EXTRANEOUS FLOW IN SANITARY SEWERS
The Infiltration Game

EXTRANEOUS FLOW

Extraneous flow in sanitary sewers is that portion of the total sewer flow not generated directly by the contributing population and industrial and commercial sources. The two components of extraneous flow are infiltration and inflow. Inflow is defined as the volume of any kind 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, perforated manhole covers, etc. It does not include and is distinguished from, "infiltration." Infiltration is defined as the volume of groundwater entering sewers and building sewer connections from the soil, through defective joints, broken or cracked pipe, improper connections, manhole walls, etc. The relationship of infiltration to inflow and the effect of each in determining the allowable extraneous flow contribution to the total design sewer flow must be thoroughly understood by the sewer designer when establishing allowable flow criteria.

SEWER SYSTEM ANALYSIS AND EVALUATION SURVEY

Cost-effective planning for improved effluent treatment, rehabilitation or expansion of a sewer system cannot be accomplished without comprehensive knowledge of the amount and sources of extraneous flow. Detailed information of this type is seldom readily available and must be determined by record studies and field surveys. A two phase comprehensive analysis and an evaluation survey of an existing sewer system is recommended. The first phase is a complex and extensive analytic procedure to determine if excessive extraneous flow exists in the sewer system. After evaluation of several sewer rehabilitation projects, EPA has determined that, depending on the total length of the sewer system, extraneous flow rates of 2,000 to 10,000 gallons per day per inch of diameter per mile of pipe are not considered excessive. Unless extraneous flow exceeds these rates, it is not cost-effective to proceed with sewer rehabilitation.

If excessive extraneous flow is found to exist, a sewer system evaluation survey is conducted as the second phase of the investigative procedure to confirm the presence, location, and types of excessive extraneous flow. A cost-benefit determination must be made for any proposed sewer rehabilitation or reconstruction of a new sewer.
EXISTING SEWER REHABILITATION

Rehabilitation of a section of an existing sewer generally will succeed only in reducing the infiltration in the rehabilitated area. Extraneous flow from private sources such as drains, sump pumps and leaking building sewers, which generally contribute more than 50 percent of the total extraneous flow, will not be eliminated. Sectional rehabilitation may also result in migration of the infiltration from the rehabilitated to a non-rehabilitated section. Migration can be reduced if all sewers in an area are included in the rehabilitation effort. The basic objective in rehabilitation is to find and correct leaks.

Cleaning
Rehabilitation usually requires the existing sewer to be cleaned as a first step. Cleaning of an existing sewer removes blockages, restores full capacity and self cleansing velocities, locates breaks and expedites inspection.

Inspection
Inspection locates the cause, source and magnitude of extraneous flow into sewers. Inspection efficiency can be increased by employing various types of tests and equipment.

Testing
Smoke and dye testing of existing sewers simplifies detection of inflow from drains, roof leaders and storm sewer cross connections. Visual and television inspection can locate and estimate volume of infiltration sources. Inspection and testing provide the information required to determine the most effective method of rehabilitation.

Rehabilitation
Rehabilitation of a sewer, depending on the type of deficiencies, may require any or all of the more common rehabilitation methods, such as root control, grouting, mortar linings, insert linings and replacement.

NEW SEWER SYSTEMS

Predesign Investigations
The sewer designer must be thoroughly familiar with site conditions. Information can be obtained from maps, records, subsurface exploration and site visits. Soil classifications and properties, and knowledge of groundwater level variations are especially important as related to infiltration.

Infow can be eliminated from a new sewer system only by complete prohibition and effective enforcement. Such conditions are never completely realized due to political and other reasons. The acceptable design inflow component, therefore, is an engineering judgment factor which must be tailored to fit the individual situation including future projected development.

Since it is the average projected infiltration that bears on treatment and pumping costs, the de-
sign infiltration allowance must be correlated with the construction test allowance. The futility of the present allowable infiltration rate numbers game is illustrated by the following example.

A sewer system is assumed to serve a total area of 1,200 acres with a population density of 20 persons per acre for a total population of 24,000. Assuming an average daily sanitary contribution of 100 gallons per person, the average daily contribution of the population is 2,400,000 gallons. The system is assumed to consist of 36 miles of 4-inch diameter building sewers, and 36 miles of 8-inch diameter, 6 miles of 10-inch diameter and 6 miles of 12-inch diameter sanitary sewers.

Based on information from similar existing areas, the design inflow allowance is assumed to be equal to the total average daily population contribution, or 2,400,000 gallons. The total infiltration is determined for assumed rates of 50 and 200 gallons per day per inch of diameter per mile of pipe (inch-gallons) for the entire sewer system. The 50 inch-gallon rate results in a total daily infiltration of 28,200 gallons and the 200 inch-gallon rate results in 112,800 gallons.

