United States
Environmental Protection
Agency

Collection Systems Technology Fact Sheet

Sewers, Conventional Gravity

DESCRIPTION

Sewers are hydraulic conveyance structures that carry wastewater to a treatment plant or other authorized point of discharge. A typical method of conveyance used in sewer systems is to transport wastewater by gravity along a downward-sloping pipe gradient. These sewers, known as conventional gravity sewers, are designed so that the slope and size of the pipe is adequate to maintain flow towards the discharge point without surcharging manholes or pressurizing the pipe.

Sewers are commonly referred to according to the type of wastewater that each transports. For example, storm sewers carry stormwater; industrial sewers carry industrial wastes; sanitary sewers carry both domestic sewage and industrial wastes. Another type of sewer, known as a combined sewer, is prevalent in older communities, but such systems are no longer constructed. Combined sewers carry domestic sewage, industrial waste, and stormwater. This fact sheet focuses on sanitary sewer systems.

APPLICABILITY

Conventional gravity sewers are typically used in urban areas with consistently sloping ground because excessively hilly or flat areas result in deep excavations and drive up construction costs. Conventional gravity sewers remain the most common technology used to collect and transport domestic wastewater.

ADVANTAGES AND DISADVANTAGES

Advantages

Conventional gravity sewer systems have been used for many years and procedures for their design are well-established. When properly designed and constructed, conventional gravity systems perform reliably. Properly designed and constructed conventional gravity sewers provide the following advantages:

- Can handle grit and solids in sanitary sewage.
- Can maintain a minimum velocity (at design flow), reducing the production of hydrogen sulfide and methane. This in turn reduces odors, blockages, pipe corrosion, and the potential for explosion (Qasim 1994).

Disadvantages

- The slope requirements to maintain gravity flow can require deep excavations in hilly or flat terrain, driving up construction costs.
- Sewage pumping or lift stations may be necessary as a result of the slope requirements for conventional gravity sewers, which result in a system terminus (i.e., low spot) at the tail of the sewer, where sewage collects and must be pumped or lifted to a collection system. Pumping and lift stations substantially increase the cost of the collection system.
- Manholes associated with conventional gravity sewers are a source of inflow and infiltration, increasing the volume of wastewater to be carried, as well as the size of pipes and lift/pumping stations, and, ultimately, increasing costs.

DESIGN CRITERIA

The design of conventional gravity sewers is based on the following design criteria:

- Long-term serviceability.
- Design flow (average and peak).

- Minimum pipe diameter.
- Velocity.
- Slope.
- Depth of bury and loads on buried conduits.
- Appurtenances.
- Site conditions.

Long-Term Serviceability. The design of long-lived sewer infrastructure should consider serviceability factors, such as ease of installation, design period, useful life of the conduit, resistance to infiltration and corrosion, and maintenance requirements. The design period should be based on the ultimate tributary population and usually ranges from 25 to 50 years (Qasim 1994).

Design Flow. Sanitary sewers are designed to carry peak residential, commercial, institutional, and industrial flows, as well as infiltration and inflow. Gravity sewers are designed to flow full at the design peak flow. Design flows are based on various types of developments. Table 1 provides a list of design flow for various development types.

Minimum Pipe Size. A minimum pipe size is dictated in gravity sewer design to reduce the possibility of clogging. The minimum pipe diameter recommended by the Ten State Standards is 200 mm (8 inches). Though the Ten State Standards are adopted by ten specific states (Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Pennsylvania, and Wisconsin) and the Province of Ontario, they often provide the basis for other state standards.

Velocity. The velocity of wastewater is an important parameter in a sewer design. A minimum velocity must be maintained to reduce solids deposition in the sewer, and most states specify a minimum velocity that must be maintained under low flow conditions. The typical design velocity for low flow conditions is 0.3 m/s (1 foot/second). During peak dry weather conditions the sewer lines must attain a velocity greater than 0.6 m/s (2 feet/second) to ensure that the lines will be self-cleaning (i.e., they will be flushed out once or twice a day by a higher velocity). Velocities higher than 3.0 m/s (10 feet/second) should be avoided because they may cause erosion and damage to sewers and manholes (Qasim 1994).

TABLE 1 AVERAGE DESIGN FLOWS FOR DEVELOPMENT TYPES

Type of Development	Design Flow (GPD)
Residential:	
general	100/person
single family	370/residence
townhouse unit	300/unit
apartment unit	300/unit
Commercial:	
general	2,000/acre
motel	130/unit
office	20/employee
	0.20/net sq.ft.
Industrial (varies with type of industry):	
general	10,000/acre
warehouse	600/acre
School site (general)	16/student

Source: Darby, 1995.

Slope. Sewer pipes must be adequately sloped to reduce solids deposition and production of hydrogen sulfide and methane. Table 2 presents a list of minimum slopes for various pipe sizes.

If a sewer slope of less than the recommended value must be provided, the responsible review agencies may require depth and velocity computations at minimum, average, and peak flow conditions. The size of the pipe may change if the slope of the pipe is increased or decreased to ensure a proper depth below grade. Velocity and flow depth may also be affected if the slope of the pipe changes. This parameter must receive careful consideration when designing a sewer.

Depth of Bury. Depth of bury affects many aspects of sewer design. Slope requirements may drive the pipe deep into the ground, increasing the amount of excavation required to install the pipe. Sewer depth averages 1 to 2 m (3 to 6.5 feet) below ground

TABLE 2 MIMIMUM SLOPES[1] FOR VARIOUS PIPE LENGTHS

Diameter		Pipe Length	
Inches	Millimeters	Up to 5'	6' or More
8	200	0.47	0.42
10	250	0.34	0.31
12	310	0.26	0.24
14	360	0.23	0.22
24	610	0.08	0.088
30	760	0.07	0.07

[1]Slopes in feet per 100'
Source: Fairfax County, VA 1995.

surface. The proper depth of bury depends on the water table, the lowest point to be served (such as a ground floor or basement), the topography of the ground in the service area, and the depth of the frost line below grade.

Appurtenances. Appurtenances include manholes, building connections, junction chambers or boxes, and terminal cleanouts, among others. Regulations for using appurtenances in sewer systems are well documented in municipal design standards and/or public facility manuals. Manholes for small sewers (610 mm [24 inches] in diameter or less) are typically 1.2 m (4 feet) in diameter. Larger sewers require larger manhole bases, but the 1.2 m (4 foot) barrel may still be used. Manhole spacing depends on regulations established by the local municipality. Manholes are typically required when there is a change of sewer direction. However, certain minimum standards are typically required to ensure access to the sewer for maintenance. Typical manhole spacing ranges between 90 to 180 m (300 to 600 feet) depending on the size of the sewer and available sewer cleaning equipment. For example, one municipality requires that the maximum manhole spacing be at intervals not to exceed 120 m (400 feet) on all sewers 380 mm (15 inches) or less, and not exceeding 150 m (500 feet) on all sewers larger than 380 mm (15 inches) in diameter (Fairfax County PFM 1995). Figure 1 shows a typical manhole profile.

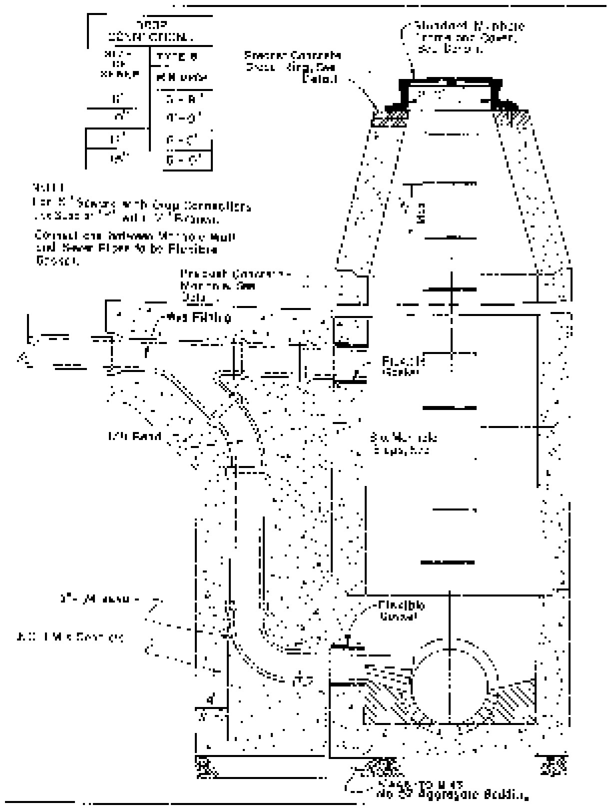
PERFORMANCE

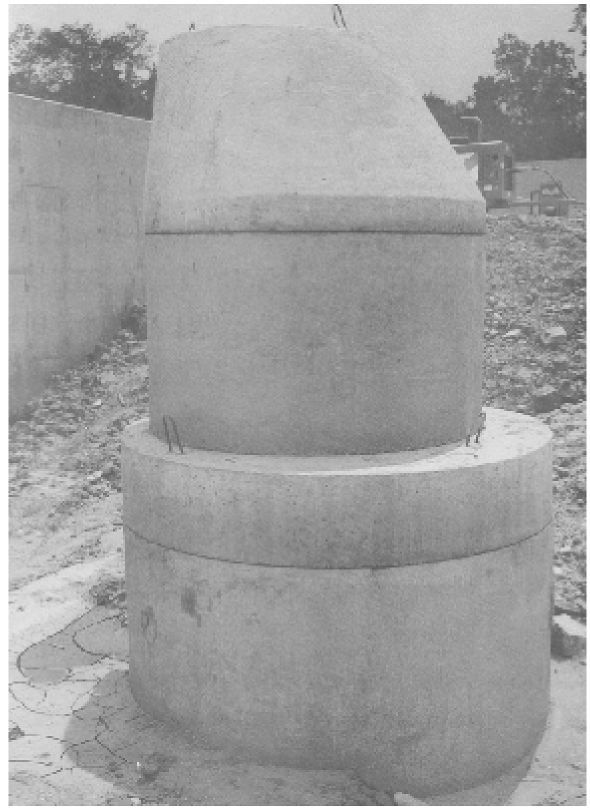
City of Alton, Texas

Alton is a small residential community of about 1,300 homes in Hidalgo County, Texas. Before 1997, all 45 subdivisions in the city used on-site septic tanks, privies, or cesspools for wastewater disposal. These methods did not meet state or county standards primarily because of unsuitable soil conditions, small lot sizes, and density of development. To rectify this situation, a conventional gravity sewer collection system was installed, consisting of 142,600 feet of 8-inch gravity sewer, 5,300 feet of 15-inch gravity sewer, 11,600 feet of 18-inch gravity sewer, 2,600 feet of 6-inch force main, and two lift stations. The system includes 453 manholes and more than 2,000 service connections to convey flow to a nearby interceptor pipeline, which then conveys flow to a nearby wastewater treatment plant in McAllen, Texas. This gravity sewer system has provided reliable performance, while eliminating unsuitable wastewater technologies.

OPERATION AND MAINTENANCE

Interruptions in sewer service may be avoided by strict enforcement of sewer ordinances and timely maintenance of sewer systems. Regular inspection and maintenance minimizes the possibility of damage to private property by sewer stoppages as well as the legal responsibility of the sewer authority for any damages. An operation and maintenance program is necessary and should be developed to ensure the most trouble-free operation of a sanitary sewer system. An effective maintenance program includes enforcement of sewer ordinances, timely sewer cleaning and inspection, and preventive maintenance and repairs. Inspection programs often use closed-circuit television (CCTV) cameras and lamping to assess sewer conditions. Sewer cleaning clears blockages and serves as a preventive maintenance tool. Common sewer cleaning methods include rodding, flushing, jetting, and bailing. Education and pollution prevention can enhance operation and maintenance programs by informing the public of proper grease disposal methods.





Source: Anne Arundel County Std. Details, 1997.

Source: Concrete Pipes and Products, Inc., 1992.

FIGURE 1 PROFILE AND PHOTOGRAPH OF MANHOLE

Effective operation of a conventional gravity sewer begins with proper design and construction. Serious problems may develop without an effective preventative maintenance program. Occasionally, factors beyond the control of the maintenance crew can cause problems. Potential problems include:

- Explosions or severe corrosion due to discharge of uncontrolled industrial wastes.
- Odors.
- Corrosion of sewer lines and manholes due to generation of hydrogen sulfide gas.
- Collapse of the sewer due to overburden or corrosion.
- Poor construction, workmanship, or earth shifts may cause pipes to break or joints to open up. Excessive infiltration/exfiltration may occur.
- Protruding taps in the sewers caused by improper workmanship (known as plumber taps or hammer taps) These taps substantially reduce line capacity and contribute to frequent blockages.
- Excessive settling of solids in the manhole and sewer line may lead to obstruction, blockage, or generation of undesired gases.
- The diameter of the sewer line may be reduced by accumulation of slime, grease, and viscous materials on the pipe walls, leading to blockage of the line.
- Faulty, loose, or improperly fit manhole covers can be a source of noise as well as inflow. Ground shifting may cause cracks in manhole walls or pipe joints at the manhole, which become a source of infiltration or exfiltration. Debris (i.e., rags, sand, gravel, sticks, etc.) may collect in the manhole and block the lines.

Tree roots may enter manholes through the cracks, joints, or a faulty cover, and cause serious blockages.

COSTS

The cost of a conventional gravity sewer system varies, based on many factors, including the depth and difficulty of excavation, the cost of labor, availability of pipe, geologic conditions, hydraulic grade line, and construction sequencing. As such, it is difficult to quantify the cost per linear foot for a particular sewer pipe size. Table 3 summarizes unit costs for various items and quantities.

TABLE 3 UNIT COSTS FOR SANITARY SEWER

Item	Cost [1]/Unit
PVC Pipe (not including excavation and backfill):	
8" Diameter	$3.77/linear foot (lf)
10" Diameter	$5.84/lf
15" Diameter	$11.85/lf
Catch Basins or Manholes (including footing and excavation, not including frame or cover):	
Brick, 4' inside diameter, 4' deep	$710 each
Concrete, cast in place, 4'x4', 8" thick, 4' deep	$643 each
Trenching: 4' wide, 6' deep, ½ cubic yard bucket	$18.05/lf
Pipe Bedding: side slope 0 to 1, 4' wide	$3.39/lf
Fill: spread dumped material by dozer, no compaction	$1.23/cubic yard

[1] Source: Means Mechanical Cost Data, 1991.

REFERENCES

Other Related Fact Sheets

Sewer Cleaning and Inspection
EPA 832-F-99-031
September 1999

Sewers, Pressure
EPA 832-F-02-006
September 2002

Other EPA Fact Sheets can be found at the following web address:

http://www.epa.gov/owm/mtb/mtbfact.htm

1. Anne Arundel County, Maryland, 1997. Standard Details for Construction.

2. Border Environmental Cooperation Commission, 1997. Step II Form (Full Proposal). City of Alton, Texas.

3. Concrete Pipe and Products Company, Inc., 1992. Technical Manual. Manassas, Virginia.

4. Crites, R. and G. Tchobanoglous, 1998. Small and Decentralized Wastewater Management Systems. The McGraw-Hill Companies. New York, New York.

5. Darby, J., 1995.

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7. Lindeburg, M. R., 1986. Civil Engineering Reference Manual. Professional Publications, Inc. Belmont, California.

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9. Qasim, S. R., 1994. Wastewater Treatment Plants. Technomic Publishing Company, Inc. Lancaster, Pennsylvania.

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11. U. S. EPA, 1986. Design Manual: Municipal Wastewater Disinfection. EPA Office of Research and Development. Cincinnati, Ohio. EPA/625/1-86/021.

12. U. S. EPA, 1991. Manual: Alternative Wastewater Collection Systems. EPA Office of Research and Development. Cincinnati, Ohio. Office of Water. Washington, D. C. EPA/625/1-91/024.

13. U. S. EPA, 1992. Manual: Wastewater Treatment/Disposal for Small Communities. EPA Office of Research and Development. Cincinnati, Ohio. Office of Water. Washington, D. C. EPA/625/R-92/005.

ADDITIONAL INFORMATION

Alton Community Development
5 Mile Line W
Alton, TX 78572

Illinois Rural Community Assistance Program
Illinois Community Action Association
P. O. Box 1090
Springfield, IL 62705

National Small Flows Clearinghouse
at West Virginia University
P. O. Box 6064
Morgantown, WV 26506

David Venhuizen, P.E.
5803 Gateshead Drive
Austin, TX 78745

Walker Baker & Associates, Ltd.
Bill Walker
102 North Gum Street
Harrisburg, IL 62946

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For more information contact:

Municipal Technology Branch
U.S. EPA
1200 Pennsylvania Avenue, NW
Mail Code 4204M
Washington, D.C. 20460

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