in diameter, mostly Orangeburg pipe, and several cast iron (CI) and PVC pipes.*

[7] *Total of 1,042϶ of mainline was CIP relined, which makes about 100% of mainline in the pilot project neighborhood. Mainlines were 8" VCP pipes*

A.2.1 Background

In Prince William County Service Authority (PWCSA), VA, the privately owned laterals extend from the house to the ROW. The average width of the ROW is about 60э. Early construction standards did not require cleanouts on laterals, which has since been remedied. Before the pilot project, the cleanouts existed on 12 out of 20 laterals, some near the house, others at the ROW. The cleanouts were, however, required to provide access into the lateral for relining of upper laterals, and were therefore installed in the course of the project on the remaining eight laterals near the house.

A.2.2 Initial Steps Preceding Lateral Relining

CCTV Inspection of Mainlines. The agency performed initial CCTV inspection of mainlines with typical mainline CCTV equipment (Aries). This allowed for in-house documentation of the exact location of lateral connections with the mainline. The inspection also revealed that many connections were hammer tap-ins[8] (Figure A-16). Frequently the lateral intruded into the mainline from 1-4".

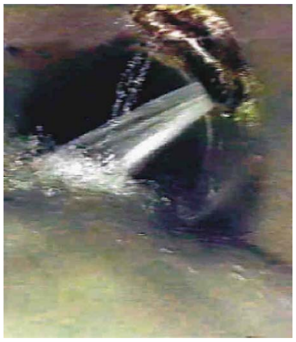


Figure A-16. Hammer Tap-ins.

CCTV Inspection of Laterals. A lateral CCTV push type camera (LMK® Lateral Push Camera) was inserted into the lateral through the cleanout and directed towards the mainline and the house. All laterals made of Orangeburg materials had failed: all were demonstrating various levels of deformation and in seven cases the condition was so pronounced that it inhibited the passage of the camera. The contractor was able to re-round two of the pipes enough to allow passage of the camera as well as the CIPP materials. The other five laterals were open cut spot-repaired in 10-12э long sections and replaced with sections of PVC pipe. The results of lateral CCTV inspection (Table A-6) clearly showed that all laterals needed rehabilitation.

Table A-6. Prince William Service Authority, VA, 2003: Condition Assessment of Laterals.

Pipe Type	Laterals	Condition
Orangeburg	16	All pipes had failed with blistering and pipe material delaminating in layers.
Cast iron	2	Pipes had severe mineral buildup over time, which reduced their hydraulic capacity from 4" pipes to 2" pipes. These pipes have reached the end of their life (40 years) and would continue to decay.
PVC	2	These pipes were in good condition, but not the connection with the mainline

---

[8] *Hammer tap-ins refer to construction practices where the contractor making the connection of the lateral to the mainline chooses to use a hammer or similar tool to knock an opening into the sewer mainline and stick the lateral pipe into it. The opening becomes a pathway for groundwater to enter into the sewer system.*

CIP Relining of Mainlines. The Performance Liner® CIPP system was utilized for relining mainlines. This air inversion and steam curing process was supplied by LMK Enterprises, Inc. (the same manufacturer that would supply the CIP T-liner). Lateral connections were re-established using typical, trenchless lateral connection procedures. Once they were opened, the system was ready and prepared for the lateral relining process.

Installation of Cleanouts on Laterals Where Necessary. Hydro excavation was utilized to make excavations for new cleanouts (Figure A-17). The soil was cut with a water jet and vacuumed out with a 6" tube connected to the vacuum truck. The pit size was about 18" in diameter. Such a small excavation was adequate because a lateral saddle assembly product would be used, which snaps onto an existing lateral pipe and requires only a small foot print compared to a typical cleanout installation. It took on average 60 minutes to complete one pit.

Figure A-17. New Cleanouts. Left: Pit Hydro Excavating. Right: Installed Vac-A-Tee® Cleanout.

For each cleanout, a piece of 4" PVC pipe was used as a riser from the lateral (Figure A-18). It was attached to the lateral using a PVC saddle assembly (4" Vac-a-Tee®) coming up to grade. The water tightness was accomplished by applying a special resin that cured in 30 minutes providing a structural seal. New cleanouts were filled with water to perform a hydrostatic test verifying a non-leaking connection.

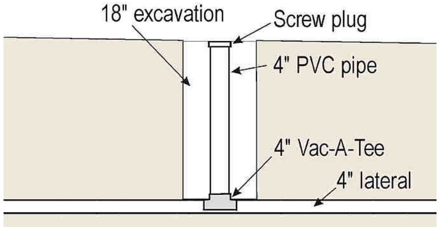


Figure A-18. Schematic of Installation of New Cleanouts.

A.2.3 Construction

Mobilization. The construction crew mobilizing from Chicago arrived on-site with a Harben® 10,000 psi water jett, a reefer unit for on-site wet out, a steam generating truck and other support equipment.

Lateral Pipe Cleaning and Inspection. Cleanouts provided access to clean and inspect the lateral pipes (Figure A-19). High-pressure water and mechanical cutters were used to remove tree roots, blisters in the orange burg and tuberculation from the cast iron. The cleaning process was done with caution as not to cause complete failure of the pipe due to significant deterioration. Each lateral was re-inspected after cleaning to ensure the pipe was adequate for liner insertion.

Once the lines were prepared, a small lateral CCTV camera was inserted through the cleanout near the house into the lateral (Figure A-20). The camera was pushed downstream close to the mainline. The camera would provide accurate robotic positioning of the T-liner and document the inversion process on a video recording equipment.

Figure A-19. Cleanout Ready for Pipe Cleaning.

Figure A-20. Inserting the Lateral CCTV Camera into the Lateral.

Liner Preparation. Liners used for rehabilitation were T-shaped. The tube had a short cylindrical section (16”) fitting the mainline pipe diameter stitched to the long section fitting the lateral pipe diameter. The T-shaped liner was then surrounded by a T-shaped translucent bladder forming a liner/bladder assembly. The liner/bladder assembly’s were constructed at the LMK Manufacturing Facility in Ottawa, IL.

The truck was used as a mobile wet-out unit (Figure A-21). The red hose shown in the picture is the launching device. It is a flexible steam inflatable device that works in all mainline pipe sizes. The resin was mixed first, then poured into the tube and vacuum impregnated (Figure A-22). The mixed resin was poured into the tube through the end that will be installed upstream, near the house. The opposite end of the tube with a short mainline section was connected to a vacuum hose. The resin was spread inside the tube utilizing vacuum impregnation. The person in the figure on right was checking the vacuum impregnation making sure that the thickness of the saturated tube was as specified.

Figure A-21. Truck Used as a Mobile Wet-out Unit.

Figure A-22. Liner Impregnation with Resin. Left: Pouring the Resin into the Tube. Middle: Vacuum Hose Connected to the Tube. Right: Vacuum Impregnation.

Loading of the Launcher. The liner/bladder assembly containing the resin-saturated tube was next pulled into the launcher (Figure A-23). Both tubes were laid out on the ground next to the truck. Inside the truck, one end of the launcher (through which a cable was stringed) was affixed onto a piece of pipe and the assembly connected to the cable. As the person outside was pulling the cable, the tube was entering the launcher. The resin remained on the inside of the tube. The loading of the launcher was completed by affixing the short mainline section onto the launcher (Figure A-24). Hydrophilic bands were added.

Figure A-23. Pulling the Liner/Bladder Assembly into the Launcher. Left: Both Tubes Laid Out on the Ground. Middle: Pulling the Cable Inside the Launcher. Right: The Assembly Entering the Launcher.

Figure A-24. Completing the Loading of the Launcher.

Inversion of the Liner. The loaded launcher was first positioned inside the mainline to enable inversion of the liner/bladder assembly into the lateral (Figure A-25). The end of the launcher opposite of mainline section was inserted through the manhole first. Once the launcher was completely inside the mainline, it was winched past the lateral connection until its end with the mainline section was positioned exactly at the connection. The CCTV camera inside the lateral was used to monitor the positioning of the launcher.

Air pressure was applied causing the liner/bladder assembly to invert up into the lateral pipe, on some laterals as far as 85э (Figure A-26). Once in place, the air pressure held the bladder/liner assembly tightly against the lateral pipe.

Figure A-25. Positioning of the Launcher. Left: Insertion through the Manhole. Right: Lateral CCTV Camera.

Figure A-26. Air Inversion of the Liner/Bladder Assembly the Lateral.

Resin Curing. Steam was used for resin curing (Figure A-27). The steam tank was connected with the bladder and steam introduced into it. The resin curing took about 30 minutes. During that time, the steam was circulating through the bladder and exiting out of the lateral at the cleanout near the house. The upstream end of the bladder was left slightly open. Once the resin curing was completed, the bladder was pulled out.

Figure A-27. Resin Cure. Left: Steam Hose Connected to the Bladder. Right: Steam Exiting at the Cleanout Near the House.

Post CCTV Inspection. The installed liner was inspected with both lateral and mainline CCTV. Figure A-28 shows the relined lateral connection viewed from inside the mainline.

Figure A-28. Installed T-liner at the Lateral-to-mainline Connection (a View from the Mainline).

A.2.4 Overview of Performed Work

Table A-7. Prince William Service Authority, VA, 2004: Overview of Performed Work.

Address	Length—Total	Length—Relined	ID
9100 Amherst Court	82.0϶	72.0϶	4”
9101 Amherst Court	82.0϶	85.0϶	4”
9102 Amherst Court	82.0϶	85.0϶	4”
9103 Amherst Court	85.0϶	81.0϶	4”
9104 Amherst Court	78.0϶	77.0϶	4”
9105 Amherst Court	24.0϶	50.4϶	4”
9106 Amherst Court	58.0϶	58.0϶	4”
9107 Amherst Court	58.0϶	57.3϶	4”
9108 Amherst Court	54.0϶	55.0϶	4”
7584 Amherst Drive	79.0϶	81.0϶	4”
7585 Amherst Drive	80.0϶	80.4϶	4”
7586 Amherst Drive	49.0϶	46.0϶	4”
7587 Amherst Drive	84.0϶	81.4϶	4”
7588 Amherst Drive	58.0϶	58.0϶	4”
7589 Amherst Drive	70.0϶	69.0϶	4”
7590 Amherst Drive	56.0϶	52.5϶	4”
7591 Amherst Drive	50.0϶	49.0϶	4”
7592 Amherst Drive	58.0϶	53.0϶	4”
7593 Amherst Drive	56.0϶	54.0϶	4”
7594 Amherst Drive	54.0϶	53.0϶	4”

A.2.5 Cost Analysis

Table A-8 summarizes the project cost. By mutual agreement, the agency paid only for the installation of four cleanouts and the installer for the remaining four cleanouts.

Table A-8. Prince William Service Authority, VA, 2004: Summary of Costs.

Activity	Unit Price	Quantity	Amount	Average
CCTV inspection of laterals (in-house by the agency's crew)		20 laterals		
Cleanout installation	$1,500/lateral	8	$12,000.00	
Point repair (open cut)	$5,800 /ea	5	$29,000.00	
T-Liner (includes cleaning and post-CCTV inspection)	$4,471.32/lateral	20 laterals	$89,426.40	
TOTAL—Excluding cleanouts			$118,426.40	$5,921.32
TOTAL—Including cleanouts		20 laterals	$130,426.40	$6,521.32

A.2.6 Project Duration

Time frame for the project, including the excavation and repairs of the failed five laterals took 10 working days. It took about three hours on average to complete installation of each T-liner (Table A-9). The Illinois field crews were able to rehabilitate two laterals per day. There were some learning experiences during the project but overall the construction process went smoothly.

The following were the challenges:

- The Orangeburg pipe material had blistered and delaminated, in some cases it had totally failed. The contractor was able to round out some of the Orangeburg material enough to allow for installation of the CIPP materials but prior to the contractor performing his work, five failed laterals required excavation and point repairs to be made
- The Vac-a-Tee saddles did not conform to the irregularity of the outside diameter of the cast iron pipe due to exterior corrosion. The exterior of the cast iron was very rough with heavy build-up making the outside diameter larger than normal. The standard operating practice for VAC-A-Tee saddles on cast iron has since been amended to sandblast the portion of pipe where the saddle will be set.
- Obtaining permission from all homeowners prior to beginning work
- Public relations (described in the following paragraph)

Table A-9. Prince William Service Authority, VA, 2004: Duration of Construction Work on Each Lateral.

Activity	Average Duration
CCTV inspection of laterals (three person crew)	45 min
Mobilization	15 min
Lateral cleaning. Simultaneously: In-situ liner preparation	45 min
Liner inversion and resin curing (20-30 min)	60 min
Post-CCTV, and demobilization	15 min
TOTAL	3 hrs

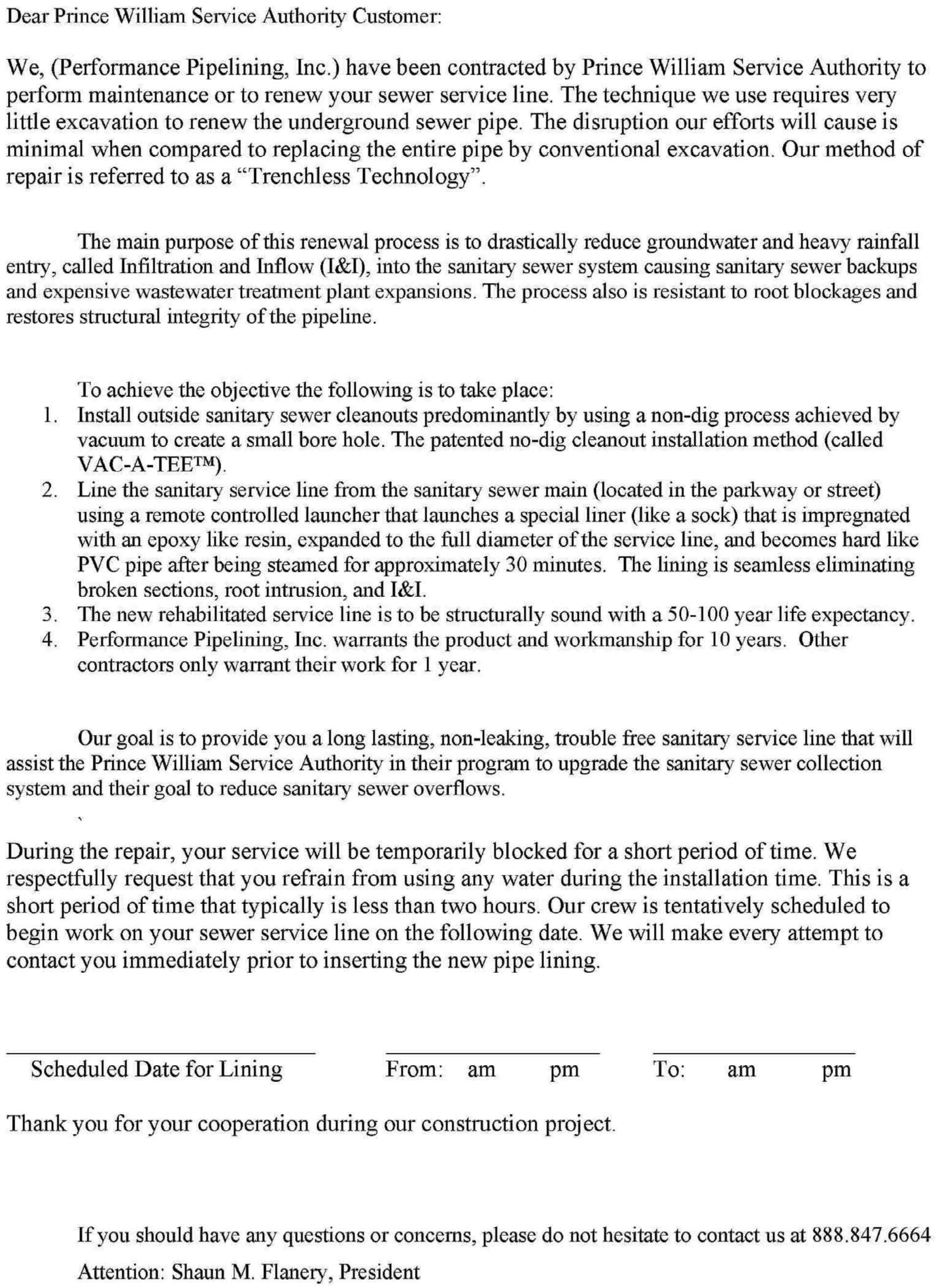
A.2.7 Public Relations

The Service Authority worked diligently on informing the public about the coming project. This paragraph shows the following prepared by the agency:

- Door hangers—One of the steps was preparing a door hanger, which explained the nature of the problem and how the relining of laterals would provide the solution (Figure A-29
- Letter to homeowners (Figure A-30)
- Access agreement allowing the crew to enter private property (Figure A-31)

A.2.8 Effectiveness of Rehabilitation

Flow monitoring equipment has been installed in several manholes collecting flow data, however, flow data analysis was still not completed at the time of this report submission. The final FM data analysis report is due in June 2005. From observation of flows however it is apparent that the rehabilitation was very effective in stopping the infiltration. The agency could not see large spikes in the flows due to rain induced infiltration and inflow after installation and believes that the system has completely sealed the relined connections and laterals.



Dear Prince William Service Authority Customer:

We, (Performance Pipelining, Inc.) have been contracted by Prince William Service Authority to perform maintenance or to renew your sewer service line. The technique we use requires very little excavation to renew the underground sewer pipe. The disruption our efforts will cause is minimal when compared to replacing the entire pipe by conventional excavation. Our method of repair is referred to as a “Trenchless Technology”.

The main purpose of this renewal process is to drastically reduce groundwater and heavy rainfall entry, called Infiltration and Inflow (I&I), into the sanitary sewer system causing sanitary sewer backups and expensive wastewater treatment plant expansions. The process also is resistant to root blockages and restores structural integrity of the pipeline.

To achieve the objective the following is to take place:

1. Install outside sanitary sewer cleanouts predominantly by using a non-dig process achieved by vacuum to create a small bore hole. The patented no-dig cleanout installation method (called VAC-A-TEE™).
2. Line the sanitary service line from the sanitary sewer main (located in the parkway or street) using a remote controlled launcher that launches a special liner (like a sock) that is impregnated with an epoxy like resin, expanded to the full diameter of the service line, and becomes hard like PVC pipe after being steamed for approximately 30 minutes. The lining is seamless eliminating broken sections, root intrusion, and I&I.
3. The new rehabilitated service line is to be structurally sound with a 50-100 year life expectancy.
4. Performance Pipelining, Inc. warrants the product and workmanship for 10 years. Other contractors only warrant their work for 1 year.

Our goal is to provide you a long lasting, non-leaking, trouble free sanitary service line that will assist the Prince William Service Authority in their program to upgrade the sanitary sewer collection system and their goal to reduce sanitary sewer overflows.

During the repair, your service will be temporarily blocked for a short period of time. We respectfully request that you refrain from using any water during the installation time. This is a short period of time that typically is less than two hours. Our crew is tentatively scheduled to begin work on your sewer service line on the following date. We will make every attempt to contact you immediately prior to inserting the new pipe lining.

Scheduled Date for Lining ____________ From: am ____ pm ____ To: am ____ pm ____

Thank you for your cooperation during our construction project.

If you should have any questions or concerns, please do not hesitate to contact us at 888.847.6664

Attention: Shaun M. Flanery, President

Figure A-29. Door Hanger Explaining the Project to Homeowners.

Manassas, VA 20111
8 August 2003

Re: Lateral replacement

Dear Mr. & Mrs. _____:

As you know, this spring has been one of the wettest in recent history. As such, there have been issues that were always present but were greatly magnified due to this high groundwater condition. We have been dealing with Inflow and Infiltration (I & I) for quite some time. However, the rains this spring inundated the system and helped us pinpoint the areas that require our focused attention. One of those areas is Amherst Court and that portion of Amherst Drive from the cul-de-sac to Yorkshire Lane. We have performed investigative work in this area, and determined that a good deal of the I & I present is coming from the laterals (the pipe that connects the sewer in your house to our main line in the street). We have recently learned of a new procedure for repairing these laterals that does not involve digging up the whole yard.

The process involves the relining of the lateral from inside the main line pipe. This is the same technology that the industry has been using for some time now, but only recently has it been adapted to apply to the small house laterals. The process involves inserting a machine in the main line which has the flexible liner attached to it. The liner is impregnated with a resin and then inserted up the lateral to within five feet (or to the stub-out from the house). Once inserted, the resin cures and you now have a new service lateral, which will give you many years of service and will eliminate most, if not all, of the I & I from the laterals. By eliminating this groundwater, we are able to save money, as this water goes to the treatment plant and must be treated, even though it is clear groundwater. This costs everyone money, since this water is not metered, (i.e. doesn't come from a building, where the sewer rate is based on the amount of water used), there is no way to recover the cost of treating this water at the treatment plant.

In order to perform this process, your lateral must have a cleanout installed at the property line or at the house. The cleanout is a pipe with a cap on it that allows access to the lateral for cleaning and inspection purposes. This cleanout, if not already present, is necessary for this process. If one is not present, we will have one installed, which will entail digging up a portion of your lawn and installing the cleanout. Also, if there is only a cleanout at the street and not one at the house, we will have to dig up the one at the street and replace it with a "straight" tee. This is necessary due to the fact that the tees installed in a typical sanitary cleanout are "swept" with the direction of flow from your house. We need to have a "straight" tee for not only the relining process, but also to facilitate our ability to insert a camera in the line and TV the lateral. This will reveal any problems that may be present, and also tell us where any cleaning must be performed. This should be the extent of the digging in your lawn, unless of course there is a complication.

However, there is one exception to this rule. If the lateral to your home is Orangeburg, the situation changes. Orangeburg is a pipe material that was used for many years, even as late as the 1970's. The pipe is made of cellulose fibers that are injected with hot coal tar pitch. If Orangeburg is present in the lateral to your home and it is in fairly good condition (i.e. it is still mostly round), the process can still be performed. However, if the pipe is severely out-of-round or collapsed, then we would not be able to perform the relining. At that point, we will have to contact you to discuss other options for repair. This will involve, most likely, digging up the lateral from the street to the house and replacing it.

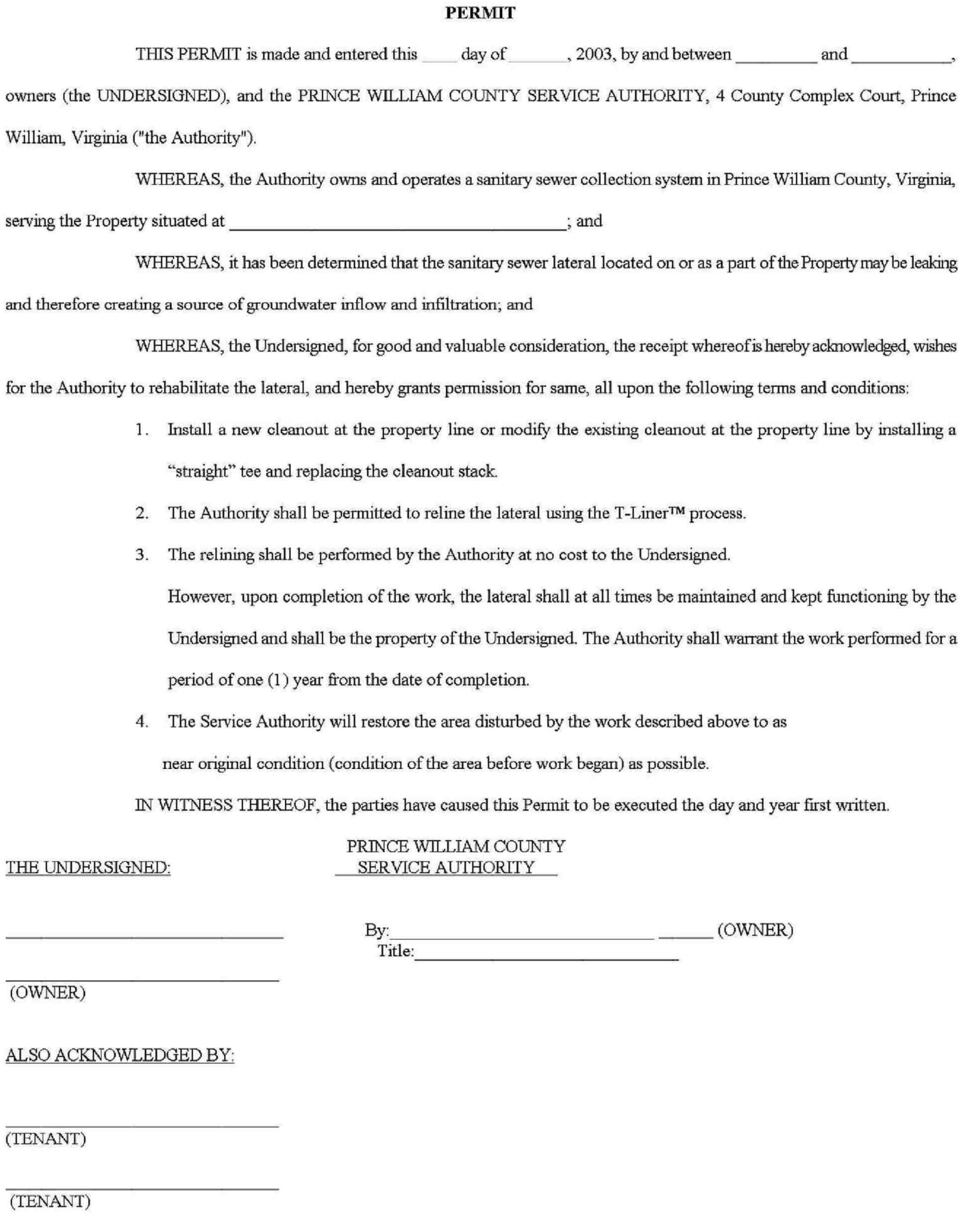
The relining project will be conducted at no cost to you, the homeowner. However, if the condition described above (collapsed or severely out-of-round Orangeburg pipe) exists, we will have to contact you to discuss the replacement options, as well as any cost. By doing this, it will benefit you, as well as everyone else on our system. We want to make this area a demonstration project for this new process and we would greatly appreciate your assistance in that effort.

You will find a permit included with this letter, which we need you to sign, if you are the owner. If you are a tenant, please sign in the appropriate section and then pass it along to the owner for his/her signature. We would like to have all of these permits returned as quickly as possible, so that we may schedule the contractor to come in and perform the work.

If I you have any questions or concerns, please feel free to contact me at 703-335-7980. You may also contact John Scott or Wayne French at the above number.

Sincerely,

Figure A-30. Letter to Homeowners.



PERMIT

THIS PERMIT is made and entered this ____ day of ______, 2003, by and between _________ and __________, owners (the UNDERSIGNED), and the PRINCE WILLIAM COUNTY SERVICE AUTHORITY, 4 County Complex Court, Prince William, Virginia ("the Authority").

WHEREAS, the Authority owns and operates a sanitary sewer collection system in Prince William County, Virginia, serving the Property situated at ________________________________; and

WHEREAS, it has been determined that the sanitary sewer lateral located on or as a part of the Property may be leaking and therefore creating a source of groundwater inflow and infiltration; and

WHEREAS, the Undersigned, for good and valuable consideration, the receipt whereof is hereby acknowledged, wishes for the Authority to rehabilitate the lateral, and hereby grants permission for same, all upon the following terms and conditions:

1. Install a new cleanout at the property line or modify the existing cleanout at the property line by installing a "straight" tee and replacing the cleanout stack.
2. The Authority shall be permitted to reline the lateral using the T-Liner™ process.
3. The relining shall be performed by the Authority at no cost to the Undersigned.
   However, upon completion of the work, the lateral shall at all times be maintained and kept functioning by the Undersigned and shall be the property of the Undersigned. The Authority shall warrant the work performed for a period of one (1) year from the date of completion.
4. The Service Authority will restore the area disturbed by the work described above to as near original condition (condition of the area before work began) as possible.

IN WITNESS THEREOF, the parties have caused this Permit to be executed the day and year first written.

THE UNDERSIGNED:

____

____
(OWNER)

PRINCE WILLIAM COUNTY
SERVICE AUTHORITY

By:________________________ ______ (OWNER)
Title:________________________

ALSO ACKNOWLEDGED BY:

____
(TENANT)

____
(TENANT)

Figure A-31. Access Agreement Allowing the County to Enter Private Property.

A.3 Case Study: CIP Standard Lining in Weymouth, MA (2003)

This case study details how another standard CIP relining system inserted from within the house can be used to rehabilitate sewer laterals. The initial project scope involved only one lateral, but it was expanded to include two laterals after another lateral tied to the selected lateral was identified during the project.

Table A-10. Project Summary.

Objective	Relining of a sewer lateral to achieve leak-tightness and protect from root intrusion
System used	**MaxLiner™** (CIP standard lateral relining)
Time	Aug 5-6, 2003
Location	Weymouth, MA
Agency	Town of Weymouth, MA Dan Annaccone, (781) 337-5100, ext. 313, dannaccone@weymouth.ma.us Hillary Lacirignola, *Weston & Sampson Engineers*, (978) 977-0110, ext. 23130, lacirigh@wseinc.com
Contractor	Roto-Rooter and MaxLiner
Soil conditions	N/A
Scope	2 laterals joined at Wye fitting to one lateral that connects to a mainline[9]
Procedure	a) Preparation of laterals ♦ Cleaning of laterals i.e. removal of debris, grease, and roots ♦ CCTV inspection of the laterals b) Liner installation ♦ In-situ felt tube preparation and calibration ♦ Inversion ♦ Curing ♦ Completion of the openings at ends (mainline connection, 2 house connections) and at the Wye ♦ CCTV Inspection "after"
QC after rehabilitation	Only CCTV inspection (before and after the rehabilitation). No air-pressure testing or water exfiltration testing.
Financing	Paid jointly by the contractor and the town[10]
Public relations	
Rehab effectiveness	Not determined

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[9] *Each lateral consisted of a 10-lf section of 4"cast iron, a 4" x 6" transition fitting, and an additional 10-lf of 6" cast iron pipe. They joined at the Wye fitting and continued as a 73-lf section of 6" cast iron pipe, which connected with the mainline.*

[10] *Before the project, the contractor agreed to cover all the cost. However, as an additional sewer lateral was discovered in the course of the project, the town agreed to cover a portion of total cost.*

A.3.1 Background

This project was carried out to demonstrate the MaxLiner technology for rehabilitation of private sewer laterals to the Town of Weymouth. Initially one lateral was scheduled for relining. The selected sewer lateral clearly needed a repair as it had been plagued by sewer back-ups over the years. However, there were other circumstances that made this particular sewer lateral "a challenge" for repair:

- The lateral was packed with tree roots, as there were a number of large trees in the vicinity of the lateral.
- There were obstacles nearby (an underground pool and a retaining wall), as well as bends in the sewer lateral, which made other methods such as open-cut replacement or pipe bursting unsuitable.

A.3.2 Steps Preceding Lateral Rehabilitation

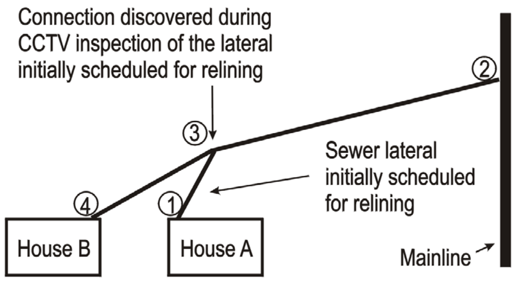
Inspection and Cleaning of Laterals. The lateral was televised using a Rigid See Snake self-leveling color camera, which was inserted through the cleanout in the basement of the home (Figure A-32) and pushed through the pipe towards the mainline in the street. The lateral was packed with roots and the camera could not reach all the way to the mainline. The lateral was cleaned with high velocity jets of water to cut the roots (Figure A-33). The equipment used was a root cutter head on a 4,000 psi jetting machine. Clearing the roots took approximately four hours.

Figure A-32. Cleanout in the House Basement.

Figure A-33. Root Cutter Equipment.

The CCTV inspection was repeated after the cleaning. During the second inspection and immediately prior to the installation, a connection of another lateral was identified, which the roots had previously obscured. It was discovered that the sewer service for the neighboring house was tied into the sewer lateral, although it was not shown on the town's sewer map. After the intersection of the two laterals, one 6” sewer lateral conveys sanitary flows from both homes to the sewer main.

For a better understanding, Figure A-34 shows the schematic layout of two laterals and steps in the project unfolding over a two-day period. Details on the relining procedure follow.



Step	Between Points	Done
◆ CCTV inspection/cleaning	1—2	Day 1
◆ CCTV inspection/cleaning	4—3	Day 1
◆ Relining/cure overnight	4—2	Day 1
◆ Relining/cure	1—3	Day 2
◆ Reopening connection:	3	Day 2

Figure A-34. Layout of Laterals Relined and Project Steps.

Selection of Product to Be Installed. Due to the diameter transition in the lateral pipe from 4” to 6”, a 5” WovoLiner tube (4.5mm wall thickness) was selected for this project. This liner tube is seamless and would conform to both pipe diameters without creating wrinkles in the liner that could disrupt the flow.

A.3.3 Construction

In-Situ Felt Tube Preparation and Calibration. The tube material was first laid out on the ground and cut to the required length (Figure A-35). A vacuum pump was connected to remove all of the air in the liner tube prior to wetting it out with the epoxy resin, and a two-component epoxy resin was mixed. Next, the resin was mixed and the tube filled with the resin (Figure A-36). A vacuum pump was used to spread the resin along the liner tube (Figure A-37). Precise calibration rollers set to match the liner wall thickness were used to evenly distribute the resin in the liner tube (Figure A-38). Once the inside of the liner was thoroughly wetted with the resin, the liner was placed in cold water mixed with ice to slow the curing of the epoxy and allow the installation crew extra time to get the liner installed (Figure A-39).

Figure A-35. Liner Tube Getting Ready for Wet Out.

Figure A-36. Resin Mixing and Pouring into the Tube.

Figure A-37. Vacuum Pump Connected to the Tube.

Figure A-38. Calibration Rollers for Even Wall Thickness of the Liner.

Figure A-39. Icing of the Liner to Prevent Premature Resin Curing.

Inversion. The impregnated liner was inserted into the lateral pipe by air-inversion. A liner gun was brought into the house basement and the liner was inserted into the gun. The liner was fed into the liner gun by hand allowing the installer to positively feel the liner going into the pipe (Figure A-40). Using compressed air, the gun inverted the liner and pushed it down the pipe. It took roughly 15 minutes to invert the longer of the two liners into the pipe, and about 10 minutes to invert the other one.

Figure A-40. Feeding the Liner into Inversion Gun.

Curing. After the liner was inverted, a bladder (Figure A-41) was inflated inside the liner to hold the liner flush against the pipe during the resin cure. The bladder was air-inverted into the pipe as was previously done for the liner. The air pressure was then applied and maintained overnight until the epoxy cured. The installers checked the compressor every hour to ensure that the appropriate pressure was held. If a hot water curing process were used, the curing time would have been reduced from six hours to between two and three hours. The process is similar, the difference being that that a hose is inserted into the bladder and hot water from a portable water heater (MaxLiner HotKick) circulated through the bladder.

Figure A-41. A Bladder Brought on the Site.

Completion of the Openings at the Wye. The second lateral was relined the following day. Once both liners were installed and cured, a cutter was used to open the hole in the liner at the Wye allowing sanitary flows to again reach the mainline.

For cutting the hole in the liner, an air-driven MaxCutter was attached to the push rods (with a CCTV camera attached to its side) and inserted into the relined pipe. The operator positioned the cutter while viewing the camera monitor. Once the cutter was in place (at the Wye connection), the sides of the cutter were expanded to hold it in place. The operator then used the air driven cylindrical cutting head to cut through the wall of the liner, moving around the inside diameter of the opening using the control handle while watching the camera monitor.

A.3.4 Cost Analysis

Table A-11. Weymouth, MA, CIP, 2003: Summary of Costs.

Activity	Unit Price	Quantity	Amount	Average
Cleaning	$9.50/ft	141’	$1,350	
CCTV inspection	$2.50/ft	141’	$350	
Rehabilitation (material/installation)	$92.20/ft	141’	$13,000	
Cut open Wye connection	$300/ea	1	$300	
TOTAL:			$15,000	$106.40/ft
Alternatives for comparison				
Pipe Bursting	$165/ft	141’	$23,265	
Dig and replace	$200/ft	141’	$28,200	

The typical cost for this type of lateral relining work ranges from $3,500-10,000 depending on the root removal required, the length of the lateral, and the number of other pipes connected to the lateral being relined that have to be reinstated with a robotic cutter. The cost of this lateral rehabilitation to the Town of Weymouth was approximately $6,000. The remaining cost ($9,000) was covered by the contractor because this was a demonstration project. It should be noted that the cost of individual demonstration projects is not normally reflective of the cost for larger projects containing multiple laterals in one area.

A.3.5 Project Duration

The duration of construction work related to CIP relining is shown in Table A-12. The curing process using ambient air takes approximately six hours after the liner has been installed. The contractor wanted to reline both laterals on the same day, however, he could reline only one the first day because a cutter for reopening the lateral connection was not available on-site. Even if the contractor had the cutter, he would have still been missing the second bladder to assist in curing of the second liner. Thus, the second liner was installed the following day.

This left both homes without the use of sewer for a 48-hour period. The contractor agreed to put both residents up in a hotel. However, this was not necessary because both residents were able to make other arrangements.

The contractor has since begun using the hot water curing process, which cures the liner in two to three hours. Using the hot water curing process would have allowed both laterals to be relined and reconnected the same day.

Table A-12. Weymouth, MA, CIP, 2003: Duration of Construction Work on Each Lateral.

Activity	Average Duration
Lateral cleaning and pre-CCTV. Simultaneously: In-situ liner preparation	4 hrs
Liner inversion and curing (ambient cure)	6 hrs
Lateral reconnection	1 hr
Post-CCTV, surface restoration and demobilization	½ hr
TOTAL	11½ hrs

A.4 Case Study: CIP Lining of Lateral Connections in Pinetops, NC (2003/04)

This case study details how short CIP connection liners can be used to rehabilitate sewer lateral-to-mainline connections.

Table A-13. Project Summary.

Objective	Sealing of lateral-to-mainline connections as a final step in sewer rehabilitation—following the rehabilitation of mainlines and manholes, and the relining of laterals with standard CIP liners.
System used	**TOP HAT® Lateral Sealing System** (CIP lateral connection relining)
Time	Dec 2003-Oct 2004
Location	Pinetops, NC
Agency	City of Pinetops, NC —Gregory Bethea, *Town Manager*, 252-827-4435, pinetops@earthlink.com
Contractor	Southwest Pipeline and Trenchless Corp, Steve Vossmeyer, 310-329-8717, COBRAMAN93@aol.com Amerik Supplies, Dick Schantz (262) 377 5653, cell. (404) 242 8816, Dick.Schantz@AMerikSupplies.com
Soil conditions	Alluvial material—layers of impervious clay, silt.
Scope	Sealed 200 lateral-to-mainline installing a CIP short connection liner TOP HAT®
Procedure	a) Initial steps preceding lateral connection sealing ♦ CCTV inspection of mainlines (12/02-01/03) ♦ CIP relining of mainlines[11] (12/03-04/04) ♦ Rehabilitation of manholes[12] (05/04-09/04) ♦ Installtion of cleanouts[13] and CIPP relining of lower laterals[14] (03/04-09/04) b) Lateral connection sealing with TOP HAT®: ♦ Mobilization ♦ Lateral Preparation (cleaning, root removal, etc.) (04/04) ♦ TOP HAT® installations (04/04-05/04, 06/04-07/04, 08/04-09/04 ♦ Demobilization
QC after rehabilitation	Only CCTV inspection. No air-pressure testing or water exfiltration testing.
Financing	Paid for by the state government (the NC grant for hurricane damage), $2.9 million from State grants and $200,000 from Rural Center funds
Public relations	No special measures required because the town was small
Rehab effectiveness	Flows coming to the WWTP have been monitored. Flows observed before any rehabilitation was performed and at different stages of rehabilitation were compared.