Plotting these values on a bar graph, Figure 1, vividly illustrates the insignificance of the infiltration component even though based on a seemingly wide range of infiltration rates. The total infiltration component is only one half of one percent of the total daily flow for the 50 inch-gallon rate and two percent for the 200 inch-gallon rate. Percentages of these magnitudes would normally be neglected in any other design calculations.

Joints

The commonly used types of pipe, pipe joints and joint material can perform satisfactorily in sanitary sewers. The effectiveness of sewer joints for the control of infiltration is so important that no sewer system is better than its joints. It should be recognized by the engineer, however, that field performance represents the sum of the manufactured joint characteristics and the contractor’s installation practice.

Inspection

Providing experienced and conscientious construction inspectors significantly lowers the incidence of leakage test failures and greatly improves long term system performance. Inadequate inspection and lack of technically consistent field supervision may result in ineffective sewer installations. Nothing could be more penny-wise but dollar foolish than to skimp on inspection control of sewer system construction.

Tests

To insure compliance with project specifications, tests are usually required during construction. Among these are gradation, moisture content and density of pipe bedding and backfill, and tests for acceptance of the installed pipe. Acceptance tests are the most effective way to control infiltration, and at the same time, assure the structural integrity and proper installation of the new sewer. Criteria for acceptance tests are established to enforce a maximum leakage limit as a condition of job acceptance. Limits may be stated in terms of water leakage limits for infiltration or exfiltration tests, or air leakage limits for the low pressure air test, and should include both a maximum allowable test section rate and a maximum allowable system average rate. For precast concrete pipe, water infiltration and exfiltration test criteria have been established in ASTM Standard C969 and air test criteria have been established in ASTM Standard C924.

Recognizing that low pressure air testing is considered a valid acceptance test for installed pipe lines, it should be understood that no direct mathematical correlation has been found between air test limits and water infiltration test limits.

Current information indicates that infiltration rates of about 200 inch-gallons can normally be achieved with minimum to no effect on construction costs. The 200 inch-gallon allowance is for manhole to manhole tests, and
is only appropriate when the average depth of the groundwater over the crown of the pipe is between two feet and six feet.

The infiltration allowance should reflect a consideration of the permeability of the soil, particularly the envelope around the pipe, in addition to the depth of the groundwater over the pipe. To obtain the correct infiltration test allowance reflecting the effect of soil permeability, an average head of six feet of groundwater over the pipe is established as the base head. With heads more than six feet, the infiltration allowance is increased by the ratio of the square root of the actual average head to the square root of the base head. For example, with an average groundwater head of 12 feet, the 200 inch-gallon test allowance is increased to 282 inch-gallons:

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\text{Infiltration Test Allowance} = 200 \cdot \frac{\sqrt{H}}{\sqrt{6}} = 200 \cdot \frac{\sqrt{12}}{\sqrt{6}} = 282 \text{ inch-gallons}
\]

For exfiltration testing, exfiltration limits, to achieve similar control of infiltration should be set somewhat higher than the infiltration limits. Accordingly, the combined leakage from the pipe and manholes is fixed at about 200 inch-gallons when the average base head on the test section is three feet. To obtain the correct exfiltration test allowance for test heads higher than the base head, the exfiltration allowance is increased by the ratio of the square root of the actual average test head to the square root of the base head, three feet. For example, if the actual average test head were eight feet, the exfiltration test allowance, including manholes, would be 327 inch-gallons:

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\text{Exfiltration Test Allowance} = 200 \cdot \frac{\sqrt{H}}{\sqrt{3}} = 200 \cdot \frac{\sqrt{8}}{\sqrt{3}} = 327 \text{ inch-gallons}
\]

Manholes may be tested separately and independently. An exfiltration allowance for manholes of 0.1 gallon per hour per foot of diameter per foot of head is appropriate.

Although infiltration, exfiltration or low pressure air may be the major factor in acceptance testing, acceptance of an installed sewer should also require testing of alignment, deflection of flexible pipe, obstruction removal, and other factors. Any of these test criteria, properly enforced, will result in high quality construction, and the difference in actual infiltration, resulting from use of one limit rather than another, should be relatively small.

Summary

Construction is the ultimate realization of the plans of the design engineer. Consideration of realistic design and acceptance test criteria for new sanitary sewers will assist in attaining the prime objective of all engineering projects, production of a cost-effective, satisfactorily functioning system, by utilizing adequate design criteria and assuring the best quality workmanship and materials reasonably obtainable through appropriate testing and inspection.

REFERENCES

Control of Infiltration and Inflow into Sewer Systems, Environmental Protection Agency, December, 1970.


ASTM C924, Recommended Practice for Testing Concrete Pipe Sewer Lines by Low-Pressure Air Test Method.

ASTM C969, Recommended Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines.