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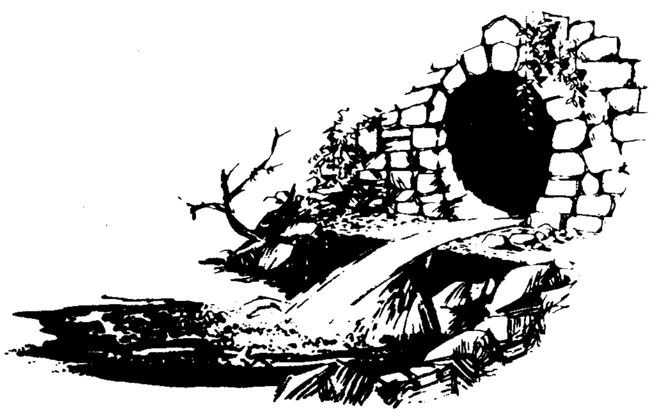
Excerpts from

Control of Infiltration and Inflow into Sewer Systems

and

Prevention and Correction of Excessive Infiltration and Inflow into Sewer Systems

A Manual of Practice



NATIONAL ENVIRONMENTAL RESEARCH CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
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PREFACE

Two publications were developed under contracts DI-14-12-550 and EPA-WQO-14-12-550 by the American Public Works Association, Chicago, Illinois, for the U.S. Environmental Protection Agency's Water Quality Office and 39 local governmental jurisdictions.

The publications are:

Prevention and Correction of Excessive Infiltration and Inflow into Sewer Systems, Manual of Practice, January 1971

NTIS PB 203 208
GPO 5501 0053

and

Control of Infiltration and Inflow Into Sewer Systems, December 1970

NTIS PB 200 827
GPO (number not available)

This publication (revised 1974) contains excerpts from these two reports. It provides a brief and quick reference source of information on infiltration and inflow problems and on correction of infiltration conditions.

Copies of the complete reports may be obtained from the National Technical Information Service, U.S. Department of Commerce, Springfield, Virginia 22151, or Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

PREVENTION AND CORRECTION OF EXCESSIVE INFILTRATION AND INFLOW INTO SEWER SYSTEMS

Manual of Practice

by the

AMERICAN PUBLIC WORKS ASSOCIATION

For the

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE
&

THIRTY-NINE LOCAL GOVERNMENTAL JURISDICTIONS

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ABSTRACT

As a result of a national study of the sources and prevention of infiltration and inflow, a Manual of Practice was proposed. The Manual is intended to serve as a guide to local officials in evaluating their construction practices, conducting surveys to determine the extent and location of infiltration and inflow, the making of economic analyses of the cost of excessive infiltration/inflow waters; and instituting corrective action.

Excerpts from sewer control legislation are given as well as information on air and exfiltration testing.

This Manual of Practice was prepared for the Environmental Protection Agency in partial fulfillment of Contract 14-12-550. The study was also supported by thirty-nine public agencies. A companion document, "Control of Infiltration and Inflow Into Sewer Systems", was also prepared.

Key Words: INFILTRATION, INFLOW, INVESTIGATION, CONSTRUCTION, LEGISLATION, TESTING, ECONOMICS.

SECTION 1

INTRODUCTORY STATEMENT: THE INFILTRATION AND INFLOW PROBLEM AND ITS PREVENTION AND CONTROL

THE PROBLEM

A serious problem results from excessive infiltration into sewers from ground water sources, and high inflow rates into sewer systems through direct connections from sources other than those which sewer conduits are intended to serve. The hydraulic and sanitary effects of these extraneous flows are of particular importance now because urban growth generally requires all available sewer capacities to handle present flows and serve future expansion. The pollutional effects of by-passed and spilled and under-treated waste water flows caused by infiltration and inflow are paradoxical at a time when higher degrees of treatment are being demanded to protect the nation's water resources.

The effects of these extraneous waters are of primary importance in separate sanitary sewers. These intrusion waters pirate greater proportions of the relatively smaller sanitary lines than of combined sewers and storm sewers. When sanitary sewers become surcharged and produce flooding of street and road areas and back-flooding into properties, the spilled flows are a serious sanitary hazard. Similarly, when by-passing of pumping stations, sanitary relief and interceptor lines, and sewage treatment processes occur because of excessive infiltration-inflow volumes, the waste waters discharged to receiving waters have great pollutional potential.

In combined sewers, such intruded waters offer less threat of surcharging and back-flooding during dry weather flows, but the hazard of local overloading during storm periods should not be discounted. Unnecessary and over-long overflows at combined sewer regulator stations introduce pollutional waste waters into receiving waters. (The effects of overflows were investigated and reported upon by the American Public Works Association for the then Federal Water Pollution Control Administration, Department of the Interior, and participating local jurisdictions in a project covering "Problems of Combined Sewer Facilities and Overflows – 1967").

