WARRANTY INSPECTION
SUPPLEMENT TO THE PILOT PROJECT REPORT

Regional Infiltration and Inflow Control Program
King County, Washington

August 2006

Prepared for King County by Earth Tech Team,
Seattle, Washington

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

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From 2002 to 2004, King County and local sewer agencies jointly sponsored 10 pilot projects to test methods of controlling infiltration and inflow (I/I) into sewers. These pilot projects, conducted as part of the County's Regional Infiltration and Inflow Program, included rehabilitation or replacement of public and private sewers within the service areas of the 12 local sewer agencies listed below.

City of Auburn
City of Brier
Coal Creek Utility District
City of Kent
City of Kirkland
City of Lake Forest Park
City of Mercer Island
Northshore Utility District
City of Redmond
Ronald Wastewater District
Skyway Water and Sewer District
Val Vue Sewer District

The October 2004 *Pilot Project Report* describes how the pilot projects were conducted, including: selecting pilot project locations, rehabilitation technologies, implementing design, bidding, administration, and construction. The *Pilot Project Report* also provides an evaluation of the effectiveness of each pilot project and describes lessons learned.

This document supplements the *Pilot Project Report* and describes the results of warranty inspections conducted after the pilot projects were completed. By conducting warranty inspections, King County and the local agencies that hosted pilot projects determined whether the techniques used and products installed during the pilot projects performed according to manufacturers' and contractors' claims. Warranty inspection resulted in contractor repair of some defects or failures in the rehabilitation work. It also provided an opportunity to see if I/I occurred in parts of the system that were not rehabilitated, and whether water migrated along the exterior of rehabilitated pipes before entering through a defect in a section of the sewer system that was not rehabilitated.

The pilot project construction contracts included warranty periods of 12, 18, and 24 months for various types of rehabilitation techniques and products. Extended warranty periods were required because: (a) many of the techniques and products had not been used in the Pacific Northwest, and (b) it was desirable to ensure that warranty inspections were conducted during wet weather months. Those items that were repaired under the initial warranty had an extended warranty and were inspected again in the winter of 2006.

King County and local agencies worked together to identify which portions of the rehabilitated sewers would be inspected. In some cases, all installations of a product were inspected; in other cases, only a sample was inspected. In one case, the number of defects noted during the initial inspection led to inspection of the entire project. Warranty inspection was performed by King County's consultant and a contractor equipped to inspect sewer pipes and manholes.

Defects discovered during warranty inspections were identified as either "product failure" or "product not performing as anticipated". When product failures were observed during inspections, the County and local agency determined which failures required repair, then contacted the contractor to arrange for repair work. This report discusses how warranty repairs were made. Products that did not perform as anticipated were not repaired; these products are noted in this report.

Warranty Inspection Results

Very few warranty defects were identified during inspection. The results are summarized as follows:

- In general, sewers replaced by pipe bursting were almost defect-free. Defects were limited to connections made at welded saddles (where the lateral connects to the sewer main) or where mechanical couplings were used to connect the pipe to the manhole. These few defects could be attributed to backfill and compaction of the excavation, to a lapse in quality control by field personnel, or to the flexibility of high density polyethylene (HDPE) pipe.
- Work involving cured-in-place (CIP) products also showed few defects; however, more defects were observed than for pipe bursting. These defects could be attributed to the limited access available inside a pipe (most CIP work is done remotely using robotic equipment). Defects were noted in CIP liners of sewer mains and in the first project that used TOP HATs™, a product that seals the lateral-to-main connection.
- Only a few rehabilitated manholes had defects. Several manholes replaced during pipe bursting developed cracks in the bottom section above the connecting pipe. It is likely that this was due to settlement or compaction of the backfill around the manhole, or due to structural defects. Immediately after construction, King County crews found and repaired several CIP manhole liners that had separated from the manhole walls. During warranty inspection, these manhole CIP liners were in good condition.

The repairs made by contractors were accepted and are covered by an extended warranty. King County performed a second warranty inspection in the winter of 2006, before the extended warranties expired. The results of the second warranty inspection are also included in this report.

1.0 Warranty Inspection Process

King County's consultant provided a proposed list of rehabilitated sewer system components for warranty inspection. The proposed warranty inspection list was based on: (a) problems identified by local agencies, (b) potential problems noted by construction inspectors during construction, and (c) a random sampling of all the techniques and products. The proposed list was reviewed and accepted by King County and the local agencies. The consultant then contracted with a local sewer system evaluation survey (SSES) contractor to perform the inspection services.

Examples of Local Agency Involvement

- One local agency asked inspectors to check an area where a homeowner repaired the side sewer.
- Another agency provided a picture of a leaking manhole.
- A few months after construction work finished, there were reports in a local agency's service area about several manholes with delaminating CIP linings. This condition was observed by King County crews preparing to install a post-construction flow monitor in one of the manholes. All the manhole linings were inspected, and 8 of 16 manholes were repaired before final acceptance. In addition, King County and the local agency requested that all lined manholes be inspected to determine if there were further problems.
- In another case, warranty inspection in one area showed numerous defects, so King County and the local agency decided to have the entire project inspected.

Two agencies managed their own construction contracts:

- In Skyway, the contractual warranty period was 24 months. The Skyway Water and Sewer District asked that its system be included in the warranty inspection even though there were 6 months left in the warranty period. Only three noteworthy "failures" were reported: (1) a case in which a resident illegally reconnected a yard drain system, (2) a location where a new irrigation system pipeline was bored through the new side sewer, and (3) two leaking lateral-to-main connections. Skyway was notified about the findings and took direct action with the homeowners and contractor.
- In the Ronald Wastewater District, King County did not perform a warranty inspection. The District used mainly pipe bursting as a means of rehabilitating its sewer pipes, which typically resulted in few if any defects. The District Manager spoke with his own consulting engineer and staff and chose not to have a warranty inspection done.

Table 1 shows the amount and types of rehabilitation work done during construction. Using this information, King County inspected a sample of between 10 and 50 percent of the rehabilitated system components for a large quantity of items (for example, 14,000 feet of HDPE pipe). For a small quantity of items (for example, 9 manhole pans), up to 100 percent of the components were inspected.

