# WASTEWATER COLLECTION SYSTEM OPERATOR CERTIFICATION MANUAL

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# Certification and Licensing Program

## ***Mission***
Promote responsible environmental stewardship.

## ***Goal***
Provide operators with the basic knowledge required to manage drinking water, wastewater and solid waste systems.

The Division of Compliance Assistance offers free compliance assistance. Our services are available to all individuals, communities and businesses regulated by the Kentucky Department for Environmental Protection. We want to help you succeed!

Hotline and Website for regulatory, technical or operational concerns
800-926-8111
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# WASTEWATER COLLECTION SYSTEM OPERATOR CERTIFICATION MANUAL

# Chapter 1: THE CERTIFIED OPERATOR

## Chapter 1 Objectives

1. Understand and identify the operator certification regulations as they relate to the definitions, boards of certification, standards of professional conduct, wastewater treatment and collection system operators classification and qualifications, certification application and renewals; and fees.

## *Why should I become a certified operator?*

Wastewater and drinking water system operators are front-line environmental professionals who ensure the quality of Kentucky's water resources and protect the public's health. Only operators that are certified by the Kentucky Certification and Licensing Branch can be in responsible charge of a wastewater or drinking water system.

Working in the water and wastewater industry can be extremely rewarding as you will be providing a critical service to your community. It just might be one of the most important positions in the world since no one can live without water. It takes knowledgeable, conscientious people to deliver clean, potable water and to ensure that wastewater is treated and returned as clean water to the environment.

## *Certification Process*

Certification is obtained by meeting minimum education and experience requirements, submitting the appropriate forms and fee and by passing the certification examination with at least a 70%. Regulations pertaining to the certification of drinking water and wastewater system operators are located in 401 KAR Chapter 11.

## *System Classifications*

The following requirements apply to collection systems with greater than 5,000 linear feet of sewer line.

| | |
|---|---|
| Class I | Collection system that transports wastewater to a treatment plant with a design capacity of ≤50,000 GPD shall be under the primary responsibility of a certified operator holding an active Class I, II, III or IV collection certificate. |
| Class II | Collection system that transports wastewater to a treatment plant with a design capacity of 50,001 to ≤ 2,000,000 GPD shall be under the primary responsibility of a certified operator holding an active Class II, III or IV collection certificate. |
| Class III | Collection system that transports wastewater to a treatment plant with a design capacity of 2,000,001 to ≤ 7,500,000 GPD shall be under the primary responsibility of a certified operator holding an active Class III or IV collection certificate. |
| Class IV | Collection system that transports wastewater to a treatment plant with a design capacity of ≥ 7,500,001 GPD shall be under the primary responsibility of a certified operator holding an active Class IV collection certificate. |

| The following applies for collection systems under a KIMOP Permit | |
|---|---|
| Collection systems that transport wastewater containing domestic sewage to a treatment plant owned by another person shall use population-served for determination of appropriate collection system certification. | |
| Class I | Collection system with a population served of ≤ 1,500 individuals shall be operated by a certified operator holding an active Class I, II, III or IV collection certificate. |
| Class II | Collection system with a population served of 1,501 to ≤ 15,000 individuals shall be operated by a certified operator holding an active Class II, III or IV collection certificate. |
| Class III | Collection system with a population served of 15,001 to ≤ 50,000 individuals shall be operated by a certified operator holding an active Class III or IV collection certificate. |
| Class IV | Collection system with a population served of ≥ 50,001 individuals shall be operated by a certified operator holding an active Class IV collection certificate. |

## *Regulatory Education and Experience*

| | |
|---|---|
| Class I | High School Diploma or GED and One (1) year of acceptable operation of a wastewater collection system shall be required. |
| Class II | High School Diploma or GED and Two (2) years of acceptable operation of a wastewater collection system shall be required. |
| Class III | High School Diploma or GED and Three (3) years of acceptable operation of a wastewater collection system with one (1) year of that experience in a wastewater collection system that transports wastewater to a treatment plant with a design capacity greater than 50,000 gallons per day shall be required. |
| Class IV | Baccalaureate degree in engineering, science or equivalent is required and at least five (5) years of acceptable operation of a wastewater collection system shall be required. Three (3) years of the required experience shall be in a wastewater collection system that transports wastewater to a treatment plant with a design capacity greater than two (2) million gallons per day and at least two (2) years of primary responsibility in a wastewater collection system that transports wastewater to a treatment plant with a design capacity greater than two (2) million gallons per day shall be required. |

## *Operators in Training (OIT) Certifications*

Operators in training certifications are available for each certification type. An individual can apply for an OIT license that is one level higher and of the same type as the certification that the individual currently holds. An individual may also apply for an entry level OIT certification. OITs must pass the appropriate operator certification exam and work under the responsible charge of a mentor. To apply for the exam, individuals must submit the following to the Certification and Licensing Branch:

- Education and Experience Documentation Form;
- Registration Form for Exams and Training;
- The appropriate fee; and
- A letter from the applicant's mentor. The letter from the mentor must include:
  - A commitment to oversee the applicant's work after the applicant becomes an OIT;
  - A commitment to mentor the applicant as long as the applicant is under the mentor's direct responsible charge;
  - Verification that the mentor is not currently mentoring any other OITs; and
  - Confirmation that the mentor holds a certification license that is equal to or greater than the certification level required to serve in primary responsibility of the facility where the mentor and prospective OIT works.

A Wastewater Treatment Class I-OIT who operates a wastewater treatment plant owned by the operator that serves only one residence may have primary responsibility for that plant. All other OITs may not be in responsible charge of a facility unless they hold an additional certification license that does not have an OIT designation.

## *Certification Renewal or Maintenance*

Wastewater treatment and collection system certifications expire on June 30 of odd-numbered years. Certifications shall remain valid until the expiration date, unless suspended, revoked or replaced by a higher classification certificate before that date. Certificates issued between Jan. 1 and June 30 of a renewal year will be issued to include the next two-year renewal period. Failure to renew before July 1 of the renewal year will result in the expiration of certification and a late fee assessment. The certificate shall terminate if not renewed on or before December 31 of the year the certification expired. Certified operators with expired certificates shall not be in responsible charge of a drinking water or wastewater facility.

Certified operators (excluding OIT certificates) may renew their license(s) electronically through the cabinet Web site using the E-Search link or by submitting the Application for Certification Renewal and the appropriate fee to the Division of Compliance Assistance, Certification and Licensing Branch, 300 Fair Oaks Lane, Frankfort, KY 40601.

Certified operators who are designated an Operator in Training may renew a certification without examination if the operator has:

- Satisfied the continuing education requirements;
- Earned the required years of operational experience;
- Submitted an Education and Experience Documentation form verifying his or her experience;
- Submitted a letter of recommendation from a mentor; and
- Submitted a completed Application for Certification Renewal form and the renewal fee to the cabinet or has renewed the certification electronically on the cabinet's Web site.

Wastewater treatment and collection certified operators training hours shall expire two years from the date earned. Certified operators holding both a treatment and a collection certificate shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for both certificates.

- ***Reminder -- Continuing education hours earned prior to certification shall not count toward certificate renewal.***

## *Operator Ethics – Standards of Professional Conduct for Certified Operators*

In order to safeguard the life, health, and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, standards of professional conduct apply to persons certified in accordance with 401 KAR Chapter 11. These standards state:

(a) A certified operator shall, during the performance of operational duties, protect the safety, health, and welfare of the public and the environment;
(b) A certified operator shall use reasonable care and judgment in the performance of operational duties;
(c) If a certified operator's judgment is overruled by an employer under circumstances in which the safety, health, and welfare of the public or the environment are endangered, the certified operator shall inform the employer of the possible consequences;
(d) A certified operator shall be objective, truthful, and complete in applications, reports, statements, and testimony provided to the cabinet; and
(e) A certified operator shall ensure the integrity of the samples that the operator collects, prepares, or analyzes so that results shall be a true representation of water quality.

The full set of standards is located in 401 KAR 11:020.

Certified operators who violate the standards in 401 KAR 11:020 are subject to disciplinary actions which include but are not limited to:

(a) Probation of the operator's certification for a specified period of time, not to exceed one (1) year;
(b) Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;
(c) Revocation of the operator's certification;
(d) Civil or criminal penalties; or
(e) A combination of the disciplinary actions listed above.

Disciplinary actions are outlined in 401 KAR 11:050, Section 4.

*All regulations related to the certification of wastewater and drinking water operators are located in 401 KAR Chapter 11. A copy of the regulations is located in this manual and it is recommended that you become familiar with the regulations that govern your profession.*

## The Certified Operator Review Questions

1. __________ is personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the drinking water treatment plant or distribution system is operated in accordance with accepted practices and with KRS Chapters 223 and 224 and 401 KAR Chapters 8 and 11.

2. A certified operator shall be _______, ___________, and ________ in applications, reports, statements, and testimony provided to the cabinet.

3. A certified operator shall ensure the ________ of the samples that the operator ______, ______, or ________ so that results shall be a true representation of water quality.

4. While on duty, a certified operator shall carry ____________________the showing the operator's current certification status.

5. If information related to the operator's employment or mailing address changes from that provided in the application for certification, the certified operator shall provide written notification to the cabinet within ___________.

6. ________ years of collection system experience shall be considered equivalent to one year of treatment experience. This substitution shall not account for more than ________ percent of the experience required.

7. One year of treatment experience shall be considered equivalent to _______ year of collection system experience.

8. A certified operator shall be subject to _____________ if the cabinet, in consultation with the board, determines that the certified operator has not satisfactorily performed the operator's duties in accordance with 401 KAR 11:020.

9. _______, _________, _________, _________, and _________, are the five types of discipline that an operator can receive if the board decides that disciplinary action is necessary.

## Answers to the Certified Operator Review Questions

1. direct responsible charge
2. objective, truthful, and complete
3. integrity, collects, prepares, analyzes
4. cabinet-issued wallet card
5. 30 days
6. 4, 50
7. 1
8. disciplinary action
9. probation, suspension, revocation, civil and criminal penalties, or a combination of the four

# Chapter 2: MAPPING

## Chapter 2 Objectives

1. Explain the importance of original, as built maps, updated and accurate maps.
2. Understand the importance of assigning identification numbers to the various components of collection systems.
3. Identify the mapping parameters of the collection system.
4. Explain Geographical Information Systems (GIS), its importance, and what objects are represented
5. Calculate distances on a map.

## *Mapping*

Always keep original maps so that as built plans are available. Update maps whenever new construction or rehabilitation is done in a particular area. Having accurate maps can save time and money when crucial decisions and actions have to be made and executed. The entire collection system should be mapped and all manholes and pipelines should be assigned identification numbers. Mapping should be done by hard copy and as computer data in a Geographic Information System (GIS) format.

Below are examples of the type of information that should be included in the mapping of the collection system

***Map of the Collection System:***

The map must show the locations of all lines and pump stations. Mapping parameters should include the following:

- a) Line size
- b) Slope (if available)
- c) Pipe material
- d) Approximate age
- e) Flow direction
- f) Manhole information
  - i) identification
  - ii) age
  - iii) materials
  - iv) type (number of inlets, etc.)
- g) Pump station information
  - i) identification
  - ii) location
  - iii) pump type (model) and capacity
  - iv) number of pumps at station
  - v) back-up power source
- h) Location of all tributary collection system connections
- i) Number of active service taps

## GPS Is A Good Tool To Use To Map The System

GIS is geographical and geospatial information about places on the earth's surface. It gives knowledge of what is where and when it was put there. There are three S's associated with GIS.

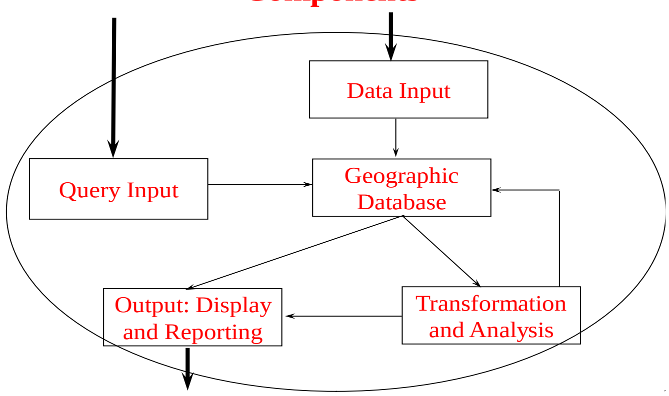
Systems- the technology
Science – concepts and theory
Studies – the societal context

Software systems with the capability for input, storage, manipulation and output of geographic data allow real world locations to be digitally represented and stored so that it can be presented in a map form. This data can also be manipulated to address specific problems. GIS systems usually contain two types of data, spatial and attribute data. Spatial data tells the where, the specific location and is stored in a shape file. Attribute data tells what, how much and when. It gives specific characteristics at that location. This data can be natural or human created and is usually stored as table data. These data types are usually joined in order to display it for analytical purposes.


**Picture 2-1 GIS Techniques and Technology**

Once the data is input it can be queried. This allows you to look for specific details or attributes. The data is stored in a database, and can be used for analysis, comparison, reporting, etc. Utilities have started taking advantage of this technology. The data collection provides a way to convert paper maps, AutoCAD files new data collected in the field and all of the information that employees have stored in their heads that has never been written down. Analyzing this data allows viewers to visualize, interpret, question and understand relationships patterns and trends in the data. Once the system is mapped, any attributes, parameters, infrastructure, appurtenances and other valuable things in the system can be added and most any vital information associated with it. It can be evaluated in the form of maps, reports and charts. This data can also be seen and share with operators, administrators, billing personnel as well as others that the information may benefit. This type of information can also be shared with public safety, planning and street departments. GIS also contains tools that can help with budgeting, planning, and managing your collection and distribution system.

**Picture 2-2 GIS System Architecture and Components**




**Manhole distance, actual and on a map**

A new manhole has been installed 500 ft from an existing manhole. On a map the scale is 1 inch equals 50 ft., what is the distance between the manholes on the map?

Given the scale 1 inch equals 50 ft, divide the actual distance by the representative distance from the scale.

$$\text{Distance (inches)} = \frac{500\text{ft}}{50\text{ ft}} = 10 \text{ inches}$$

The distance between two manholes on a map is ¾ of an inch. The scale for the map is 1 inch equals 200 ft. What is the actual distance between the manholes?

Distance (ft) = ¾ x 200 ft = 150 ft

## Mapping Review Questions

1. The entire __________ should be mapped and all manholes and pipelines should be assigned identification numbers. Mapping should be done by ______ and as ______ data.

2. A new manhole has been installed 650 ft from an existing manhole. On a map the scale is 1 inch equals 25 ft., what is the distance between the manholes on the map?

## Mapping Review Answers

1. Collection system, hard copy, computer
2. 26 inches

# Chapter 3: BIOLOGY

## Chapter 3 Objectives

1. Identify and describe Total Solids and Total Suspended Solids and their components.
2. Know the characteristics of domestic wastewater.
3. Understand the effects of high Total Suspended Solids.
4. Understand what Biological Oxygen Demand (BOD) is and its effect on the treatment process.
5. Understand how Nitrates and Phosphates affect BOD.
6. Identify sources of Dissolved Oxygen creation.
7. Define and understand the role of aerobic bacteria, anaerobic bacteria, and facultative bacteria.
8. Understand diffusion and how it relates to the wastewater treatment process.
9. Identify standards used in population equivalent estimates.
10. Identify ideal nutrient requirements for carbon, nitrogen, phosphorus, and their relationship to wastewater treatment.
11. Estimate the population served by a municipality or system.

## *Total Suspended Solids and Total Solids*

The term total solids refers to matter suspended or dissolved in water or wastewater, and is related to both specific conductance and turbidity. Total Solids includes both total suspended solids, the portion of total solids retained by a filter and total dissolved solids, the portion that passes through a filter.

**Table 3-1 Solids Concentration in wastewater**

| Type of Solids | % composition in wastewater | Concentration |
|---|---|---|
| Total Solids | .1% | 700-1000 mg/L |
| Total Dissolved Solids | | 400-700 mg/L |
| Total Suspended Solids | | 180-300 mg/L |

A certain level of these minerals in water is necessary for aquatic life. Changes in total dissolved solids concentrations can be harmful because the density of the water determines the flow of water into and out of an organism's cells.

Total suspended solids are the solids captured on the special filter when performing the TSS test, as specified by Standard Methods for the Examination of Water and Wastewater. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

**Picture 3-1. Suspended solids on left…..settled solids on the right**

Suspended solids are capable of settling out of the water column onto the bottom when velocities are low. They include silt, clay, plankton, organic wastes, and inorganic precipitates such as those from acid mine drainage.

Approximately 70 percent of the suspended solids and 40 percent of the dissolved solids are organic in nature. This leaves 30 percent of the suspended and 60 percent of the dissolved solids that are inorganic. These solids are made up of minerals, such as carbonate, sulfate, phosphate, nitrate, calcium, magnesium, sodium, grit, and others. Some of these minerals may be removed through chemical precipitation.

High TSS causes less dissolved oxygen to be released into the water. If light is completely blocked from bottom dwelling plants, the plants will stop producing oxygen and will die. Low dissolved oxygen can lead to fish kills. High TSS can also cause an increase in surface water temperature, because the suspended particles absorb heat from sunlight. This can cause dissolved oxygen levels to fall even further (because warmer waters can hold less DO), and can harm aquatic life in many other ways, as discussed in the temperature section.

High TSS in a water body can often mean higher concentrations of bacteria, nutrients, pesticides, and metals in the water. These pollutants may attach to sediment particles. High TSS can cause problems because the solids may clog or scour pipes and machinery. Treatment Some types of wastewaters, such as noncontact cooling water, are naturally low in suspended solids and do not require treatment.

Suspended solids interfere with effective drinking water treatment. High sediment loads interfere with coagulation, filtration, and disinfection. More chlorine is required to effectively disinfect turbid water. They also cause problems for industrial users. Suspended sediments also interfere with recreational use and aesthetic enjoyment of water. A positive effect of the presence of suspended solids in water is that toxic chemicals such as pesticides and metals tend to adsorb to them or become complexed with them which make the toxic less available to be absorbed by living organisms.

### *BOD*

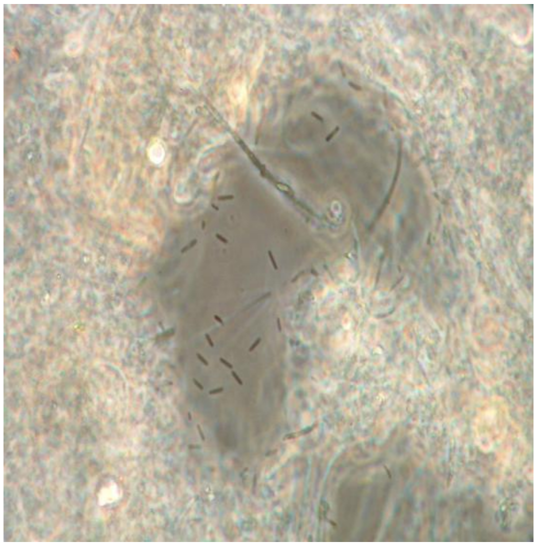
Biochemical oxygen demand or BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.

It is not a precise quantitative test, although it is widely used as an indication of the quality of water. The biochemical oxygen demand is a measure of the organic strength of wastewater. In domestic wastewater, it has a range of 160 – 280 mg/L. It is also a measure of the quantity of dissolved organic pollutants that can be removed in biological oxidation by the bacteria. It is expressed in mg/l of oxygen. Some of the $BOD_5$ (organic material) that is degraded is utilized by the bacteria in the production of new bacteria cells. The $BOD_5$ test only measures the $BOD_5$ (organic material) that is oxidized in bacterial respiration, so it does not measure the carbon used for cell growth.

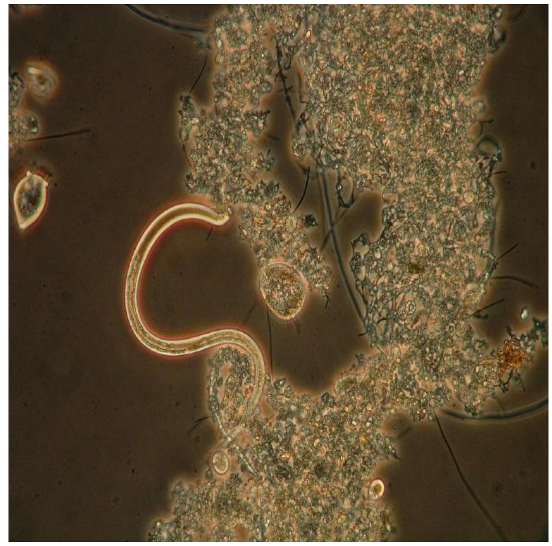
BOD can be used as a gauge of the effectiveness of wastewater treatment plants. It is listed as a conventional pollutant in the U.S. Clean Water Act.

- ✓ Biochemical oxygen demand is a measure of the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in the oxidation of organic matter.
- ✓ Natural sources of organic matter include plant decay and leaf fall. However, plant growth and decay may be unnaturally accelerated when nutrients and sunlight are overly abundant due to human influence.
- ✓ Urban runoff carries pet wastes from streets and sidewalks; nutrients from lawn fertilizers; leaves, grass clippings, and paper from residential areas, which increase oxygen demand.
- ✓ Oxygen consumed in the decomposition process robs other aquatic organisms of the oxygen they need to live. Organisms that are more tolerant of lower dissolved oxygen levels may replace a diversity of more sensitive organisms.

BOD is the most commonly used parameter for determining the oxygen demand on the receiving water of a municipal or industrial discharge. BOD can also be used to evaluate the efficiency of treatment processes, and is an indirect measure of biodegradable organic compounds in water.



**Picture 3-2 Bacteria in wastewater**



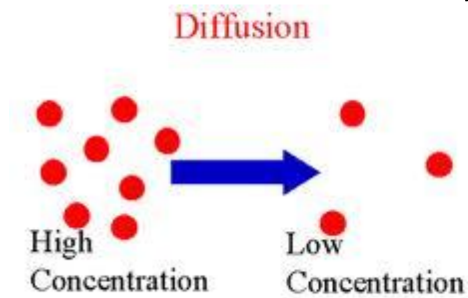
**Picture 3-3 Bacteria in wastewater**

Aerobic (oxygen requiring) bacteria and fungi use oxygen as they break down the components of the leaf into simpler, more stable end products such as carbon dioxide, water, phosphate and nitrate. As oxygen is consumed by the organisms, the level of dissolved oxygen in the stream begins to decrease. Water can hold only a limited supply of dissolved oxygen and it comes from only two sources, diffusion from the atmosphere at the air/water interface, and as a byproduct of photosynthesis. As the break down organic matter, rotten egg -smelling hydrogen sulfide can be produced.

### *Aerobic Bacteria*

Water, the home of most bacteria, contains oxygen in two forms. The first form, free oxygen, is the most readily available form. Free oxygen is basically the same as dissolved oxygen—oxygen from the atmosphere that has become dissolved in water. Aerobic bacteria require free oxygen in order to survive. Bacteria may be aerobic, anaerobic or facultative. Aerobic bacteria require oxygen for life support whereas anaerobes can sustain life without oxygen. Facultative bacteria have the capability of living either in the presence or in the absent of oxygen. Aerobic bacteria live and multiply in the presence of free oxygen. Facultative bacteria always achieve an aerobic state when oxygen is present. While the name "aerobic" implies breathing air, dissolved oxygen is the primary source of energy for aerobic bacteria. The metabolism of aerobes is much higher than for anaerobes. The by-products of aerobic bacteria are carbon dioxide and water. If there is very little oxygen in water, then the water is very attractive to oxygen. But when water has a high concentration of DO, then the water is saturated, meaning that the water contains as much oxygen as it can hold at that temperature.

Saturated water is not very attractive to oxygen. The process of oxygen moving from an area with a high oxygen concentration to an area with a low oxygen concentration is known as diffusion. Water temperature is very important in determining the amount of oxygen that will become dissolved in water. Cold water is able to hold more oxygen than warm water.




