WATER AGENCIES' STANDARDS

Design Guidelines for Water and Sewer Facilities

SECTION 12.5
PIPELINE REHABILITATION

12.5.1 PURPOSE

The purpose of this section is to provide guidelines on the methods and selection criteria for pipeline rehabilitation.

12.5.2 STANDARD TERMS AND DEFINITIONS

Wherever technical terms occur in these guidelines or in related documents, the intent and meaning shall be interpreted as described in Standard Terms and Definitions.

The following terms and definitions as found in this section shall have the following meaning:

Close-Fit Pipe (CFP):	A procedure of installing a polyethylene (PE) pipe with a temporarily condensed or modified cross-section into an existing pipe. Once in place, the pipe is expanded to its normal shape forming a tight fit with the existing pipe.
Cured In Place Pipe (CIPP):	A lining process in which a slim pliable tube of fiberglass fabric or polymer is infused with a resin. The tube is then expanded by means of fluid pressure into position on the inner wall of a defective pipeline before thermally curing the resin to harden the material. This technology has been commonly used by Insituform® Technologies Inc.
Localized Repair (LR):	Localized repair is a name given to the use of a number of varying technologies to refurbish an isolated segment of pipe rather than the replacement of an entire reach. This may also serve to repair a defective point in a pipe due to a manufacturer's defect or poor installation. The localized repair techniques consist of robotic repair, grouting, internal seal, and cured in place pipe.
Modified Sliplining (MSL):	Method in which a liner is segmented and inserted into an existing pipe and pieced together inside of the faulty pipe. One common method is Spiral Wound pipe where a continuous strip of Polyvinyl Chloride is fed into a winding machine that wraps the interior of a defective pipe. A second method is Panel Lining in which panels of a smaller diameter than the existing facility are inserted and chemically bonded or welded in place.
Pipe Bursting (PB):	See Section 12.3 for definition and guidelines.
Pipe Removal (PR):	Pipe removal is a similar technology to pipe bursting, but relies on horizontal directional drilling or mictrotunneling to excavate and remove pipe fragments rather than displacing them into the surrounding ground.
Sliplining (SL):	Insertion of a new pipe by pulling or pushing it into the existing pipe and grouting the annular space.

Thermoformed Pipe (ThP): The use of a new polyvinyl chloride (PVC) or polyethylene (PE) pipe that is folded or deformed until it is inserted in the existing pipe and then expanded with a hot fluid (typically steam) and pressure to fit tightly inside the existing pipe.

Underground Coatings and Linings (UCL): The use of cement, epoxy, shotcrete, or gunite to provide a monolithic layer that inhibits further deterioration of the pipe.

Carbon Fiber Relining (CFR): The use of carbon fiber cloth and epoxy resin placed on the interior surface of the pipe.

12.5.3 GENERAL

It is the responsibility of the user of these documents to become familiar with rehabilitation technique and applicability for a particular situation. Not all techniques are appropriate for a given pipe material, pipe diameter, pressure condition, or to provide support to an existing pipe with degraded structural integrity. Many of the methods discussed in this section require highly skilled engineers and contractors with experience in the given rehabilitation process. It is not the intent of this document to replace the knowledge gathered by a competent engineer or contractor, but to assist in the selection of applicable and cost effective rehabilitation technique. The ultimate selection of the pipe repair method will be at the sole discretion of the agency's District Engineer.

12.5.4 PROCESS OVERVIEW

The process for implementing a pipeline rehabilitation program occurs in the following four steps, Inspection, Planning, Preparation, and Execution:

A. PIPELINE INSPECTION

The inspection and identification of the location repairs are needed are critical to the success of a rehabilitation program. Inspection is typically done by either closed circuit television (CCTV) or visual inspection for pipelines large enough to accommodate the entry of a person. Other techniques may be pipe specific such as the use of Remote Field Eddy Current/Transformer Coupling for Pre-stressed Concrete Cylinder Pipe (PCCP). Other inspection techniques such as "smoke testing" may identify that a problem exists, but may not adequately locate where the pipeline defect is located or what the defect is. For pressurized mains, there are acoustical methods such as the Sahara® leak location system from the Pressure Pipe Inspection Company that may with reasonable accuracy locate leaks in a pressurized main. However, this will still require some form of visual inspection to determine what the failure is. Since leaks in pressure mains may not necessarily be located in the immediate vicinity of where the leak is located, it may be necessary at times to employ locating techniques to identify where to excavate. Some of the types of pipeline defects are:

1. Break-in Connection Damage (Sewer)
2. Capacity or hydraulic problems
3. Corrosion
4. Cracks and Fractures
5. Debris/Obstructions
6. Deformation
7. Holes
8. Inflow, Infiltration, and Exfiltration
9. Offset Joints
10. Separated Joints
11. Sags