Table 1 – Constructed Rehabilitation Techniques and Products

Pilot Project	Constructed Rehabilitation Techniques and Products	Constructed Facilities	Inspected During Warranty Inspection
Auburn[2]	Pipe burst mains Pipe burst or dig/replace laterals and side sewers Replace manholes with new manholes Install manhole pans in existing manholes	2,169 linear feet (lf) main 19 laterals / side sewers 11 manholes 9 manhole pans	944 linear feet (lf) main 3 laterals / side sewers 11 manholes 9 manhole pans
Brier[2]	Install polyester resin and felt CIP liners in mains Seal service connections with TOP HAT™ Chemical grout manholes Install Poly-Triplex® fiberglass liners in manholes Install manhole pans	2,938 lf of main 51 manholes	1,844 lf of main 26 manholes
Kent[1]	Install polyester resin and felt CIP liners in side sewers Install T-Liner® in laterals	172 laterals / side sewers	1,460 lf of main 32 laterals / side sewers
Kirkland[2]	Pipe burst sewer mains and pipe burst or dig/replace laterals Replace existing manholes with new manholes	4,157 lf of main 74 laterals 19 manholes	822 lf of main 13 laterals 19 manholes
Lake Forest Park[2]	Install epoxy resin and felt CIP liners in sewer mains Seal service connections with TOP HAT™ Interior cementitious coating or chemical grouting of manholes	8,723 lf of main 41 manholes	2,109 lf of main 10 manholes
Manhole Project in Coal Creek, Northshore, and Val Vue	Chemical grout manholes or install interior coating Install interior chimney coating or chimney boot Replace a paving ring with WhirlyGig™ Raise frame and lid on manholes	228 manholes	78 manholes
Mercer Island [2]	Install polyester resin and felt CIP liners in sewer mains Seal service connections with TOP HAT™	16,411 lf of main	16,411 lf of main
Redmond[2]	Install MultiLiner® in mains (polyester resin with fiberglass fabric) and pipe burst one 264-foot section of main Seal service connections with TOP HAT™ Install T-Liner® in laterals Interior cementitious coating or chemical grouting of manholes	6,422 lf of main 109 laterals 37 manholes	2,413 lf of main 14 laterals 20 manholes
Ronald	Pipe burst laterals and side sewers		No warranty inspection performed.
Skyway[2]	Pipe burst mains Pipe burst laterals and side sewers Replace existing manholes and cleanouts with new manholes	9,521 lf of main 140 lf laterals / side sewers 36 manholes	9,521 lf of main 14 laterals / side sewers 9 manholes

1 The Kent project switched from CIPP to pipe bursting of laterals and side sewers during construction.
2 Warranty inspection performed on sewer mains also examined the lateral connections.

Product Sampling Selection Process

- King County selected a sample of the rehabilitated sewer mains, manholes, laterals, and side sewers for inspection from each of the pilot projects. The facilities were either randomly selected or were chosen to focus on potential problems observed during construction. In some instances, the local agency requested inspection of certain areas based on information noted by its maintenance crews or in areas where the local agency had historically experienced problems. Warranty inspection quantities are shown in Table 1. For one pilot project, the number of defects noted in the initial sample prompted the local agency to request that the remainder of the pilot project construction be inspected. In other cases, all of one type of repair product was inspected because of the small number installed (for example, the nine manhole pans in Auburn).
- King County's consultant selected a Sewer System Evaluation Survey (SSES) contractor who was not involved in the original SSES or pilot project construction work. The consultant provided the SSES contractor with copies of as-built drawings marked up to indicate which parts of the rehabilitated sewer system to inspect. The contractor cleaned and videotaped each of the areas, recording information for later reference and review. The contractor delivered compact disks containing video information and paper reports, then reviewers used the WinCan™ Reader program to "read" and review the information.
- Using the information provided by the SSES contractor, the consultant identified items needing repair work. Following this review, the consultant met with King County and the local agency to discuss the findings and also met with the contractor to discuss options for repairs. The construction contractor was allowed 2 weeks to propose repair options and a schedule for the repair work.
- Following all inspection, review, and warranty repair work, copies of the information were given to each local agency. This provided each agency with an updated reference from the pilot project area. For two agencies, the initial warranty inspection pointed out problems that were repaired; therefore, these agencies received extended warranties. The second warranty inspection results were also provided to these agencies.

2.0 Rights-of-Entry, Public Notification, and Permits

Once the warranty repair items and affected properties were identified, King County staff sought new rights-of-entry (ROE) onto property for the purpose of inspection and repair. Most of the pilot project construction ROEs expired in December 2004. The new forms will expire in December 2006, providing time for the SSES contractor to complete inspection and time for construction contractors to repair any defects.

Since new ROEs were obtained from homeowners who had previously signed, gathering new signatures was not difficult. However, a few homeowners would not sign ROEs or return phone calls. In some instances, the homeowner had changed since the time of pilot project construction and the new homeowner had no history with the program. The County sent detailed letters to homeowners explaining the pilot program, the work done on the side sewer or lateral, and

requesting that the new homeowners sign an ROE form. In the future, agencies should consider obtaining ROEs that encompass the entire project schedule from initial SSES through construction and warranty inspection.

In two of the three manhole project basins, local agency staff gathered the ROEs or received permission from a property owner for the inspection. Another local agency has permanent easements and rights to enter the properties. This local agency considered the warranty inspection to be an extension of system maintenance.

In Skyway, the district set up a 24-month warranty period. Because this warranty inspection occurred with about 6 months remaining, Skyway asked that the County send affected property owners a letter notifying them of the inspection. This was completed about a month before inspection.

For each pilot project area, the SSES contractor was provided information about necessary contacts prior to beginning work. Some local agencies identified a staff member to contact and others requested that the contractor also notify police or fire departments. This notification process worked well.

Permit requirements for the warranty inspection and repairs were limited to right-of-way permits, business licenses, and a State of Washington contractor license.

3.0 Weather Conditions during Warranty Inspection

Warranty inspection occurred between February and April 2005. The region received very little precipitation during this period (however, some record-tying rains were recorded in the following weeks). Even during the dry period, there was some evidence of I/I in laterals and leaks in other system components. Local agencies were notified of these leaks so they could schedule repairs.

In Brier and Mercer Island, a second warranty inspection occurred in March and April 2006. During the winter, the region received slightly higher than average precipitation; however, the rainfall was relatively light in the weeks prior to the inspections. In Mercer Island, the April 2006 inspection continued to show evidence of I/I in laterals and leaks in other system components.

4.0 Pilot Project Warranty Results

This section describes defects discovered during warranty inspection and the products that did not perform as anticipated. The results are presented initially by pilot project (Section 4.1), then by product (Section 4.2). Section 4.2 contains more detailed information, including pictures.