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[11] *Total of 2,080' of mainline were CIP relined, which is about 30 % of existing mainlines in the project area.*

[12] *Total of 197 manholes were repaired.*

13 Total of 200 cleanouts were installed at the property line of laterals to be rehabilitated.

14 Total of 200 laterals were CIP relined.

A.4.1 Background

The Pinetops WWTP is designed for treating wastewater daily flows up to 0.300 mgd but flows were traditionally significantly higher during wet weather due to I/I. About 17,000э of mainline, which constituted about 33% of the sewer collection system, was replaced in 1996 showing no effect on reduction of I/I and flows at the WWTP. Before rehabilitation, dry weather daily flow to the plant was about 0.200 mgd[15], however during wet weather, the flow was about 400,000 gpd[16]. Peak wet weather flow was close to 1,000,000 gpd[17].

The town was required to enter into a special order of consent with the State to be able to continue to treat more than the 300,000 gpd (average daily flow). The town agreed to aggressively find ways to reduce its flow. The grants were vital in funding the solution to this problem.

A two-year study was completed next to determine ways to reduce the I/I and meet state guidelines. Town funds were used along with the state grant to pay for the studies needed to determine the best way to deal with the I/I problem.

A.4.2 Steps Preceding Lateral Connection Sealing

CCTV Inspection of Mainlines. The CCTV inspection of mainlines revealed that I/I occurred through leaking joints between sections of old pipe throughout the system and that some new PVC pipes (less than 10 years old) were broken.

Laterals could not be inspected because there were no cleanouts on them. In Prince William Service Authority, VA, the privately owned laterals extend from the house to the ROW. The average width of the ROW is between 30э and 60э, however, current practice does not require cleanouts on the laterals.

Decision What to Rehabilitate. Sections of mainline where most of the I/I was coming in were selected for relining with CIP liners. Leaking manholes were selected for repair as well.

All sewer laterals that were connecting to deep mainlines (approximately 10э on average) were also selected for relining with standard CIP lateral liners, averaging 30э in length, cleanout to mainline. The deeper areas were believed to be in the worst condition. Each of these laterals had at least two 45° bends in that region and pipe bursting was considered to be unsuitable. Lastly, sealing of lateral connections with the mainline was planned with a CIP product designed for that purpose.

A.4.3 Construction

Installation of Cleanouts on All Laterals Where Missing. There were originally no cleanouts on any of the laterals. The cleanouts were installed on all 200 laterals on the property line because they were required for lateral inspection before relining of lower laterals. The lateral lining preceded the installation of lateral connection seals at the mainlines.

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[15] *For example, between July 25-30, 2003, the flow to the plan was between 0.179 mgd and 0.209 mgd*

[16] *For example, between January 1-4, 2003, the flow to the plan was between 0.381 mgd and 0.4242 mgd*

[17] *For example, on March 2, 2003, the flow was 0.881 mgd*

Installation of TOP HATS®. The TOP HAT® is made of ECR corrosion resistant fiberglass that is impregnated with UV-light curing resin and epoxy. The factory impregnated TOP HAT® laminate is removed from its packaging at the job site (Figure A-42) and placed onto the packer (Figure A-43). The packer is attached to a crawler that is used to maneuver the packer through the pipe. The packer is equipped with two cameras. The external camera is used for locating the lateral, then aligning the TOP HAT® with the lateral.

Figure A-42. Factory Impregnated TOP HAT® Delivered to Site.

Figure A-43. Packer for Installation with Lateral Bladder Inflated.

The loaded packer with lateral bladder inverted (Figure A-44) is inserted through the manhole and aligned in the mainline with the lateral. The transparent bladder is inflated at approximately 7.0 psi, pressing the laminate tightly to the pipe. At this point, the internal camera is turned on. This camera is located inside the packer and is used to make final adjustments before turning on the UV-lights.

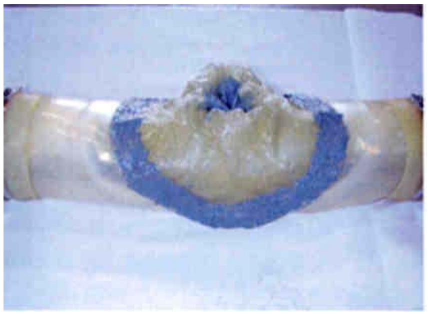

Figure A-44. Loaded Packer for with Lateral Bladder Inverted Ready for Installation.

The transparent bladder allows the internal camera to see up the lateral and make sure the TOP HAT® has been installed correctly. The use of UV-light allows for a quick curing time that minimizes the disruption of mainline/lateral flow. If everything looks good, the UV-lights are turned on, the light is passed through the transparent bladder, and the TOP HAT® laminate is cured just seven minutes later. In the end, the packer is deflated and removed from the mainline (Figure A-45).

Figure A-45. Packer Deflation After Completed UV-light Resin Cure.

A.4.4 Overview of Performed Work

Table A-14. Pinetops, NC, 2004: Overview of Performed Work.

Liners Installed	Quantity	Mainline ID	Mainline Type	Lateral ID	Length in Lateral Sealed with TOP HAT®
TOP HAT®	60	8”	CIPP	4”	4-6”
TOP HAT®	24	8”	CIPP	6”	6”
TOP HAT®	15	10”	CIPP	4”	4-6”
TOP HAT®	64	8”	PVC	4”	4-6”
TOP HAT®	9	8”	PVC	6”	6”
TOP HAT®	7	10”	PVC	6”	6”
TOP HAT®	21	8”	Clay	4”	4-6”
CIP sectional liners	13	8”	Clay	6”	N/A

A.4.5 Cost Analysis

Table A-15 summarizes the cost of installation of TOP HATS®. The whole program was paid by the agency and the homeowners were not responsible for any payments. The funds were provided by the state government through the NC grant for hurricane damage, $2.9 million from State grants, and $200,000 from Rural Center funds.

Table A-15. Pinetops, NC, 2004: Summary of Costs.

Activity	Unit Price	Quantity	Amount	Average
CIP sectional lining (capping of dead laterals with TOP HAT® equipment)	$1,250/ea	13 laterals	$16,250	
TOP HAT® (includes pre/post CCTV, cleaning, root removal, traffic control, jetting and by-pass if needed)	$1,250/ea	200 laterals	$250,000	
TOTAL		213 laterals	$266,250	$1,250/lateral

A.4.6 Project Duration

Overall, the TOP HAT® portion of the project took 46 working days. It took about 1.5 hours on average to install each TOP HAT® (Table A-16) and the crew could install four or five TOP HATS® per day. The project went generally smoothly.

The job was challenging since there were many different types of lateral connections and many different types of materials in the ground. Some laterals were break-ins, some were 4" and 6" factory Wyes, and some transitioned from 4" to 6" at the mainline. The majority of the laterals were relined VCP, but there were also several cast iron and PVC laterals. Due to the variety of connections and materials in the ground, crews were forced to constantly alter installation techniques. They were also forced to swap parts and adjust the equipment for each lateral due to the random lateral dimension change from house to house.

Table A-16. Pinetops, NC, 2004: Duration of Construction Work on Each Lateral.

Activity	Average Duration
Mobilization, Pre-CCTV	10 min
Preparation (main line jetting, de-rooting, grinding, etc.)	15 min
Plugging of the mainline (if needed)	10 min
TOP HAT® preparation, insertion and curing	40 min
Post-CCTV, and demobilization	10 min
TOTAL	1 hr 25 min

A.4.7 Public Relations

For installation of TOP HAT®s there was no need to enter private properties. The TOP HAT® only disrupts mainline and lateral flow for about 15 minutes, so there was no need to notify homeowners. However, when using the Max Liner CIP lateral lining product, a small hole needed to be excavated for the installation of a cleanout and liner. Therefore, 24-hour notices were passed out notifying the resident to minimize the use of their water for a few hours. The agency did not do any special advertising because it was a small town and most citizens were aware of the "visitors" in town.

A.4.8 Effectiveness of Rehabilitation

Flow monitoring data analysis has not been completed at the time of this report submission. Table A-17 shows measured flows at the WWTP on selected days before any rehabilitation and after rehabilitation (mainline/manhole and TOP HAT® installation), however the actual rainfall data were not provided with flows. If the rainfall "before" and "after" was similar during wet weather period, as well as during peak wet weather period, the effectiveness of rehabilitation can be presumed in both periods.

Some excessive flows on the WWTP can still be seen after this rehabilitation project. These flows are attributed to the following:

- Manholes still leaking
- Areas of the city that were not rehabilitated—some of the infiltration could still be coming in through the lateral upstream of the new cleanouts and lateral liners.
- Groundwater migration—after much of the system has been rehabilitated, the groundwater rises and looks for the next available spot to leak in, which could be through a crack in a pipe that had never leaked before

Table A-17. Pinetops, NC, 2004: Flow at the WWTP Before and After Sewer Rehabilitation.

	Dry Weather		Wet Weather			Peak Wet Weather		
	Date	Flow	Date	Rainfall	Flow	Date	Rainfall	Flow
Before any rehab	07/03	246,000 gpd	01/03		329,000 gpd	03/03		544,000 gpd
After mainline/manhole rehab								
After lateral CIP lining								
After TOP HAT® installation	07/04	125,000 gpd	11/04		193,000 gpd	09/04		288,000 gpd

A.5 Case Study: CIP Standard Lining in West Vancouver, Canada (2003)

This case study details another CIP relining project for rehabilitation of sewer laterals, in which the contractor inserted the resin-saturated liners into laterals by winching. This is one part of a pilot project in which approximately same number of laterals was replaced by pipe bursting—A.6 in this Appendix). The whole project involved only the upper laterals because the lower laterals had already been replaced earlier.

Table A-18. Project Summary.

Objective	Rehabilitation of laterals to achieve leak-tightness and structurally sound sewer system
System used	**Custom built CIP liners**[18] (CIP standard lateral relining)
Time	Oct 6-Dec18, 2003
Location	West Vancouver, Canada
Agency	District of West Vancouver Saleem Mahmood, P. (604) 925-7027, smahmood@westvancouver.net
Contractor	Mar-Tech Underground Services Ltd Bob Kennedy P. (604) 533-4262 mar-tech@telus.net
Soil conditions	Shallow layer of topsoil/fill on hard glacial till. Many laterals directly under a lawn, garden, retaining wall or driveway
Scope	Relined 16 upper laterals (between the property line and the home, in either direction) [19]
Procedure	a) Initial inspection and locating of all laterals (1-2 weeks prior to rehabilitation): ◆ Pre-CCTV [20] b) Rehabilitation: ◆ Mobilization (site setup) ◆ Lateral cleaning and Re-CCTV ◆ Pit excavation and, if applicable, removal of existing cleanouts ◆ In-situ felt tube preparation and calibration ◆ Liner installation and curing ◆ Control-CCTV ◆ Cleanout installation (if applicable) and lateral reconnection ◆ Surface restoration and demobilization b) After rehabilitation (2-3 weeks after the rehabilitation): ◆ Post-CCTV
QC after rehabilitation	Only CCTV inspection. No air-pressure testing or water exfiltration testing.
Financing	Paid in full by the city.
Public relations	Open house with homeowners. Notice to homeowners, agreement form
Rehab effectiveness	Continuous flow monitoring before and after sewer replacement/rehabilitation to show combined effectiveness of lateral pipe bursting and CIP relining, as well as rehabilitation of public sewers in the pilot area Dayton &Knight, Gurjit Sangha (604) 990-4800, gsangha@dayton-knight.com

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[18] *The contractor used a tube purchased from Applied Felts and unsaturated polyester resin purchased separately.*

[19] *There were 37 laterals in the pilot area. An additional 15 laterals were replaced by pipe bursting. Six laterals were left out: two were new and four had no homeowner's permission to be repaired.*

[20] *The laterals were first inspected two or three years ago as part of the overall study for this pilot project.*

A.5.1 Background

In West Vancouver, the lower lateral (distance between the property line and the manhole) is typically 10-13э (3-4 m). On each lateral, there is one cleanout at the property line[21]. As in most cities, the records about sewer laterals only go to the property line and not the house. Within this project, the laterals were initially inspected to locate them, i.e. identify their layout. Each site was also examined to look for difficult digging conditions and potential obstructions such as pools, etc.

A.5.2 Steps Preceding Lateral Rehabilitation

Initial Inspection and Locating of Laterals (Pre-CCTV). The locating was carried out with a CCTV camera (CUES) with a radio-wave emitting sonde (Radio Detection®) built into the camera's head (Figure A-46). The depth of pipes did not exceed 12-13э, which is the upper limit for application of this equipment. The camera with the sonde was inserted into the lateral through the inspection chamber and cable-pushed through the lateral. An operator walked along the path of the lateral and traversed a hand-held receiver left and right, thus identifying their layout (path and depth, and both vertical and horizontal bends). The location where the lateral entered the house was marked on the ground with orange paint (see arrow in Figure A-47).

Figure A-46. Left: Portable CCTV Inspection Equipment. Middle: Orange Arrow Pointing at the Camera. Right: Portable VCR and Monitor.

Figure A-47. Mark of Lateral Location Near the House.

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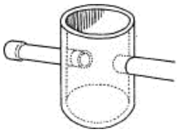
[21] *An Inspection Chamber (IC) is a special cleanout that allows the lateral to be plugged when required. It looks like an 8" manhole on the lateral and is built of PVC. A new IC comes pre-plugged and the plumber can test the pipe when installing the cleanout.*



The locating identified both vertical and horizontal 45° bends in the laterals. Although the inspection was not focused on determining the pipe condition (because such inspection had been completed two years before this project), it was again confirmed that the pipe material varied greatly (VCP, PVC, asbestos cement, and cast iron), as they were all put in at different times when the houses were built. Also was evident that, in most pipes, the joints were leaking badly, and some pipes were cracked and broken.

Selection of Rehabilitation Method. Most laterals in this pilot area (approx. 80%) could have been repaired by either pipe bursting or relining. Only a small percentage of laterals (approx 10%) was suitable only for pipe bursting due to offset joints in the pipe or because of collapsed pipe. About the same percentage of laterals was suitable only for CIP relining because of more than three bends on the lateral or obstacles for excavating the required pits (Figure A-48).

Figure A-48. Retaining Wall Near the Lateral Made Pipe Bursting Unsuitable.

A.5.3 Construction

Mobilization. To each site, the crew brought a hydro excavator and an equipment trailer with a CCTV system, equipment for resin impregnation (wet-out equipment) and installation bladders.

Lateral Cleaning and Re-Inspection (Re-CCTV). First, upon arrival, each lateral was cleaned. The duration of cleaning depended on the condition of the pipe. Typically, the cleaning took only a few minutes and the equipment used was a jetter (cleaning by water velocity). However, if there were significant amounts of roots, cleaning might have taken longer—up to an hour. For roots, a root-cutting machine was used. After cleaning, the lateral was inspected with CCTV to make sure that all obstructions had been removed and that the pipe was clean.

Pit Excavation and Cleanout Removal (If Applicable). The only required excavation for insertion of the liner was digging of one small pit either at the property line or near the house. The location where exactly to dig was decided based on digging conditions at each site and potential obstructions. However, because the liner length was limited to approximately 50э (15 m), some longer laterals required excavation of an additional pit and were relined with two liners.

The pit size was typically 3’×3’ (1.0 m×1.0 m) and the pit depth often quite shallow (Figure A-49). If the pit was on the property line, the cleanout was removed. Otherwise, once the lateral was exposed, it was cut open for access.

Figure A-49. Excavation Showing the Shallow Depth of Some Pipes.

In-Situ Felt Tube Preparation and Calibration. The liner was prepared in-situ. A precut felt tube (manufactured by Applied Felts, 3.0 mm thick) was laid on the ground and saturated with resin (Stypol to unsaturated polyester resin manufactured by Cook Composites and Polymer). A vacuum line for impregnation (plastic bag) and a bladder (dark hose) were laid on the tarp (Figure A-50). A tarp was used to assure a clean job site. The resin was poured into a clear plastic bag that had a felt liner placed inside. A vacuum was used to draw all air out of the clear plastic bag and ensure that the resin would penetrate the felt liner (Figure A-51). With the vacuum connected, the resin spread inside the tube. In its raw state, the resin was white, and it turned green when the green catalyst was mixed in (Figure A-52). Finally, a pipe was rolled along the liner to help evenly disperse the resin (Figure A-53). The liner was visually inspected after the wet-out to ensure that no areas were devoid of resin.

Figure A-50. Liner Tube Laid Out on the Ground.

Figure A-51. Vacuum Connected to the Tube.

Figure A-52. Resin Progressing Through the Tube.

Figure A-53. Using a Roller to Spread the Resin along the Liner.

Liner Insertion and Curing. For insertion of the prepared liner into the lateral, a bladder was used (Figure A-54). The bladder also helped to hold the liner in shape during the resin cure. The bladder was inserted into the liner and then fixed onto it firmly with a tape (Figure A-55). The result was a combination bladder/liner assembly. The bladder/liner assembly was carefully carried to the excavation and typically pushed into the lateral (Figure A-56). Only rarely, if there were numerous bends in the pipe, it was attached to a string and pulled in place (less than 5% of relined laterals).

Figure A-54. The Bladder alongside the Prepared Liner.

Figure A-55. Taping the Liner Tightly around the Bladder.

Figure A-56. Carrying the Liner/Bladder Assembly to the Excavation.

A PVC sweep bend was used in the pit to protect the bladder from being scratched on the sharp edges (Figure A-57). Pressurized air was used to inflate the bladder and press the liner tightly against the pipe (Figure A-58, Figure A-59). The resin was ambient temperature cured and the duration of curing depended on the air temperature (the colder the weather, the longer the cure). The air temperature was in 50s and 40s, and, on average, it took about 1½ hour for resin cure.

Figure A-57. Sweep Bend.

Figure A-58. Excess Bladder Extending out of the Trench with Air-pressure Hose Connected.

Figure A-59. The Regulator Shows the Pressure in the Bladder.

Control–CCTV. Immediately after relining, the liner was inspected to make sure everything was done properly. Minor wrinkles could be seen in some laterals, typically where small imperfections (such as hard deposits less than ¼” at the crown of the pipe) in the host pipe were not removed with cleaning nor were broken with the bladder. All liners were regarded as properly installed.

Cleanout Installation (If Applicable) and Lateral Reconnection. If the cleanout was removed earlier, it was re-installed. Fernco fittings were used for reconnecting the lateral in most cases.

Surface Restoration and Demobilization. Once the new pipe and cleanouts were in place and all the connections completed, the pit was backfilled and any required surface restorations made (Figure A-60).

Figure A-60. Surface Restoration Underway.

Final Inspection (Post-CCTV). A few weeks after the rehabilitation, the CCTV inspection of all rehabilitated laterals was carried out. A few minor wrinkles were found as in the CCTV control inspection immediately after the relining, and none required any repair.

A.5.4 Overview of Performed Work

Table A-19. West Vancouver, Canada, CIP Relining 2003: Overview of Performed Work.

Lateral:	Relined Length		Pipe Diameter (ID)		Pipe Type
1. 1425 Palmerston	13.70 m	45∍	100 mm	4”	Asbestos
2. 1410 Queens	18.00 m	59∍	100 mm	4”	Asbestos
3. 1380 Queens	14.50 m	48∍	100 mm	4”	Cast iron
4. 1385 Palmerston	10.00 m	33∍	100 mm	4”	Asbestos
5. 1375 Palmerston	6.50 m	21∍	100 mm	4”	Asbestos
6. 1345 Palmerston	14.10 m	46∍	100 mm	4”	Asbestos
7. 1441 Ottawa	3.10 m	10∍	100 mm	4”	Cast iron
8. 1395 Queens	17.10 m	56∍	100 mm	4”	Asbestos
9. 1435 Palmerston	15.00 m	49∍	100 mm	4”	Asbestos
10. 1415 Ottawa	20.10 m	66∍	100 mm	4”	Asbestos
11. 1395 Palmerston	10.70 m	35∍	100 mm	4”	Asbestos
12. 1375 Ottawa	22.00 m	72∍	100 mm	4”	Asbestos
13. 1455 Ottawa	12.20 m	40∍	100 mm	4”	Asbestos
14. 1340 Palmerston	31.60 m	104∍	100 mm	4”	Asbestos
15. 1415 Queens	20.10 m	66∍	100 mm	4”	Asbestos
16. 1365 Ottawa	17.70 m	58∍	100 mm	4”	Asbestos
TOTAL	246.40 m	808∍			
Min-Max	3.10-31.60 m	10-104∍			
Average	15.40 m	50.5∍			
Explanation: Relined length shown is the length of lateral between the cleanout and the house.					

A.5.5 Cost Analysis (CAN $)

Table A-20 summarizes the project cost.

Table A-20. West Vancouver, Canada, CIP Relining 2003: Cost in CAN $ Billed to Each Homeowner.

Lateral:	Mob/Demob [22]	CIP [23]			CCTV			Total [24]
1425 Palmersto	$2,800.00/LS	$160.00/m	$48.78/ft	$2,192.00	$3.0/m	$0.91/ft	$41.10	$5,115.30
1410 Queens	$2,860.00/LS	$143.00/m	$43.60/ft	$2,574.00	$3.0/m	$0.91/ft	$54.00	$5,596.00
1380 Queens	$1,930.00/LS	$143.00/m	$43.60/ft	$2,073.50	$3.0/m	$0.91/ft	$43.50	$4,134.00
1385 Palmersto	$2,800.00/LS	$180.00/m	$54.88/ft	$1,800.00	$3.0/m	$0.91/ft	$30.00	$4,690.00
1375 Palmersto	$2,200.00/LS	$153.00/m	$46.65/ft	$994.50	$3.0/m	$0.91/ft	$19.50	$3,253.00
1345 Palmersto	$1,800.00/LS	$130.00/m	$39.63/ft	$1,833.00	$3.0/m	$0.91/ft	$42.30	$3,759.90
1441 Ottawa	$2,400.00/LS	$170.00/m	$51.83/ft	$527.00	$3.0/m	$0.91/ft	$9.30	$2,954.90
1395 Queens	$1,740.00/LS	$155.00/m	$47.26/ft	$2,650.50	$3.0/m	$0.91/ft	$51.30	$4,544.40
1435 Palmersto	$2,800.00/LS	$160.00/m	$48.78/ft	$2,400.00	$3.0/m	$0.91/ft	$45.00	$5,335.00
1415 Ottawa	$3,960.00/LS	$120.00/m	$36.59/ft	$2,412.00	$3.0/m	$0.91/ft	$60.30	$6,552.90
1395 Palmersto	$2,700.00/LS	$160.00/m	$48.78/ft	$1,712.00	$3.0/m	$0.91/ft	$32.10	$4,508.30
1375 Ottawa	$2,050.00/LS	$160.00/m	$48.78/ft	$3,520.00	$3.0/m	$0.91/ft	$66.00	$5,768.00
1455 Ottawa	$2,600.00/LS	$140.00/m	$42.68/ft	$1,708.00	$3.0/m	$0.91/ft	$36.60	$4,417.80
1340 Palmersto	$3,500.00/LS	$130.00/m	$39.63/ft	$4,108.00	$3.0/m	$0.91/ft	$94.80	$7,892.40
1415 Queens	$1,800.00/LS	$140.00/m	$42.68/ft	$2,814.00	$3.0/m	$0.91/ft	$60.30	$4,794.90
1365 Ottawa	$2,050.00/LS	$160.00/m	$48.78/ft	$2,832.00	$3.0/m	$0.91/ft	$53.10	$5,041.30
TOTAL:	$39,990.00			$36,150.5			$739.20	$78,358.10
Min	$1,740.00/LS	$120.00/m	$36.59/ft	$527.00			$9.30	$2,954.90
Max	$3,960.00/LS	$180.00/m	$54.88/ft	$4,108.00			$94.80	$7,892.40
Ave	$2,499.38			$2,259.41			$46.20	$4,897.38

Table A-21. West Vancouver, Canada, CIP Relining 2003: Average Costs.

Activity	Unit Price		Quantity	Amount
Preliminary inspection				
Locating (Pre-CCTV)	$0.91/ft	$3.00/m	808’246.4 m	$739.20
Re-inspection (Re-CCTV)	$0.91/ft	$3.00/m	808’246.4 m	$739.20
Rehabilitation				
Mob/Demobilization25	$2,499/lateral		16	$39,990.00
CIP relining 26	$44.74/ft	$146.7/m	808’246.4 m	$36,150.50
Final inspection				
Post-CCTV inspection	$0.91/ft	$3.00/m	808’246.4 m	$739.20
TOTAL				$76,879.70

The cost of construction was paid in full by the municipality. West Vancouver is the city with the highest taxable income in Canada, and is considered by some the “Beverly Hills of Canada.”

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[22] *Pit excavation, cleaning, lateral reconnection, pit backfill, and surface restoration*

[23] *Liner material and installation (including control-CCTV)*

[24] *Includes pre-CCTV, re-CCTV and post-CCTV, i.e. all laterals were inspected three times!*

[25] *Depending on digging conditions $1,740.00-3,960.00*

[26] *Depending on length between $36.59/ft and $54.88/ft, or $120/m and $180/m.*

A.5.6 Project Duration

The duration of construction work related to CIP relining is shown in Table A-22. Overall, the project took 30 working days and was only a few days late. The actual working time was faster that anticipated, the relining part of the project went smoothly and there were no problems. The only challenge, this being the first project on private properties in this municipality, was to coordinate the activities between the homeowners, the municipality and the contractors. Scheduling was occasionally an issue, two homeowners resisted signing the agreement form for a while but they eventually did, some homeowners forgot that they had signed it, etc.

Table A-22. West Vancouver, Canada, CIP Relining 2003: Duration of Construction Work on Each Lateral.

Activity	Average Duration
Locating (pre-CCTV with two people)	20 min[27]
Rehabilitation	
Mobilization, cleaning and pre-CCTV, pit excavation. In-situ liner preparation (simultaneous)	2-3 hrs
Liner installation and curing, Control-CCTV (5 min)	3-4 hrs
Lateral reconnection with cleanout installation. Surface restoration and demobilization	1-1½ hrs
TOTAL— Rehabilitation	7 hrs
Post-CCTV	20 min

A.5.7 Public Relations

An open house was held prior to the construction phase to inform and educate homeowners within the study area. This open house provided the owners with a better understanding of the project along with an opportunity to meet the people involved and ask specific questions about how the rehabilitation would be carried out.

Each homeowner was asked to agree to the new connection and had to sign an agreement form giving permission to the city to have this work done (Figure A-61—Left). This was done about two months in advance. Out of 37 homeowners, 30 signed the form promptly, and an additional three sometime later when they saw the work completed on their neighbors' properties. Four homeowners did not sign at all. A reminder notice was sent to homeowners again one to five days before the work on their property (Figure A-62—Right). In this project, the city did all the paperwork and the contractor carried out the construction work.

A.5.8 Effectiveness of Rehabilitation

Continuous flow monitoring was carried out before and after rehabilitation in the pilot area, which included not only rehabilitation/replacement of upper laterals (case studies A.5 and A.6) but also replacement of all mainlines, manholes and lower laterals (within the ROW) with new material that was pressure tested. This enabled the determination of the combined effectiveness of all applied measures in reducing the I/I.

The analysis of FM data indicated that the pilot area had initially I/I of about 80,000 lphpd (liter/hour/day) and that the rehabilitation reduced the I/I to about 20,000 lphpd. For

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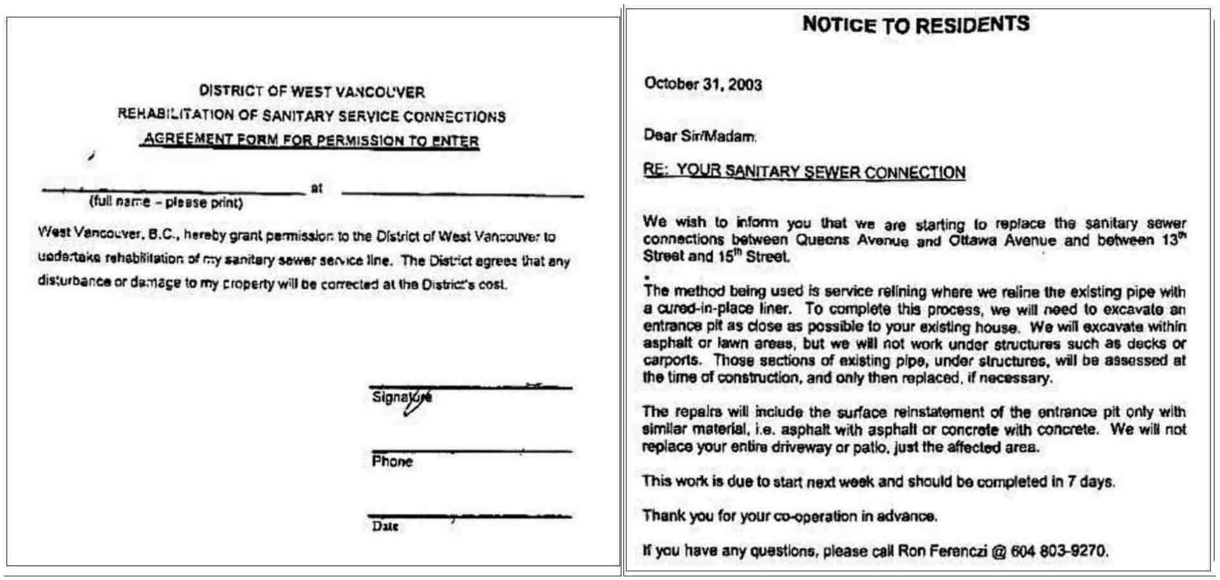
[27] *All 37 laterals were inspected at the same time, and it took two days to complete the work.*

reference, the local provincial liquid waste management plan mandates the city to reduce I/I to about 11,200 lphpd.



DISTRICT OF WEST VANCOUVER
REHABILITATION OF SANITARY SERVICE CONNECTIONS
AGREEMENT FORM FOR PERMISSION TO ENTER

______________________ at ______________________
(full name – please print)

West Vancouver, B.C., hereby grant permission to the District of West Vancouver to undertake rehabilitation of my sanitary sewer service line. The District agrees that any disturbance or damage to my property will be corrected at the District's cost.

____
Signature

____
Phone

____
Date

NOTICE TO RESIDENTS

October 31, 2003

Dear Sir/Madam:

RE: YOUR SANITARY SEWER CONNECTION

We wish to inform you that we are starting to replace the sanitary sewer connections between Queens Avenue and Ottawa Avenue and between 13th Street and 15th Street.

The method being used is service relining where we reline the existing pipe with a cured-in-place liner. To complete this process, we will need to excavate an entrance pit as close as possible to your existing house. We will excavate within asphalt or lawn areas, but we will not work under structures such as decks or carports. Those sections of existing pipe, under structures, will be assessed at the time of construction, and only then replaced, if necessary.

The repairs will include the surface reinstatement of the entrance pit only with similar material, i.e. asphalt with asphalt or concrete with concrete. We will not replace your entire driveway or patio, just the affected area.

This work is due to start next week and should be completed in 7 days.

Thank you for your co-operation in advance.

If you have any questions, please call Ron Ferenczi @ 604 803-9270.

Figure A-61. Left: Notice to the Residents. Right: Access Agreement Allowing the Crew to Enter the Private Property.

A.6 Case Study: Pipe Bursting in West Vancouver, Canada (2003)

This case study details how pipe bursting can be used for replacement of sewer laterals. This is one part of a pilot project in which approximately same number of laterals was CIP relined—A.5 in this Appendix). The whole project involved only the upper laterals because the lower laterals had already been replaced earlier.

Table A-23. Project Summary.

Objective	Replacement of laterals to achieve leak-tightness and a structurally sound sewer system
System used	**Grundotugger®** by TT Technologies (Lateral pipe bursting—static pull)
Time	Oct 6-Dec18, 2003
Location	West Vancouver, Canada
Agency	District of West Vancouver Saleem Mahmood, P. (604) 925-7027, smahmood@westvancouver.net
Contractor	PW Trenchless Inc. David O'Sullivan, P. (604) 597-0446, david@pwtrenchless.com
Soil conditions	Shallow layer of topsoil/fill on hard glacial till. Many laterals directly under a lawn, garden, retaining wall or driveway
Scope	Replaced 15 upper laterals (between the property line and the home)[28]
Procedure	a) Initial inspection and locating of all laterals (1-2 weeks prior to rehabilitation): ♦ Pre-CCTV [29] b) Rehabilitation: ♦ Mobilization (site setup) ♦ Pit excavation and removal of existing cleanouts (if applicable) ♦ Replacement pipe preparation (pipe fusing) ♦ Pipe bursting with simultaneous pull-in of the replacement pipe ♦ Reconnection of the new pipe with the lower lateral and the house. Installation of cleanouts. ♦ Surface restoration and demobilization b) After rehabilitation (2-3 weeks after the rehabilitation): ♦ Post-CCTV
QC after rehabilitation	Only CCTV inspection. No air-pressure testing or water exfiltration testing.
Financing	Paid in full by the city.
Public relations	Open house with homeowners. Notice to homeowners, agreement form
Rehab effectiveness	Continuous flow monitoring before and after sewer replacement/rehabilitation to show combined effectiveness of lateral pipe bursting and CIP relining, as well as rehabilitation of public sewers in the pilot area Dayton &Knight, Gurjit Sangha (604) 990-4800, gsangha@dayton-knight.com

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[28] *There were 37 laterals in the pilot area. An additional 16 laterals were CIP relined, 2 laterals were new and 4 laterals had no homeowner's permission to be repaired.*

[29] *The laterals were first inspected two or three years ago as part of the overall study for this pilot project.*

A.6.1 Background and Steps Preceding Lateral Rehabilitation

See A.5.

A.6.2 Construction

Mobilization. To each site, the crew brought a backhoe and the pipe bursting equipment Grundotugger® by TT Technologies (Figure A-62, Figure A-63, Figure A-64).

Figure A-62. Mini-hoe Trailed to the Site.

Figure A-63. Control Box and Hydraulic Lines.

Figure A-64. Left: Nose Cone/Splitter. Right: Winch for 4" Lateral.

Pit Excavation and Removal of Existing Cleanouts (If Applicable). For each lateral, two pits were excavated: one at the point where the service connection goes under the house and one at the cleanout on the property line (also called an inspection chamber[30]).

The pit near the house was used as an entry pit for pipe bursting (Figure A-65), and the pit at the property line as an exit pit. The mini-hoe made excavating fast. The required

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[30] *See note 21 on page A-2.*

excavation was rather small and the pits were typically 3э wide, 3-4э long and about 4э deep (Figure A-66). The pits were excavated and burst on the same day, and on average a total of two or three laterals were replaced in one day. The pits were never left open overnight. At the property line, excavating of the exit pit exposed the inspection chamber, which would be removed for the duration of pipe bursting (Figure A-67, Figure A-68).

Figure A-65. Excavating of the Entry Pit Near the House.

Figure A-66. Excavated Entry Pit.

Figure A-67. Excavating of the Exit Pit at the Property Line.

Figure A-68. Exposed Inspection Chamber.

Replacement Pipe Preparation (Pipe Fusing). The replacement pipe was an HDPE DR17 pipe of the same inside diameter 4” (100 mm). The pipe was fused using normal fusion methods. As the pipe lengths were short, i.e. about 30-50э (10-15m), they could be fused on any reasonable road shoulder. Replacement pipe was very light and would not damage the landscaping (Figure A-69).

Figure A-69. Left: Replacement Pipe Laid on the Property. Right: Replacement Pipe Laid alongside the House.

Pipe Bursting. Once the excavations were made and the cleanout removed, the exposed pipe in each pit was cut out. The winch was then lowered into the exit pit and braced with some timber behind it to spread the load prior to use (Figure A-70). Next, hydraulic lines were attached to the control box (Figure A-71).

Figure A-70. Winch in the Exit Pit.

Figure A-71. Hydraulic Lines Attached to the Control Box.

Near the entry pit, the bursting head (the nose cone-splitter) was attached on one end to the pre-cut section of HDPE pipe and on the other end to the pulling cable (Figure A-72). The cable had been strung through the existing lateral pipe thus connecting the winch and the replacement pipe (Figure A-73).

Figure A-72. Bursting Head Attached to the Replacement Pipe and the Pulling Cable Near the Entry Pit.

Figure A-73. Entry Pit Showing the Pulling Cable and Cut-off Section of the Lateral Near the House.

The bursting was done by pulling the bursting head through the existing lateral pipe. It was breaking the existing pipe apart into fragments, which were pushed into the surrounding soil. The backhoe was used to keep the winch from raising under the tension in the exit pit (Figure A-74). Once the replacement pipe was pulled in place (leaving a little extra pipe length to extend beyond the pit wall on both ends) (Figure A-75), the bursting tool was detached and the pipe cut to the correct length.

Figure A-74. Backhoe Assisting the Bursting in the Exit Pit.

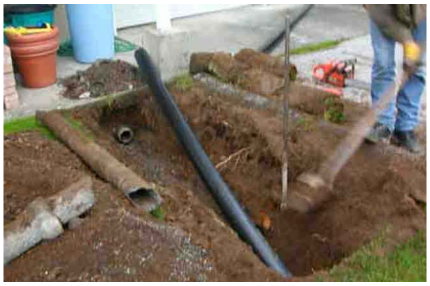

Figure A-75. Replacement Pipe Pulled in Place (Entry Pit Shown).

Reconnection of the New Pipe and Installation of Cleanouts. Once the replacement pipe was in place, the cleanout at the property line was reinstalled and a new cleanout installed near the house. The cleanouts were cut into the pipe and flexible rubber couplings were used to re-seal the pipe (Mission couplings with stainless steel shear bands shown in Figure A-76).

Figure A-76. Flexible Rubber Couplings with Stainless Steel Shear Bands.

Surface Restoration and Demobilization. See A.5.

A.6.3 Overview of Performed Work

Table A-24. West Vancouver, Canada, Pipe Bursting 2003: Overview of Performed Work.

Lateral	REPLACED Length[31]		Pipe Diameter (ID)		Pipe Type
1430 Palmerston	18.00 m	59϶	100 mm	4”	Asbestos cement
1465 Ottawa	16.50 m	54϶	100 mm	4”	Asbestos cement
1355 Palmerston	25.00 m	82϶	100 mm	4”	Cast iron
1370 Palmerston	21.00 m	69϶	100 mm	4”	Cast iron
1466 Palmerston	19.00 m	62϶	100 mm	4”	Asbestos cement
1450 Palmerston	14.00 m	46϶	100 mm	4”	Asbestos cement
1370 Queens	17.00 m	56϶	100 mm	4”	Asbestos cement
1360 Queens	20.00 m	66϶	100 mm	4”	Asbestos cement
1350 Queens	12.00 m	39϶	100 mm	4”	Asbestos cement
1390 Palmerston	20.00 m	66϶	100 mm	4”	VCP
1410 Palmerston	23.00 m	75϶	100 mm	4”	VCP
1365 Palmerston	19.00 m	62϶	100 mm	4”	VCP
1395 Ottawa	16.00 m	52϶	100 mm	4”	PVC
1385 Ottawa	20.00 m	66϶	100 mm	4”	PVC
1380 Palmerston	16.00 m	52϶	100 mm	4”	PVC
TOTAL:	276.50 m	907϶			

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[31] *Upper lateral, i.e. distance between the cleanout and home*

A.6.4 Cost Analysis (CAN $)

Table A-25. West Vancouver, Canada, Pipe Bursting 2003: Cost in CAN $Billed to Each Homeowner.