**Picture 3-2. Diffusion…..oxygen molecules moving form high to low concentration**

## *Anaerobic Bacteria*

The oxygen can be ripped out of the water molecule by anaerobic bacteria, but it takes much more energy to break apart food and water in search of oxygen than it does to simply use free oxygen. Anaerobic bacteria are the major cause of hydrogen sulfide production in the collection system. Through anaerobic respiration, sulfur-reducing bacteria produce Hydrogen sulfide gas (H2S), which is an inhalation hazard and causes corrosion of collection system equipment. Anaerobic bacteria release hydrogen sulfide as well as methane gas, both of which can create hazardous conditions. Even as the anaerobic action begins in the coll ection lines of a sewer system, deadly hydrogen sulfide or explosive methane gas can accumulate and be life threatening. The bacteria work in the sludge layer, eating as much of the edible portions of the waste as possible. (How do bacteria clean wastewater?) Anaerobic bacteria live and reproduce in the absence of free oxygen, and produce carbon dioxide and methane. They utilize compounds such as sulfates and nitrates for energy and their metabolism is substantially reduced. In order to remove a given amount of organic material in an anaerobic treatment system, the organic material must be exposed to a significantly higher quantity of bacteria and/or detained for a much longer period of time.

## *Facultative Bacteria*

Most of the bacteria that absorb the organic material in a wastewater treatment system are facultative in nature. This means they are adaptable to survive and multiply in either anaerobic or aerobic conditions. The nature of individual bacteria is dependent upon the environment in which they live. Usually, facultative bacteria will be anaerobic unless there is some type of mechanical or biochemical process used to add oxygen to the wastewater. When bacteria are in the process of being transferred from one environment to the other, the metamorphosis from anaerobic to aerobic state (and vice versa) takes place within a couple of hours. The third type of microorganisms, those which are facultative, have properties of both aerobic and anaerobic organisms. They can live with or without free oxygen. When the oxygen content of water is high, facultative bacteria consume food very quickly using the free oxygen in the water. In low oxygen concentrations, facultative bacteria are still able to consume organic material, although they do so much more slowly.

## *Population Equivalent Estimates*

Population equivalents that are used to calculate hydraulic and organic loadings for domestic wastewater treatment if actual operating information is not available are as follows:

**$BOD_5$ = 0.17 lbs./capita/day**
**TSS = 0.20 lbs./capita/day**
**Phosphorus = 0.0048 lbs/capita/day**
**Flow = 100 gallons/capita/day**

Estimate the population served if a treatment plant is processing .885 MGD.

The number of people can be determined by dividing the flow by the population equivalent. Change MGD into gpd.

$$\text{\# of people served} = \frac{885{,}000 \text{ gal/day}}{100 \text{ gal/day/person}} = 8{,}850 \text{ people}$$

Ideal nutrient requirements for biological stabilization of organic matter result in the following ratio:

**Carbon/Nitrogen/Phosphorus = C/N/P = 100/5/1**

Another way of viewing this nutrient balance is to consider the $BOD_5$ as the carbon source so that for every 100 ppm of $BOD_5$ removed, there would have to be 5 mg/L of nitrogen and 1 mg/L of phosphorus available for cell synthesis. The units of measure, if the same, do not matter because it is the ratio that is important.

## Review Questions for Biology

1. Total Solids includes both __________, the portion of total solids retained by a filter and ___________, the portion that passes through a filter.

2. The range of total suspended solids should be from _______________.

3. High TSS can cause problems because the solids may ___________.

4. ___________ is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.

5. BOD has a range of ___________ .

6. Three common types of bacteria are_____, ________, and _______.

7. _______ ________ are used to calculate hydraulic and organic loadings for domestic wastewater treatment.

8. What are the population equivalents for the following:

   $BOD_5$ = _____ TSS = ______ Phosphorus =________ Flow = __________

9. 100/5/1 is the nutrient balance for _________ /_________/___________.

10. When anaerobic bacteria break down organic matter, ________can be produced.

## Answers to Regulations Review Questions

1. total suspended solids, total dissolved solids
2. 180-300 mg/L
3. clog or scour pipes and machinery
4. Biological oxygen demand
5. 160-280 mg/L
6. aerobic, anaerobic, and facultative
7. population equivalents
8. .17 lbs./capita/day, .20 lbs./capita/day, .0048 lbs/capita/day, 100gallons/capita/day
9. Carbon, nitrogen, phosphorus
10. Hydrogen sulfide

# Chapter 4: TYPES OF COLLECTION SYSTEMS

## Chapter 4 Objectives

1. Understand what a sewer is, the types of sewers and their functions.
2. Identify and understand the advantages, disadvantages, and design criteria of gravity sewer systems
3. Know manhole spacing requirements and installation procedures.
4. Know the purpose of backflow preventers, air jumpers, junction structures, and inverted siphons.
5. Know the importance of sewer ordinance enforcement, timely sewer inspection and cleaning techniques, preventive maintenance, and repairs.
6. Know and recognize problems and factors caused beyond the control of the maintenance crew.
7. Know and identify advantages, disadvantages, operation and maintenance principles, and design criteria of pressure sewer systems.
8. Know and identify safety precautions when servicing pressure sewer systems.
9. Define, identify and understand the advantages and disadvantages of vacuum sewer systems.
10. Identify three major items to consider when designing and selecting a vacuum sewer system.
11. Calculate
    a. Area
    b. Average daily flows.
    c. Percent grades.
    d. Flows in a tee connection.
    e. The height of wastewater standing in a manhole.
    f. Velocity and flow rates.
    g. Detention time.
    h. Time needed to flush lines clear of clogs

## *Sewers*

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. In some areas, sanitary sewers are separate sewer systems specifically for the carrying of domestic and industrial wastewater, and are operated separately and independently of storm drains, which carry the runoff of rain and other water which wash into city streets.

Sewers are usually pipelines that begin with connecting pipes from buildings to one or more levels of larger underground trunk mains, which transport the sewage to sewage treatment facilities. Vertical pipes, called manholes, connect the mains to the surface. The manholes are used for access to the sewer pipes for inspection and maintenance, and as a means to vent sewer gases. They also facilitate vertical and horizontal angles in otherwise straight pipelines.

## *Gravity systems*

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 storm water; 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 storm water.

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.

**Picture 4-1 collection system installation**

## *Types*

1) Building Sewers are what connect a building's internal wastewater collection system to the municipal sewer system. They can connect to a lateral, main or trunk sewer line.
2) Lateral and Branch Sewers are the upper ends of the municipal sewer system. Laterals dead-end at their upstream end with branch sewers collecting the wastewater from several lateral sewer lines.
3) Main Sewers are collectors for numerous lateral and branch sewers from an area of several hundred acres or a specific neighborhood or housing development. They convey the wastewater to larger trunk sewer lines, to lift stations or to a neighborhood package wastewater treatment plant.
4) Trunk Sewers serve as the main arteries of the wastewater collection system. They collect and convey the wastewater from numerous main sewer lines either to a wastewater treatment plant or to a interceptor sewer.
5) Interceptor Sewers receive the wastewater numerous from trunk sewers and convey it to a wastewater treatment plant. These are the largest diameter lines in the sewer system and the furthest downstream in the system.

## *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.

### *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 3-1 provides a list of design flow for various development types.

If it is assumed that the average velocity of the wastewater in the collection system is 2.89 feet per second. How long does it take the wastewater in hours to reach the treatment plant if the maximum distance from the treatment plant to the farthest lateral is 12 miles?

First calculate the number of feet in 12 miles. Then divide that distance by the velocity to determine the distance.

# of feet in 12 miles 12 x 5,280 ft = 63,360 ft

$$\frac{63{,}360 \text{ ft}}{2.89 \text{ ft/sec}} = 21{,}923.88 \text{ sec}$$

Now convert sec into hrs $\frac{21{,}923.88\text{sec}}{3{,}600 \text{ sec/hr}} = 6.09 \text{ hrs}$

**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 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.

**Calculating areas**

What is the area of the top of a tank that is 55 ft long 70 ft wide and 60 ft deep?

The tank is a rectangle. So the area will be length * width.
Area = 55 ft * 70 ft = 3,850 $ft^2$

What is the area of the face in square feet of a 30 inch diameter pipe?

A pipe face is a circle. So the area would be .785 x D x D.
Diameter = $\frac{30 \text{ inch}}{12 \text{ inch}}$ = 2.5 ft

Area = .785 x 2.5 ft x 2.5 ft = 4.9 ft

**TABLE 4-1 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** | |
| General | 10,000 / acre |
| warehouse | 600 / acre |
| School site (general) | 16 / student |

## *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 1 foot/second. During peak dry weather conditions the sewer lines must attain a velocity greater than 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 10 feet/second should be avoided because they may cause erosion and damage to sewers and manholes.

**Calculating Flow in a tee connection**

The flow entering the leg of a tee is 25 gal/min. If the flow through one branch is 17 gal/min, what is the flow through the other branch?

The flow through the leg is equal to the sum of the branches. Subtract the branch from the leg to solve for the missing branch flow.

Flow in $2^{nd}$ branch = 25 gal/min – 17 gal/min = 8 gal/min

**Calculating Average daily Flow**

What is the daily average flow for a lift station in MGD given the following data?

| Date | Time | Meter reading |
|---|---|---|
| 4/12/2011 | 8:00 AM | 3,567,657 gallons |
| 4/19/2011 | 8:00 AM | 6,763,269 gallons |

You will take total flow and divide it by 7 since the time period is 7 days.

$$\frac{6{,}763{,}269 - 3{,}567{,}657}{7} = 456{,}516.00 \text{ gallons} = .46 \text{ MGD}$$

## *Slope*

Sewer pipes must be adequately sloped to reduce solids deposition and production of hydrogen sulfide and methane. Table 4-2 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.

**TABLE 4-2 MIMIMUM SLOPES[1] FOR VARIOUS PIPE LENGTHS**

| Diameter | Pipe | Legnth |
|---|---|---|
| *Inches* | *Up to 5 ft* | *6 ft or more* |
| 8 | 0.47 | 0.42 |
| 10 | 0.34 | 0.31 |
| 12 | 0.26 | 0.24 |
| 14 | 0.23 | 0.22 |
| 24 | 0.08 | 0.088 |
| 30 | 0.07 | 0.07 |

**1=slopes in ft per 100 ft**

## Calculating percent grade

The invert elevation for a sewer line at adjacent manholes is 1400 feet apart. Elevation 1 is 456 feet and elevation 2 is 450 feet?

The percent grade is the rise in feet over the run in feet times 100. First subtract to find the rise.

Rise in feet = 456-450 ft = 6 ft

$$\% \text{ grade} = \frac{6 \text{ feet}}{1400 \text{ feet}} \times 100 = .43\ \%$$

The grade for a sewer pipe is .5% for a length of 8,000 ft and then changes to .3% for an additional 4,000 feet, how many feet lower would the downstream end of the pipe be than the upstream end?

Given the percent grade and the run, solve for the rise. Multiply the grade by the distance for each section and then add them together.

.005 x 8,000 = 40 ft          .003 x 4000 ft = 12 ft

40 ft + 12 ft = 52 ft

## *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 3 to 6.5 feet below ground 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 are devices that facilitate and control the flow of wastewater and allow access for maintenance activities. They 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 24 inches in diameter or less are typically 4 feet in diameter. Larger sewers require larger manhole bases, but the 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 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 400 feet on all sewers 15 inches or less, and not exceeding 500 feet on all sewers larger than15 inches in diameter.

Manholes are installed in the following places:

- Lateral
- Main
- Trunk
- Interceptor

**Picture 4-2 at left Brick manhole**
**Picture 4-3 at right Concrete manhole**

Manholes are used to place persons, equipment and materials in these sewers for inspection, maintenance and solids removal from cleaning operations. Manholes, on straight runs, should be spaced between 300 and 600 ft. Manholes are also placed at changes in:

- Slope
- Elevation
- Direction
- Pipe size
- Junctions

## Calculate the height of water standing in a manhole

What is the height of wastewater in a manhole if there is 350 gallons in it? The manhole has a radius of 4 ft.

The manhole is a cylinder. To find out the height of the water solve for the heighth in the volume of a cylinder equation. Convert the radius into the diameter.

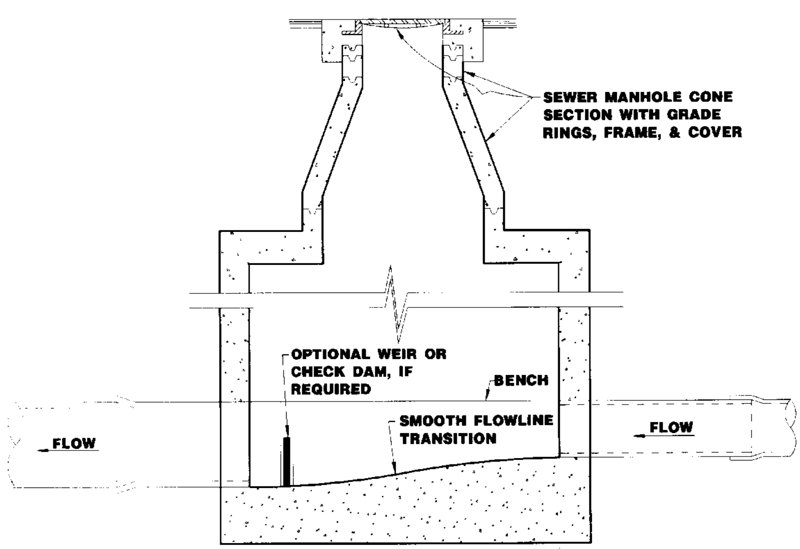
$$\text{Height} = \frac{350 \text{ gal}}{7.48} = 46.79 \text{ ft}^3 \quad \frac{\text{volume}}{.785 \times D \times D} = \frac{46.79 \text{ ft}^3}{.785 \times 8 \text{ ft} \times 8 \text{ ft}} \quad \frac{46.79 \text{ ft}^3}{50.24 \text{ ft}^2} = .93 \text{ ft}$$

Drop manholes should be used when the difference in elevation between the influent and the effluent of the manhole cannot handle the drop into the barrel without creating excessive turbulence which reduces the production of $H_2S$

Back flow preventers are used to stop the accidental backflow or reverse flow of wastewater into buildings. They are used when the lowest overflow point in the buildings plumbing is above the rim elevation line of the manhole in the lateral or street main immediately upstream of the buildings sewer connection. There are two types, the mechanical check valves and the atmospheric overflow device with floatable ball seal.

Junction structures are used to join large diameter sewers without a manhole. They usually contain a structure that "breaks" the turbulence thus reducing the possibility of $H_2S$ production.

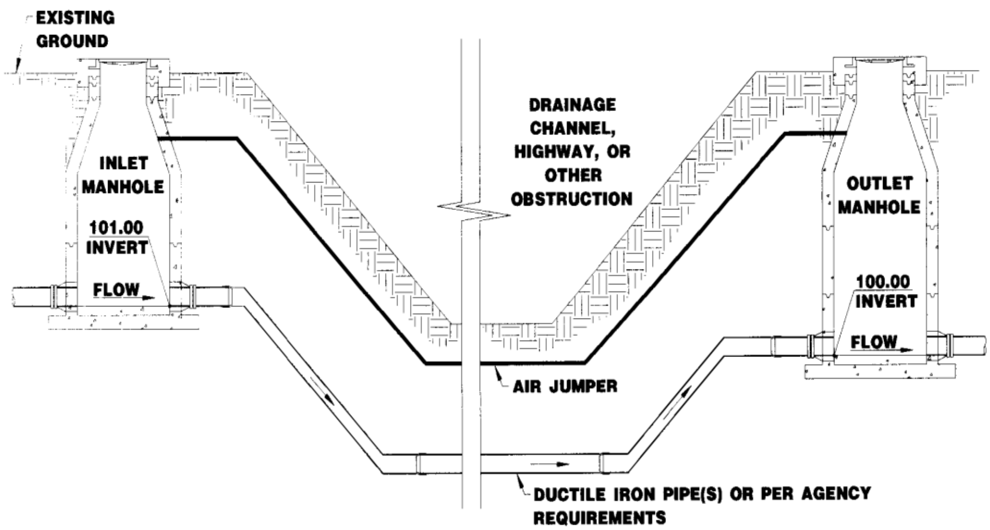
**Figure 4-4 Junction structure**



<u>Inverted siphons</u> are sewer lines installed lower than the normal gradient to pass under obstructions such as streams and roadways. Wastewater is “pushed” thru the siphon by the pressure because the upstream sewer, at a junction box, is higher than the downstream sewer. Siphons need more maintenance due to slowing of flow and solids build-up.

<u>Air Jumpers</u> are used to equalize air pressure on inverted siphons.

**Picture 4-5 Air Jumper**




*NOTE:* Air jumpers are sometimes constructed as part of an inverted siphon. Since the siphon is completely filled with wastewater, a blockage in the flow of air in the sewer line occurs without an air jumper. This blockage may cause a continuous release of toxic, odorous, and corrosive hydrogen sulfide at the upstream siphon manhole. Installation of air jumpers prevents this from happening by providing the downstream flow of air that usually occurs above the wastewater in a partially filled sewer line.

## *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.

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:

1. Explosions or severe corrosion due to discharge of uncontrolled industrial wastes.
2. Odors.
3. Corrosion of sewer lines and manholes due to generation of hydrogen sulfide gas.
4. Collapse of the sewer due to overburden or corrosion.
5. Poor construction, workmanship, or earth shifts may cause pipes to break or joints to open up. Excessive infiltration/exfiltration may occur.
6. 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.
7. Excessive settling of solids in the manhole and sewer line may lead to obstruction, blockage, or generation of undesired gases.
8. 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.
9. Faulty, loose, or improperly fit manhole covers can be a source of noise as well as inflow.
10. Ground shifting may cause cracks in manhole walls or pipe joints at the manhole, which become a source of infiltration or exfiltration.
11. Debris (i.e., rags, sand, gravel, sticks, etc.) may collect in the manhole and block the lines.
12. 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 4-3 UNIT COSTS FOR SANITARY SEWER**

| ITEM | UNIT COST 2011$ |
|---|---|
| PVC pipe (not including excavation) | |
| 8” diameter | $5.94 |
| 10” diameter | $9.20 |
| 15” Diameter | $18.65 |
| Brick Manhole 4 ft ID 4 ft deep | $1,117.93 |
| Concert Cast in place 4 ft X4 ft X 8 in | $1,016.30 |
| Trenching 4 ft wide 6 ft deep | $28.46 per ft |
| Pipe bedding side slope 0, 1-4 ft wide | $5.34 per ft |
| Fill by dozer no compaction | $1.93 Cu yd. |

## *Pressure Sewer Systems*

### Applicability

Pressure sewer systems are most cost effective where housing density is low, where the terrain has undulations with relatively high relief, and where the system outfall must be at the same or a higher elevation than most or all of the service area. They can also be effective where flat terrain is combined with high ground water or bedrock, making deep cuts and/or multiple lift stations excessively expensive. They can be cost effective even in densely populated areas where difficult construction or right of way conditions exist, or where the terrain will not accommodate gravity sewers.

Since pressure systems do not have the large excess capacity typical of conventional gravity sewers, they must be designed with a balanced approach, keeping future growth and internal hydraulic performance in mind.

### Advantages

- Pressure sewer systems that connect several residences to a “cluster” pump station can be less expensive than conventional gravity systems. On-property facilities represent a major portion of the capital cost of the entire system and are shared in a cluster arrangement.
- This can be an economic advantage since on-property components are not required until a house is constructed and are borne by the homeowner. Low front-end investment makes the present-value cost of the entire system lower than that of conventional gravity sewerage, especially in new development areas where homes are built over many years.

- Because wastewater is pumped under pressure, gravity flow is not necessary and the strict alignment and slope restrictions for conventional gravity sewers can be relaxed. Network layout does not depend on ground contours: pipes can be laid in any location and extensions can be made in the street right-of-way at a relatively small cost without damage to existing structures.

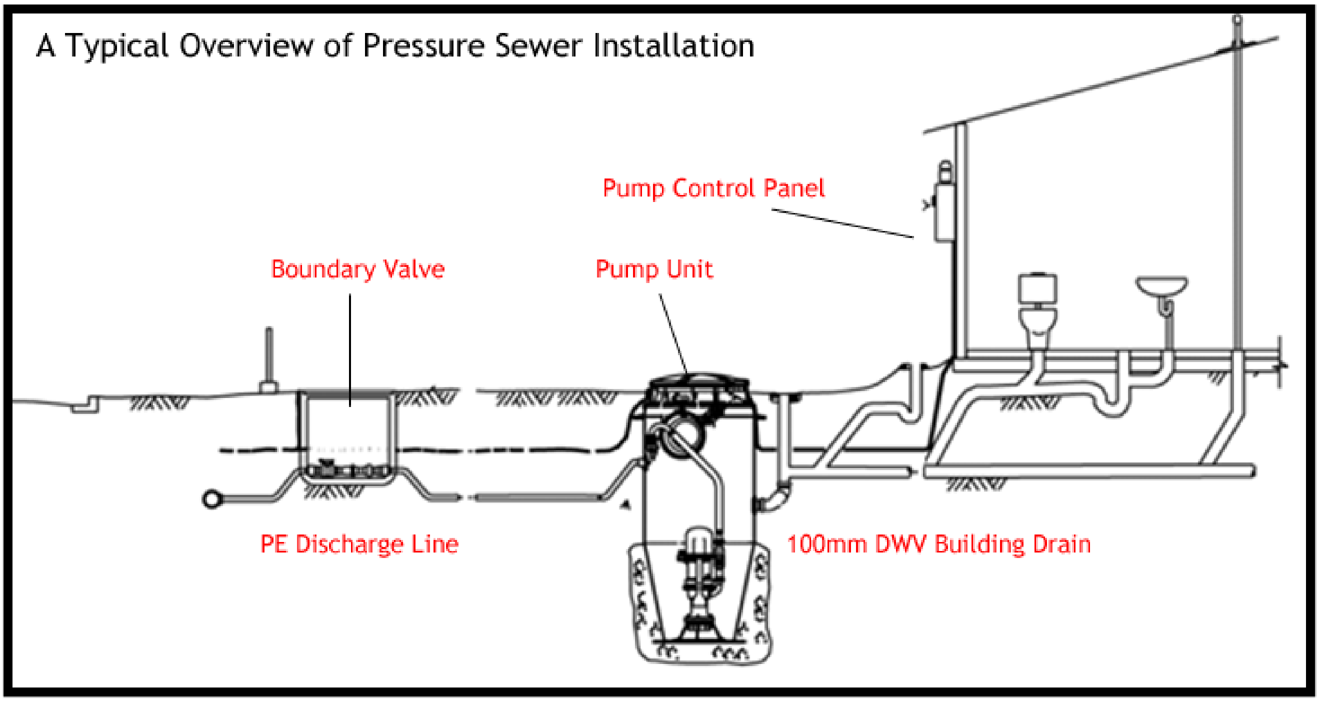
Other advantages of pressure sewers include:

1. Material and trenching costs are significantly lower because pipe size and depth requirements are reduced.
2. Low-cost clean outs and valve assemblies are used rather than manholes and may be spaced further apart than manholes in a conventional system.
3. Infiltration is reduced, resulting in reductions in pipe size.
4. The user pays for the electricity to operate the pump unit. The resulting increase in electric bills is small and may replace municipality or community bills for central pumping eliminated by the pressure system.
5. Final treatment may be substantially reduced in hydraulic and organic loading in septic tank effluent pump systems. Hydraulic loadings are also reduced for grinder pump systems.
6. Because sewage is transported under pressure, more flexibility is allowed in sighting final treatment facilities and may help reduce the length of outfall lines or treatment plant construction costs.

## Disadvantages

- Requires much institutional involvement because the pressure system has many mechanical components throughout the service area.
- The operation and maintenance (O&M) cost for a pressure system is often higher than a conventional gravity system due to the high number of pumps in use. However, lift stations in a conventional gravity sewer can reverse this situation.
- Annual preventive maintenance calls are usually scheduled for grinder pump (GP) components of pressure sewers. Septic tank effluent pump(STEP)systems also require pump-out of septic tanks at two to three year intervals.
- Public education is necessary so the user knows how to deal with emergencies and how to avoid blockages or other maintenance problems.
- The number of pumps that can share the same downstream force main is limited.
- Power outages can result in overflows if standby generators are not available.
- Life cycle replacement costs are expected to be higher because pressure sewers have a lower life expectancy than conventional systems.

- Odors and corrosion are potential problems because the wastewater in the collection sewers is usually septic. Proper ventilation and odor control must be provided in the design and non-corrosive components should be used .
- Air release valves are often vented to soil beds to minimize odor problems and special discharge and treatment designs are required to avoid terminal discharge problems.




**Picture 4-6 Pressure sewer system diagram**

## *Design Criteria*

Many different design flows can be used in pressure systems. When positive displacement grinder pump units are used, the design flow is obtained by multiplying the pump discharge by the maximum number of pumps expected to be operating simultaneously. No allowances for infiltration and inflow are required. No minimum velocity is generally used in design, but grinder pump systems must attain three to five feet per second at least once per day.