4.1 Warranty Results by Pilot Project

Auburn

The Auburn pilot project consisted of new manholes, pipe burst mains and laterals, and manhole pans in existing manholes. No defects were noted in the pipe work done in Auburn.

Only two problems were noted for the stainless steel manhole pans in Auburn: (1) in two of the pans, the vent was missing, leaving a hole in the bottom of the pan and rendering it ineffective; and (2) several pans were stuck in place by rust (presumably rust from the frame, not the pan), or they were "glued" in place because the neoprene gasket decayed due to the heat and weight of the manhole lid.

Brier

The Brier pilot project consisted of chemically grouted and CIP-lined manholes, CIP pipe lining, and several manhole pans. The lateral connections were either chemically grouted or had a TOP HAT™ installed.

Although there were substantial problems with the CIP manhole liners at the end of construction (8 of 16 were repaired as part of the punch list work), no other defects in the manhole liners were observed. (See Section 4.2.4.)

The only pipeline defect discovered during warranty inspection involved a 12-inch-diameter pipe that received a CIP lining. The defect was repaired and re-inspected in March 2006. (See Section 4.2.1 for more details.)

Kent

The Kent pilot project consisted of CIP liners, T-Liners®, and pipe burst laterals and side sewers. Because this project switched early in construction from CIP products to pipe bursting of laterals and side sewers, most of the rehabilitation involved pipe bursting. No work was done on the sewer mains or manholes; however, the sewer mains were inspected so that the lateral-to-main connections could be reviewed. Most of the CIP liners and T-Liners® were inspected, while proportionally fewer pipe burst lines were reviewed. The CIP liners and T-Liners® installed in Kent had no defects and the portion of each T-Liner® inside the main was well sealed.

While no defects were noted in the rehabilitated sewer work done in Kent, there were several places where the mains were cracked and one place where there was a hole in the main.

Kirkland

The Kirkland pilot project consisted of new manholes, pipe burst mains, and pipe burst or dig-and-replace laterals. No defects were noted in the work done in Kirkland.

Additional details about couplings located immediately adjacent to manholes in Kirkland are provided in Section 4.2.1.

Lake Forest Park

The Lake Forest Park pilot project consisted of interior-coated or chemically grouted manholes, epoxy resin CIP pipe lining for sewer mains, and TOP HATs™ for the lateral connections. One section of sewer main could not be lined with CIP products so the joints were chemically grouted.

No defects were noted in the work done in Lake Forest Park. It is believed that little to no gap exists between the liner and sewer main; no leakage was observed through the liner, at lateral connections, or out the end of the liner into the manholes. This may be due to: (a) the use of epoxy resin, (b) the compatibility between TOP HATs™ and the epoxy resin liner, or (c) a combination of the two. Further research regarding this issue should be considered.

Manholes – Coal Creek, Northshore, and Val Vue

The Manhole Project (conducted in Coal Creek, Northshore, and Val Vue) included installing interior-coated or chemically grouted manholes and interior chimney coatings and boots, replacing one paving ring, and raising or repairing the frame or lid. Almost all of the rehabilitation work was defect-free. The exceptions are noted below.

In Val Vue, an actively leaking manhole was considered to exhibit a warranty defect. During rehabilitation, chemical grout was injected in the bottom of the channel. This grout was subsequently exposed to the flow in the pipe. The constant flow eroded the chemical grout and a small leak developed. The contractor repaired the defect by re-grouting and protecting the hole with a cement grout patch. This manhole has continuing structural problems. During rehabilitation, it was very difficult to seal the manhole with chemical grout, so it also received an interior cementitious coating. After 1 year in service, however, the coating shows minor cracks. It is believed that this manhole may fail structurally in the future, and manhole repairs to control I/I will not prevent future problems.

In Northshore, a number of leveling ring boots were installed. The portions of the leveling ring boots not held in place by the expansion bands were bulging where the manholes were subjected to water pressure. This was not considered a defect needing repair and it did not cause leaking. This occurred when the manhole was located in a wetland or near a creek and the groundwater was at the ground surface. The problem with the bulge was that it decreased the diameter of the chimney section, making it difficult for a person to enter the manhole.

Mercer Island

The Mercer Island pilot project consisted of CIP pipe lining of sewer mains and installation of TOP HATs™ at the lateral connections to the mains.

Numerous defects were noted in the CIP pipe linings and TOP HATs™. See Section 4.2.1 for details and pictures. The defects discovered during the warranty inspection were repaired and re-inspected in April 2006. (See Section 4.2.1 for more details.)

Another issue noted was homeowner repair of a side sewer using a CIP liner. The liner projects into the sewer main, as seen in Figure 1. Although not a warranty issue, it is an example of a

potential problem that any agency will face when it uses rehabilitation methods in its sewer system.

Figure 1 – Homeowner installation of CIP liner in lateral

Note that the CIP liner blocks the sewer main and the TOP HAT™ has been partially destroyed and is no longer effective.

Redmond

The Redmond pilot project consisted of interior-coated or chemically grouted manholes, CIP pipe lining for mains and laterals, CIP spot repairs in the mains, and one section of pipe burst main. No defects were noted in the work done in Redmond.

Ronald

No warranty inspection information is available because the agency chose not to perform a warranty inspection.

Skyway

The Skyway pilot project consisted of new manholes, pipe burst mains, and pipe burst or dig-and-replace laterals and side sewers. Only two defects involving leaks were noted in the work done in Skyway: two connections between an HDPE sewer main and a lateral were actively leaking. See Figure 3 for a picture of one of these leaks. Other issues noted were an illicit yard drain connection to the system and the new irrigation system pipeline bored through the new side sewer. See Figure 2 for a picture of the new irrigation system pipeline bored through the new side sewer.

Figure 2 – Irrigation pipe bored through a side sewer in Skyway
Picture was taken with a push camera so orientation is unknown.

4.2 Warranty Results by Sewer System Component

4.2.1 Sewer Mains

Pipe Bursting of Sewer Mains

The four pilot projects that included pipe bursting of sewer mains were Auburn, Kirkland, Redmond (one 264-foot-long section), and Skyway. No warranty defects were noted in Auburn, Kirkland, or Redmond.

In Skyway, leaks were noted in two connections between an HDPE main and a lateral. See Figure 3 for a picture of one of these defects. These leaks were observed at the bottom edge of two welded saddle connections. It is likely that there was an insufficient seal between the main and the saddle when the saddle was welded in place. These connections were made by hand by first placing the curved heater plate between the main and the saddle, then removing the heater plate before the saddle was pressed against the main using a 6-foot-long pry bar. The connections were not tested before drilling the hole in the main.