Lateral	Mob/Demob [32]	Pipe bursting [33]			CCTV			Total [34]
1430 Palmerston	$1,600.00/LS	$160.00/m	$48.78/ft	$2,880.00	$3.0/m	$0.91/ft	$54.00	$4,588.00
1465 Ottawa	$2,000.00/LS	$135.00/m	$41.16/ft	$2,227.50	$3.0/m	$0.91/ft	$49.50	$4,326.50
1355 Palmerston	$2,800.00/LS	$150.00/m	$45.73/ft	$3,750.00	$3.0/m	$0.91/ft	$75.00	$6,700.00
1370 Palmerston	$2,000.00/LS	$130.00/m	$39.63/ft	$2,730.00	$3.0/m	$0.91/ft	$63.00	$4,856.00
1466 Palmerston	$1,700.00/LS	$140.00/m	$42.68/ft	$2,660.00	$3.0/m	$0.91/ft	$57.00	$4,474.00
1450 Palmerston	$1,600.00/LS	$160.00/m	$48.78/ft	$2,240.00	$3.0/m	$0.91/ft	$42.00	$3,924.00
1370 Queens	$1,600.00/LS	$160.00/m	$48.78/ft	$2,720.00	$3.0/m	$0.91/ft	$51.00	$4,422.00
1360 Queens	$1,600.00/LS	$166.00/m	$50.61/ft	$3,320.00	$3.0/m	$0.91/ft	$60.00	$5,040.00
1350 Queens	$2,400.00/LS	$160.00/m	$48.78/ft	$1,920.00	$3.0/m	$0.91/ft	$36.00	$4,392.00
1390 Palmerston	$2,100.00/LS	$140.00/m	$42.68/ft	$2,800.00	$3.0/m	$0.91/ft	$60.00	$5,020.00
1410 Palmerston	$1,800.00/LS	$166.00/m	$50.61/ft	$3,818.00	$3.0/m	$0.91/ft	$69.00	$5,756.00
1365 Palmerston	$2,300.00/LS	$140.00/m	$42.68/ft	$2,660.00	$3.0/m	$0.91/ft	$57.00	$5,074.00
1395 Ottawa	$2,700.00/LS	$160.00/m	$48.78/ft	$2,560.00	$3.0/m	$0.91/ft	$48.00	$5,356.00
1385 Ottawa	$2,200.00/LS	$137.00/m	$41.77/ft	$2,740.00	$3.0/m	$0.91/ft	$60.00	$5,060.00
1380 Palmerston	$1,900.00/LS	$140.00/m	$42.68/ft	$2,240.00	$3.0/m	$0.91/ft	$48.00	$4,236.00
TOTAL:	$30,300.00/LS			$41,265.50			$829.50	$73,224.50
Min	$1,600.00/LS	$130.00/m	$36.63/ft	$1,920.00			$36.00	
Max	$2,800.00/LS	$166.00/m	$50.61/ft	$3,818.00			$75.00	
Ave	$2,020.00/LS			$2,751.03			$55.30	$4,881.63

Table A-26. West Vancouver, Canada, Pipe Bursting 2003: Average Costs.

Activity	Unit Price		Quantity	Amount
Preliminary inspection				
Locating (Pre-CCTV)	$0.91/ft	$3.00/m	907'276.5 m	$829.50
Pipe replacement				
· Mob/Demobilization[35]	$2,020/lateral		15	$30,300.00
· Pipe bursting [36]	$44.50/ft	$149.24/m	907'276.5 m	$41,265.50
Final inspection				
Post-CCTV inspection	$0.91/ft	$3.00/m	906.92'276.5 m	$829.50
TOTAL				$73,224.50

The cost of construction was paid in full by the municipality

A.6.5 Project Duration

The duration of construction work related to pipe bursting is shown in Table A-27. Overall, the project took 30 working days and was only a few days late. The actual working time was faster that anticipated, the bursting part of the project went smoothly and there were no problems. The only challenge, this being the first project on the private properties in this

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[32] *Pit excavation, cleaning, lateral reconnection, pit backfill, and surface restoration*

[33] *Cost of replacement pipe, fusion and bursting*

[34] *Includes pre-CCTV, re-CCTV and post-CCTV, i.e. all laterals were inspected three times!*

[35] *Depending on digging conditions $1,600-2,800*

[36] *Depending on length of bursting between $40/ft and $ 50/ft, or $130/m and $166/m.*

municipality, was to coordinate the activities between the homeowners, the municipality and the contractors. Scheduling was occasionally an issue, three homeowners resisted signing the agreement form initially but they eventually did, some homeowners forgot that they had signed it, etc.

Table A-27. West Vancouver, Canada, Pipe Bursting 2003: Duration of Construction Work on Each Lateral.

Activity	Average Duration
Locating (pre-CCTV with two people)	20 min[37]
Pipe replacement	
Mobilization, pit excavation, pipe fusing	½-2 hrs
Pipe bursting	¼ hrs
Lateral reconnection with cleanout installation. Surface restoration and demobilization	1 hrs
TOTAL— Pipe replacement	4 hrs
Post-CCTV	20 min

A.6.6 Public Relations

See A.5.

A.6.7 Effectiveness of Rehabilitation

See A.5.

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[37] *All 37 laterals were inspected at the same time, and it took two days to complete the work.*

A.7 Case Study: Pipe Bursting in Sarasota, FL (2001/02)

This is another case study in which pipe bursting was used for replacement of sewer laterals. Lateral pipes were replaced using Tric™ Trenchless system. Numerous photos showing this replacement system in action are included in Chapter 5.0 of the report and are therefore not repeated in this case study. Instead, this case study is focused on explaining how the city had evaluated different options for locating of laterals (even invented its own method) and how pipe bursting was selected as the most suitable repair option. The case study also presents detailed cost information of the project, whereas the project effectiveness in reducing I/I is discussed in Chapter 4.0.

Table A-28. Project Summary.

Objective	Replacement of laterals to achieve peak flow shaving
System used	**TRIC™ Trenchless** (Lateral pipe bursting—static pull)
Time	May 2001-May 2002
Location	Sarasota, FL
Agency	City of Sarasota, FL —Rick Ray, (941) 365-2200, Rick_Ray@sarasotagov.com
Contractor	Omni Eye, Inc—Jim Theriault, President, (941) 739-2810, omnieye@juno.com
Scope	Replaced 297 upper laterals with pipe bursting and 1 lateral with open cut
Procedure	a) Initial steps preceding lateral replacement (3-6 years earlier): ◆ Comprehensive smoke testing[38] and removal of inflow sources (1996/97) ◆ Public sewer rehabilitation (mainlines/manholes/pump stations)[39] (1997) ◆ Evaluation of lateral locating methods[40] (1997) ◆ Evaluation of lateral rehabilitation options[41] (1999) b) Concluding steps before lateral replacement (1-2 years earlier): ◆ Locating and CCTV inspection of 530 laterals, installation of cleanouts (4” Inserta Tee) (2000/01) c) Lateral replacement: ◆ Excavation of access pits ◆ Pipe bursting ◆ Installation of 719 cleanouts (4” and 6” double-sweep Tees) and reconnection ◆ Surface restoration
QC after rehabilitation	Only CCTV inspection. No air-pressure testing or water exfiltration testing.
Financing	Paid in full by the city.
Public relations	Open house with homeowners. Notice to homeowners, Agreement form.
Rehab effectiveness	Continuous flow monitoring at the pump stations to compare peak flows at extreme wet weather conditions before and after the rehabilitation.

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[38] *Done on 100% mainlines, manholes and laterals*

[39] *1,420э mainline open-cut replaced with PVC; 2,451э CIPP, Deform/Reform; 5 point repairs; 19 manholes (Super-Coat)*

[40] *Ground Penetrating Radar (GPR) and CCTV with lateral launcher tested on same 65 laterals*

[41] *CIPP for lateral relining*

A.7.1 Background

The whole project involved only the upper laterals because the objective was to shave off the peak flows in the sewer system that occur during extreme wet weather conditions. Some of the lower laterals (public sewer) had already been repaired before but most would be addressed in the future phase of rehabilitation.

In Sarasota, the length of the lower lateral (between the property line and the mainline) is typically 30э. The current practice requires cleanouts near the house and at every 75э along the lateral. In most cases, this means one cleanout near the house and the other at the property line. The length of upper lateral was between 20э and 230э, and on average 64э. Before the lateral replacement project, however, the cleanouts existed only near the houses, and a large number of new cleanouts was installed in the course of project.

A.7.2 Steps Preceding Lateral Replacement (3-6 Years Earlier)

Evaluation of Lateral Locating Methods. A few years before this project in 1997, selected methods for lateral locating were tested in one area for applicability and effectiveness:

- Mini-CCTV camera (by a German manufacturer Rausch) was tried in one lateral first but unsuccessfully. The camera was mounted on a full size mainline CCTV camera and launched from the mainline into the lateral, however it got stuck halfway because of sand and debris in the lateral.
- Ground penetrating radar (GPR) was the second method tried. It was successful in locating 52 laterals.
- The third method used a cleaning hose/nozzle with sonde attached, combined with lateral launcher—an original design developed within the municipality (Figure A-77). A sonde was attached with a tape to a regular cleaning hose (1-1½”, 50-60’ long) and inserted into the mainline through the nearest manhole. A specially shaped plastic form was positioned in the mainline near the lateral opening (pulled in place with a cable). The CCTV camera was positioned in the mainline just past the lateral opening to monitor the operation. As the water in the hose was turned on, it created a pressure and the whole assembly would move forward and up the lateral.

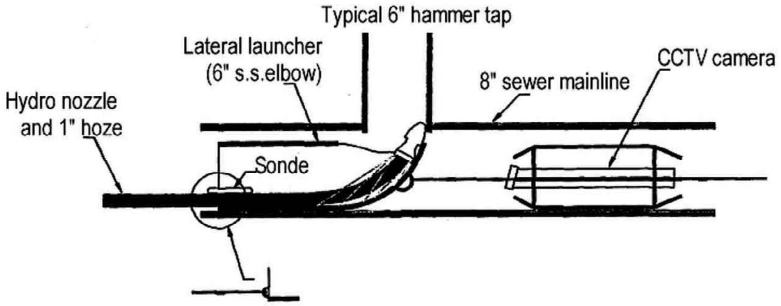


Figure A-77. Cleaning Hose/Nozzle with Sonde Attached Combined with Lateral Launcher.

The third method had advantage over the lateral CCTV because the water from the hose was cleaning the sand in pipe and allowing the unit to pass through. The method located 65 laterals in the same area that the GPR was tested. This means that GPR was effective in locating 80% of existing laterals. The depth of pipes did not exceed 6э and was not a limiting factor, however, the presence of groundwater was held responsible for the GPR missing some laterals (the signal dissipates more quickly in the more conductive wet soil and hence the reflections from buried objects are weaker). If the groundwater were below the lateral pipe, the GPR may also have been 100% effective.

Installation of Cleanouts on the Property Line on All Laterals Located in this Phase. On 65 laterals identified with the cleaning hose/nozzle with sonde, a new cleanout was installed (Figure A-78). A stake was placed at the property line and the sod was removed at the location of the stake. Next, a hydro-vacuum excavating process was applied. The soil was cut with a water jet and vacuumed out with a 6” tube (connected to the vacuum truck). The pit size was about 2э×3э. It took on average 60 minutes to complete one pit. While the pit was open, a mini CCTV camera, which was mounted on a rod, was hand pushed through both the upper lateral and the lower lateral (Figure A-79). After inspection, a cleanout (4” Inserta Tee®) was installed in each pit and the surface was restored (Figure A-80).

Figure A-78. Installation of Cleanouts at the Property Line. Left: Sod Removal. Right: Pit Hydro Excavating.

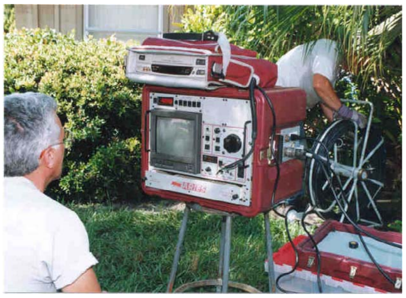


Figure A-79. CCTV Inspection of Laterals from the Pit at the Property Line.

Figure A-80. Cleanout Installed in the Pit.

Condition Assessment of Lateral Pipes. Based on the pipe inspection of a sample of the laterals (10% of all existing laterals in the area), the condition assessment of pipes was made and extrapolated to all laterals in the area (Table A-29). The decision was reached to rehabilitate all pipes that were failing or were going to fail in the immediate future, i.e. all except the PVC pipes.

Table A-29. Sarasota, FL, 1997: Condition Assessment of Pipe.

Pipe type	Estimated	Condition
Cast iron	52%	Pipes had severe mineral buildup over time, which reduced their hydraulic capacity from 4” to 2” pipes. These pipes have reached the end of their life (40 years) and would continue to decay.
Orangeburg	6%	All pipes had failed.
VCP	19%	All old 3϶ and 4϶ joint pipes were leaking and others would continue to fail due to root intrusion.
PVC	23%	These pipes were new and in good condition.

Evaluation of Lateral Rehabilitation Options. In the next step, several lateral rehabilitation options were evaluated for applicability and cost:

- Open cut—this method was not seriously considered because of existing landscaping on the private properties. The restoration would have been very costly.
- CIP relining—this method was considered and field tested on three laterals. The liners (Textron) were blind-shot from the property line to the mainline. The length of relining was between 35-60϶, and the laterals were 6” in diameter. The method was mainly rejected because of the inadequate hydraulic capacity of many existing pipes. Although the relining would work in VCP pipes, it would not be effective in cast iron pipes. It would also not work in the Orangeburg pipes, which simply disintegrate over time.
- Pipe bursting—this methods was considered a good option because it would restore the lost hydraulic capacity of pipes and provide a long lasting solution. Two systems were tested on one lateral, which was 4” in diameter and 150϶ long, and went under a driveway, sidewalks and huge tropical trees, and was filled with roots. Pneumatic bursting proceeded for 4϶ and then stopped. Due to vibrations in the soil with high groundwater level, the soil was liquefied to the point where the borehole stability was lost and the bursting tool became stuck. A static pull was attempted next on the same lateral and it pulled through successfully. Thus, static pull was selected as the method of rehabilitation.

A.7.3 Final Steps Before Lateral Replacement (1-2 Years Earlier)

Locating and CCTV Inspection of Remaining Laterals. In this phase, the laterals were systematically located using the CCTV with lateral launcher. A total of 530 new laterals were located and their exact layout identified.

The recording technique was improved from what had been practiced three years earlier (Figure A-81) and a more accurate and complete set of records was made (Figure A-82). A 3/4” rope was laid on the ground following the path of the lateral as determined by the sonde during the video operation. The rope was digitally photographed as an additional record of the path of the sewer lateral. The lateral layout was recorded from the mainline to the building roof drip line (2-3϶ from the building foundation). Also, exact measurements were made of the property corners, trees and other objects on the property.

While the pits were open, new cleanouts were installed. As before, the pits were hydro vacuum excavated. In each pit on the property line, a new 4" double sweep Tee (a two-way Tee) was installed as the base for the cleanout.

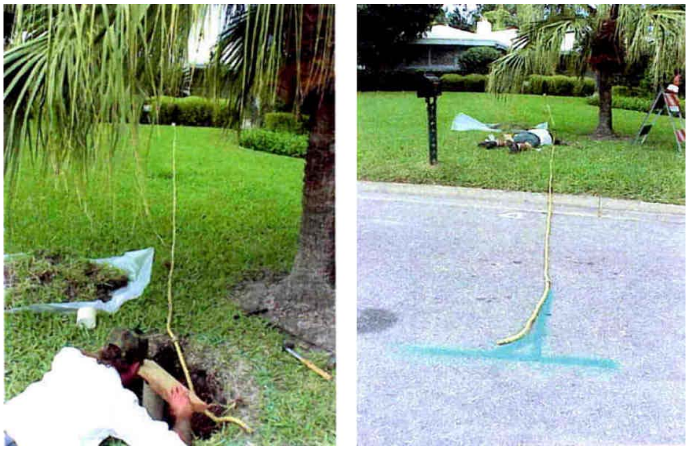
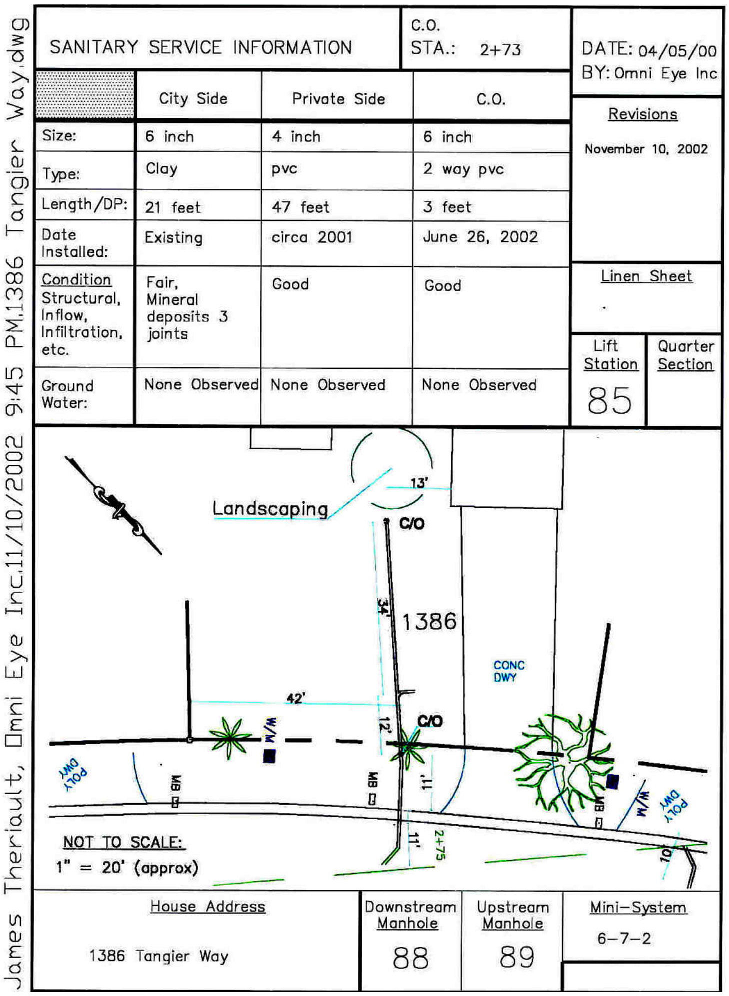


Figure A-81. Improved Recording Technique During Locating of Laterals. Left: Lateral Marking Rope Laid on the Ground. Right: Rope Extending from the Mainline.



James Theriault, Omni Eye Inc.11/10/2002 9:45 PM.1386 Tangier Way.dwg

SANITARY SERVICE INFORMATION

C.O. STA.: 2+73

DATE: 04/05/00
BY: Omni Eye Inc

	City Side	Private Side	C.O.
Size:	6 inch	4 inch	6 inch
Type:	Clay	pvc	2 way pvc
Length/DP:	21 feet	47 feet	3 feet
Date Installed:	Existing	circa 2001	June 26, 2002
Condition Structural, Inflow, Infiltration, etc.	Fair, Mineral deposits 3 joints	Good	Good
Ground Water:	None Observed	None Observed	None Observed

Revisions
November 10, 2002

Linen Sheet

Lift Station
85

Quarter Section

NOT TO SCALE:
1" = 20' (approx)

House Address
1386 Tangier Way

Downstream Manhole
88

Upstream Manhole
89

Mini–System
6–7–2

Figure A-82. Example of Agency Records of Lateral Location.

A.7.4 Construction

This paragraph provides very few construction details trying to avoid repeating details and information already presented in Chapter 5.0 and the other pipe bursting case study.

Replacement Pipe. The replacement pipe was a white 4” SDR 17 HDPE pipe supplied on 800э reels (Figure A-83). The white color would enhance future video inspections, and the length greatly reduced the need for onsite pipe fusion.

Figure A-83. Replacement Pipe. Left: Delivery to Site. Right: Handling the Pipe.

Pits. For each pipe bursting operation a small pit was excavated at the property line (Figure A-84) and another one where the sewer lateral enters the house. As explained before, vacuum excavation was used to open the pits.

Figure A-84. Excavated Pit.

The Pull. The contractor used small, modular equipment manufactured by Tric Tools, Inc. to install the new lateral lines (Figure A-85).

Figure A-85. Small Hydraulic Puller by Tric Tools, Inc.

The small hydraulic puller was able to generate up to 60,000 pounds of pulling force. A diesel-powered Vermeer high-pressure pump supplied hydraulic power to the puller. Once the pull began, the new HDPE pipe was pulled into place at 5-10’ per minute.

Cleanouts. During lateral replacement, cleanouts were installed every 75э to comply with city codes. For laterals over 75’ long, pits were sometimes dug for extra cleanouts, and the new pipe was pulled from one pit to the next. At other times, the entire length of the new line was pulled first and the cleanouts were installed later. Cleanouts installed were 4” or 6” double-sweep Tees (Figure A-86).

Figure A-86. A Two-Way Tee and Cleanout Assembly.

A.7.5 Overview of Performed Work and Cost Analysis

The project involved replacement of 297 laterals with pipe bursting and installation of 719 cleanouts. A summary of project costs is shown in Table A-30. The City of Sarasota paid for the total cost of the pilot program and the homeowners were not responsible for any payments. Additional cost information is provided in Table A-31.

Table A-30. Sarasota, FL, 2001-2002: Summary of Project Costs.

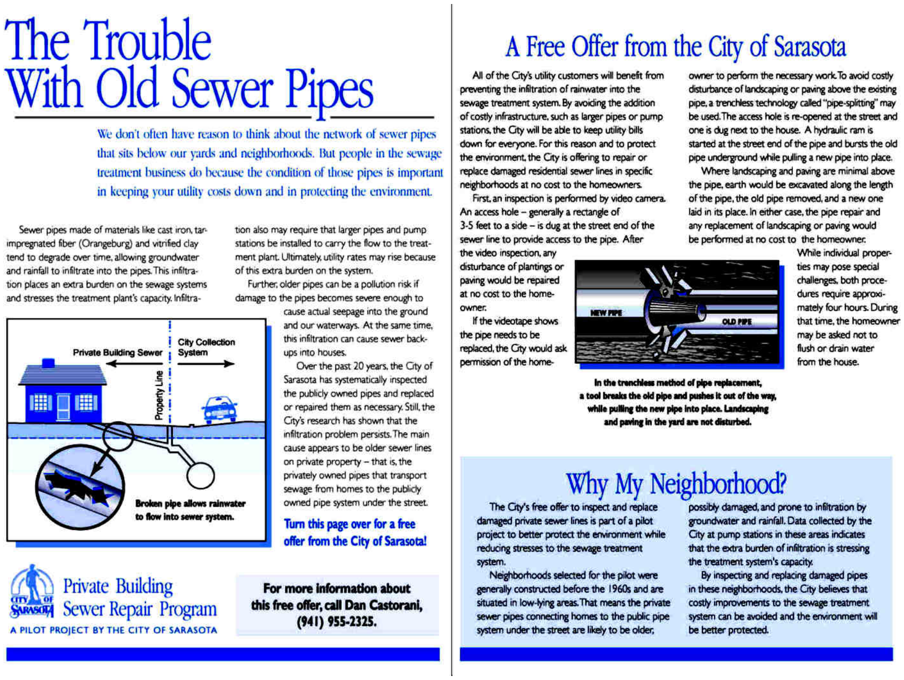
	Unit:	Unit Price	Quantity:	Amount	Average
Mobilization	LS	$ 32,400.00	1	$ 32,400.00	
Maintenance of Traffic	LS	$ 6,074.08	1	$ 6,074.08	
Utility Notification	LS	$ 1,012.36	1	$ 1,012.36	
Audio-Video Pre-Construction Record	LS	$ 3,037.04	1	$ 3,037.04	
4” Concrete Restoration	SY	$ 50.00	131.50	$ 6,575.00	
6” Concrete Restoration	SY	$ 60.00	295.41	$ 17,724.60	
Vacuum Excavation (L.S.#5)(0-3.9э Depth)	Each	$ 750.00	139	$ 104,250.00	
Vacuum Excavation (L.S.#5)(4-7э Depth)	Each	$ 1,000.00	55	$ 55,000.00	
Vacuum Excavation (L.S.#1)(0-3.9э Depth)	Each	$ 100.00	588	$ 58,800.00	
Vacuum Excavation (L.S.#1)(4-7э Depth)	Each	$ 558.00	73	$ 40,734.00	
Rehabilitation Equipment Setup	Each	$ 300.00	398	$ 119,400.00	
4” HDPE Building Sewer Pipe	ft	$ 4.00	19,204.00	$ 76,816.00	
6” HDPE Building Sewer Pipe	ft	$ 14.00	270.00	$ 3,780.00	
6” 2-way Tee & Clean-out Assembly, Installed	Each	$ 300.00	208	$ 62,400.00	
4” 2-way Tee & Clean-out Assembly, Installed	Each	$ 200.00	511	$ 102,200.00	
Shallow Point Repair (0-5э Deep)	Each	$ 500.00	40	$ 20,000.00	
Sanitary Service Information Documentation	LS	$ 16,200.00	1	$ 16,200.00	
Open cut replacement 55э	LS	$ 1,122.00	1	$ 1,122.00	
TOTAL:			297 laterals	$ 727,525.08	$2,449.58/lateral

Table A-31. Sarasota, FL, 1996-2002: Additional Cost Information.

Year	Activity		Unit Price
1996-97	Smoke testing	$	0.25/ft
1996-97	Removal of inflow sources	$	0.25/ft
1997	GPR	$	97.00/lateral
1999	CIP (Textron)	$	67.00/ft
1991	CIP (literature review, Nashville, TN)	$	80.00/ft
2000	Lateral launcher locating	$	421.00/lateral

A.7.6 Public Relations

The city worked diligently on informing the public about the upcoming project. One of the tasks was preparing a brochure, which explained the nature of the problem and how the pipe bursting of laterals would provide the solution (Figure A-87). The city and the contractor also gave presentation about the Private House Sewer Rehabilitation Pilot Project to homeowners and answered their questions (Figure A-88).



The Trouble With Old Sewer Pipes

We don't often have reason to think about the network of sewer pipes that sits below our yards and neighborhoods. But people in the sewage treatment business do because the condition of those pipes is important in keeping your utility costs down and in protecting the environment.

Sewer pipes made of materials like cast iron, tar-impregnated fiber (Orangeburg) and vitrified clay tend to degrade over time, allowing groundwater and rainfall to infiltrate into the pipes. This infiltration places an extra burden on the sewage systems and stresses the treatment plant's capacity. Infiltration also may require that larger pipes and pump stations be installed to carry the flow to the treatment plant. Ultimately, utility rates may rise because of this extra burden on the system.

Further, older pipes can be a pollution risk if damage to the pipes becomes severe enough to cause actual seepage into the ground and our waterways. At the same time, this infiltration can cause sewer back-ups into houses.

Over the past 20 years, the City of Sarasota has systematically inspected the publicly owned pipes and replaced or repaired them as necessary. Still, the City's research has shown that the infiltration problem persists. The main cause appears to be older sewer lines on private property – that is, the privately owned pipes that transport sewage from homes to the publicly owned pipe system under the street.

Turn this page over for a free offer from the City of Sarasota!

CITY OF SARASOTA Private Building Sewer Repair Program
A PILOT PROJECT BY THE CITY OF SARASOTA

For more information about this free offer, call Dan Castorani, (941) 955-2325.

A Free Offer from the City of Sarasota

All of the City's utility customers will benefit from preventing the infiltration of rainwater into the sewage treatment system. By avoiding the addition of costly infrastructure, such as larger pipes or pump stations, the City will be able to keep utility bills down for everyone. For this reason and to protect the environment, the City is offering to repair or replace damaged residential sewer lines in specific neighborhoods at no cost to the homeowners.

First, an inspection is performed by video camera. An access hole – generally a rectangle of 3-5 feet to a side – is dug at the street end of the sewer line to provide access to the pipe. After the video inspection, any disturbance of plantings or paving would be repaired at no cost to the homeowner.

If the videotape shows the pipe needs to be replaced, the City would ask permission of the homeowner to perform the necessary work. To avoid costly disturbance of landscaping or paving above the existing pipe, a trenchless technology called "pipe-splitting" may be used. The access hole is re-opened at the street and one is dug next to the house. A hydraulic ram is started at the street end of the pipe and bursts the old pipe underground while pulling a new pipe into place.

Where landscaping and paving are minimal above the pipe, earth would be excavated along the length of the pipe, the old pipe removed, and a new one laid in its place. In either case, the pipe repair and any replacement of landscaping or paving would be performed at no cost to the homeowner.

While individual properties may pose special challenges, both procedures require approximately four hours. During that time, the homeowner may be asked not to flush or drain water from the house.

In the trenchless method of pipe replacement, a tool breaks the old pipe and pushes it out of the way, while pulling the new pipe into place. Landscaping and paving in the yard are not disturbed.

Why My Neighborhood?

The City's free offer to inspect and replace damaged private sewer lines is part of a pilot project to better protect the environment while reducing stresses to the sewage treatment system.

Neighborhoods selected for the pilot were generally constructed before the 1960s and are situated in low-lying areas. That means the private sewer pipes connecting homes to the public pipe system under the street are likely to be older, possibly damaged, and prone to infiltration by groundwater and rainfall. Data collected by the City at pump stations in these areas indicates that the extra burden of infiltration is stressing the treatment system's capacity.

By inspecting and replacing damaged pipes in these neighborhoods, the City believes that costly improvements to the sewage treatment system can be avoided and the environment will be better protected.

Figure A-87. Brochure Explaining the Project to Homeowners.

The City's Free Offer Includes

- Install clean-out in public right-of-way
- Video inspection of building sewer
- Repair or replace building sewer as needed
- Restore property to original conditions, or better

What We Need from You

- Minimize use of water during video inspection (typically less than 2 hrs)
- Signed agreement (if repairs are required)
- Minimize use of water during construction, if repairs are required (typically less than 4 hrs)

What Happens Next

- The next time you will hear from us will be between January and June next year
- Door hanger - notice of inspection activities

Figure A-88. Slides from the Presentation Shown to Homeowners.

A.8 Case Study: Flood Grouting in Lafayette, LA (2003)

This case study gives details of how flood grouting can be performed to seal mainlines, laterals and manholes. The City of Lafayette wanted to try this method and evaluate if it would be as a cost-effective rehabilitation option for stopping infiltration in the city.

Table A-32. Project Summary.

Objective	Sealing (non-structural repair) of manholes, mainlines and laterals to achieve leak-tightness
System used	**Sanipor**® (Flood grouting)
Time	Apr 7-16, 2003
Location	Lafayette, LA
Agency	Lafayette Utilities System (LUS) Steve Rainey (337) 291-5751, srainey@lus.org
Contractor	Insituform Technologies Inc (ITI) and Sanipor Csilla Pall, Sanipor@t-online.de
Soil conditions	Fluvial mud and silty clay from the Mississippi delta
Scope	Sealed 26 whole[42] laterals, together with 5 mainline sections and 7 manholes[43]
Procedure	a) Preliminary inspection and preparation work (2 months prior to rehabilitation) ◆ Mainline CCTV inspection ◆ Installation of cleanouts near the houses b) Sanipor® installation on each section ◆ Mobilization (site setup) ◆ Cleaning of pipes and manholes ◆ Plugging and initial water exfiltration test[44] ◆ Flooding with two proprietary solutions S-1 and S-2 ◆ Demobilization b) After rehabilitation (2-3 weeks after the rehabilitation): ◆ Post-CCTV
QC after rehabilitation	Fluid exfiltration testing ("before" and "after" the rehabilitation)
Financing	Paid by the agency. Portion of total job cost applicable to laterals determined from proportion in volume of rehabilitated laterals vs. rehabilitated mainlines, manholes and laterals[45]
Public relations	Letter to homeowners and authorization form for entering the private property
Rehab effectiveness	No flow monitoring[46]

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[42] *From the mainline to the cleanout near the house or the lateral's dead end*

[43] *Sealing was done in 10 sections of sewer system, each consisting of a varied number of mainline segments, manholes and laterals. The total sealed was 5 mainlines (1,473∋ of 8∀ VCP), 7 manholes (36∀ and 48∀ brick, 7∋ deep on average), and 24 active and 2 inactive laterals (1,752∋ of 4∀ and 6∀, mainly VCP and partly PVC). The laterals were 30- 120∋ long.*

[44] *In the future, the City will carry this out well before selecting the project.*

[45] *Cost of lateral rehabilitation is an integral part of the total job cost*

[46] *"Before" and "after" flow monitoring will be done in the future.*

A.8.1 Background

Lafayette has serious problems with I/I especially in areas with clay and concrete pipes. The pipes are structurally sound but heavy rains cause infiltration through joints, lateral connections to mainlines, gaps in brick manholes, and cracks in concrete manholes. Based on sewer system inspection (mostly smoke testing, dye testing, and mainline CCTV throughout the system) over the years, sewer laterals are also recognized as a severe source of infiltration. The agency wanted to try a new method of simultaneous sealing of all parts of the pipe system (laterals, manholes and mainlines) in one operation. Sanipor® was selected for evaluation as a potentially cost-effective trenchless rehabilitation option for stopping infiltration in Lafayette.

A.8.2 Selection of Sections Within the Sewer System for Rehabilitation

The pipes selected for rehabilitation were in the residential neighborhood of Lafayette. The pictures in Figure A-89 show that the subdivision had a flat topography.

Figure A-89. Pictures Showing the Neighborhood Selected for Rehabilitation.

The project was designed to isolate flow in five sewer system sections and rehabilitate them by the flood-and-grout method. Flow isolation would be done by inserting plugs in mainlines where they connect to manholes and in laterals at cleanouts near houses. Before the project, there were no such cleanouts and they were installed as close to the houses as possible. The sections chosen for flooding varied in the number of components—depending on the volume to be filled and the grade of infiltration in the manhole (Figure A-90, Table A-33). For efficiency, the sections that include only one manhole were first scheduled for sealing, the sections with one or more laterals were next, and the last were the sections with a mainline.

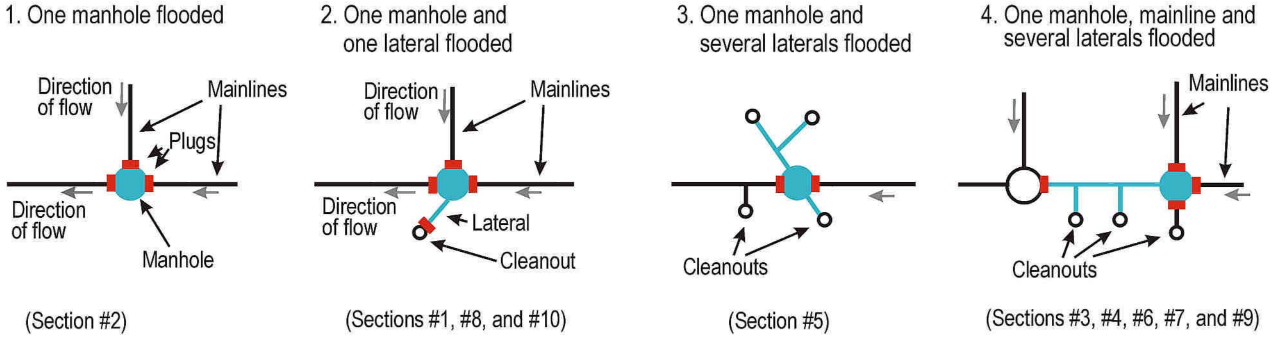

Figure A-90. Types of Plugged Sections with Position of Plugs.

Table A-33. Lafayette, LA, 2003: Sections Selected for Rehabilitation

Section	Street	Mainlines		Manholes		Laterals		
#1	Robert Lee/Ophelia	0		1	(MH 1257)	1	(CO 304 to MH 1257)	Active
#2	Robert Lee/Billeaud	0		1	(MH 1252)	0		-
#3	Robert Lee	1	(MH 1257 to MH 1252)	1	(MH 1257)	2	(CO 302 to main) (CO 300 to main) (CO 304 to main)	Active Active Inactive
#4	Robert Lee	1	(MH 1260 to MH 1257)	1	(MH 1260)	2	(CO 500 to MH 1260) (CO 402 to main) (CO 400 to main)	Inactive Active Active
#5	Ophelia	0		1	(MH 1258)	3	(CO 110 to lateral—from CO 112) (CO 112 to MH 1258) (CO 111 to MH 1258)	Active Active Active
#6	Ophelia	1	(MH 1258 to MH 1257)	1	(MH 1258)	4	(CO 113 to main) (CO 115 to main) (CO 114 to main) (CO 116 to lateral—from CO 114) (CO 117 to main)	Active Active Active Active Active
#7	Beverly	1	(MH 2987 to MH 2986)	1	(MH 2987)	6	(CO 510 to MH 2987) (CO 511 to MH 2987) (CO 513 to main) (CO 512 to main) (CO 514 to main) (CO 515 to main)	Active Active Active Active Active Active
#8	Beverly			1	(MH 2986)	1	(CO 517 to MH 2986)	Active
#9	Beverly	1	(MH 2993 to MH 2992)	1	(MH 2993)	4	(CO 607 to MH 2993) (CO 607b to MH 2993) (CO 602 to main) (CO 604 to main) (Dead End—CO 605 to main)	Active Active Active Active Inactive
#10	Beverly/Primerose	0		1	(MH 1260)	1	(CO 500 to MH 1260	Active
TOTAL:		1		10		24		

A.8.3 Initial Sewer System Inspection and Preparation Work

Mainline CCTV Inspection. The preliminary CCTV inspection was limited to mainlines, which were televised to ensure that the lines were in good shape and had little or no sags. The CCTV was done after the lines were cleaned from roots, grease, debris and sewage, so that the camera could freely pass through the pipes. Laterals were CCTV inspected later when the Sanipor work began, one by one, in order to identify sags, roots, cracks or other potential hindrance for the process.

Installation of Cleanouts. In Lafayette, the distance between the mainline and the property line is typically 10-20' on the short side, and 40-60' on the long side. Before the rehabilitation, there was only one cleanout at the property line. At this time, new cleanouts near the house were installed on each lateral, by open cut construction (Figure A-91). The length of laterals between the new cleanouts and the mainline or manhole was between 20-120'.

Some laterals were over 3' deep and guessing where exactly to place the cleanout was difficult, making this the most time consuming task. In addition, three homes had two laterals that connected into a single lateral at some distance from the house. Without prior CCTV, this was not known ahead of time and thus only one cleanout was installed at each of these addresses instead of two. The municipality is now considering hiring a private company for televising and locating the laterals, where the roof vents or toilets will be used as an access point for the camera into the laterals.

Figure A-91. Newly Installed Cleanout Close to the House.

The installed cleanouts had a two-way access to allow plug insertion downstream or upstream from the cleanout.

A.8.4 Construction

Mobilization (Site Setup). To each site, the crew brought the following equipment: a jetting truck, a CCTV truck, buckets for filling the cleanouts with water, pneumatic plugs, a three-chamber tanker with the two solutions (S-1 and S-2), two hoses, and two separate pumps. Figure A-92 shows typical site setup. At the beginning of project, the contractor did not have the proper pumps for a quick and thorough pumping out of the solutions and therefore not all the chemicals could be recovered out of the manhole, which caused serious delays.

