

Rehabilitation of Water Mains

Third Edition



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Manual of Water Supply Practices — M28, Third Edition

Rehabilitation of Water Mains

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Cover Art: Cheryl Armstrong

Production: Janice Benight Design Studio

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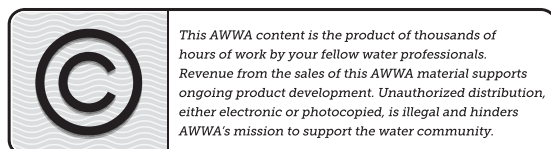
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Foreword

The water industry in the United States is faced with quite a challenge. Much of its buried infrastructure is aged and approaching the end of its useful life. Water system pipeline infrastructure primarily installed in the 1950s and 1960s or earlier has served its communities well. Across the country, water mains provide water to communities with day and night reliability except for the occasional water main interruption. However, that is changing as the pipelines have met or are already exceeding the expected life spans of the pipeline materials. Increasing failures of aged pipeline networks may reach a performance level unacceptable to customers and burdensome to the operators of the systems.

Conventional pipeline replacements of older pipeline infrastructure have not occurred fast enough, largely owing to financial constraints. Failures are now impacting major transmission mains. As a result, communities now are faced with an almost insurmountable challenge to perform the inevitable task of replacing these key and critical water main pipelines. Coupled with reductions in revenue and a slowly recovering economy, the task is especially daunting. Water main rehabilitation may offer part of the solution by renewing more pipe at less cost.

Water main rehabilitation is not a new concept. Cement-mortar lining of water main pipelines is one of the oldest rehabilitation methods. The oil and gas industry was the first to develop systems and techniques beyond cement-mortar lining to rehabilitate critical pipeline networks without the use of conventional open-trench construction. The wastewater industry was the next utility group to firmly adopt pipeline rehabilitation techniques. The expansion of various technologies among these pipe-focused industries created numerous companies, processes, and materials as many groups scrambled to “build a better mousetrap.” The fervor that resulted saw the installation of millions of feet of pipeline rehabilitation products in communities across the country and overseas.

The water industry, particularly in the United States, is the last to fully realize the economic, social, and community benefits of rehabilitation. Conventional construction has its place and continues to be utilized on a widespread scale; however, water main and water service rehabilitation has been steadily increasing in use and effectiveness. Companies that were engaged in the wastewater pipe rehabilitation process expanded their technologies to develop products that could withstand the internal pipeline pressures as well as be approved for potable water use. The number of rehabilitation projects being performed is expected to grow as the price of raw materials has risen and competition for limited space in public right-of-ways has increased with other buried utilities (including systems that have moved from aerial to burial).

The second edition of the M28 *Water Main Rehabilitation* manual, published in 2001, provided an expanded exposure of the technologies present at the time. The intent of the manual was to provide an overview of the processes used, considerations for what rehabilitation process to use, and suggestions for a successful project. This third edition of the manual continues with the same intent. It updates technologies since the last edition, expands categories to encompass available, proven processes, and provides exposure to other rehabilitation considerations such as keyhole technology and cathodic protection. The goal of the manual is to provide engineers, contractors, and decision makers with an overview of the processes used for water main rehabilitation. It is recognized that different pipe installations and types will warrant different rehabilitation options. These considerations are explained in detail including a decision flow chart to aid in the process and get the user to a narrow, more situation-specific set of options for their project.

It is recognized that the water main rehabilitation industry is continually offering new technologies to assist communities with rehabilitating their water pipeline infrastructure. This manual specifically addresses only those technologies with a proven track record within the water industry that can be employed by a water utility to successfully rehabilitate water mains. No attempt was made to evaluate one method of water main rehabilitation over another, and no attempt was made to evaluate relative costs between competing systems. It remains for the user of the manual to decide which system will best suit a specific project. In 2011, the AWWA Water Main Rehabilitation Committee decided to not consider any more new and upcoming technologies for chapter discussion. Because the field is up and coming, there are always new technologies that have been tried overseas that are taking hold here in the North American market.

The chair of the committee, Jon Turner, would like to thank the Executive Committee in place at the time of the manual preparation and to thank contributing authors responsible for new material supplied to continue to provide an up-to-date water main rehabilitation manual for water industry professionals.

Executive Committee

Jon Turner, PE, Chair

Mike Queen, Vice Chair

Leonard Assard, Secretary

George Mallakis, Past Chair

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Executive Committee

Jon Turner, PE, Chair, Phoenix Civil Engineering, Inc., Ventura, Calif.

Mike Queen, Vice Chair, Consolidated Mutual Water Company, Lakewood, Colo.

Leonard Assard, Secretary, Heitkamp, Inc., Watertown, Conn.

George Mallakis, Past Chair, TT Technologies, Inc., Simi Valley, Calif.

George Bontus, PENG, Insituform Technologies, Edmonton, AB., Canada

Richard "Bo" Botteicher, Underground Solutions, Inc., Denver, Colo.

Brien Clark, PE, HDR/Schiff, Claremont, Calif.

Dan Cohen, Western Slope Utilities, Inc., Breckenridge, Colo.

Steve Cooper, Uni-Bell PVC Pipe Association, Louisville, Ky.

Michael Davison, Sanexen, Varennes, Que., Canada

Benedict Ebner, Heitkamp Inc., Watertown, Conn.

Dan Ellison, PE, HDR Engineering, Inc., Ventura, Calif.

Dawn Flancher, PE, Staff Engineer Liaison, AWWA, Denver, Colo.

Steve Fox, HDR/Schiff, Claremont, Calif.

*Michael Grahek, PE, Los Angeles Department of Water and Power,
Los Angeles, Calif.*

Behnam Hashemi, IUPUI, Indianapolis, Ind.

Kathie Hirata, Los Angeles Department of Water and Power, Los Angeles, Calif.

John Hohider, Heitkamp Inc., Watertown, Conn.

Derrick Horsman, Alltech Solutions Inc., Moncton, N.B., Canada

David Hughes, PE, American Water, Voorhees, N.J.

Joe Loiacono, Sanexen Varennes, Que., Canada

Tom Marti, Underground Solutions Inc., Poway, Calif.

Kenneth Morgan, PE, Town of Gilbert, Gilbert, Ariz.

Keith Oxner, PE, Inliner Technologies, LLC, Chesterfield, Mo.

Tom Rockaway, University of Louisville, Louisville, Ky.

Brian Rohan, PE, Rohan Engineering, PC, Merrick, N.Y.

Ryan Rogers, 3M Company, Saint Paul, Minn.

Jeremy Ross, PE, Denver Water, Denver, Colo.

Laurance Vaisey, Cempipe Ltd., New Haven, England, United Kingdom

Marc Wegner, PE, HDR Engineering, Inc., Claremont, Calif.

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Chapter **1**

Pipeline Renewal Methods

Pipeline renewal is typically accomplished by one of two approaches: rehabilitation or open-trench construction, although other trenchless methods are also used. Trenchless technology is a type of subsurface construction work that requires little or no surface excavation and no continuous trenches. This chapter provides guidance in selecting between rehabilitation and open-trench construction and in determining which rehabilitation method is most appropriate for meeting goals.

The renewal of water mains is performed for three primary reasons:

1. Water Quality Improvement: to improve the quality of the water received by the consumer
2. Hydraulic Improvement: to increase the hydraulic capacity of the pipeline
3. Structural Improvement: to reduce leakage, decrease repair frequencies, lessen risk of property damage, and improve reliability.

Compared with conventional open-trench replacement, pipeline rehabilitation methods are often less expensive and less disruptive to the community; however, rehabilitation is not appropriate for all situations.

As described in other chapters in this manual, many different water main rehabilitation techniques exist, offering a variety of benefits. The best choice of method for each situation will depend on several factors, including: (1) the reason for the rehabilitation, (2) comparative costs, (3) site conditions, and (4) expected life-cycle performance.

This chapter provides guidance in selecting a pipeline renewal method, including a series of decision trees that can be used to help determine which types of methods should be considered.

DISTRIBUTION SYSTEM WATER QUALITY IMPROVEMENT

Water main rehabilitation is frequently performed to mitigate water quality deterioration that occurs within the distribution system. The goal is to improve water quality at the point of use. The improvements can be very dramatic, particularly when the existing main is unlined cast iron.