Pressure mains generally use 50 mm (2 inch) or larger PVC pipe (SDR 21) and rubber-ring joints or solvent welding to assemble the pipe joints. High-density polyethylene (HDPE) pipe with fused joints is widely used in Canada. Electrical requirements, especially for grinder pump systems, may necessitate rewiring and electrical service upgrading in the service area. Pipes are generally buried to at least the winter frost penetration depth; in far northern sites insulated and heat-traced pipes are generally buried at a minimal depth. grinder pump and septic tank effluent pump pumps are sized to accommodate the hydraulic grade requirements of the system. Discharge points must use drop inlets to minimize odors and corrosion. Air release valves are placed at high points in the sewer and often are vented to soil beds. Both septic tank effluent pump and grinder pump systems can be assumed to be anaerobic and potentially odorous if subjected to turbulence (stripping of gases such as H2S).

## *Calculating Detention Time*

What is the detention time in hours in an interceptor sewer ½ mile long and 24 inches in diameter if the average flow is .14 MGD?

First find the number of feet in ½ mile. Convert diameter from inches to feet. Convert MGD to gpm.

Calculate the detention time from the formula.

2640 ft in ½ mile  d = 2 ft

$$\text{Detention time} = \frac{\text{Volume (gal)}}{\text{Flow (gal/min)}} =$$

$.785 \times 2\text{ft} \times 2\text{ ft} \times 2{,}640 = 8{,}289.6\text{ ft}^3$

$8{,}289.6 \times 7.48 = 62{,}006.21\text{ gal}$

$$\frac{62{,}006.21\text{ gal}}{97.22\text{ gal/min}} = 637.80\text{ min}$$

$$\frac{637.80\text{ min}}{60} = 10.63\text{ hours}$$

## Flushing

A pipe from a subdivision is clogged. The main is 900 feet long and 12-inches in diameter. The pipe delivers an average flow of 50 $ft^3$/min. The collection crew is flushing the main to remove the clog. How long should they flush the line to achieve 3 pipe volumes?

First calculate the volume of the pipe. Divide the volume by the flow rate to determine how long you will have to flush to achieve 3 pipe volumes.

Volume = .785 x 1 ft x 1 ft x 900 ft = 706.50 $ft^3$
Pipe volume x 3 = 2,119.5 $ft^3$

$$\text{Time to flush} = \frac{2{,}119.5\ ft^3}{50\ ft^3/min} = 42.39 \text{ minutes}$$

**Picture 4-7 Line flushing**

## Operation And Maintenance

Routine operation and maintenance requirements for both septic tank effluent pump and grinder pump systems are minimal. Most system maintenance activities involve responding to homeowner service calls usually for electrical control problems or pump blockages. Septic tank effluent pump systems also require pumping every two to three years.

The inherent septic nature of wastewater in pressure sewers requires that system personnel take appropriate safety precautions when performing maintenance to minimize exposure to toxic gases, such as hydrogen sulfide, which may be present in the sewer lines, pump vaults, or septic tanks. Odor problems may develop in pressure sewer systems because of improper house venting. The addition of strong oxidizing agents, such as chlorine or hydrogen peroxide, may be necessary to control odor where venting is not the cause of the problem.

Generally, it is in the best interest of the municipality and the homeowners to have the municipality or sewer utility be responsible for maintaining all system components. General easement agreements are needed to permit access to on-site components, such as septic tanks, septic tank effluent pump units, or grinder pump units on private property.

### *Costs*

Pressure sewers are generally more cost-effective than conventional gravity sewers in rural areas because capital costs for pressure sewers are generally lower than for gravity sewers. While capital cost savings of 90 percent have been achieved, no universal statement of savings is possible because each site and system is unique.

Table 4-4 presents data from evaluations of the costs of pressure sewer mains and appurtenances (essentially the same for grinder pump and septic tank effluent pump), including items specific to each type of pressure sewer. Purchasing pumping stations in volume may reduce costs by up to 50 percent. The linear cost of mains can vary by a factor of two to three, depending on the type of trenching equipment and local costs of high-quality backfill and pipe. The local geology and utility systems will impact the installation cost of either system.

The homeowner is responsible for energy costs, which will vary from $2.00 to $5.00/month for grinder pump systems, depending on the horsepower of the unit. Septic tank effluent pump units generally cost less than $2.00/month.

Preventive maintenance should be performed annually for each unit, with monthly maintenance of other mechanical components. Septic tank effluent pump systems require periodic pumping of septic tanks. Total O&M costs average $200-500 per year per unit, and include costs for troubleshooting, inspection of new installations, and responding to problems. Mean time between service calls data vary greatly, but values of 4 to 10 years for both grinder pump and septic tank effluent pump units are reasonable estimates for quality installations.

**TABLE 4-4 AVERAGE INSTALLED UNIT COSTS FOR PRESSURE SEWER MAINS & APPURTENANCES**

| Item | Unit Cost ($) @ 2011 |
|---|---|
| 2 inch mains | $14.99 L/Ft |
| 3 inch mains | $15.85 L/Ft |
| 4 inch mains | $17.91 L/Ft |
| 6 inch mains | $25.20 L/Ft |
| 8 inch mains | $28.06 L/Ft |
| Extra for mains in asphalt concrete | |
| Pavement | $9.98 L/Ft |
| 2 inch isolation valves | $502.31 EACH |
| 3 inch isolation valves | $550.12 EACH |
| 4 inch isolation valves | $701.60 EACH |
| 6 inch isolation valves | $797.80 EACH |
| 8 inch isolation valves | $1,148.42 EACH |
| Individual Grinder pump | $2,403.55EACH |
| Single package pump system | $8,196.46 EACH |
| Package installation | $1,910.64-2,998.09 EACH |
| Automatic air release stations | $2,002.11 EACH |

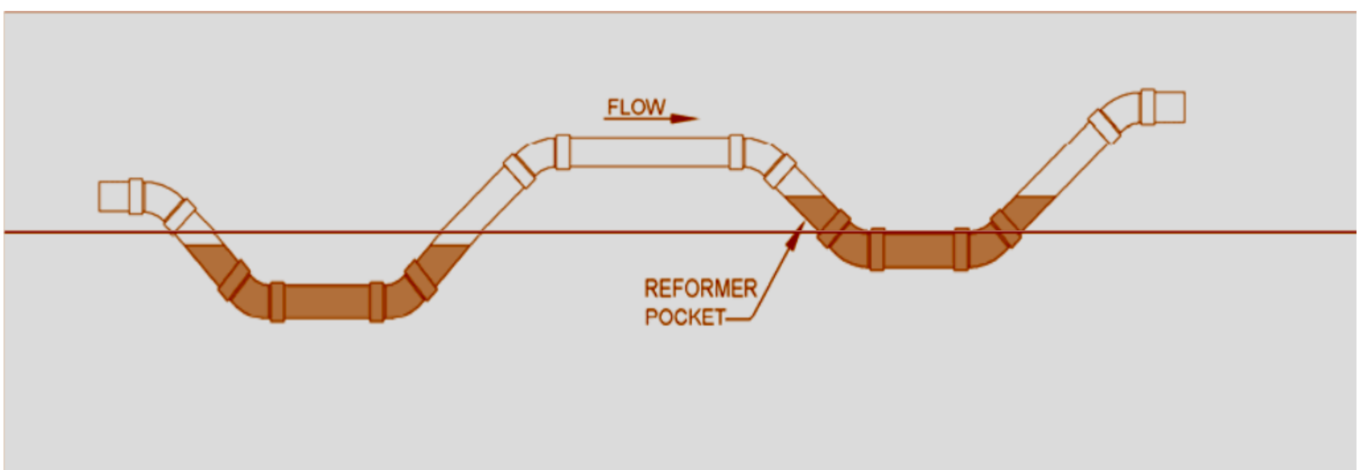
## *Vacuum Sewer Systems*

### Applicability

Vacuum sewers have become an acceptable alternative in the proper application and are providing efficient and reliable sewer service to communities all around the world. A vacuum sewer system consists of three major components: the valve pit, the vacuum mains, and the vacuum station.

Vacuum sewerage is a mechanized system of wastewater transport. Unlike gravity flow, vacuum sewers use differential air pressure to move the sewage. A central source of power to operate vacuum pumps is required to maintain vacuum (negative pressure) on the collection system. The system requires a normally closed vacuum/gravity interface valve at each entry point to seal the lines so that vacuum can be maintained. These valves, located in valve pits, open when a predetermined amount of sewage accumulates in collecting sumps. The resulting differential pressure between atmosphere and vacuum becomes the driving force that propels the sewage towards the vacuum station.

An early concept centering on liquid plug flow assumed that a wastewater plug completely sealed the pipe bore during static conditions. The movement of the plug through the pipe bore was attributed to the pressure differential behind and in front of the plug. Pipe friction would cause the plug to disintegrate, thus eliminating the driving force. Therefore, reformer pockets were located in the vacuum sewer to allow the plug to reform by gravity and thus restore the pressure differential (Picture 4-8). In this concept, the re- establishment of the pressure differential for each disintegrated plug was a major design consideration.




**Picture 4-8 Reformer pockets in vacuum sewer system…early design concept**

In the current saw-tooth profile design concept, the reformer pockets are eliminated so that the wastewater does not completely fill or "seal" the pipe bore. Air flows above the liquid, thus maintaining a vacuum condition throughout the length of the pipeline (Picture 4-9). In this concept, the liquid is assumed to take the form of a spiral, rotating, hollow cylinder. The momentum of the wastewater and the air carries the previously disintegrated cylinders over the downstream sawtooth lifts. The momentum of each subsequent air/liquid slug and its contribution to the progressive movement of the liquid component of the previous slugs are the major design considerations.

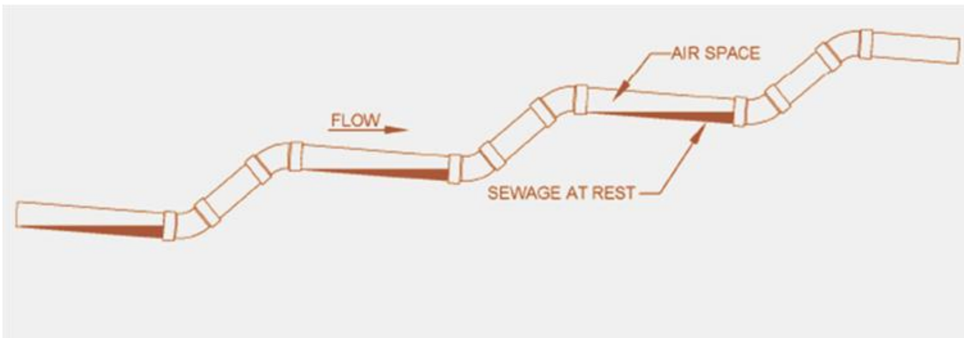



Figure 2
Current Design Concept – Sawtooth Profile

**Picture 4-9 current design where air flows above the liquid keeping the vacuum.**

A vacuum created by vacuum pumps located at the vacuum station is transferred through the vacuum mains and to the valve pit. The valve pit is where the interface between gravity and vacuum occurs.

Housed in the top chamber of the valve pit is an interface valve. This valve is normally closed in order to seal the vacuum mains. This ensures that vacuum is maintained on the piping network at all times. The lower chamber of the valve pit is a sump that receives the sewage from the house. When sewage accumulates in the sump, the interface valve automatically opens. This is done without any electrical power being required. The valve opens and the contents of the sump are evacuated. The valve stays open momentarily to allow for atmospheric air to enter the system. This air comes from the air-intake located by the house.

The resulting pressure differential between the positive pressure of atmosphere air and the negative pressure in the vacuum main becomes the driving force that propels the sewage towards the vacuum station. The pressure differential that exists at the normal operating vacuum levels provides the energy to propel the sewage at velocities of 15-18 ft/s.

When the sewage enter the vacuum main it travels as far as its initial energy allows, until frictional forces cause it to come to rest. As other valves in the piping network open, additional slugs of sewage and air enter the system. Each subsequent energy input continues to move the sewage toward the vacuum station. Many view the vacuum pipeline as a “vacuum-assisted gravity sewer”. Like gravity sewers, vacuum sewers are installed with a positive slope toward the vacuum station. When vacuum mains start to become deep, a “lift” is used to return the main to a more acceptable depth. It is at these lifts that vacuum “assists” the sewage on its travel toward the vacuum station. The lifts are part of the saw-tooth configuration of the vacuum mains, which is a key feature of a vacuum system. The saw-tooth profile is used to keep an open passageway on the top of the piping network, thereby preventing the pipe from becoming sealed. By doing this, air flows above the liquid, and the vacuum that is created at the vacuum station can be transferred to every valve pit. This ensures that the maximum pressure differential, and hence, maximum energy, can be obtained at each valve pit.

Eventually the sewage reaches the vacuum station. The vacuum station has 3 major components: <u>the collection tank, the vacuum pumps and the sewage pumps</u>. The vacuum pumps and the vacuum mains are connected to the top part of the collection tank. This part of the tank is kept open so that the vacuum that is created by the vacuum pumps can be transferred to the vacuum mains and ultimately to the valve pits.

The vacuum pumps do not run continually, but rather in cycles. They run for a short period in order to establish the high level vacuum. When this level is achieved, they turn off. As valves throughout the system open and admit atmospheric air, vacuum levels gradually drop. When the vacuum levels become low, the vacuum pumps come on again and run to re-establish the high vacuum levels. Sewage from the vacuum mains enters the collection tank and accumulates in the bottom part of the tank. When enough accumulates, the sewage pumps come on and pump the sewage out of the collection tank through a force main to the ultimate point of disposal.

Experience has shown that for vacuum systems to be cost effective, a minimum of <u>75 to 100 customers (houses or equivalents) per vacuum station is generally required</u>. The average number of customers per station in systems presently in operation is about 200 to 500, but that average is increasing every year. Vacuum systems are to a degree limited by topography. The most successful applications have been in relatively dense developments with moderate terrain changes. The vacuum produced by a vacuum station is generally capable of lifting sewage <u>15- 20 ft</u>, depending on the operating vacuum level of the system.

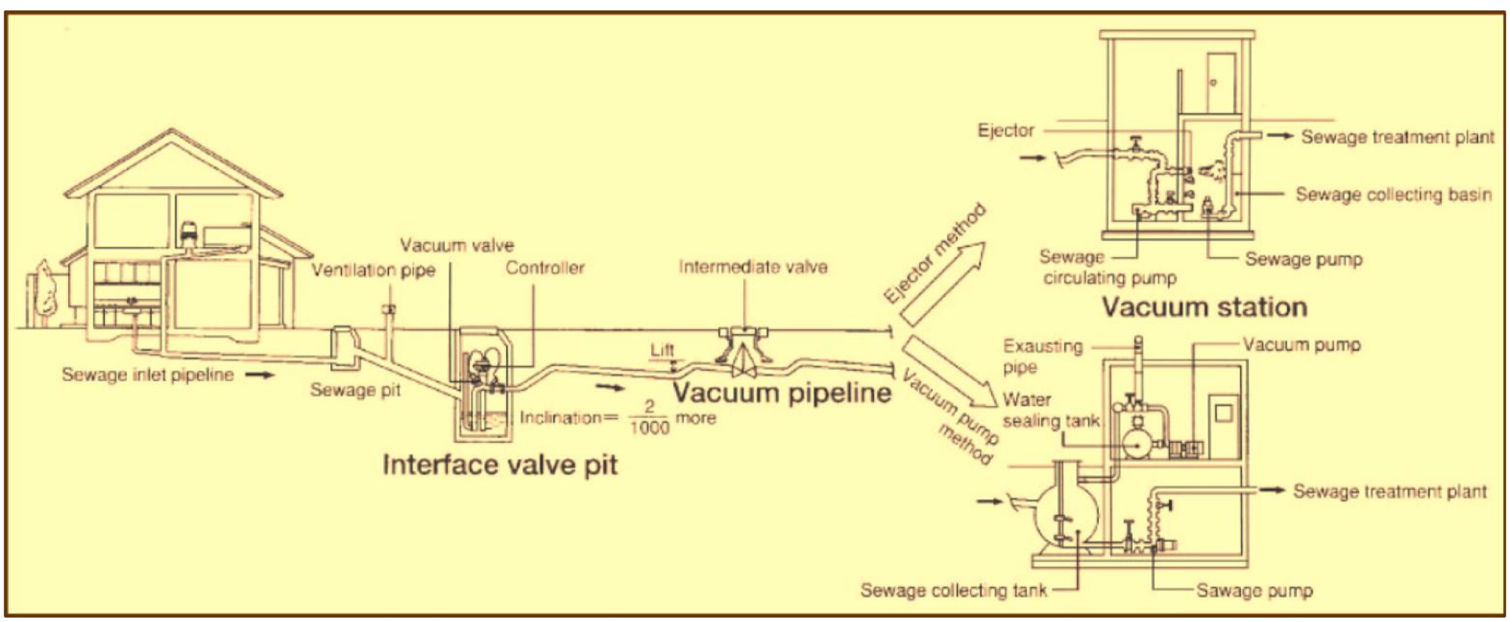
This amount of lift is often sufficient to allow the designer to avoid all or many of the lift stations that would be required in a conventional gravity system.

The consulting engineer usually drives the community's choice of collection system type during the planning stages of a wastewater facilities project. This choice is normally based on the result of a cost-effectiveness analysis. While gravity may appear to be less costly in situations where the terrain is favorable for gravity flow, many small factors considered collectively may result in a vacuum system being the proper choice.

Below are the general conditions that are conducive to the selection of vacuum sewers.

- Unstable soil
- Flat terrain
- Rolling land with many small elevation changes
- High water table
- Restricted construction condition
- Rock
- New urban development in rural areas
- Existing urban development where built-out conditions exist
- Sensitive eco-system

**Picture 4-10 vacuum sewer system**



## Advantages

The advantage of vacuum collection systems may include substantial reductions in water use, material costs, excavation costs, and treatment expenses. In short, there is a potential for overall cost effectiveness.

Specifically, the following advantages are evident:

- Small pipe sizes, usually 4”, 6”, 8” and 10” are used.
- No manholes are necessary.
- Field changes can easily be made as unforeseen underground obstacles can be avoided by going over, under, or around them.
- Installation of smaller diameter pipes at shallow depths eliminates the need for wide, deep trenches reducing excavation costs and potential dewatering costs.
- High scouring velocities are attained, reducing the risk of blockages and keeping wastewater aerated and mixed.
- Elimination of the exposure of maintenance personnel to the risk of H2S gas hazards.
- The system will not allow major leaks to go unnoticed, resulting in a reduced environmental damage from exfiltration of wastewater.
- Only one source of power, at the vacuum station, is required. No on-lot power demand exists at valve pits.
- The elimination of infiltration permits a reduction of size and cost of the treatment plant.
- Vacuum stations can be designed to blend with the surroundings more so than traditional lift stations.
- Valve pits are more concealable at the customer’s property than are grinder pump stations.
- A single source responsibility exists as one operating entity operates and maintains the entire system, including the on-lot valve pit and valve.

## Disadvantages

There are a number of disadvantages to vacuum systems. First, while the mains are small and require shallow burial (just below the frost line), they are limited to approximately 20 feet of head. The sewer lines must have a specific profile of pockets or running traps, so installation requires the same attention to grade as a gravity sewer main.

The biggest disadvantage is system size. The central vacuum stations require a large capital investment, so a system for less than 50 homes is not economically feasible.

Valve pits and sumps are needed to accept the wastes from the house. These may consist of one unit with two (2) separate chambers. The upper chamber houses the vacuum valve and the bottom chamber is the sump into which the building sewer is connected. These two chambers are sealed from each other. The combination valve pit/sump is usually made of fiberglass, and is able to withstand traffic loads. Buffer tanks are used for large customers or when a pressure/vacuum or gravity/vacuum interface is desired, as would be the case with a hybrid system.

## Design Criteria

The vacuum valve provides the interface between the vacuum in the collection piping and the atmospheric air in the building sewer and sump. System vacuum in the collection piping is maintained when the valve is closed. With the valve opened, system vacuum evacuates the contents of the sump. The valve is entirely pneumatic by design, and has a 3-in. opening size. Some states have made this a minimum size requirement, as this matches the throat diameter of the standard toilet.

A 4-in. air-intake is installed on the homeowner's building sewer, downstream of all of the house traps. This air-intake is necessary to provide the volume of air that follows the sewage into the main resulting in the pressure differential that becomes the driving force. This also circumvents the problem of inadequate house venting which can result in trap evacuation. Some operating entities require the air-intake to be located near a permanent structure for aesthetic and protection reasons. In some instances, local ordinances may stipulate a minimum setback distance from the building structure.

The piping network connects the individual valve pits to the collection tank at the vacuum station. Schedule 40, SDR 21 or SDR 26 PVC pipe is used, with SDR 21 being the most common. Early systems used solvent-welded joints, but most recent systems use O-ring rubber gasketed pipe. Where gasketed pipe is used, the gaskets must be certified for use under vacuum conditions. Typical sizes include 3-in, 4-in, 6-in, 8-in and 10-in pipe. PVC pressure fittings are needed for directional change as well as for the crossover connections from the service line to the main line. These fittings may be solvent-welded or gasketed. The recent trend is to avoid solvent-welded fittings where possible, although there is a cost trade-off to consider, as the gasketed fittings typically are more expensive, but are less labor intensive than the solvent welded fittings. Lifts or vertical profile changes are used for to maintain shallow trench depths as well as for uphill liquid transport. These lifts are made in a saw-tooth fashion. A single lift consists of two (2) 45-degree fittings connected with a short length of pipe.

**Picture 4-11 Vacuum sewer system tank**

Division valves are used to isolate various sections of vacuum mains thereby allowing operations personnel to troubleshoot maintenance problems in a timely fashion. Both plug and resilient-wedge gate valves have been used, although most recent systems use gate valves. Some designs have included gauge taps installed just downstream of the division valve. This tap makes it possible for one person to troubleshoot without having to check vacuum at the station. This greatly reduces emergency maintenance expenses, both from a time and manpower standpoint.

Different pipe location identification methods have been used. These include magnetic trace tape in the top of the trench, metal-toning wires above the pipe during construction; utility frequency based electronic markers, and color-coding of the pipe itself.

## Operation and Maintenance

Vacuum stations function as transfer facilities between a central collection point for all vacuum sewer lines and a pressurized line leading directly or indirectly to a treatment facility. Picture 4-10 shows the major components of the vacuum station. Vacuum pumps are needed to produce the vacuum necessary for liquid/air transport. They may be either the liquid-ring or sliding-vane type, although most recent systems use the sliding vane type. Efficiency in the normal operating range is often cited as the reason for this. The optimum operating range is 16-20 in. of mercury (Hg). The vacuum pumps, however, should have the capability of providing up to 25 in. of mercury (Hg) as this level is sometimes needed during emergency conditions and in the troubleshooting process. Redundancy is required, as design capacity must be met with one pump out of service. Discharge pumps are required to transfer the liquid that is pulled into the collection tank by the vacuum pumps to its ultimate point of disposal. Dry pit pumps have been used extensively, although submersible sewage pumps located on guide rails within the collection tank may be used as an alternative. The most frequently used pump has been the non-clog type. Redundancy is required, with each pump capable of providing 100 percent of the design capacity. The level controls are set for a minimum of 2 minutes pump running time to prevent excessive pump starting and related, increased wear. The pumps should have shutoff valves on both the suction and discharge piping to allow for removal during maintenance without affecting the vacuum level. Check valves are used on each pump discharge line or on a common manifold after the discharge lines are joined to it. Equalizing lines are to be installed on each pump. Their purpose is to equalize the liquid level on both sides of the impeller so that air is removed. This ensures that the impeller is filled with liquid, which allows the discharge pump to start without having to pump against the vacuum in the collection tank. Since this setup will result in a small part of the discharge flow being re-circulated to the collection tank, a decreased net pump capacity results.