The effects of infiltration, and inflow are alike, except for two specific conditions. Infiltration, and its counterpart – exfiltration – often produce local washout of soil bedding around defective pipe or joints, followed by actual failure of the sewer barrel or cave-in of roadways and pavements and loss of nearby utilities and utility vaults. No such effects are attributable to inflow connections. In infiltration, a direct relationship exists between the entry of sewer flows through defective pipe and joints and the intrusion of water seeking tree roots through the same cracks or openings. No such relationship exists in the case of points of inflow into sewer systems. The clogging of sewers with intruded sand, clay, or gravel at points of infiltration is a specific infiltration effect not duplicated in the phenomenon of inflow.

When infiltration waters and inflow waters become commingled within sewer systems they are not readily distinguishable from each other. The net effect of their presence is the same: robbed sewer system capacities and usurped capabilities of system facilities such as pumping, treatment, and regulator-overflow structures. What is different about these two types of extraneous waste waters is their source.

This difference is borne out by the definitions of "infiltration" and "inflow" chosen as guidelines for the study of this problem in 1969-70 by the American Public Works Association Research Foundation for the Federal Water Quality Administration and 39 participating local jurisdictions in the United States and Canada. For a clear understanding of the purposes of this Manual of Practice (which is the end-product of the national investigation of the infiltration and inflow problem), it is essential to restate these basic definitions:

> "INFILTRATION" covers the volume of ground water entering sewers and building sewer connection from the soil, through defective joints, broken or cracked pipe, improper connections, manhole walls, etc.
>
> "INFLOW" covers the volume of any kinds of water discharged into sewer lines from such sources as roof leaders; cellar and yard area drains; foundation drains; commercial and industrial so-called "clean water" discharges; drains from springs and swampy areas; etc. It does not include, and is distinguished from, "infiltration."
>
> "INFILTRATION/INFLOW" is the volume of both infiltration water and inflow water found in existing sewer systems, where the indistinguishability of the two components of extraneous waters makes it impossible to

ascertain the amounts of both or either.

These basic definitions serve two purposes – to define the difference between the two extraneous water flows, and to show that the difference relates to sources, rather than characteristics, of such flows. Definitions of other words and phrases used in this Manual of Practice are contained in the Glossary of *Pertinent Terms, Section 8.*

Infiltration results from soil conditions in which sewer lines are laid; the quality of materials and construction workmanship; ground water levels; precipitation and percolation of surface waters; waters retained in the interstices of surrounding soils, and the stability of pipe and joints and appurtenant sewer structures after periods of service.

Inflow is the result of deliberately planned or expediently devised connections of sources of extraneous waste water into sewer systems. These connections serve to dispose of unwanted storm water or other drainage water and wastes into a convenient drain conduit. They are interpreted, in terms of this Manual, to include the deliberate or accidental draining of low-lying or flooded areas into sewer systems through manhole covers.

Infiltration and inflow conditions have two characteristics in common, in that each problem is divided into two parts: prevention of excessive extraneous flows, and correction of conditions already imposed on existing sewer systems.

In the case of infiltration, prevention of excessive entries into new sewer systems depends on effective design; choice of effective materials of sewer construction; imposition of rigid specifications limiting infiltration allowances; and alert and unremitting inspection and testing of construction projects to assure tightness of sewers and minimization of infiltration waters.

Correction of infiltration conditions in existing sewer systems involves evaluation and interpretation of sewage flow conditions to determine the presence and extent of excessive extraneous water flows from sewer system sources, the location and gauging of such infiltration flows, and the elimination of these flows by various corrective, repair and replacement methods.

In the case of inflow onditions, the problem is similarly two-faceted: prevention and cure. Prevention of excessive inflow volumes is a matter of regulating sewer uses and enforcement of such precepts and codes by means of vigilant surveys and surveillance methods. Correction of existing inflow conditions involves location of points of inflow connections; determination of their legitimacy or illicit nature; evaluation of the responsibility for correction of such conditions; establishment of inflow control policies where none have been in effect; institution of corrective policies and measures, backed up by investigative and enforcement procedures to make such policies potent.

THE NEED FOR GUIDELINES: THE MANUAL OF PRACTICE

Control of infiltration and inflow in all future sewer construction work, and the search for and correction of excessive intrusion of excessive flows of extraneous waters into existing sewer systems, is an essential part of sewer system management.

Past practices often have been based on inadequate technical policies, usually devoid of substantiating data on causes and effects of infiltration and inflow conditions. There has been a dearth of standardization of such practices; the policy of "standardization" has been limited to a follow-the-leader attitude of accepting and using the criteria of others without consideration of their applicability to present-day materials and methodologies.

In fairness to the great advances made in the manufacture of pipe and joint materials, a review of practices is long overdue. This Manual has been prepared to provide a stimulus to improve practices in the design, construction and operation-maintenance of sewer systems.