In most cases, the water quality benefits achieved by the various pipeline rehabilitation methods are fairly equal. This assumes that the materials being employed are certified in accordance with NSF/ANSI Standard 61, and industry accepted standards are employed. It also assumes that the water is not particularly soft. When the water is soft, problems with high pH can occur if cement-mortar lining is used.

The quality of treated drinking water can vary considerably, both from system to system and within a system, as a result of deterioration after it leaves the treatment plant and comes in contact with the interior of distribution system piping. Over time, changes in water chemistry can cause problems throughout the distribution system, ultimately affecting the quality of the water delivered to the end user. The deterioration of water quality that occurs within the water distribution system is often signaled by customer complaints regarding the clarity, color, taste, and odor of the water. Although the water may be safe to drink, it may be aesthetically unpleasant due to sediment that has been stirred up or by biological processes that can thrive in highly scaled pipelines and impart an odor to the water. However, the concern is not always simply about aesthetics. Water stagnation and chlorine depletion occur in highly scaled pipelines, resulting in greater risk of coliform regrowth. The majority of these problems fall into three categories: sedimentation, scaling, and biofilm formation.

Sedimentation

Sedimentation is the process whereby solids settle out of water moving at low velocity in a main, reducing interior cross section and capacity and becoming a potential source of customer complaints about water quality. Source water pipelines or pipelines carrying unfiltered or improperly treated water can be subject to deposits of sand, silt, or organic materials. In pipelines receiving well water, particulates from oxidation of iron or manganese are also common, if the water is not filtered. In extreme cases, sedimentation can also contribute to hydraulic problems, particularly at low points in the pipe. The most common source of sediment is the internal corrosion of the pipeline itself.

In smooth-walled pipelines, sediment generally moves through the system at moderate flow velocities and does not accumulate. However, where the pipeline is heavily scaled, sediment settles into the recesses of the scale and builds up over time. This sediment can then be stirred up when the flow velocity increases (e.g., a fire hydrant is opened) or the direction of flow reverses. The result can be severely discolored water as a large volume of sediment becomes suspended and is delivered to the customer's tap.

Scaling or Tuberculation

Scaling is the formation of hard deposits on the inside wall of the pipe. These deposits are frequently the by-product of pipe corrosion, wherein iron combines with calcium and other minerals within the water to form *tubercles*. The process, often called *tuberculation*, is assisted by bacteria within the scale that feed on iron leached from the pipe. Although scaling is most pronounced in cast-iron pipes, it is also commonly found in unlined steel pipes, copper pipes, concrete, and asbestos-cement pipes. Figure 1-1 shows a fairly typical tuberculated cast-iron pipeline.



Figure 1-1 Pipe with tuberculation caused by corrosion

Before the 1960s, many iron pipes were installed without effective, long-lasting linings to protect the interior surfaces. These pipes often experience internal corrosion and develop tubercular scales. This scaling restricts the flow and creates areas where sediment is deposited, and chlorine depletion occurs.

Water discoloration complaints can occur when these sediment deposits are stirred up as previously described; however, discoloration can also occur if the corrosion activity within the pipeline is particularly high. If the scales are removed and a lining is not subsequently installed, exposure of the underlying iron or steel pipeline often results in increased corrosion activity and more frequent complaints about water discoloration. Such corrosion activity can be controlled to some extent through water chemistry (corrosion inhibitors), but cleaning of pipelines without lining is generally not recommended.

Biofilm Formation

Biofilms can develop within pipe made from any type of material; however, biofilms are most common within highly scaled cast-iron pipe, where sediments and recesses allow iron-reducing bacteria to thrive in the absence of effective disinfectant. As the pipelines corrode and tubercles develop, the hospitality of the environment for biofilm increases. The greater the roughness of the pipe surface, the harder it is for an effective disinfectant residual to be maintained near the pipe surface. The reduction of the iron leached from the pipe also provides the energy source for the bacteria.

Biofilms also form readily in raw water systems or portions of the finished water system where water is high in iron or manganese or other nutrients. Such biofilms take the form of slimes, i.e., soft and filamentous. Even where scales do not form, these biofilms can severely affect water clarity and produce taste-and-odor problems. They can also significantly diminish hydraulic capacity.

HYDRAULIC IMPROVEMENT

Increasing roughness and the buildup of scale or slime inside water distribution piping can greatly reduce the hydraulic performance of the system. This can significantly impact

the ability to deliver adequate fire flows and can also affect pressures and flows available to customers.

Hydraulic engineers are able to calculate head losses and flow in pipes using the empirically derived Hazen–Williams formula, which relates flow to the physical properties of the pipe and pressure changes due to friction; however, the Hazen–Williams equation cannot be applied to all fluids in all conditions. It is only valid for ambient temperatures (40°F to 75°F [4.4°C to 23.8°C]) and at turbulent flow (Reynolds numbers above 10^5). For liquids outside these parameters, the Darcy–Weisbach formula is more reliable for frictional head loss calculations at steady-state flow. In more complicated instances, computer models based on Hardy Cross are more accurate. For the discussion in this manual, the Hazen–Williams equation is:

$$V = kCR^{0.63} S^{0.54} \quad (\text{Eq. 1-1})$$

where:

- V = velocity, ft/sec (m/sec)
- k = conversion factor
- R = hydraulic radius, ft (m), which is the cross-sectional area of the pipe divided by the wetted perimeter
- C = Hazen–Williams roughness coefficient
- S = slope of the hydraulic grade line, ft/ft (m/m)

C is a measure of the roughness of the interior of the pipe. Expressed in terms of C , the formula can be stated several ways. Once such way is stated as:

$$C = 2,466 Q D^{-2.63} H^{0.54} L^{0.54} \quad (\text{Eq. 1-2})$$

where:

- C = Hazen–Williams roughness coefficient
- Q = quantity of flow in a pressure conduit, mgd (m^3/d)
- D = nominal diameter of the pipe, in. (mm)
- H = head loss, ft (m) of water
- L = length of pipe, ft (m)

The Hazen–Williams C factor, and hence the flow in a pipeline, depends on the type of pipe and its interior condition (see Table 1-1). For a given velocity, increased internal surface roughness (changing laminar to turbulent flow) leads to greater pressure loss. By measuring pipe flows and pressure changes between two points along a pipeline, operators can calculate Hazen–Williams C factors and determine the degree the pipeline has become roughened and constricted. These data help in making informed decisions about which process to employ to restore hydraulic efficiency. Collecting data for the Hazen–Williams C factor after employing a cleaning or pipe rehabilitation process is also a useful way to gauge the impact of the system improvements.

Table 1-1 Hazen–Williams roughness coefficient

Condition	C
New pipe	130–140
Fair to normal (interior clean)	100
Significant reduction in pipe capacity	70
Severe problem—interior cross section greatly reduced	30–50

Pipeline rehabilitation very frequently results in significant improvement of system hydraulics, particularly where a cast-iron main is choked with tuberculation. Not only is a smoother pipe surface achieved, but at times, the effective flow cross section can be increased significantly.

Because the various methods use different materials and result in different internal diameters, the various methods achieve different degrees of hydraulic improvement. Table 1-2 provides a general comparison of the hydraulic improvements that the various rehabilitation methods can provide.

Moderate hydraulic improvement can also be achieved by some of the pipeline cleaning methods.

STRUCTURAL IMPROVEMENT

The structural performance of water mains deteriorates over time due to several causes. Cast-iron, ductile-iron, and steel piping are subject to internal and external corrosion, resulting in pitting and wall thinning, which can lead to leaks and eventual burst failures. Cement-based pipes such as asbestos-cement and concrete pipe may also be subject to deterioration due to corrosion of the cement matrix and/or steel reinforcement. In addition, all types of pipe, including plastic, may be subject to joint failure between pipe lengths and hence excessive leakage, which can in turn lead to washout of bedding and subsequent structural failure.

Such structural and leakage failures can have direct consequences such as high repair costs, water quality problems, service interruptions, and loss of treated water. They may also have indirect consequences in terms of the economic damage associated with pipe bursts and the public relations damage to the service provider.

The structural improvements afforded by the techniques discussed in this manual vary considerably. Cement-mortar lining and epoxy lining are generally considered *non-structural* because they offer very minor structural improvements at best. Other methods arguably offer the same structural integrity achieved by a new pipeline installed using conventional open-trench construction. In selecting a pipeline rehabilitation method, one of the key considerations is matching the method to the pipeline. A nonstructural method (i.e., Class I*) is absolutely appropriate for a pipeline that has experienced very little deterioration, but this method would not be appropriate where external corrosion has caused significant weakening of the pipe and where this corrosion is expected to continue.