B. PLANNING

Once the defect is located and identified, planning is the next stage of rehabilitation (See Chart 1 as an example of the planning process.) The following list of items should be gathered before the decision making process begins:

1. Pipeline inspection results (location and defect)
2. Fluid type and characteristics (pH, potential for corrosive gas production, salinity, etc.)
3. Pipeline environmental conditions (soil pH, physical site constraints, other utility conflicts, ability to remove pipe from service, live and dead loads on pipe).
4. Pipe properties (diameter, material, types of joints, existing cathodic protection, connection of dissimilar metals nearby)
5. Pipeline capacity.
6. Location and number of service connections on pipe reach.
7. Structural integrity of damaged pipe.
8. Joint locations (if available)
9. Prioritization of the repair and likelihood of a pending catastrophic failure.
10. Modeling of potential solutions that reduce pipe diameter or change friction values.

The selection of the rehabilitation technique is based on a number of factors and ultimately the cost of repair versus the cost associated with replacement of the entire facility. In many cases when a pipe has reached the end of its lifecycle and additional capacity is needed, repair may not be as efficient as replacement or upsizing to a larger diameter facility. The following two tables may be used to select the pertinent rehabilitation technique for the specified defect (Table 1) and the limitations in the use of the methods for particular applications (Table 2).

Table 1 - Applicability of Rehabilitation Method for Specified Defects

Rehabilitation Method	Joint Separation	Joint Problems	Corrosion	Cracks/ Holes	Inflow, Infiltration, and Exfiltration	Structural Problems	Inadequate Hydraulic Capacity[1]
Cured-In Place Pipe	Yes	Marginal	Yes	Yes	Yes	Yes	No
Slip Lining	Yes	Marginal	Yes	Yes	Yes	Yes	No
Close-Fit Pipe	Yes	Marginal	Yes	Yes	Yes	Yes	No
Pipe Bursting	Yes	Marginal	Yes	Yes	Yes	Yes	Yes
Pipe Removal	Yes	Marginal	Yes	Yes	Yes	Yes	Yes
Localized Repair-Robotic Repair	Yes	Marginal	No	Marginal	Yes	Marginal	No
Localized Repair-Grouting	Yes	Marginal	No	Marginal	Yes	No	No
Localized Repair-Internal Seal	Yes	Marginal	Yes	Yes	Yes	Yes	Yes
Localized Repair-Cured-In-Place	Yes	Marginal	Yes	Yes	Yes	Yes	No
Modified Sliplining - Panel Lining	Yes	Marginal	Yes	Yes	Yes	Yes	No
Modified Sliplining - Spiral Wound	Yes	Marginal	Yes	Yes	Yes	Yes	No
Underground Coatings & linings-Cement Mortar	Yes	Marginal	Yes	Yes	Marginal	No	No
Underground Coatings & Linings-Epoxy Lining	Yes	Marginal	Yes	Yes	Marginal	No	No
Underground Coatings & Linings-Shotcrete	Yes	Marginal	Marginal	Yes	Marginal	Yes	No
Underground Coatings & Linings-Gunite	Yes	Marginal	Marginal	Yes	Marginal	Yes	No
Thermoformed Pipe	Yes	Marginal	Yes	Yes	Yes	Yes	No
Carbon Fiber Relining	Yes	Marginal	Yes	Yes	Yes	Yes	Yes

1. This column assumes that there will not be any change in friction from the existing pipe to the rehabilitated pipe. Most methods will reduce pipe diameter, but may also decrease friction loss, and may result in no net change in capacity. An example of this would be if a vitrified clay pipe was lined with a PVC material.

2. This table was modified from the original version published in "Trenchless Technology Pipeline and Utility Design, Construction, and Renewal" by Narafi and Gokhale, copyright 2005 by McGraw Hill. Permission for reproduction granted by McGraw Hill per license dated February 27, 2007.