No structural defects were noted at welded joints in the HDPE pipe where the interior bead was left in place. However, some beads showed evidence of catching debris, and it appears that beads cause minor amounts of turbulence in the flow. Removal of these interior beads is not difficult and is recommended for future work. These beads can also interfere with the tracks on

the robotic closed circuit television (CCTV) camera, making traction for moving the camera within the pipe more difficult at times. In addition, HDPE is smooth and slippery, adding to the camera traction issue, especially in steeper slope pipes. In one case, the CCTV operators resorted to installing screws into the treads of the wheels to improve traction.

Another potential problem included two separated joints where non-HDPE couplings were used for the joint immediately outside the manhole. See Figure 4. Although the work was not considered to be a warranty defect since the work was not in violation of the specifications and there was no visible leakage, there appears to be a potential for future failures of these joints. The ends of each pipe were cut with a chain saw and then stabbed into the coupling. Ragged edges were visible inside the pipe. Future evaluations should consider how well a rigid coupling seals against flexible HDPE pipe, and electrofusion-welded couplings should be considered for joints immediately outside the manhole.

Recommendations for pipe bursting future work include:

- Perform either an air or water pressure test of the welded lateral connection before cutting into the main.
- Select a welding method that forces the main to be round before the lateral connection weld is made. This is basically a clamping system that controls the fit between the main and the saddle during the process.
- Consider using a small amount of controlled density fill around the connection prior to backfilling to avoid problems with the compaction of soils around the connection.
- In the future, consider electrofusion-welded couplings for joints immediately outside the manhole.

Another interesting comparison is the difference between black and gray HDPE pipe. See Figures 5 and 6 for pictures. Gray pipe reflects light better than black and is recommended.

Figure 3 – Leak at the bottom of a welded saddle connection in Skyway

Picture was taken looking up the lateral from inside the sewer main.

Figure 4 – Non-HDPE coupling used during pipe busting

Used for the joint immediately outside a manhole in Kirkland.

Figure 5 – Black HDPE pipe in Skyway

Pipe is visible only when light from the camera is aimed at it. The photograph also shows a lateral cut through the sewer main.

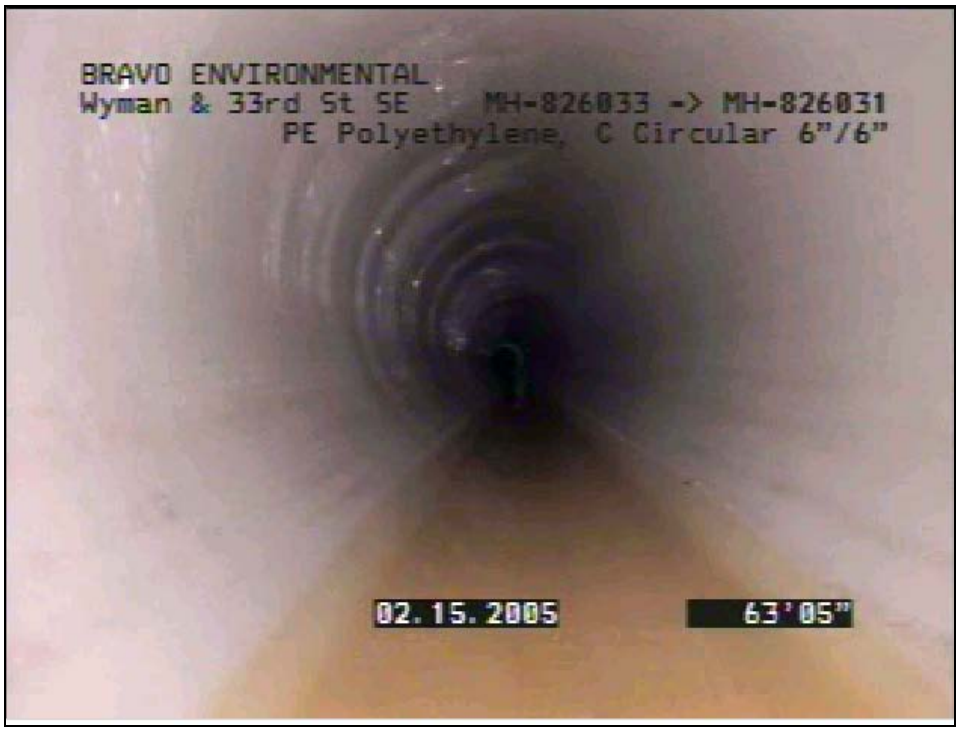

Figure 6 – Gray HDPE pipe in Auburn

Pipe reflects light from the camera better than black HDPE pipe.

Cured-in-Place Pipe (CIPP) Sewer Mains

The four pilot projects that included cured-in-place pipe (CIPP) sewer mains were Brier, Lake Forest Park, Mercer Island, and Redmond.

No defects were noted for the MultiLiner® product installed in Redmond or the epoxy resin liner installed in Lake Forest Park. Minor linear wrinkles did not appear to cause problems such as catching debris in the pipe. No holes or leaks were observed and no visible defects resulting from the curing process were noted during warranty inspection. The CIP products appear to have worked well in conjunction with TOP HATs™ and T-Liners®.

For the Redmond and Lake Forest Park pilot projects, it is believed that little or no annular gap exists between the liners and sewer mains, as evidenced by the lack of leakage through the liner or out the end of the liner into the manholes. This apparent lack of an annular gap has not been directly observed, but could be tested if a section of each type of liner was removed from the main for inspection. In Redmond, all the ends of the CIP liner were sealed with epoxy. This practice appears to have prevented leaks. For the Mercer Island and Brier pilot projects, it is believed that an annular gap exists between the liner and sewer main in some places, as evidenced by leakage through holes in the liner or out the end of the liner into the manholes. Some of the ends of the liners in Mercer Island were also sealed with epoxy; however, one of the liners was found to be leaking and was chemically grouted during the warranty repair work.

In Brier, there was a curing failure in the bottom portion of a 12-inch-diameter CIP liner. It was not observed in the August 2004 post-construction video. This area was first seen during the March 2005 warranty inspection as a long bubble about 3 inches wide in the bottom of the 12-inch-diameter pipe. The bubble protruded upward approximately 1-1/2 to 2 inches. The bubble occurred only in the flow line of the pipe and extended approximately the last 60 feet in the 135-foot-long section of pipe. The cause of this bubble is believed to be: (a) an inadequate liner curing process (inadequate heat from the steam), and (b) the long length of the liner (a 600-foot length of 12-inch-diameter CIP liner was installed in one piece through three sections of pipe). According to the inspector's field notes, the contractor had several problems with this section of liner during construction. The initial problem was discovered the day the liner was installed. The contractor reapplied air pressure and steam the following day. A 3-foot section of the liner was removed and a spot repair was installed inside the pipe at the downstream manhole several days later.