Figure A-92. Typical Site Setup Showing Tanker in the Background and Truck with Equipment in the Front.

Cleaning. Manholes and pipes were again cleaned shortly before each start of Sanipor work to insure that the chemicals used for sealing would not be contaminated by the sewage. A 300-gallon trailer flusher was used for water jetting (Figure A-93).

Figure A-93. Jetting Truck.

Plugging and Initial Water Exfiltration Test. For plugging the lines, 4∀ and 6∀ plugs were used in the laterals, and 8∀ plugs in the mainlines. For the water exfiltration test, the plugged sections were completely flooded to the top of manholes, and the loss of water in 5-minute intervals was measured in the manholes.

The water exfiltration test provided a quantitative order-of-magnitude of the leakage of the chosen section. The amount of exfiltrating water could be compared with the achieved tightness of the pipe system after the Sanipor treatment. Generally, when infiltration is not visible on the CCTV camera, the water exfiltration test is a means of providing reliable data about the leakage in an apparently good sewer system.

Figure A-94. Buckets Were Used for Adding the Water from a Nearby Hydrant Through the Cleanouts[47].

Flooding with Two Sanipor® Solutions. After plugging the sections, the Sanipor process was performed in four steps (Figure A-95).

- The section was completely filled with the solution S-1 from its tanker, i.e. the liquid level in the manhole was brought up to the street level. This created the necessary hydrostatic head for the injection of S-1 through the defects into the soil. While the level of S-1 was gradually sinking, the liquid was being refilled (once or several times) up to street level in order to maintain the hydrostatic head required for exfiltration.
- After a certain time, S-1 was pumped out completely and all pipes flushed with water (the laterals were flushed with the help of buckets and the mainline with a quick interim flush of water with the jetting truck).

---

[47] *Buckets of water were also used in the next step, i.e. during the Sanipor installation to flush the remaining chemicals out of the pipes at the end of each flooding.*

- Next, the section was completely filled with the solution S-2 from its tanker in the same manner as previously with the solution S-1. In the soil, two components reacted with each other and the soil particles, stabilizing the soil and creating a watertight isolation layer around the leaks.
- After a certain time, S-2 was pumped out completely and all pipes flushed with water.

A three-chamber tanker was used to transport S-1 and S-2 to site (Figure A-96). Each chemical component had its own hose in order to avoid mixing and polluting S-1 and S-2 with each other (Figure A-97).

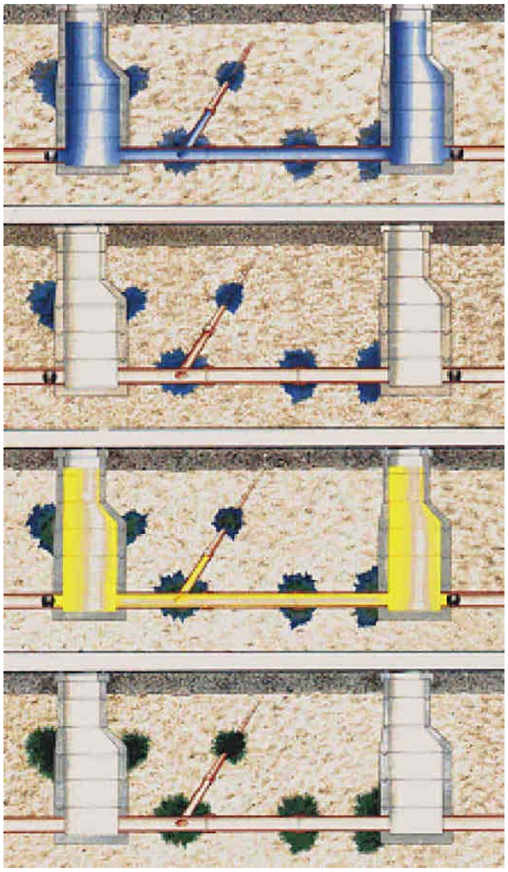

Figure A-95. Four Steps in Flood Grouting Procedure.

Figure A-96. Three-chamber Tanker for Transporting the Chemicals.

Figure A-97. Hoses for Pumping the Chemicals.

Strong and reliable pumps have a very important role in the Sanipor technology (Figure A-98). Having no vacuum pumps on the tankers, two separate pumps were used to pump out the large volumes of the sealing liquids from the sewer sections/manholes (circa 2,000-3,000 gal each).

Figure A-98. Pumps.

Duration of Flooding. The flooding procedure using both components was performed in cycles (one, two or three cycles, as shown in Chapter 8.0). The flooding with either solution within the cycle was typically between 25-40 minutes. During this time, the level of solution in the manhole was decreasing and the system was periodically refilled. At the end of the final cycle, the level of S-2 in the manhole stabilized, and thus the leak tightness was visually confirmed. The drop of solution S-2 level in the manhole was measured with the help of a wooden stick and a folding rule (Figure A-99).

Figure A-99. Manhole Filled with Solution to the Ground Surface.

Loss of Solution. The loss of solution[48] due to sealing was determined after completing each section by calculating the remaining quantity of each solution in the truck. A centrifugal pump was used to pump the unused solution out from the invert and return it into the truck to be reused. A calibrated rod was inserted into the tanker from the opening on the top and the level of solution in the tanker was measured[49]. The centrifugal pump did not pump the solution S-2 out as well as it handled the solution S-1, and thus some of solution S-2 was lost for reuse.

Surface Exfiltration. In several locations, the Sanipor solution reached the surface appearing on the pavement or on the grass (Figure A-100). Surface exfiltration happened because there were channels in the soil (from rainwater draining over time) that extended from rather shallow mainline pipes. These channels were filled and sealed with Sanipor as well. The white stains on the grass show where the Sanipor Silicate gel has formed.

Figure A-100. Left: Exfiltration onto the Pavement (Section #7). Right: Surface Exfiltration onto the Grass (Section #9).

Manhole Sealing. One brick manhole (MH 1252) close to a hydrant was badly leaking whenever the hydrant was opened (section #2). The water was pouring through all gaps between the bricks into the manhole. All gaps in the manhole were successfully sealed with one cycle. White stains in Figure A-101 (MH 1252) show the product of reaction between S-1 (draining from the soil back into the manhole) and S-2 (being filled into the manhole). Five days after the Sanipor sealing, a test was made by opening the nearby hydrant and flooding the surface surrounding the manhole. No infiltration was visible in the manhole anymore.

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[48] *Both solutions exfiltrate into the surrounding soil through cracks and other defects in the pipe and manhole walls. Used quantities are referred to as the "loss of solution" and they depend on the volume of voids in the ground to be filled. Although the loss of solution varies from one section to another, the typical value (order of magnitude) in one project is visible after completing several sections. The loss of solution is important for determining the costs.*

[49] *In Germany, a volume meter is typically installed on the tanker, which gives the loss of solution every day (at least an order of magnitude). Another option to determine the loss of solution is by measuring the weight of tanker before the job (morning) and after (evening). From the weight difference and the specific gravity of each solution, the daily loss of each is calculated. A problem occurs when it rains because the rainwater collects on the surface of big tankers. This distorts the results of weight measurement, adding the weight of water to the net weight of S-1 and S-2 in the tankers.*

Figure A-101. Sealed Gaps on the Manhole Wall (Section #2).

Demobilization. When leak tightness was observed in the manhole, the S-2 component was pumped out of the whole system through the manhole. A last jetting of the main and manhole and a flush of water with buckets at the end of each lateral removed the remaining liquids from the pipes. All plugs were removed from the mainlines and the laterals, and the cleaned sewer section was recommissioned for normal use. The equipment was transported back with the tankers to the working base.

A.8.5 Overview of Performed Work

The following table gives the summary of performed work.

Table A-34. Lafayette, LA, 2003: Overview of Performed Work.

Section	Mainlines				Manholes				Laterals	
	Number		Length	Diameter/Type	Number		Diameter	Depth	Number	Length
#1	0	-	-	-	1	(MH 1257)	48”	8’ 2”	1	27∍
#2	0	-	-	-	1	(MH 1252)	48”	8’ 2”	0	-
#3	1	(MH 1257 to MH 1252)	298.5∍	8” VCP	0	(~~MH 1257~~)	~~48~~”	~~8’ 2~~”	2	44∍
#4	1	(MH 1260 to MH 1257)	254.7∍	8” VCP	1	(MH 1260)	48”	7’ 4”	2	80∍
#5	0	-	-	-	1	(MH 1258)	36”	8’ 0”	3	288∍
#6	1	(MH 1258 to MH 1257)	259.0∍	8” VCP	0	(~~MH 1258~~)	~~36~~”	~~8’ 0~~”	4	269∍
#7	1	(MH 2987 to MH 2986)	293.9∍	8” VCP	1	(MH 2987)	36”	6’ 4”	6	567∍
#8	0	-	-	-	1	(MH 2986)	48”	7’ 10”	1	70∍
#9	1	(MH 2993 to MH 2992)	266.7∍	8” VCP	1	(MH 2993)	36”	7’ 7”	4	320∍
#10	0	-	-	-	0	(~~MH 1260~~)	~~48~~”	~~7’ 4~~”	1	30∍
TOTAL:	5		1,372.8∍		7				24	1,695∍

Explanations: Crossed manholes were sealed as part of some sections rehabilitated earlier (in this project).
Individual laterals were 30-120∍ long.

A.8.6 Quality Control

As test of reliability and performance of the installed product, a water exfiltration test was performed on sections before the rehabilitation and compared with exfiltration of the remaining Sanipor solution in the closing stages of the rehabilitation. The water exfiltration test “after” was not done because the Sanipor solution (S-2) behaves like water.

All manholes but one in this project have dimensions as shown in Figure A-102. Only the manhole MH 2992 has the cone very shallow (approx 6”) and the full diameter of 4э goes almost to the surface.

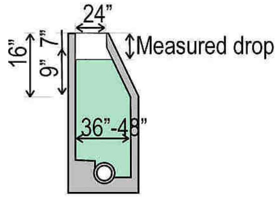

Figure A-102. Manholes in Water Exfiltration Test.

With such geometry, the exfiltrated volume was calculated depending on the depth of the water level drop for up to three distinctive parts of the manhole:

$$E = \Delta E_T + \Delta E_C + \Delta E_B \qquad \text{(A-1)}$$

Where: E......... Total volume of leakage (gal)

ΔE_T .... Exfiltrated volume in the top part of the manhole (D_{MH} =24”)

ΔE_C .... Exfiltrated volume in the coned part of the manhole (D_{MH} changes)

ΔE_B .... Exfiltrated volume in the bottom part of the manhole (D_{MH} =36” or 48”)

In the top and the bottom part of the manhole, exfiltrated volumes ΔE_T and ΔE_B were calculated using the formula for volume of cylinder:

$$\Delta E = 0.4894 \cdot D_{MH}^2 \cdot \Delta H \qquad \text{(A-2)}$$

Where: ΔD_{MH} . Manhole diameter in given part of manhole (ft)

ΔH .... Drop of water level in given part of manhole (in)

0.4894 Coefficient determined as follows:

$$\frac{D_{MH}^2 \cdot \pi}{4} \cdot \frac{1}{12} \cdot 7.481\,\text{gal/ft}^3 = 0.4894 \cdot D_{MH}^2 \qquad \text{(A-3)}$$

In the coned part of the manhole, the exfiltrated volume ΔE_C was calculated using the formula for volume of frustum of a cone.

Exfiltration Test “Before”. The water was introduced into the plugged section through the downstream manhole, which was filled to the street level (Figure A-103). The upstream manhole was filled only partially due to the different elevation of manholes and leaking. Because the water level was sinking in both manholes, the lost volume of water was calculated in both manholes and summed[50]. Table A-35 shows the measured drop of the water level in the manhole in the first 8-15 min of filling the sections with the water.

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[50] *The calculation is simplified by assuming that the upstream manhole was filled below the cone.*

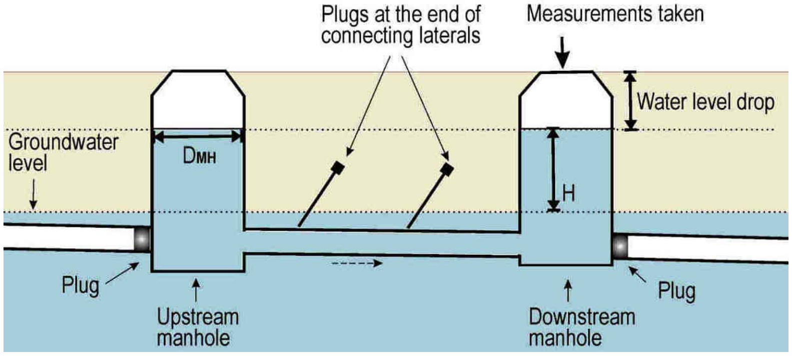

Figure A-103. Water Exfiltration Test “Before”.

Table A-35. Lafayette, LA, 2003: Leakage Rates Before Rehabilitation.

	Manholes filled with water:		Water drop measured:	Time interval	Water drop	Leaked volume (gal)			Leakage rate (gpm)
	Upstream:	Downstream:				Downstream manhole:	Upstream manhole:	Total:	
#3	MH 1257 (48”)	MH 1252 (48”)	MH 1252	8 min	22.5”	105.71	176.18	281.88	35.24
#4	MH 1260 (48”)	MH 1257 (48”)	MH 1257	10 min	13.5”	37.83	105.71	143.53	14.35
#6	MH 1258 (36”)	MH 1257 (48”)	MH 1257	8 min	18.5”	52.61	144.86	197.47	24.68
#7	MH 2987 (36”)	MH 2986 (48”)	MH 2986	15 min	11.0”	23.40	86.13	109.53	7.30
#9	MH 2992[51]	-	MH 2992						

Exfiltration Test “After”. The exfiltration test “after” was performed by measuring the water level drop in the upstream manhole. The downstream manhole was plugged off and remained empty during the sealing (Figure A-104).

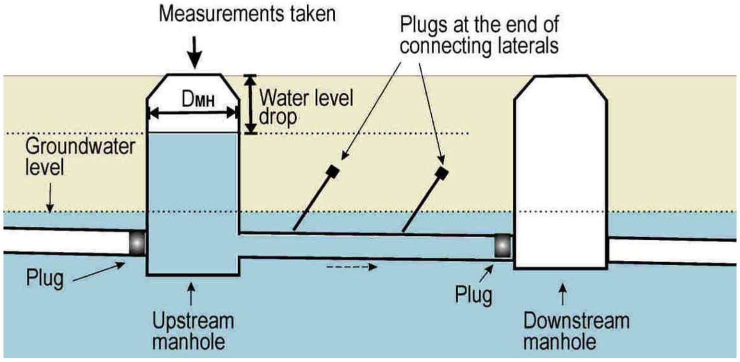

Figure A-104. Water Exfiltration Test “After”.

Table A-36 shows the measured drop of the level of solution S-2 in the last five minutes of the sealing, when the level stabilized. Based on the observed level of S-2, sections 3, 4, and 6 did not appear completely sealed but additional cycles were not repeated due to some technical problems with the pumps and equipment. However, as the reaction between two solutions typically continues in the soil, the sealing effect was expected to continue to develop with time and further prevent infiltration into these sections.

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[51] *During the water exfiltration test, the water did not reach the upstream manhole as it escaped through the inactive lateral. Section #9 was not therefore tested for exfiltration “before”.*

Table A-36. Lafayette, LA, 2003: Leakage Rates After Rehabilitation.

	Manholes filled with water: Upstream:	Downstream:	Water drop measured:	Time interval	Water drop	Leaked volume (gal) Upstream manhole:	Downstream manhole:	Total:	Leakage rate (gpm)
#3	MH 1257 (48”)	-	MH 1257	5 min	0.25”	0.49	0.00	0.49	0.10
#4	MH 1260 (48”)	-	MH 1260	5 min	0.50”	0.98	0.00	0.98	0.20
#6	MH 1258 (36”)	-	MH 1258	5 min	0.25”	0.49	0.00	0.49	0.10
#7	MH 2987 (36”)	-	MH 2987	5 min	0.00”	0.00	0.00	0.00	0.00
#9	MH 2993 (48”)	-	MH 2993	5 min	0.00”	0.00	0.00	0.00	0.00

Allowable Leakage Rates. One standard that regulates in-situ tests of the required leak-tightness in sewers[52] is the Greenbook SSPWC 306-1.4. According to this standard, the section in a water exfiltration test has to be filled to a point 4’ above the invert of the pipe at the center of the upstream manhole, or a minimum of 4’ above the average groundwater level (Figure A-105). The allowable leakage is calculated as follows:

- For mortared joints:

$$E = 0.0001 \cdot L \cdot D\sqrt{H} \tag{A-4}$$

Where: E......... Allowable leakage rate (gpm)
L......... Length of mainlines and laterals in the section (ft)
D .... Internal diameter of the tested mainline (in)

- For all other joints:

$$E = 0.00002 \cdot L \cdot D\sqrt{H} \tag{A-5}$$

Where: H .... Difference in the elevation between 1) the water surface in the upper manhole and the invert of the pipe at the lower manhole, or 2) the water surface in the upper manhole and the groundwater at the lower manhole.

---

[52] *Some standards that regulate in-situ tests of required leak-tightness in sewers are:*
(1) Greenbook SSPWC 306-1.4 (APWA Southern Californian Chapter), which requires that gravity sewer pipelines 24-in or less in diameter be tested for leakage depending on the difference in elevation between inverts of adjacent manholes:
6 *If the difference is less than 10э, the water exfiltration test or water infiltration test should be used, but air pressure test may be used instead.*
6 *If the difference is greater than 10э, an air pressure test or water infiltration test should be used.*
(2) EN 1610: 1997 (European Standard), which requires the leak-tightness be tested with either an air or water pressure test.
(3) AS 2032:1997 (Australian Standard), which requires the leak-tightness be tested with either a hydrostatic test or an air test.

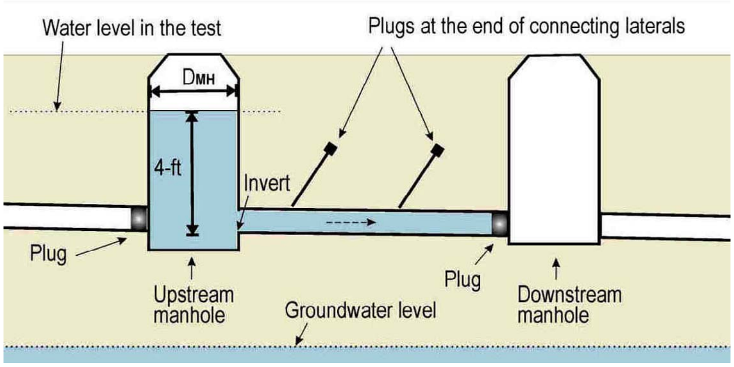

Figure A-105. Greenbook Water Exfiltration Test.

The allowable leakage rate in the Sanipor sealing tests was calculated using formula (4), where ΔH was assumed to be 5' (Figure A-106). The groundwater level in Lafayette is usually deep, however, the project was performed shortly after heavy rains and the groundwater level was approximately at 5'depth. Table A-37 shows the calculated rates that should be allowable in the tests compared with earlier determined rates.

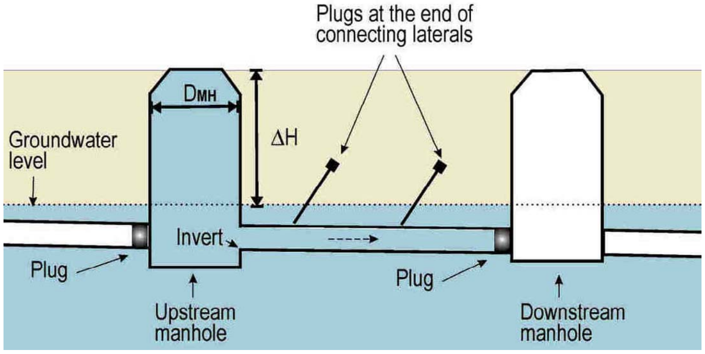

Figure A-106. Allowable Leakage Rates in Sanipor Water Exfiltration Tests.

Table A-37. Lafayette, LA, 2003: Allowable Leakage Rates Compared with Rates "Before" and "After" Rehab.

Section	Upstream Manhole	Length			Mainline Diameter	ΔH	Leakage Rate (gpm)		
		Mains	Laterals	Total			Allowable	"Before"	"After"
#3	MH 1257	298.5'	44.0϶	342.5϶	8"	5'	0.12	35.24	0.49
#4	MH 1260	254.7'϶	80.0϶	334.7϶	8"	5'	0.12	14.35	0.98
#6	MH 1258	259.0'	269.0϶	528.0϶	8"	5'	0.17	24.68	0.49
#7	MH 2987	293.9'	567.0϶	860.9϶	8"	5'	0.31	7.30	0.00
#9	MH 2993	266.7'	320.0϶	586.7϶	8"	5'	0.21	-	0.00

Exfiltration Test 21 Months Later. The test was repeated on 01/18/05, approximately 21 months after the project completion. It was similar to the test "before" having both manholes filled with water[53], however the connecting laterals were not plugged at the cleanouts near the houses and the water was able to leak out at those locations (Figure A-107).

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[53] *Again, the upstream manhole was filled below the top due to the different elevation of manholes at the street level.*

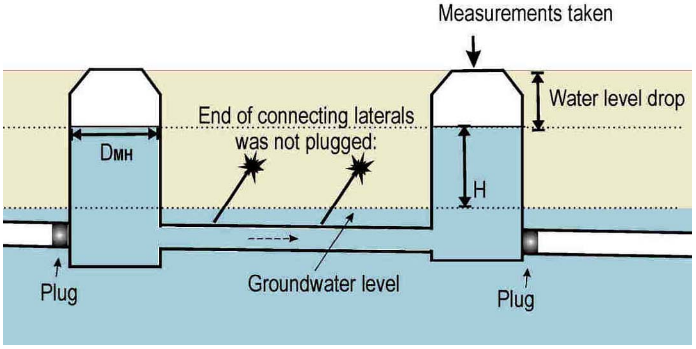

Figure A-107. Water Exfiltration Test 21 Months Later.

Table A-38 shows the measured level drops and calculated values. Two sections had no level drop showing that the installed material was performing well. On three other sections, there was a significant water level drop, which was however was not surprising because the laterals were not plugged.

Table A-38. Lafayette, LA, 2003: Leakage Rates 21 Months After Rehabilitation.

	Section Filled with Water			Water Drop Measurement			Calculated Leaked Volume (gal)			Leakage Rate (gpm)
	Upstream	Downstream	Less	Location	Duration	Drop	Downstream	Upstream	Total:	
#3	MH 1257 (48”)	MH 1252 (48”)	20”	MH 1252	20 min	4”	31.35	31.42	62.77	3.14
#4	MH 1260 (48”)	MH 1257 (48”)	9”	MH 1257	20 min	7”	36.28	54.61	90.89	4.54
#6	MH 1258 (36”)	MH 1257 (48”)	12”	MH 1257	20 min	0”	0.00	0.00	0.00	0.00
#7	MH 2987 (36”)	MH 2986 (48”)	12”	MH 2986	20 min	0”	0.00	0.00	0.00	0.00
#9	MH 2992 (48”)	MH 2993 (48”)	12”	MH 2992	20 min	14”	109.97	109.97	219.94	11.00

Explanation: “Less” indicates depth (from the street level) that the downstream manhole was filled to.

A.8.7 Project Duration

The average duration of flood grouting steps and duration of sealing is given in Table A-39, Table A-40, and Table A-41.

Table A-39. Lafayette, LA, 2003: Average Duration of Flood Grouting.

Activity	Average Duration	
Mobilization (tankers from base to site, stoppers inserted)	120 min	2.0 hrs
Cleaning and CCTV (if done on the same day)	180 min	3.0 hrs
Sealing with both solutions (1 cycle)	120 min	2.0 hrs
Demobilization	90 min	1.5 hrs
TOTAL		8.5 hrs

The shortest sealing cycle took only 45 min (section #10) and the longest about four hours (section #6, although the third application of solutions was repeated on the following working day). Overall, the crew was able to rehabilitate one or two sections per day and the project took seven working days, which was a little longer than the initially planned schedule of five days.

Table A-40. Lafayette, LA, 2003: Duration of Sealing and Number of Refills per Cycle.

Section	Date	Cycle 1		Cycle 2		Cycle 3		Total
		S-1	S-2	S-1	S-2	S-1	S-2	
#1	04/08/03	40 min (1)	55 min (2)					95 min
#2	04/09/03	45 min (1)	45 min (0)					90 min
#3	04/09/03	60 min (3)	40 min (2)	40 min (1)	60 min (2)			200 min
#4	04/10/03	45 min (3)	50 min (0)					95 min
#5	04/11/03	30 min (1)	35 min (1)					65 min
#6	04/11/03	30 min (0)	30 min (1)	55 min (3)	60 min (1)			245 min
	04/14/03					40 min (2)	30 min (0)	
#7	04/15/03	5 min (0)	5 min (0)	15 min (0)	35 min (0)			60 min
#8	04/15/03	25 min (0)	25 min (0)					50 min
#9	04/16/03	25 min (0)	50 min (2)	25 min (0)	50 min (0)			150 min
#10	04/10/03	25 min (1)	20 min (0)					45 min
Min								45 min
Max								245 min
Ave								109 min

Explanation: Numbers in parenthesis are the number of refills.

Table A-41. Lafayette, LA, 2003: Duration of Sealing per Day.

Day	Date		Sections Sealed	Duration of Sealing
1	Tue	04/08/03	#1	95 min
2	Wed	04/09/03	#2, #3	285 min
3	Thu	04/10/03	#4, #10	140 min
4	Fri	04/11/03	#5, #6	240 min
5	Mon	04/14/03	#6	70 min
6	Tue	04/15/03	#7, #8	110 min
7	Wed	04/16/03	#9	150 min

The challenges of this project were the following:

- Inexperience was the biggest issue. Without any previous experience with this method, the project was a learning experience for both the contractor and the municipality. The crew was initially slow in changing the solutions, but their speed increased significantly with practice over several days. The required equipment was not immediately available. For example, the contractor did not have a proper pump on the first day, and the municipality had to locate and bring in their hydraulic submersible pump. In the course of the project, the performance of the crew improved due to training and better functioning of the equipment, which reflected in achieving faster and more effective utilization of working time as the project progressed.
- Groundwater conditions were difficult because the sewer system (Beverly Drive area) was heavily surcharged from heavy rain before the project (a 2” event). The heavy rain surcharged the capacity of lift stations: the pumps were operating continuously but slowly, and the manholes were still half-filled with water. The section #7 (MH 2987—MH 2986) had to be plugged and dewatered.
- Multiple houses sharing a common lateral were discovered late at Ophelia Drive. Three homes were with two laterals that connected into a single lateral at some distance from the home, but this was not known ahead of time because the laterals were not CCTV inspected.

Another comment worth mentioning is that some existing defects could have been repaired with some other method prior to the project to save time and use of chemicals, however Sanipor® ultimately provided a complete solution. For example, one manhole (Beverly MH 2986) had a crack and a large hole in the soil behind the crack. This defect could have been fixed easily with a trowelable mortar. With Sanipor®, the soil and the void behind the manhole were solidified sealing the ground around the manhole as well as the manhole wall and eliminating voids that could cause further deterioration.

A.8.8 Cost Analysis

Table A-42. Lafayette, LA, 2003: Summary of Costs.

	Unit Price	Quantity	Amount	Note
Prior to Sanipor® installation				
Mainline CCTV	$507.60	5	$2,538	
Lateral CCTV	$137.75	36	$2,538	
Installation of cleanouts	$167.04	25	$4,176	
Purchase of plugs[54]				
Water drop test	$200.00	5	$1,000	
Legal fees for letters sent to property owners				
TOTAL			$10,252	Cost to the agency [55]
Sanipor® installation				
Equipment and a 5-people crew	$3,600/day	6.5 days	$23,400	
Chemicals Solution S1	$3.60/gal	2,675 gal	$9,630	
Chemicals Solution S2	$17.99/gal	2,220 gal	$39,938	
TOTAL			$72,968	Cost to the agency was $50,000 (by contract), the rest paid by the contractor
Alternatives to Sanipor® (for comparison)				
CIP relining of mainlines	$22.00/ft	1,473’	$32,406	
Reopening of laterals	$150/ea	24	$3,600	
Rehabilitation of manholes	$56/ft	49’	$2,744	
Rehabilitation of laterals	$3,000/ea	24	$72,000	
TOTAL:			$111,750	

The cost of lateral rehabilitation in this project can be estimated by comparing the volume of laterals and the total rehabilitated volume (mainlines, manholes and laterals together). The approximate calculation is as follows:

Table A-43. Lafayette, LA, 2003: Breaking Down the Total Cost between Mainlines, Manholes and Laterals.

	Diameter	Length	Volume (CF)	Cost	
Mainlines	8∀	1,372.8∋	479 (40%)	$28,932.95	
Manholes			498 (41%)	$30,080.53	
Laterals	5∀	1,695.0∋	231 (19%)	$13,954.53	Approx. $580/lateral or $8.25/ft.
TOTAL:			1,208	$72,968.00	

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[54] *Plugs had to be purchased but they are reusable and are not considered a relevant item in the cost analysis.*

[55] *These items would have been required with other methods and are not considered a relevant item in the cost analysis.*

A.8.9 Public Relations

Public relations involved sending the homeowners a letter explaining the project and the benefit to the homeowner (having the lateral cleaned and sealed, and a new cleanout installed at no cost to the homeowner). Before any work started, the homeowners had to sign a customer authorization form allowing the city crews to work on the private property.

In addition to signing the authorization form, one homeowner (a lawyer) made his consent contingent upon the municipality signing and returning to him the following indemnities inserted into the form.

"LUS agrees to indemnify and hold harmless the homeowner for any property damage or personal injury arising out of or in any way connected with this project including but not limited to claims of third parties, and so including attorney fees, litigation costs, and all judgments or settlements."

A.9 Case Study: Slug Grouting in Honolulu, HI (2004)

This case study details the first field application of an innovative rehabilitation method—modified flood grouting (End-i™). It is one of several tests being performed to demonstrate the applicability and performance of this newly developed rehabilitation system, and evaluate its effectiveness in infiltration removal.

Table A-44. Project Summary.

Objective	Sealing of laterals and mainline between manholes in one setup
System used	**End-i™** (Slug grouting)
Time	May 2004
Location	Kaneohe, HI (Honolulu County)
Agency	City and County of Honolulu Craig Nishimura, Environmental Services Dept, P. (808) 527-5131, cnishimura2@co.honolulu.hi.us
Contractor	Eckard Brandes, Inc. (EBD)/End-i Jeff Iwasaki-Higbee, *Inventor and system owner*, P. (808) 282-2832, pipedr@hawaii.rr.com
Soil conditions	Coral and coral fill material
Scope	Sealed a mainline (140') and 3 lower laterals (60') connected to it in one set up
Procedure	a) Steps preceding rehabilitation ♦ Preliminary cleaning and CCTV inspection of pipes (mainline and laterals)—2 months before rehab ♦ Flow measuring (pre-rehabilitation infiltration)—few days before rehab b) Rehabilitation: ♦ Final cleaning of pipes ♦ Flow bypassing ♦ Grouting of both mainline and laterals (End-i™) ♦ Point repair in the manhole ♦ Removal of residual green cement grout on pipes' interior b) Steps following rehabilitation (1 week after rehabilitation): ♦ Flow measuring (post-rehabilitation infiltration)
QC after rehabilitation	Only CCTV inspection. No air-pressure testing or water exfiltration testing. On the spot flow measuring.
Financing	Paid by the owner of rehabilitation system[56]. Accurate costing is not yet available
Public relations	Notice to homeowners
Rehab effectiveness	Brief flow measuring before and after rehabilitation to show combined effectiveness of lateral and mainline sealing[57] Contractor

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[56] *The project was beneficial to both the agency (the potential infiltration reduction would come at no cost to it) and the process owner (saved from the cost of constructing a collection system as a test bed for demonstrating the effectiveness of the process).*

[57] *The second field test carried out in vicinity of this test applied End-i process only on the mainline and hence tested the effectiveness in infiltration removal of this rehabilitation. Comparison of two tests indicates the role of laterals in infiltration.*

A.9.1 Background

Selection of Location for Rehabilitation. The agency selected pipes for rehabilitation that had very severe infiltration. The mainline was an 8” VCP pipe and three laterals were 6” VCP pipes (lower laterals) with 4” cast iron pipes (risers and upper laterals).

Because of the close proximity of the ocean and porous soil conditions (coral and coral fill material), the groundwater elevation in the test area is affected by the tides (Figure A-108). In Honolulu, the laterals are typically laid at a shallow depth and there is a marked drop in elevation where they connect with the mainline (Figure A-109). Thus, for the selected pipes, the invert elevation was from 5.54-6.41’ below the mean tide, and approximately the same below the mean groundwater level. Downstream the pipe invert went deeper (approximately 15’). With high groundwater pressures, defective sewer pipes leak badly and the rehabilitation effectiveness in reducing the infiltration would be evident.

The project location was also good because there were no obstacles on private properties (such as walls, pools, etc.) that would limit access to sewer pipes, traffic control was easy to maintain in this residential area, and disturbance to residents was minimal (no excavation was required because the laterals had cleanouts on the property line)(Figure A-110).

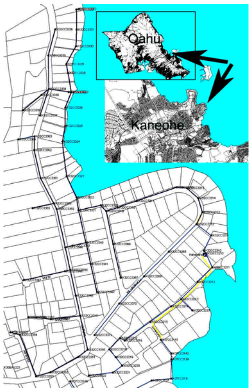

Figure A-108. Map Showing the Location of the Project on the Island of Oahu.

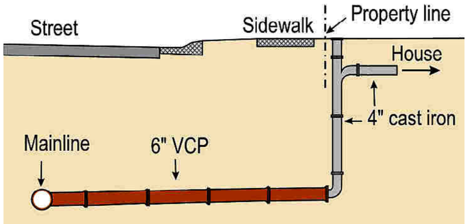

Figure A-109. Typical Connection of Private Laterals with the Mainline in Honolulu.

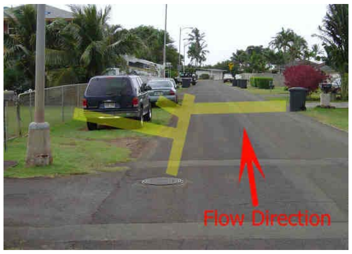

Figure A-110. Project Location in Residential Area.

A.9.2 Steps Preceding Rehabilitation

Preliminary Cleaning and CCTV Inspection of Pipes. The mainline was first cleaned and CCTV inspected. The inspection revealed infiltration at several joints, infiltration from laterals, a shear crack at the downstream manhole wall, and mainline sag of about 3”.

The site survey identified the location of cleanouts: one was found under a planter, one in the grass, and one under a 6” pile of dirt from some previous construction. The distance between the cleanouts from the mainline was about 15’ in two laterals and 30’ in the third lateral (that was crossing the street). This distance was to be rehabilitated in this project. Cleaning and CCTV inspection of the laterals revealed infiltration at most joints in the lower portion of the laterals. (R.S. Technical, mounted on a push rod and inserted from cleanout).

Measuring of Pre-Rehabilitation Infiltration. For measuring infiltration before the rehabilitation, the section was first isolated from the upstream wastewater flows in the upstream manhole. Flow bypassing was not necessary because the measurement would take 30 minutes.

The upstream manhole had two pipe inlets bringing upstream flows: one 8” pipe and one 6” pipe. The inlets were plugged. The laterals in the tested section were not plugged. With the upstream flow isolated, a weir was placed in the inlet of the downstream manhole.

The weir measured the total flow consisting of both infiltration (coming from the mainline and three laterals) and the sewage from three residences (Figure A-111). However, the last component was very small because the measurement was taken in the middle of the day when two residences were unoccupied and, in the third residence, no laundry or bathrooms were used. Flow going over the weir was approximately 43,750 gpd.

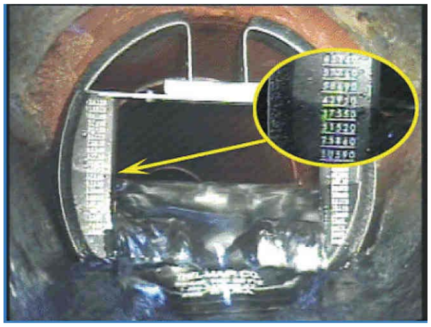

Figure A-111. Weir for Flow Monitoring in the Downstream Manhole.

A.9.3 Rehabilitation

Last Cleaning of Pipes Before Rehabilitation. The pipes were again cleaned one day before rehabilitation with conventional hydro jetting[58].

Flow Bypassing. On the day of rehabilitation, the upstream flows were plugged. The plugs were connected to the pumps, which discharged the flow into the downstream manhole. Flow bypassing was necessary because application of End-i rehabilitation system would take several hours (mainline pipe was bypassed between 8 AM and 5 PM and laterals between 10 AM and 3:30 PM.

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[58] *The importance of removing any existing mineral deposits was shown in the second field test, which followed about three months after this project. It was shown that such deposits inhibit the exfiltration of cement grout.*

Grouting of Both Mainline and Laterals (End-I™). Bladders required for application of End-i rehabilitation system are thin reinforced poly type tubes. Multiple bladders are needed: two mainline bladders and several[59] lateral bladders, all matching diameter (ID) of the pipes.

Step 1: Inversion of lateral bladders. First, each lateral bladder was inverted from the cleanout into the lateral and slightly into the mainline (protruding into the mainline for about half mainline ID, i.e. about 4"), which was necessary because of the Wye connection of the lateral with the mainline. The inversion was monitored with a CCTV positioned in the mainline slightly downstream of the lateral-to-mainline connection. Once in place, the lateral bladder, which was under a pressure greater than the groundwater, acted as a plug stopping any infiltration from the lateral.

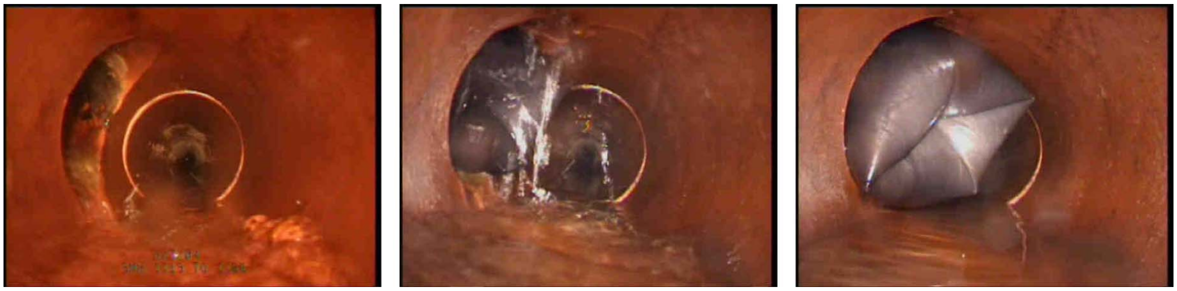

Figure A-112. Left: Lateral Connection in the Mainline. Middle: Lateral Bladder Emerging from the Lateral Connection. Right: The Bladder Protruding into the Mainline. (View from the CCTV Camera in the Mainline just Downstream of the Connection).