**Picture 4-12 Vacuum system in home connection diagram**

Discharge pumps are typically located at an elevation below the collection tank to minimize the net positive suction head (NPSH) requirement. In conjunction with net positive suction head requirements, pump heads (TDH) must be increased by 23 ft to account for collection tank vacuum. Both vertical and horizontal pumps can be used. Materials of construction for discharge pumps are commonly cast iron with stainless steel shafts. Cast aluminum, bronze, and brass should be avoided. Double mechanical seals, which are adaptable to vacuum service, should be used. An emergency (or standby) generator is a must. It ensures that on-lot flooding or backup will be prevented through the continuing operation of the system in the event of a power outage. Standard generators are available from a variety of manufacturers. The wastewater is stored in the collection tank until a sufficient volume accumulates, at which point the tank is evacuated. It is a sealed, vacuum-tight vessel made of carbon steel, fiberglass, or stainless steel. Fiberglass or stainless steel tanks are generally more expensive, but do not require the periodic maintenance of a carbon steel tank, which may require painting every 5 to 6 years. Vacuum, produced by the vacuum pumps, is transferred to the collection system through the top part of this tank. The part of the tank below the invert of the incoming vacuum collection lines acts as the wet well.

A bolted hatch provides access to the tank should it be necessary. Most collection tanks are located at a low elevation relative to most of the components of the vacuum station. This minimizes the lift required for the sewage to enter the collection tank, since sewage must enter at or near the top of the tank to ensure that vacuum can be restored upstream. This may result in a deep basement required in the vacuum station. Vacuum switches located on the collection tank control the vacuum pumps. The usual operating level is 16-20 in. of Hg with a low level alarm of 14-in. of Hg. Seven (7) probes, one for each of the six (6) set points of the pumping cycle and one (1) as a ground, are located inside of the collection tank and control the discharge pumps.

The vacuum system control panel houses all of the motor starters, overloads, control circuitry, and the hours run meter for each vacuum and sewage pump. The vacuum chart recorder, collection tank level control relays, and fault monitoring equipment are also normally located within the vacuum system control panel. Fault monitoring systems include telephone dialers or other telemetry equipment including radio based SCADA systems, digital or fiber optic based SCADA systems and telephone based SCADA communications systems.

Vacuum gauges, required to allow the operator to monitor the system, are used on all incoming lines as well as on the collection tank. These gauges are very important in the troubleshooting procedures. Chart recorders for both the vacuum and sewer pumps are needed so that system characteristics can be established and monitored.

It is standard practice in the U.S. for the vacuum station equipment to be supplied by the vacuum manufacturer who pre-assembles and tests the equipment and then ships it to the job-site on a skid(s). These skids can then be lifted into the building and connected to the incoming vacuum mains and the outgoing force main.

The vacuum station equipment must be installed in a protective structure. Materials of construction are the choice of the consulting engineer and typically are selected to match the architecture of the surrounding community.

All of the major vacuum system components are sized according to peak flow, expressed in gallons per minute (gpm). Peak flow rates are calculated by applying a peaking factor to an average daily flow rate.

## Calculate Flow Rates

A 2 feet wide rectangular channel is flowing 30 inches deep with an average velocity of .8 feet per second. What is the approximate flow rate?

To find the flow rate use a variation of the velocity equation. First calculate the area of the channel, and we have the velocity. Then plug it into the Q = A * V formula. Convert inches into feet for the depth.

Area = 2 ft x 2.5 ft = $5ft^2$

Q = 5 $ft^2$ x .8 ft/sec = 4.0 $ft^3$/sec

Based on the current Ten State Standards, sewage flow rates shall be based on one of the following:

1. Documented wastewater flow for the area being served. Water use records are typically used for this purpose.
2. 100 gallons per person per day combined with home population densities specific to the service area. Most approval agencies will accept published U.S. Census Bureau home density for this criterion.

The vacuum system is a sealed system that eliminates ground water infiltration from the piping network and the interface valve pits. However, ground water can enter the system as a result of leaking house plumbing or as a result of building roof drains being connected to the plumbing system. While vacuum systems have some inherent reserve capacity, significant amounts of homeowner I&I can result is severe system operating problems. For this reason, it is recommended that designers consider methods of eliminating ground water from plumbing systems during the design phase of a project rather than adding a homeowner infiltration component to the design flow.

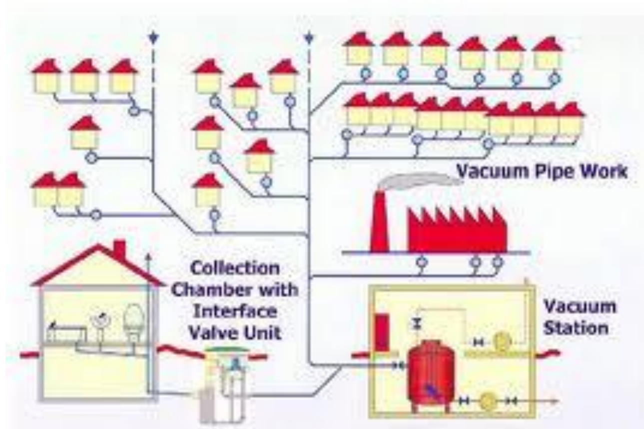
The geometry of a vacuum sewer system is similar to that of a water distribution system. Rather than looped, however, it is normally designed in a tree pattern. The length of vacuum mains is generally governed by two factors. These are static lift and friction losses. The determination of these losses is beyond the scope of this course.

**Sewers: Design & Installation Guidelines**

Due to restraints placed upon each design by topography and sewage flows, it is impossible to give a definite maximum line length (length from vacuum station to line extremity). In perfectly flat terrain with no unusual subsurface obstacles present, a length of 10,000 ft can easily be achieved. With elevation to overcome, this length would become shorter. With positive elevation toward the vacuum station, this length could be longer. As an example, one operating system has a line that, from the vacuum station to the line extremity, 16,500 ft in length. There are three (3) major items for the designer to consider when laying out a vacuum system:

1. Minimum distance between lifts
2. Minimum slopes
3. Slopes between lifts

By locating the vacuum station centrally, it is possible for multiple vacuum mains to enter the station, which effectively divides the service area into zones. This results in operational flexibility as well as service reliability. With multiple service zones, the operator can respond to system problems, such as low station vacuum, by analyzing the collection system on a zone by zone basis to see which zone has the problem. The problem zone can then be isolated from the rest of the system so that normal service is possible in the unaffected zones while the problem is identified and solved.




**Picture 4-7 vacuum sewer station diagram**

**Minimize Pipe Sizes**

By dividing the service area into zones, the total peak flow to the station is also spread out among the various zones, making it possible to minimize the pipe sizes.

**Minimize Static Loss**

Static loss is generally limited to 13 ft. Items that result in static loss are increased line length, elevation differences, utility conflicts and the relationship of the valve pit location to the vacuum main. Vacuum sewer design rules have been developed largely as a result of studying operating systems.

An advantage to the use of vacuum sewers is that the small diameter PVC pipe used is flexible and can be easily routed horizontally around obstacles. The feature allows vacuum sewers to follow a winding path as necessary. In most cases, vacuum sewer mains are located outside of and adjacent to the edge of pavement and approximately parallel to the road or street, which reduces the expenses of pavement repair and traffic control. In areas subject to unusual erosion, the preferred location is often within the paved area. Some municipalities also favor installation within the paved area since subsequent excavation is less likely and more controlled (via permit application only), and therefore a location more protected from damage.

However, community disruption potential during construction and maintenance for this approach increases substantially. With two or more houses sharing one valve pit, overall system construction costs can be significantly reduced, resulting in major cost advantage. In some circumstances, however, this approach may require the main line to be located in private property, typically in the back yard. There are two disadvantages to this type of routing.

1. It requires permanent easements from one of the property owners, which may be difficult to obtain.
2. Experience has shown that multiple house hookups can be a source of neighborhood friction unless the pit is located on public property. The designer should carefully consider the tradeoff of reduced costs to the social issues prior to making the final routing decision.

In most valve pits, up to <u>four separate building sewers</u> can be connected to one sump, each at 90 degrees to one another. However, this is rarely done as property lines considerations and other factors may render this impractical. By far, the most common valve pit sharing arrangement is for two adjacent houses to share a single valve pit. Some have attempted to reduce costs by having additional houses sharing a single valve pit. Experience has shown that, while this may appear to be viable on paper, many times it is not achievable during construction. And, even if it is, the perceived cost savings does not always materialize. Longer runs of <u>gravity laterals</u> are required which results in deeper valve pits needed to accommodate this. Also, the additional 2 or 3 ft of excavation of not just the pit, but the gravity laterals as well, may result in extensive dewatering. In certain cases, such as the existence of a cul-de-sac or when small lots with short front footage exists, it may be possible to serve 3 or even 4 houses with a single valve pit; however, all other design factors must be considered.

## Review Questions for Types of Collection Systems

1. Three main types of collection systems used in Kentucky are ___________, ___________, and __________.

2. A __________ is a hydraulic conveyance structures that carry wastewater to a treatment plant or other authorized point of discharge.

3. Vertical pipes, used for access to the sewer pipes for inspection and maintenance, and as a means to vent sewer gases are called _________.

4. 5 types of sewers are ___________, ___________, __________, ____________, ______________.

5. During peak dry weather conditions the sewer lines must attain a velocity greater than __________ 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).

6. ____________are devices that facilitate and control the flow of wastewater and allow access for maintenance activities. They include manholes, building connections, junction chambers or boxes, and terminal cleanouts.

7. Typical manhole spacing ranges between __________ depending on the size of the sewer and available sewer cleaning equipment.

8. __________________ are used to stop the accidental backflow or reverse flow of wastewater into buildings. They are used when the ______________ in the buildings plumbing is above the rim elevation line of the manhole in the lateral or street main immediately upstream of the buildings sewer connection.

9. _____________ are most cost effective where housing density is low, where the terrain has undulations with relatively high relief, connects several residences to a “cluster” pump station can be less expensive than conventional gravity systems, and where the system outfall must be at the same or a higher elevation than most or all of the service area.

10. Parts of a typical pressure sewer system include _______, ________, _________, ________, and ____________.

11. Manholes associated with conventional gravity sewers are a source of ____________ and _____________.

12. Odor problems may develop in pressure sewer systems because of ____________ __________ ____________. The addition of strong oxidizing agents, such as _________ or _____________ _________, may be necessary to control odor where venting is not the cause of the problem.

13. A vacuum sewer system consists of three major components: ________, ___________, and ______________.

14. An ___________ _____________ is a must in a vacuum sewer system. It ensures that on-lot flooding or backup will be prevented through the continuing operation of the system in the event of a power outage.

15. There are three major items for the designer to consider when laying out a vacuum system: _________, __________, and ____________.

16. If it is assumed that the average velocity of the wastewater in the collection system is 2.66 feet per second. How many hours does it take the wastewater in hours to reach the treatment plant if the maximum distance from the treatment plant to the farthest lateral is 9 miles?

17. What is the area of the top of a tank that is 70 ft long 50 ft wide and 30 ft deep?

18. The flow entering the leg of a tee is 44 gal/min. If the flow through one branch is 27 gal/min, what is the flow through the other branch?

19. What is the daily average flow for a lift station in MGD given the following data?

| Date | Time | Meter reading |
|---|---|---|
| 4/12/2011 | 8:00 AM | 333,326,621 gallons |
| 4/19/2011 | 8:00 AM | 381,222,213 gallons |

20. The grade for a sewer pipe is .7% for a length of 9,600 ft and then changes to .25% for an additional 5,280 feet, how many feet lower would the downstream end of the pipe be than the upstream end?

21. What is the height of wastewater in a manhole if there is 1,550 gallons in it? The manhole has a radius of 3.5 ft.

22. What is the detention time in hours in an interceptor sewer ½ mile long and 24 inches in diameter if the average flow is .14 MGD?

23. A pipe from a subdivision is clogged. The main is 2500 feet long and 18-inches in diameter. The pipe delivers an average flow of 1050 $ft^3$/min. The collection crew is flushing the main to remove the clog. How long should they flush the line to achieve 4 pipe volumes?

24. A 5 feet wide rectangular channel is flowing 60 inches deep with an average velocity of 2.8 feet per second. What is the approximate flow rate?

**Answers to Types of Collection Systems Questions**

1. gravity, pressure, vacuum
2. sewer
3. manholes
4. building sewers, lateral or branch sewers, main sewers, trunk sewers, interceptor sewers
5. 2 ft/s
6. Appurtenances
7. 300-600 ft
8. Back flow preventers, lowest overflow point
9. Pressure sewer systems
10. Discharge line, boundary valve, pump control panel, pump unit, and building drain
11. Inflow, infiltration
12. Improper house venting, hydrogen peroxide, chlorine
13. Valve pit, vacuum mains, vacuum station
14. emergency (or standby) generator
15. minimum distance between lifts, minimum slopes, slopes between lifts
16. 4.96 hrs
17. 3,500 $ft^2$
18. 17 gal/min

19. 6,842,227 gal
20. 80.40 ft
21. 5.39 ft
22. 10.6 hrs
23. 16.82 min
24. 70 $ft^3/s$

# Chapter 5: PIPES

## Chapter 5 Objectives

1. Define crown of the pipe, invert of the pipe, and force main.
2. Identify four major materials/types of pipe used in the collection system.
3. Know and understand the characteristics of each type and the conditions in which each is used.
4. Know and understand what soils types, topography, groundwater, chemistry, and etc works best for each type of pipe.
5. Know and understand the advantages and disadvantages of each type of pipe.
6. Define pipe bedding, pipe laying, and pipe joining.
7. Know and understand the design criteria for pipe bedding, pipe laying, and pipe joining.
8. Define and understand the concept of backfilling.
9. Know, identify, and understand the classes of pipe bedding.
10. Know, identify and understand the factors associated with cost, cost analysis, and budgeting as it pertains to pipes in the collection system.
11. Know, identify, and understand techniques, cost, and methods associated with pipe rehabilitation in the collection system.
12. Calculate volume.

This chapter will discuss pipes and you should be aware of the following **definitions** that are used when referring to piping in the collection system.

Crown - inside top of pipe
Invert - the lowest point of the inside of a pipe or manhole
Force main - A pipe that carries wastewater under pressure from the discharge side of the pump.

## *Pipe Construction and Materials*

There are several different pipe materials available for wastewater collection systems, each with a unique characteristic used in different conditions. The four different pipe materials described below are:

- Ductile iron
- Concrete
- Plastic
- Vitrified clay

Pipe material selection considerations include:

- Trench conditions (geologic conditions)
- Corrosion
- Temperature
- Safety requirements
- Cost

Key pipe characteristics areas follows:

- Corrosion resistance (interior and exterior)
- Scouring factor
- Leak tightness
- Hydraulic characteristics

Pipe manufacturers follow requirements set by the American Society of Testing Materials (ASTM) or American Water Works Association (AWWA) for specific pipe materials. Specification standards cover the manufacture of pipes and specify parameters such as:

- Internal diameter
- Loadings (classes)
- Wall thickness (schedule)

The methods of pipe construction vary greatly with the pipe materials. Some new pipe materials and construction methods use the basic materials of concrete pipes with modifications (i.e., coatings). Other pipe manufacturing methods use newly developed resins which offer improvements in strength, flexibility, and resistance to certain chemicals. Construction methods may also allow for field modifications to adapt to unique conditions (i.e., river crossings, rocky trenches, etc.) or may allow for special, custom ordered diameters and lengths.

**Picture 5-1 Pipe installation**

## Ductile Iron Pipe

Ductile iron pipe (DIP) is an outgrowth of the cast iron pipe industry. Improvements in the metallurgy of cast iron in the 1940's increased the strength of cast iron pipe and added ductility, an ability to slightly deform without cracking. This was a major advantage and ductile iron pipe quickly became the standard pipe material for high pressure service for various uses (water, gas, etc.)

## Concrete Pipe

Two types of concrete pipe commonly used today are Prestressed concrete cylinder pipe (PCCP) and reinforced concrete pipe (RCP). PCCP is used for force mains, while RCP is used primarily for gravity lines. PCCP may be of either embedded cylinder (EC) or lined-cylinder construction (LC).

The construction process for both the LC and EC begins by casting a concrete core in a steel cylinder. This single process produces the LC pipe. Once the cylinder cures, it is wrapped with a prestressed steel wire and coated with cement slurry and a dense mortar or concrete coating to produce the EC pipe.

The manufacturing process for reinforced concrete cylinder pipe (RCCP) is similar to embedded cylinder, however, a reinforcing cage and the steel cylinder are positioned within a reusable vertical form and the concrete is cast instead of using the prestressed wire. RCCP can be cured by using either water or steam.

## Plastic Pipe

Plastic pipe is made from either thermoplastic or thermoset plastics. Characteristics and construction vary, but new materials offer high strength and good rigidity. Fluorocarbon plastics are the most resistant to attack from acids, alkalies, and organic compounds, but other plastics also have high chemical resistance. Plastic pipe design must include stiffness, loading, and hydrostatic design stress requirements for pressure piping.

Thermoplastics are plastic materials which change shape when they are heated. Common plastics used in pipe manufacturing include Polyvinyl Chloride (PVC), Polyethylene (PE or HDPE for High- Density PE), Acrylonitrile-butadiene-styrene (ABS), and Polybutylene (PB). HDPE is commonly used with pipe bursting.

PVC is strong, lightweight, and somewhat flexible. PVC pipe is the most widely used plastic pipe material. Other plastic pipes or composites with plastics and other materials may be more rigid. Thermoset plastics are rigid after they have been manufactured and are not able to be reformed. Thermoset plastic pipes are composed of epoxy, polyester, and phenolic resins, and are usually reinforced with fiberglass. Resins may contain fillers to extend the resin and to provide specific characteristics to the final material. The glass fibers may be wound around the pipes spirally, in woven configurations, or they may be incorporated into the resin material as short strands. The pipes may be centrifugally cast. Stiffness may also be added in construction as external ribs or windings.

Reinforced Plastic Mortar (RPM) and Reinforced Thermosetting Resin (RTR) (or Fiberglass Reinforced Plastic Pipe (FRP)) are the two basic classes of these pipes. Another name is Fiberglass Reinforced Polymer Mortar (FRPM). Thermoset pipes are often manufactured according to the specific buyer requirements and may include liners of different composition for specific chemical uses.

For plastic pipes, resins composed of polymerized molecules are mixed with lubricants, stabilizers, fillers, and pigments, to produce mixtures with different characteristics. Plastic pipes are generally produced by extrusion.

Plastic pipe may be used for Sliplining or for rehabilitating existing pipes by inserting or pulling them through a smaller diameter pipe. HDPE pipes may also be used for bursting and upgrading. The smaller diameter pipe may be anchored into place with mortar or grout.

### Vitrified Clay Pipe

Vitrified clay pipes are composed of crushed and blended clay that are formed into pipes, then dried and fired in a succession of temperatures. The final firing gives the pipes a glassy finish. Vitrified clay pipes have been used for hundreds of years and are strong, resistant to chemical corrosion, internal abrasion, and external chemical attack. They are also heat resistant. These pipes have an increased risk of failure when mortar is used in joints because mortar is more susceptible to chemical attack than the clay. Other types of joints are more chemically stable. It has been shown that the thermal expansion of vitrified clay pipes less than many other types.

## *Applicability*

The applicability of different pipe materials varies with each site and the system requirements. The pipe material must be compatible with the soil and groundwater chemistry. The pipe material also must be compatible with the soil structure and topography of the site, which affects the pipe location and depth, the supports necessary for the pipe fill material, and the required strength of the pipe material.

The following list shows background information to be used in determining what type of pipe best fits a particular situation:

- Maximum pressure conditions (force mains)
- Overburden, dynamic, and static loading
- Lengths of pipe available
- Soil conditions, soil chemistry, water table, stability
- Joining materials required
- Installation equipment required
- Chemical and physical properties of the wastewater
- Joint tightness/thrust control
- Size range requirements
- Field and shop fabrication considerations
- Compatibility with existing systems
- Manholes, pits, sumps, and other required structures to be included
- Valves (number, size, and cost)
- Corrosion/cathodic protection requirements
- Maintenance requirements

## *Advantages and Disadvantages*

The advantages and disadvantages for specific pipe materials are listed in Table 5-1. The primary advantages and disadvantages to consider for pipes used in sewer applications include those that are related to construction requirements, pressure requirements (force mains), depth of cover, and cost.

**TABLE 5-1**

**ADVANTAGES & DISADVANTAGES OF DIFFERENT MATERIAL**

| ***Advantages*** | ***Disadvantages*** |
|---|---|
| **Ductile Iron** | |
| Good corrosion resistance | Heavy |
| High strength | |
| | |
| **Concrete** | |
| Good corrosion resistance | Requires careful installation |
| Widespread availability | Heavy |
| High strength | Not $H_2S$ resistant |
| Good load support capacity | |
| | |
| **Vitrified Clay** | |
| Resistant to acids and most chemicals | Joints susceptible to chemical attack |
| Strong | Brittle , may crack, careful installations |
| | Short joins and many joints make it prone to infiltration |
| | |
| **Thermoplastics (PVC, PE, HDPE, ABS)** | |
| Very lightweight | Susceptible to chemical attack, particularly by solvents |
| Easy to install | Strength affected by sunlight unless UV protected |
| Economical | Requires special bedding |
| Good corrosion resistance | |
| Smooth surface reduces friction losses | |
| Long pipe sections reduce infiltration Potential | |
| Flexible | |
| | |
| **Thermosets (FRP)** | |
| Corrosion resistant | High installation cost |
| High strength | High material cost |
| Lightweight | Brittle (may crack); requires careful installation |

## *Design Criteria*

Design requirements may vary greatly. Pipe design is approached differently for both materials and construction methods. The mechanics of the soil that will surround the pipes is a fundamental design aspect for the support characteristics, especially for flexible pipes. The soil type, density, and the moisture content are important characteristics.

## *Benchmarking*

The benchmark is the starting set-out position from which control marks are derived. The set-out means to set out site by survey methods using pegs. A fundamental benchmark is a point with a precisely known relationship to the level datum of the area, typically mean sea level. Temporary Mench Marks (TBM's) are recommended to be set every 500 feet on construction projects. It is important to run the center line. Benchmarks are typically placed by a government agency or private survey firm, and many governments maintain a register of these marks so that the records are availableto all. These records are usually in the form of a geographically searchable database (computer or map-based), with links to sketches, diagrams, photos of the marks, and any other technical details.

## *Bedding*

Sewer pipe <u>bedding</u> is the material upon which the pipe is laid and serves as it foundation. <u>Initial backfill</u> is the material surrounding the pipe.

Classes of Bedding (LF = Load Factor, Bedding factor from pipe supplier)

Class A1 = LF = 2.2 = <u>Native backfill</u> lightly hand tamped full cover to crown of pipe with min 100 mm under pipe
Class A1 = LF = 2.8 = 67 crushed stone full pipe cover with 100 mm min. under pipe
Class A1 = LF = 3.4 = Reinforced concrete

Class B = LF = 1.9 = <u>Native soil</u> hand tamped or granular material to cover half the pipe with min 100 mm under the pipe with hand placed backfill above.

Class C = LF = 1.5 = shaped trench bottom with full pipe coverage with hand placed backfill
Class C = LF = 1.5= Min 100 mm native soil or granular bedding with shaped bottom, full pipe coverage with hand placed back fill

Class D = LF = 1.1 = flat or unshaped trench bottom with full pipe coverage with hand place backfill

Granular bedding material (Class B&C) may be used to facilitate a true grade on an imperfect or undercut trench bottom. Can also be used to arranged material to accommodate the pipe bells. Granular material is crushed rock aggregate with 1/4-3/4 inch particle size.

**Picture 5-2 HDPE pipe installation**

## Calculate the Volume of Asphalt Removed

How many cubic yards of asphalt paving material will be required to pave over a trench 600 feet long, 4.5 feet wide using a 6 inch deep patch?

First convert the inches to feet and find the volume. Then convert $ft^3$ to $yd^3$.

Volume = 600 ft x 4.5 ft x .5 ft = 1,350 $ft^3$

Volume = 1,350 $ft^3$/27 $ft^3$/$yd^3$ = 50 $yd^3$

**Advantages:**

1. Most commonly used for class B & C bedding applications
2. Fairly high BF 1.5-1.9
3. Moderately priced
4. Easy to work with
5. It is superior to sand or pea gravel due to water infiltration/washout.
6. Native soils
    a. Use in place of granular material because more available
    b. Low bedding factor of 1.1 must have undisturbed trench bottom
    c. Use high strength pipe

### *Pipe laying*

1. Follow manufactures instructions
2. Use care when unloading at the site protect the bell and spigot
3. Use proper sized lifting equipment
4. For small diameter pipe <10 inches it may be hand laid on the bedding and connected
5. Larger pipe >10 inches should be supported in place so they can be connected while supported

It may be necessary to use the weight of the pipe to obtain the proper grade.