One word of clarification and caution is necessary. This Manual is designed as a compilation of practices in the subjects outlined, in terms of their applicability to the actual conditions under which specific new sewer system projects are to be constructed or existing systems are to be operated and maintained. In short, what is offered here are *general guidelines* for better practices – pointing the way to improvements in control of infiltration and inflow, sewer service, and water quality control. It is hoped that the guidelines contained in this Manual will result in the eventual development of so-called "standards of practice," with the understanding that each project, each sewer system, must be designed, equipped, constructed, and operated to meet specific local conditions.

SECTION 3

CORRECTION OF INFILTRATION CONDITIONS, EXISTING SYSTEMS

The correction of infiltration involves a lengthy, systematic approach or plan of action. The haphazard deployment of investigative devices and sealing equipment is ineffectual and extremely costly. Interwoven with correction is maintenance. Preventive Maintenance that restores the full capacity of the pipe will permit the sewer to take the full capacity for which it was designed, including infiltration waters, and will, therefore, reduce the rate of surcharge in upstream manholes.

There must be an orderly plan of approach when investigating infiltration conditions. Excessive infiltration is occurring and when it is determined where visual insnection is needed, sewer cleaning is an important consideration because of the cost and time involved. It is impossible to run a camera through a sewer that has restricted flow due to sand deposits or other debris. Cleaning serves to produce the maximum available carrying capacity in the sewer pipe. Sewer cleaning will dictate the rate at which inspection can be accomplished in accordance with the availability and capability of the sewer cleaning crews. The following general procedure for the inspection of infiltration conditions is an adaptation of a program developed by American Pipe Services, Minneapolis, Minnesota.

3.1 OBJECTIVES

The first step in analyzing the extraneous water problem is to define that problem as clearly as possible. Before retaining consultants and sewer service organizations, the public works director should review and evaluate such questions as:

1. In what condition is the system?
   a. How can this be determined?
   b. What will it cost to determine the condition?
2. Is there an infiltration/inflow problem?
   a. How large is it?
   b. What is its effect?
3. What will it cost to identify and correct?
4. Is adequate preventative maintenance being performed?
5. Are state agencies forcing action?
6. Is correction an economically justified procedure?

He may not have all the answers but it is essential that he know the questions.

The goals and objections usually can be outlined as an effort to:

1. Determine the need for a sewer system analysis;
2. Establish an effective sewer maintenance program;
3. Determine and project minimum and optimum needs for equipment and manpower;
4. Determine if infiltration is a significant problem; and
5. Correlate cleaning and inspection with any contemplated street paving program.

When the public works official has identified and evaluated the problem, he may look for guidance from a qualified consulting engineering firm, supplemented by competent sewer service organizations if he does not have adequate manpower and equipment.

3.2 IDENTIFY SYSTEM

3.2.1 Plot Maps

The first request by a consultant or infiltration analyst will be for detailed maps of the sewer system. Only in rare instances are all such maps available. Even in jurisdictions that take pride in maintaining excellent records, the existing maps often will be found inaccurate as to utility locations because as-built records never were made or kept in past practices.

It is imperative that the existing sewer maps be completely checked in the field for verification of line, grade, and sizes. Future studies and corrective action will be rendered difficult and expensive unless adequate attention is given at the very outset of operations. Such mapping also is essential for routine preventive maintenance programs.

Scales, types of maps, and information must be tailored to each community or area. If the public works department or sewer agency does not possess such maps or if there are no personnel available to produce them, a consultant or a separate land surveying firm may be engaged for this vital step.

3.2.2 Identify Drainage Systems

Maps should be analyzed to develop a series of small drainage areas or "mini-systems." Key manholes should be selected for each "mini-system" through which the total "mini-system" flow enters the trunks or the next area. A theoretical office analysis of key manholes should be made to identify the sections and manholes that are bottlenecks. This operation requires that true invert elevations and pipe sizes be known so that hydraulic computations can be made. At this point some feeling for the scope of the problem can be gained.

3.3 IDENTIFY SCOPE OF INFILTRATION

3.3.1 Flow Measurements

In conjunction with the identification of drainage systems, actual dry-weather and wet-weather flow measurements should be made at key manholes. A series of such measurements may extend over many months of observation during daily periods of low domestic and industrial flow.