The reason that the bubble was not seen in the late summer post-construction video, but was seen in the springtime warranty inspection, could be due to changes in groundwater pressure; that is, higher groundwater levels could have pushed up this portion of the liner. Figure 7 shows a portion of the defect.

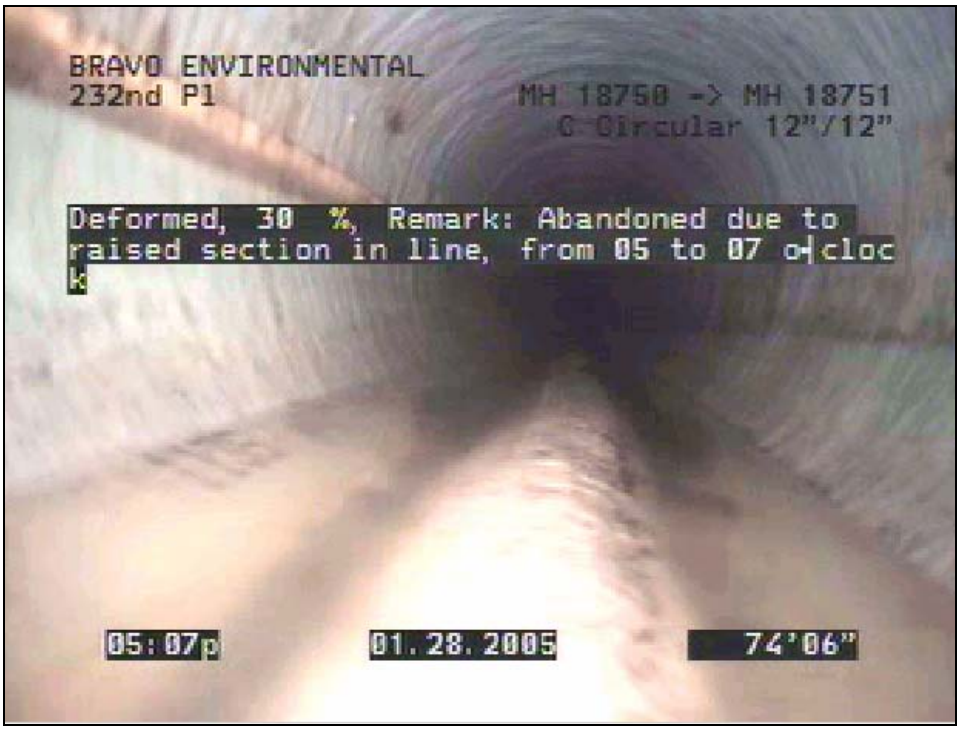

Figure 7 – Defective CIPP in 12-inch-diameter sewer main in Brier

In March 2006, the contractor inserted a liner with no resin and used it as a bladder to reheat and pressurize the bubble in the bottom of the pipe. This appears to have removed the bubble.

In Mercer Island, leaks through holes in the liner were noted at stitched and taped seams and at some random spots. Active leakage, staining, and debris buildup on the liner indicated the location of holes. The contractor installed six spot repairs during the warranty period to fix this type of defect, in addition to the four spot repairs installed as part of the punch list during construction. There were also numerous minor linear wrinkles. Although the wrinkles are not a warranty issue and do not appear to cause flow problems, they caused minor difficulties in getting the CCTV camera through the pipe. Figure 8 shows an example of an active leak through a CIP liner.

TOP HATs™ did not appear to work well in conjunction with CIP liners. (See Section 7.0 for details.)

The warranty repairs were re-inspected in April 2006 and all leaks appeared to have been successfully plugged. The Top Hats™ also appeared to be securely attached to the CIP liner and were not leaking. However, the CCTV videos taken for the second warranty repairs filmed the entire length of each pipe, not just the repaired portion. For one section of pipe, the videos showed two small squirting leaks in portions of the pipe that were no longer covered by a warranty. Other portions of the inspected pipes had deposits on the walls, which were considered to be indications of potential leaks. The leaks indicated that there was groundwater pressure outside the pipe and there was a route for the water to get to the hole in the liner, either directly through a crack in the old pipe or by flowing through a void between the old pipe and the liner.

The potential leaking spots either were not defects or may not have been leaking, because the groundwater was not above the defect.

Figure 8 – Active leak through CIP liner in Mercer Island

The white stripe is plastic tape covering the seam and is part of the liner. Behind the tape is the stitched seam in the felt.

CIPP Spot Repairs in Sewer Mains

The pilot projects that included CIPP spot repairs inside sewer mains were Redmond, Brier, and Mercer Island. All of the CIPP spot repairs installed in Redmond and Brier remained in place. One of the Mercer Island spot repairs had a raised lip on the upstream end (see Figure 9). A second spot repair was installed during the warranty period to fix the defect. None of the spot repairs that were observed during the warranty inspection showed evidence of failure or leakage. There was also no indication that leaks had migrated to nearby defects.

Figure 9 – Curled edge on the upstream edge of a CIPP spot repair in Mercer Island

Grouting Joints in Sewer Mains

Lake Forest Park was the only pilot project where grouting of pipe joints was used as the rehabilitation method. Joint grouting was used for one pipe because the pipe could not be lined with a CIP product. No defects in the grouting were noted. Figure 10 shows the remnants of grout remaining inside the pipe after grouting the joint. The grout has remained in place over a year.

Figure 10 – Photo of pipe in Lake Forest Park

Remnants of grout remain inside the pipe after grouting the joint.

4.2.2 Laterals and Side Sewers

Cured-in-Place Liner for Laterals and Side Sewers

The Kent CIPP laterals and side sewers showed no defects during inspection.

Pipe Bursting of Laterals and Side Sewers

The welded connections in Auburn were in good condition. In Kent, the lateral connections to the sewer mains were polyvinyl chloride (PVC) fittings cut into concrete sewer mains (there were no welded HDPE connections). No problems were observed with these connections. The Kent and Auburn pipe burst laterals and side sewers showed no defects.