Table 1-2 General comparison of hydraulic improvements

Hydraulic Improvement Anticipated	Rehabilitation Method
Modest hydraulic improvement	Loose sliplining
Moderate hydraulic improvement	Cement-mortar lining Epoxy and other polymer lining Modified sliplining (close-fit) Cured-in-place lining
Greater hydraulic improvement	Pipe bursting
Unlimited hydraulic improvement	Open-trench construction

* See appendix A for definition of Class I, II, III, and IV linings.

WATER MAIN CONDITION EVALUATION

Before employing a nonstructural or semistructural method, an evaluation of the structural condition of the water main is warranted. This evaluation can range from simple and inexpensive, to high-tech and quite costly. The more valuable the pipeline, the more time and money the utility should invest in making the right decision.

The following methods have been used successfully to guide decisions regarding pipeline renewal:

- **Leak/break performance.** Where repair records indicate that a pipeline has had few or no corrosion-caused failures and the pipeline has been in service for many decades, it is often assumed that external corrosion activity is minimal, and the pipeline is a good candidate for a nonstructural lining.
- **Sample extraction/evaluation.** In the United Kingdom, pipeline samples are exhumed then grit blasted to remove graphitization and expose the corrosion pits. The remaining life of the pipeline is then estimated using a method that examines pit depth and pit spacing. One U.K. utility replaces the pipe, for instance, if the estimated remaining life is less than 20 years, and uses a nonstructural lining where the life expectancy is 30 years and more. Semistructural linings are used for those in the middle, with life expectancies between 20 and 30 years.
- **In-situ testing.** For pipelines where a greater investment is warranted, non-destructive evaluation methods should be considered. Depending on the type of pipe, remote field technology or remote field eddy current can be used to find areas of weaknesses throughout the pipeline. Other techniques have been used for spot evaluations at locations of particular concern. Acoustic detection methods of various types are used to search for leaks or detect the sounds of incipient failure.

PRIORITIZATION

Because budgets are always limited, a method of prioritizing work is important. If a primary driver for the renewal program is structural improvement, the pipelines that pose the highest risk should receive the highest priority. In assessing risk, it is helpful to recognize that risk has two components: probability and consequence. For something to be risky, it must be both likely to occur and have significant consequences. This concept is often expressed mathematically:

$$\text{Risk} = \text{Probability} \times \text{Consequence} \quad (\text{Eq. 1-3})$$

To perform this mathematical calculation requires more data (and better data) than are typically available. So instead, it is often helpful to look at *relative* risk as expressed in Table 1-3.

Prioritization can also be performed using regression analysis. With sufficient data regarding the age, soil conditions, pressure, pipe characteristics, etc., effective statistical models have been developed for specific systems. However, regression models built for one system have not been demonstrated to work on other systems.

Table 1-3 Relative risk assessment

Probability	High	Repair on failure	Schedule renewal	Fix now
	Medium	Repair on failure	Assess proactively	Schedule renewal
	Low	Repair on failure	Monitor	Assess proactively
		Low	Medium	High
Consequence				

COSTS AND BENEFITS

Many factors influence the cost of a water main renewal project. Some of the factors are: project size, pipeline size, method used, bypass system requirements, traffic conditions, number of laterals, number of valves or fittings, paving requirements, etc. Costs are also influenced by the availability of local contractors who have the equipment and knowledge needed to perform the rehabilitation. Generally, the less-structural spray-applied methods (Class I) will be less expensive than more fully structural (Class IV) methods.

The cost of a rehabilitated pipeline typically ranges from 25 percent to 100 percent of the cost of conventional open-trench construction. However, even where there are no significant cost savings, rehabilitation may still be preferred because it results in fewer construction impacts to the community.

When properly applied to an appropriate pipe, the life expectancy goal of a rehabilitated pipeline should be similar to that of a new pipeline—50 to 100 years.

REHABILITATION SOLUTIONS

This manual describes several possible solutions to problems arising from corrosion and deposition of internal scales. These range from simple periodic cleaning to replacement of the pipe using trenchless techniques. All of the solutions discussed in the manual make some use of the existing pipe, either as part of the rehabilitated system (renovation solutions) or as a convenient route for installation of new piping (replacement solutions). Solutions involving installation of a replacement pipe along a new route, such as open-trench laying, directional drilling, and microtunneling, are outside the scope of this manual.

Selecting the optimal solution to a specific pipeline problem is a complex process involving both technical and economic considerations. Both the Water Research Foundation and several AWWA Technical and Educational Council (TEC) committees are developing computer-based decision tools to assist utility engineers in this process. This work is expected to come to fruition while this edition of the manual remains in effect. In the meantime, the following guidelines may prove useful.

SELECTION OF REHABILITATION SOLUTIONS

Key elements in the selection of a rehabilitation solution are:

1. The exact nature of the problem(s) to be solved
2. The hydraulic and operating pressure requirements for the rehabilitated main
3. The materials, dimensions, and geometry of the water main
4. The types and locations of valves, fittings, and service connections
5. The length of time in which the main can be taken out of service
6. Site-specific factors

The aim of the selection process is to consider all these factors and to arrive at the most cost-effective, technically viable solution. Ideally, the cost estimate should include not only direct contracting and related costs but also indirect costs associated with public disruption and longer-term maintenance and other life-cycle costs.

One approach to rehabilitation method selection is summarized in Figures 1-2, 1-3, and 1-4. Together, these charts provide a framework for selecting or rejecting groups of rehabilitation methods, depending on the nature of the performance problems, hydraulic requirements, and some site-specific factors. In some cases, the charts indicate use of lining techniques classified as either Class I (nonstructural), Class II/III (semistructural), or Class IV (structural). A more detailed discussion of this classification system and of other key design issues associated with such lining techniques is presented in appendix A.

The figures do not list cleaning as a solution for water quality or flow and pressure problems. Cleaning with one of the various techniques discussed in the manual may well offer the lowest-cost immediate solution to many of these problems. It may offer a long-term solution if repeated as required or combined with chemical treatment of water to prevent or delay recurrence of the original problem. However, cleaning is more frequently used as a necessary preliminary step before carrying out one of the lining processes described in the manual.