The flow in the sewers can be obtained by various methods:

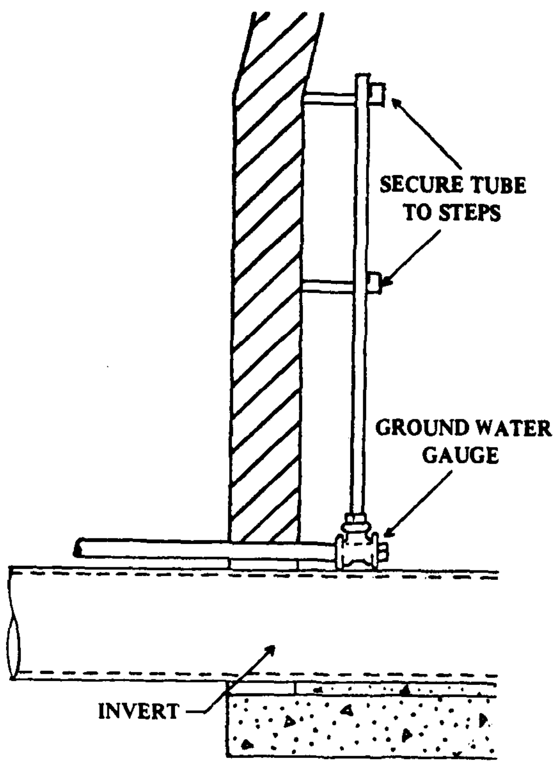
1. *Measure depth and obtain velocity* by *timing* floating material, appearances of dye, conductivity of injected salt solutions, radioactive tracers, or mechanical velocity measuring devices.
2. Utilize various types and shapes of calibrated measuring devices such as V-notch and sutro weirs and orifices.
3. Use electronic flow recorders that can transmit records to distant points.
4. Utilize photograpic installations that will automatically record levels of water behind weirs.
5. Install float-actuated devices that can record depths of flow.
6. Evaluate pumping records at all pumping stations, lift stations and treatment plants.
7. Make flow measurements at major metering installations such as Parshall flumes, venturi devices and wet well float meters at treatment plants.

Ground water elevations also should be obtained from ground water gauges installed in manholes where wet ground conditions are suspected. These gauges are like glass water level gauges in boilers, are permanently placed by inserting a pipe with elbow through the manhole wall, sealing it carefully, and attaching a visible plastic viewing tube with a calibrated scale behind it. Figure 3.3, Ground Water Gauge, shows a gauge in place. Water rises in the plastic tube to the height of the ground water outside of the manhole.

Ground water elevation is extremely important in planning an infiltration study. Unless the ground water elevation is higher than the sewer pipe, little actual infiltration – other than during storms – can be expected. Thus, gauging and inspection should be carried out on those sections located under the ground water table.

FIGURE 3.3

GROUND WATER GAUGE



Courtesy of American Pipe Services Minneapolis, Minnesota

Ground water gauges should be inspected weekly for an extended period, such as an entire year, to determine seasonal variations. Inspection and gauging then can be planned for maximum conditions.

The amount of infiltration flow as observed within a pipe often can be judged when the head is known.

All of this information should be collected carefully, along with rainfall records for the area, and evaluated in terms of variations of dry-weather to wet-weather flows and time relationships to major storms. When compared with the theoretical computations and analysis of the drainage system as outlined in 3.3, a clear picture of the actual situation can be developed.

3.3.2 Rainfall Simulation

If the infiltration/inflow problem has been identified as rain-connected and the system is supposedly separate, a rainfall simulation in the *storm sewers* can help pinpoint the source. In this simulation study, storm sewers that are adjacent to sanitary sewers are plugged and filled with dyed water. If this water shows up in the sanitary sewer, there is serious infiltration or a direct inflow connection between the two systems. Further investigations, as described in Section 4, can be used to identify inflow.

The preceding step has illustrated a basic factor in such surveys – which is the identification of, and distinction between, infiltration and inflow. Although this section of the manual is devoted to the infiltration component, it should be emphasized that inflow is of equal or greater significance in some systems. For that reason it is suggested that when extraneous water flows are shown to be immediately sensitive to rainfall, an inflow investigation be made as described in Section 4.

3.4 PHYSICAL SURVEY OF SEWER SYSTEMS

In conducting a complete physical and lamping survey of the entire sewer system, every manhole is entered and sewers are examined visually for degree and nature of deposition, flows, pipe condition, etc. Manholes also are examined. Mirror and periscope devices can facilitate viewing lines, but it is imperative that someone physically enter each manhole. Very little information can be obtained by peering into even a shallow one. The proper safety checks for combustible gas, oxygen deficiency, etc., must be carried out prior to entry into any manhole.

If the static ground water gauges have not been installed, they should be placed during the lamping survey.

Smoke tests used in the inflow study also may reveal infiltration sources under low ground water conditions.

It should be emphasized that proper forms for recording field data, experienced survey personnel, and means for recording results on a visual plot map are essential for subsequent evaluation. If local staff personnel are not available, the consultant or the professional survey team can perform these duties and produce the data as well as analyzing them.

