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AN ANALYSIS OF THE CURED-IN-PLACE PIPE (CIPP) SUBPROJECT OF THE SANITARY SEWER REHABILITATION PROJECT

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An Analysis Of The Cured-In-Place Pipe (CIPP) Subproject Of The Sanitary Sewer Rehabilitation Project

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ABSTRACT

The comprehensive rehabilitation of the Lawrence Livermore National Laboratory Sanitary Sewer System centers around a Cured-in-Place Pipe project. Driven by regulatory requirements to eliminate the potential for exfiltration, a careful condition assessment of the existing infrastructure was conducted. Under programmatic constraints to maintain continuous operations, the INLINER USA cured-in-place pipe system was selected as the appropriate technology, and the project is currently under contract.

INTRODUCTION

Lawrence Livermore National Laboratory (LLNL)

Lawrence Livermore National Laboratory is operated by the University of California under contract with the U.S. Department of Energy (DOE). Founded in 1952 as a nuclear weapons design laboratory, and located on the site of a former naval air station constructed in 1942, LLNL has since diversified into other fields. The mission of LLNL is to serve as a national resource in science and engineering, focused on national security, energy, the environment, biomedicine, science, mathematics education, and economic competitiveness, with a special responsibility for nuclear weapons.

LLNL main site, located at the eastern end of the Livermore Valley in southeastern Alameda County, is 821 acres and slopes at 1.5%, essentially flat. The workforce population as of 1/4/93 was 10,200 people on site. There are 537 buildings and temporary structures totaling 5.5 million square feet.

The LLNL Sanitary Sewer System

The sanitary sewer system at LLNL was installed in stages as the site developed and expanded over the last 52 years. The sanitary sewer discharge goes to the City of Livermore's waste-water collection system. Waste water flow from adjacent Sandia

National Laboratory (SNL) also passes through the LLNL collection system and exits through a single outfall in the northwest corner of the LLNL site.

The LLNL sanitary sewer system is a relatively shallow collection system averaging only about 8 feet in depth and is constructed primarily of vitrified clay pipe (VCP), with diameters ranging in size from 6 to 15 inches. Building laterals are either 4 or 6 inches in diameter. The LLNL system contains a total of approximately 56,650 linear feet of main sewer lines, 36,220 linear feet of laterals and 247 manholes. From the Navy, LLNL inherited a pipe routing that followed a traditional grid street pattern covering almost half the site. In 1968, a looped circulation system was adopted and all new installations have reflected the new configuration. See Figure 1.

A capacity analysis was performed on the sanitary sewer system as the first part of a comprehensive sewer master plan the current estimated capacity is 1,684,800 gallons per day (GPD) with the current usage at 400,000 GPD, and a projected usage of 525,000 GPD by the year 2000. The capacity analysis identified areas subject to infiltration after a rainfall event. It followed exfiltration was possible throughout the system.

The LLNL sanitary sewer system also includes a diversion facility. Sensors in continuous operation will divert the entire discharge to storage tanks in the event of a release of unauthorized materials. LLNL's diversion capacity is 200,000 gallons.

Environmental Regulations

Under the Federal Clean Water Act, the California Porter-Cologne Water Quality Control Act [Water Code section 13000 et seq.] applies to LLNL. This legislation prohibits a discharge without a permit, of any waste (i.e. sewage, liquid, solid, gaseous or radioactive waste substance) to the environment which may have potentially adverse impact on water quality in the State. The Sanitary Sewer Rehabilitation Project was required to eliminate the potential for releases to the environment from LLNL's sanitary sewer pipes and ensure compliance with Federal and State regulations. Project Authorization and funding was approved beginning in Fiscal Year 92.