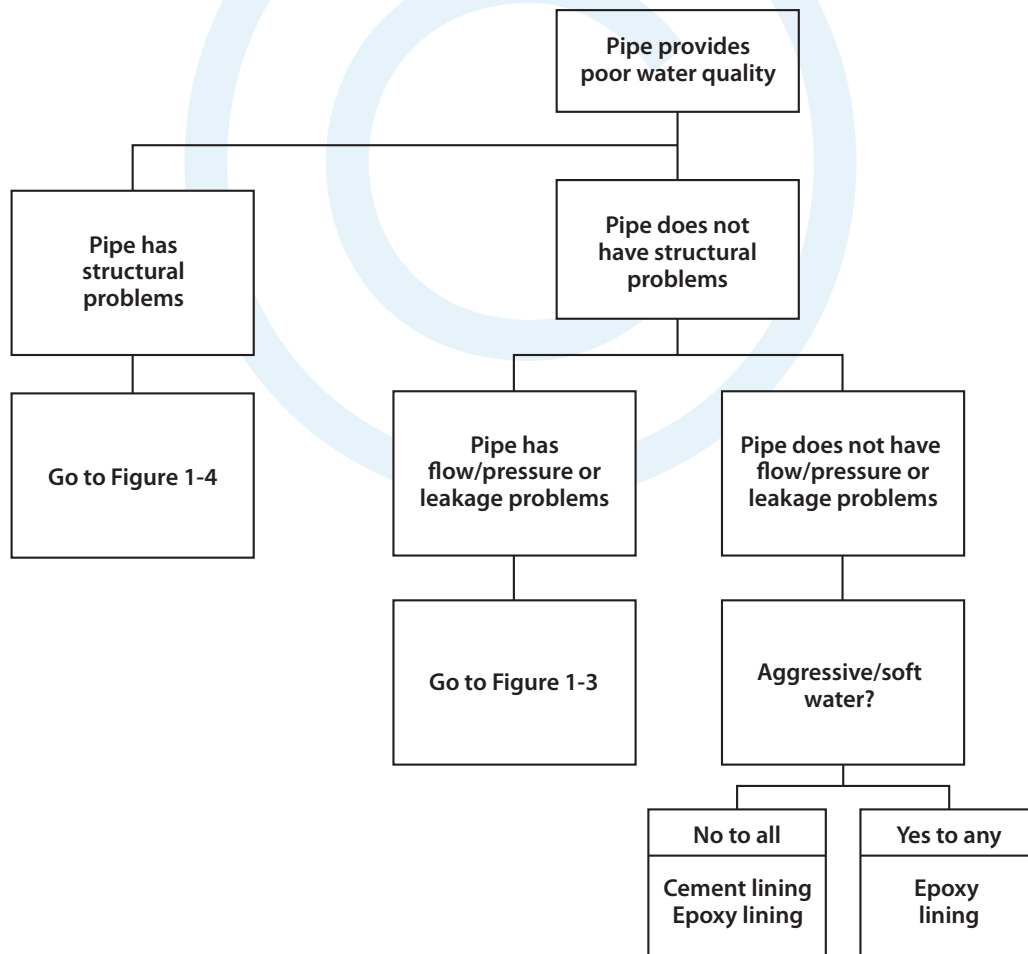
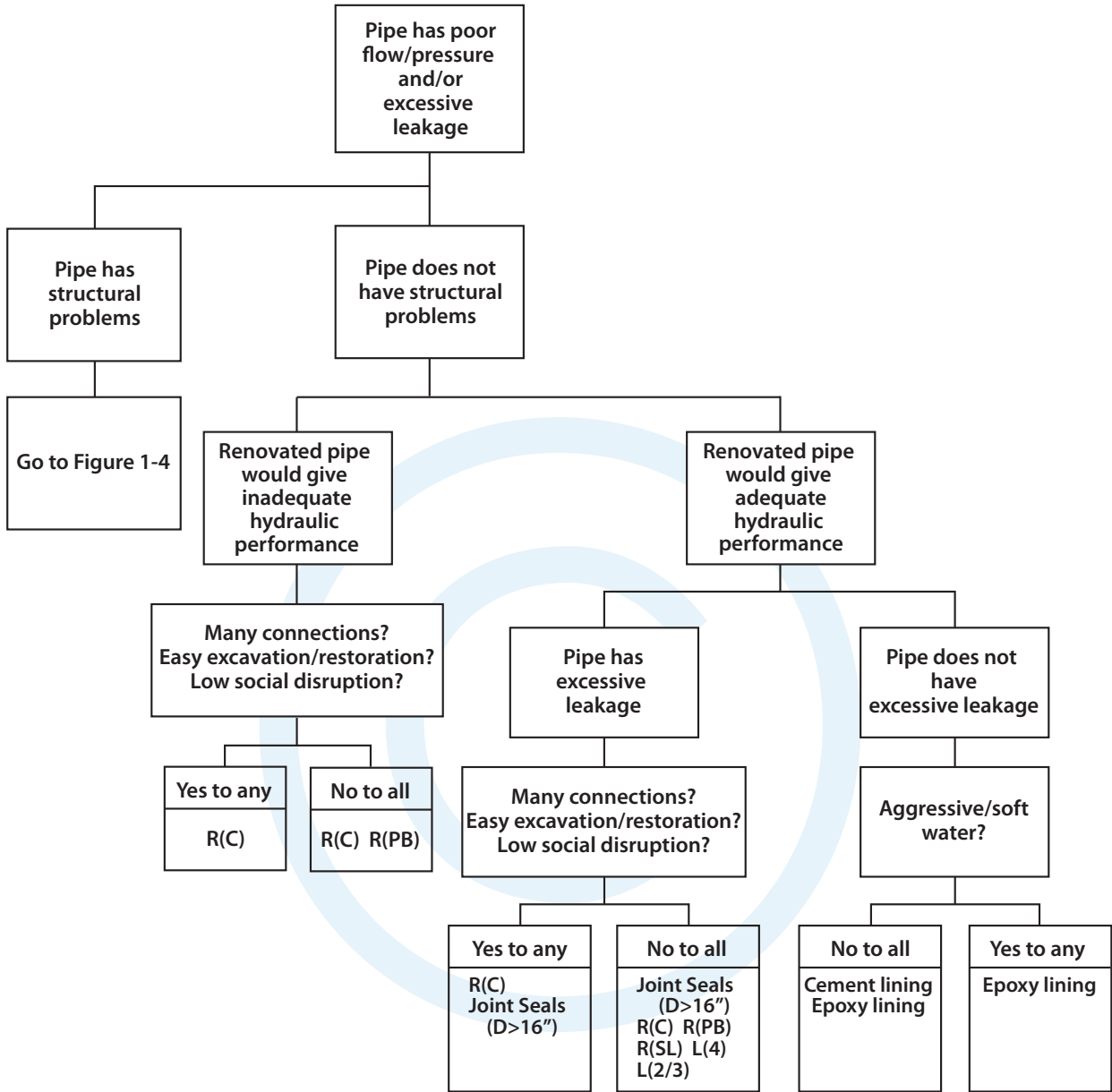


Figure 1-2 Selection of rehabilitation techniques to resolve water quality problems



Notes:
R(C)—Replacement (conventional or boring/directional drilling)
R(PB)—Replacement (pipe bursting)
R(SL)—Replacement (sliplining)
L(2/3)—Lining (semistructural—Class II/III)
L(4)—Lining (structural—Class IV)

Figure 1-3 Selection of rehabilitation techniques to resolve flow, pressure, and leakage problems

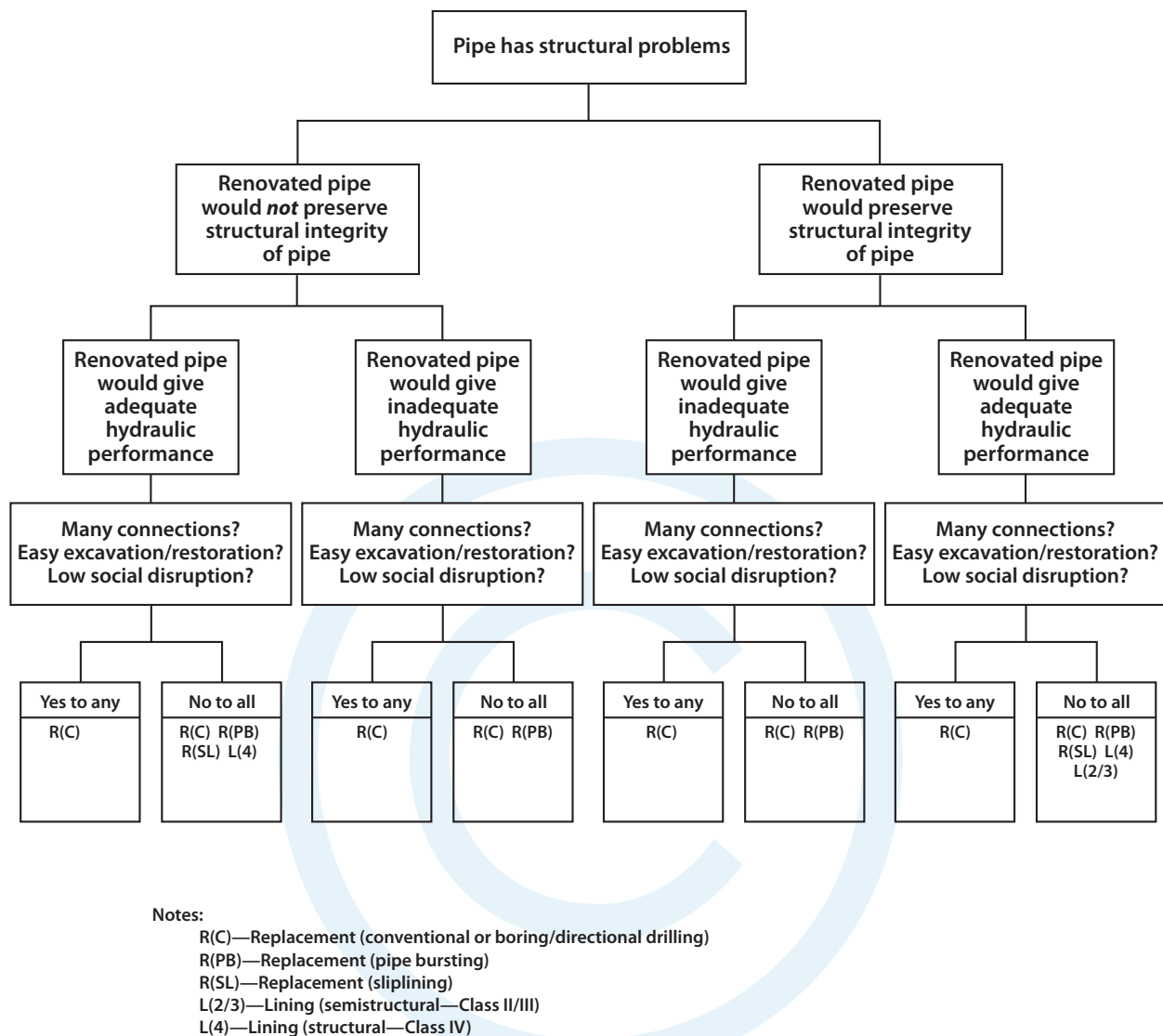


Figure 1-4 Selection of rehabilitation techniques to resolve structural problems

REFERENCE

American National Standards Institute (ANSI). 2012. Drinking Water System Components—Health Effects. NSF/ANSI 61-2012. 198. Ann Arbor, Mich.: NSF International.