3.4.1 Effects of Poor Soil Conditions

Sewers constructed in poor soils may be subjected to settlement that will tend to open the joints or cause cracking of pipe, with subsequent infiltration or exfiltration. Because such settlement takes place over long periods of time and is accelerated as new construction in the vicinity of the pipe creates additional loads on the soils below the sewer, the failure of the sewer installation can occur after many years of satisfactory performance. This indicates that, as increased infiltration has been noted and poor soils conditions prevail, new construction along or above the pipe is subject to suspicion and investigation.

Man-made fill should be considered as poor soil unless the fill was placed under rigid construction control. This is especially true where fill has been placed on soft materials such as clay, swamp, tree roots, or debris.

An abrupt change of foundation conditions is often the cause of cracking. Pipes connected to deep manholes, the latter founded on harder material than the pipes, can spell trouble. A pumping station on pile foundation, with the sewer and adjacent manholes laid in soft soils, always is cause for suspicion.

Elimination of infiltration due to the above sources usually will require complete reconstruction of the affected portion of the system and should be based on a revised design. This design must include elimination of future settlements or the choice of pipe and joint type as well as use of pipe cradles and other means that will permit settlement without failure of the sewer system.

3.4.2 Effects of Ground Water Conditions

If the ground water level is at or above the sewer installation, the ground water can affect infiltration in two basic ways: attack on the pipe or joint materials, and an increase in the rate of infiltration once openings in the system have occurred for a variety of reasons, not necessarily connected with ground water.

Chemicals in the ground water, such as sulfates and organic acids, will attack certain pipe and joint materials. The rate of attack depends on the rate of flow through the ground and the resistance of the sewer materials to the attack.

The presence of ground water may induce electrolytic corrosion of metal pipes by stray currents. Correction depends on the degree and type of deterioration, and could involve replacement with different materials, external coatings, and cathodic protection.

Ground water has a very pronounced effect on infiltration after a sewer system has lost its water-tightness for any reason. Given a certain number and size of openings in a portion of the pipe system, infiltration will be influenced by the flow of ground water through the surrounding soils, the distance between the pipe and top of ground water surface (head), and the composition of the soils.

For soils of high permeability, such as gravel and clean sand which permit a high rate of ground water flow, the openings in the sewer will determine the rate of infiltration, together with the ground water head which dictates the hydrostatic pressure. Conversely, soils of low permeability such as clay may retard the rate of ground water entry through openings in the sewer; for example, a dense clay may seal openings and reduce or eliminate the effect of the hydrostatic pressure of the ground water at sewer level. The silt content of the soil can have a dual effect on infiltration; it influences the permeability but it can also increase the amount of solids entering the sewer lines with the ground water.

Trench backfill and bedding materials different from the in-situ soils should be taken into account in the above described considerations. Trench backfill can act as a ground water barrier or, on the other hand, as an artificially created undergound stream.

3.5 ECONOMIC AND FEASIBILITY STUDY

Equaling in importance the identification of infiltration is the evaluation of costs and benefits. Although frequently there are overriding health and environmental reasons for correcting infiltration, exfiltration and inflow, there may be situations in which the jurisdiction or agency has a choice between either accepting the extraneous flows and treating them, or eliminating them. Each choice has an associated cost and requires a careful analysis prior to any policy decision. Section 5 provides a detailed economic analysis that most communities can apply in arriving at meaningful conclusions.

The public works engineering staff or the consulting engineer should make this economic evaluation in conjunction with a review of existing design features that would indicate the system's adequacy. The current market value of the system also should be weighed to illustrate the magnitude of the investment which must be protected.

At this stage in the survey, fiscal decisions can be made to proceed with correction programs only if found economically and technically feasible. By this time, cost estimates can be developed for the subsequent correctional stages.

Generally, the pre-investigation will delineate those sections of the system where high ground water elevations, high flows, and defective pipe conditions indicate the possibility of more than average infiltration flows. Analysis at this point will enable the identification of the areas with the most infiltration and the drainage areas with less infiltration where the economics of the corrective actions dictate.

3.6 SEWER CLEANING

3.6.1 Initial Cleaning

A planned sewer cleaning program is essential for the following reasons:

1. Full capacities and self-scouring velocities are restored.
2. The difficult areas to clean are discovered. Areas indicating possible breaks, offset joints, restrictions, and poor house taps may require photography or television inspection.
3. The most economical method and frequency of cleaning can be established. This will permit more realistic annual budgeting.
4. Individual flow readings by weir or recorders will be more accurate in clean sewers.
5. Clean sewers are a necessary prerequisite for any television inspection program and correction sealing procedures.

Through past experience it has been found that many municipalities are not equipped or experienced enough to clean sewers adequately in preparation for inspection by closed-circuit television or sealing by pressure injection of sealants. Closed-circuit TV is used basically to inspect the pipe line to determine whether or not there are any structural failures, misalignment, or points of infiltration. In this phase, small amounts of debris left in the bottom of the line, such as sand, stone, or sewage solids, may not interfere with a good inspection except in pipe of less than 10 inches in diameter. However, initial cleaning preparatory to inspection should be done more thoroughly than for routine maintenance. A full diameter gage or "full gauge squeegee" should be passed through the sewer to insure optimum cleanliness.