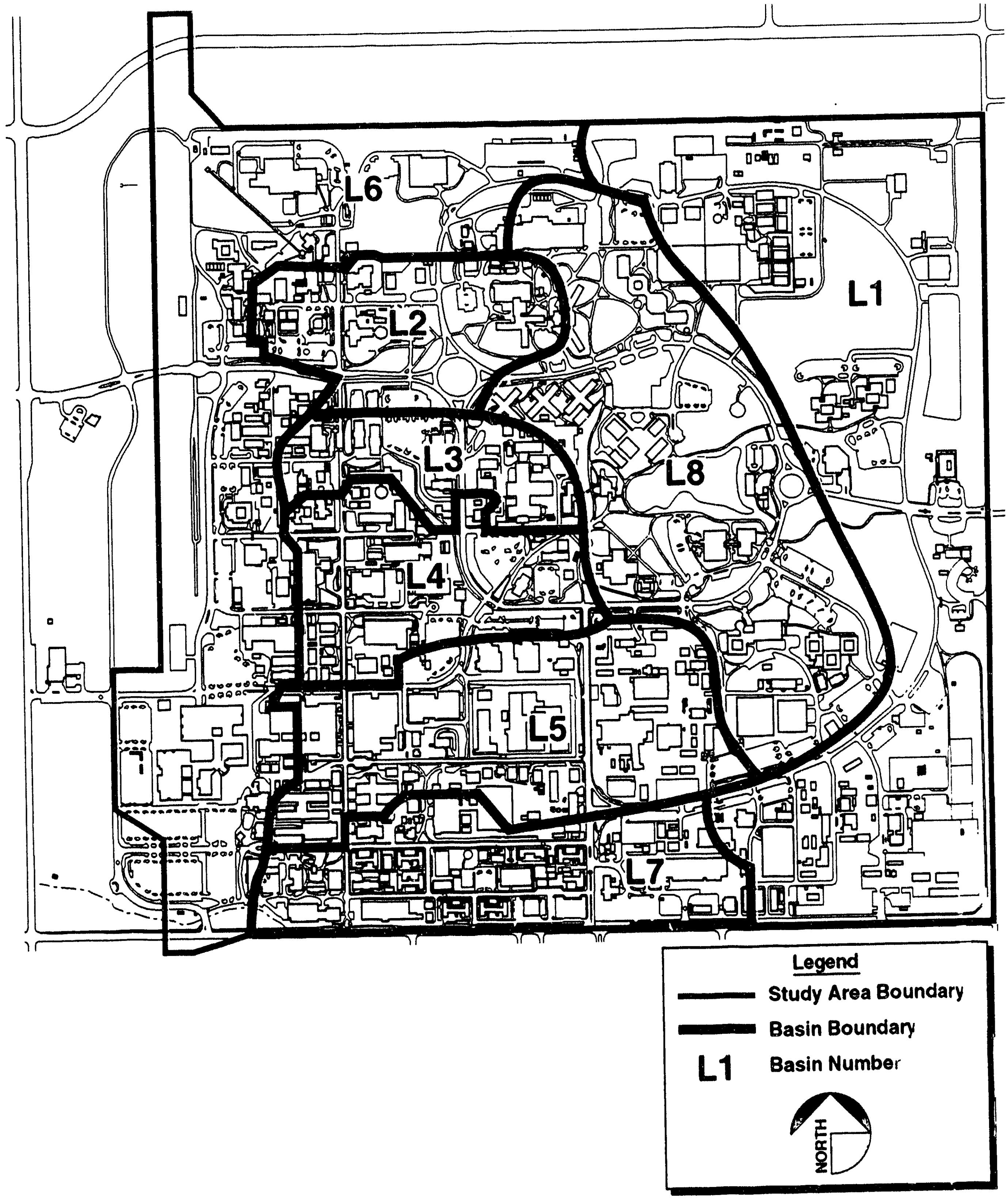

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Figure 1. LLNL Sanitary Sewer Rehabilitation Project Basin Boundaries and Numbers.

The Sanitary Sewer Rehabilitation (SSR) Project

Closed Circuit Camera Television (CCTV) Inspection and Scoring

CCTV inspection of the LLNL sewer collection system was conducted from September 1992 through January 1993 by Pacific Pipeline Survey. Pacific Pipeline inspected 710 pipelines totaling approximately 89,700 lineal feet of mainlines and building laterals (Security restrictions interfered with complete site video taping). The balance of video taping has been completed by LLNL Maintenance and Operations (M&O) crews. During the inspection, structural defects, lateral connections, abnormal conditions and other pertinent information were recorded on videotape and log sheets.

Conditions observed and documented :

- *Visual Structural Inspection.* The number, type and extent of cracks in the pipe (e.g. radial, closed or open; longitudinal closed or open) and the extent of crushed, broken, deformed or collapsed pipe.

- *Offset or Open Joints.* Offset joints and open joints, to determine the need for spot repairs before pipe lining, and identifying points of potential exfiltration.

- *Lateral Defects.* Protrusion of any laterals into the pipeline to determine possible interferences with rehabilitation; defects at the connection, such as cracks, pieces missing or structural defects.

- *Root Intrusion.* The degree and location of root intrusions, including whether it originated from the main line or service lateral.

- *Infiltration.* Infiltration into the mains and from service laterals.

- *Alignment.* The extent of vertical sags and horizontal misalignments to determine the structural integrity of the pipeline and suitability for various rehabilitation methods.

Analysis and Rehabilitation Recommendations

The initial condition assessment was performed by CH2M HILL. Point score assignments to specific defects were used to rank pipelines with respect to visually observed defects. The results of the CCTV coding were entered into a database analyzing the condition of each pipe. A cost analysis of various rehabilitation options was performed with existing CH2M HILL software to determine the least cost alternatives. The system was modified to account for operational constraints and target budgeting. Based on the calibrated scoring system, pipes with a score of at least 100 points were classified as "absolutely" needing rehabilitation while pipelines scoring below 100 points were classified as "deferred". Pipes that scored 0 points were classified as "no action". This scoring provided a ranking of all pipelines for final review and priority ranking.

CH2M Hill's least-cost rehabilitation analysis was limited to pipes that scored 100 points or more. The least-cost rehabilitation analysis considered three alternative methods for rehabilitating pipelines; point repair, inversion lining (CIPP), and pipe replacement.

- *Point Repair.* Point repair is used for lines in fairly good condition with the exception of one or more isolated areas. Point repair consists of replacing sections of pipe, about 8 feet long.

- *Inversion Lining.* Inversion lining is used when the line has suffered structural deterioration. The process uses a flexible polyester-felt liner impregnated with a thermosetting resin, which is inserted into the pipe and cured to form a durable pipe within the old pipe (thus, the term Cured-in-Place Pipe or CIPP). Lining completely seals the pipe leaving it impervious to root intrusion, infiltration and exfiltration.

- *Pipe Replacement.* Total pipe replacement would give the highest strength of the alternatives considered, however, total replacement would also cause more surface disruption, service interruption and/or bypass pumping. Additionally, utility conflicts and environmentally-sensitive soil management practices at LLNL decrease the cost effectiveness of this alternative.

The cost assumptions for the analysis were as follows:

- Equivalent useful life of 50 years (all techniques)
- Uniform pipe depth of 8 feet
- Engineering and inspection costs of 15%
- A 10% contingency
- A 15% utility interference cost where excavation is required.

A second pipeline evaluation process was performed by LLNL. The review considered the rehabilitation cost analysis, and detailed site information including soil contamination conditions, above ground development, operational constraints of the system, maintenance history and pipe age. Additional review of video tapes, log sheets, and specific site conditions was included. This review expanded the number of rehabilitation techniques considered and added a new category "other". Pipelines classified in the "other " category included areas which required additional video inspection, engineering design or abandonment.

Results were compiled into spreadsheets and presented on Auto CAD generated site maps. The overall pipeline condition at LLNL is considered good. Only 26% of the pipes scored greater than 200 points. See Figure 2.

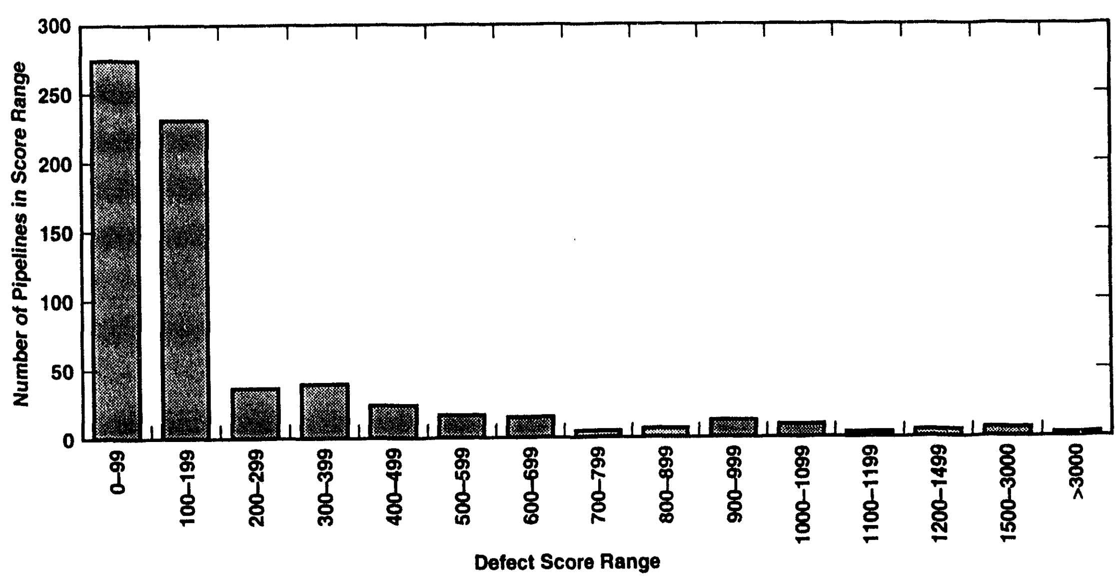

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Figure 2. Pipeline Condition Distribution, Lawrence Livermore National Laboratory.

Point Repair and Replacement Subprojects

The results of the analysis identified approximately 90 point repair and 75 small replacements. The most severe problems found were small sections of broken or crushed pipe. These severe defects were repaired as found by M&O crews. Onsite crews also performed lateral point repairs. The small replacements and mainline point repairs were divided into three packages and have been competitively bid among small disadvantaged business contractors. The first project is complete, the second under construction and the third is in the bid process.

Manhole Rehabilitation

All 247 manholes were inspected by Pacific Pipeline during the initial condition assessment. All are generally in good to fair condition, and re-grouting will be performed on an as-needed basis upon completion of pipe rehabilitation.

Database Requirements

Managing the information for the entire SSR project required the development of three data bases: 1) geographical, 2) cost tracking, and 3) analysis, implementation and recording. These databases will be used to minimize project impact on ongoing operations at LLNL, and control changes to the sanitary sewer system during the rehabilitation project. After the completion of the project, this information will be essential for system management and maintenance.

Operational Constraints

The following are examples of the constraints that apply to any project at LLNL, and make the CIPP alternative particularly appealing for the Sanitary Sewer Rehabilitation Project. LLNL is in operation 24 hours a day, as many research projects must run uninterrupted to generate valid data. Critical facilities and their support always remain on-line. Certain facilities have restricted access due to hazardous and/or sensitive activities, and U.S. citizenship is a requirement for entry that is rarely modified. OSHA and NEPA along with a host of other applicable regulations are followed strictly.

THE CIPP PROJECT

History

The original condition assessment identified 121 pipelines as potential candidates for inversion lining rehabilitation. LLNL presently has approximately 10,000 lineal feet of inversion-lined mainline pipes, and is proceeding with a contract that would bring the total of lined pipe to 30%, site wide.

DOE directed efforts to ensure competitive bidding and the project was reviewed for applicability to the Small Business Set-Aside. It was determined appropriate for open bidding. Protests were filed with the Superior Court and the General Accounting Office (GAO) regarding issues of equivalency and qualifications, however the GAO ruled in favor of the University and a contract was awarded to MOCON Construction utilizing INLINER USA technology. This project is presently under construction.

Description

The current estimated project consists of approximately 28,100 lineal feet of pipe ranging in size from 4" to 12" in diameter. The breakdown as currently planned is :

- 4" 900 linear feet
- 6" 5,800 linear feet
- 8" 17,800 linear feet
- 10" 2,600 linear feet
- 12" 1,000 linear feet

Specifications

The project specifications are a compilation of previous LLNL work and new information furnished by the Pipe User Group, (PUG) as part of their generic specifications in the CSI section and master formats. The University took advantage of PUG recommendations and included warranty and quality assurance clarifications consistent with ASTM F 1216, the standard used for pipe rehabilitation by this process. Unique features to the LLNL specifications include a unit price approach, and the utilization of "winched-in application" procedures to further open, competitive bidding and the requirement for third-party testing (also unit priced).

The unit price approach was used because the aggressive schedule required for the project did not allow for sequential analysis and determination, then rehabilitation implementation. CCTV and analysis phases were conducted staggered but simultaneous to bidding the CIPP project. Total estimated quantities from the original project proposal to DOE were used for bidding purposes and unit prices derived from the estimated totals. Values were broken down by pipe size per lineal feet, set-up charges, remote lateral reinstatement, and testing fees. The cumulative total of all unit costs defined the lowest proposed bid price. The specifications also addressed bidder qualifications and a combination of qualifications and bid price to determine the lowest responsive bidder.

To respond to the DOE directive for a competitive bid, the specification were amended during the bidding process to allow winched-in installation of the liner. This is a deviation from the ASTM F 1216 standard for CIPP installation, which describes inversion application but the standard still applied as written to the rest of the process.

Independent third-party testing by a Nationally recognized testing laboratory (NRTL) is a normal requirement for DOE work. This requirement is also supported by the conduct-of-operations audits that accompany such large projects. Approval for Braun Intertec Northwest Laboratory located in Portland, Oregon is underway. The tests to be conducted on the liner are for flexural, tensile, and creep modulus, strength, and elongation consistent with ASTM test methods D 790, D 638 and D 2990.

Inliner, USA

INLINER USA installation practices are essentially the same as other inversion lining procedures. The pipe is thoroughly cleaned and video taped to check that all obstructions have been removed. The pre-made liner is impregnated with resin, and —this is the differing practice— positioned into the host pipe with the aid of a cable and winch. A calibration hose is inserted into the open end of the lining hose and fixed into position. Utilizing hydrostatic head, the calibration hose inverts into place and causes the lining hose to expand and conform to the contours of the deteriorated pipe. The resin is then forced into the crevices through perforations in the outer layer. Curing commences once the calibration hose is fully inverted, and hot water is circulated to activate the resin. Lateral connections are reestablished using robotic cutters.

Although this project is concerned with all sewer services exterior to buildings, in 1993 another LLNL project contracted Inliner to perform necessary lining to upgrade a secondary containment system. The SSR lining specification was utilized in advertising this work. The problem was how to correct pipe deficiencies within a laboratory's mechanical-equipment room, and not shut the building down. Pipes were located within the floor slab, underneath large HVAC equipment. A CIPP was the logical choice, and since hot air was available within the room the resin was modified to cure at the temperature of the available air supply. The upgrade was performed with minimal impact to the program.

Soil Testing

Soil contamination potential is a main concern at LLNL. A soil management program has been set up to coordinate the testing, excavation releases, material handling, temporary storage and final disposal. Cooperation between the LLNL Environmental Organizations, and Plant Engineering results in safe and traceable soil management practices. All locations scheduled for digging are reviewed for potential contamination problems. Excess soil is stockpiled on plastic, covered and tagged. Soil samples are tested and excess soil is disposed of at the appropriate Land Fill sites.

Safety Plan

Safety is of primary concern to LLNL. The CIPP project and pipe replacement work, as with all construction projects at LLNL, are required to follow the Code of Federal Regulations (CFR) 1926. Individual Project Safety Plans are required to be submitted and approved prior to start of work. The safety plans include Work/Task Hazard

Analyses. The task with associated hazards, must be reviewed for personnel protection requirements, corrective action issues, monitoring methods and frequency. Material Safety Data Sheets (MSDS) are included within the safety plans.

Due to the CIPP onsite resin impregnation process a work/task hazard analysis was performed for the mixing and handling of these products. A typical construction safety plan also will include employee training information, fire protection, hazardous material handling procedures and general instructions for common construction hazards (i.e. fall protection, shoring, hand tools, machinery and vehicles).

Working in Confined Spaces was the most common hazard of both CIPP and conventional trenching work. Confined Space Training is required and confined space permitting procedures set up and implemented. Sanitary sewer manholes and trenches are monitored as confined spaces at LLNL.

COSTS

This sanitary sewer rehabilitation project was funded as a $13.5M congressional line item FY(92-95) with completion scheduled in December 1994. Currently we anticipate completing the project for $6.5M on schedule. The current advancement and competition within trenchless technologies contributed significantly to the cost savings. The following additional conditions also contributed to the SSR project running substantially below budget. 1) Existing conditions of the sanitary sewer has been found to be in better condition than anticipated. 2) Extensive surveys and preliminary work performed by LLNL personnel resulted in a cost savings for the video inspection phase of the project. 3) Actual inflation was much lower than the escalation budgeted in 1990. 4) Current economic conditions resulted in highly competitive bidding.

CONCLUSIONS

As the project proceeds one thing has become very clear: good, well-maintained documentation is essential to the continued operation of sanitary sewer infrastructure systems. Even for a relatively small system such as at LLNL it is difficult to keep track of all the new service connections, and prevent inappropriate methods. Maintenance is different for CIPP pipes and mistakes are expensive. Repairs become an issue, and information from the manufacturers has not always been adequate.

Lastly, while there are indications that CIPP manufacturers may not stay with the under-12" market since deformed pipes may be cheaper. This would affect availability for small collection systems like LLNL. However, our experience has been very positive and the University can recommend CIPP as a successful rehabilitation method.

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