### *Joining of Pipe*

Most pipes in sanitary WW use a bell on one end and a spigot on the other and a resilient type gasket to make the joining of the bell and spigot watertight. The bell should be pointed upgrade when installing. The most resilient gasket is the "O" ring type sealed in a groove on the spigot or a of mating of rings precast in the bell and on the spigot.

Steps to join <u>bell and spigot</u>

1. Clean bell and spigot
2. Lube gasket and place in position
3. Guide spigot end of pipe into bell
4. Push or pull pipe into place
5. Inspect joint and seating of gasket
6. Check alignment and grade

### *Costs*

Costs for piping comparisons should include both the costs of the materials as well as the construction costs. The pipe cost is usually given in dollars per unit length, traditionally in $/linear foot, plus the costs of the fittings, connections, and joints.

Construction costs will depend on the type of digging necessary, special field equipment requirements, and an allowance for in-field adjustments to the system. Access to pipe systems will also be a relevant cost factor, as manhole spacing is dependant on pipe size. Sanitary sewer construction costs depend on several variables, including:

- Depth
- Type of soil
- Presence of rock
- Type of bedding material
- Location (rural vs. urban areas)
- Clearing costs
- Other factors

Typical pipe materials for small diameter sanitary sewers (8" through 24" diameter) include:

- PVC
- Vitrified clay
- Ductile iron

Typical average costs for sanitary sewers (excluding service connections and manholes) are provided in Table 4-2. The cost per linear foot in the table is based on an average trench depth of eight feet and excludes service connections and manholes. The following is not included in the cost per linear foot:

- Asphalt and gravel driveway repair.
- Open cut of roads.
- Boring and jacking.
- Concrete encasement of pipe at stream crossings or other locations.
- Erosion control.
- Relocation of other utilities.

Soil material is assumed to be silt, clay, or other soil mixtures with no requirement for shoring, rock removal, or dewatering.

**TABLE 5-2 (2011)**

| Pipe materials | 2” | 4” | 6” | 8” | 12” | 15” | 18” | 24” |
|---|---|---|---|---|---|---|---|---|
| Vitrified Clay | | | $33.54 | $40.65 | $50.82 | $68.09 | $88.42 | $148.38 |
| Ductile Iron | | | | $50.82 | $68.09 | NA | $101.63 | $148.38 |
| Reinforced concert | | | | | $15.24 | $23.37 | $30.49 | $40.65 |
| PVC | $20.33 | $25.41 | $31.51 | $33.54 | $40.65 | $50.82 | $68.09 | $101.63 |
| PE | | $9.15 | $16.26 | $19.31 | | | | |
| Fiberglass reinforced | $28.46 | $40.65 | $53.86 | $81.30 | | | | |
| ABS | $14.23 | | | | | | | |

## Review Questions for Pipes

1. _____________is the inside top of pipe and the _______is the lowest point of the inside of a pipe or manhole.
2. 4 common pipe materials are ______, _____, ________, and _________.
3. ____________ pipe is good for use when lots of industrial or chemical flows will be present.
4. ________ pipe is heavy and corrosion resistant, but is not $H_2S$ resistant.
5. __________ is the material upon which the pipe is laid and serves as it foundation.
6. Some background information used in determining what type of pipe best fits a particular situation include _________, __________, __________, ________, etc.
7. _________, pipe has short runs, is brittle, but good with chemical resistance.
8. Larger pipe >_________ should be supported in place so they can be connected while supported.
9. The pipe material must be compatible with the ______and _________ chemistry.
10. The ____________ ____ ______ _______ that will surround the pipes is a fundamental design aspect for the support characteristics, especially for flexible pipes.
11. How many cubic yards of asphalt paving material will be required to pave over a trench 2600 feet long, 7.5 feet wide using a 18 inch deep patch?

## Answers to Review Questions on Pipes

1. Crown, invert

2. PVC, concrete, ductile iron, vitrified clay

3. PVC or plastic

4. Concrete

5. Bedding

6. Maximum pressure conditions, soil conditions, soil chemistry, water table, stability, installation equipment required, chemical and physical properties of the wastewater

7. Vitrified clay

8. 10 inches

9. Soil, groundwater

10. Mechanics of the soil

11. 1,083 $yd^3$

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# Chapter 6: PUMPS

## Chapter 6 Objectives

1. Know and identify the classifications of pumps, the types of pumps and their uses as pertaining to wastewater treatment.
2. Know, identify, and understand the proper techniques associated with pump maintenance, and when they should be replaced or repairs.
3. Know, identify, and understand the techniques associated with the operating problems and causes of failed or reduced operating efficiency.
4. Recognize the functions of metering pumps.
5. Understand proper ways to restart pumps after maintenance.
6. Know, identify, and understand the purpose, functions, advantages, disadvantages, and issues with lift stations.
7. Know, identify, and understand the effective design criteria for cost effectiveness in designing, replacing, maintaining, and repairing lift stations.
8. Know and identify odor control techniques in lift stations.
9. Know, identify, and understand what emergency power supply equipment is used for collection systems in back up plans and power loss situations.
10. Define capacity, head, power, and overall efficiency as it pertains to pumps and how it affects performance optimization.
11. Know, identify, and understand the cost, cost analysis, and budgeting techniques associated with lift stations and force mains.
12. Define force mains and know their purpose, functions, design criteria, operation and maintenance principles, advantages and disadvantages.
13. Be familiar with the Hazen-Williams formula and roughness coefficient.
14. Calculate
    a. lbs, concentrations and flow rates using the lbs formula.
    b. Estimatate the number of days it will take to fill a bar screen.
    c. Volumes
    d. Pump rates.
    e. Overflow in lift stations.
    f. Water rising in a wet well.
    g. Cost of painting lift stions.
    h. Pump efficiency, horsepower, power costs, and pump rates.
    i. Operations and construction costs.
    j. Chlorine dosage in lift stations.

Pumps are the backbone of the collection system. A basic knowledge and understanding of how these devices work can help optimize your collection system.

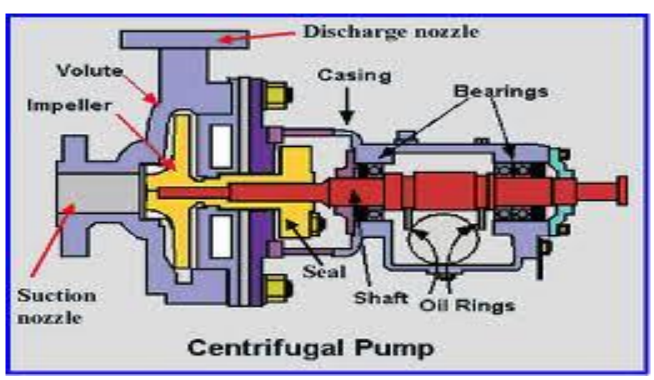
## *Classification*

1. They may be classified by the character of the material handled – raw wastewater, grit, effluent, activated sludge, raw sludge, or digested sludge.
2. They may be classified by pumping conditions – high lift, low lift, recirculation, or high capacity.
3. They may be classified by the principle of operation – centrifugal, propeller, reciprocating, incline screw, progressive cavity, or pneumatic ejector.

## *Types of Pumps*

Determining the proper pump for the proper application can be a very critical part of designing or maintaining proper flow throughout the collection system.

1. **Centrifugal pumps**: These pumps have an impeller (paddle-wheel type piece) rotating in a casing. The impeller is supported on a shaft which is then supported by bearings. Liquid enters the casing through the eye (at the center) of the impeller. It is then picked up by the curved impeller vanes and by the rotation of the impeller and is thrown out by the centrifugal force into the discharge. Impellers usually have large openings at their center to prevent clogging. A screen should be used at the intake end of the suction piping to prevent clogging. Impellers may be in closed casings or they may be open if the pump is submersible and being used to pump wastewater from lift station wet wells. The motor or drive mechanism can be connected directly to the shaft or connected by a coupling flange depending upon the application. These pumps should be replaced when groves appear on the shaft. Also when these pumps gradually begin pumping at lower flow rates over a period of time, the impellers could be wearing down.




**Picture 6-1 Centrifugal pump interior**

a. Shaft sleeves are used to cover the shaft that supports the impeller to protect the shaft from the corrosive and abrasive effects of the liquid going through the pump. The sleeves are mounted to the shaft on ball or roller bearings.

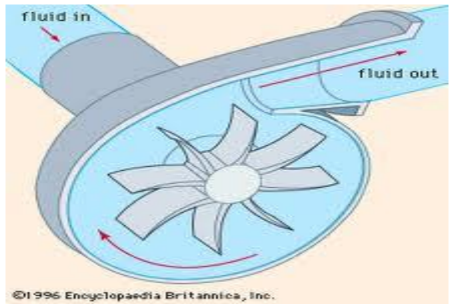
b. Wearing rings are used to plug the space between the impeller and the casing to prevent internal liquid leakage. These rings are either attached to the casing, the impeller, or both. Wearing rings should be inspected regularly and replaced when serious wear or leakage is observed. Since water is the lubricant between the rings and the impeller, a pump should never be allowed to run dry.

c. Stuffing boxes are used to prevent air from being sucked into the pump. Air affects the efficiency of the pump and could cause it to lose prime. It consists of a casing containing rings of packing and a gland or membrane at the outside end. Water is used in the stuffing box to block out the intake of air and to lubricate the packing. The water is brought into a seal cage in the center of the stuffing box under pressure by connector piping to a point near the impeller rim *provided it is clean liquid.* If the liquid being pumped contains grit or other solids, it may be necessary to use potable water to provide the seal. To prevent the possibility of a cross-connection, the connection with the potable water supply must include either an air gap separation or an approved backflow preventer to avoid contamination. Back flow preventers should stop the accidental backflow or reverse flow of wastewater into buildings.

d. The end gland or membrane is used to control liquid flow from the stuffing box. The gland should be tightened just enough such that a thin stream of water flows from the stuffing box. Excessive leakage is indicative of the need to replace the packing.

e. Lantern rings provide the water seal connection between the water supply line and the stuffing box. When packing is being replaced, the lantern ring should be completely filled with grease (if grease seals are used) before all the rings of packing are in place.

f. The efficiency of centrifugal non-clog pumps starts at zero at shut-off and increases rapidly until a peak is reached at approximately the mid-point of the overall capacity range of the pump. Therefore, for peak efficiency, best mechanical performance, and quietest operation; a pump should be selected so that the range of operation will be at the mid-point of the total pump curve. They should be operated near their rated heads (pressure). Otherwise, the pump is apt to operate under unsatisfactory and unstable conditions which reduce the efficiency and operating life of the unit.




**Picture 6-2 Centrifugal Pump with flow direction**

**<u>Propeller pumps</u>**: Two basic types.

<u>Axial-flow</u> pumps have flow parallel to the axis of the impeller.

**Picture 6-3 Axial flow propeller pump**

<u>Mixed-flow</u> pumps have flow that is both axial and radial (perpendicular to the shaft) to the impeller.

**Picture 6-4 Mixed flow propeller pump**

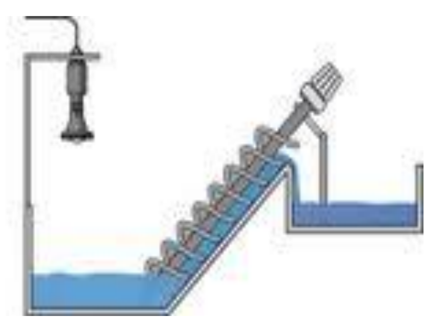
## Reciprocating or Piston pumps

Pumps used to move sludge by a piston that moves back and forth. Reciprocating pumps should never be allowed to pump against a closed discharge valve due to a build up of pressure that could damage the pump and/or the piping.

**Picture 6-5 Piston Pump**

## Incline screw pumps

An auger type pump housed in a trough that is on an incline. The auger is supported by bearings on both ends. The screw or auger operates at a constant speed moving the wastewater up the trough to a point of discharge. These are commonly used on influent and effluent waste streams where low lift, high capacity, non-clog pumping is required. They may range in size from 12 to 144 inches in diameter with rated capacities from 100 to 70,000 gpm. They are primarily suited for lifts up to 25 feet but are available for higher lifts.

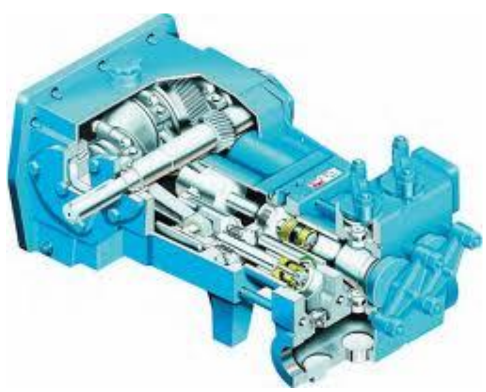


**Picture 6-6 inclined screw pump**

## Progressive cavity pumps

These are similar to incline screw pumps except that the screw shaped rotor is enclosed in a housing (stator). The spacing between the rotor and the inside casing walls form a series of cavities. As the rotor turns, the threads make contact with the walls and move the water along in auger fashion. The size of the cavities along the rotor determines the capacity of the pump. These pumps are recommended for liquids containing higher concentrations of solids. Like reciprocating pumps, they should never be operated dry nor against a closed discharge valve.

**Picture 6-7 Progressive cavity pump**



**Picture 6-8 Pneumatic injector or air lift pump**

## Pneumatic ejectors (Air Lift)

An air lift ejector consists of a receiving container, inlet and outlet check valve, air supply, and liquid level detector. When the wastewater reaches a preset level, air is forced into the container, ejecting the wastewater. Following the discharge cycle, the air supply is cut off and wastewater flows through the inlet into the receiver. With flow ranges from 30 to 150 gpm, they are mostly used for pumping raw wastewater. These pumps are capable of passing solids up to the size of the inlet and discharge valves since there is nothing on the inside of the ejector-receiver to restrict the flow. They are, however, a high maintenance problem. If a stick or other object gets stuck in either check valve, the ejector will not operate.

## Metering pumps

These pumps are used to measure a quantity of substance that is being pumped into the system. These pumps can be used to add hypochlorite, peroxide, and other chemicals such as odor controlling liquids to the collection system.

**Picture 6-9 Metering Pump**

**Picture 6-10 Metering Pump**

## Calculate the Time it takes to Pump out a Tank

If two 337.5 gpm pumps are used how, long will it take in hours to de-water a rectangular tank. 60 feet long by 35 feet wide and 14 feet deep?

First calculate the volume of the tank and convert to gallons.

Volume = 60 ft x 35 ft x 14 ft = 29,400 $ft^3$ = 29,400 $ft^3$ x 7.48 = 219,912 gallons

Divide the pump rate by the number of gallons to find the time. Convert to hours.

$$\frac{219{,}912 \text{ gal}}{675 \text{ gal/min}} = 325.80 \text{ min} \qquad \frac{325.80 \text{ min}}{60 \text{ min/hr}} = 5.42 \text{ hrs}$$

### Calculate Horsepower and Kilowatt Hours

A pump has a capacity of 2500 gpm and it uses 55 kilowatts. Pump efficiencies average 90% for this size pump, what size horsepower motor is required?

You will calculate the horsepower of the pump that is required by using the kilowatts equation.

$$\text{hp} = \frac{\text{kilowatts x efficiency}}{.746}$$

$$\text{hp} = \frac{55 \text{ kilowatts x } .90}{.746} = 66.35 \text{ hp is the minimum hp needed for proper operation}$$

## *Maintenance of Pumps and Motors*

Maintaining pumps and motors can be critical to keeping the collection system operating at an optimum rate. In addition to good system operation, maintaining the pumps and motors can prevent costly repairs and replacements. Before doing work on pumps or other equipment it is important to practice lock out tag out principles. The equipment should be locked in such a way that it can only be turned back on by the person working on the equipment. Also a tag identifying who locked the equipment out and the type of maintenance being performed on the equipment should be placed on the lock to identify the problem and so the proper person can be contacted about the maintenance.

1. Check the condition of the motor for dirt, dust, moisture, air circulation obstructions, and excessive leakage of grease from the bearings.
2. Observe any unusual conditions including noise, excessive heat, vibration, intermittent to continuous sparking of brushes, or sluggish operation. A stethoscope is sometimes used to check for bearing whines, gratings, or uneven noises. Cavitations can be a reason for a pump to run noisy or sound like a marble is trapped in the volute.
3. Keep close watch on the amperage being pulled by the motors. A sudden increase could be indicative of a pumping restriction while a sudden decrease may be the result of a drop in pumping head caused by a break in the discharge line.

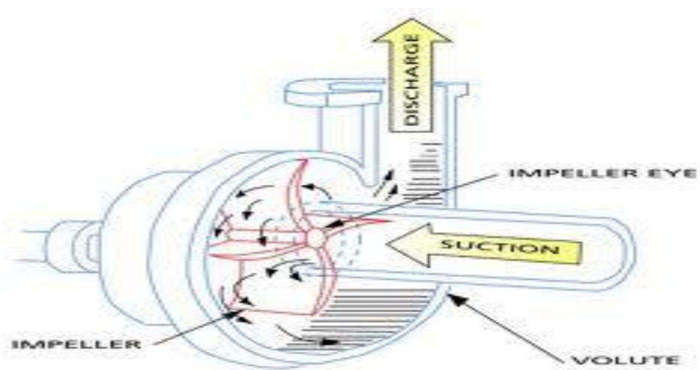
4. When restarting a pump after maintenance or repair, you should calibrate it to verify that it is operating in accordance with its design parameters.

For motors wound for 3-phase current, periodically check to insure equal distribution across all three phases. If one phase cuts out while in operation the motor may overheat and become damaged unless it is stopped by a thermal control device.

## Pump Operating Problems & Causes of Failure or Reduced Operating Efficiency

Causes for pump not starting:

1. Blown fuses or circuit breakers due to:
2. Rating of fuses or circuit breakers not correct
3. Switch (breaker) contacts corroded or shorted
4. Terminal connections loose or broken somewhere in the circuit
5. Automatic control mechanism not functioning properly
6. Motor shorted or burned out
7. Wiring hookup or service not correct
8. Switches not set for operation
9. Contacts of the control relays dirty and arcing
10. Fuses or thermal units too warm
11. Wiring short-circuited
12. Shaft binding or sticking due to rubbing impeller, tight packing glands, or clogging of pump
13. Loose connection, fuse, or thermal unit




**Picture 6-11 Pump parts diagram**

Causes for reduced pump discharge rates:

1. Pump not primed
2. Mixture of air in the wastewater
3. Speed of motor too low
4. Improper wiring
5. Defective motor
6. Discharge head too high
7. Suction lift higher than anticipated
8. Impeller clogged
9. Discharge line clogged
10. Pump rotating in wrong direction
11. Air leaks in suction line or packing box
12. Inlet to suction too high, permitting air to enter
13. Valves partially or entirely closed
14. Check valves stuck or clogged
15. Incorrect impeller adjustment
16. Impeller damaged or worn
17. Packing worn or defective
18. Impeller turning on shaft because of broken key
19. Flexible coupling broken
20. Loss of suction during pumping may be caused by leaky suction line, ineffective water or grease seal
21. Belts slipping
22. Worn wearing ring

Causes for high power requirements:

1. Speed of rotation too high
2. Operating heads lower than rating for which pump was designed, resulting in excess pumping rates
3. Check valves open, draining long force-main back into wet-wall
4. Specific gravity or viscosity of liquid pumped too high
5. Clogged pump
6. Sheaves on belt drive misaligned or maladjusted
7. Pump shaft bent
8. Rotating elements binding
9. Packing too tight
10. Wearing rings worn or binding
11. Impeller rubbing

Causes for noisy pump operation:

1. Pump not completely primed
2. Inlet clogged
3. Inlet not submerged
4. Pump not lubricated properly
5. Worn impellers
6. Strain on pumps caused by unsupported piping fastened to the pump
7. Foundation insecure
8. Mechanical defects in pump
9. Misalignment of motor and pump where connected by flexible shaft
10. Rags or sticks bound (wrapped) around impeller

## *Lift Stations*

Wastewater lift stations are facilities designed to move wastewater from lower to higher elevation through pipes. Key elements of lift stations include a wastewater receiving well (wet-well), often equipped with a mechanically cleaned bar screens in larger pump stations in order to protect the pumps, or grinders to remove coarse materials; pumps and piping with associated valves; motors; a power supply system; an equipment control and alarm system; and an odor control system and ventilation system. Pressure control valves are used to reduce pipeline pressures below a safe operating pressure during liftstation startup and shut-down. Critical pumping stations are often equipped with diesel generators to provide power to critical equipment in the event of a blackout or loss of electricity. Connection points to a generator in a lift station should be checked and tightened annually.

**Estimating the number of days it will take to fill a bar screen:**

A pump station has been averaging a screenings removal of 3.2 $ft^3$ per million gallons. The average daily flow to the pump station is 4.5 MGD. How many days will it take to fill a screen with a 96 $ft^3$ capacity?

First find out how much is screened out per day by multiplying the flow times the volume. Then find out how many days by dividing the capacity by the flow.

Materials screened per day = 4.5MGD x 3.2 $ft^3$/MG = 14.4 $ft^3$ per day

Days to fill the screen = $\frac{96\ ft^3}{14.4\ ft^3/day}$ = 6.67 days

**Calculating cost for solids removal**

A collection system has an average daily flow of 7.44 MGD with an average daily screenings load of 205 mg/L. If this facility removes 92% of the screenings, at $75.50 per ton for land fill disposal, what is the yearly cost of disposal? There is .75 lbs of screenings removed that can go to landfill after being removed.

First calculate the lbs of BOD produced. Then calculate the amount of solids that are produced and determine the cost.

Lbs of BOD per day = 7.44 MGD x 8.34 x 205 mg/L = 12,720.17 lbs
Lbs of BOD removed per day = 12,720.17 lbs x .92 = 11,702.55 lbs
Lbs of BOD removed per year = 11,702.55 lbs x 365 = 4,271,430.75 lbs

Tons of BOD removed per year = $\frac{4,271,430.75\ lbs}{2,000\ lb/\ ton}$ 2,135.72 tons

# of lbs of solids removed per year = 2,135.72 tons x .75 = 1,601.79

Cost per year = 1,601.79 tons x $75.50 = $120,934.95

Lift station equipment and systems are often installed in an enclosed structure. They can be constructed on-site (custom-designed) or prefabricated. Lift station capacities range from 20 gallons per minute to more than 100,000 gallons per minute. Pre-fabricated lift stations generally have capacities of up to 10,000 gallons per minute.

Centrifugal pumps are commonly used in lift stations. A trapped air column, or bubbler system, that senses pressure and level is commonly used for pump station control. Other control alternatives include electrodes placed at cut-off levels, floats, mechanical clutches, and floating mercury switches. A more sophisticated control operation involves the use of variable speed drives.

Lift stations are typically provided with equipment for easy pump removal. Floor access hatches or openings above the pump room and an overhead monorail beam, bridge crane, or portable hoist are commonly used.

The two most common types of lift stations are the dry-pit or dry-well and submersible lift stations. In dry-well lift stations, pumps and valves are housed in a pump room (dry pit or dry-well), that is easily accessible. The wet-well is a separate chamber attached or located adjacent to the dry-well (pump room) structure. Pictures 6-12 and 6-13 illustrate the two types of pumps.

Submersible lift stations do not have a separate pump room; the lift station header piping, associated valves, and flow meters are located in a separate dry vault at grade for easy access. Submersible lift stations include sealed pumps that operate submerged in the wet-well. These are removed to the surface periodically and reinstalled using guide rails and a hoist.

## *Dry Pit*

A key advantage of dry-well lift stations is that they allow easy access for routine visual inspection and maintenance. In general, they are easier to repair than submersible pumps. An advantage of submersible lift stations is that they typically cost less than dry-well stations and operate without frequent pump maintenance. Submersible lift stations do not usually include large aboveground structures and tend to blend in with their surrounding environment in residential areas. They require less space and are easier and less expensive to construct.

Pre-fabricated pump stations are available in various forms and can be either dry-well or submersible. Pre-fabricated pump stations are typically used for smaller flows because they are more compact and generally lower in cost than custom-designed pump stations. Pre-fabricated drywell pump stations usually include steel or plastic shell that is designed to house one to three vertical shaft flooded suction pumps. Pumps, valves and other equipment are installed at the factory prior to shipment.