Where repairs are going to be made by means of internal pressure injection, it is also important that all such deposits be removed. Two basic problems that will result from debris left in the line are (1) the damage that would be done to the inflatable ends of the sealing machine or packing device, and (2) inability of inflatable ends to create the perfect seal required during the pumping period of sealants and for pulling the sealing device through the line.

It is desirable to have little or no flow within the sewer lines during the inspection or pressure sealing. In most cases it is not possible to achieve this condition. It has been found that flow depths of one-third of the pipe or less are tolerable in the performance of these services. It should be understood that inspections under submerged conditions will give questionable results.

3.6.2 Sewer Cleaning Plan

OBJECTIVE:

Sewer pipe cleaning in preparation for television, photography or internal injection

PRE-CLEANING INSPECTION:

Determine condition of pipe to be cleaned and type of equipment to be used.

CLEANING EQUIPMENT:

The equipment can include, but not be limited to:

1. Rodding Machine - sectional rodding machine with 36-inch, 39-inch or 48-inch sectional rods either 5/16-inch or 3/8-inch diameter – hydraulically or mechanically powered.
2. Rodding Machine – continuous rodding machine with a minimum of ;375 diameter rod.
3. Bucket Machine – 10.5 hp up to 100 hp; buckets 6 inches up to any size for cleaning round or square box sewers.
4. High Velocity Water Machine – air or water-cooled power plant; sewer cleaning hose 3/4-inch minimum with operating pressure up to 1500 psi; maximum pressure at the pump.
5. Hydraulically Propelled Devices or Cleaning Tools – with or without harness.

CLEANING OPERATION:

The actual cleaning operation and the type of equipment selected generally is determined by the size and condition of the pipe to be cleaned. Ordinary conditions in most cases may require the use of more than one type of equipment or a combination of more than one piece or type of equipment. These can include, but not be limited to, the following:

1. Rodding machines, either sectional or continuous, can be used to clean the pipe in preparation for final inspection prior to grouting; however, under severe cleaning requirements they are used primarily to thread the sewer or pipe line for cleaning operations and use of bucket machines.

   There are many tools that can be attached to the front of the rod which will effectively remove debris, such as heavy conglomerates of grease, root intrusions, etc. The rodding machine also can be used to pull such cleaning tools as a stiff wire brush or swab, to clean light debris from within sewer lines It should be noted that with those two tools, a tag line connected to a bucket machine should be used in order to pull the swab or brush back if adverse conditions are encountered.

   It is necessary that in the above type of cleaning methods a head of water, like that which could be furnished by a fire hydrant, should be used to help propel the solids within the sewer line to the downstream manhole.
2. Bucket machines provide a positive means of cleaning pipe. Their operation allows a positive connection of cable from one manhole to the other, with applicable power to pull a bucket loaded with sand or gravel back to the manhole for dumping on the street, into a container, or truck bed (if a truck loader machine is used). This method of cleaning removes solid materials such as sand, gravel, and roots, and renders the pipe clean for sealing if followed up with a stiff wire brush and swab or squeegee.

   It is important that final cleaning tools be as close to pipe size as possible to obtain the necessary results preparatory to a good grouting job.

   It also is necessary that a sufficient amount of flushing water be available during the final cleaning operation, to scour and flush the pipe.
3. The high velocity or hydraulic pipe cleaning machine is mobile and provides a fast and, under most conditions, effective cleaning. Operation of this machine with a specially designed cleaning nozzle will produce a cleaning or scouring action from streams of water directed to strike the inside wall of the pipe under high velocity. As a result of the jet action from the rearward orifices, the cleaning nozzle and hose is propelled forward. As the hose and nozzle is pulled back to the manhole, the high velocity spray produces a hydraulic rake effect bringing the debris back to the manhole. Care is necessary in using hydraulic cleaning equipment. In sandy soil where the sewer may be defective, creation of voids may cause collapse of the pipe.
4. Hydraulically propelled cleaning tools are placed in the pipe with the proper tolerances between the outside diameter of the device and the inside diameter of pipe. Water is put

into the manhole or sewage is allowed to build up behind the ball to produce a head of pressure moving the device down the sewer line and allowing some water to escape. With the rush of water, turbulence is created to cause sand or solid materials to go into suspension, thereby moving down the line. Caution must be used in the operation of these devices because the water pressure created behind the ball can affect bad joints in the pipe. The pressure may in some cases damage private property because of water entering basements through house laterals.