Step 2: Inversion of first mainline bladder. The CCTV camera was moved to the upstream end of the mainline (the lateral tubes were retracted a few inches to allow the camera to pass through the mainline). The first bladder started being inverted into the mainline from the upstream manhole. The pressure of inversion was approximately 200% of the groundwater pressure above the pipe invert. As the bladder was being inverted, the CCTV camera was retracted backwards in direction of the downstream manhole.

The camera operator was telling the person controlling the bladders when the mainline bladder was approaching the lateral connection for reference. As the camera pulled past each connection (and before the mainline bladder reached the connection), the lateral bladder was extended to protrude again into the mainline (Figure A-113).

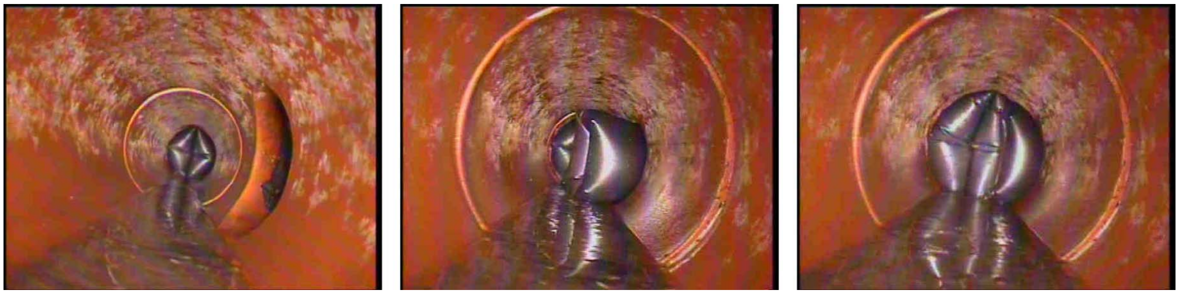

Figure A-113. Left: Lateral Bladder Retracted to Allow CCTV Camera to Pass. Middle: The Lateral Bladder Extended Again to Protrude as the Mainline Bladder was Approaching. Right: Mainline Bladder Inverting Past the Lateral Bladder.

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[59] *All laterals need to have the bladders in them during the process to stop infiltration and occupy the volume of space so as to minimize any dilution of the grout*

The mainline bladder from the upstream was stopped at about 18” from the downstream manhole (Figure A-114). All infiltration into the main was blocked off except from the shear residing at the outside of the manhole wall.

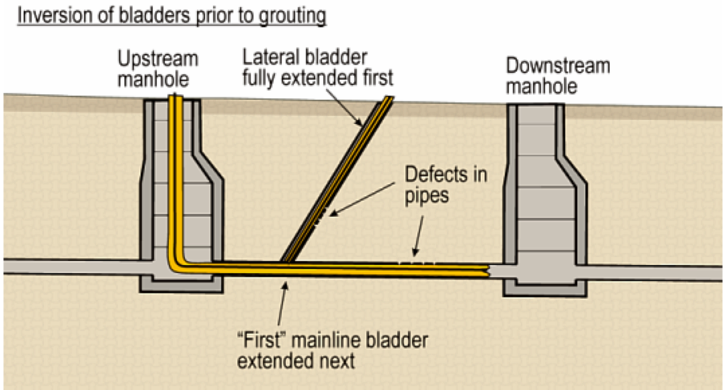


Figure A-114. Lateral and Mainline Bladders Prior to Grouting.

Step 3: Insertion of grout shoe. Inversion of second mainline bladder. A special End-i grout shoe was inserted approximately 18” in from the downstream manhole against the bladder (Figure A-115). The second mainline bladder was then to be inverted into the mainline at a pressure about exceeding the groundwater pressure, this time from the downstream manhole. Thus, the second mainline bladder would be inverted against the first bladder, which would retract towards the upstream manhole. The grout shoe would remain in-between the two mainline bladders and allow the grout to be inserted between them.

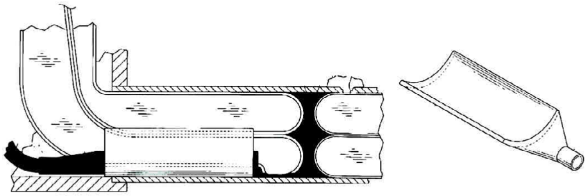


Figure A-115. Grout Shoe.

Step 4: Grouting. Cement grout (ultra fine) was injected between the mainline tubes while the bladder from the upstream manhole was retracted. Roughly 100 gal of cement grout was maintained between the mainline tubes. Being under a pressure exceeding the groundwater pressure, the cement grout migrated through any cracks or openings in the pipe into the soil. As the mainline bladders were simultaneously inverted and retracted, the slug of cement grout moved along the mainline pipe in direction of the upstream manhole grouting defects in the mainline (Figure A-116).

When the slug of cement grout reached the lateral connection, the mainline bladder that was being retracted was stopped. The other mainline bladder continued inverting and the retraction of the bladder within the lateral was started. Thus, the path of the slug of cement grout was diverted into the lateral, grouting the soil behind any opening in the lateral pipe (Figure A-117).

After the slug of cement grout has passed the entire length of the lateral and was held long enough to exfiltrate, the mainline bladder being held in place to that point continued now retracting in the mainline. The lateral bladder was now inverted simultaneously until it reached the mainline forcing any excess cement grout into the mainline. Next, mainline grouting resumed (Figure A-118).

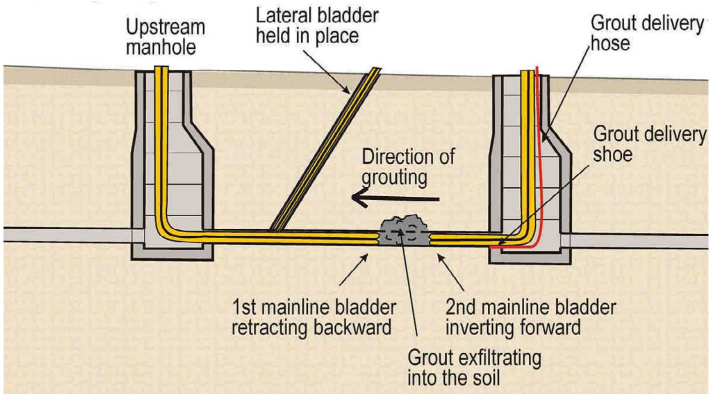


Figure A-116. Mainline Grouting—Slug of Cement Grout Moving Towards Upstream Manhole.

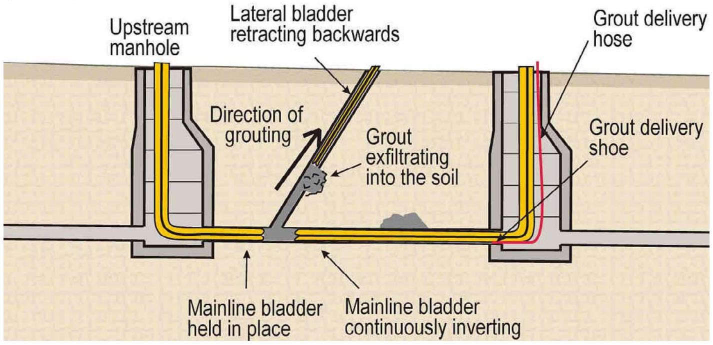


Figure A-117. Lateral Grouting—Slug of Cement Grout Diverted Through the Lateral.

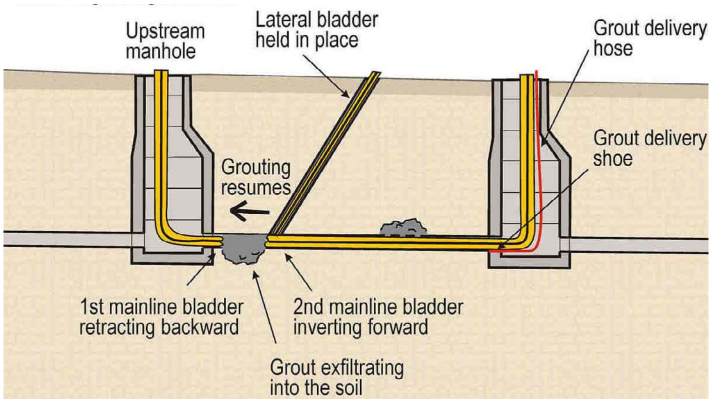


Figure A-118. Mainline Grouting Resumed—Slug of Cement Grout Resuming Its Path through the Mainline After Completing the Lateral Grouting.

Step 5: Removal of the first mainline bladder manhole. Grout curing. When the slug of cement grout reached the upstream manhole, the first mainline bladder (that was being retracted) was removed through the upstream manhole along with any excess cement grout. The second mainline bladder (that was being inverted) and the lateral bladders were held in place for another three hours to allow the cement grout to cure (Figure A-119).

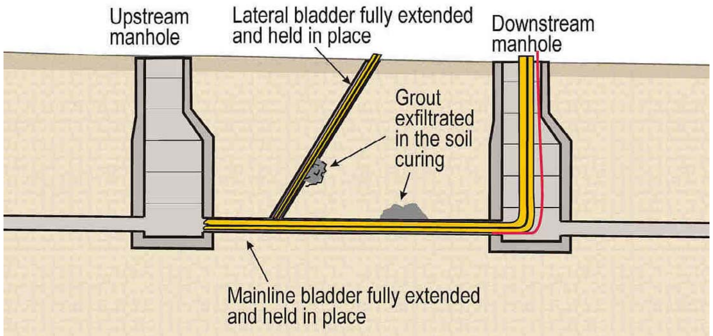


Figure A-119. Curing of Cement Grout.

Step 6: Removal of all bladders. Cleaning of residual. Following the cement grout cure, all bladders were removed. On the interior of pipes, there was a residual green cement grout, which had to be removed (Figure A-120). The thickness of residual grout depended on how well the bladder was pressed against the host pipe, and was even up to 1” at some places. The residual also showed wrinkles from the bladder. The residual was removed with a combination of hydro-jetting device and a root-cutter type device (SECA® three-bladed root cutter). This step took about half a day with a two-man crew. The look of pipe interior after cleaning is shown in Figure A-120—Right.

Point Repair in the Manhole. After all the bladders were removed, the crack in the downstream manhole, which was originally not leaking started leaking (it was covered with the bladder during the End-i rehabilitation). The leak was repaired with a simple part liner (CIP point repair).

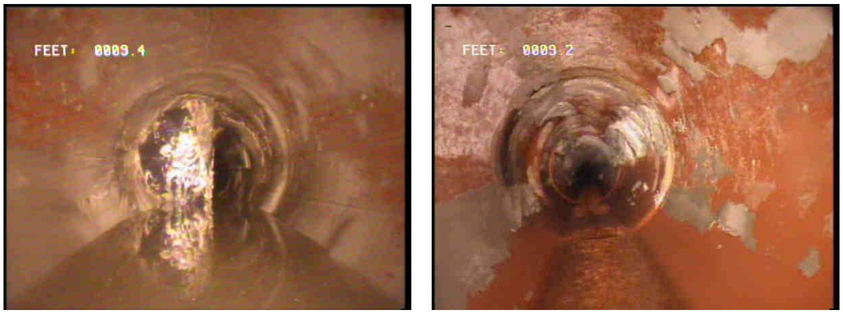


Figure A-120. Left: Residual Cement Grout Before Cleaning. Right: Residual Cement Grout After One Hydro Jet Pass.

A.9.4 Steps Following Rehabilitation

Measuring of Post-Rehabilitation Infiltration. For measuring infiltration after rehabilitation, the upstream flows were isolated and the weir installed in the same location (downstream manhole) as during pre-rehabilitation flow measuring. The flow was, however, significantly smaller and was going over the bottom part of the weir only (Figure A-121). Total flow measured after the repair was less than 500 gpd. Thus, neglecting a very small sanitary flow in both pre and post-rehab measurements, the rehabilitation removed 43,250 gpd.

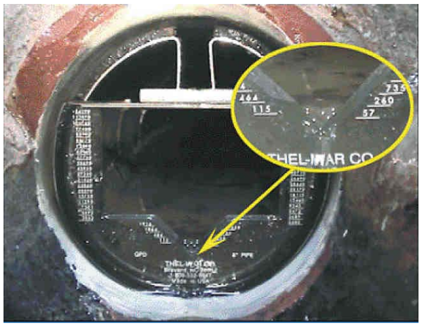


Figure A-121. Weir for Flow Monitoring in Downstream Manhole.

A.9.5 Cost Analysis

The field test costs were out of proportion to what actual production costs would be. However, because the End-i rehabilitation system is still in its infancy, it was too early to accurately estimate costs.

Table A-45. Honolulu, HI, Modified Flood-and-Grout, 2004: Summary of Rehabilitation Costs.

Item	Unit Price	Qty	AMOUNT	Average
Last pre-rehabilitation cleaning of pipes	$750.00	1	$750.00	
Flow bypass				
Sealing (material/installation)	$8,000.00	1	$8,000.00	
Removal of residual green cement grout	(Estimate)		(Estimate)	
Flow measuring before and after rehab				
Point repair in the manhole	$950.00	1	$950.00	
TOTAL:			$9,700.00	

With this system, the ultimate cost is more dependent on the number of setups than on the linear footage of pipes in each setup.

A.9.6 Project Duration

The duration of construction work related to slug grouting is shown in Table A-46. Duration of rehabilitation depends mostly on the number of laterals. This setup (one mainline and three laterals) took approximately six hours to complete the rehabilitation. This excludes the point repair in the manhole, which was not part of the project originally. The rehabilitation left the homes without the use of their sewer from 10:00 AM to 3:30 PM.

Table A-46. Honolulu, HI, Modified Flood-and-Grout, 2004: Duration of Rehabilitation.

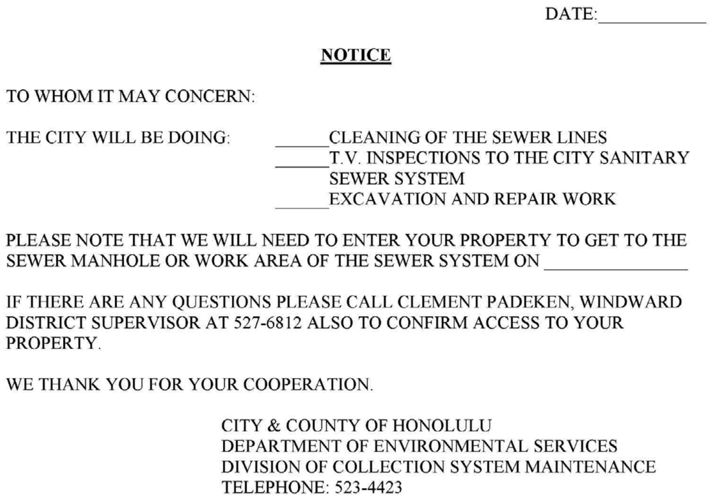
Activity	Average Duration
Last pre-rehab cleaning of pipes (day before)	6 hrs
Setting up the flow bypass	1 hr
Sealing of 1 mainline and 3 laterals (including grout cure)	6 hrs
Removing the flow bypass	1 hr
TOTAL (Slug grouting)	8 hrs
Removal of residual green cement grout (few days after)	6 hrs
Point repair in the manhole	2 hrs + 1 hr on another day
Flow measuring before and after rehab (30min data readings)	2 hrs

The project duration could have been shortened if a different grout mixer had been available. Because the cement grout is ultra-fine, a special high shear mixer would obtain optimum viscosity in a shorter time. A mixer of that type was not available for this test, but one has been built for future installations in Honolulu and another for use on the mainland.

In future applications of this system, a challenge might come from the lack of cleanouts on the sewer laterals. Because the lateral bladders are an integral part of the process, all sections of pipe to be rehabilitated with End-i need to have cleanouts. In this project, this was not an issue because the City and County of Honolulu has a plumbing ordinance requiring cleanouts. However, there are agencies that do not have such a code. The necessity to install new cleanouts would increase the cost of End-i rehabilitation. However, owners of these collection systems often prefer having the cleanouts on their laterals and take advantage of the opportunity to install them during their rehabilitation.

A.9.7 Public Relations

For public relations, the agency sent a brief notice to the homeowners in the area informing them of the coming project (Figure A-122).



DATE:___________

NOTICE

TO WHOM IT MAY CONCERN:

THE CITY WILL BE DOING:
______CLEANING OF THE SEWER LINES
______T.V. INSPECTIONS TO THE CITY SANITARY SEWER SYSTEM
______EXCAVATION AND REPAIR WORK

PLEASE NOTE THAT WE WILL NEED TO ENTER YOUR PROPERTY TO GET TO THE SEWER MANHOLE OR WORK AREA OF THE SEWER SYSTEM ON _______________

IF THERE ARE ANY QUESTIONS PLEASE CALL CLEMENT PADEKEN, WINDWARD DISTRICT SUPERVISOR AT 527-6812 ALSO TO CONFIRM ACCESS TO YOUR PROPERTY.

WE THANK YOU FOR YOUR COOPERATION.

CITY & COUNTY OF HONOLULU
DEPARTMENT OF ENVIRONMENTAL SERVICES
DIVISION OF COLLECTION SYSTEM MAINTENANCE
TELEPHONE: 523-4423

Figure A-122. Notice Letter to Homeowners.

A.9.8 Effectiveness of Rehabilitation

As already mentioned, the total removed infiltration was approximately 43,250 gpd. However, comparison of flows measured before and after rehabilitation (with isolation of upstream flows) showed the combined effectiveness of lateral and mainline sealing. To determine how much the laterals contributed in total infiltration and whether it was necessary to rehabilitate them, another field test was carried out in vicinity of this test four months later.

In the second field test, End-i rehabilitation was limited to the mainline. The mainline was an 8” VCP pipe (240э) with five laterals (6” VCP pipes on lower laterals and 4” cast iron pipes on risers and upper laterals). The pre and post rehabilitation flows were 54,180 gpm and 47,280 gpm, respectively (Figure A-123). The reduction in infiltration was thus only 6,900 gpm.

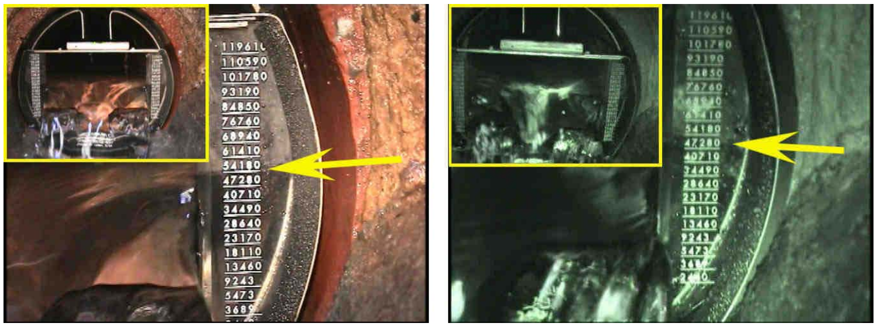


Figure A-123. Weir Readings “Before” and “After” in the Second Field Test Without Lateral Rehabilitation.

In general, cost-effectiveness of the rehabilitation would come from eliminating the cost of pumping and treating of the removed infiltration. For illustration, if the costs to pump and treat the infiltration were $0.75 per 1,000 gal, the annual saving from the infiltration reduction from the first section would be almost $12,000 per year.

A.10 Case Study: Sliplining in Stege, CA (1987)

This case study details how sliplining could be used to rehabilitate sewer laterals. This project was done in late 1980s. The method is practically no longer used by any agency.

Table A-47. Project Summary.

Objective	Rehabilitation of laterals to achieve leak-tightness and a structurally sound sewer system
System used	**Sliplining** (Lateral slipning)
Time	Jun-Sep 1987
Location	El Cerrito, CA (San Francisco Bay Area)
Agency	Stege Sanitary District, CA Doug Humphrey, (510) 524-4668, doug@stegesd.dst.ca.us Larry Rugaard, (925) 362-1880, rugaard@icommm.com
Contractor	Dalton Construction Co [60]
Soil conditions	The Franciscan formation, Sandy clay. Of more interest, the service area is bisected by the Hayward Fault, an active earthquake fault. All laterals directly under a lawn, garden, retaining wall or driveway
Scope	Sliplined 111 laterals between[61] the mainline and the home[62]
Procedure	a) Preliminary inspection (no more than 10 days before rehabilitation) ♦ CCTV of mainlines to locate lateral connections b) Preparation for sliplining ♦ Mainline/lateral cleaning, and re-CCTV of mainlines ♦ Water exfiltration testing of laterals ♦ Excavation of pits (at lateral/mainline connections) c) Mainline sliplining ♦ Sliplining of mainline; Air-testing of mainline ♦ Reopening of laterals d) Lateral sliplining ♦ Excavation of additional pits (near the building foundations, at any bend in the lateral) ♦ Sliplining of laterals (by pushing) ♦ Air-testing of laterals ♦ Reconnection of laterals with the mainline, see 9 above
QC after rehabilitation	Air-testing (before and after lateral sliplining)
Financing	Paid in full by the city
Public relations	Open house with homeowners, letter notices, letter follow-up for agreement. Notice to homeowners, Agreement form

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[60] *No longer in business (not related to this project)*

[61] *Both ends were open to allow work towards a joint or a bend somewhere along the lateral.*

[62] *This was an 8,500 lf of 4" pipes. In addition, 13,400 lf of mainlines (6" and 8" VCP pipe) was sliplined as well. The mainlines were sliplined first, which was followed by the sliplining of all connecting laterals. The work on the laterals started the following day and typically took several days (on average about 2 laterals were sliplined per day).*

Table A-47. Project Summary.

Rehab effectiveness	Flow monitoring before and immediately after rehabilitation, and again 5 years later[63]. Almost 100% reduction in service callouts from the rehabilitated area. Measured 86% I/I flow reduction.

A.10.1 Background

In Stege Sanitary District, the lower lateral is typically 25' in length, and the laterals in this area averaged between 60-65' in total length. None of the laterals originally had a cleanout at the property line and there often weren't cleanouts outside the building foundation. Some cleanouts near the house had difficult access (Figure A-124)

Figure A-124. Difficult Cleanout Location Near the House.

A.10.2 Steps Preceding Rehabilitation

Preliminary Inspection. Several years before rehabilitation, following flow monitoring, all pipes and manholes were smoke tested to identify inflow sources to the system. All known or found illegal connections (such as yard drains, etc.) were disconnected. The CCTV inspection conducted by the sliplining contractor located lateral connections and determined whether the lateral was live and in use.

Typically, the laterals had vertical 45° bends near the connection to the mainline. Depending on the terrain, the laterals had other horizontal and/or vertical bends.

Selection of Rehabilitation Method. In initial planning, several different methods were considered for mainline and lateral rehabilitation. Chemical grouting was rejected because the agency had been told about short useful life of pipes rehabilitated with this method (five years). Pipe bursting, CIP and sliplining were all good rehabilitation options, however, public works bidding showed sliplining to be less costly than the other two methods. Pipe bursting had an additional advantage of pipe diameter upsizing over other two methods, but the flow capacity was not an issue. (There was such an excess of flow capacity that even sliplining was suitable despite the reduced cross section it would create.) The pipes did not have many offset joints, which would also be a reason to favor pipe bursting. The pipes were not very deep nor the soil unstable to favor the CIP relining. The same reasoning applied to the selection of sliplining for both rehabilitation of mainlines and laterals.

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[63] *Only combined effectiveness of mainline and lateral rehabilitation could be evaluated from flow monitoring data.*

A.10.3 Steps Preceding Sliplining

Each mainline and the connecting laterals were first cleaned using water jetting. The mainline was then inspected using CCTV equipment.

Water exfiltration testing (hydrostatic pressure test) was carried out on all laterals to identify the laterals that needed rehabilitation (Figure A-125). The testing was done just before the mainline sliplining, after the lateral was disconnected by inserting a plug at the lower end of the lateral. Only one of 111 laterals passed the test. It was a new cast iron lateral that was less than five years old.

Pits were excavated at each lateral/mainline connection (Figure A-126). The excavations were small potholes (about 2.5’×2’ near the surface). Once the excavations were made, the exposed lateral pipe in each pothole was cut out.

Additionally, point repairs were required in many locations on the laterals where the laterals failed structurally in order to provide the ability to slipline them.

Figure A-125. Water Exfiltration Test Through Cleanout.

Figure A-126. Entry Pit at Lateral-to-Mainline Connection.

A.10.4 Construction

Sliplining of Mainlines. The pipe used for sliplining was SDR21 HDPE pipe of slightly smaller outer diameter (OD) than the host pipe inner diameter (ID) (6” or 8”)[64].

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[64] *Many point repairs were necessary in order to provide a pipe with enough integrity that could accept a sliplining process and subsequent HDPE pipe.*

The pipe was fused using normal heat fusion methods and inserted by pulling in place (using a high tension winch). Next, the HDPE pipe was left overnight to relax. The following day, the mainline was air-tested to assure mainline joint integrity[65] and holes were cut for lateral connections.

Figure A-127. Fuse Welding Machine.

Sliplining of Laterals. Additional pits were excavated at the property line, at any other bend in the lateral, and near the house (if the cleanout was there, it was temporarily removed). Next, the exposed pipe in each pit was cut out.

Figure A-128. One of the Additional Pits Excavated Along the Lateral.

The pipe used for lateral sliplining was SDR21[66] HDPE pipe with an OD of 4”. Thus, the diameter of the sliplined lateral was reduced from 4” to 3.1”. Pipe segments were butt fused on site. The pipe was pushed manually into the lateral, first downstream towards the mainline and then upstream towards the house. If there were other pits along the lateral, they were used for insertion of the sliplining pipe into the adjacent lateral segments. The typical length of laterals was from 40-70’, and the maximum length that the pipe was pushed was about 40’.

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[65] *Each test was passed as satisfactory. If there had been a failure, the leak would have been found and corrected.*

[66] *It would not be possible to push any thinner pipe into the lateral.*

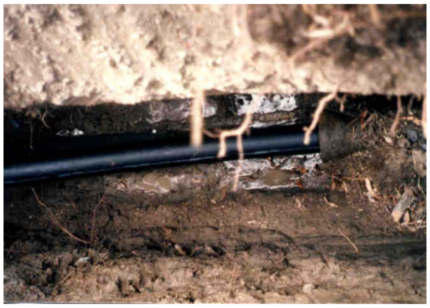

Figure A-129. New HDPE Pipe Extending Beyond Old VCP Pipe—a View from Above.

Figure A-130. Lateral Pulling Cable.

Point repairs were required in many locations on the laterals in order to provide the ability to slipline. A new cleanout was installed near the house and the HDPE pipe connected to it. At intermediate pits (on horizontal or vertical bends), a standard cast iron fitting with a rubber coupling and stainless steel bands was used for connection. The lateral was then air tested, after inserting plugs and taps[67] at the downstream and upstream terminus points.

After successful air testing, the lateral was reconnected with the mainline and the house. The laterals have been installed typically at a minimum slope of ¼" per foot and reached the mainline-to-lateral connection point at shallower depth than the mainline. Therefore, the connection to the mainline was done using a butt-fused HDPE saddle with HDPE riser.

Figure A-131. Mainline Tee Ready for Lateral Connection—a View from Above.

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[67] *Tap is for air entry and release*

Figure A-132. Test Plug in the Lateral at the Property Line.

Once the new pipe and cleanouts were in place and all the reconnections completed, the pits were backfilled and any required surface restorations made.

A.10.5 Cost Analysis

This project was done many years ago and the project manager for the District has in the meantime left the agency, so it is hard to explain why the contractor billed the quantities shown in the table (water exfiltration test on 106 laterals only, reconnection after sliplining of 55 laterals only). The cost of construction was paid in full by the District.

Table A-48. Stege, CA, Sliplining, 1987: Summary of Costs.

Activity	Unit Price	Quantity	Amount	Average
Mainlines				
Sliplining of 8”	$29.00/ft	2,445’	$70,905	
Sliplining of 6”	$25.00/ft	11,018’	$275,450	
Mainline air testing, reopen laterals and point repairs		LS	$444,733	
TOTAL—Mainlines only		13,463’	$791,088	$58.76/ft ($55.00-65.00/ft)
Laterals				
Cleaning	$1.00/ft	5,930’	$5,930	
Locate and disconnect laterals;				
And Water exfiltration test	$500.00/lateral	106 laterals	$53,000	
Sliplining of 4”	$16.00/ft	7,160’	$114,560	
Air testing of laterals;				
And Reconnect lateral to mainline	$500/lateral	55 laterals[68]	$27,500	
New cleanout installation	$400/cleanout	131 cleanouts	$52,400	
Point repairs	$450/ea	281	$126,450	
TOTAL—Laterals only		111 laterals	$379,840	$3,422/lateral ($53.00/ft)

A.10.6 Project Duration

The construction work was organized with a goal to save homeowners from disruption of service. Thus, the work on each lateral was planned and usually completed within a 24-hour period, and any sewage from the home was flowing into the pit at the planned cleanout location adjacent to the home.

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[68] *The contractor charged for reconnection of only 55 laterals.*

Table A-49. Stege, CA, Sliplining, 1987: Duration of Construction Work on Each Lateral.

Activity	Average Duration
Water exfiltration test	1 hr
Pit excavation, pipe fusing	4 hrs
Sliplining	3 hrs
Lateral segments reconnection; cleanout installation	3 hrs
Air testing	Included as bid item.
Reconnection to mainline and the house	Included as bid item.
Surface restoration	Up to 3 months

In cases where the work was not completed in a timely fashion, the Contractor had to be sure to plate over the cleanout pit to control odors and prevent passersby or family pets from falling into the pit. In fact, a separate subcontractor performed the pit closing and surface restoration, and his work was often several days behind the schedule. Thus, even with sliplining completed and all the pipes reconnected and in service, the pits stayed open longer than necessary, which was a problem for the Contractor and the District in public relations.

Overall, a two-person crew for the contractor was able to complete the pipe work at a rate of about one lateral per day. The project took approximately 90 working days.

A.10.7 Public Relations

With an objective to test the effectiveness of comprehensive mainline/lateral sliplining in regards to I/I reduction, the District made a decision to pay in full for the rehabilitation of private laterals. If the method were shown to be successful, the homeowners would be advised in the future to rehabilitate laterals at their own cost.

The district obtained temporary ownership of the laterals (see access agreement below), which resolved the liability issues of entering the private property.

Table A-50. Stege, CA, Sliplining, 1987: Public Information Program.

Activity	Result
Pre-construction phase (Dec 1986-May 1987)	
Mailing list of property homeowners in the area developed	
Information brochure about the project mailed to the homeowners	
Access agreement prepared	
Two neighborhood meetings held [69]	Low attendance: only 18 of 111 homeowners attended, only 15 signed the agreement promptly.
Access agreement mailed[70] to homeowners emphasizing "no-cost" to them	Over 75 agreements signed in three weeks.
Direct customer contact	The remaining needed signatures obtained.
Construction phase (Jun-Sep 1987)	
Weekly schedules to the affected property homeowners mailed	
Door hanger notices about the work posted 7-days in advance	
"Hot line" for customer questions/complaints established	
Photo ID cards for the personnel[71] entering private properties made	
Problems monitored and resolved immediately [72]	
Post construction (less than 6months)	
Letters informing of completed work and return of ownership mailed	
A questionnaire to evaluate the customer satisfaction with the public information program and contractor performance mailed (Figure A-134)	56 of 111 homeowners responded
Post-construction complaints resolved	
Report of the questionnaire findings prepared	

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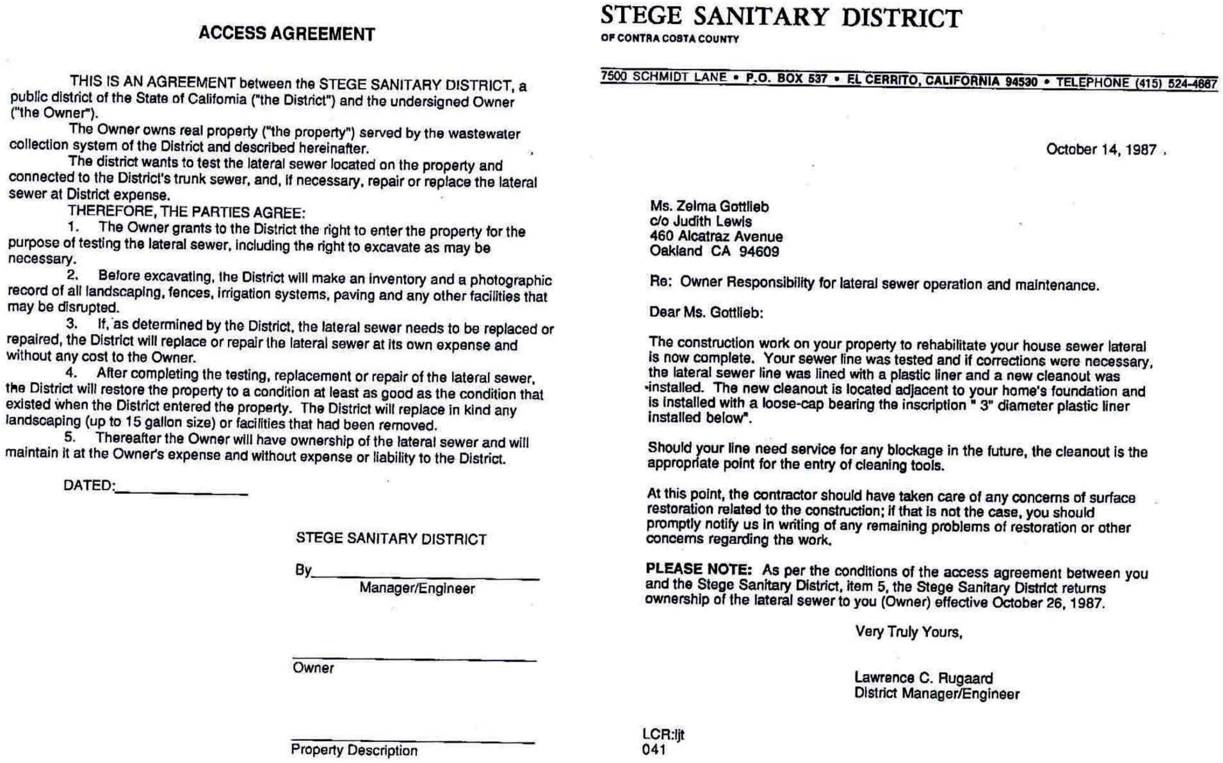
[69] *Friday evening/Saturday morning, in January 1987.*
[70] *Several mailings were made to reluctant homeowners.*
[71] *District and contractor.*
[72] *While the contractor was still on the job.*



ACCESS AGREEMENT

THIS IS AN AGREEMENT between the STEGE SANITARY DISTRICT, a public district of the State of California ("the District") and the undersigned Owner ("the Owner").

The Owner owns real property ("the property") served by the wastewater collection system of the District and described hereinafter.

The district wants to test the lateral sewer located on the property and connected to the District's trunk sewer, and, if necessary, repair or replace the lateral sewer at District expense.

THEREFORE, THE PARTIES AGREE:

1. The Owner grants to the District the right to enter the property for the purpose of testing the lateral sewer, including the right to excavate as may be necessary.
2. Before excavating, the District will make an inventory and a photographic record of all landscaping, fences, irrigation systems, paving and any other facilities that may be disrupted.
3. If, as determined by the District, the lateral sewer needs to be replaced or repaired, the District will replace or repair the lateral sewer at its own expense and without any cost to the Owner.
4. After completing the testing, replacement or repair of the lateral sewer, the District will restore the property to a condition at least as good as the condition that existed when the District entered the property. The District will replace in kind any landscaping (up to 15 gallon size) or facilities that had been removed.
5. Thereafter the Owner will have ownership of the lateral sewer and will maintain it at the Owner's expense and without expense or liability to the District.

DATED:______________

STEGE SANITARY DISTRICT

By______________________
Manager/Engineer

____
Owner

____
Property Description

STEGE SANITARY DISTRICT
OF CONTRA COSTA COUNTY
7500 SCHMIDT LANE • P.O. BOX 537 • EL CERRITO, CALIFORNIA 94530 • TELEPHONE (415) 524-4667

October 14, 1987

Ms. Zelma Gottlieb
c/o Judith Lewis
460 Alcatraz Avenue
Oakland CA 94609

Re: Owner Responsibility for lateral sewer operation and maintenance.

Dear Ms. Gottlieb:

The construction work on your property to rehabilitate your house sewer lateral is now complete. Your sewer line was tested and if corrections were necessary, the lateral sewer line was lined with a plastic liner and a new cleanout was installed. The new cleanout is located adjacent to your home's foundation and is installed with a loose-cap bearing the inscription " 3" diameter plastic liner installed below".

Should your line need service for any blockage in the future, the cleanout is the appropriate point for the entry of cleaning tools.

At this point, the contractor should have taken care of any concerns of surface restoration related to the construction; if that is not the case, you should promptly notify us in writing of any remaining problems of restoration or other concerns regarding the work.

PLEASE NOTE: As per the conditions of the access agreement between you and the Stege Sanitary District, item 5, the Stege Sanitary District returns ownership of the lateral sewer to you (Owner) effective October 26, 1987.

Very Truly Yours,

Lawrence C. Rugaard
District Manager/Engineer

LCR:ljt
041

Figure A-133. Left: Access Agreement Allowing the Crew to Enter Private Property. Right: Letter Informing About Completed Work and Return of Lateral Ownership—Responsibility for Maintenance.

Table A-51 summarizes the results of a survey questionnaire. Half of the homeowners (56 of 111) responded to the questionnaire[73]. The activities were rated based on the average score, where each answer scored as follows: Poor = 0.33, Fair = 0.67, Good = 1.00.

Table A-51. Stege, CA, Sliplining, 1987: Customer Satisfaction with Public Information Program/Contractor Performance.