In Skyway, the only defects in the laterals and side sewers were leaks in the bottom side of two welded saddle connections. See Section 4.2.1 for further details and recommendations. The pipe burst laterals and side sewers in Kirkland and Skyway showed no defects. Where larger sections of pipe (6-inch diameter) are used to replace the lateral/side sewer, removal of the bead is recommended because the bead can catch debris and disrupt the flow in the pipe, particularly in shallow sloped pipe. The 4-inch-diameter pipe used for these projects came in a roll so it typically had very few welded joints.

Open-Cut Replacement of Laterals and Side Sewers

In Kirkland, open-cut trenches were used when replacing laterals. No defects were noted in these pipes or the associated fittings.

Grouted Connections for Laterals and Side Sewers

Brier was the only pilot project where grouting was used as the rehabilitation method for lateral-to-main connections. (TOP HATs™ were also used in Brier for some of the lateral-to-main connections.) No defects were noted for the grouted connections.

TOP HATs™ for Lateral Connections

No warranty-type defects were noted for TOP HATs™ used in conjunction with the MultiLiner® CIP liner product installed in Redmond or for the epoxy resin liner installed in Lake Forest Park. Some of the TOP HATs™ installed in Lake Forest Park showed minor peeling around the edges, but not enough to impact flows or require warranty repairs.

In Mercer Island, the TOP HATs™ showed various defects. Some TOP HATs™ showed varying degrees of loose edges inside the CIPP sewer main and some failed to seal to the CIPP sewer main, as evidenced by staining and leaks through the seal. Eight repairs were made during the warranty period in addition to the 11 repairs made as part of the punch list during construction. There were a total of 229 TOP HATs™ installed during construction; therefore, 8 percent of the TOP HATs™ had defects. See Figures 11 and 12 for photographs of the portion of a TOP HAT™ inside the sewer main. Figure 13 shows a TOP HAT™ in Lake Forest Park that had no defects.

Figure 11 – Photo of a Mercer Island TOP HAT™

Note that the edge of the TOP HAT™ brim is not attached to CIP liner in the sewer main. In this case there is no evidence of leakage.

Figure 12 – Photo of a Mercer Island TOP HAT™

Black staining around outside edges of the TOP HAT™ brim is evidence of leakage.

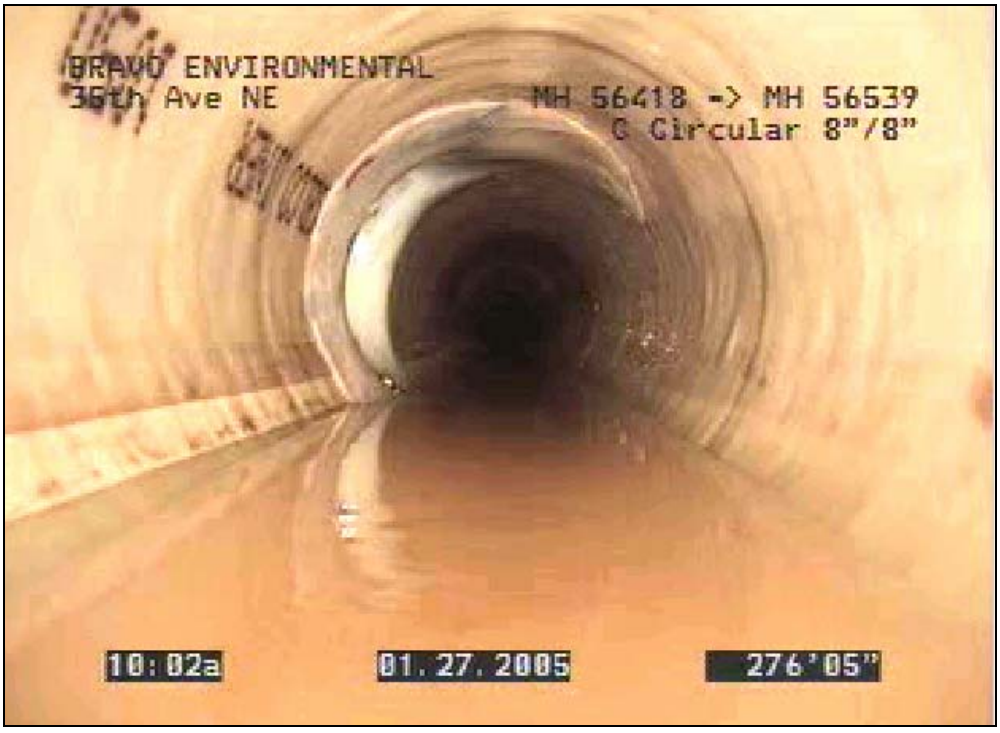

Figure 13 – TOP HAT™ in Lake Forest Park that has no defects

In addition to the potential incompatibility between the TOP HAT™ and the CIP liner, King County sees an additional drawback with TOP HATS™ in that they usually do not extend far enough up the lateral to seal the first joint. If the mainline CIP liner and TOP HATs™ seal leaks in mains and connections, the next place for water to enter the line is the first side sewer joint. Although not a warranty defect, leaks and roots were observed at this first joint. See Figure 14 for a photograph taken up inside a lateral.

Figure 14 – Photo of a Mercer Island TOP HAT™

Photo is looking up inside a lateral. Top edge of TOP HAT™ is white. Note that the first joint in the concrete pipe is not covered by the TOP HAT™.

In one case on Mercer Island, a homeowner had a CIP liner installed in the property's side sewer to prevent roots. During the de-rooting process or lining process, the TOP HAT™ was destroyed. Although it does not represent a warranty defect, this type of situation should be considered by any agency considering the use of TOP HATs™. A TOP HAT™ is susceptible to damage during sewer cleaning and is difficult to replace because a qualified and licensed contractor must install it. At this time, that contractor is based in California.

T-Liners® for Lateral Connections

T-Liners® were installed in Redmond and Kent. In Kent, only a few were installed because of the switch to pipe bursting laterals and side sewers. In Redmond and Kent, no defects were noted and the portion of T-Liner® inside the main was well sealed. In Kent, a manufacturer's representative supervised the local contractor's crew. In Redmond, the contractor hired the manufacturer's crew to install the liners. During inspection, the only defect noted was a single case where the upstream end did not seal well inside the side sewer and could catch debris. The

photos in Figures 15 and 16 were taken in Redmond. The photos show T-Liners® with no defects.

Figure 15 – Photo of T-Liner® from Redmond

Photo was taken from inside the sewer main looking up a lateral lined with a T-Liner®.

Figure 16 – Photo of T-Liner® from Redmond

Photo was taken inside the sewer main and shows the portion of T-Liner® inside the main.