Chapter **2**

Preconstruction Activities

ADVANCE PLANNING CONSIDERATIONS

Prior to undertaking a water main rehabilitation project or program, advance planning should be undertaken to fully understand the effects such a project will have on the affected customers, the community at large, and with other public agencies, and to determine strategies to mitigate the negative impacts such projects produce.

The reasons a utility decides to undertake water main rehabilitation will vary (see chapter 1 for discussion on water main rehabilitation techniques) and the method chosen will reflect those parameters. However, it is important to recognize that different water main rehabilitation techniques may impact the community differently. Therefore, it is important to have a clear understanding how each water main rehabilitation technique is performed and what the impacts will be to the community.

Once the water main rehabilitation technique has been determined, the utility should begin to develop a scope of work for the project and determine the overall project boundaries or hire an agent to do so. Once all the affected streets have been determined, the project team should begin the coordination process with other public agencies, such as the street paving department, to ensure that any streets that are planned for resurfacing can be rescheduled so the resurfacing work is done after the water main rehabilitation work has been completed. Likewise coordination with the other public agencies should be planned to prevent competing construction projects within the same right-of-way. The local governmental representative should also be notified of proposed work within their area of responsibility.

Because weather may play a key role in the success of certain water main rehabilitation techniques, it is important that projects are planned with seasonal weather patterns in mind. Projects that encompass sensitive environmental areas need additional planning and mitigation efforts to avoid negative impacts to those areas.

PREPARATION OF PLANS AND SPECIFICATIONS

During the preparation of plans and specification for a water main rehabilitation project, a thorough research should be conducted of the utility's records to identify the locations of the water main, valve, services, fire hydrants, and other appurtenances that will be affected by the water main rehabilitation project. Failure to identify and locate the affected water mains and appurtenances can lead to significant project delays and costly change orders during the water main rehabilitation project. A substructure investigation is critically important to identify all other substructures located within the project boundaries, because unidentified substructures can have the same negative impact on the project schedule and costs as unidentified water mains and appurtenances.

Most work on water mains occurs in a roadway that carries vehicular traffic. A study of the impact the project will cause to the flow of traffic should be performed. Some cities have traffic departments that are responsible for determining what traffic mitigation efforts will be required for any construction work that takes place within the roadway. The project team should include the requirements for proper traffic delineation in its plans and specifications.

The project team should have detailed plans and specifications indicating the beginning and ending points for the rehabilitation process, as well as the method of pipe closure when the rehabilitation process is complete. The specifications should also detail the minimum acceptable requirements for the rehabilitation process along with the pertinent ASTM (American Society for Testing and Materials) standards for the materials used in the rehabilitation process.

Because there will most likely be interruptions in water service to the utility's customers, the utility should have a customer notification process in place, so that the customers can be given ample notice of water service interruptions. The utility should also provide the customers with prior written notice of the project detailing the scope of work and the reasons the work should be done. The notice to the customers should also provide them with a telephone number that can be accessed for information or to report a water outage or other project-related problems.

During the job planning process, the project team should determine what additional work should be performed on the water distribution system while the project is underway. Water main rehabilitation projects provide an opportune time to replace water meters, water valves, fire hydrants, and other ancillary water-works materials.

WATER MAIN REHABILITATION CONTRACTS

Once the plans and specifications have been produced, and the necessary permits obtained from the various agencies involved, the project team will be ready to obtain a water main rehabilitation contractor for the project. Because there are many different requirements for different cities when it comes to bidding, it would be difficult to outline a process here, but there are several points that are common to every water main rehabilitation project.

The project team should endeavor to hire a qualified water main rehabilitation contractor with sufficient experience and expertise in selected water main rehabilitation process to ensure the project will be completed with satisfactory results. The project team may want to establish minimum experience levels for the contractor before being allowed to bid on the contract.

The project team should advertise the project in the appropriate trade magazines or other such venues to attract contractors with the necessary experience. Other utilities can be contacted to obtain contractor references. It is also advisable that the project team have its own quality control/quality assurance officer involved in the process.



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Chapter **3**

Maintaining Service

The purpose of any water supply system is to maintain a continuous supply of safe water sufficient for customer's needs, including fire protection. This purpose remains of primary importance even as rehabilitation work is performed. As noted previously in this manual, depending on the cleaning or lining method used, temporary distribution system shutdowns may occur. Some processes require relatively brief shutdowns, so work can be completed without installing bypass lines. Conversely, some cleaning techniques and all lining methods require more extensive shutdowns that may create the need to install bypass piping. In cases where rapid return to service linings are employed, special disinfection practices and boil water advisories may be necessary if bypass piping is to be avoided.

BYPASS PIPING

Installing bypass piping must be a carefully planned and well-coordinated procedure, and each project has unique considerations. The utility and contractor should jointly review the plan, with regard to customer service issues and traffic concerns. Other considerations include (1) individual service connections, (2) overall demand, and (3) fire protection demand (e.g., pipe sizing). Note that bypass lines are connected to fire hydrants or other temporary connections outside of the area of the shutdown.

The installation of bypass lines can be time consuming and labor intensive. However, the use of bypass piping does allow fairly long shutdowns while still maintaining acceptable service to customers. The hydraulic requirements of the portion of the water system to be removed from service will establish the parameters for sizing the bypass piping network. Temporary connections may be required for fire protection, depending on local jurisdiction.

After the piping has been sized and installed, it must be disinfected as directed in ANSI/AWWA Standard C651 before being placed in service. The piping and hoses used in bypass piping should be ANSI/NSF Standard 61 approved for use in potable water

systems. Connections should always maintain positive pressure in the bypass pipes. Leakage should be minimized to limit damage, save money, and maintain customer confidence.

Residential Installations

A residential area bypass line is usually 2 in. (50 mm) in diameter with provisions for a 0.75-in. (19-mm) or 1-in. (25-mm) hose connection to each residence along the main (Figure 3-1). The bypass hose is connected to the customer's service line through a meter pit, an outside hose bib on the dwelling, or interior pipes accessed through a basement window. The bypass line is usually installed along the curb or in the gutter so that it can be buried under driveway aprons and street intersections. Cold-mix asphalt, stone dust, or other suitable material can be used to cover and protect bypass piping in traffic areas. The exact location of the bypass line installation depends on the project-specific circumstances. Site conditions affect the amount of potential damage to the line, possible tripping hazards, and any obstructions to pedestrians and vehicular traffic.

Commercial Installations

In a business or commercial area, bypass lines are usually 4 in. (100 mm) or larger in diameter. Additional precautions may be required to avoid problems with parallel parking of vehicles, damage to the bypass line, or damage by vehicle tires when parking or turning. Damage usually occurs because of in-line taps, couplings, or valves. Building connections are made through hoses similar to residential installations, except that larger hoses may be required. Depending on local street and traffic concerns, bypass piping may traverse driveways and street intersections by (1) burying temporary pipes in a shallow pavement trench, (2) placement on the street surface with asphalt or suitable material ramping, (3) boring under the street, or (4) running pipe through existing culverts, etc. Whenever possible, street crossings should be made perpendicular to the street.