Activity	Rating	Average Score	Answers
1. The neighborhood meeting (Jan 1987) addressing individual concerns/questions	Good	0.82	15
2. The I/I information package accompanying the Access Agreement	Good	0.78	28
3. Direct mailings and door hangers	Good	0.93	47
4. Work on the property (time, efficiency)	Fair	0.55	52
5. Construction crews (courteousness, considerate)	Good	0.91	53
6. District office handling the calls/complaints (speed, courteousness)	Good	0.80	30
7. Restoration of property after completed work (speed)	Fair/Good	0.67	53

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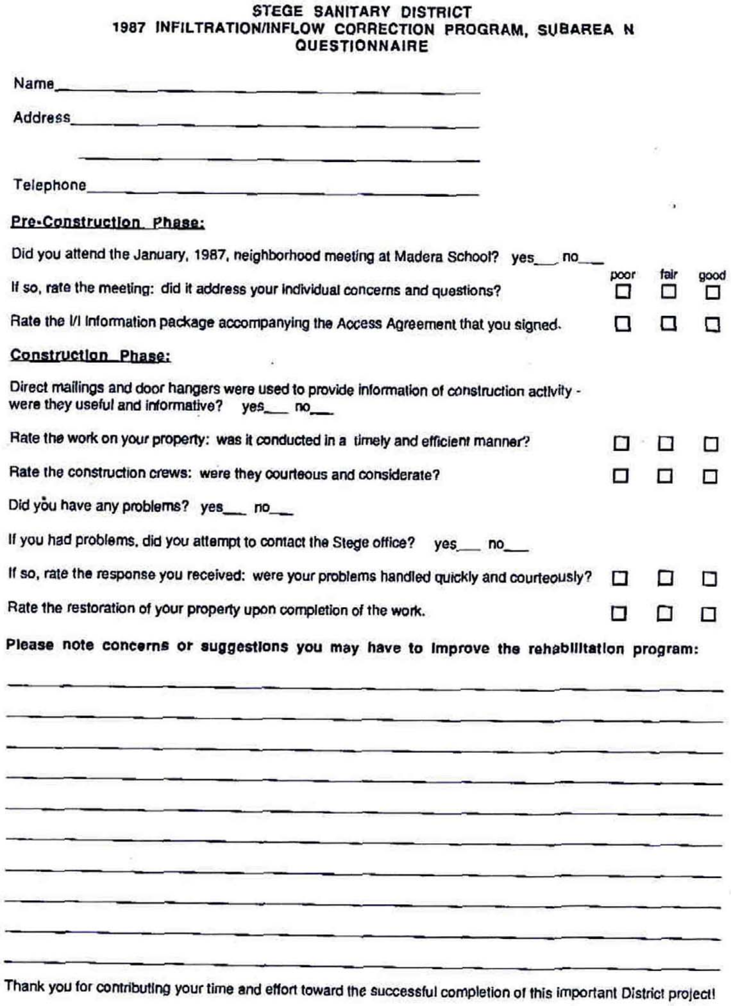
[73] *The questionnaire had 10 questions but some questions were conditional (if the homeowner attended the meeting, had contacted the District office with a problem, etc.) and the responses typically had less than 10 answers.*



STEGE SANITARY DISTRICT
1987 INFILTRATION/INFLOW CORRECTION PROGRAM, SUBAREA N
QUESTIONNAIRE

Name______________________________

Address______________________________

____

Telephone______________________________

Pre-Construction Phase:

Did you attend the January, 1987, neighborhood meeting at Madera School? yes___ no___

	poor	fair	good
If so, rate the meeting: did it address your individual concerns and questions?	☐	☐	☐
Rate the I/I Information package accompanying the Access Agreement that you signed.	☐	☐	☐

Construction Phase:

Direct mailings and door hangers were used to provide information of construction activity - were they useful and informative? yes___ no___

	poor	fair	good
Rate the work on your property: was it conducted in a timely and efficient manner?	☐	☐	☐
Rate the construction crews: were they courteous and considerate?	☐	☐	☐

Did you have any problems? yes___ no___

If you had problems, did you attempt to contact the Stege office? yes___ no___

	poor	fair	good
If so, rate the response you received: were your problems handled quickly and courteously?	☐	☐	☐
Rate the restoration of your property upon completion of the work.	☐	☐	☐

Please note concerns or suggestions you may have to improve the rehabilitation program:

Thank you for contributing your time and effort toward the successful completion of this important District project!

Figure A-134. Questionnaire about Customer Satisfaction with the Public Information Program.

A.10.8 Effectiveness of Rehabilitation

Pre-rehabilitation I/I was determined during the I/I study by flow monitoring. The cost-effectiveness goal for the project sub-basin was a 55% reduction in RDII. Ten distinct storms were selected from two months of flow and rainfall monitoring to determine I/I volume. Linear regression was performed on the pre-rehab and post-rehab data, and the I/I reduction volumes were determined. The actual I/I reduction as a result of the sub-basin rehabilitation work was 86%.

APPENDIX B

COMMERCIAL SYSTEMS FOR LATERAL CCTV INSPECTION

This appendix reviews systems for lateral CCTV inspection currently found to be available on the market. The information and data shown are provided by the manufacturers. Any omission of an additional commercial lateral CCTV system is inadvertent and does not imply any quality judgment.

Page:

Self-propelled commercial systems for lateral CCTV inspection:

Push-type commercial systems for lateral CCTV inspection:

B.1 Aries Industries (Waukesha, WI): LETS® [74]

Table B-1. General Information.

Description	Mainline and from mainline launched (self-propelled) lateral CCTV inspection system
Internet	www.ariesindustries.com
History	Developed in U.S. in (1997).
Market	Used in U.S. and Canada. Also in Mexico, Philippines.
Contact	Dan Bodendorfer, P. (800) 234-7205, daniel.bodendorfer@ariesindustries.com

Figure B- 1. Two LETS® Models. Left: LETS® Pan & Tilt. Right: Variable Chute Launch LETS®.

Table B-2. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	48 white LED's with 10,000 hr life cycle
Camera head diameter	1.8" diameter	Stainless steel housing
Camera self-leveling	Yes	Standard
Monitor	Any make or model, color or B&W	
Resolution	570 TV lines (horizontal)	
VCR recording	Yes (4-Head)	
DVD recording	Yes	
Transfer to CD-ROM	Yes, via Inspection Software	
Sonde for locating	Yes—standard, 512 Hz	
Access point	Mainline, 8-48"	
Max. length of single run	2,000' (standard)	
Lateral pipe diameter (ID)	2-10"	
Bends in lateral pipe	Yes, multiple 90°	
Lateral-to-mainline connect.	Tee or Wye	No limitations
Vertical riser in lateral pipe	Yes	
Speed of inspection	15 ft/min	
Duration of inspection	6-7 minutes	With setup, for a 50' lateral
Daily inspection rate	Up to 50 laterals in one working day (8 hrs)	On average, assuming 50' laterals

---

[74] *LETS stands for Lateral Evaluation Television System.*

B.2 CUES (Orlando, FL): LAMP®[75]

Table B-3. General Information.

Description	Mainline and from mainline launched (self-propelled) lateral CCTV inspection system
Internet	www.cuesinc.com
History	Developed in U.S. in 2001.
Market	Used in U.S. and Canada.
Contact	Paul Stenzler, P. (800) 327-7790, pauls@cuesinc.com

Figure B-2. Left: LAMP System (with Push Cable). Right: LAMP Launched into the Lateral.

Table B-4. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	
Camera head diameter	1.5”	Mainline camera: 1.5”, pan & tilt
Camera self-leveling	Yes—optional	
Monitor	9” or 17” color (industrial models only)	
Resolution	460 lines (horizontal)	
VCR recording	Yes	(4-Head)
DVD recording	Yes—optional	
Transfer to CD-ROM	Yes—optional	
Sonde for locating	Yes—optional	
Access point	Mainline, 8-36”	
Max. length of single run	100’	1,000’ for mainline
Lateral pipe diameter (ID)	3-8”	
Bends in lateral pipe	Multiple 45° and 90° bends	
Lateral-to-mainline connect.	Tee, Wye, or Chimney	
Vertical riser in lateral pipe	Yes	
Speed of inspection	30 ft/min	Mainline inspection: 60 ft/min
Duration of inspection	3.5-4.0 minutes	With setup, for a 50’ lateral
Daily inspection rate	Up to 35-50 laterals in one working day (8 hrs)	On average, assuming 50’ laterals

---

[75] *LAMP stands for Lateral and Mainline Probe.*

B.3 Hydrovideo (Durtal, France): Satel 200

Table B-5. General Information.

Description	Mainline and from mainline launched (self-propelled) lateral CCTV inspection system
Internet	www.hydrovideo.com
History	Developed in France in 1987.
Market	Used in France and worldwide.
Contact	Stephane Thevenot, P. 00-33-2-41-76-01-90, hydrovideo@wanadoo.fr

Figure B-3. Satel 200.

Table B-6. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	
Camera head diameter	2.2"	56 mm
Camera self-leveling	No	
Monitor	9" color	23 cm
Resolution	460 TV lines (horizontal)	
VCR recording	Yes	4-Head
DVD recording	Yes	Portable digital recorder (MPEG4)
Transfer to CD-ROM	Yes	At the office from the digital recorded video (MPEG4)
Sonde for locating	No	
Access point	Mainline, 8" or up	200 mm or up
Max. length of single run	66', plus 500' distance from mainline entry	20m, plus 150 m distance from mainline entry
Lateral pipe diameter (ID)		
Bends in lateral pipe		
Lateral-to-mainline connect.	Tee or Wye	No limitations
Vertical riser in lateral pipe		
Speed of inspection		
Duration of inspection		
Daily inspection rate	Up to 30 laterals in one working day (8 hrs)	On average, assuming 50' laterals

B.4 IBAK (Kiel, Germany): LISY 150M

Table B-7.General Information.

Description	Mainline and from mainline launched (self-propelled) lateral CCTV inspection system, used with Juno (a camera with fixed lens) or optionally Orion (pan-and-tilt).
Internet	http://www.ibak.de/layouts/standard.asp?m_id=151 www.rapidview.com
History	The system was developed in Germany in 1992 and commercialized in 1993.
Market	The system is sold all over Europe and is available in the U.S.
Contact	Matt Sutton, *RapidView IBAK U.S.*, P. (574) 223-5426, matt@rapidview.com Anja Wilhelm, *IBAK Helmut Hunger GmbH & Co. KG*, P. 49+431-72-70-391, a.wilhelm@ibak.de

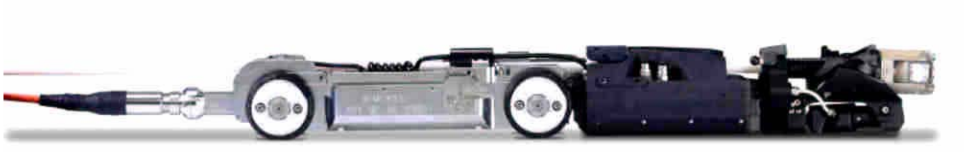


Figure B- 4. LISY 150M System.

Table B-8. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	
Camera head diameter	2.36” (Orion)	
Camera self-leveling	Yes	
Monitor	10” Color	In the portable control unit. Larger monitors are available if the system is truck-mounted.
Resolution	350 TV lines (horizontal)	
VCR recording	Yes	
DVD recording	Yes—Optional	
Transfer to CD-ROM	Yes—Optional	
Sonde for locating	Yes	33 mHz
Access point	Mainline, 6-40”	
Max. length of single run	110’ in the lateral (330’ in the mainline)	33 m in the lateral (100 m in the mainline)
Lateral pipe diameter (ID)	4-8”	
Bends in lateral pipe	Multiple 45° and 90° bends	The ORION-L lateral camera also allows navigation of bends and Tees, and is usable with the LISY 150M system
Lateral-to-mainline connect.	Tee or Wye	No limitations
Vertical riser in lateral pipe	Yes	
Speed of inspection	75 ft/min	2 m/min
Duration of inspection	About 5-15 minutes per lateral	With setup, assuming a 50’ sewer lateral
Daily inspection rate	Approx 25 laterals per day (8 hours)	

B.5 RS Technical Services (Petaluma, CA): RST Lateral Inspection System

Table B-9. General Information.

Description	A self-propelled lateral inspection system launched from a mainline
Internet	www.rstechserv.com
History	Developed in U.S. in 2000/01, commercialized in 2004
Market	Used in U.S., Canada, Mexico, Central South America.
Contact	Marilyn Shepard, P. (800) 767-1974, mrsrst@msn.com Rod Sutliff, P. (800) 767-1974, rsutliff@rstechserv.com

Figure B- 5. Left: RST Lateral Inspection System. Right: Close View of Lateral Camera.

Table B-10. System Features.

Feature	Description	Comment
Lighting	Eight high intensity white LED's	Illuminates 3-16" pipes
Camera head diameter	1.31"	
Camera self-leveling	Yes	
Monitor	Color	
Resolution	480 TV lines (horizontal)	
VCR recording	Yes	
DVD recording	Yes	With DVD recording device
Transfer to CD-ROM	Yes	With software
Sonde for locating	Yes	
Access point	Mainline, 8-24"	
Max. length of single run	100'	At a distance up to 1,000' from a manhole
Lateral pipe diameter (ID)	4-8"	
Bends in lateral pipe	Multiple 45°	90° bends are harder but will push beyond as long as the pipe permits
Lateral-to-mainline connect.	Tee or Wye	No limitations
Vertical riser in lateral pipe	Yes	
Speed of inspection	30 ft/min	
Duration of inspection	2 hours	With setup, assuming a 300' mainline and 5 number of laterals
Daily inspection rate	Up to 20 typical laterals in one working day (8 hrs)	On average, assuming 50' laterals

B.6 Sewer Depot Inc. (Mississauga, ON, Canada): Lateral Navigator

Table B-11. General Information.

Description	Mainline and from mainline launched (self-propelled) lateral CCTV inspection system
Internet	www.sewerdepot.com
History	Developed in 2000
Market	Used in U.S. and Canada
Contact	Mike Akermanis, P. (905) 795-7913 or (877) 730-7010, sales@sewerdepot.com

Figure B-6. Lateral Navigator.

Table B-12. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	
Camera head diameter	1.25”	Additional two mainline cameras are onboard: one front view camera and one side view camera
Camera self-leveling	Yes—Optional	
Monitor	Color	
Resolution	470 TV lines (horizontal)	
VCR recording	Yes (4-Head)	
DVD recording	Yes	
Transfer to CD-ROM	Available	
Sonde for locating	Yes	
Access point	Mainline, 6- 36”	
Max length of single run	200’ lateral	500’ mainline
Lateral pipe diameter (ID)	2-10”	
Bends in lateral pipe	Up to 90º	
Lateral-to-mainline connect.	Tee or Wye	No limitations
Vertical riser in lateral pipe	Yes	
Speed of inspection	30 ft/min	
Duration of inspection	45 minutes	Approximately, assuming a setup, inspection of 500’ mainline and 3-50’ laterals
Daily inspection rate	Up to 30-35 laterals in one working day (8 hours)	On average, assuming 50’ laterals

B.7 Aries Industries (Wakukesha, WI): Seeker®; Saturn III Push System®

Table B-13. General Information.

Description	Push-type lateral CCTV inspection system with two camera options:
Internet	www.ariesindustries.com
History	Developed in U.S.: Seeker® in 2000 and Saturn III® in 1997.
Market	Used in U.S. and Canada. Also in Mexico, Brazil, Puerto Rico, Middle East and Far East Regions, Central and South America.
Contact	Dan Bodendorfer, P. (800) 234-7205, daniel.bodendorfer@ariesindustries.com

Figure B- 7. Left: Seeker®. Right: Saturn III®.

Table B-14. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	48 white LED's with 10,000 hr life cycle
Camera head diameter	1.8" diameter	Stainless steel housing
Camera self-leveling	Yes (standard)	
Monitor	6.4" LCD color	Seeker®
	9" color (Model JVC)	Saturn III®
Resolution	570 TV lines (horizontal)	
VCR recording	Yes	
DVD recording	Yes	
Transfer to CD-ROM	Yes, via inspection software	
Sonde for locating	Yes—Standard, 512 Hz	
Access point	Cleanout, small pit or manhole	
Max. length of single run	100' (standard), 300' (optional)	Seeker®
	200' (standard), 400' (optional)	Saturn III®
Lateral pipe diameter (ID)	2-15"	
Bends in lateral pipe	Up to 90º	
Vertical riser in lateral pipe	Yes	
Speed of inspection	Operator dependant	
Duration of inspection	Varies with operator	
Daily inspection rate	Varies with operator	

B.8 CUES (Orlando, FL): MiniPush 20 20

Table B-15. General Information.

Description	Push-type lateral CCTV inspection system with two camera options:
Internet	www.cuesinc.com
History	Developed in U.S. in late 1999
Market	Used in U.S., Canada, South America, Europe, and Asia.
Contact	Paul Stenzler, P. (800) 327-7790, pauls@cuesinc.com

Figure B-8. Left: Mini-Push 20 20. Right: PS3 Camera.

Table B-16. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	
Camera head diameter	1.5”	
Camera self-leveling	Yes—optional	
Monitor	6.4” LCD—Tiltable	
Resolution	460 lines (horizontal)	
VCR recording	Yes	4-Head
DVD recording	Yes—optional	
Transfer to CD-ROM	Yes—optional	
Sonde for locating	Yes—optional	
Access point	Cleanout or a small pit.	
Max. length of single run	200’ (standard) or 300’ (optional)	
Lateral pipe diameter (ID)	2-15”	
Bends in lateral pipe	Multiple 45° and 90° bends	
Vertical riser in lateral pipe		
Speed of inspection	Hard to specify	Varies per operator and conditions
Duration of inspection	Hard to specify	Varies per operator and conditions
Daily inspection rate	Up to 50 laterals in one working day (8 hrs)	On average, assuming 50’ laterals

B.9 Hydrovideo (Durtal, France): Mini; Evolutis

Table B-17.General Information.

Description	Push-type lateral CCTV inspection systems, each compatible with several cameras Mini with BO37 and BO49 Evolutis with TA 49 (Color); TO 70 (Rotating Head); and TO 100 Zoom Camera
Internet	www.hydrovideo.com
History	Developed in France in 1987
Market	Used in France and worldwide
Contact	Stephane Thevenot, P. 00-33-2-41-76-01-90, hydrovideo@wanadoo.fr

Figure B-9. Left Two: Hydrovideo Mini. Right: Evolutis.

Table B-18. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	
Camera head diameter	1.5-2"	37-49 mm, depending on camera
Camera self-leveling	Yes—Optional with some cameras	
Monitor	6.8" color LCD	
Resolution	460 TV lines (horizontal)	
VCR recording	Yes	4-Head
DVD recording	Yes	Portable digital recorder (MPEG4)
Transfer to CD-ROM	Yes	At the office from the digital recorded video (MPEG4)
Sonde for locating?	Yes	
Access point	Cleanout or a small pit	
Max. length of single run	105' (standard), up to 165'	30 m (standard), up to 50 m
Lateral pipe diameter (ID)	1.5-10"	40-250 mm, depending on camera
Bends in lateral pipe	Up to 90º	With BO 37 camera
Speed of inspection	30 ft/min	
Duration of inspection	About 5 min	With setup, assuming 50' lateral
Daily inspection rate	Up to 30 laterals in one working day (8 hrs)	On average, assuming 50' laterals

B.10 Pearpoint, Inc. (Thousand Palms, CA): P571 Flexicoiler

Table B-19.General Information.

Description	Push-type lateral CCTV inspection system with two camera options: P415Mk2 or P455 Twinview
Internet	http://www.pearpoint.com
History	Developed in U.K. in the mid 1990s
Market	Used in U.S. and around the world.
Contact	Suzan Marie Chin, P. (760) 343-7350 x 233, Suzan.Chin@radiodetection.spx.com

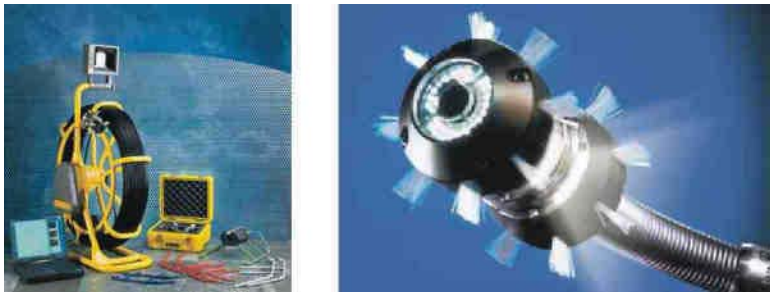


Figure B-10. Left: P571 Flexicoiler. Right: P455 Twinview Camera.

Table B-20. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	
Camera head diameter	1.73” (P415Mk2) or 2.36” (P455)	
Camera self-leveling	Yes	P415Mk2 is forward view camera only, P455 is forward view and side view rotating camera
Monitor	5.6” Built-in LED	
Resolution	450 TV lines (horizontal)	(Approx. lines per picture height)
	Pixels 760×492 NTSC; 760×582 PAL	
	Sensitivity 1 lux (approx)	
VCR recording	Yes	Composite video input/output for any external recording system
DVD recording	Yes	
Transfer to CD-ROM	Yes	
Sonde for locating?	Yes	
Access point	Cleanout, manhole or a small pit.	Requires a minimum 4” diameter access point.
Max length of single run	500’ (standard)	
Lateral pipe diameter (ID)	3-24”	
Bends in lateral pipe	Up to 90º	
Speed of inspection	Determined by operator	
Duration of inspection	5-10 minutes per lateral	On average, assuming 50’ laterals
Daily inspection rate	On the order of 15-20 laterals per day if located in close proximity (same neighborhood), or 2-4 laterals per day if spread across miles.	

B.11 Pearpoint, Inc. (Thousand Palms, CA): GatorCam2

Table B-21. General Information.

Description	Push-type lateral CCTV inspection system
Internet	http://www.pearpoint.com
History	Developed in U.K. in the mid 1990s
Market	Used in U.S. and around the world.
Contact	Suzan Marie Chin, P. (760) 343-7350 x 233, Suzan.Chin@radiodetection.spx.com

Figure B- 11. Left: GatorCam2. Right: P392 Camera.

Table B-22. System Features.

Feature	Description	Comment
Lighting	Built-in hi-intensity LED lighting	
Camera head diameter	1.5"	
Camera self-leveling	Optional	
Monitor	9" color	
Resolution	570 TV lines (horizontal)	
VCR recording	Yes	
DVD recording	Yes	
Transfer to CD-ROM	Yes	
Sonde for locating?	Yes	
Access point	Cleanout or a small pit.	
Max. length of single run	200' (standard)/400' (optional)	
Lateral pipe diameter (ID)	2-10"	
Bends in lateral pipe	Up to 90º	
Speed of inspection	Determined by operator	
Duration of inspection	5-10 minutes per lateral	On average, assuming 50' laterals
Daily inspection rate	On the order of 15-20 laterals per day if located in close proximity (same neighborhood), or 2-4 laterals per day if spread across miles.	

B.12 Ratech Electronics (Vaughan, ON, Canada): Plumber's Elite Series; Plumber's Mate; Plumber's Inspector PC; Plumber's Fast Peek

Table B-23. General Information.

Description	Push-type lateral CCTV inspection systems with different monitors and data recording options
Internet	www.ratech-electronics.com
History	Developed in 2001 (Elite); 1998 (Mate); 2003 (Inspector PC); 2000 (Fast Peek)
Market	Used worldwide.
Contact	Rocky Veselisin, P. (800) 461-9200, sales@ratech-electronics.com

Figure B-12. From Left to Right: 1) Plumber's Elite-Duo; 2) Mate; 3) Inspector PC; 4) Fast Peek; 5) Camera Head.

Table B-24. System Features.

Feature	Description	Comment
Lighting	Variable high intensity LED lighting	With polycarbonate cover
Camera head diameter	1.375" color and 1.2" black and white	
Camera self-leveling	1.375" color self leveling camera	
Monitor	15" high resolution flat panel LCD monitor	Plumber's Elite Series
	9" high resolution industrial CRT monitor	Plumber's Mate
	Variable (depends on laptop, usually 15-17")	Plumber's Inspector PC
	7" high resolution LCD monitor w/speaker	Plumber's Fast Peek
Resolution	380TVL or 470 TVL (enhanced)	
VCR recording	Yes (4 Head Hi-Fi VCR)	Plumber's Elite Series; Plumber's Mate
	No	Plumber's Inspector PC
	Optional	Plumber's Fast Peek
DVD recording	Yes (DVD recorder with 160 gig hard drive)	Plumber's Elite Series
	Optional	Plumber's Mate
	Yes [76]	Plumber's Inspector PC
	Optional	Plumber's Fast Peek
Transfer to CD-ROM	NA	Plumber's Elite Series; Plumber's Mate
	Yes [77]	Plumber's Inspector PC
	No	Plumber's Fast Peek
Sonde for locating	Yes (512Hz Sonde Transmitter)	
Access point	Cleanout or a small pit	
Max. length of single run	200' standard with optional 300' and 400'	
Lateral pipe diameter (ID)	2-2"	
Bends in lateral pipe	Multiple 45° and 90° bends	
Daily inspection rate	25-50 Inspections Daily	

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[76] *Capture digital MPEG -1, 2 and 4 via laptop computer with auto generated lateral reports via software, JPEG image capture*

[77] *Store and burn MPEG video, JPEG images and reports to DVD-/+R or CD-ROM*

B.13 The Ridge Tool Co. (Elyria, OH): Ridgid SeeSnake Systems

Table B-25. General Information.

Description	Push-type lateral CCTV inspection system (four systems as shown in Figure B-13)
Internet	www.seesnake.com
History	Developed in U.S. and commercialized In 1996
Market	Used in U.S. and worldwide (Canada, South America, Europe, Asia)
Contact	Technical Service Department, P. (800) 519-3456, online email: www.ridgidtechnicalservice.com

Figure B-13. From Left to Right: Ridgid SeeSnake Systems (Plus; Mini Plus; FlatPack Plus; Compact Plus), Self-Leveling Camera.

Table B-26. System Features.

Feature	Description	Comment
Lighting	High Intensity Fully Adjustable LED’s	
Camera head diameter	1.36” (Standard), 1.16” (Mini, Compact)	
Camera self-leveling	Yes	On systems designated “self leveling”
Monitor	10” color or 9” B&W	Additional 5” or 5.5” color monitors included in some toolboxes
Resolution	350 lines on color 400 on B&W (horizontal)	
VCR recording	Yes	
DVD recording	No	Not at this time
Transfer to CD-ROM	Yes	With a USB-LIVE adapter
Sonde for locating?	Yes	All systems contain locating sonde
Access point	Cleanout or small pit	
Max length of single run	325’; 200’; 100’; 100’	For systems in order as shown in Figure B-13
Lateral pipe diameter (ID)	2-12”; 1.25-6”; 1.5-4”; 1.5-4”	
Bends in lateral pipe	Up to two 90° bends and three P-traps	
Speed of inspection	Hard to specify	Varies
Duration of inspection	Hard to specify	Varies
Daily inspection rate	Hard to specify	Varies

B.14 RS Technical Services (Petaluma, CA): RST 1300 Series

Table B-27. General Information.

Description	Push-type lateral[78] CCTV inspection system (can be used on a self-propelled tractor)
Internet	www.rstechserv.com
History	Developed in U.S. and used since mid 1990s.
Market	Used in U.S., Canada, Mexico, Central South America
Contact	Marilyn Shepard, P. (800) 767-1974, mrsrst@msn.com Rod Sutliff, P. (800) 767-1974, rsutliff@rstechserv.com

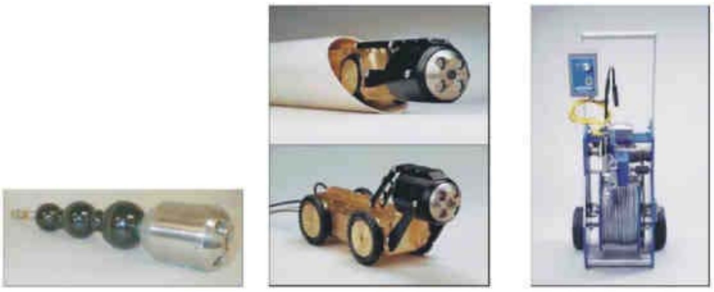

Figure B-14. Left: 1306 Mini Camera. Middle: Mighty Mini Tractor. Right: Compact Portable Reel.

Table B-28. System Features.

Feature	Description	Comment
Lighting	Four 3.8V xenon lamps, with reflectors	Illuminates 3-16” pipes
Camera head diameter	2.25”	
Camera self-leveling	No	
Monitor	9” Color	
Resolution	480 TV lines (horizontal)	
VCR recording	Yes	
DVD recording	Yes w DVD recorder option	
Transfer to CD-ROM	Yes	With Software, JPEG or MPEG Option
Sonde for locating?	Yes	
Access point	Cleanout	
Max. length of single run	1,000’	
Lateral pipe diameter (ID)	3-16”	4-10” with a tractor
Bends in lateral pipe	Multiple 90° in 4” or larger pipes	If used on a push cable. Tractor is capable of small deflection.
Speed of inspection	25 ft/min with a tractor, depends on operator with a push cable	With 2.5” tires on a tractor
Duration of inspection	10-20 minutes	With setup, assuming a 50’ lateral
Daily inspection rate	30-60 laterals per day	On average, assuming 50’ laterals

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[78] *1300 Series is also used in small mainlines (3”-16” in diameter).*

B.15 RS Technical Services (Petaluma, CA): RST 1500 Series

Table B-29. General Information.

Description	Push-type lateral CCTV inspection system with two camera options: 1530 or 1535
Internet	www.rstechserv.com
History	Developed in U.S. and used since mid 1990s.
Market	Used in U.S., Canada, Mexico, Central South America
Contact	Marilyn Shepard, P. (800) 767-1974, mrsrst@msn.com Rod Sutliff, P. (800) 767-1974, rsutliff@rstechserv.com

Figure B-15. Left: Complete RST 1500 System. Right: 1500 Series Ultra Mini Camera.

Table B-30. System Features.

Feature	Description	Comment
Lighting	Eight bright white LED lamps, with reflectors	Illuminates 1.75-6" pipes
Camera head diameter	1.31"	
Camera self-leveling	No	1530 camera is not self leveling, 1535 is
Monitor	9" Color	
Resolution	480 TV lines (horizontal)	
VCR recording	Yes	
DVD recording	Yes w DVD recorder option	
Transfer to CD-ROM	Yes	With Software, JPEG or MPEG Option
Sonde for locating?	Yes	
Access point	Cleanout	
Max. length of single run	400'	
Lateral pipe diameter (ID)	1.75-6"	
Bends in lateral pipe	Multiple 90° in 3" or larger pipes	If used on a push cable..
Speed of inspection	Depends on operator with a push cable	
Duration of inspection	10-20 minutes	With setup, assuming a 50' lateral
Daily inspection rate	30-60 laterals per day	On average, assuming 50' laterals

B.16 Scooter Video Inspection Systems (Tehachapi, CA): Scooter™ Mini

Table B-31. General Information.

Description	Push-type lateral CCTV inspection system (four systems available)
Internet	www.tvinspection.com/index.html
History	Developed in U.S.
Market	U.S.
Contact	Jerry Northcutt or Vince Villareal, P. (800) 772-6165, email: scooter1@lightspeed.net

Figure B-16. Left: Scooter™ Mini Camera on the Coiler. Right: Attach'e System.

Table B-32. System Features.

Feature	Description	Comment
Lighting	Lighting diffuser technology	
Camera head diameter	1.50" (Color and B&W)	
Camera self-leveling	Yes	Image inverter
Monitor	10" LCD (Attache) or 9" (B&W)	
Resolution	420 lines on color and B&W (horizontal)	
VCR recording	Yes	
DVD recording	Yes	
Transfer to CD-ROM	No	Not at this time
Sonde for locating?	Yes	Locating sonde can be added
Access point	Cleanout or small pit	
Max length of single run	200'	
Lateral pipe diameter (ID)	2-12"	
Bends in lateral pipe	Up to three 90° bends and though 2" P-traps	
Speed of inspection	Varies	
Duration of inspection	Varies	
Daily inspection rate	Varies	

APPENDIX C

SYSTEMS AND TECHNOLOGIES FOR LATERAL REHABILITATION

This appendix reviews rehabilitation systems and technologies currently found to be available on the market. The information and data shown are provided by the manufacturers and have not been independently verified. Any omission of an additional rehabilitation system is inadvertent and does not imply any quality judgment. For updated product information about these systems please refer to the TTC web page www.ttc.latech.edu.

C.1 Link Pipe (Richmond Hill, Ontario, Canada): DrainLiner™

Table C-1. General Information for DrainLiner™

Type	CIP—Standard Liner
Internet	http://www.linkpipe.com/drain.htm
History/availability	Developed in-house, 1999. Available in U.S., since 2001. Used in Canada.
Contact	Maria Liao, *Sales coordinator*, P. (905) 886-0335, mliao@linkpipe.com

Figure C-1. Left: Roller System. Middle: Inversion Drum. Right: Drain Repair Sleeve in Elbows.

Table C-2. System Features of DrainLiner™.

Feature	Description	Comment
Tube material	Polyester needle felt (stitched and fused)	Different suppliers
Protective coating	Polyurethane or PVC	PVC and PU (different suppliers)
Position of coating after inst.	Inside	Protects epoxy resin from exposure to sewage
Preliner	Polyethylene	To extend service life of resin
Resin type	Epoxy	By Link Pipe Inc
Resin impregnation	In-situ (vacuum impregnation)	Also wet-out rollers used
Nominal liner thickness	3.0 mm; 4.5 mm; 6.0 mm	
Liner insertion	Inversion (air-pressure) or winched in	Inversion drum used
Curing process	Hot water, ambient temperature	
Max length of single run	≤ 150’	
Lateral pipe diameter (ID)	4-8”	Typically used in 4-6”
Diameter transition in lateral	¼”	
Bends in lateral	45º bends	
Offset joints in lateral pipe	Yes	Link-Pipe stainless steel sleeves advised
Cracks, holes in lateral pipe	Yes	Link-Pipe stainless steel sleeves advised
Active leaks	Yes	
Roots, debris in lateral pipe	Yes	Root preventer sleeve recommended
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range	3-10	
Sewage max temperature	≤ 60ºC i.e. 140ºF	
Duration of repair	≤ 1-2 hrs (single lateral),	With hot water cure, Includes cleaning
Productivity	Up to 3-4 laterals in one working day	
Average cost	Confidential information	Varies with local conditions
Flexural modulus	297,000 psi	Exceeds ASTM D-790
Flexural strength	8,300 psi	Exceeds ASTM D-790
Tensile strength		See Flexural strength
Patents	NA	
Product testing	Triodem Laboratory (2001, 2002, 2003)	

C.2 Easy Liner Inc (Thomasville, PA): Cleanout Liner™ and House Liner™

Table C-3. General Information for Cleanout Liner™ and House Liner™

Type	CIP—Standard Liner
Internet	http://easy-liner.com
History/availability	Developed in Great Britain, 1989. Available in U.S., since 2000. Used in U.S., Europe, and Australia. Estimated 10,000' laterals relined in U.S. and 8,500,000' laterals worldwide.
Contact	Andrew Chettle, *Research and Development Engineer*, P. (888) 639-7717, andyc@easy-liner.com

Figure C-2. Left: Vacuum Impregnation. Middle: Calibration Rollers. Right: Inversion Drum to Receive Warm Water.

Table C-4. System Features of Cleanout Liner™ and House Liner™

Feature	Description	Comment
Tube material	Polyester (knitted or needle punched)	Cleanout Liner™ and House Liner™ respectively
Protective coating	PU or PVC	
Position of coating after inst.	Internal	
Preliner		
Resin type	Polyester or epoxy	
Resin impregnation	Automatic vacuum	
Nominal liner thickness	3-5 mm	
Liner insertion	Two stage or double inversion	
Curing process	Warm water (1hr) or ambient cure (2-3hr)	
Max length of single run	300'	
Lateral pipe diameter (ID)	2-6"	
Diameter transition in lateral	Up to 50%	E.g. 4" to 6"
Bends in lateral	Multiple 90 degree; single 45 degree	Cleanout Liner™ and House Liner™ respectively
Offset joints in lateral pipe	Up to 10% of diameter	
Cracks, holes in lateral pipe	Yes	
Active leaks	Yes	
Roots, debris in lateral pipe	Yes	
Flow isolation required	Yes if over 15% of bore of pipe	
Type of flow in lateral	Gravity	
Sewage pH range	N/a	
Sewage max temperature	160 deg F	
Duration of repair	1-3 hrs	Including cleaning, CCTV, demobilization
Productivity	4-6 per day	
Average cost	$2,500 – 3,500	
Flexural modulus	> 250,000 psi	
Flexural strength	> 4500 psi	
Tensile strength	N/a	
Patents	Patent applied	
Product testing	Third Party verification of compliance to ASTM F1216.	

C.3 Formadrain (Montreal, Quebec, Canada): Formadrain®

Table C-5. General Information for Formadrain®.

Type	CIP—Standard Liner
Internet	http://www.formadrain.com
History/availability	Developed in Montreal, Canada, 1994. Distributed and installed in North America. Over 25 installers.
Contact	Stephane Therrien, P. (888) 337-6764, stephane@formadrain.com

Figure C-3. Left: Liner Preparation. Right: Liner Insertion.

Table C-6. System Features of Formadrain®.

Feature	Description	Comment
Tube material	Bi-directional woven fiberglass, overlap sheet	Has very high mechanical resistance
Protective coating	Polyethylene	
Position of coating after inst.	Outside	
Preliner		
Resin type	100% solid epoxy	
Resin impregnation	On site (resin manually spread)	Using a spreader on each fiberglass sheet (2)
Nominal liner thickness	2.0 mm	
Liner insertion	Pull in place	Winched in place
Curing process	Steam	30-50 minutes
Max length of single run	100’	
Lateral pipe diameter (ID)	≥ 2” (unlimited)	
Diameter transition in lateral	One diameter size	For example 4” to 6”, 6” to 8”
Bends in lateral	Several 22°, 45°, and sweeping 90° bends	Multiple bends in a single pipeline
Offset joints in lateral pipe	≤ 2”	
Cracks, holes in lateral pipe	Yes	Can bridge missing pipe sections and gaps
Active leaks	Yes	May affect liner curing depending on water flow and pressure
Roots, debris in lateral pipe		
Flow isolation required	Yes	
Type of flow in lateral	Gravity or force mains	
Sewage pH range	Can tolerate very strong acids/basic chemicals	With FORMAPOX 301 industrial liner
Sewage max temperature	150º F	More than 300º F
Duration of repair		30-50 minutes (curing time)
Productivity	1-2 laterals in one crew day	
Average cost	$70-125/ft	
Flexural modulus	1,305,000 psi	ASTM D-790
Flexural strength	36,250 psi	ASTM D-790
Tensile strength	36,250 psi	ASTM D-638
Patents	NSF	
Product testing		

C.4 Reline America (Apalachin, NY): INFlex Liner™

Table C-7. General Information for INFlex Liner™.

Type	CIP—Standard Liner
Internet	http://www.brandenburger.de (US site under construction)
History/availability	Developed in Germany, 1993. Available in Europe and Japan. Expected in U.S. in 2005.
Contact	Michael Burkhard, P. (607) 625-4979, mlburkhard@stny.rr.com

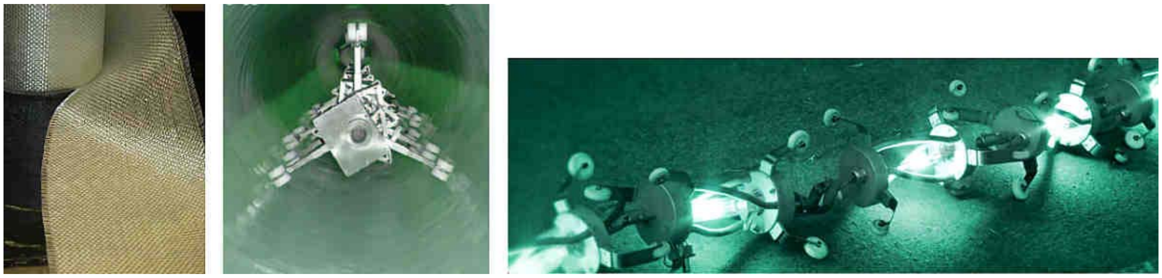

Figure C-4. Left: Tube. Middle: UV-light Source in the Pipe. Right: Several UV-lamps Used for Uniform Curing.

Table C-8. System Features of INFlex Liner™.

Feature	Description	Comment
Tube material	Polypropylene, polyester (needled), or fiberglass (woven)—stitched	Developed/made in house
Protective coating	PVC, polyurethane	Developed/made in house
Position of coating after inst.	Inside	Removed after UV-light curing
Preliner		
Resin type	Epoxy	Developed/made in house
Resin impregnation	In-situ (vacuum impregnation)	Calibration rollers used
Nominal liner thickness	2.0 mm	Can vary
Liner insertion	Inversion (air or water pressure)	Inversion gun can be used
Curing process	Hot water, ambient temperature, or UV-light	
Max length of single run	≤ 165' (50m)	
Lateral pipe diameter (ID)	3-12" (70-300 mm)	
Diameter transition in lateral	Will be made to customer's specifications	
Bends in lateral	Up to 90º bends	
Offset joints in lateral pipe	≤ 40% of diameter	
Cracks, holes in lateral pipe	Yes	Pipe must be reasonably structurally sound
Active leaks	Yes	Preliner or separate sealing in advance
Roots, debris in lateral pipe	Yes	Cleaning required to allow liner inversion
Flow isolation required	Yes	Lateral is plugged during relining
Type of flow in lateral	Gravity	
Sewage pH range		
Sewage max temperature		
Duration of repair	Up to 12 hrs if cold curing, faster if hot cure	
Productivity	Up to 8 laterals in one working day (8 hrs)	
Average cost	$700-2,500 per lateral	50' lateral, moderate root intrusion
Flexural modulus	417,000 psi	DIN EN ISO 178 (2,875 N/mm^2)
Flexural strength	8,990 psi	DIN EN ISO 178 (62 N/mm^2)
Tensile strength		
Patents		
Product testing	1992-1993 (Tested chemical and abrasion resistance, mechanical characteristics)	

C.5 Reynolds Inliner (Orleans, IN): Inserv™ (formerly Houseliner)

Table C-9. General Information for Inserv™.