CLEANING EXAMPLE:

A 12-inch line with severe sand, gravel, and root intrusion will require the use of bucket machines and flushing equipment or a high water velocity machine. In some cases where roots are the main problem, a rodding machine with a saw or auger-type cutter may be required, with a follow-up wire brush tool to clean the pipe. In every case a swab-type tool incorporating a rubber disc to clean or wipe the pipe to the full pipe diameter can be used to free the inside pipe wall completely from any obstruction. This is not only important to effect the proper application of the sealants; it will prevent possible damage to the inflated rubber ends of the sealing machine or packing device and create the perfect seal required during the pumping period of the sealants.

3.7 TELEVISION AND PHOTOGRAPHIC INSPECTION

As a result of the findings of the previous stages, the best utilization of television or photographic inspection can now be determined. Arbitrary use of these techniques without pre-planning and budget review is not recommended. The most economical results are not achieved on a random basis. These techniques are useless when flows in the sewer exceed one-third of the depth.

The following are some of the more pertinent factors associated with TV and photography:

3.7.1 Reasons for Inspection

a. As part of a planned sewer system restoration as outlined in the previous stages.
b. As assurance of sound underground facilities prior to a "permanent surface" type paving program.
c. For the inspection of new construction prior to final acceptance.
d. To determine deficiencies in "troubled areas".
e. To pinpoint the cause, source, and magnitude of infiltration problems.

3.7.2 Methods of Inspection

a. Draw the camera through the sewer and record deficiencies on forms, polaroid pictures, stereo slides, video tape, and/or movie film. Take shots of adjacent "typical" sound pipe for comparison purposes so that the degree of the deficiencies may be ascertained. Locate pertinent features.
b. Record results of the study and draft final report.
c. Summarize and analyze, and recommend corrective measures.

3.7.3 Testing and Sealing

A variation of the above mentioned method is to use television and a testing device. Upon visual inspection of a potentially leaky joint, the testing device is pulled over the joint and a pressurized test made. If the test indicates defects, sealing is accomplished immediately. The cost of this method may be high, although the cost of two setups, one for inspection and then for sealing should be evaluated.

This method of "grouting as you go" does not allow an economic and engineering analysis of the optims which are available such as replacement of the sewer or sealing only those defects which allow major contributory flows.

3.7.4 Results of Inspection

a. Location of sources and magnitude of infiltration.
b. Location and extent of structural deficiencies.
c. Accurate location of wyes, taps, manholes, lampholes, surreptitious connections of any kind, cross-connections to the storm sewer, and any other physical features of consequence:

3.7.5 Benefits of Inspection

a. Provides the information necessary for the drafting of a sewer system map or the updating of an existing one.
b. Enables the engineer to recommend the redesign, reconstruction, rehabilitation, repair, or replacement of any specific part or parts of the system.
c. Provides a permanent written and pictorial record of the system which can be utilized at any time.

3.8 RESTORATION OF THE SEWER SYSTEM

Based on the results and recommendations of the inspection report, sound budgeting and planning for the restoration of the system can now be achieved. The engineer can now appropriately decide how to correct the structural deficiencies and eliminate the infiltration. The following is a suggested approach:

3.8.1 Structural Deficiencies

a. Take into consideration the age, type, and depth of the pipe and the severity and extent of the damage.

b. Depending on the engineering and economic evaluations, either repair the pipe on a partial basis or replace the entire section between manholes. (The economic evaluation must include the cost of repair of the roadway surface.)

c. Isolated or minor damage may be tolerable or corrected at nominal cost.

d. It is obvious pavements should not be placed over damaged or defective pipe. Remember that marginal damage could become severe before the life of the pavement expires.

3.8.2 Infiltration

a. In a structurally sound pipe, most infiltration can be eliminated by the internal injection of sealants. This method of repair precludes excavation. Frequently this internal sealing is performed simultaneously with internal testing, as described in 3.10.3.

b. *Weigh the cost of sealing against the cost of* treating this extraneous water.

c. Think in terms of the hydraulic load placed on the collection system and on the treatment plant. If, during periods of high static head, the treatment plant must be by-passed, compute the cost of plant expansion to handle these peak loads.

d. Consider the fact that small leaks may become larger with the passage of time and/or increase in static head.

e. Compare grouting costs with partial and total replacement costs.

f. Define those sources of infiltration that could be considered livable.

3.8.3 Correction Alternates

a. Replacement of broken sections.

b. Insertion of sleeves or liners.

c. Internal sealing with gels or slurries.

d. External sealing by soil injection grouting.

3.8.4 Building Sewers

An internal grouting method for eliminating waters of infiltration from building sewers has been devised. A pilot project recently completed by American Pipe ervices indicates how sealing may be accomplished if economically desirable.

The first step in the process was to identify the building sewers that were leaking by the use of closed circuit television in the mains. It must be determined whether observed flows are from domestic usage, footing drain tile discharge or as a result of exfiltration from a flooded storm sewer and subsequent infiltration into the building sewer which crosses under the storm sewer.