4.2.3 Cleanouts

Buried cleanouts were difficult to locate. A metal detector was used to locate buried cleanouts in locations where a metal plate was installed above the cleanout. Those without metal plates could be found only if there were detailed side sewer cards. Cleanouts installed at the surface are targets either for people dropping in rocks or for being replaced with a yard drain. Although not a warranty defect, one Skyway cleanout was illegally connected to a yard drain system. The Skyway Water and Sewer District was notified so it could work with the homeowner to make corrections.

4.2.4 Manholes

Interior Cementitious Coatings for Manholes

Interior cementitious coatings were applied to manholes in Redmond and Lake Forest Park. No defects in the coatings were noted in Redmond or Lake Forest Park.

The Val Vue pilot project had five manholes where an interior cementitious coating was used for rehabilitation. One of these manholes could not be sealed with chemical grout during rehabilitation, so it received an interior cementitious coating. After 1 year the coating has minor cracks. It is believed that this manhole may fail structurally in the future and repairs for I/I control will not prevent future problems.

Chemical Grouting for Manholes

Chemical grouting was used for the majority of rehabilitated manholes. There was no evidence that the grout failed to perform its intended purpose. Chemical grout was injected in one of the Val Vue manholes in the bottom of the channel. The grout was exposed to the flow in the pipe. The constant flow eroded the grout and a small leak developed. The contractor repaired the defect by re-grouting and protecting the hole with a cement grout patch.

Cured-in-Place Fiberglass Manhole Liners

Cured-in-place fiberglass manhole liners were problematic during construction (refer to the *Pilot Project Report*); however, the repairs appear to be working. Repairs were made during construction because the liners did not adhere to the manhole walls or to the channel. In a manhole located in Brier, the lining in the channel section was peeling and catching debris.

Paving Rings

A paving ring was used in one manhole in Coal Creek. No defects were found in the ring.

Leveling Ring Boots

Leveling ring boots were installed in the Northshore Utility District, one of three project basins where manholes only were repaired. No defects were noted; that is, there were no leaks. However, portions of the boots not held in place by expansion bands were bulging where the manholes were subjected to water pressure. This normally occurred when the manhole was located in a wetland or near a creek and the groundwater was at the ground surface. The problem

with the bulge is that it decreases the diameter of the chimney section and makes it difficult for a person to enter the manhole.

Interior Chimney Coatings

Coating of interior manhole chimneys was done in the Northshore Utility District and in Redmond. No defects were noted and there was no evidence of post-rehabilitation I/I such as staining. The only thing noted during inspection was development of a yellow substance on the interior surface. This may be a mold or fungus that is growing on the asphalt-based product; however, no tests were performed to characterize the growth. Long-term inspection may determine how well this type of coating product holds up to the conditions.

Manhole Pans

Stainless steel manhole pans were used in Brier and Auburn. No plastic pans were tested.

Two defects were noted for the stainless steel manhole pans in Auburn. In two of the pans the vent was missing, leaving a hole in the bottom of the pans and thereby rendering them ineffective. The second defect was that several pans were stuck in place by rust (presumably rust from the frame, not the pan) or they were "glued" in place because the neoprene gasket decayed due to the heat and weight of the manhole lid.

Reset Manhole Frame and Raise to Grade

No defects were noted in locations where a manhole frame was reset.

Cement Patching Grouts

The inspection reports were insufficient to indicate whether defects were associated with this type of repair. No information is available.

New Manholes

Two new manholes in Kirkland had cracks above one of the pipes in the base section, although no leaks were evident. It is likely that this problem is associated with settling of the backfill bedding or insufficient reinforcing in the base section. Better bedding of the manhole and pipes, and the possible use of controlled density fill may alleviate the problem.

5.0 CCTV Standards

The warranty inspection contractor used WinCan™ software as the method for recording inspection work. Besides pipeline CCTV, the data included video footage of each manhole inspection. The Reader program version of the software is functional and relatively easy to use. One of the software's convenient functions is the ability to easily reverse or fast forward to a spot on the video with a click of the mouse (this can be compared to the function of video tapes, which require waiting for the tape to move). A separate program was used to clip still photos or sections from the video.

6.0 Warranty Inspection Costs

The warranty inspection contractor used the pipe lengths from the record drawings to avoid keeping track of pipe length quantities. The engineering costs were $48,000. The SSES costs for the warranty inspection are shown in Table 2. No warranty inspection was performed for the Ronald pilot project. King County staff costs are not included.

Table 2 - Warranty Inspection Costs

Pilot Project	SSES Costs
Auburn	$3,730
Brier	$8,350
Kent	$10,780
Kirkland	$7,340
Lake Forest Park	$4,010
Manholes	$11,070
Mercer Island	$21,640
Redmond	$11,760
Ronald	N/A
Skyway	$15,600
TOTAL	$94,280

The engineering costs related to the extended warranty inspection in Mercer Island and Brier were $8,600. The SSES costs for the extended warranty inspection in Mercer Island were $7,800. There was no contractor cost in Brier for the extended warranty inspection since the contractor inspected the repairs under the terms of the extended warranty. As noted above, King County staff costs are not included.

Overall, the total cost of the warranty inspection and extended warranty inspection was $158,680. This does not include King County's costs or the costs incurred by the contractor for repairing rehabilitation work. In the *Executive's Recommended Regional Infiltration and Inflow Control Program Report* (Table 3-3, page 3-13), the total cost for all the pilot projects is listed as $12,003,500. This translates to warranty inspection and extended warranty inspection costs of approximately 1.3 percent of the total cost for all the pilot projects. Since relatively few repairs were needed, these warranty inspection funds were used mainly to verify the quality of the work.

7.0 Lessons Learned

The warranty inspection revealed several problems and positive points. Some leaks in the rehabilitated components were uncovered and many of the products and processes performed according to manufacturer and contractor claims. Some I/I that continues to occur in non-rehabilitated parts of the system was noted, such as in laterals that are clearly leaking after the main was repaired.

Rehabilitation in General

Sewer system rehabilitation requires the use of new products and processes that agencies are not always familiar with. Some of the new products are susceptible to damage by equipment meant for working in non-rehabilitated sewers. Other products such as HDPE pipe and CIP liners present new challenges. There are several lessons to be learned:

- Local agencies need to understand new products and processes and how to work with them in the system once they are installed. For example, when HDPE pipe is installed during pipe bursting operations, the agency needs to have the equipment for working with this type of pipe or standards for allowing a contractor to work with it. In the case of the Mercer Island homeowner who repaired a side sewer using a CIP liner, the TOP HAT™ was destroyed and the lateral liner projected into the sewer main. Another potential situation is a contractor digging up a concrete pipe to make a lateral connection and discovering that it has a CIP liner.
- Local agencies need to closely monitor where rehabilitation work has occurred and use their permitting process to flag situations where work is occurring on rehabilitated parts of the sewer system.
- Agency maintenance crews and homeowner's contractors (such as sewer cleaning companies or root cutting companies) need to be educated about the limitations of working on rehabilitated sewers. These groups rarely have a permit, so using the permitting process to flag situations when work is occurring on rehabilitated parts of the sewer system may be impractical.