Reconnection of Service Lines

Care during the reconnection phase is very important to avoid service interruptions. Upon completing the cleaning or lining, the permanent pipelines must be flushed and disinfected according to ANSI/AWWA Standard C651. Following this step, the lines will be ready for service. The bypass lines can be disconnected and customers reconnected to the permanent service lines.

Some cleaning and lining operations may require that individual service lines be blown back to the main before reconnection; this can be accomplished by various means. High-pressure water can be forced back through the service line from inside the building to the main. Blowback can also use compressed air fed directly from a compressor or from portable worker-borne tanks. Note that all blowback air should be generated by oil-free compressors.

Problems

Exposed bypass lines may be subject to overheating problems during periods of warm weather. In this situation, the bypass line may be coated with white or other heat-reflective paint to minimize solar heat gain, and/or provided with bleeder valves at the ends of the bypass to allow for periodic flushing.

Conversely, during periods of cold weather, freezing of temporary pipes may present problems. If scheduling permits, rehabilitation or cleaning projects should be conducted during more temperate months. However, if work during extreme cold weather

is unavoidable, provisions must be made to maintain water flow in all bypass lines to prevent freezing.

The temporary network also represents a potential for emergency repairs due to hose ruptures or vandalism. As discussed in the next section, bypass service increases the need for good communication with various groups of consumers.

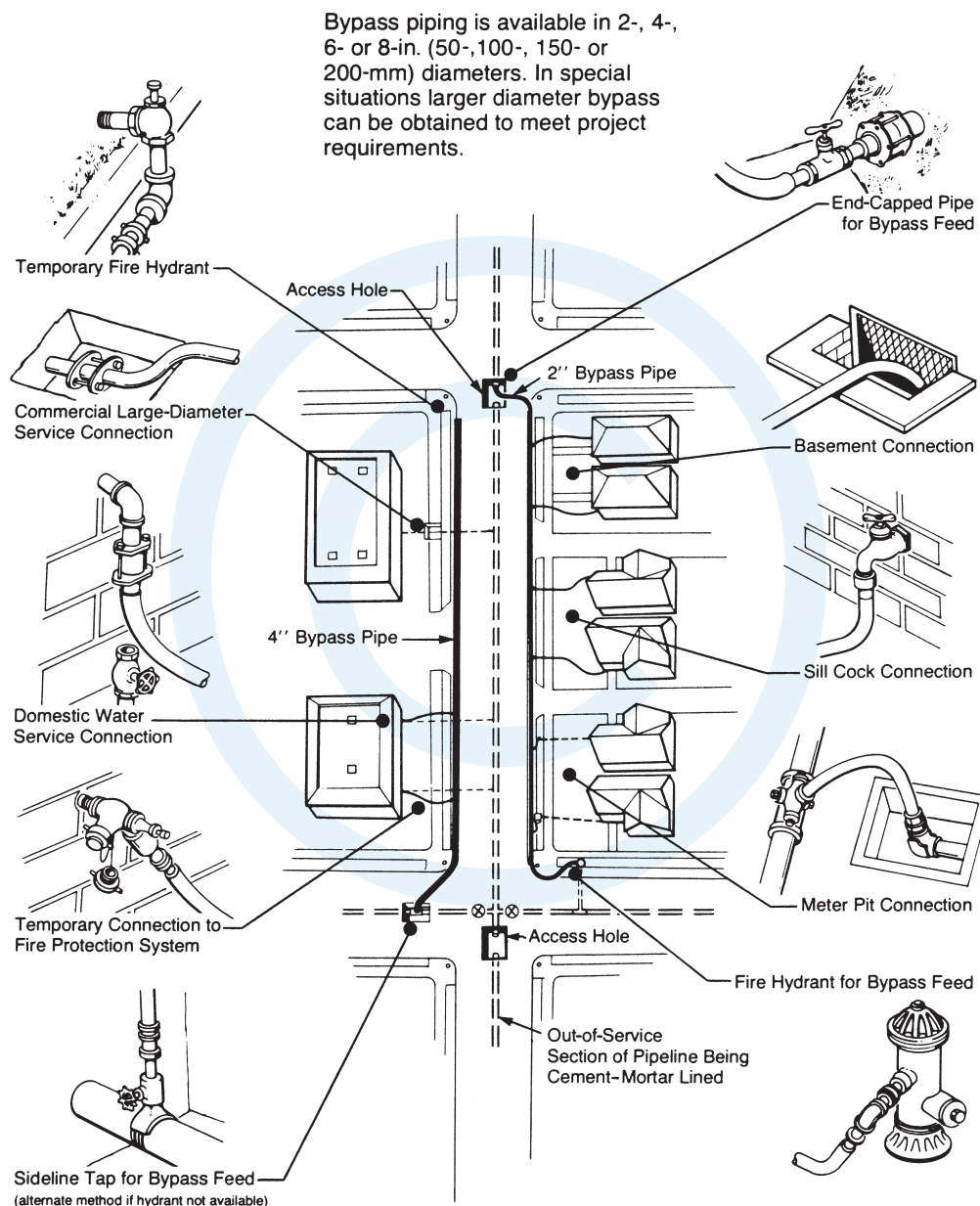


Figure 3-1 Bypass installation for residential and commercial water service

COMMUNITY RELATIONS

Prior to the installation of a temporary water system, the project team and contractor should agree on a specific plan for notifying government agencies, emergency service providers, and their customers of an upcoming project. The plan should include the streets to be bypassed, the location of the feed hydrants, and the size and location of the bypass piping. Notification to the general public can be via newspaper articles, social media, utility bill mailings, or the utility's website; however, individual door hangers are recommended to notify the affected customers. These door hangers should be provided 24 to 48 hr in advance and should include contact information for general questions and emergency contact numbers as well. Refer to chapter 13 for more information on community outreach.

In addition to contacts with individual customers, overall community relations are equally important. Police and traffic control personnel and transit district representatives must be included in planning meetings to discuss detours and work schedules. The fire department also must be informed of the project and any effects on emergency access to all fire hydrants in the project area. Hydrants removed from service should be covered or otherwise marked to indicate their unavailability.

Other utilities, such as sewage, gas, electric service, and telecommunications (telephone, cable, and fiber-optic cable) should also be notified to allow coordination between the water line project and any other scheduled utility work. The local chamber of commerce or other local business groups may be contacted for assistance. Notices posted in store windows may help to avoid parking complaints.

SUMMARY

All notifications should include an emergency telephone number that is active 24 hours a day, 7 days a week. Good customer relations can be severely damaged by a customer's inability to report an emergency or discuss questions about water service. If a project requires entering private property to disconnect meters and hook up temporary lines, notices should clearly discuss the need for the work and how it will be conducted. As with any aspect of customer service, follow-up is extremely important and personnel must be available to respond promptly to all calls. Finally, an established policy and procedure for handling damage claims should be established.

REFERENCES

- American National Standards Institute (ANSI). 2012. Drinking Water System Components—Health Effects. NSF/ANSI 61-2012. 198. Ann Arbor, Mich.: NSF International.
- American Water Works Association (AWWA). 2005. Standard for Disinfecting Water Mains. ANSI/AWWA C651. Denver, Colo.: AWWA.

Chapter 4

Pipeline Cleaning Methods

Water mains can be cleaned in place in a water distribution system using one or more of the following methods:

- Flushing
- Air scouring
- Mechanical cleaning techniques
- Cable-attached devices
- Fluid-propelled devices
- Power boring
- Ball cleaning
- Other methods

Dispose of cleaning water and debris in accordance with applicable regulations. Refer to ANSI/AWWA Standard C651, *Disinfecting Water Mains*, for guidance in disinfecting pipelines before returning them to service.

FLUSHING

Water main flushing has a definite place in distribution system operation. It is particularly effective for light cleaning jobs. Mains should be flushed to clean newly installed and repaired mains prior to and after disinfection. Routine flushing is needed to remove impurities that cause complaints or are considered hazardous to public health and has become a vital part of maintaining the quality of water throughout the distribution system. Refer to the AWWA handbook titled *Disinfection of Pipelines and Storage Facilities Field Guide* for specific flushing program guidelines.

Flushing should never be considered the only solution to water quality problems identified in the distribution system. Proper design and operation of distribution facilities and an effective backflow-prevention program should also be part of any effort to maintain water quality. While quality control is the primary purpose of flushing, careful observation of system hydraulics during flushing may indicate problems in mains, such as inadequate capacity, undiscovered restrictions, or closed or partially closed valves.

All flushing and the disposal of the water should be done in accordance with federal, state or provincial, and local requirements.