Domestic usage can be determined by a check of the house at the time of TV inspection to make sure no water is being used and that there are no cooling waters or cistern over-flows discharging to the system.

Footing drain tile contribution can be eliminated from consideration by knowing what the elevation of the ground water table is in the study area. This is done through the use of groundwater gages installed in the sanitary manholes nearby. If the groundwater table is higher than the footing drain tile a check for building sewer infiltration should not be initiated until the groundwater subsides.

If the discharge from the building sewer can be directly attributable to rainfall connected infiltration as a result of flooding storm sewers, internal grouting can be used if an economic analyses indicates a favorable cost-benefit ratio. There must be enough infiltration, either joint leaks and/or building sewer leaks, in a specific run of pipe to make the cost of both camera and packer in the line at the same time worthwhile.

If the economic analyses indicates the advisibility of sealing, the camera-packer tandem is placed in the street sewer with the camera pulled into a position such that it can view the building sewer discharge. Simultaneously, the adjacent storm sewer is re-flodded. When the infiltrating water appears in the sewer a technician is sent into the connecting house basement where he inserts a small inflatable bag into the service cleanout and pushes it all the way out to the main where the camera can view it. It is then retracted toward the house in two foot increments being inflated and deflated at each increment. Initial inflations will stop the water from getting to the main, but eventually the bag will be retracted to a point where the full-flow infiltration will again be evident. At this point the bag is left inflated in the building sewer. Then the grouting "packer" in the main is positioned with its anular opening over the house service connection and inflated. Grout is pumped into the building sewer until sufficient pressures have been reached. The catalyst is triggered and the grout gels. At this point the "packer" is deflated and moved away from the building sewer and the bag in the building sewer itself if deflated and removed. A domestic type sewer cleaning machine is employed through the house sewer cleanout to remove the gel from the line and the sealing process is complete.

The cost range for this procedure has been found to vary from $200 to $500 per house service, depending on the number of services per manhole setup and the amount of chemical used. It also has been found that it is not economically justified to seal building sewers when the infiltration flow is less than 10 gpm. In some areas replacement of the building sewer may be more economical than internal sealing.

3.9 TREATMENT PLANT DESIGN CRITERIA

Besides the obvious advantages of restoring needed capacities and reducing costs and pollution, the final study goal of the complete restoration program is the more accurate estimate of hydraulic loading for future plant design. The design criteria will be tempered by the knowledge that nominal and predictable amounts of extraneous clean water can now be anticipated.

The accomplishments and benefits of pursuing a logical, orderly program for infiltration/inflow correction can be listed as follows:

1. The sewer systems can now be reasonably maintained, usually at lower unit costs. Annual budget needs can be accurately and realistically projected.
2. Serious structural deficiencies will be corrected.
3. Any subsequent paving programs can be carried out with reasonable assurance that the sewers will not require repair at a later date and can easily be maintained.
4. The waste water treatment plant, lift stations, and other facilities will be of adequate size to serve present and projected needs.
5. Treatment or pumping costs in the future will be reduced as much as possible.
6. Infiltration volumes will be reduced to a minimum.

CONTROL OF INFILTRATION AND INFLOW INTO SEWER SYSTEMS

by the

AMERICAN PUBLIC WORKS ASSOCIATION

for the

ENVIRONMENTAL PROTECTION AGENCY
WATER QUALITY OFFICE

and

THIRTY-NINE LOCAL GOVERNMENTAL JURISDICTIONS

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ABSTRACT

Two hundred and twelve public jurisdictions in the United States and Canada were contacted, and twenty-six communities were visited. Practices of consulting engineers and state and provincial water pollution control agencies were also surveyed.

The surveys indicated that infiltration and inflow are widespread problems.

Reduction of infiltration should be stressed in both new and old systems. For new sewers a construction allowance of no more than 200 gallons per day per inch of diameter per mile of pipe is recommended. Existing systems must be extensively investigated to determine the extent and location of infiltration. Reduction of inflow waters can be accomplished after sources of such flows have been identified, alternate methods of disposal identified, and the backing of public and governing bodies secured.

Twenty recommendations are given indicating the need for extensive investigation of the extent of the infiltration/inflow problem before relief sewers are constructed or wastewater treatment plants built or enlarged.

The report includes 43 tables, an extensive review of reports concerning local infiltration studies, and a bibliography of 135 references.

This report was prepared for the Environmental Protection Agency in fulfillment of Contract 14-12-550. The study was also supported by thirty-nine public agencies. A companion document, "Manual of Practice, Prevention and Correction of Excessive Infiltration and Inflow into Sewer Systems," was also prepared.

Key Words: **INFILTRATION, INFLOW, INVESTIGATION, INSPECTION, SURVEY.**