Type	CIP—Standard Liner
Internet	NA
History/availability	Developed in U.S., 2003 Available in U.S. and Canada, about 100,000’ installed.
Contact	Denise McClanahan, P. (812) 865-3232 x.262, DMcClanahan@reynoldsinc.com

Figure C-5. InServ™. Left: Tube Material. Right: Insertion through a Small Pit.

Table C-10. System Features of Inserv™.

Feature	Description	Comment
Tube material	Polyester needled (stitched i.e. seamed)	Made by Liner Products.
Protective coating	Polyurethane	Developing PVC/polyurethane blend
Position of coating after inst.	Outside (between the liner and the host pipe)	Made by Liner Products
Preliner	Polyester resin	
Resin type	Factory pre-impregnated (vacuum)	Made by Reichhold or Interplastic.
Resin impregnation	3.75 mm (in 4” pipes), 4.5 mm (in 6” pipes)	Calibration rollers used
Nominal liner thickness	Inversion (air-pressure)	
Liner insertion	Hot water or steam (moving towards steam)	Inversion unit used
Curing process	≤ 60’	
Max length of single run	4-6”	
Lateral pipe diameter (ID)	4-6”	
Diameter transition in lateral	Up to two 90º bends	One-piece liner with two diameters
Bends in lateral	≤ 5% of pipe diameter	
Offset joints in lateral pipe	Yes	
Cracks, holes in lateral pipe	Yes	Can bridge missing parts (structural repair)
Active leaks	Yes	Preliner or chem. grout used for heavy leaks
Roots, debris in lateral pipe	Yes	Cleaning required to allow liner inversion
Flow isolation required	No	Lateral is plugged during relining.
Type of flow in lateral	Gravity	
Sewage pH range	1-12	Depends on resin used
Sewage max temperature	300º F	
Duration of repair	4 hrs (single lateral), 2.5 hrs (multiple laterals)	Includes cleaning
Productivity	Up to 3-4 laterals in one working day (8 hrs)	
Average cost	$3,000-3,200 per lateral	Includes InSeal, moderate root intrusion
Flexural modulus:	300,000-350,000 psi	ASTM D-790
Flexural strength	5,000-5,500 psi	ASTM D-790 (Expected)
Tensile strength	3,500-4,000 psi	ASTM D-638
Patents		
Product testing	HTS Lab, Houston, TX; Hauser Lab, Boulder, CO (2003 ongoing)—Flexural modulus, strength	

C.6 Easy Liner Inc (Thomasville, PA): Junction Liner ™

Table C-11. General Information for Junction Liner ™

Type	CIP—Standard Liner (remotely installed needing access from the main only)
Internet	http://easy-liner.com
History/availability	Developed in Great Britain, 2002. Available in U.S., since 2004. Used in UK, Europe, and U.S. Estimated 2,000' laterals relined in U.S. and 100,000' laterals worldwide.
Contact	Andrew Chettle, *Researc and Development Engineer*, P. (888) 639-7717, andyc@easy-liner.com

Figure C-6. Left: Liner Shown on Inverted Bladder. Middle: A 90° Junction Liner Right: A 45° Junction Liner

Table C-12. System Features of Junction Liner™

Feature	Description	Comment
Tube material	Polyester, knitted	
Protective coating	Polyester, needle punched	
Position of coating after inst.	PU or PVC	
Preliner	Internal	
Resin type	Polyester or epoxy	
Resin impregnation	Automatic vacuum	
Nominal liner thickness	3-5 mm	
Liner insertion	Inversion–remotely from the mainline	Special vessel tube is used.
Curing process	Ambient cure 1-2 hrs	
Mainline pipe diameter	8-15"	
Lateral pipe diameter (ID)	4-6"	
Diameter transition in lateral	4" to 6"	
Brim in the mainline	None	
Max length of single run	30-50'	
Bends in lateral	Multiple 45°	
Offset joints in lateral pipe	Up to 10%	
Cracks, holes in lateral pipe	Yes	
Active leaks	Yes	
Roots, debris in lateral pipe	Yes	
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range	N/a	
Sewage max temperature	160 deg F	
Duration of repair	1-2 hrs	Cleaning, CCTV, demobilization not included
Productivity	3-5 per day	
Average cost	$1,500-3,500	
Flexural modulus	> 250,000 psi	
Flexural strength	> 4500 psi	
Tensile strength	N/a	
Patents	Patent applied	
Product testing	(See Cleanout Liner™ and House Liner™)	

C.7 MaxLiner LCC (Martinsville, VA): MaxLiner™

Table C-13. General Information for MaxLiner™.

Type	CIP—Standard Liner
Internet	www.maxlinerusa.com
History/availability	Developed in Switzerland, 1995. Used worldwide, in U.S. since 1999 (estimated 5,000 laterals relined).
Contact	Tim Moody, *New England Sales Representative*, P. (603) 312-2132, moodys@empire.net

Figure C-7. MaxLiner. Left: Calibration Rollers. Middle: Liner Air Inversion with Liner Gun. Right: Bladder Inversion.

Table C-14. System Features of MaxLiner™.

Feature	Description	Comment
Tube material	Polyethylene, woven or needled (stitched)	Made in-house
Protective coating	Polyurethane	In-house
Position of coating after inst.	Outside	Between liner and host pipe
Preliner		
Resin type	Epoxy resin	Two qualified companies (not specified)
Resin impregnation	In-situ (vacuum impregnation)	Calibration rollers used
Nominal liner thickness	4.5 mm	
Liner insertion	Inversion (air-pressure)	Inversion gun used
Curing process	Ambient temperature or hot water	
Max length of single run	≤ 200'.	
Lateral pipe diameter (ID)	2-10"	
Diameter transition in lateral	4" to 6"; 6" to 8"; 8" to 10"	One-piece liner with midpoint diameter
Bends in lateral	Multiple 90° bends	
Offset joints in lateral pipe	≤ 15% of offset	
Cracks, holes in lateral pipe	Yes	Pipe must be reasonably structurally sound
Active leaks	Yes	Preliner used on most leaks, chemical grouting on heavy leaks.
Roots, debris in lateral pipe	Yes	Cleaning required to allow liner inversion
Flow isolation required	Yes	Lateral is plugged during relining.
Type of flow in lateral	Gravity	
Sewage pH range	Not determined	
Sewage max temperature	94° F	With MaxPox Thermo epoxy
Duration of repair	3-4 hrs (single lateral), 2-3 hrs (multiple)	
Productivity	Up to 4 laterals in one working day	With hot water cure, Includes cleaning
Average cost	$3,500-5,000 per lateral	Assuming 50' lateral, moderate root intrusion
Flexural modulus	250,000 psi	ASTM D-790
Flexural strength	4,500 psi	ASTM D-790
Tensile strength	3,000 psi	ASTM D-638
Patents	# 6,170,531 (01/09/01)	Flexible tubular lining material
Product testing		

C.8 Perma-Liner Industries, Inc. (Largo, FL): Perma-Lateral Lining System™

Table C-15. General Information for Perma-Lateral Lining System™.

Type	CIP—Standard Liner
Internet	www.perma-liner.com
History/availability	Developed in 1999 in Clearwater, FL. Distributed and installed worldwide. Over 300 installers
Contact	Travis Bohm, P. (727) 507-9749, travis@perma-liner.com

Figure C-8. Left: Liners 8” through 2”. Middle: Preparation for Air Inversion. Right: Liner in Broken Pipe Sample.

Table C-16. System Features of Perma-Lateral Lining System™.

Feature	Description	Comment
Tube material	Polyester needled (butt-fuse welded)	Has a thermo-bonded seam. Patented Material
Protective coating	PVC	
Position of coating after inst.	Inside	
Preliner		
Resin type	100% solids epoxy	
Resin impregnation	In situ (vacuum impregnation or rolled in)	Calibration rollers used
Nominal liner thickness	3.0 mm	
Liner insertion	Inversion (air-pressure)	Inversion unit used
Curing process	Ambient temperature	
Max length of single run	150’	
Lateral pipe diameter (ID)	2-8”	
Diameter transition in lateral	4” to 6”, 6” to 8”	
Bends in lateral	Several 22°, 45°, sweeping 90° bends	Multiple bends in a single pipeline
Offset joints in lateral pipe	≤ 2”	
Cracks, holes in lateral pipe	Yes	Can bridge missing pipe sections and gaps
Active leaks	Yes	No action needed (will cure under water)
Roots, debris in lateral pipe	Yes	Cleaning required to allow liner inversion
Flow isolation required	Yes	
Type of flow in lateral	Gravity or force lines	
Sewage pH range	Not determined	Like other CIP liners
Sewage max temperature	150º F	
Duration of repair	3 hrs	
Productivity	Up to 3-7 laterals in one working day	
Average cost	$75-150/ft	
Flexural modulus:	416,000 psi	ASTM D-790
Flexural strength	14,000 psi	ASTM D-790
Tensile strength	14,000 psi	ASTM D-638
Patents		
Product testing	NSF, IAPMO, CRT Labs, HTS Labs	

C.9 Primeline Products, Inc. (Edgewater, FL): Primeliner™ Lateral Lining System

Table C-17. General Information for Primeliner™ Lateral Lining System.

Type	CIP—Standard Liner
Internet	http://www.primelineproducts.com
History/availability	Developed in U.S., in 1999. Estimated over 100,000' repaired so far.
Contact	Bob Rothenburg, P. (877) 409-7888, bob@prime-line.net

Figure C-9. Primeliner Insertion Drum.

Table C-18. System Features of Primeliner™ Lateral Lining System.

Feature	Description	Comment
Tube material	Polyester Felt: needled (Stitched) or fiberglass	Made by MaxLiner or Applied Felts
Protective coating	Polyurethane or PVC	Made by MaxLiner or Applied Felts
Position of coating after inst.	Inside	
Preliner		
Resin type	Silicate	Made by Polinvent Budapest, Hungary
Resin impregnation	In-situ (vacuum impregnation)	Calibration rollers used
Nominal liner thickness	3.0, 4.5, 6.0 mm, or variable	
Liner insertion	Inversion (air-pressure)	Inversion drum used
Curing process	Ambient temperature or hot water	
Max length of single run	≤ 200'	
Lateral pipe diameter (ID)	2-8"	
Diameter transition in lateral	4" to 6"	One-piece liner for midpoint diameter
Bends in lateral	Several 90° bends	
Offset joints in lateral pipe	≤ 2"	
Cracks, holes in lateral pipe	Yes	Can bridge missing pipe sections and gaps
Active leaks	Yes	No action needed (will cure under water)
Roots, debris in lateral pipe	Yes	Cleaning required to allow liner inversion
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range		Like others
Sewage max temperature	150° F	
Duration of repair	2-3 hrs (single lateral), 1.5 hrs (multiple)	
Productivity	Up to 5-6 laterals in one crew day (8 hrs)	
Average cost	$750-2,500 per lateral	
Flexural modulus:	1,400,000 psi	ASTM D-790
Flexural strength	38,000 psi	ASTM D-790
Tensile strength	35,000 psi	ASTM D-790
Patents		
Product testing		

C.10 Verline (Houston, TX): Verline Lateral Rehabilitation System

Table C-19. General Information for Verline Lateral Rehabilitation System.

Type	CIP—Standard Liner
Internet	www.verline.com
History/availability	Developed in Houston, TX, 1999. Used only in U.S. so far, approximately 10,000' installed.
Contact	Bob Davis, P. (713) 622-5900, bdavis@verline.com

Figure C-10. Left: Inversion Drum. Right: Power Pack for Electric Curing.

Table C-20. System Features of Verline Lateral Rehabilitation System.

Feature	Description	Comment
Tube material	Polyester: knitted (seamless)	Haartz (a supplier), DayStar Composites
Protective coating	Polyethylene	
Position of coating after inst.	Inside	
Preliner		
Resin type	Polyester, vinyl ester or epoxy resin	By Reichhold, Interplastic, Dow, or others
Resin impregnation	Factory pre-impregnated (vacuum)	Calibration rollers used
Nominal liner thickness	3.0 mm, 4.5 mm, 6.0 mm	
Liner insertion	Inversion (air-pressure)	Inversion canister or gun used
Curing process	Electrically heated bladders or liner	Heating elements in the lining material
Max length of single run	≤ 120' usually	
Lateral pipe diameter (ID)	3-8"	
Diameter transition in lateral	4" to 6"	Other custom fabrications possible
Bends in lateral	Up to 90º bends	
Offset joints in lateral pipe	≤ 20% of pipe diameter	
Cracks, holes in lateral pipe	Yes	Can bridge ≤ 18" cracks or missing parts
Active leaks	Yes	Point repair (Hybrid composite) for heavy leaks
Roots, debris in lateral pipe	Yes	Cleaning required to allow liner inversion
Flow isolation required	Yes	
Type of flow in lateral	Gravity or pressure (≤250 psi)	
Sewage pH range	0-11	
Sewage max temperature	Up to 300º F (function of resin)	With Hybrid epoxy
Duration of repair	2 hrs (single lateral), 1-2 hrs (multiple)	Includes cleaning
Productivity	Up to 5-6 laterals in one working day (10 hrs)	
Average cost	$40-75/ft, or $2,000-3,750 per lateral	For 50' lateral, moderate root intrusion
Flexural modulus:	750,000 psi	ASTM D-790. Exceeds ASTM F-1216
Flexural strength	10,000 psi	ASTM D-790. Exceeds ASTM F-1216
Tensile strength	4.000 psi	ASTM D-790. Exceeds ASTM F-1216
Patents	U.S. #5,606,997	Six patents pending
Product testing	City of Houston, TX—flexural, tensile, fatigue, chemical resistance	

C.11 Amerik Supplies (Marietta, GA): TOP HAT® Lateral Sealing System

Table C-21. General Information for TOP HAT® Lateral Sealing System.

Type	CIP—Lateral connection liner
Internet	www.ameriksupplies.com
History/availability	Developed in Austria, in 1995. Used in Europe, Australia. In U.S. from 1999, about 5,000 laterals repaired.
Contact	Erik Nielsen, P. (770) 924-2899, AMerikSupplies@AMerikSupplies.com

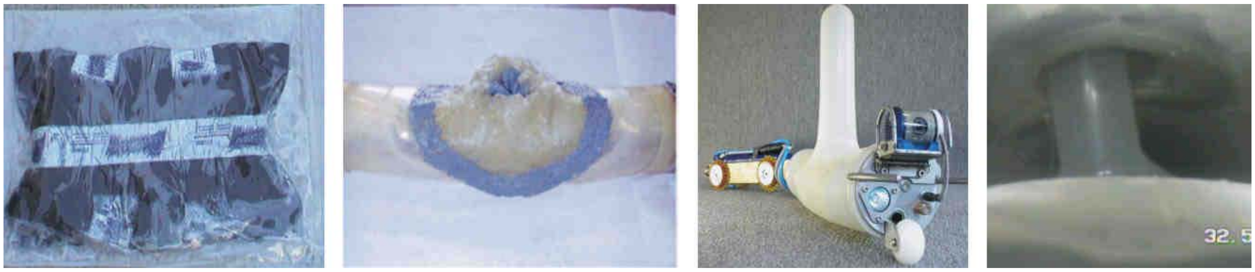

Figure C-11. Left: Delivered to Site. Middle Two: Loaded Applicator. Right: Bladder Deflation after Resin Cure.

Table C-22. System Features of TOP HAT® Lateral Sealing System.

Feature	Description	Comment
Material	ECR fiberglass laminate (seamless)	Corrosion-grade glass
Resin type	Polyester or vinylester resin, and epoxy bonding agent	
Resin impregnation	Factory pre-impregnated, bonding agent on site	Shelf time over 5 months at room temperature
Nominal liner thickness	1-1.5 mm	
Liner insertion	Insertion using an applicator	
Curing process	UV-light	
Lateral pipe diameter (ID)	4", 6", 8"	
Mainline pipe diameter (ID)	4-20"	
Brim in the mainline	3"	
Length in the lateral	6"	
Offset joints in lateral pipe	≤ 25% of pipe diameter	E.g. ≤ 2" in 8" lateral
Cracks, holes in lateral pipe	Yes	As long as pipe structurally sound
Active leaks	Yes	Conventional grouting for heavy leaks
Roots, debris in lateral pipe	Yes	Cleaning required
Flow isolation required	Yes	Only briefly (30 min)
Type of flow in lateral	Gravity	
Sewage pH range		
Sewage max temperature		
Duration of repair	45 min per lateral	Same for single or multiple laterals
Productivity	Up to 10 laterals in one working day (8 hrs)	
Average cost	$800-1,200 per lateral	
Flexural modulus:	800,000 psi	
Flexural strength		
Tensile strength		
Patents		
Product testing	Ingeneurburo for Kunststoftechnik, Hamburg, Germany, 1997: strength (870,000-1,595,000 psi), bonding to surface wetted with oil emulsion (300 psi)	

C.12 Primeline Products, Inc. (Edgewater, FL): PrimeLiner LC™

Table C-23. General Information for PrimeLiner LC™.

Type	CIP—Lateral connection liner or T-Liner
Internet	http://www.primelineproducts.com
History/availability	Developed in U.S. (2004). Estimated over 1,000 laterals repaired so far in U.S.
Contact	Bob Rothenberg, P. (877) 409-7888, bob@prime-line.net

Figure C-12. Left: Material. Middle: Carrier Packer. Right: Impregnated Composite on Carrier Packer.

Table C-24. System Features of PrimeLiner LC™.

Feature	Description	Comment
Material	Felt (stitched)	Made in Europe
Resin type	Silicate resin	
Resin impregnation	On site (submerged in pail of mixed resin)	
Nominal liner thickness	3.0 mm	
Liner insertion	Insertion using a carrier packer	
Curing process	Ambient temperature	
Mainline pipe diameter (ID)	6-15”	
Lateral pipe diameter (ID)	3-6”	
Brim in the mainline	3-4”	
Length in the lateral	12”	
Length in mainline section (T-liners only)	12”	
Offset joints in lateral pipe		
Cracks, holes in lateral pipe	Yes	Fully structural
Active leaks	Yes	
Roots, debris in lateral pipe	Yes	Cleaning required first
Flow isolation required	No	A flow-thru packer is used
Type of flow in lateral	Gravity	
Sewage pH range		
Sewage max temperature		
Duration of repair	1.5-5 hrs	Depending on type of resin
Productivity	4-5 per day	
Average cost	$500 –$1,000	
Flexural modulus:		
Flexural strength		
Tensile strength		
Patents	Pending	
Product testing	Presently underway, not available as of this date.	

C.13 Insituform Technologies, Inc. (Chesterfield, MO): Insituform® Lateral

Table C-25. General Information for Insituform® Lateral.

Type	CIP—Long connection liner or standard liner
Internet	www.insituform.com/munsewers/mun_1_05.html
History/availability	Developed in U.K./U.S., Available in U.S., since 1986. Used in many countries in Europe.
Contact	Rick Baxter, *ITI Product Engineer*, P. (636) 530-8046, RBaxter@insituform.com

Figure C-13. Left: Loading of Inversion Device. Right: Inversion Device Ready for Installation.

Table C-26. System Features of Insituform® Lateral.

Feature	Description	Comment
Tube material	Polyester: woven or needled (stitched)	Made by Insituform
Protective coating	Polyethylene or polyurethane	Made by Insituform
Position of coating after inst.	Outside (between liner and host pipe)	
Resin type	Polyester resin	Made by Insituform
Resin impregnation	In-situ (vacuum impregnation)	Gap rollers used
Nominal liner thickness	3.0 mm, 4.5 mm (usually)	
Liner insertion	Inversion (air-pressure) or winched-in-place	Inversion assembly (for mainline access)
Curing process	Ambient temperature or hot water, steam	
Mainline pipe diameter (ID)		
Lateral pipe diameter (ID)	4-6”	
Diameter transition in lateral	6-18”	
Brim in the mainline	3”	
Length in the lateral	Typically 1-25’	Longer lengths possible
Bends in lateral	Multiple 90º bends	
Offset joints in lateral pipe	≤ 40% of diameter	
Cracks, holes in lateral pipe	Yes	Pipe must be reasonably structurally sound
Active leaks	Yes	Open-cut point repair for heavy leaks.
Roots, debris in lateral pipe	Yes	Cleaning required to allow liner inversion
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range	2-10.5	
Sewage max temperature	140º F	
Duration of repair	3-5 hrs (single lateral), 2-3 hrs (multiple)	Includes cleaning
Productivity	3 laterals or more in one working day	
Average cost	$1,500-4,000 per lateral	Moderate root intrusion
Flexural modulus	250,000 psi	ASTM D-790
Flexural strength	4,500 psi	ASTM D-790
Tensile strength	3,000 psi	ASTM D-638
Patents		
Product testing	Bodycote Mat. Testing, 2001; Louisiana Tech, 1994; Sverdrup Corp, 1990; Utah State Uni, 1988	

C.14 Master Liner Inc (Hammond, LA): MasterFlex and Insta T

Table C-27. General Information for Insta T

Type	CIPP—Standard liner (MasterFlex) and long connection liner (Insta T)
Internet	http://www.masterliner.com
History/availability	Developed in U.S, in 1996 (MasterFlex) and 2004(Insta T). Estimated 100s of laterals repaired in U.S. only.
Contact	Dwayne Rovira, *CEO*, P. 985-386-3006, Dwayne@masterliner.com

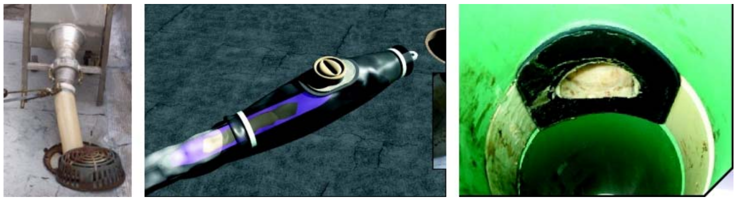

Figure C-14. Left: Inversion of MasterFlex though Cleanout. Middle: Insta T Inversion Device. Right: Insta T Installed.

Table C-28. System Features of MasterFlex.

Feature	Description	Comment
Tube material	Polyester felt (knitted, looped)	
Protective coating	Polyurethane	
Position of coating after inst.	Outside (winched in) or inside (inverted)	
Preliner	No	
Resin type	Vinylester, or epoxy	
Resin impregnation	Vacuum (MasterFlex); Manual (Insta T)	
Nominal liner thickness	3.0-4.5mm (MasterFlex); 3.0mm (Insta T)	
Liner insertion	Inversion or winching in through cleanout (MasterFlex); inversion (Insta T)	
Curing process	Ambient or heat	
Mainline pipe diameter (ID)	8-12”	Insta T only!
Lateral pipe diameter (ID)	4-6”	
Diameter transition in lateral	No	
Brim in mainline	1.5-3” (non-ciruclar)	Insta T only!
Length in lateral relined	50’ (MasterFlex); 5’ (Insta T)	
Bends in lateral	Limited to several (22, 45 deg, 90 deg)	
Offset joints in lateral pipe	Up to about 25% of lateral ID	
Cracks, holes in lateral pipe	Yes	Structural liner
Active leaks	Yes	Heavy leaks might be grouted first
Roots, debris in lateral pipe	Must be removed	
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range	“Normal” for domestic sewage	
Sewage max temperature	“Normal” for domestic sewage	Depends on resin
Duration of repair	2-6 hrs (MasterFlex); 2-3 hrs (Insta T)	
Productivity	2-4 (MasterFlex); 4-6 (Insta T)	Laterals repaired per day per crew
Average cost	$1,500-3,000 (MasterFlex); $1,500-2,000 (Insta T)	
Flexural modulus	250,000 psi	
Flexural strength	4,500 psi	
Tensile strength	3,000 psi	
Patents	6688377; 6206049; 6082411; 5971032; 6652690	Insta T only
Product testing	Yes	

C.15 LMK Enterprises (Ottawa IL): LMK T-Liner®

Table C-29. General Information for LMK T-Liner®.

Type	CIP T-liner
Internet	www.performanceliner.com
History/availability	Developed in U.S., 1994. Also used in Canada, Australia, South America.
Contact	Larry Kiest, Jr., *President,* P. (815) 433-1275, sales@lmkenterprises.com

Figure C-15. Left: Liner. Middle Two: Manhole Access; Remote Positioning Device. Right: Installed Liner.

Table C-30. System Features of LMK T-Liner®.

Feature	Description	Comment
Tube material	PVC: needled (stitched), knitted or braided	Made in house/Lantor Inc.
Protective coating	Polyurethane	Made in house/Lantor Inc.
Position of coating after inst.	Inside	Between liner and host pipe
Resin type	Unsaturated Iso-Polyester, epoxy based vinyl ester, silicate with hardener 100% solids and epoxy with catalyst	By Interplastic Corporation
Resin impregnation	In-situ (vacuum impregnation)	
Nominal liner thickness	3.0 mm and 4.5 mm	For 3-4” pipe, and 5-6” pipe respectively
Liner insertion	Air Inversion (liner/bladder assembly)	T-Launching device used
Curing process	Ambient temperature or steam	
Mainline pipe diameter (ID)	6-24”	
Lateral pipe diameter (ID)	3-6”	
Diameter transition in lateral	3” to 6”, and any in-between	Two-piece liner matching diameters
Length in the mainline	16”	
Length in the lateral	≤ 160’	
Bends in lateral	Up to six soft 90° bends (in 4” lateral)	
Offset joints in lateral pipe	≤ 25% of pipe diameter	
Cracks, holes in lateral pipe	Yes	Pipe must be reasonably structurally sound
Active leaks	Yes	Chem. grout (heavy leaks)
Roots, debris in lateral pipe	Yes	Cleaning required
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range	3-11 or 0-14 (if hybrid resin used)	
Sewage max temperature	180° F, 200° F, or 250° F	Depending on resin
Duration of repair	3-4 hrs (single lateral), 1-4 hrs (multiple)	Includes cleaning
Productivity	Up to 10 laterals in one working day	Six-men crew
Average cost	$3,500	$2,500-6,000
Flexural modulus	443,642 psi (ASTM D-790)	
Flexural strength	6,693 psi (ASTM D-790)	
Tensile strength		
Patents	38 patents	In U.S., Australia, Canada, Europe
Product testing	HTSm Inc., Houston (1998)—A 10,000-hour chemical resistance testing	

C.16 Easy Liner Inc (Thomasville, PA): Saddle Liner™

Table C-31. General Information for Saddle Liner™ .

Type	CIP T-Liner
Internet	http://easy-liner.com
History/availability	Developed in Great Britain, 2000. Available in U.S., since 2004. Used in UK, Europe, and U.S. Estimated 500 laterals relined in U.S. and 4,000 laterals worldwide.
Contact	Andrew Chettle, *Research and Development Engineer*, P. (888) 639-7717, andyc@easy-liner.com

Figure C-16. Left: Mounting the Liner onto the Packer. Middle: Repair in Y Junction. Right: Cutout of Installed Liner.

Table C-32. System Features of Saddle Liner™ .

Feature	Description	Comment
Tube material	Polyester and fiberglass laminate	Polyester needle punched
Protective coating	N/A	
Position of coating after inst.	N/A	
Preliner	N/A	
Resin type	Silicate Polyurethane	
Resin impregnation	Hand impregnation	
Nominal liner thickness	3-4 mm	
Liner insertion	Inversion–remotely from the mainline	T- shaped packer is used
Curing process	Ambient cure	
Mainline pipe diameter	8-15”	
Lateral pipe diameter (ID)	4”, 6”	
Diameter transition in lateral	N/A	
Length in the mainline	12”	
Length in the lateral	4-8"	1
Bends in lateral	N/A	
Offset joints in lateral pipe	Up to 10%	
Cracks, holes in lateral pipe	Yes	
Active leaks	No	
Roots, debris in lateral pipe		
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range	Normal sewage flow	
Sewage max temperature	160 deg F	
Duration of repair	1-2 hours	Cleaning, CCTV, demobilization not included
Productivity	3-5 per day	
Average cost	$1,000-2,000	
Flexural modulus	>250,000 psi	
Flexural strength	> 4,500 psi	
Tensile strength	N/A	
Patents	Yes	
Product testing	(See Cleanout Liner™ and House Liner™)	

C.17 Buno Construction (Snohomish, WA): Buno Replacement System

Table C-33. General Information for Buno Replacement System.

Type of rehabilitation	Pipe bursting
Internet	N/A
History/availability	Developed in U.S. in 1995. Used in U.S. Northwest. Estimated 43,500' replaced to date.
Contact	Dan Buno, P. (425) 423-4512, danbuno@msn.com, Bill Buno, billbuno@msn.com

Figure C-17. Buno B-100 Pipe Bursting/Slip Lining Machine.

Table C-34. System Features of Buno Replacement System.

Feature	Description	Comment
Pipe bursting type	Static pull (pipe splitting)	
Static Pull Power	50 tons (100,000 lbs)	For 4" and 6"
Upsizing	One pipe size	4" to 6", 6" to 8"
Access into lateral	Two small pits	Pulling pit: 3'×4'×1' below invert; Entry pit: 2'×3'×1' below invert
Max length of single run	280' typically	200-500', depending on diameter
Lateral pipe diameter (ID)	2-8"	
Lateral pipe type	Any	Cast iron, clay, concrete, asbestos cement, PVC, Orangeburg, steel
Diameter transition in lateral	One size	
Bends in lateral	Two 90° or three 45° bends	
Offset joints in lateral pipe	No limit	As long as pulling cable can get through the pipe
Cracks, holes in lateral pipe	No limit	
Active leaks	No limit	
Roots, debris in lateral pipe	Yes	As long as pulling cable can get through the pipe
Soil conditions—best	Expandable clay.	
Soil conditions—worst	Hard, solid dry clay	
Groundwater conditions	Operable	
Flow isolation required	Yes	
Replacement pipe	HDPE 3408 SDR 17	Fusible PVC pipe if requested, DI
Bursting speed:	30 ft/min	
Duration of repair	2 hrs with a three-person crew	For a typical 60-80' lateral, includes pits excavation
Productivity	Average 6-7, max 13 laterals per day	In 8 hrs, pits prepared
Average cost	$30-40/ft	Includes excavation and surface restoration
Patents		

C.18 TT Technologies (Aurora, IL): Grundocrack®

Table C-35. General Information for Grundocrack®.

Type of rehabilitation	Pipe bursting
Internet	www.tttechnologies.com
History/availability	Developed in U.S. in 2000. Used worldwide. Estimated 300,000' replaced in five years.
Contact	Collins Orton, P. (800) 533-2078, pipedr96@aol.com Ben R. Cocogliato, bcocogliato@tttechnologies.com

Figure C-18. Grundocrack. Left: Bursting Heads and Pulling Cable. Right: Pneumatic Winch in Manhole.

Table C-36. System Features of Grundocrack®.

Feature	Description	Comment
Pipe bursting type	Pneumatic	
Static Pull Power	N/A	
Upsizing	One pipe size	4" to 6"
Access into lateral	Two small pits	
Max length of single run	150'	
Lateral pipe diameter (ID)	4-8"	
Lateral pipe type	Any	
Diameter transition in lateral	One size	
Bends in lateral	Two 45° or 90° bends	
Offset joints in lateral pipe	No limit	As long as pulling cable can get through the pipe
Cracks, holes in lateral pipe	No limit	
Active leaks	No limit	
Roots, debris in lateral pipe	Yes	As long as pulling cable can get through the pipe
Soil conditions—best	Expandable clay	
Soil conditions—worst	Hard, solid dry clay	
Groundwater conditions	Operable	
Flow isolation required	Yes	
Replacement pipe		
Bursting speed:		
Duration of repair	3-4 hrs	With a two-person crew
Productivity	2-3 laterals in one working day	8 hrs
Average cost		
Patents		

C.19 TT Technologies (Aurora, IL): Grundotugger®

Table C-37. General Information for Grundotugger®.

Type of rehabilitation	Pipe bursting
Internet	www.tttechnologies.com
History/availability	Developed in U.S. in 2000. Used worldwide. Estimated 300,000’ replaced in five years.
Contact	Collins Orton, P. (800) 533-2078, pipedr96@aol.com Ben R. Cocogliato, bcocogliato@tttechnologies.com

Figure C-19. Grundotugger. Left: Winch Unit. Right: Special Bursting Head (Nose Cone/Splitter).

Table C-38. System Features of Grundotugger®.

Feature	Description	Comment
Pipe bursting type	Static pull (pipe splitting)	
Static Pull Power	30 tons i.e. 60,000 lbs	For 4” and 6”
Upsizing	One pipe size	4” to 6”
Access into lateral	Two small pits	
Max length of single run	150’	
Lateral pipe diameter (ID)	4” and 6”	
Lateral pipe type	Any	Cast iron, clay, concrete, asbestos cement, PVC, Orangeburg, steel
Diameter transition in lateral	One size	
Bends in lateral	Two 45° or 90° bends	
Offset joints in lateral pipe	No limit	
Cracks, holes in lateral pipe	No limit	As long as pulling cable can get through the pipe
Active leaks	No limit	
Roots, debris in lateral pipe	Yes	As long as pulling cable can get through the pipe
Soil conditions—best	Expandable clay.	
Soil conditions—worst	Hard, solid dry clay	
Groundwater conditions	Operable	
Flow isolation required	Yes	
Replacement pipe	HDPE 3408	Or fusible PVC pipe
Bursting speed:		
Duration of repair	3-4 hrs	With a two-person crew
Productivity	2-3 laterals in one working day	8 hrs
Average cost		
Patents	U.S. #6830234B2	

C.20 Hammerhead/Vermeer (Oconomowoc, WI): PortaBurst™

Table C-39. General Information for PortaBurst™.

Type of rehabilitation	Pipe bursting
Internet	www.Hammerheadmole.com
History/availability	Developed in U.S., in 2000. Available worldwide. Estimated 600,000' replaced in 4 years.
Contact	Jeff Wage, P. (262) 244-0219 or (800) 331-6653, jwage@hammerheadmole.com

Figure C-20. PortaBurst PB30.

Table C-40. System Features of PortaBurst™.

Feature	Description	Comment
Pipe bursting type	Static pull (pipe splitting)	
Static Pull Power	60,000 lb	
Upsizing	One pipe size	2" to 4", 3" to 4", 4" to 6", 6" to 8"
Access into lateral		
Max length of single run	200'	
Lateral pipe diameter (ID)	2-8"	
Lateral pipe type	Any	Cast iron, clay, concrete, asbestos cement, PVC, Orangeburg, steel
Diameter transition in lateral	Two 45º bends in a single run	
Bends in lateral	No limit.	
Offset joints in lateral pipe	No limit	As long as pulling cable can get through the pipe
Cracks, holes in lateral pipe	No limit	
Active leaks	No limit	
Roots, debris in lateral pipe	Yes	As long as pulling cable can get through the pipe
Soil conditions—best	Loam	
Soil conditions—worst	Hard, dry clay	
Groundwater conditions	Does not affect bursting	Only affects man entry in pits during pipe connection
Flow isolation required		
Replacement pipe	HDPE 3408	Or fusible PVC pipe
Bursting speed:		
Duration of repair	3 hrs with a two-person crew	Controlled by time required to excavate pits.
Productivity	8 laterals in one working day	With pits prepared in advance
Average cost		No consumables, all expense based on man hours
Patents	U.S. Application #20040218982	Others applied for

C.21 TRIC Tools, Inc. (Alameda,CA): TRIC™ Trenchless

Table C-41. General Information for TRIC™ Trenchless.

Type of rehabilitation	Pipe bursting
Internet	http://www.trictrenchless.com
History/availability	Developed in U.S., 1996. Available in U.S. only. Estimated 10,000,000' replaced in 8 years.
Contact	Bob Carter, *Founder & Director of Engineering*, P. (510) 865-8742, bob@trictrenchless.com Gregg Abbott, *Director of Sales,* P. (888) 883-8742, gregg@trictrenchless.com

Figure C-21. TRIC™ Trenchless Lateral Replacement System.

Table C-42. System Features of TRIC™ Trenchless.

Feature	Description	Comment
Pipe bursting type	Static pull (pipe splitting)	
Static Pull Power	18 tons i.e. 36,000 lbs	For laterals ≤ 4";
	30 tons i.e. 60,000 lbs	For laterals 5-6"
Upsizing	Several pipe sizes	E.g. 4" to 8"; 8" to 14"
Access into lateral	Two small pits	2'×2' at depth up to 5'; 3'×8' at depth 10'
Max length of single run	Practically unlimited	1,400' continuous pull done
Lateral pipe diameter (ID)	2-12"	
Lateral pipe type	Any	Cast iron, clay, concrete, asbestos cement, PVC, etc.
Diameter transition in lateral	One diameter size	3" to 4"; 4" to 6"; 6" to 8"
Bends in lateral	Up to three 45º bends or one 90º bend in single run	The pulling cable cuts through 90º bends and the new HDPE pipe is installed in an "arch"
Offset joints in lateral pipe	No limit	As long as pulling cable can get through the pipe
Cracks, holes in lateral pipe	No limit	As long as pulling cable can get through the pipe
Active leaks	No limit	As long as pulling cable can get through the pipe
Roots, debris in lateral pipe	Yes	As long as pulling cable can get through the pipe
Soil conditions—best	Wet sand	
Soil conditions—worst	Hard clay	
Groundwater conditions	Groundwater helps	By reducing the pressure required to pull
Flow isolation required	Yes	
Replacement pipe	HDPE 3408	Or fusible PVC pipe
Bursting speed:		
Duration of repair	3-5 hrs	With a 2-person crew
Productivity	Easily 3 laterals in one working day	With pits prepared in advance
Average cost	$60-120/ft	Varies by contractor, often affected by cost of alternative open-cut replacement
Patents	#U.S. 6,305,880 10/23/01 #U.S. 6,524,031 02/25/03 Other applications are pending	

C.22 Spartan Tools (Mendota, Ill): Undertaker™

Table C-43. General Information for Undertaker™.

Type of rehabilitation	Pipe bursting
Internet	www.spartantool.com
History/availability	Developed in U.S., in 2004. Available in the United States.
Contact	Bill Madden, P. (800) 435-3866, bmadden@spartantool.com

Figure C-22. Undertaker. Left: The System. Right: Hydraulic Power Pack.

Table C-44. System Features of Undertaker™.