These examples highlight potential issues facing any agency that uses rehabilitation methods in its sewer system. Maintaining a leak-free system does not have to be difficult; however, problems can be avoided with some forethought, planning, and standards.

Pipe Bursting

Welded fittings and couplings appeared to work better than rigid couplings. When welding saddles, some type of system for ensuring that the main is round during saddle installation should be utilized. The connections should be leak tested before being put in service. Use of controlled density fill may be warranted in some cases. Removal of the weld beads is not difficult and is recommended for future work.

New Manholes

For future designs, additional attention should be given to manhole bedding, especially when a new manhole is used to replace an existing one and the pipe alignment is restricted by the pipe bursting process. Attention should also be given to construction of the base section, specifically the reinforcing.

Interior Cementitious Coatings for Manholes

Interior cementitious coatings are unlikely to prevent future leaks if the manhole is failing structurally and the cracks are opening or shifting. Flexible coatings may work better; however, none were installed in the pilot projects so no information on flexible coatings is available in this report or the *Pilot Project Report.*

Leveling Ring Boots

Although the leveling ring boots prevent I/I, they make the chimney of the manhole substantially narrower, which makes the leveling ring boots susceptible to damage during maintenance or when otherwise accessing the manhole. Use of these products should be carefully considered before they are specified. Also, since the water table must be high enough for water to leak into the chimney of the manhole, consideration should be given to addressing I/I for the manhole frame and lid as well as for the chimney.

Manhole Pans

The manhole pans used in the pilot projects were not successful. Although the stainless steel material may not have problems, the gasket and vent were susceptible to damage during maintenance or when otherwise accessing the manhole. Further research is necessary and should include examination of plastic pans.

Cured-in-Place Pipe (CIPP)

The work done in the field has a greater effect on the end product than the factory wet-out process. Field quality assurance/quality control (QA/QC) is critical for this type of work.

During warranty inspection, the epoxy resin/felt liner and the MultiLiner® with polyester resin/fiberglass fabric had no leaks or defects. However, installation of the epoxy resin left a slug of resin inside the laterals during construction. The slugs cured and the hardened slugs had to be removed before any work could be done on the lateral connections.

Although the epoxy resin liner and the MultiLiner® CIPP liners are more complex to install and more expensive, use of them may lead to liner defects. The epoxy resin/felt liners are stronger and therefore a better choice if there are structural defects in the pipe.

The polyester resin/felt liner used in Mercer Island had several leaks that were associated with the stitched seam.

In Brier, one section of the polyester resin/felt liner had a curing defect where a bubble formed in the bottom of the pipe. The problem was resolved, but the large diameter and long length of the installed liner (600 feet of 12-inch-diameter liner) may have contributed to the defect. The

contracts for the pilot projects had no provisions limiting the length of large diameter CIP liners or how many sections of pipe could be lined at one time; therefore, the County and local agency were dependent on the contractor's expertise. Consideration should be given to adding language to the specifications that allows the owner to veto such practices. This lesson applies to other aspects of CIP work as well: Quality control is in the hands of the contractor and inspection occurs after the CIP product has been installed (or again after the warranty inspection is done). The definition of a defect can become a point of argument, and it is typically left to the contractor to determine the necessary type of repair.

TOP HATs™

More research is needed regarding TOP HAT™ compatibility with CIP liners and how far up the lateral that the TOP HATs™ seal. If the first joint in the lateral is leaking, this type of product is insufficient for preventing a leak. The methods for repairing a TOP HAT™ also need more consideration.

CIP Manhole Liners

CIP manhole liners have problems associated with the interface at the sewer mains and channels, adhesion to manhole walls, and installation procedures. More research is recommended before this type of product is specified for future projects.

Warranty Inspection Scheduling

The ideal time to conduct warranty inspection is during the rainy season. The inspection period for this program was February and March 2005. However, the region suffered a drought during the 3 months preceding this inspection and the water tables were lower than normal. Lower water tables meant that some leaks were non-existent when compared with earlier in the season. While weather cannot be controlled, local agencies can help provide valuable information throughout the months leading up to the inspection. This was evident during the second warranty inspection in April 2006 in Mercer Island, when two leaks were discovered in a pipe that had not been leaking the previous year.

General Local Agency Input

Between construction completion and warranty inspection, local agency staff members continue to work within their system. It is important for these staff members to collect information about how well the rehabilitated system components work or do not work. One local agency sent electronic pictures and a detailed e-mail to the County project manager to provide notification about a leaking manhole. The picture provided useful details because during the warranty inspection, the water table was lower and the manhole showed no leaks. With information provided by the picture and details, the contractor was able to repair the manhole.

Cleanouts and the Use of Record Drawings for Warranty Inspection

Local agencies need good quality as-built drawings of any rehabilitation work done on sewer mains, laterals, and side sewers. These records are important for future maintenance, homeowner-planned additions, and for locating cleanouts. A steel plate is frequently placed above cleanouts, about 6 inches below grade. The benefit of using a steel plate is that a metal

detector can subsequently locate the cleanout. Buried cleanouts without steel plates are more difficult to locate.

Rights-of-Entry for Warranty Inspection

Rights-of-entry (ROE) are a vital part of working on private property. To impact private property owners as little as possible, the ROE should encompass all of the work. The end date should be far enough in the future to cover the warranty inspection and any possible corrections and extended warranties. Homeowners should be notified that the warranty inspection will occur about a year after construction is completed, and will take place during the rainy season. A letter notifying homeowners and residents about the inspection should be mailed 30 to 45 days before inspection begins. The letter should discuss the course of action if inspectors find a defect that requires repairs.

For this warranty inspection, notification was sent only to residents of the property where inspection was scheduled to take place. For future reference, notices should be sent to all residents in the work area due to the impacts of line cleaning, work trucks, and people walking onto private property. In three areas, homeowners experienced small sewer backups into their bathrooms during sewer main cleaning even though the SSES contractor was not working on their property. The SSES contractor quickly responded to each of these situations.