AIR SCOURING

The use of pressurized air to clean water distribution mains is not one of the more common processes. The sections of main to be cleaned have to be isolated to reduce the problems associated with the procedure. If the line to be air scoured has service connections on it, they will have to be isolated as well or placed on a bypass water delivery system so that the customers remain in service during cleaning. Air scouring is more effective for removing film and light-weight debris from the interior of the pipe by forcing high pressure air at a high velocity.

MECHANICAL CLEANING TECHNIQUES

Cable-Attached Devices

Systems that use cable-attached devices for cleaning distribution mains include drag cleaning, hydraulic jet cleaning, and electric scraper cleaning. In each case, the length of hose or cable determines the length of the pipe section that can be cleaned.

Drag Cleaning

In drag cleaning, a winch pulls a mechanical cleaner composed of a series of steel scraper blades and rubber squeegees through the pipe (Figure 4-1). The mechanical cleaner is usually flexible, allowing it to negotiate bends of up to 45°. Both ends of the cleaner are fastened to steel cables, which are attached to winches at either end of the pipe section to be cleaned. The cleaner is winched first in one direction and then in the other, and this process continues until the pipe is satisfactorily cleaned.

This cleaning method offers important advantages:

- Cleaning can be accomplished when water pressure or volume is insufficient to propel a hydraulically driven device, or when excessive pressure would be required for hydraulic cleaning, especially with small-diameter mains.
- Very hard deposits and encrustation can be removed.
- Dry solids allow easy disposal.

Chain Scraper

A combined hydraulic and mechanical tool called a *rotating chain scraper* or *reamer* may also be used to remove more difficult deposits from the pipe surface. This process incorporates the flailing of the chain on the interior of the pipe to dislodge encrusted material. The accompanying jet stream of water then flushes the particles outside the pipe to a point where they are disposed of. This provides a more aggressive method of cleaning the pipe while reducing the possibility of damaging penetrating service connections.



Figure 4-1 Drag cleaning, in which a winch pulls a mechanical cleaner through the pipe

Hydraulic-Jet Cleaning

To clean pipe with a hydraulic jet, a special nozzle attached to a hose emits a jet of water at high velocity and pressure that removes debris and deposits from the interior of the pipe. Nozzle pressures of 1,000 to 10,000 psi (6,900 to 69,000 kPa) and above can be generated using this system. The jetted stream of water must bear hard enough against the scale or deposit to breach and dislodge particles. Once the scale or depositional material is penetrated, the fluid forms a wedge between the deposit and the surface, and strips off the deposit, exposing the clean metal surface. In many jetting operations, dislodged particles are entrained in the jetting stream and effectively dislodge more particles. The principal advantage of this method is removal of very tough deposits.

Hydraulic-jet cleaning uses a large volume of water and is more effective in larger diameter mains and conduits.

Electric Scrapers

Electric scrapers are used to clean large diameter lines. A variation of this cleaning method is the use of an electrically powered, operator-driven scraper. This power-driven scraper incorporates revolving brushes or rotating arms to clean the line. The principal advantage of this method is the ability of the operator to evaluate the effectiveness of the cleaning process as it proceeds through the line.

FLUID-PROPELLED CLEANING DEVICES

This section of the chapter describes fluid-propelled cleaning devices such as foam pigs and mechanical metal scrapers.

Foam Pigs and Swabs

Foam pigs are flexible, bullet-shaped cleaning tools manufactured of high-quality (1.5 to 2.0 lb/ft³ [24 to 32 kg/m³] 5 to 8 lb/ft³ [80 to 128 kg/m³] density) polyurethane foam, some coated with polyurethane synthetic rubber coatings (70 lb/ft³ [1,121 kg/m³] density). (See Figures 4-2 and 4-3.) The sizes of the pigs range from 2-in. through 60-in. Pigs are propelled down water mains by the pressure and volume of water in the distribution system. Cleaning is accomplished by the frictional drag and flexible characteristics of the

foam pig, which removes foreign objects, iron tuberculation, and other matter as it passes through the pipes, leaving the interior surfaces smooth and free from irregularities as age, attrition of use, and type of piping material will allow. When water pressure is applied for propulsion, a certain amount of water bypass (approximately 10 percent) helps to keep loose debris suspended in front of the foam pig (Figure 4-4).

Cleaning of deteriorating mains generally requires a series of swabs and foam pigs applied in progressively larger diameters and often with wire brushes attached (referred to as *progressive pigging*) until the pipe is restored to its original diameter.



Figure 4-2 Foam pig: A bullet-shaped device made of polyurethane foam



Figure 4-3 A foam pig with hardened coatings



Figure 4-4 Loose debris flushed ahead of the pig

Operating Procedures

The following steps briefly describe the most common operating procedures for cleaning water distribution mains with foam pigs. The described procedure is based on a best-case scenario; actual procedures may vary for certain applications.

1. Review drawings of lines to be cleaned to identify (a) possible entry and exit points, and (b) all valves to be used to isolate the section of system to be cleaned.
2. Exercise all valves in the section to be cleaned before the pigging operation to ensure isolation of the section to be cleaned.
3. Flow tests should be performed before and after the pigging operation to evaluate the efficacy of the cleaning and determine the resulting condition of the water main.
4. Provide adequate means for disposing any debris exiting the pipe. The disposal of debris and the water used should be performed in compliance with local, regional, and governmental requirements. However, the best arrangement for handling large amounts of heavy debris would be to direct the flow to a temporary settling pond, the bed of a dump truck, etc., to facilitate removal of solids once the water has drained away.
5. Notify all affected customers (commercial and residential) as well as fire department officials of the scheduled interruption of service.
6. Confirm that all valves in the section to be cleaned are fully opened and working properly and that the section is properly isolated.
7. Follow the direction of flow, which must be controlled by the valve locations.
8. Introducing the foam pigs into the water main may be accomplished either by hand or through the use of mechanical equipment commonly called a *pig launcher*.

Several types of fire hydrants, once they are disassembled, can be used as entry and exit points for pigging of some water mains 6 in. (150 mm) and smaller (Figure 4-5).

9. To produce the best cleaning results, foam pigs should travel through a water main at a rate of 3 to 9 ft/sec (0.91 to 2.74 m/sec).
10. Sequence of foam pig runs:
 - a. Introduce a line-sized, soft-foam swab (1.5 to 2.0 lb/ft³ [24 to 32 kg/m³] density, uncoated), called a *prover pig*, to determine the actual effective inside diameter of the pipe to be cleaned. The swab wears down while passing deposits in and along the pipe wall.
 - b. Introduce a line-sized bare foam pig (5- to 8-lb/ft³ [80- to 128-kg/m³] density, uncoated) to remove soft deposits and help gauge the true opening in the line.
 - c. Introduce a line-sized, coated foam pig (5- to 8-lb/ft³ [80- to 128-kg/m³] density, coated with urethane elastomer). This type of foam pig should be run repeatedly until one emerges in reusable condition. A water line with excessive buildup should be pigged using the progressive pigging method, beginning with undersized, coated foam pigs and gradually increasing the size in successive passes until a line-sized foam pig emerges in reusable condition.
 - d. Line-sized, wire brush foam pigs may be introduced following these applications for final removal of extremely hard deposits (such as tuberculation).
 - e. Introduce a line-sized swab (1.5- to 2.0-lb/ft³ [24- to 32-kg/m³] density foam, uncoated) to sweep out any loose debris and determine the effectiveness of the cleaning process.
11. Flush in accordance with requirements and disinfect as required.
12. Place the water main back into service.



Figure 4-5 Pigs launched through a disassembled fire hydrant for a 6-in. (150-mm) or smaller line

Foam pigs are flexible enough to negotiate short-radius bends and pass through full-port valves and some types of plug valves. Their capability to be compressed up to 35 percent of their cross-sectional area allows them to pass through multidimensional lines and full-port valves. A piggable valve is one through which a pig will pass every time. Foam pigs do not pass through butterfly valves. Foam pigs can clean long sections of piping from one entry point, thus reducing the number of excavation sites required. Pigging is a fast, simple, and cost-effective method of returning most deteriorated piping systems to as-designed capacity and efficiency.

METAL SCRAPERS

A metal cleaning scraper consists of a steel frame shaped like a piston. Specially tempered steel blades are attached around the scraper at various angles to create a scraping and brushing action (Figures 4-6 through 4-8). The cleaner is propelled through the water main using water pressure.

Cleaning is often accomplished with a single pass in a continuous operation; sometimes, however, interior pipe conditions may require additional passes. The length of pipeline that can be cleaned hydraulically in one operation is limited only by the availability of volume and water pressure and a proper means of disposing of water and deposits. An opening must be provided at each end of the section to be cleaned for entry and exit of the cleaning tool. The volume of water required to hydraulically clean a pipeline will depend, to a great extent, on how dirty the water is as well as the amount of tuberculation build up inside the pipe.

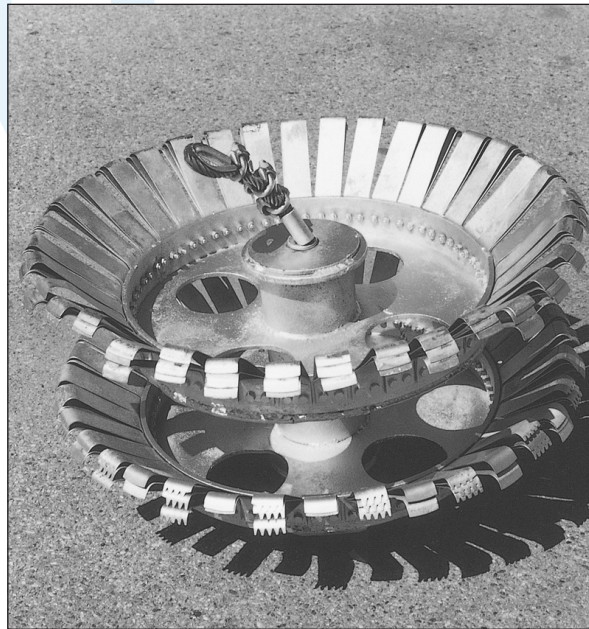


Figure 4-6 Scraper unit with specially tempered steel blades



Figure 4-7 Several scraper units assembled together in the field

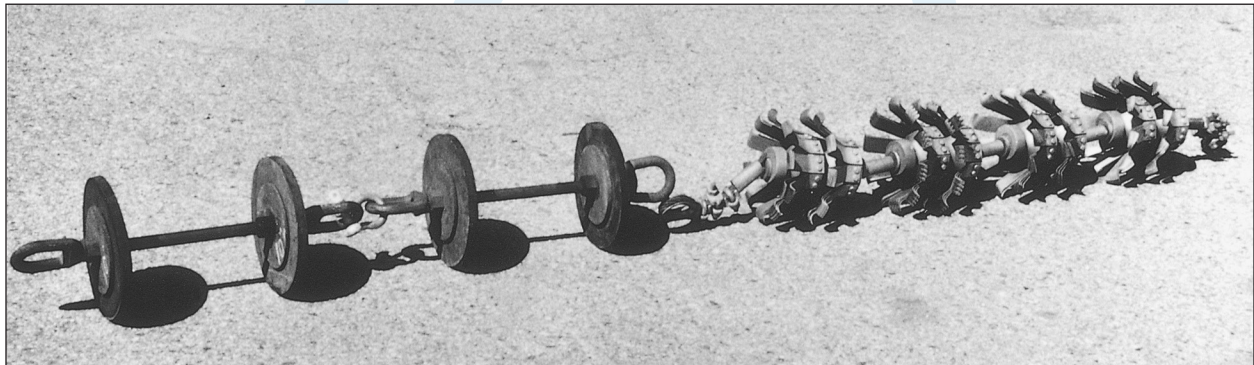


Figure 4-8 A series of disks to act as a hydraulic piston, pulling scrapers through the line

Sufficient water must be added behind the cleaner to fill the pipe as the cleaner moves ahead. The water that passes the cleaner scours the wall of the pipe and washes ahead the material that is scraped off the pipe. While the velocity of water ahead of the cleaner is independent of cleaner speed, it must be sufficient to remove the deposits. Experience indicates that a flow velocity ahead of the cleaner of between 2 and 10 ft/sec (0.6 and 3.0 m/sec) is required to remove the deposits. In a small pipe, because a relatively large amount of material must be moved for the volume of the pipe, a relatively high velocity is required.

The cleaning water and deposits must be discharged from the pipeline in a way that avoids creating a nuisance or environmental problem and in accordance with the requirements of regulatory agencies. A sandbag dam can be constructed to create a pond for particle settlement (Figure 4-9). This allows the clean water to be decanted, dechlorinated, and disposed of in accordance with local regulations while any solid material is collected and properly disposed of. Another method may be to pipe the water to a dump truck, catching the solids in the truck.

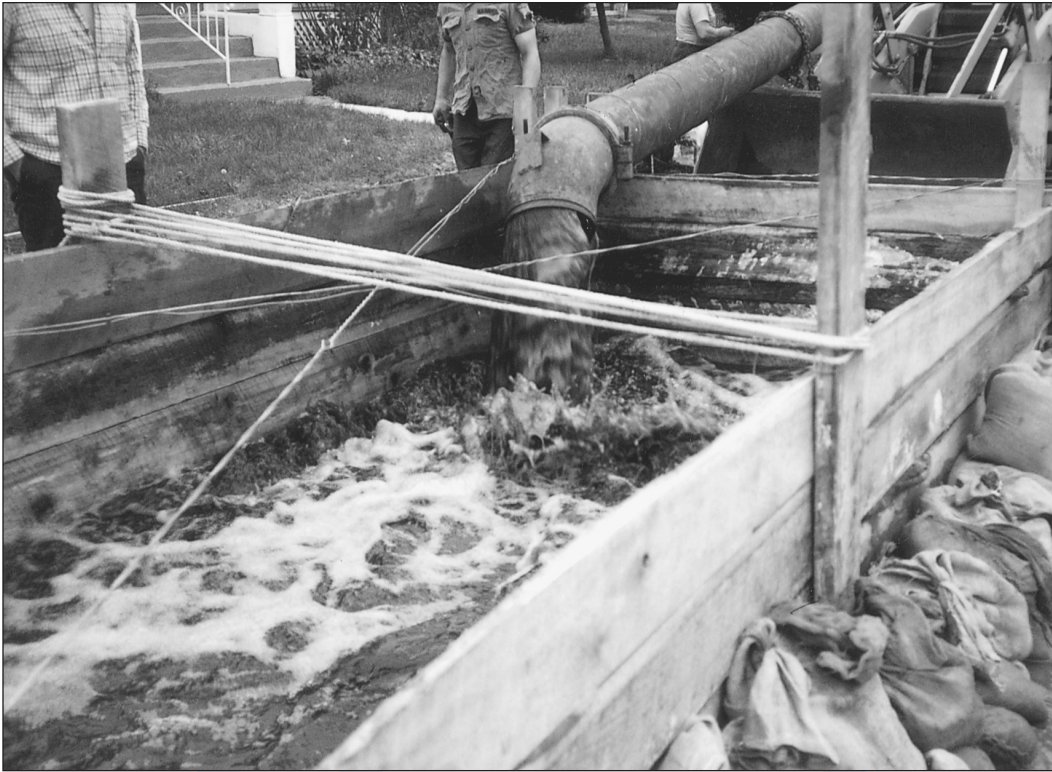


Figure 4-9 A sandbag dam to create a pond for particle settling

Operating Procedures

The following steps describe the operating procedures commonly used when cleaning water pipes with mechanical scrapers.

1. Review drawings of lines to be cleaned. Identify logical entry and exit points for the cleaning tool. Note all valves, service connections, and other components that must be opened or closed to isolate the line to be cleaned. As described in chapter 1, conduct flow testing of the pipeline to determine the Hazen–Williams C factor (if not previously completed) to determine the condition of the line.
2. Excavate and install a spool piece at each entry and exit point (Figure 4-10). Obtain a sample of deposits in the line and determine their average thickness.
3. Determine source of cleaning water (e.g., reservoir, feeder mains, parallel lines, etc.). Cleaning for lines 12 in. (300 mm) in diameter and smaller may require auxiliary pumps to provide adequate flow and pressure; flow and pressure within the system generally are adequate to clean mains over 12 in. (300 mm) in diameter.
4. Provide suitable means for disposing water and removed solids that meets with the regulatory requirements.
5. Notify all affected commercial and residential customers, as well as fire department officials, of the scheduled interruption of service.
6. Completely isolate the section to be cleaned. Close valves slowly to prevent water hammer.