Feature	Description	Comment
Pipe bursting type	Static pull (pipe splitting)	
Static Pull Power	60,000 lb	
Upsizing	One pipe size	2" to 4", 3" to 4", 4" to 6", 6" to 8"
Access into lateral	Two small pits	
Max length of single run	200'	
Lateral pipe diameter (ID)	2-8"	
Lateral pipe type	Any	Cast iron, clay, concrete, asbestos cement, PVC, Orangeburg, steel
Diameter transition in lateral	One diameter size	3" to 4"; 4" to 6"; 6" to 8"
Bends in lateral	Up to two 45º bends in a single run	
Offset joints in lateral pipe	No limit	As long as pulling cable can get through the pipe
Cracks, holes in lateral pipe	No limit	As long as pulling cable can get through the pipe
Active leaks	No limit	As long as pulling cable can get through the pipe
Roots, debris in lateral pipe	Yes	As long as pulling cable can get through the pipe
Soil conditions—best	Loam	
Soil conditions—worst	Hard dry clay	
Groundwater conditions		
Flow isolation required	Yes	
Replacement pipe	HDPE 3408	Or fusible PVC pipe
Bursting speed:		
Duration of repair	3 hrs	With a two-person crew
Productivity	Up to 8 laterals in one working day	With pits, pipe and puling cable prepared in advance.
Average cost		Depends on pipe diameter and length, and man hours
Patents		

C.23 American Logiball, Inc. (Jackman, ME): Lateral Connection Test & Seal Packers

Table C-45. General Information for American Logiball Lateral Connection Test & Seal Packers.

Type of rehabilitation	Chemical grouting
Internet	www.logiball.com
History/availability	Developed in Canada, early 1980s. Used in U.S. from early 1990s. Also used in Canada, Germany, Australia, New Zealand, Ireland, and Singapore. Estimated 100,000-150,000 laterals repaired worldwide.
Contact	Marc Anctil, P. (800) 246-5988, marc@logiball.com

Figure C-23. Lateral Connection Packers. Left: Standard Bladder. Right: Long Bladder.

Table C-46. System Features of American Logiball Lateral Connection Test & Seal Packers.

Feature	Description	Comment
Type of lateral grouting	Grouting from mainline	Connection and up the lateral
Max length in lateral	Typically first 1-6' of the lateral	Can go further up the lateral (30')
Mainline diameter	6-24”	
Lateral pipe diameter (ID)	4”, 5”, and 6”	
Diameter transition in lateral	4” to 6”	Internal grout ring in 6” part will be thicker but can be flushed out afterwards
Bends in lateral	Multiple 90º bends	
Lateral pipe type	Any	
Slope of lateral pipe	No limit	Can go up the vertical pipe
Lateral-to-mainline connect.	No limit	Can be Tee or Wye
Offset joints in lateral pipe	≤ 20 % of lateral pipe diameter	
Cracks, holes in lateral pipe	No limit	As long as pipe is structurally sound
Active leaks	No limit	Heavy leaks easier to seal
Roots, debris in lateral pipe	Yes	Cleaning required
Soil conditions		
Groundwater conditions		
Flow isolation required	Yes	In mainline and lateral. Flow-through models for mainlines ≥15”
Type of flow in lateral	Gravity	
Grout used	Acrylamide, acrylate or urethane	
Quality control	Air-pressure testing (integral part of procedure)	ASTM F 2454-05
Duration of repair	15-30 min per connection plus setup time	2 hrs setup
Productivity	7-12 laterals per day	2 setups in 8 hrs, 6' of the lateral
Average cost	$350-1,200 per lateral connection up to 6'	
Patents	None	

C.24 American Logiball, Inc. (Jackman, ME): Push Type Test & Seal Packers

Table C-47. General Information for American Logiball Push Type Test & Seal Packers.

Type	Chemical grouting of lateral pipes
Internet	www.logiball.com
History/availability	Developed in Canada (mid 1980s). Used in U.S., Canada, Germany, Australia, New Zealand, and Singapore. Estimated 5,000 laterals repaired so far worldwide.
Contact	Marc Anctil, P. (800) 246-5988, marc@logiball.com

Figure C-24. Push Type Packers. Left: Fitting for Cleanout Installation. Middle: Inside the Lateral. Right: The Packer.

Table C-48. System Features of American Logiball Push Type Test & Seal Packers.

Feature	Description	Comment
Type of lateral grouting	Grouting from cleanout	Along the lateral
Max length in lateral	150’	May vary with pipe configuration
Mainline diameter	-	
Lateral pipe diameter (ID)	4”, 5”, and 6”	
Diameter transition in lateral	4” to 6”	Internal grout ring in 6” part will be thicker but can be flushed out afterwards.
Bends in lateral	Multiple 22-90º bends	
Lateral pipe type	Any	
Slope of lateral pipe	No limit.	Can go up the vertical pipe.
Lateral-to-mainline connect.	No limit.	Can be Tee or Wye
Offset joints in lateral pipe	≤ 20 % of lateral pipe diameter	
Cracks, holes in lateral pipe	No limit	As long as pipe is structurally sound
Active leaks	No limit	Heavy leaks easier to seal
Roots, debris in lateral pipe	Yes	Cleaning required
Soil conditions		
Groundwater conditions		
Flow isolation required	Yes	The packer isolates the flow.
Type of flow in lateral	Gravity	
Grout used	Acrylamide, acrylate or urethane	
Quality control	Air-pressure testing (integral part of procedure)	ASTM F 2454-05
Duration of repair	30-60 min per lateral	Depends on configuration, length and number of joints in the lateral
Productivity	7-12 laterals per day	8 hrs
Average cost	$350-700 per lateral	Depending on length, access etc…
Patents	None	

C.25 Sanipor, Ltd. (Feldkirchen-Westerham, Germany): Sanipor®

Table C-49. General Information for Sanipor®.

Type	Flood grouting of a mainline and connected laterals
Internet	http://www.sanipor.com
History/availability	Developed in Hungary, 1987 Available in U.S. and Canada. Also used in Europe, Australia, New Zealand. Estimated 35,000' of mainlines/laterals rehabilitated in U.S., and 300 miles total. The foundation of a new Sanipor company in the U.S. is planned in 2005.
Contact	Csilla Pall, P. 011-49-8063-7707, Sanipor@t-online.de

Figure C-25. Sanipor. Left: Truck with Chemicals Near a Manhole. Right: Manhole Filled with a Solution.

Table C-50. System Features of Sanipor®.

Feature	Description	Comment
Access into plugged sections	Manhole	For pouring solutions
Access into lateral	Cleanout	For cleaning and plugging the lateral
Max length of pipes	Limited by the volume of sections	I.e. volume of available vacuum tanks (3,000 gal)
Lateral pipe diameter (ID)	No limit	
Lateral pipe type	Any	
Bends in lateral	Any	
Offset joints in lateral pipe	No limit	
Cracks, holes in lateral pipe	Yes	Pipe must be structurally sound.
Active leaks	Yes	No limit
Roots, debris in lateral pipe	Yes	Lateral pipe must be cleaned
Soil conditions—best	Sand, gravel, clay	
Soil conditions—worst	Not applicable in some bedding conditions	Non-permeable material (concrete) around the pipe, no bedding, or cavities in soil that cannot be closed
Groundwater conditions	No limit	Can flood grout when pipes below groundwater
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range	Up to pH 9	Acids strengthen the chemical system
Sewage max temperature	Up to 200° F	But not hot and dry conditions
Grout used	Silicate based	Supplier: EKA Chemicals.
Oil contaminated soil	No limitation	Encapsulates organic contamination in situ.
Duration of repair	8 hrs per section (with interruptions)	Depends on defects in pipes and soil conditions
Productivity	1-2 sections per day (8 hrs)	Section is one mainline and/or laterals.
Average cost	$1,200-2,100 per lateral	Approximately
Patents	Registered U.S. Patent and Trademark	
Product testing	Berlin University of Technology; Institut of Hygiene, Gelsenkirchen; Federal Office of Public Health, Berlin; German Institute for Construction Technologies (approval); Senate Council for City Development and Environment, Berlin, Germany; WRc, U.K.	

C.26 EBD/End-i (Honolulu, HI): End-i™

Table C-51. General Information for End-i™.

Type	Slug grouting of a mainline and connected laterals
Internet	www.sewersealing.com
History/availability	Developed in U.S. in 2004.
Contact	Jeff Iwasaki-Higbee, *Inventor and system owner*, P. (808) 282-2832, pipedr@hawaii.rr.com

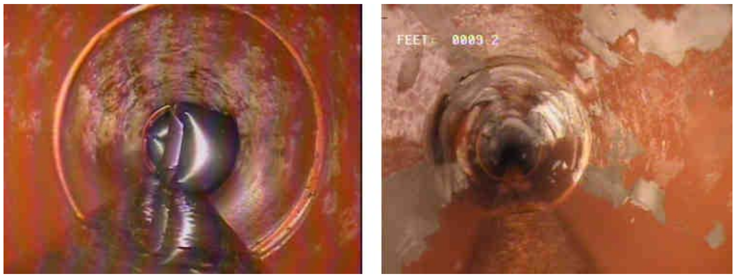

Figure C-26. End-i™. Left: A Mainline Bladder Approaching a Bladder Protruding from the Lateral. Right: Residual Grout Will Be Removed after Repair.

Table C-52. System Features of End-i™.

Feature	Description	Comment
Access into mainline	Manhole	
Access into lateral	Cleanout	
Max length of pipes	50' or more (in the lateral)	Up to 600' in the mainline
Mainline pipe diameter (ID)	6-12"	Currently
Lateral pipe diameter (ID)	Any up to 12"	
Lateral pipe type	Any	
Bends in lateral	One 90° bend and multiple 45° bends	At least
Offset joints in lateral pipe	Up to 50% of diameter (in the lateral)	Same in the mainline.
Cracks, holes in lateral pipe	Yes	No limit
Active leaks	Yes	No limit
Roots, debris in lateral pipe	Yes	Pipe cleaning required prior to rehab
Soil conditions—best	Any	
Soil conditions—worst	Any	
Groundwater conditions	Dry or saturated	
Flow isolation required	Yes	
Type of flow in lateral	Gravity	
Sewage pH range	To be Determined	
Sewage max temperature		
Grout used	Cement based	
Duration of repair	About 8 hrs per section	Assuming one mainline and three laterals
Productivity	One section per day	
Average cost	$500-1,500 per lateral	$8,000-10,000 per section (mainline and 3 laterals)
Patents	One granted in U.S., Germany, U.K., Ireland	One pending.
Product testing	To be performed	

C.27 Janssen Process, LLC (Brownsborro, AL): Janssen Lateral Renovation System

Table C-53. General Information for Janssen Lateral Renovation System.

Type	Robotic repair
Internet	www.janssen-umwelttechnik.de
History/availability	Developed in Germany, 1999. Available in U.S., since year 2006. Over 10,000 laterals repaired in Europe.
Contact	Don Barnhart, *General manager,* P. 256-509-2204, janssenprocess@comcast.net

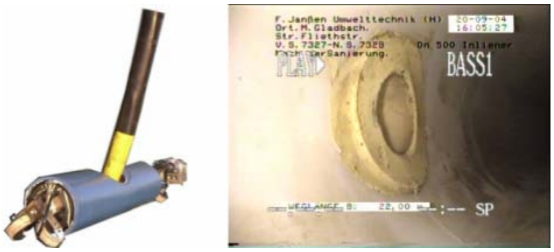

Figure C-27. Left: Packer. Right Renovated Lateral Connection (Originally a Protruding Lateral).

Table C-54. System Features of Janssen Lateral Renovation System.

Feature	Description	Comment
Lateral pipe diameter (ID)	4-12”	
Mainline diameter	8-24” (200-600 mm)	
Max length in lateral	24” (60 cm)	Repaired length shown!
Max length in mainline	24” (60 cm)	Same as above.
Diameter transition in lateral	NA	Repairs only the short distance into lateral.
Bends in lateral	90 deg	Can repair a band if at the connection
Cracks, holes in lateral pipe	Any	Area of pipe wall is ground and removed first
Offset joints in lateral pipe	Any	
Active leaks	No limit	
Roots, debris in lateral pipe	Any	Removed first with a root cutter
Soil conditions	Applicable in almost any soil conditions, even porous soils	The owner has an option to stop if the quantity of used sealant becomes extremely large
Groundwater conditions	No limit	High groundwater level is not a problem
Type of flow in lateral	Gravity	
Sewage pH range	2-12	Tested in the range shown
Sewage max temperature		
Type of grout used	Resin (silica-based)	Cures in 20-30 min
Quality control	CCTV and pressure testing (optional)	Selected by the owner
Flow isolation required	No	Flow through mainline and laterals is allowed
Duration of repair	About 2 hours for single lateral, 1.5-2 hours per lateral if multiple laterals in the area	Including pipe preparation, CCTV, demobilization
Productivity	Up to 3-5 laterals in one day	Assuming 2-men crew
Average cost	$2,000 for single lateral	Depends on preparation work, quantity of sealant used, number of laterals repaired
Flexural modulus		
Flexural strength		
Tensile strength		
Patents	Multiple U.S. and European patents	
Product testing	Stork Twin City Testing Co, Minneapolis, MN (2005): Adhesion, tensile strength, elongation Hygiene Institute DES Ruhrgebiets (2002): Environmetal impact of resin on groundwater	

C.28 SAF-r-DIG Utility Surveys, Inc. (Palm Desert, CA): KA-TE

Table C-55. General Information for KA-TE.

Type	Robotic repair of lateral-to-mainline connections
Internet	http://safrdig.com
History/availability	Developed in Switzerland (1986). Used mainly in Europe, Australia and the Far East, but also available in U.S. Over 200 robot systems sold (over 150 of them with the lateral shoe device). Estimated 500,000 laterals repaired worldwide. Estimated 4,000 laterals in USA since 1992.
Contact	John Marcinek, (760) 776-8274, jMarcinek@safrdig.com

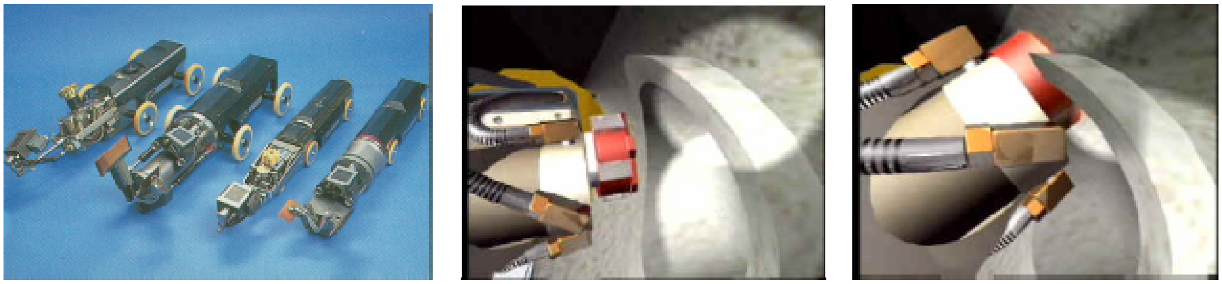

Figure C-28. Left: KA-TE Robots. Middle: Grinding Protruding Lateral. Right: Close-up of Grinding at Lateral Connection.

Table C-56. System Features of KA-TE.

Feature	Description	Comment
Lateral pipe diameter (ID)	4-6”	
Mainline diameter	8-24”	
Max length in lateral	Up to 4”	Length of repair that extends in lateral typically
Max length in mainline		Length of repair that extends in mainline
Diameter transition in lateral	N/A	
Bends in lateral	Up to 45°	Angle that lateral connects with mainline
Cracks, holes in lateral pipe	No limit	
Offset joints in lateral pipe	Up to 4”	
Active leaks	Limited	
Roots, debris in lateral pipe	Yes	Cleaning required prior to robotic repair
Soil conditions	Any	
Groundwater conditions	Any	
Type of flow in lateral	Gravity	
Sewage pH range		Has not been a major concern
Sewage max temperature		Has not been a major concern
Type of grout used	Epoxy resin	
Quality control	CCTV inspection	Optional pressure testing
Flow isolation required	Not totally	Robots and epoxy work under water
Duration of repair	Approx 5 hours per connection	This includes 4 hours for resin cure
Productivity	4-6 laterals per day	Realistically can be done
Average cost	$1,000-1,500 per connection	
Flexural modulus		ASTM C 638
Flexural strength	9,400 psi	ASTM C 580
Tensile strength	2,500 psi	ASTM D 4541
Patents		
Product testing		

GLOSSARY OF TERMS

Where available, this glossary uses definitions consistent with the WERF report, 00-CTS-6, *Best Practices for Wet Weather Wastewater Flows* which in turn draws from the following sources: U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Water Supply and Water Resources Division, Urban Watershed Management Branch.

As-built	Scaled and dimensioned drawing that accurately depicts the location of all buildings/utilities on a property.
Asbestos- cement pipe	A type of pipe made of asbestos-cement material. It is no longer manufactured for sewer applications and care must be taken not to allow asbestos fibers to become airborne when replacing or exposing existing pipes.
Backflow	Flow of sewage opposite to the normal direction of flow within the collection system. Often caused by a blockage or lack of flow capacity downstream.
Backflow preventer	Device or assembly designed to prevent backflow.
Base infiltration	Infiltration that occurs when the groundwater level is at its minimum in the absence of rainfall. It occurs year round when the groundwater level is above the level of a leakage point into the sewer system.
Basement backup	Backflow from the sewer into the basement of a house caused by a blockage or lack of downstream flow capacity.
Biological treatment processes	Means of treatment in which bacterial or biochemical action is intensified to stabilize, oxidize, and nitrify the unstable organic matter present. Trickling filters, activated sludge processes and lagoons are examples.
Blockage	Any obstruction that interferes with the movement of a fluid. This term is most often used to describe an unwanted flow obstruction in a pipe, channel, hydraulic combined sewer overflow regulator or other regulator, tide gate, orifice, storm inlet grating, filter bed, screen, or other location where flow occurs.
Break-in tap	Lateral-to-mainline connection in which a hole is made in the mainline pipe using a hammer and the lateral pipe is crudely connected to the sewer using this hole. Such connections typically are poorly sealed and may also partially block the mainline sewer. They are also known as “hammer taps.”
Capacity, Management, Operations and Maintenance	A federal audit program to insure proper local operation of a wastwater collection system.

Chemical grouting	The use of chemicals that change from a liquid form to a gel or solid material to seal openings or defects in a sewer system. Various base chemicals and catalysts to initiate the change of phase may be used as well as various physical arrangements to force the grout into the defects or voids.
Clean Water Act	The Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972), Public Law 92-500, as amended by Public Law 96-483 and Public Law 97-117, 33 U.S.C. 1251 et seq. Originally enacted in 1948, it was totally revised by amendments in 1972 that gave the Act its current shape. Congress made certain amendments in 1977, revised portions of the law in 1981, and enacted further amendments in 1987.
Cleanout	Access pipe that leads from the sewer pipe to the ground surface giving sufficient access to the sewer pipe for remote cleaning and inspection tools.
Cleanout cap	A cap used at the surface end of the cleanout pipe to close the cleanout when not in use. These caps are easily lost or broken allowing direct inflow to the sewer system during rainfall.
Closed-circuit television	Electronic video camera system. For sewer use, the camera is designed for immersion in the sewer environment and is combined with a lighting system and a powered tractor or push rod system to move through the sewer. CCTV for mainline sewer use may be combined with a satellite camera that can be launched into a sewer lateral.
Code	Ordinance, rule or regulation that a city or governing body may adopt to control the work within its jurisdiction.
Combined sewer	A sewer receiving intercepted surface (dry- and wet-weather runoff, municipal (sanitary and industrial) sewage, and subsurface waters from infiltration.
Combined sewer overflow	Discharge of a mixture of stormwater and domestic waste when the flow capacity of a sewer is exceeded during rainstorms.
Condition assessment	The process of using inspection data and other information to classify the estimated condition of a pipe segment or other infrastructure element.
Consent decree order	A legal agreement, under the jurisdiction of the U.S. Federal court system, entered into by the agency, the U.S. Environmental Protection Agency (EPA) and a state Environmental Protection Division (EPD) for violations of the federal Clear Water Act.
Compliance schedule	A schedule of remedial measures included in a permit or an enforcement order, including a sequence of interim requirements (for example, actions, operations, or milestone events) that lead to compliance with the CWA and regulations.

Cured-in-place pipe lining	A pipe lining technique in which a fabric impregnated with a flowable plastic resin material is inserted into a pipe, expanded against the walls of the existing pipe and then hardened (cured) in place to form a lining within the old pipe. The hardening can be accomplished by heat or ultraviolet light depending on the resin type.
Curing (pipe liners)	Preparation by chemical or physical processing to change the state of the liquid resin into a hardened form.
Defect classification	A form of condition assessment in which particular classes of defects are identified and recorded. Also known as a defect rating system.
Defect rating system	See *defect classification*.
Delayed inflow/infiltration	Inflow or infiltration caused by a rainfall event that occurs after the end of the rainfall event.
Design storm	A storm of given return interval and duration often used in the quantification of I/I. The choice of interval and duration may vary among agencies.
Detention	The slowing, dampening or attenuating of flows either entering the sewer system or within the sewer system by temporarily holding the water on a surface area, in a storage basin, or within the sewer itself.
Deteriorated pipe (“fully deteriorated”)	Pipe with missing sections and voids in the soil around the pipe, where the pipe-soil system cannot support the external loads from hydrostatic and live loads. Used in ASTM F-1216 standard to differentiate pipe liner design approach.
Deteriorated pipe (“partially deteriorated”)	Pipe with cracks and/or offset joints, often having leaks and/or root intrusion, but without missing sections of the pipe, where the pipe-soil system can support the external loads from hydrostatic and live loads. Used in ASTM F-1216 standard to differentiate pipe liner design approach.
Dewatering	The removal of groundwater to lower the groundwater table in an area or during an excavation. Dewatering can cause ground movements and affect nearby buildings and vegetation.
Directional drilling	See *horizontal directional drilling*.
Direct inflow/infiltration	Inflow or infiltration occurring during a rainfall event.
Discharge	Flow of surface water in a stream or canal or the outflow of groundwater from a flowing artesian well, ditch, or spring. Can also apply to discharge of liquid effluent from a facility or to chemical emissions into the air through designated venting mechanisms.

Discharge permit/consent	A discharge permit is a formal permission to release water, stormwater, combined sewer overflow, or wastewater to a receiving water body obtained by an individual, commercial or industrial business entity, institutional entity, or governmental entity from an agency that regulates discharges to waters. A permit can also be issued to a group of dischargers; this type of permit is referred to as a general permit. Regulating agencies that issue discharge permits are typically governmental or privatized agencies. The term discharge permit may apply to either the concept of permission or to the actual document that confers permission. Discharge consent is used synonymously with discharge permit.
Diurnal flow cycle	Flow variation that exhibits a daily cycle. In relation to sewage flows, for example, the nighttime flow (while residents are sleeping) contains very little sanitary sewage flow—allowing estimates to be made of system infiltration.
Domestic sewage	Sewage originating principally from residential homes or business buildings that does not contain storm water. Human excrement and gray water (household showers, dishwashing operations, etc.).
Dry weather flow	As it pertains to combined and sanitary sewerage, or stormwater drainage systems, is the flow in a system that occurs during dry weather, without a stormwater component. In these systems, dry-weather flow may include one or all of the following: sanitary wastewater; pre-treated industrial wastewater; unauthorized industrial wastewater; groundwater that has infiltrated or leaked into the system; latent or delayed stormwater flows through the vadose zone that have leaked into the system; chemical and sanitary landfill leachate; lawn irrigation runoff; foundation drainage; washwater such as from cars and industrial sites; unauthorized disposal of oil and hazardous chemicals; and other miscellaneous entries.
Dry weather infiltration	See *base infiltration*.
Dry-weather overflow/discharge	An overflow or discharge from a combined or sanitary sewerage system or storm drainage system that is not the result of wet-weather flows into the system. These flows may be the result of a variety of processes (see *dry-weather flow*). Dry-weather overflows from combined sewer systems are generally not permitted.
Dye testing	The injection into a pipe system or flooding of an area using water with a colored and/or fluorescent dye. This testing allows the source of infiltration and inflow to be checked and lateral connections to buildings to be verified.
Easement	See *utility easement*.
Effluent	Treated, untreated, or partially treated, wastewater that flows out of a wastewater treatment plant, sewer, or industrial outfall.

Electro scanning	A commercial technique that uses conductivity changes caused by defects in non-conducting pipes to identify the location and characteristics of such defects.
Flood-and-grout	A commercial technique that uses sequential flooding of a portion of a sewer system to grout and seal pipe defects and the surrounding soil.
Flow monitoring	The use of *flow recording* or experimentally determined data (e.g. pump run time) to determine the flow characteristics of a portion of a sewer system over time. Allows determination, by measurement, of peak flows, total flow volumes, rate of response to storm events, etc.
Flow recording	The recording of flowrate measurements, often by an automatic recording device. Typically an instrument is used to measure a physical parameter(s) that can be easily related to flowrate, such as water level, water velocity, or pressure variances in a closed conduit. This parameter(s) is then recorded and used to calculate the flowrate at a given time. For example, in conveyances, one practice is to record the height of the free water surface behind a weir and use this measurement to calculate flowrate using the calibrated weir equation, although other measurements and calculation schemes may be used.
French drain	A pathway for groundwater drainage created by the presence of granular materials with a high permeability. For example, a granular backfill around a pipe laid in a clay soil provides a natural pathway for water migration should the pipe develop leakage defects at a later date.
Geographical information system	An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.
Global positioning system	A system of satellites and receiving devices used to compute positions on the Earth. GPS is used in navigation and surveying. Positional accuracy varies according to the level of sophistication of the system and also differs in the horizontal and vertical directions.
Gravity Flow/Gravity System	The movement of fluids in reaction to the force of gravity on the fluid. All open channels as well as most storm sewers, sanitary sewers, and combined sewers in which the pipes are less than completely full operate based on gravity flow and are thus considered gravity systems. However, segments of a sewer system may at times flow under surcharged conditions whereby the water level is above the crown of the pipe causing pressurized flow in these segments. In addition to sewer systems flowing under surcharged conditions, those systems or portions of systems that utilize pumps to increase fluid pressures and induce flow are not gravity systems.

Ground penetrating radar	An imaging technology used for subsurface earth exploration. GPR uses electromagnetic wave propagation and scattering to image and identify changes in electrical and magnetic properties in the ground. Such changes can be used to locate underground utility lines and other subsurface structures or soil conditions.
Groundwater level	The elevation of the upper extent of saturated ground conditions within the soil. Also known as the phreatic surface and represents the zero pressure contour for groundwater pressure. Above this level, the ground may still be wet but is only partially saturated
Hammer tap	See *break-in tap*.
High density polyethylene pipe	A pipe made of polyethylene with material characteristics that allow it to be classified as “high-density.” Other classifications of polyethylene pipe are available but HDPE is the most commonly used polyethylene pipe in North America.
Horizontal directional drilling	Steerable method for the installation of pipes, conduits and cables using a sub-horizontal drilling operation. Drilling may be surface launched at a shallow angle or launched horizontally from a pit. The operation may include one or more stages of hole enlargement using a reamer followed by pipe or cable installation in the created hole.
Hydrograph	Graph showing variation of water elevation, velocity, streamflow, or other property of water with respect to time
I/I	Combination of infiltration and/or inflow in sewer systems without distinguishing the type of source. Both inflow and infiltration have the same effect of usurping the capacities of sewer systems and treatment facilities. See Section 4.2.1 for a discussion of different sources of I/I.
I/I study	Study conducted to evaluate and quantify infiltration and inflow (I/I) of rainwater and groundwater into the sanitary sewer system, and locate areas within the collection system with high levels of I/I.
Illegal connection	In relation to sewer laterals, this denotes an inflow source from a type of connection to the sewer system that is not permitted by the local code and/or ordinance. In some cases, connections were historically allowed but changes to the code have made them illegal at the present time.
Impact moling	A technique for creating a small hole through the ground using a percussive action to displace the soil around the moling device. Typically these devices are non-steerable and are used over short distances.
Infiltration	Water entering a sewer system from the ground through defective pipes, pipe joints, connections, or manhole walls (see section 4.2.1 for a more complete discussion in relation to sewer laterals).

Inflow	Water discharged to a sewer system from such sources as roof downspouts; basement, cellar, yard, and area drains; foundation drains; cooling water discharges; drains from springs and swampy areas; manhole covers; cross-connections from storm sewers; combined sewers; catch basins; storm waters; surface runoff; street wash waters; or drainage (see section 4.2.1 for a more complete discussion in relation to sewer laterals).
Influent	Untreated wastewater that flows into a wastewater treatment plant.
Inserts	In connection with sewer lateral rehabilitation, these are preformed connection pieces that are used to seal the lateral to mainline connection.
Intralaminar heat cure	Uses a liner with a conductive material to generate the heat for resin curing from resistive or inductive currents.
Inversion	A process in which a pipe liner unfurls itself along a pipe under applied water or air pressure thus, at the same time, turning the pipe liner inside-out.
Invert	Line that runs along the base of the pipe at the lowest point on its wetted perimeter.
Joint packer	A sealing device (typically using inflated bladders on either side of a joint) that allows a pipe joint to be isolated and pressure tested. The same packer may also be used to allow a sealing grout to be injected in joints failing the pressure test.
Lateral	Sewer pipe conveying wastewater from a house or other private building to a sewer mainline in the street or in a utility easement.
Lateral, privately owned	The section of a lateral sewer that is considered to be privately owned and with the owner responsible for its condition, operation and maintenance. The extent of private ownership of the sewer may not coincide with the property line. See Section 2.2.1 for further information. Also referred to as the “upper lateral” if portions of the lateral length are both publicly and privately owned.
Lift station	A structure built to allow sewage to be lifted from a lower to a higher elevation so that it can again flow via gravity in sewage pipes without the pipes being at too great a depth. Pumps to lift the sewage are installed within the structure and level controls, backup pumps, etc. are provided to allow unattended operation under normal circumstances.
Linear regression	The creation of a straight line *regression* that best fits a set of data.
Lower lateral	Typically, the section of a lateral’s length that is publicly owned.
Mainline	Sewer pipe (normally publicly owned) in the street or in an off-street easement area to which the sewer laterals are connected.
Manning Coefficient (n)	A coefficient used in hydraulic calculations of pipe flow to indicate the roughness of a pipe wall and its effect on flow velocity and discharge capacity.

Marker ball	An electromagnetic marker that can be buried adjacent to an underground object so that its position can be determined easily at a later date using an electromagnetic detector.
Net present value	The economic value of an object or planned activity that is calculated by taking into account expenses, income, savings, etc. and the time intervals at which each occurs. The value is expressed as a net worth at the present time. This allows the economic analysis to include allowance for interest rates and inflation.
NPDES	A national program under Section 402 of the Clean Water Act for regulation of discharges of pollutants from point sources to waters of the United States. Discharges are illegal unless authorized by an *NPDES permit*.
NPDES permit	A permit issued by the state authority to a municipality, industry, or other entity that wishes to discharge water to a surface water. NPDES permits regulate wastewater discharges by limiting the quantities of pollutants to be discharged and imposing monitoring requirements and other conditions.
NSF/ANSI standards	Over 50 voluntary American National Standards under the scope of public health and safety. NSF International, The Public Health and Safety Company™, is accredited by the ANSI to develop American National Standards.
Offset joint	Joint where there is transverse displacement of adjacent pipe sections.
"One Call"	A single phone number notification system established to inform all underground facility operators in the area of intended excavation. This is a communication link between the excavator and the various underground facility owners to increase public safety while decreasing underground facility damage, monetary loss, and personal injury. Anyone planning to excavate is generally required by law to contact the One-Call service prior to excavation—even when excavating on private property.
Open cut replacement	Traditional dig up method for replacing an existing pipe. It requires a continuous trench along the full length of the pipe.
Orangeburg pipe	Pipe made of cellulose (wood) fibers that were impregnated with coal-tar pitch. Manufactured until the 1970s and widely used in private laterals prior to that time. This type of pipe has experienced a significant failure rate in recent years.
Peak wet weather flow	The maximum flow rate in the sewer system caused by a rainfall event. It is typically assessed over a certain time period such as the peak flow volume in a 1-hr period.
pH	Measure of the intensity of the acid or base condition of a solution, expressed in standard units. A value of 7 is neutral, below 7 is acidic, and above 7 is basic.

Pipe bursting	One of a family of trenchless pipe replacement methods. It allows a brittle old pipe to be broken in place and the pipe fragments and surrounding soil to be displaced sufficiently to allow a new pipe to be drawn into the created hole.
Pipeline Assessment Certification Program	A comprehensive and consistent set of CCTV inspection codes that describes sewer pipe conditions. Developed to provide standardization and consistency in the way sewer pipe condition is evaluated and CCTV inspection results managed.
Pipeline Assessment Certification Program	An education and certification program designed to help standardize and make consistent the *defect classification* and *condition assessment* of sewer pipes.
Pipe replacement	The installation of a new pipe in place of an existing pipe. It may be carried out using open cut construction—either on the same alignment (removing the old pipe first) or on a parallel alignment (abandoning the old pipe and possibly removing it); or it may done as a trenchless pipe replacement project using *pipe bursting* or another means of fragmenting, splitting or removing the existing pipe and creating an enlarged hole into which the new pipe is drawn.
Pipe splitting	One of a family of trenchless pipe replacement methods. It allows a ductile old pipe to be split or sliced open in place and the pipe and surrounding soil to be displaced sufficiently to allow a new pipe to be drawn into the created hole.
Plug	In connection with sewer pipe use, an insertable barrier to flow within a pipe. Typically, it is an inflatable bladder that can be inserted within the pipe and expanded until is seals the pipe. It is used to temporarily block flow while testing a pipe or doing rehabilitation work.
Plumber's snake	A flexible rod used to clean sewer lines that can be pushed through internal plumbing and/or a sewer lateral.
Point repair	A pipe repair that is made at a specific location or only on a short segment (a few feet or less) of pipe.
Present worth	The value today of an investment or expense that occurs at a different time. It allows for the interest cost of money and for value changes caused by inflation.
Pressure testing	The isolation of a segment of a sewer system or sewer pipe or joint to test for leaks. Pressure testing can be done using air pressure or water pressure according to the circumstances.
Private disconnect program	A agency program designed to encourage/require the removal of illegal inflow sources to a sewer system.
Protruding tap	Lateral-to-mainline connection in which the lateral pipe extends inside the mainline beyond the pipe wall.

Public right-of-way	Any land where a public utility owns the right to do maintenance, repairs, improvements, and clearing (cut down trees, pave the roadbeds, place sewer and water lines, and permit other companies such as power, telephone and cable companies to use the right-of-way).
Polyvinyl chloride pipe	Pipe made of the material polyvinyl chloride and widely used in newer home laterals.
Pump station	See Lift station
Rainfall derived inflow and infiltration	Rainfall derived inflow and infiltration is the I/I that is caused by a rainfall event rather as opposed to any continuous infiltration or inflow that occurs in dry weather (usually referred to as base infilitration). Also known as rainfall dependent inflow and infiltration
Rainfall simulation	In sewer testing, the use of sprinkler hoses to mimic rainfall at a known rate and duration and in a specific location.
Regression	The statistical process of creating the equation of a curve or line that provides a "best fit" relationship for a set of data between particular parameters being studied.
Rehabilitation	Upgrading of defective sewer pipes (without complete replacement) to provide acceptable performance conditions for continued use. The design life for rehabilitation varies with the technique used but may be in excess of 50 years.
Relining	A form of pipe rehabilitation in which the pipe is sealed and/or structurally renovated by inserting a new lining within the old pipe.
Resin	In connection with sewer rehabilitation, any of a large class of synthetic plastic materials that have some of the physical characteristics of natural resins but are different chemically.
Resin impregnation	The introduction of a liquid resin material into a fabric sheet. The impregnated fabric sheet can then be inserted within a pipe and cured to form a liner. The creation of an initial vacuum within the fabric sheet can aid in full impregnation of the liner fabric.
Sanitary sewer overflow	A wastewater discharge from a sanitary sewer on land or public area in the sewer collection system serving a wastewater treatment plant. It occurs through manholes and lift stations, and deteriorated pipes throughout the system. Sewer basement backups and flooding of homes with sewage are also SSOs, as is an emergency sewer bypass used at a treatment plant.
Sanitary sewer system	A system of pipes, pump stations, sewer lines, etc., used to collect and convey sewage to a treatment plant.
Sewage	Any wastewater collected in and conveyed by sewers.

Sewer basin	A portion of a sewer system that represents a useful subdivision of the system in terms of analyzing or monitoring behavior of the system.
Sewershed	Defined area tributary to a single point along an interceptor pipe (a community connection to an interceptor) or tributary to a single lift station. Community boundaries are also used to define sewershed boundaries.
Sewer interceptor	Sewer pipe or tunnel that is designed to capture sewage from an existing sewage pipe or system and to transport the wastewater to a storage area or treatment facility. Interceptor sewers are typically used to prevent overflows in existing portions of a system and may be designed to provide significant shortterm storage within the interceptor sewer itself.
Sewer, private	Sewer pipe located on the private property.
Sewerage	A system of sewers or the process of the removal and disposal of sewage and surface water by sewers.
Sliplining	A technique of pipe rehabilitation by *relining* in which a new pipe or pipe lining is simply slid into place within the old pipe. A loss of diameter occurs which is more critical in small diameter sewer pipes.
Slug grouting	A newly developed commercial technique using moving bladders within a pipe system to control the position and extent of liquid grout material within a pipe system and hence to sequentially grout portions of the pipe system.
Smoke testing	The use of artificially created smoke injected into a segment of a sewer system to help identify defects in the system. When a defect is near the surface and not beneath the water table or another impermeable surface, smoke leaking through the defect will appear at the surface.
Sonde	A device that emits an electromagnetic signal that permits the detection of the position and depth of the device to a reasonable degree of accuracy. A walkover sonde is a sonde designed to be detected by a handheld device carried across the ground surface. A sonde used for directional drilling may also transmit information about the inclination and rotational position of the sonde itself.
Stormwater inflow/infiltration	Inflow or infiltration resulting from rainfall events.
Street right-of-way	Strip of land dedicated for public streets, sidewalk and utilities.
Sump pump	A pump used to evacuate water from a water filled pit. Often used to provide drainage for a house basement.
Surcharge	Overload of sewage flow—beyond the capacity of the sewage system. The sewage pipes then run under pressure and the water level rises within the sewer manholes. If large enough, the surcharge may result in a sanitary sewer overflow.

Tap	The connection of a sewer lateral to the sewer mainline.
Tidal infiltration	Infiltration caused by a raised groundwater level due to tidal fluctuations near a coastline.
U.L. certification	A U.S. product safety certification issued by an independent, not-for-profit certification organization Underwriters Laboratories, Inc. (U.L). This is one of the most recognized certifications around the globe.
Upper lateral	See *lateral, privately owned*.
Utility easement	Defined area, normally across private property, within which a utility agency is granted the right to install a utility and to have future access for maintenance, repair and replacement.
Vacuum excavation	A process using a jet of compressed air or water to loosen the soil after which the loosened soil is vacuumed into a receiving tank. It can be used to make small diameter excavations for a variety of purposes.
Vitrified clay pipe	Pipe made of clay that has been heated to a high temperature (vitrified) to change its physical properties. Found extensively in older sewer laterals. Older clay pipes did not have flexible gasketed joints and hence have been prone to damage caused by differential ground movements.
Wastewater treatment plant	Portion of a publicy owned treatment works (POTW) designed to provide treatment of municipal sewage and other compatible wastewater.
Wet weather flow	Usually referred to as the flow in a combined sewer system with stormwater, but may also constitute the flow in a separate storm or sanitary drainage system with stormwater. The wet weather flow in a sanitary system will include sanitary sewage flow, base infiltration and rainfall derived inflow and infiltration (RDI/I). In a combined system, direct stormwater drainage will also be present.
Wet weather overflow	An overflow or discharge from a combined or sanitary sewerage system or storm drainage system that is the result of wet-weather flows into the system (i.e caused by a rainfall event or continued wet weather).

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