Circular station shells are more common and larger pump stations can have an oval shape. Pump station shells are typically bolted to cast-in place concrete base slabs at the job site. In wet well configurations, the wet well usually is constructed of pre-cast concrete. Pre-fabricated submersible stations are typically constructed of pre-cast concrete or steel and can accommodate one or two submersible pumps. For pre-cast concrete stations, the pump manufacturer may provide a complete package of equipment, including submersible pumps, discharge elbows, check valves, access hatches, and level controls. For steel stations, the equipment is typically pre-packaged at the factory. Fiberglass tanks are typically used for smaller pump stations.

**Calculating volumes**

What is the volume of a tank in cubic feet if it is 100 ft long, 30 ft wide and 20 ft deep?

The tank is a rectangle. Therefore the volume will equal length * width * height.

Volume = 100 ft * 30 ft * 20 ft = 60, 000 $ft^3$

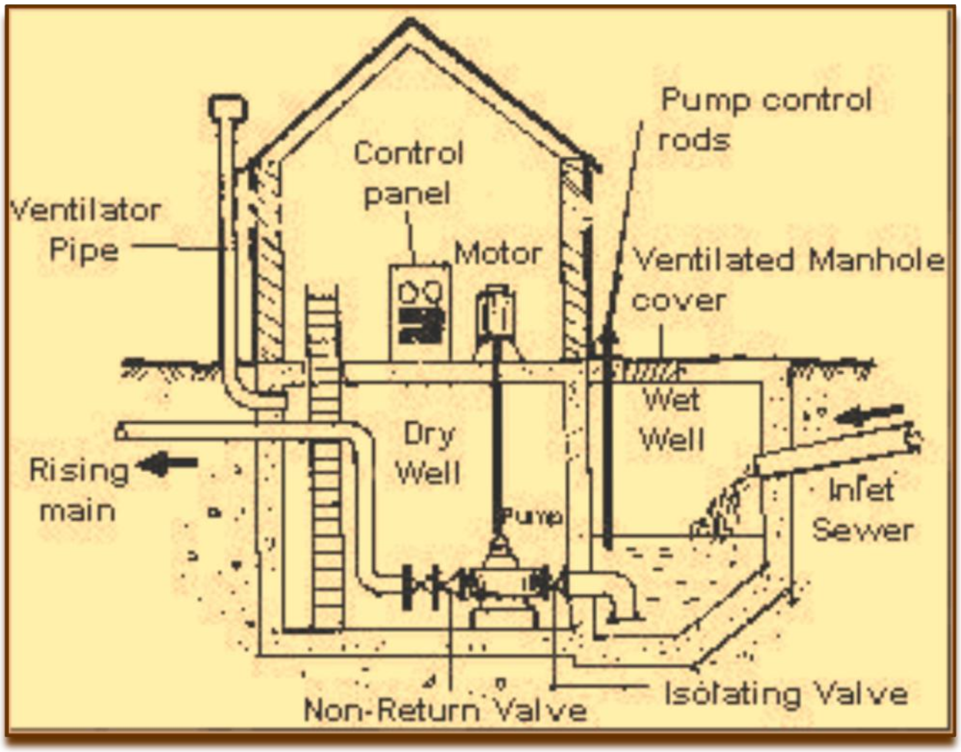
What is the volume of asphalt removed in cubic feet if a manhole is to be constructed that is 25 feet in diameter and 6 inches deep?

This section removed from the asphalt would be a cylinder.

Length= $\frac{\text{6inches}}{\text{12 inches}}$ = .5 ft     diameter = .785 x D x D x Length

Volume = .785 x 25ft x 25 ft x .5 ft = 245.31 $ft^3$

**Picture 6-12 Dry well and wet well station**



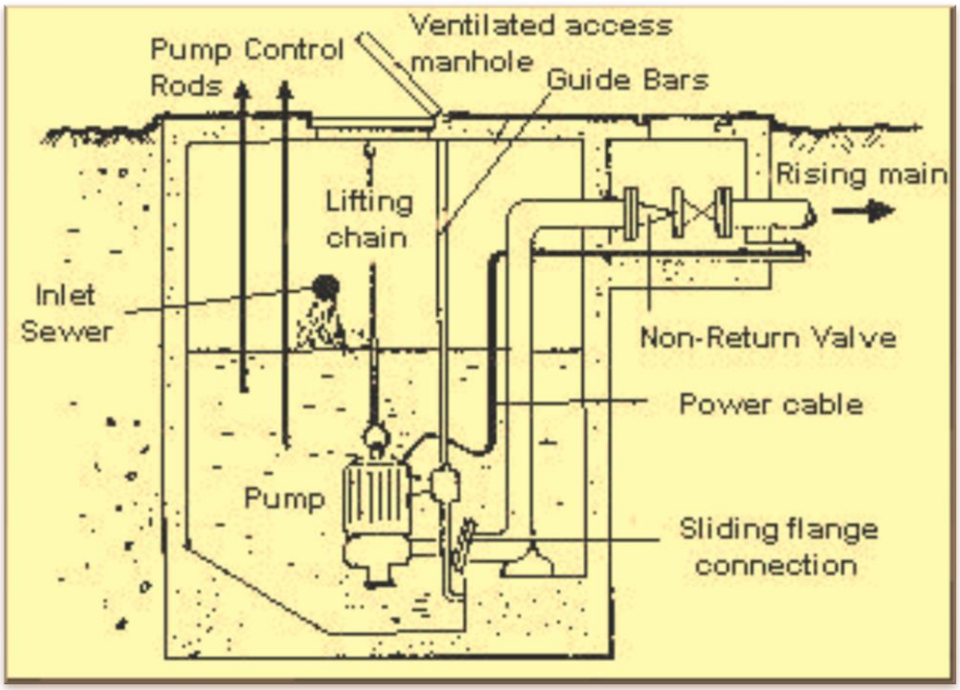

## *Applicability*

Lift stations are used to move wastewater from lower to higher elevation, particularly where the elevation of the source is not sufficient for gravity flow and/or when the use of gravity conveyance will result in excessive excavation depths and high sewer construction costs.

Lift stations are widely used in wastewater conveyance systems. Dry-well lift stations have been used in the industry for many years. However, the current industry-wide trend is to replace drywell lift stations of small and medium size (typically less than 24,000 liters per minute or 6,350 gallons per minute) with submersible lift stations mainly because of lower costs, a smaller footprint, and simplified operation and maintenance.

Variable speed pumping is often used to optimize pump performance and minimize power use. several types of variable-speed pumping equipment are available, including variable voltage and frequency drives, eddy current couplings, and mechanical variable-speed drives. Variable-speed pumping can reduce the size and cost of the wet well and allows the pumps to operate at maximum efficiency under a variety of flow conditions. Because variable-speed pumping allows lift station discharge to match inflow, only nominal wet-well storage volume is required and the well water level is maintained at a near constant elevation.

**Picture 6-13 wet well**




Variable-speed pumping may allow a given flow range to be achieved with fewer pumps than a constant-speed alternative. Variable-speed stations also minimize the number of pump starts and stops, reducing mechanical wear. Although there is significant energy saving potential for stations with large friction losses, it may not justify the additional capital costs unless the cost of power is relatively high. Variable speed equipment also requires more room within the lift station and may produce more noise and heat than constant speed pumps.

Lift stations are complex facilities with many auxiliary systems. Therefore, they are less reliable than gravity wastewater conveyance. However, lift station reliability can be significantly improved by providing stand-by equipment (pumps and controls) and emergency power supply systems. In addition, lift station reliability is improved by using non-clog pumps suitable for the particular wastewater quality and by applying emergency alarm and automatic control systems.

Modern pump stations are equipped with automatic controls for pump starting and operational sequencing. The pump stations typically have standby pumps to increase reliability and provide adequate capacity for unusually high flows. In unattended pumping stations, automatic controllers are frequently used to allow switch over to standby units when a pump fails. Flow recording equipment is often installed to record instantaneous pumping rates and the total flow pumped.

The useful life of pump station equipment is typically limited to 20 to 30 years, with good maintenance. Pump station structures typically have a useful life of 50 years. The useful life of pump station equipment and structures can be prolonged by using corrosion-resistant materials and protective coatings.

**Calculating velocity**

Wastewater is pumped into a 6 inch line by a 300 gal/min pump that is 85% efficient, what is the velocity of the wastewater in the line?

The velocity can be found by using the velocity equation V = Q/A. the flow (Q) is given and solving for the area using the area of a circle for the 6 in line. First convert inches into feet and gallons into $ft^3$.

$A = .785 \times .5\ ft \times .5\ ft = .1963\ ft^2$  $300\ gal = \frac{300\ gal}{7.48} = 40.11\ ft^3/min$

$$V = \frac{40.11\ ft^3/min}{.1963\ ft^2} = 204.31\ ft/min$$

Divide by 60 to get the number of ft per second. Then multiply by the efficiency.

$$V = \frac{204.31\ ft/min}{60 sec/min} = 3.40\ ft/sec \times .85 = 2.89\ ft/sec$$

## Advantages

Lift stations are used to reduce the capital cost of sewer system construction. When gravity sewers are installed in trenches deeper than 10 feet, the cost of sewer line installation increases significantly because of the more complex and costly excavation equipment and trench shoring techniques required. The size of the gravity sewer lines is dependent on the minimum pipe slope and flow. Pumping wastewater can convey the same flow using smaller pipeline size at shallower depth, and thereby, reducing pipeline costs.

## Disadvantages

Compared to sewer lines where gravity drives wastewater flow, lift stations require a source of electric power. If the power supply is interrupted, flow conveyance is discontinued and can result in flooding upstream of the lift station, It can also interrupt the normal operation of the downstream wastewater conveyance and treatment facilities. This limitation is typically addressed by providing an emergency power supply.

Key disadvantages of lift stations include the high cost to construct and maintain and the potential for odors and noise. Lift stations also require a significant amount of power, are sometimes expensive to upgrade, and may create public concerns and negative public reaction. The low cost of gravity wastewater conveyance and the higher costs of building, operating, and maintaining lift stations means that wastewater pumping should be avoided, if possible and technically feasible.

Wastewater pumping can be eliminated or reduced by selecting alternative sewer routes or extending a gravity sewer using direction drilling or other state-of-the-art deep excavation methods. If such alternatives are viable, a cost benefit analysis can determine if a lift station is the most viable choice.

## Reliability

Pump stations are complex facilities that contain a significant number of equipment and auxiliary systems. Therefore, they are less reliable than gravity wastewater conveyance but the pump station reliability can be significantly improved.

A way to improve the situation is by providing standby equipment (pumps and controls) and emergency power supply systems. In addition, pump station reliability is improved by using screens to remove debris, by using non-clog pumps suitable for the particular wastewater quality, and by applying emergency alarm and automatic control systems.

In an emergency (pump malfunction, power failure, etc.) a portion of the wastewater conveyed to the pump station may overflow to nearby surface waters causing potential health risk. Emergency sewer overflows are mitigated by installation of highly reliable equipment, providing redundant control systems and installing facilities for overflow storage and/or treatment prior to discharge to surface waters.

Potential odor problems are mitigated by installation of various odor control systems, including reduction of odor release by adding chemicals upstream of the pump station and odorous gases evacuation and treatment at the pump

## Design Criteria

Cost effective lift stations are designed to:

- Match pump capacity, type, and configuration with wastewater quantity and quality;
- Provide reliable and uninterruptible operation
- Allow for easy operation and maintenance of the installed equipment
- Accommodate future capacity expansion
- Avoid septic conditions and excessive release of odors in the collection system and at the lift station
- Minimize environmental and landscape impacts on the surrounding
- Residential and commercial developments
- Avoid flooding of the lift station and the surrounding areas

## Wet-well

Wet-well design depends on the type of lift station configuration (submersible or dry-well) and the type of pump controls (constant or variable speed). Wet-wells are typically designed large enough to prevent rapid pump cycling but small enough to prevent a long detention time and associated odor release.

Wet-well maximum detention time in constant speed pumps is typically 20 to 30 minutes. Use of variable frequency drives for pump speed control allows wet-well detention time reduction to 5 to 15 minutes. The minimum recommended wet-well bottom slope is to 2:1 to allow self-cleaning and minimum deposit of debris.

Effective volume of the wet-well may include sewer pipelines, especially when variable speed drives are used. Wet-wells should always hold some level of sewage to minimize odor release. Bar screens or grinders are often installed in or upstream of the wet-well to minimize pump clogging problems.

## Wastewater Pumps

The number of wastewater pumps and associated capacity should be selected to provide head capacity characteristics that correspond as nearly as possible to wastewater quantity fluctuations. This can be accomplished by preparing pump/pipeline system head-capacity curves showing all conditions of head (elevation of a free surface of water) and capacity under which the pumps will be required to operate.

The number of pumps to be installed in a lift station depends on the station capacity, the range of flow and the regulations. In small stations, with maximum inflows of less than 2,640 liters per minute (700 gallons per minute), two pumps are customarily installed, with each unit able to meet the maximum influent rate.

For larger lift stations, the size and number of pumps should be selected so that the range of influent flow rates can be met without starting and stopping pumps too frequently and without excessive wet-well storage. Depending on the system, the pumps are designed to run at a reduced rate.

The pumps may also alternate to equalize wear and tear. Additional pumps may provide intermediate capacities better matched to typical daily flows. An alternative option is to provide flow flexibility with variable speed pumps.

For pump stations with high head-losses, the single pump flow approach is usually the most suitable. Parallel pumping is not as effective for such stations because two pumps operating together yield only slightly higher flows than one pump. If the peak flow is to be achieved with multiple pumps in parallel, the lift station must be equipped with at least three pumps: two duty pumps that together provide peak flow and one standby pump for emergency backup.

Parallel peak pumping is typically used in large lift stations with relatively flat system head curves. Such curves allow multiple pumps to deliver substantially more flow than a single pump. The use of multiple pumps in parallel provides more flexibility.

Several types of centrifugal pumps are used in wastewater lift stations. In the straight-flow centrifugal pumps, wastewater does not change direction as it passes through the pumps and into the discharge pipe. These pumps are well suited for low-flow/high head conditions. In angle-flow pumps, wastewater enters the impeller axially and passes through the volute casing at 90 degrees to its original direction (Picture 5-3). This type of pump is appropriate for pumping against low or moderate heads.

Mixed flow pumps are most viable for pumping large quantities of wastewater at low head. In these pumps, the outside diameter of the impeller is less than an ordinary centrifugal pump, increasing flow volume.

## Ventilation

Ventilation and heating are required if the lift station includes an area routinely entered by personnel. Ventilation is particularly important to prevent the collection of toxic and/or explosive gases. According to the Nation Fire Protection Association (NFPA) Section 820, all continuous ventilation systems should be fitted with flow detection devices connected to alarm systems to indicate ventilation system failure.

Dry-well ventilation codes typically require six continuous air changes per hour or 30 intermittent air changes per hour. Wet-wells typically require 12 continuous air changes per hour or 60 intermittent air changes per hour.

Motor control center (MCC) rooms should have a ventilation system adequate to provide six air changes per hour and should be air conditioned to between 13 and 32 degrees Celsius (55 to 90 degrees F). If the control room is combined with an MCC room, the temperature should not exceed 30 degrees C or 85 degrees F. All other spaces should be designed for 12 air changes per hour. The minimum temperature should be 13 degrees C (55 degrees F) whenever chemicals are stored or used.

## Odor Control

Odor control is frequently required for lift stations. Four major ways to control odors are chemical addition, air injection, carbon adsorption, and biofilters. Another relatively simple and widely used odor control alternative is minimizing wet-well turbulence. Chemicals typically used for odor control include chlorine, hydrogen peroxide, metal salts (ferric chloride and ferrous sulfate) oxygen, air, and potassium permanganate. Chemicals should be closely monitored to avoid affecting downstream treatment processes, such as extended aeration. Scrubber and biofilters are a more expensive form of odor control. Air injection is less effective than the other methods. If odorous compounds are present at the point of air injection, they will diffuse in dissolved air and escape to the atmosphere. This can sometimes worsen the odor. Also, depending on the amount of air injected, turbulence can release odors and make the problem with odors even worse.

**Using the lbs formula**

What is the chlorine feed rate per day to a lift station for a flow of 2,800,000 gal with a dose rate of 17 mg/L?

Since the feed rate in lbs is required, use the numbers provided and place them in the lbs formula. First convert gallons into MGD.

$$2,800,000 \text{ gallons} = \frac{2,800,000}{1,000,000} = 2.8 \text{ MGD}$$

Lbs = 2.8 MGD x 8.34 x 17 mg/L = 397 lbs

**Calculate the chlorine dosage in a lift station**

A lift station pumps 1.4 MGD of wastewater per day. The water contains an average of 330 lbs of solids. How much chlorine in mg/L would be needed for keeping this system fresh?

Using the lbs formula find out the amount chlorine needed.

$$\text{Concentration} = \frac{330 \text{ lbs}}{8.34 \times 1.4 \text{ MGD}}$$

Concentration = 28.26 mg/L of chlorine

## Power Supply

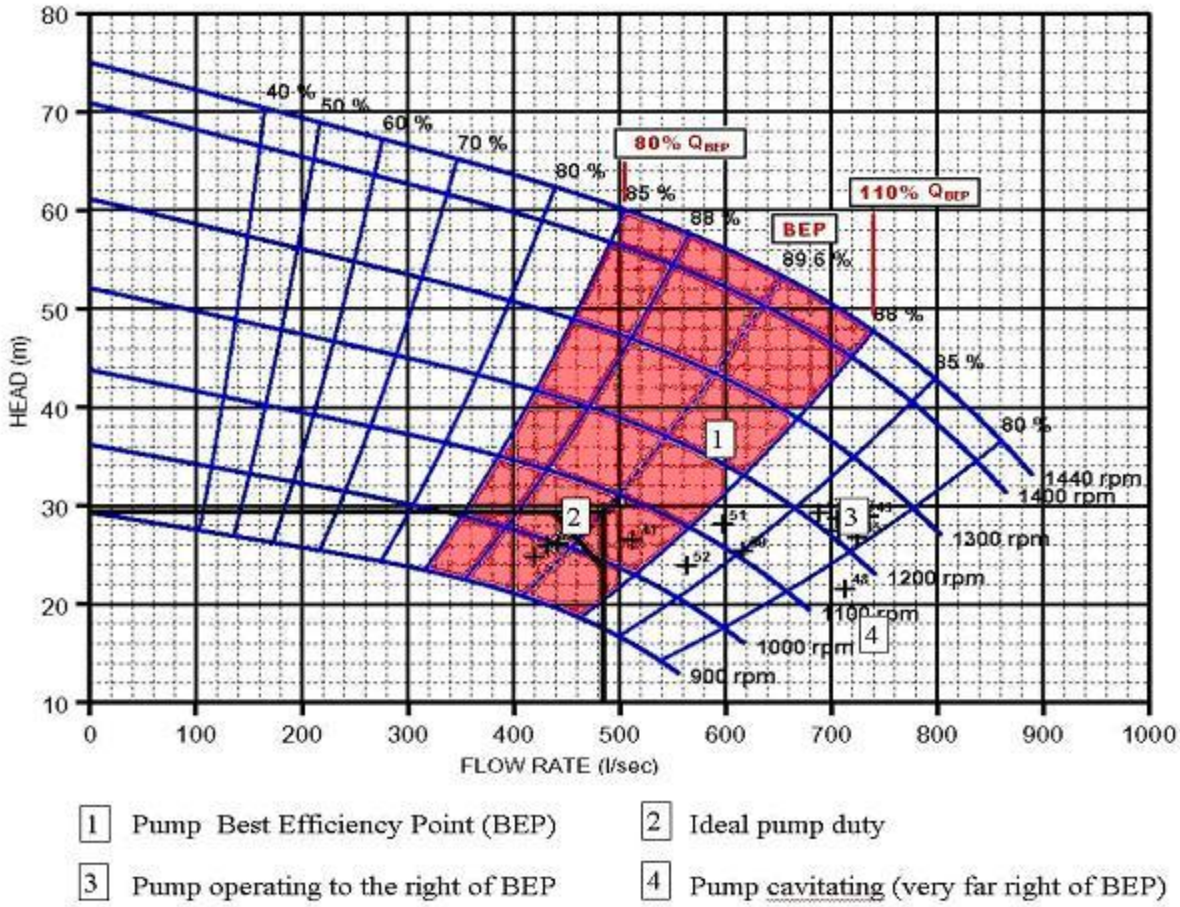
The reliability of power for the pump motor drives is a basic design consideration. Commonly used methods of emergency power supply include electric power feed from two independent power distribution lines; an on-site standby generator; an adequate portable generator with quick connection; a stand-by engine driven pump; ready access to a suitable portable pumping unit and appropriate connections; and availability of an adequate holding facility for wastewater storage upstream of the lift station. Critical pumping stations are often equipped with diesel generator to provide power to critical equipment in the event of a blackout or loss of electricity.

## Performance

The overall performance of a lift station depends on the performance of the pumps. All pumps have four common performance characteristics: capacity, head, power, and overall efficiency. Capacity (flow rate) is the quantity of liquid pumped per unit of time, typically measured as gallons per minute (gpm) or million gallons per day (MGD).
Head is the energy supplied to the wastewater per unit weight, typically expressed as feet of water. Power is the energy consumed by a pump per unit time, typically measured as kilowatt-hours. Overall efficiency is the ratio of useful hydraulic work performed to actual work input. Efficiency reflects the pump relative power losses and is usually measured as a percentage of applied power.

Pump performance curves are used to define and compare the operating characteristics of a pump and to identify the best combination of performance characteristics under which a lift station pumping system will operate under typical conditions (flows and heads.

**Chart 6-1**
**Pump Efficiency Curve**



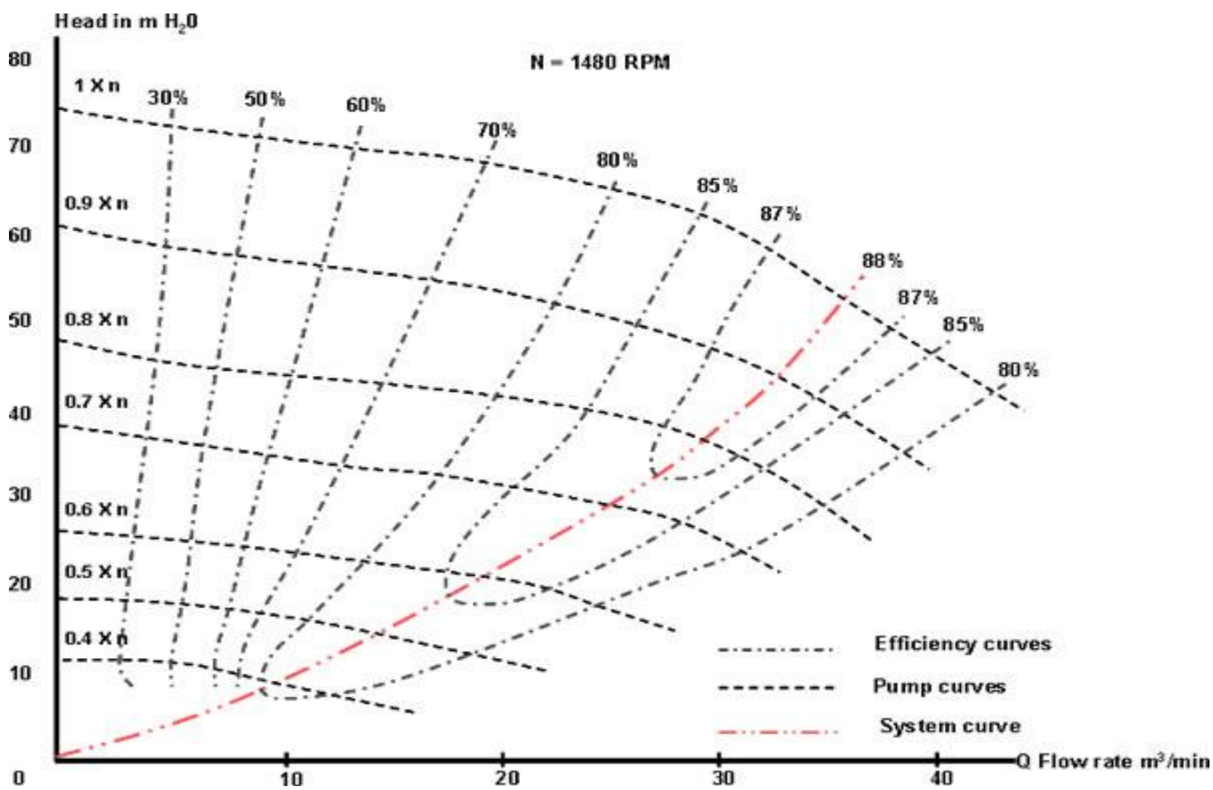

Pump systems operate at 75 to 85 percent efficiency most of the time, while overall pump efficiency depends on the type of installed pumps, their control system, and the fluctuation of influent wastewater flow. Performance optimization strategies focus on different ways to match pump operational characteristics with system flow and head requirements.