CHART 1
PLANNING FLOWCHART

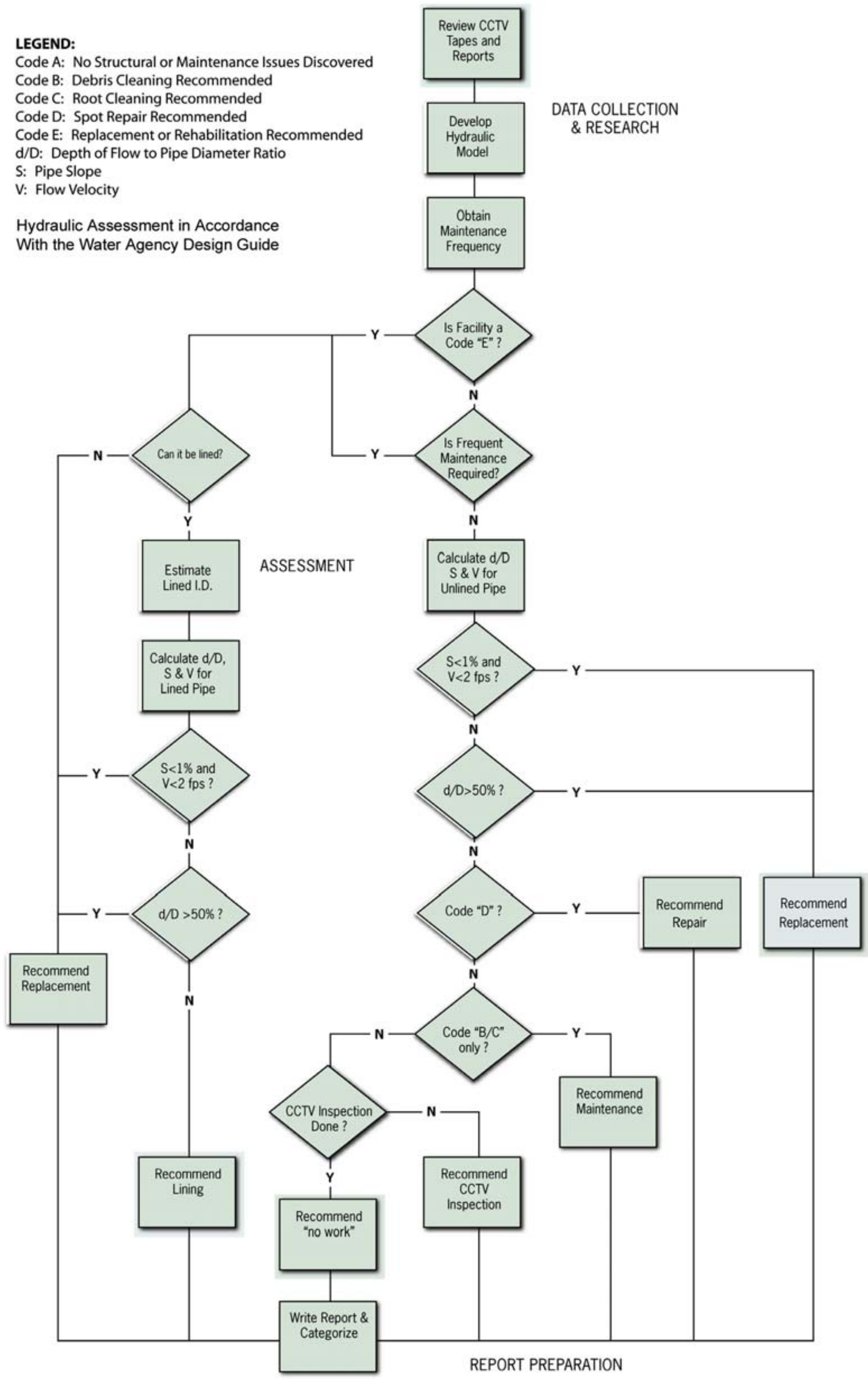

Table 2 - Selection Considerations of Various Pipeline Rehabilitation Methods

Renewal Method	Experience Indicator$_2$	Cost Indicator$_3$	Minimum Pipe Diameter	Maximum Pipe Diameter	Must Seal Liner Ends and/or Laterals	Need Bypass	Need Entrance Pit	Difficult to Install if Existing Pipe is Misaligned	No Structural Support	More than 10% Loss of Diameter	Must Grout Annular Space	Open Cut Needed to Reconnect Laterals	Many Joints In New Pipe	Might Damage Nearby Utilities	Not Suitable for All Pipe Materials	Personnel Entry Into Pipeline
Cured-In Place Pipe	High	See Note 1	4	108	X	X										
Slip Lining	High	Low	4	160	X	X	X	X		X	X	X	X			
Close-Fit Pipe	High	Medium	3	63	X		X	X								
Pipe Bursting	Medium	Medium	4	48	X	X	X	X				X		X	X	
Pipe Removal	Low	High	12	36	X	X	X					X	X	X	X	
Localized Repair-Robotic Repair	High	High	8	30	X	X	X		X	X						
Localized Repair-Grouting	High	Low	3	180	X	X			X							
Localized Repair-Internal Seal	Medium	Medium	6	110		X			X							
Localized Repair-Cured-In-Place	High	High	4	48		X			X	X						
Modified Sliplining - Panel Lining	Medium	Medium	48	N/A	X	X	X	X			X					X
Modified Sliplining - Spiral Wound	High	Medium	6	108		X	X				X					
Underground Coatings And linings-Cement Mortar	Medium	Medium	3	180	X	X	X	X	X							
Underground Coatings And Linings-Epoxy Lining	Medium	Medium	3	24	X	X	X	X	X							
Underground Coatings And Linings-Shotcrete	High	Low	48	180	X	X		X		X						X
Underground Coatings And Linings-Gunite	High	Low	48	180	X	X				X						X
Thermoformed Pipe	Medium	Low	4	30	X		X	X								
Carbon Fiber Relining	Low	High	48	N/A	X	X									X	X

1 - For pipe diameters below 10-inches there is a low cost indicator. For pipe diameters higher than 10 inches, there is a high cost indicator.

2 - "High" experience is 20 years, "medium" experience is 10 to 20 years, "low" experience is less than 10 years.

3 - "High" cost is more than $10/inch diameter per foot of pipe, "medium" cost is between $5 and $10 per inch diameter per foot, and "low" cost is less than $5 per inch diameter per foot.

4 - This table was modified from a version published in "Trenchless Technology Pipeline and Utility Design, Construction, and Renewal" by Narafi and Gokhale, copyright 2005 by McGraw Hill. Permission for reproduction granted by McGraw Hill per license dated February 27, 2007

C. PREPARATION

1. CLEANING - Many of the pipeline rehabilitation processes require a clean inner pipe surface prior to the implementation of the method. The cleaning method may be mechanically powered equipment, high velocity hydraulic equipment (hydro-cleaning), and hydraulically propelled cleaning equipment. For severely defective pipes, care should be taken not to cause further damage when cleaning. Damage to a pipeline in many cases is accompanied by obstructions such as tree roots, collapsed pipe material, or deformed pipes. It may be necessary to use a root cutting apparatus and/or a mechanical tool to reshape the pipe.

2. TEMPORARY SERVICE CONNECTIONS – Prior to executing a pipe rehabilitation method any existing customer that may be impacted by an outage will need to be notified. When at all feasible, customers should remain in service or be provided with temporary service. When not feasible, the project may need to be done in phases to alleviate the time any given reach of pipe is out of service. Appropriate communication to the effected occupants of a property should be done as directed by the applicable Agency.

3. BYPASS REQUIREMENTS – For areas that do not have multiple or redundant service from several directions, a plan will need to be implemented for bypassing the reach of pipe being repaired. The bypass requirements should be completed far enough in advance of the arrival the labor force and materials for the pipe rehabilitation to allow for adequate time to resolve any unforeseen problems. See Section 12.7 – Temporary Bypass Requirements (Sewer) for additional information.

D. EXECUTION

1. INSPECTION – An inspector familiar with the selected rehabilitation process is imperative to the successful repair of a facility. Many repair processes are proprietary in nature, so the ability to find an experienced inspector may need to be considered during the planning stage.

2. SERVICE RECONNECTION – Any services within the reach of pipe being worked on will need to be reconnected. Some techniques require the excavation of each service and manually reconnected. Other processes may implement a robotic cutting arm to cut a hole in the new pipe where the existing services were located. As with inspection, the number of services that need to be reconnected may need to be considered during the planning phase. If an excavation is needed every 10 feet to reconnect a service lateral, then an open cut replacement of the existing facility may be more cost effective than a pipe repair.

3. POST REPAIR CLOSED CIRCUIT TELEVISION - The new facility should be televised and/or visually inspected after the repair has been made. Some processes or linings may not have uniform coverage. Additional repairs may be necessary prior to the acceptance of the job. The specifications for the job should reflect the conditions that are needed for job approval.

12.5.5 REFERENCE

A. Should the reader have any suggestions or questions concerning the material in this section, contact one of the member agencies listed.

B. The publications listed below form a part of this section to the extent referenced and are referred to in the text by the basic designation only. Reference shall be made to the latest edition of said publications unless otherwise called for. The following list of publications, as directly referenced within the body of this document, has been provided for the users convenience. It is the responsibility of the user of these documents to make reference to and/or utilize industry standards not otherwise directly referenced within this document.

1. Water Agencies' Standards (WAS):

   a. Design Guidelines:

      1. Section 12.3, Pipe Bursting
      2. Section 12.7, Temporary Bypass Requirements (Sewer)

2. Additional Resources:

   a. Standard Specifications for Public Works Construction, 2006 Edition, Part 5, System Rehabilitation, Section 500 – Pipeline.

   b. Najafi and Gokhale, Trenchless Technology – Pipeline and Utility Design, Construction, and Renewal. Water Environment Federation. © 2005.

END OF SECTION