They may include the following options:

- Adjusting system flow paths
- Installing variable speed drives
- Using parallel pumps
- Installing pumps of different sizes
- Trimming a pump impeller
- Putting a two-speed motor on one or more pumps in a lift station

While savings will vary with the system, electrical energy savings in the range of 20 to 50 percent are possible by optimizing system performance.

**Chart 6-2**
**Pump Efficiency Curve**



## *Operation and Maintenance*

Lift station operation is usually automated and does not require continuous on-site operator presence. However, frequent inspections are recommended to ensure normal functioning and to identify potential problems early. Weekly pump station inspection typically includes observation of the following:

- Pumps, motors and drives for unusual noise, vibration, heating or leakage
- Check of pump suction and discharge lines for valving arrangement and leakage
- Check of control panel switches for proper position; monitoring of discharge pump rates and pump speed
- Monitoring of pump suction and discharge pressure

Lift station inspection typically includes observation of pumps, motors and drives for unusual noise, vibration, heating and leakage, check of pump suction and discharge lines for valving arrangement and leakage, check of control panel switches for proper position, monitoring of discharge pump rates and pump speed, and monitoring of the pump suction and discharge pressure. Weekly inspections are typically conducted, although the frequency really depends on the size of the lift station.

If a lift station is equipped with grinder bar screens to remove coarse materials from the wastewater, these materials are collected in containers and disposed of to a sanitary landfill site as needed. If the lift station has a scrubber system for odor control, chemicals are supplied and replenished typically every three months. If chemicals are added for odor control ahead of the lift station, the chemical feed stations should be inspected weekly and chemicals replenished as needed.

**Calculate the pump rate**

A circular wet well measures 9 feet in diameter. If the pump lowers the water level 2.5 feet in 6 minutes, what is the pumping rate of the pump in gallons per minute? Assume no inflow.

First we find the volume of the cylinder in gallons. Then we divide it by the time to get the pump rate.

Volume = .785 x 9 ft x 9 ft x 2.5 = 158.96 $ft^3$ = 158.96 $ft^3$ x 7.48 = 1,189 gal

$$\text{Pump rate} = \frac{1{,}189 \text{ gal}}{6 \text{ min}} = 198.17 \text{ gal/min}$$

**Calculating overflow**

A lift station is 17 feet by 15 feet and a depth of 100 feet. If the depth is now is at elevation of 81 feet. How many additional gallons can the lift station hold before it overflows?

First calculate the total number of gallons that the lift station can hold. Then calculate how much water is in there currently. Find the difference in the two.

Total Volume = 17 ft x 15 ft x 100 ft = 25,500 $ft^3$ 25,500$ft^3$ x 7.48 = 190,740 gal

Current Volume = 17 ft x 15 ft x 81 ft = 20,655 $ft^3$ 20,655ft x 7.48 = 154,499.4 gal

Total volume – Current Volume = 190,740 gal - 154,499.4 gal = 36,240.6 gal

The most labor-intensive task for lift stations is routine preventive maintenance. A well-planned maintenance program for lift station pumps prevents unnecessary equipment wear and downtime. Lift station operators must maintain an inventory of critical spare parts. The number of spare parts in the inventory depends on the critical needs of the unit, the rate at which the part normally fails, and the availability of the part. The operator should tabulate each pumping element in the system and its recommended spare parts. This information is typically available from the operation and maintenance manuals provided with the lift station.

## Sanitary Sewer Lift Station Maintenance Tips

Performance of routine and preventative maintenance can save the onsite lift station owner from costly repair bills. The following are suggestions that may insure fewer breakdowns and problems:

- ✓ Wet wells should be pumped out and cleaned at least twice a year, or more often if necessary, to prevent solids and grease build-up. Build-up of solids can create odors and damage the pump.
- ✓ Inspection of submersible pumps should be performed quarterly. Inspection of the impeller should be performed quarterly or when motor hours are not within 10% of each other. The inspections would assure that the impeller is free of debris.

- ✓ Inspection of the check valves should be performed at least twice a year to insure proper working order and to prevent backflow from the force main to the wet well.
- ✓ Cleaning and inspections of floats four times a year assure proper performance. The buildup of grease prevents floats from working properly.
- ✓ Inspection of the light and alarm systems should be performed weekly. An alarm system in working order can alert you to problems immediately.
- ✓ Installation of hour meters on each motor will give one an accurate record of how often each motor is cycling; and hence, the amount of water being pumped through the system. A logbook of motor hours, dates and maintenance performed should be kept.
- ✓ Amp readings should be taken at least once a month on each motor in the on-site lift station. If the amp readings do not meet the manufacturer's specifications, it is an indication that debris is lodged in the propeller within the motor, or that water has entered the motor housing or the wiring.
- ✓ A semi-annual inspection of all electrical motor control equipment to find poor connections and worn parts should be performed.
- ✓ Connection points to a generator in a lift station should be checked and tightened annually.

**Picture 6-14 Lift station**

## Costs

Lift station costs depend on many factors, including:

- Wastewater quality, quantity, and projections
- Zoning and land use planning of the area where the lift station will be located
- Alternatives for standby power sources
- Operation and maintenance needs and support
- Soil properties and underground conditions
- Required lift to the receiving (discharge) sewer line
- The severity of impact of accidental sewage spill upon the local area
- The need for an odor control system

These site and system specific factors must be examined and incorporated in preparing a lift station cost estimate. The most important factors influencing cost are the design lift station capacity and the installed pump power. Another cost factor is the lift station complexity.

Factors which classify a lift station as complex include two or more of the following:

- Extent of excavation
- Subsurface condition
- Congested site and/or restricted access
- Rock excavation
- Extensive dewatering requirements, such as cofferdams
- Site conflicts, including modification or removal of existing facilities
- Special foundations, including piling
- Dual power supply and on-site switch stations and emergency power generator
- High pumping heads (design heads in excess of 200 ft)

Mechanical, electrical, and control equipment delivered to a pumping station construction site typically account for <u>15 to 30 percent of total construction costs</u>. Lift station construction has a significant economy-of-scale. Typically, if the capacity of a lift station is increased 100 percent, the construction cost would increase only 50 to 55 percent. An important consideration is that two identical lift stations will cost 25 to 30 percent more than a single station of the same combined capacity. Usually, complex lift stations cost two to three times more than more simple lift stations with no construction complications.

**Picture 6-15 Dual pump lift station**

Lift station operation and maintenance costs include power, labor, maintenance, and chemicals (if used for odor control). Usually, the costs for solids disposal are minimal, but are included if the lift station is equipped with bar screens to remove coarse materials from the wastewater. Typically, power costs account for 85 to 95 percent of the total operation and maintenance costs and are directly proportional to the unit cost of power and the actual power used by the lift station pumps. Labor costs average 1 to 2 percent of total costs. Annual maintenance costs vary, depending on the complexity of the equipment and instrumentation.

**Calculating Overflow**

A 75,000 gallon tank receives 270,000 gpd flow. A 195 gpm pump is attached to the tank, but it is broken. How long do they have to repair or replace the pump before the tank will overflow? Assume the tank is empty now.

First find the average flow per hour. Then find the number of hours till the overflow occurs.

$$\text{Hourly flow} = \frac{270{,}000 \text{ gal}}{24 \text{ hrs}} = 11{,}250 \frac{\text{gal}}{\text{hr}}$$

$$\text{Hours till overflow} = \frac{75{,}000 \text{ gal}}{11{,}250 \text{gal/hr}} = 6.67 \text{ hrs or 6 hrs 40 minutes}$$

## Calculating Rising water in a Wet Well

The wet well at a lift station receives a flow of 465 gpm. The wet well has a diameter of 18 feet. How many minutes will it take to raise the water level 6 feet in the wet well?

First calculate the volume of water it will take to fill 6 feet of the wet well. Then determine based on the gallons per minute how long it will take to rise to a level of 6 feet.

Volume = .785 x 18ft x 18 ft x 6 ft = 1,526.04 $ft^3$    1,526.04 $ft^3$ x 7.48 = 11,414.77 gal

Minutes to rise to 6 feet = $\frac{11,414.77 \text{ gal}}{465 \text{ gal/min}}$ = 24.55 min

## Cost of painting a tank

An open topped rectangular tank is 12 feet wide, has a total depth of 13 feet and is 50 feet long. a) What is the total inside tank surface area? And b) what would the cost be to coat the inside of the tank at 5.25 per square foot?

First find the total surface area. Calculate the cost by multiplying the surface area by the cost.

area of wall 1 ($ft^2$) 12 x 13 = 156 $ft^2$
area of wall 2 ($ft^2$) 13 x 50 = 650 $ft^2$
area of wall 3 ($ft^2$) 12 x 13 =156 $ft^2$
area of wall 4 ($ft^2$) 13 x 50 = 650 $ft^2$
bottom of tank ($ft^2$) 12 x 50 = 600 $ft^2$
total area ($ft^2$) = 2,212 $ft^2$

Cost = $5.25 x 2,212 = $11,613.50

**Calculate Operation and Construction Costs**

Two 65 hp pumps operate a lift station. The lift station runs 15 hours per day. The power in this municipality is charged at a rate of $.11 per kW*hr. what is the cost per day for running the pumps?

First calculate the total horsepower. Then use the kilowatt hours equation to find the kilowatt hours. Then multiply by the rate to find the cost.

Hp = 2 x 65 = 130

Kilowatts = hp x .746 = 130hp * .746 = 96.98 kW

Kilowatt hrs = kW used x number of hours run = 96.98 x 15 = 1,454.70 kW hrs

Cost = kW hrs x cost = 1,454.70 kW hrs x $.11 = $160.02 per day

You have three lift stations, #1 has a 9 hp motor and runs for 30 minutes per hour, #2 has a 12.5 hp pump and it runs 45 minutes per hour; and #3 has a 10 hp pump that runs 30 minutes every 2 hrs. What is the yearly electrical cost to operate these three stations if each kilowatt hour cost $.09?

First calculate the number of hours that the pumps run. Calculate the kilowatts, kilowatt hrs, and then the power cost.

Pump 1 kW = 9 hp x .746 = 6.71 kW
Pump 1 kW hrs = 6.71 kW x 12 hrs = 80.52 kW hrs x 365 = 29,389.80 kw hrs per year
Pump 1 cost per year = 29,389.80 x $.09 = $2,645.08

Pump 2 kW = 12.5 hp x .746 = 9.33 kW
Pump 2 kW hrs = 9.33 kW x 18 hrs = 167.94 kW hrs x 365 = 61,298.10 kw hrs per year
Pump 1 cost per year = 61,298.10 x $.09 = $5,516.83

Pump 3 kW = 10 hp x .746 = 7.46 kW
Pump 3 kW hrs = 7.46 kW x 6 hrs = 44.76 kw hrs x 365 = 16,337.40 kw hrs per year
Pump 1 cost per year = 16,337.40 x $.09 = $1,470.37
Cost = $2,645.08 + $5,516.83 + $1,470.37 = $9,632.28

## Force Mains

Force mains are pipelines that convey wastewater under pressure from the discharge side of a pump or pneumatic ejector to a discharge point. Pumps or compressors located in a lift station provide the energy for wastewater conveyance in force mains.

The key elements of force mains are:
- Pipe
- Valves
- Pressure surge control devices
- Force main cleaning system

Force mains are constructed from various materials and come in a wide range of diameters. Wastewater quality governs the selection of the most suitable pipe material. Operating pressure and corrosion resistance also impact the choice. Pipeline size and wall thickness are determined by wastewater flow, operating pressure, and trench conditions.

**Picture 6-16 Force Main**

**Common Modifications**

Force mains may be aerated or the wastewater chlorinated at the pump station to prevent odors and excessive corrosion. Pressure surge control devices are installed to reduce pipeline pressure below a safe operating pressure during lift station start-up and shut-off. Typically, automatically operated valves (cone or ball type) control pressure surges at the pump discharge or pressure surge tanks.

Normally, force main cleaning includes running a manufactured “pigging” device through the line and long force mains are typically equipped with **“pig”** insertion and retrieval stations. In most cases, insertion facilities are located within the lift station and the pig removal station is at the discharge point of the force main. Several launching and retrieval stations are usually provided in long force mains to facilitate cleaning of the pipeline.

## Applicability

Force mains are used to convey wastewater from a lower to higher elevation, particularly where the elevation of the source is not sufficient for gravity flow and/or the use of gravity conveyance will result in excessive excavation depths and high sewer pipeline construction costs.

Ductile iron and polyvinyl chloride (PVC) are the most frequently used materials for wastewater force mains. Ductile iron pipe has particular advantages in wastewater collection systems due to its high strength and high flow capacity with greater than nominal inside diameters and tight joints. For special corrosive conditions and extremely high flow characteristics, polyethylene-lined ductile iron pipe and fittings are widely used.

Cast iron pipe with glass lining is available in standard pipe sizes, with most joints in lengths up to 6.1 meters (20 feet). Corrosion-resistant plastic lined piping systems are used for certain waste carrying applications. Polyethylene-lined ductile iron pipe and fittings known as “poly-bond-lined” pipe is widely used for force mains conveying highly corrosive industrial or municipal wastewater.

The types of thermoplastic pipe materials used for force main service are PVC, acrylonitrilebutadiene- styrene (ABS), and polyethylene (PE).

The corrosion resistance, light weight, and low hydraulic friction characteristics of these materials offer certain advantages for different force main applications, including resistance to microbial attack. Typically, PVC pipes are available in standard diameters of 100 to 900 mm (4 to 36 inches) and their laying lengths normally range from 3 to 6 meters (10 to 20 feet). The use of composite material pipes, such as fiberglass reinforced mortar pipe (“truss pipe”), is increasing in the construction of force mains. A truss pipe is constructed on concentric ABS cylinders with annular space filled with cement. Pipe fabricated of fiberglass reinforced epoxy resin is almost as strong as steel, as well as corrosion and abrasion resistant.

Certain types of asbestos-cement pipe are applicable in construction of wastewater force mains. The advantage of asbestos-cement pipes in sewer applications is their low hydraulic friction. These pipes are relatively lightweight, allowing long laying lengths in long lines. Asbestos-cement pipes are also highly corrosion resistant. At one time it was thought that many asbestos containing products (including asbestos-cement pipe) would be banned by the Environmental Protection Agency. However, a court ruling overturned this ban and this pipe is available and still used for wastewater force main applications (Sanks, 1998).

Force mains are very reliable when they are properly designed and maintained. In general, force main reliability and useful life are comparable to that of gravity sewer lines, but pipeline reliability may be compromised by excessive pressure surges, corrosion, or lack of routine maintenance.

**Advantages**

Use of force mains can significantly reduce the size and depth of sewer lines and decrease the overall costs of sewer system construction. Typically, when gravity sewers are installed in trenches deeper than 20 feet, the cost of sewer line installation increases significantly because more complex and costly excavation equipment and trench shoring techniques are required. Usually, the diameter of pressurized force mains is one to two sizes smaller than the diameter of gravity sewer lines conveying the same flow, allowing significant pipeline cost reduction. Force main installation is simple because of shallower pipeline trenches and reduced quantity of earthwork. Installation of force mains is not dependent on site specific topographic conditions and is not impacted by available terrain slope, which typically limits gravity wastewater conveyance.

**Disadvantages**

While construction of force mains is less expensive than gravity sewer lines for the same flow, force main wastewater conveyance requires the construction and operation of one or more lift stations. Wastewater pumping and use of force mains could be eliminated or reduced by selecting alternative sewer routes, consolidating a proposed lift station with an existing lift station, or extending a gravity sewer using directional drilling or other state-of-the art deep excavation methods.

The dissolved oxygen content of the wastewater is often depleted in the wet-well of the lift station, and its subsequent passage through the force main results in the discharge of septic wastewater, which not only lacks oxygen but often contains sulfides. Frequent cleaning and maintenance of force mains is required to remove solids and grease buildup and minimize corrosion due to the high concentration of sulfides.

Pressure surges are abrupt increases in operating pressure in force mains which typically occur during pump start-up and shut-off. Pressure surges may have negative effects on force main integrity but can be reduced by proper pump station and pipeline design.

## Design Criteria

Force main design is typically integrated with lift station design. The major factors to consider in analyzing force main materials and hydraulics include the design formula for sizing the pipe, friction losses, pressure surges, and maintenance.

The Hazen-Williams formula is recommended for the design of force mains. This formula includes a roughness coefficient C, which accounts for pipeline hydraulic friction characteristics. The roughness coefficient varies with pipe material, size, and age.
Hazen-Williams equation: $f = 0.2083\ (100/c)^{1.852}\ q^{1.852} / d_h^{4.8655}$

***where***

***f** = friction head loss in feet of water per 100 feet of pipe ($ft_{h20}$/100 ft pipe)*

***c** = Hazen-Williams roughness constant*

***q** = volume flow (gal/min)*

***$d_h$** = inside hydraulic diameter (inches)*

## Table 6-3

### FRICTION LOSS OF WATER IN FEET PER 100 FEET LENGTH OF PIPE. BASED ON WILLIAM & HAZEN FORMULA USING CONSTANT 100. SIZES OF STANDARD PIPE IN INCHES

| U.S. Gals. Per Min. | 1/2" Pipe Vel. ft. per Sec. | 1/2" Pipe Loss in feet | 3/4" Pipe Vel. ft. per Sec. | 3/4" Pipe Loss in feet | 1" Pipe Vel. ft. per Sec. | 1" Pipe Loss in feet | 1 1/4" Pipe Vel. ft. per Sec. | 1 1/4" Pipe Loss in feet | 1 1/2" Pipe Vel. ft. per Sec. | 1 1/2" Pipe Loss in feet | 2" Pipe Vel. ft. per Sec. | 2" Pipe Loss in feet | 2 1/2" Pipe Vel. ft. per Sec. | 2 1/2" Pipe Loss in feet | 3" Pipe Vel. ft. per Sec. | 3" Pipe Loss in feet | 4" Pipe Vel. ft. per Sec. | 4" Pipe Loss in feet | 5" Pipe Vel. ft. per Sec. | 5" Pipe Loss in feet | 6" Pipe Vel. ft. per Sec. | 6" Pipe Loss in feet | U.S. Gals. Per Min. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 2.10 | 7.4 | 1.20 | 1.9 | | | | | | | | | | | | | | | | | | | 2 |
| 4 | 4.21 | 27.0 | 2.41 | 7.0 | 1.49 | 2.14 | .86 | .57 | .63 | .26 | | | | | | | | | | | | | 4 |
| 6 | 6.31 | 57.0 | 3.61 | 14.7 | 2.23 | 4.55 | 1.29 | 1.20 | .94 | .56 | .61 | .20 | | | | | | | | | | | 6 |
| 8 | 8.42 | 98.0 | 4.81 | 25.0 | 2.98 | 7.8 | 1.72 | 2.03 | 1.26 | .95 | .82 | .33 | .52 | .11 | | | | | | | | | 9 |
| 10 | 10.52 | 147.0 | 6.02 | 38.0 | 3.72 | 11.7 | 2.14 | 3.05 | 1.57 | 1.43 | 1.02 | .50 | .65 | .17 | .45 | .07 | | | | | | | 10 |
| 12 | | | 7.22 | 53.0 | 4.46 | 16.4 | 2.57 | 4.3 | 1.89 | 2.01 | 1.23 | .79 | .78 | .23 | .54 | .10 | | | | | | | 12 |
| 15 | | | 9.02 | 80.0 | 5.60 | 25.0 | 3.21 | 6.5 | 2.36 | 3.00 | 1.53 | 1.08 | .98 | .36 | .68 | .15 | | | | | | | 15 |
| 18 | | | 10.84 | 108.2 | 6.69 | 35.0 | 3.86 | 9.1 | 2.83 | 4.24 | 1.84 | 1.49 | 1.18 | .50 | .82 | .21 | | | | | | | 18 |
| 20 | | | 12.03 | 136.0 | 7.44 | 42.0 | 4.29 | 11.1 | 3.15 | 5.20 | 2.04 | 1.82 | 1.31 | .61 | .91 | .25 | .51 | .06 | | | | | 20 |
| 25 | | | | | 9.30 | 64.0 | 5.36 | 16.6 | 3.80 | 7.30 | 2.55 | 2.73 | 1.63 | .92 | 1.13 | .38 | .64 | .09 | | | | | 25 |
| 30 | | | | | 11.15 | 89.0 | 6.43 | 23.0 | 4.72 | 11.0 | 3.06 | 3.84 | 1.96 | 1.29 | 1.36 | .54 | .77 | .13 | .49 | .04 | | | 30 |
| 35 | | | | | 13.02 | 119.0 | 7.51 | 31.2 | 5.51 | 14.7 | 3.57 | 5.10 | 2.29 | 1.72 | 1.59 | .71 | .89 | .17 | .57 | .06 | | | 35 |
| 40 | | | | | 14.88 | 152.0 | 8.58 | 40.0 | 6.30 | 18.8 | 4.08 | 6.6 | 2.61 | 2.20 | 1.82 | .91 | 1.02 | .22 | .65 | .08 | | | 40 |
| 45 | | | | | | | 9.65 | 50.0 | 7.08 | 23.2 | 4.60 | 8.2 | 2.94 | 2.80 | 2.04 | 1.15 | 1.15 | .28 | .73 | .09 | | | 45 |
| 50 | | | | | | | 10.72 | 60.0 | 7.87 | 28.4 | 5.11 | 9.9 | 3.27 | 3.32 | 2.27 | 1.38 | 1.28 | .34 | .82 | .11 | .57 | .04 | 50 |
| 55 | | | | | | | 11.78 | 72.0 | 8.66 | 34.0 | 5.62 | 11.8 | 3.59 | 4.01 | 2.45 | 1.58 | 1.41 | .41 | .90 | .14 | .62 | .05 | 55 |
| 60 | | | | | | | 12.87 | 85.0 | 9.44 | 39.6 | 6.13 | 13.9 | 3.92 | 4.65 | 2.72 | 1.92 | 1.53 | .47 | .98 | .16 | .68 | .06 | 60 |
| 65 | | | | | | | 13.92 | 99.7 | 10.23 | 45.9 | 6.64 | 16.1 | 4.24 | 5.4 | 2.89 | 2.16 | 1.66 | .53 | 1.06 | .19 | .74 | .076 | 65 |
| 70 | | | | | | | 15.01 | 113.0 | 11.02 | 53.0 | 7.15 | 18.4 | 4.58 | 6.2 | 3.18 | 2.57 | 1.79 | .63 | 1.14 | .21 | .79 | .08 | 70 |
| 75 | | | | | | | 16.06 | 129.0 | 11.80 | 60.0 | 7.66 | 20.9 | 4.91 | 7.1 | 3.33 | 3.00 | 1.91 | .73 | 1.22 | .24 | .85 | .10 | 75 |
| 80 | | | | | | | 17.16 | 145.0 | 12.59 | 68.0 | 8.17 | 23.7 | 5.23 | 7.9 | 3.63 | 3.28 | 2.04 | .81 | 1.31 | .27 | .91 | .11 | 80 |
| 85 | | | | | | | 18.21 | 163.8 | 13.38 | 75.0 | 8.68 | 26.5 | 5.56 | 8.1 | 3.78 | 3.54 | 2.17 | .91 | 1.39 | .31 | .96 | .12 | 85 |
| 90 | | | | | | | 19.30 | 180.0 | 14.71 | 84.0 | 9.19 | 29.4 | 5.88 | 9.8 | 4.09 | 1.08 | 2.30 | 1.00 | 1.47 | .34 | 1.02 | .14 | 90 |
| 95 | | | | | | | | | 14.95 | 93.0 | 9.70 | 32.6 | 6.21 | 10.8 | 4.22 | 4.33 | 2.42 | 1.12 | 1.55 | .38 | 1.08 | .15 | 95 |
| 100 | 8" PIPE | | | | | | | | 15.74 | 102.0 | 10.21 | 35.8 | 6.54 | 12.0 | 4.54 | 4.96 | 2.55 | 1.22 | 1.63 | .41 | 1.13 | .17 | 100 |
| 110 | | | | | | | | | 17.31 | 122.0 | 11.23 | 42.9 | 7.18 | 14.5 | 5.00 | 6.0 | 2.81 | 1.46 | 1.79 | .49 | 1.25 | .21 | 110 |
| 120 | | | | | | | | | 18.89 | 143.0 | 12.25 | 50.0 | 7.84 | 16.8 | 5.45 | 7.0 | 3.06 | 1.17 | 1.96 | .58 | 1.36 | .24 | 120 |
| 130 | | | | | | | | | 20.46 | 166.0 | 13.28 | 58.0 | 8.48 | 18.7 | 5.91 | 8.1 | 3.31 | 1.97 | 2.12 | .67 | 1.47 | .27 | 130 |
| 140 | .90 | .08 | | | | | | | 22.04 | 190.0 | 14.30 | 67.0 | 9.15 | 22.3 | 6.35 | 9.2 | 3.57 | 2.28 | 2.29 | .76 | 1.59 | .32 | 140 |
| 150 | .96 | .09 | | | | | | | | | 15.32 | 76.0 | 9.81 | 25.5 | 6.82 | 10.5 | 3.82 | 2.62 | 2.45 | .88 | 1.70 | .36 | 150 |
| 160 | 1.02 | .10 | | | | | | | | | 16.34 | 86.0 | 10.46 | 29.0 | 7.26 | 11.8 | 4.08 | 2.91 | 2.61 | .98 | 1.82 | .40 | 160 |
| 170 | 1.08 | .11 | 10" PIPE | | | | | | | | 17.36 | 96.0 | 11.11 | 34.1 | 7.71 | 13.3 | 4.33 | 3.26 | 2.77 | 1.08 | 1.92 | .45 | 170 |
| 180 | 1.15 | .13 | | | | | | | | | 18.38 | 107.0 | 11.76 | 35.7 | 8.17 | 14.0 | 4.60 | 3.61 | 2.94 | 1.22 | 2.04 | .50 | 180 |
| 190 | 1.21 | .14 | | | | | | | | | 19.40 | 118.0 | 12.42 | 39.6 | 8.63 | 15.5 | 4.84 | 4.01 | 3.10 | 1.35 | 2.16 | .55 | 190 |
| 200 | 1.28 | .15 | | | | | | | | | 20.42 | 129.0 | 13.07 | 43.1 | 9.08 | 17.8 | 5.11 | 4.4 | 3.27 | 1.48 | 2.27 | .62 | 200 |
| 220 | 1.40 | .18 | .90 | .06 | | | | | | | 22.47 | 154.0 | 14.38 | 52.0 | 9.99 | 21.3 | 5.62 | 5.2 | 3.59 | 1.77 | 2.50 | .73 | 220 |
| 240 | 1.53 | .22 | .98 | .07 | | | | | | | 24.51 | 182.0 | 15.69 | 61.0 | 10.89 | 25.1 | 6.13 | 6.2 | 3.92 | 2.08 | 2.72 | .87 | 240 |
| 260 | 1.66 | .25 | 1.06 | .08 | | | | | | | 26.55 | 211.0 | 16.99 | 70.0 | 11.80 | 29.1 | 6.64 | 7.2 | 4.25 | 2.41 | 2.95 | 1.00 | 260 |
| 280 | 1.79 | .28 | 1.15 | .09 | | | | | | | | | 18.30 | 81.0 | 12.71 | 33.4 | 7.15 | 8.2 | 4.58 | 2.77 | 3.18 | 1.14 | 280 |
| 300 | 1.91 | .32 | 1.22 | .11 | | | | | | | | | 19.61 | 92.0 | 13.62 | 38.0 | 7.66 | 9.3 | 4.90 | 3.14 | 3.40 | 1.32 | 300 |
| 320 | 2.05 | .37 | 1.31 | .12 | 12" PIPE | | | | | | | | 20.92 | 103.0 | 14.52 | 42.8 | 8.17 | 10.5 | 5.23 | 3.54 | 3.64 | 1.47 | 320 |
| 340 | 2.18 | .41 | 1.39 | .14 | | | | | | | | | 22.22 | 116.0 | 16.43 | 47.9 | 8.68 | 11.7 | 5.54 | 3.97 | 3.84 | 1.62 | 340 |
| 360 | 2.30 | .45 | 1.47 | .15 | | | 14" PIPE | | | | | | 23.53 | 128.0 | 16.34 | 53.0 | 9.19 | 13.1 | 5.87 | 4.41 | 4.08 | 1.83 | 360 |
| 380 | 2.43 | .50 | 1.55 | .17 | 1.08 | .069 | | | | | | | 24.84 | 142.0 | 17.25 | 59.0 | 9.69 | 14.0 | 6.19 | 4.86 | 4.31 | 2.00 | 380 |
| 400 | 2.60 | .54 | 1.63 | .19 | 1.14 | .075 | | | | | | | 26.14 | 156.0 | 18.16 | 65.0 | 10.21 | 16.0 | 6.54 | 5.4 | 4.55 | 2.20 | 400 |
| 450 | 2.92 | .68 | 1.84 | .23 | 1.28 | .95 | | | | | | | | | 20.40 | 78.0 | 11.49 | 19.8 | 7.35 | 6.7 | 5.11 | 2.74 | 450 |
| 500 | 3.19 | .82 | 2.04 | .28 | 1.42 | .113 | 1.04 | .06 | | | | | | | 22.70 | 98.0 | 12.77 | 24.0 | 8.17 | 8.1 | 5.68 | 2.90 | 500 |
| 550 | 3.52 | .97 | 2.24 | .33 | 1.56 | .135 | 1.15 | .07 | | | | | | | 24.96 | 117.0 | 14.04 | 28.7 | 8.99 | 9.6 | 6.25 | 3.96 | 550 |
| 600 | 3.84 | 1.14 | 2.45 | .39 | 1.70 | .159 | 1.25 | .08 | | | | | | | 27.23 | 137.0 | 15.35 | 33.7 | 9.80 | 11.3 | 6.81 | 4.65 | 600 |
| 650 | 4.16 | 1.34 | 2.65 | .45 | 1.84 | .19 | 1.37 | .09 | | | | | | | | | 16.59 | 39.0 | 10.62 | 13.2 | 7.38 | 5.40 | 650 |
| 700 | 4.46 | 1.54 | 2.86 | .52 | 1.99 | .22 | 1.46 | .10 | | | | | | | | | 17.87 | 44.9 | 11.44 | 15.1 | 7.95 | 6.21 | 700 |
| 750 | 4.80 | 1.74 | 3.06 | .59 | 2.13 | .24 | 1.58 | .11 | 16" PIPE | | | | | | | | 19.15 | 51.0 | 12.26 | 17.2 | 8.5 | 7.12 | 750 |
| 800 | 5.10 | 1.90 | 3.26 | .66 | 2.27 | .27 | 1.67 | .13 | | | | | | | | | 20.42 | 57.0 | 13.07 | 19.4 | 9.08 | 7.96 | 800 |
| 850 | 5.48 | 2.20 | 3.47 | .75 | 2.41 | .31 | 1.79 | .14 | 1.36 | .08 | 20" PIPE | | | | | | 21.70 | 64.0 | 13.89 | 21.7 | 9.65 | 8.95 | 850 |
| 900 | 5.75 | 2.46 | 3.67 | .83 | 2.56 | .34 | 1.88 | .16 | 1.44 | .084 | | | | | | | 22.98 | 71.0 | 14.71 | 24.0 | 10.20 | 10.11 | 900 |
| 950 | 6.06 | 2.87 | 3.88 | .91 | 2.70 | .38 | 2.00 | .18 | 1.52 | .095 | | | | | | | | | 15.52 | 26.7 | 10.77 | 11.20 | 950 |
| 1000 | 6.38 | 2.97 | 4.08 | 1.03 | 2.84 | .41 | 2.10 | .19 | 1.60 | .10 | 1.02 | .04 | | | | | | | 16.34 | 29.2 | 11.34 | 12.04 | 1000 |
| 1100 | 7.03 | 3.52 | 4.49 | 1.19 | 3.13 | .49 | 2.31 | .23 | 1.76 | .12 | 1.12 | .04 | | | | | | | 17.97 | 34.9 | 12.48 | 14.55 | 1100 |
| 1200 | 7.66 | 4.17 | 4.90 | 1.40 | 3.41 | .58 | 2.52 | .27 | 1.92 | .14 | 1.23 | .05 | | | | | | | 19.61 | 40.9 | 13.61 | 17.10 | 1200 |
| 1300 | 8.30 | 4.85 | 5.31 | 1.62 | 3.69 | .67 | 2.71 | .32 | 2.08 | .17 | 1.33 | .06 | 24" PIPE | | | | | | | | 14.72 | 18.4 | 1300 |
| 1400 | 8.95 | 5.50 | 5.71 | 1.87 | 3.96 | .78 | 2.92 | .36 | 2.24 | .19 | 1.43 | .064 | | | | | | | | | 15.90 | 22.60 | 1400 |
| 1500 | 9.58 | 6.24 | 6.12 | 2.13 | 4.26 | .89 | 3.15 | .41 | 2.39 | .21 | 1.53 | .07 | | | | | | | | | 17.02 | 25.60 | 1500 |
| 1600 | 10.21 | 7.00 | 6.53 | 2.39 | 4.65 | .98 | 3.34 | .47 | 2.66 | .24 | 1.63 | .08 | | | 30" PIPE | | | | | | 18.10 | 26.9 | 1600 |
| 1800 | 11.50 | 8.78 | 7.35 | 2.96 | 5.11 | 1.21 | 3.75 | .58 | 2.87 | .30 | 1.84 | .10 | 1.28 | .04 | | | | | | | | | 1800 |
| 2000 | 12.78 | 10.71 | 8.16 | 3.59 | 5.68 | 1.49 | 4.17 | .71 | 3.19 | .37 | 2.04 | .12 | 1.42 | .05 | | | | | | | | | 2000 |
| 2200 | 14.05 | 12.78 | 8.98 | 4.24 | 6.25 | 1.81 | 4.69 | .84 | 3.61 | .44 | 2.25 | .15 | 1.56 | .06 | | | | | | | | | 2200 |
| 2400 | 15.32 | 14.2 | 9.80 | 5.04 | 6.81 | 2.08 | 5.00 | .99 | 3.83 | .52 | 2.45 | .17 | 1.70 | .07 | 1.09 | .02 | | | | | | | 2400 |
| 2600 | | | 10.61 | 5.81 | 7.38 | 2.43 | 5.47 | 1.17 | 4.15 | .60 | 2.66 | .20 | 1.84 | .08 | 1.16 | .027 | | | | | | | 2600 |
| 2800 | | | 11.41 | 6.70 | 7.95 | 2.75 | 5.84 | 1.32 | 4.47 | .68 | 2.86 | .23 | 1.98 | .09 | 1.27 | .03 | | | | | | | 2800 |
| 3000 | | | 12.24 | 7.62 | 8.52 | 3.15 | 6.01 | 1.49 | 4.79 | .78 | 3.08 | .27 | 2.13 | .10 | 1.37 | .037 | | | | | | | 3000 |
| 3200 | | | 13.05 | 7.8 | 9.10 | 3.51 | 6.68 | 1.67 | 6.12 | .88 | 3.27 | .30 | 2.26 | .12 | 1.46 | .041 | | | | | | | 3200 |
| 3500 | | | 14.30 | 10.08 | 9.95 | 4.16 | 7.30 | 1.97 | 6.59 | 1.04 | 3.59 | .35 | 2.49 | .14 | 1.56 | .047 | | | | | | | 3500 |
| 3800 | | | 15.61 | 13.4 | 10.80 | 4.90 | 7.98 | 2.36 | 60.7 | 1.20 | 3.88 | .41 | 2.69 | .17 | 1.73 | .05 | | | | | | | 3800 |
| 4200 | | | | | 11.92 | 5.88 | 8.76 | 2.77 | 6.70 | 1.44 | 4.29 | .49 | 2.99 | .20 | 1.91 | .07 | | | | | | | 4200 |
| 2500 | | | | | 12.78 | 6.90 | 9.45 | 3.22 | 7.16 | 1.64 | 4.60 | .66 | 3.20 | .22 | 2.04 | .08 | | | | | | | 2500 |
| 5000 | | | | | 14.20 | 8.40 | 10.50 | 3.95 | 8.01 | 2.03 | 6.13 | .68 | 3.54 | .27 | 2.26 | .09 | | | | | | | 5000 |
| 5500 | | | | | | | 11.55 | 4.65 | 8.78 | 2.39 | 5.64 | .82 | 3.90 | .33 | 2.5 | .11 | | | | | | | 5500 |
| 6000 | | | | | | | 12.60 | 5.50 | 9.58 | 2.79 | 6.13 | .94 | 4.25 | .38 | 2.73 | .13 | | | | | | | 6000 |
| 6500 | | | | | | | 13.65 | 6.45 | 10.39 | 3.32 | 6.64 | 1.10 | 4.61 | .45 | 2.96 | .15 | | | | | | | 6500 |
| 7000 | | | | | | | 14.60 | 7.08 | 11.18 | 3.70 | 7.15 | 1.25 | 4.97 | .52 | 3.18 | .17 | | | | | | | 7000 |
| 8000 | | | | | | | | | 12.78 | 4.74 | 8.17 | 1.61 | 5.68 | .66 | 3.64 | .23 | | | | | | | 8000 |
| 9000 | | | | | | | | | 14.37 | 5.90 | 9.20 | 2.01 | 6.35 | .81 | 4.08 | .28 | | | | | | | 9000 |
| 10000 | | | | | | | | | 15.96 | 7.19 | 10.20 | 2.44 | 7.07 | .98 | 4.54 | .33 | | | | | | | 10000 |
| 12000 | | | | | | | | | | | 12.25 | 3.41 | 8.60 | 1.40 | 5.46 | .48 | | | | | | | 12000 |
| 14000 | | | | | | | | | | | 14.30 | 4.64 | 9.95 | 1.87 | 6.37 | .63 | | | | | | | 14000 |
| 16000 | | | | | | | | | | | | | 11.38 | 2.40 | 7.28 | .81 | | | | | | | 16000 |
| 18000 | | | | | | | | | | | | | 12.76 | 2.97 | 8.18 | 1.02 | | | | | | | 18000 |
| 20000 | | | | | | | | | | | | | 14.20 | 3.60 | 9.10 | 1.23 | | | | | | | 20000 |

### *Force Main Pipe Materials*

Selection criteria for force main pipe materials include:

- Wastewater quantity, quality, and pressure
- Pipe properties, such as strength, ease of handling, and corrosion resistance
- Availability of appropriate sizes, wall thickness, and fittings
- Hydraulic friction characteristics
- Cost

Ductile iron pipe offers strength, stiffness, ductility, and a range of sizes and thicknesses and is the typical choice for high-pressure and exposed piping. Plastic pipe is most widely used in short force mains and smaller diameters. Table 1 lists the types of pipe recommended for use in a force main system and suggested applications:

**TABLE 6-1 CHARACTERISTICS OF COMMON FORCE MAIN PIPE MATERIALS**

| Material | Application | Advantages | Disadvantages |
|---|---|---|---|
| Cast or Ductile Iron | High pressure<br>Available in 4- 54 in pressure surges | Good resistance to pressure surges | More expensive than concrete and fiberglass |
| Steel Cement Lined | High pressure<br>All pipes sizes | Excellent resistance to pressure surges | More expensive than concrete and fiberglass |
| Asbestos Cement | Moderate pressure for 36-inch + pipe | No corrosion Slow grease buildup | Relatively brittle |
| Fiberglass Reinforced Epoxy Pipe | Moderate pressure for up to 36-inch pipe | No corrosion Slow grease buildup | 350 psi max pressure |
| Plastic | Low pressure for up to 36-inch pipe | No corrosion Slow grease buildup | Suitable for small pipe sizes and low pressure |

**Velocity**

Force mains from the lift station are typically designed for velocities between 2 to 8 feet per second). Such velocities are normally based on the most economical pipe diameters and typical available heads.

For shorter force mains (less than 2,000 feet) and low lift requirements (less than 30 feet), the recommended design force main velocity range is 6 to 9 feet per second. This higher design velocity allows the use of smaller pipe, reducing construction costs. Higher velocity also increases pipeline friction loss by more than 50 percent, resulting in increased energy costs. To reduce the velocity, a reducer pipe or a pipe valve can be used. Reducer pipes are often used because of the costly nature of pipe valves. These reducer pipes, which are larger in diameter, help to disperse the flow, therefore reducing the velocity.

The maximum force main velocity at peak conditions is recommended not to exceed 10 feet per second). Table 2 provides examples of force main capacities at various pipeline sizes, materials, and velocities. The flow volumes may vary depending on the pipe material used.

**TABLE 6-2 FORCE MAIN CAPACITY**

| Diameter Inches | 2 fps GPM | 4 fps GPM | 6 fps GPM |
|---|---|---|---|
| 6 | 176 | 362 | 528 |
| 8 | 313 | 626 | 1,252 |
| 10 | 490 | 980 | 1,470 |
| 18 | 1,585 | 3,170 | 4,755 |
| 24 | 2,819 | 5,638 | 8,457 |
| 36 | 6,342 | 12,684 | 19,026 |

***Vertical Alignment***

Force mains should be designed so that they are always full and pressure in the pipe is greater than 10 pounds per square inch to prevent the release of gases. Low and high points in the vertical alignment should be avoided; considerable effort and expense are justified to maintain an uphill slope from the lift station to the discharge point. High points in force mains trap air, which reduces available pipe area, causes non-uniform flow, and creates the potential for sulfide corrosion. Gas relief and vacuum valves are often installed if high points in the alignment of force mains cannot be avoided, while blow-offs are installed at low points.

***Pressure Surges***

The possibility of sudden changes in pressure (pressure surges) in the force main due to starting and/or stopping pumps (or operation of valves appurtenant to a pump) must be considered during design. The duration of such pressure surges ranges between 2 to 15 seconds. Each surge is site specific and depends on pipeline profile, flow, change in velocity, and inertia of the pumping equipment, valve characteristics, pipeline materials, and pipeline accessories. Critical surges may be caused by power failure. If pressure surge is a concern, the force main should be designed to withstand calculated maximum surge pressures.

***Valves***

Valves are installed to regulate wastewater flow and pressure in the force mains. Valves can be used to stop and start flow, control the flow rate, divert the flow, prevent backflow, and control and relieve the pressure. The number, type, and location of force main valves depends on the operating pressures and potential surge conditions in the pipeline. Although valves have a lot of benefits, the costliness of them prevents them from being used extensively.

**Picture 6-17 Effluent force main valve**

**Performance**

Force main performance is closely tied to the performance of the lift station to which it is connected. Pump-force main performance curves are used to define and compare the operating characteristics of a given pump or set of pumps along with the associated force main. They are also used to identify the best combination of performance characteristics under which the lift station-force main system will operate under typical conditions (flows and pressures). Properly designed pump-force main systems usually allow the lift station pumps to operate at 35 to 55 percent efficiency most of the time. Overall pump efficiency depends on the type of pumps, their control system, and the fluctuation of the influent wastewater flow.

## Operation and Maintenance

The operation of force main-lift station systems is usually automated and does not require continuous on-site operator presence. However, annual force main route inspections are recommended to ensure normal functioning and to identify potential problems.

Special attention is given to the integrity of the force main surface and pipeline connections, unusual noise, vibration, pipe and pipe joint leakage and displacement, valving arrangement and leakage, lift station operation and performance, discharge pump rates and pump speed, and pump suction and discharge pressures. Depending on the overall performance of the lift station-force main system, the extent of grease build-up and the need for pipeline pigging are also assessed.

If there is an excessive increase in pump head and the head loss increase is caused by grease build-up, the pipeline is pigged. Corrosion is rarely a problem since pipes are primarily constructed of ductile iron or plastic, which are highly resistant to corrosion. Buildup can be removed by pigging the pipeline.

## Costs

Force main costs depend on many factors including:

- Conveyed wastewater quantity and quality
- Force main length
- Operating pressure
- Soil properties and underground conditions
- Pipeline trench depth
- Appurtenances such as valves and blow offs
- Community impacts

These site and system specific factors must be examined and incorporated in the preparation of force main cost estimates.

Unit force main construction costs are usually expressed in $ per linear foot of installed pipeline and costs typically include labor and the equipment and materials required for pipeline installation. Table 3 unit pipeline construction costs for ductile iron and plastic (PVC) pipes used for force main construction.

These costs are base installation costs and do not include the following:

- General contractor overhead and profit
- Engineering and construction management
- Land or right-of-way acquisition
- Legal, fiscal, and administrative costs
- Interest during construction
- Community impacts

**Table 6-3**

.

| Pipe diameter inches | Ductile Iron $ linear ft | PVC pressure pipe $ linear ft |
|---|---|---|
| 8 | 30.50 | 20.00 |
| 10 | 38.50 | 26.60 |
| 12 | 48.00 | 34.50 |
| 14 | 61.00 | 44.00 |
| 16 | 70.50 | 54.50 |
| 18 | 88.00 | 64.00 |
| 20 | 95.00 | 75.00 |
| 24 | 112.00 | 86.50 |
| 30 | 190.00 | 120.00 |
| 36 | 252.50 | 179.50 |

*All unit pipeline costs are adjusted to 2009 dollars*

Force main operation and maintenance costs include labor and maintenance requirements. Typically, labor costs account for 85 to 95 percent of total operation and maintenance costs and are dependent on the force main length.

The maintenance costs usually vary from $9 to $26/meter ($3 to $8/linear foot), depending on the size and number of appurtenances installed on the force main. An internal inspection using TV equipment can be completed, if visual inspection is not sufficient. TV inspection can be costly, ranging from $1,300 to $15,250 per mile with an average cost of $6,120 per mile.

## Review Questions for Pumps

1. Popular types of pumps for wastewater applications are _______, _______, _______, _________, _________, _________, and _________.

2. Before doing work on pumps or other equipment it is important to practice ______ ____ _____ ______ principles.

3. For motors wound for ____________ _________, periodically check to insure ______ ________ across all three phases. If one phase cuts out while in operation the motor may overheat and become damaged unless it is stopped by a thermal control device.

4. Key elements of ______ _______ include a wet-well, mechanically cleaned bar screens or grinders to remove coarse materials; pumps, piping, valves, motors, a power supply system, equipment control and alarm system, and odor control and ventilation system.

5. _________ lift stations do not have a separate pump room; the lift station header piping, associated valves, and flow meters are located in a separate dry vault at grade for easy access.

6. A key advantage of __________ lift stations is that they allow easy access for routine visual inspection and maintenance.

7. ______ _______ are often installed to record instantaneous pumping rates and the total flow pumped.

8. Key disadvantages of lift stations include the high cost to construct and maintain and the potential for ________ and _______.

9. Wet-wells typically require ____ continuous air changes per hour or ____ intermittent air changes per hour.

10. Four major ways to control odors are ___________, ____________, _______________, and ____________.

11. ________ ____________ ____________ are used to define and compare the operating characteristics of a pump and to identify the best combination of performance characteristics under which a lift station pumping system will operate under typical conditions (flows and heads).

12. _________ _________ are pipelines that convey wastewater under pressure from the discharge side of a pump or pneumatic ejector to a discharge point.

13. Force mains should be designed so that they are __________ _______ and pressure in the pipe is greater than 10 pounds per square inch to prevent the release of gases.

14. _________ are installed to regulate wastewater flow and pressure in the force mains.

15. The ____________________ formula is recommended for the design of force mains. This formula includes a roughness coefficient C, which accounts for pipeline hydraulic friction characteristics. The roughness coefficient varies with pipe material, size, and age.

16. If two 400 gpm pumps are used how, long will it take in hours to de-water a rectangular tank. 200 feet long by 135 feet wide and 14 feet deep?

17. Two 50 hp pumps operate a lift station. The lift station runs 20 hours per day. The power in this municipality is charged at a rate of $.11 per kW*hr. what is the cost per day for running the pumps?

18. A pump station has been averaging a screenings removal of 4.2 $ft^3$ per million gallons. The average daily flow to the pump station is 7.33 MGD. How many days will it take to fill a screen with a 159 $ft^3$ capacity?

19. What is the volume of a tank in gallons if it is 90 ft long, 60 ft wide and 27 ft deep?
20. Wastewater is pumped into a 8 inch line by a 500 gal/min pump that is 87% efficient, what is the velocity of the wastewater in the line?

21. A lift station pumps .8 MGD of wastewater per day. The water contains an average of 226 lbs of solids. How much chlorine in mg/L would be needed for keeping this system fresh?

22. A sewer line is to be filled with a root control substance containing 830 mg/L of a specific chemical. How much chemical in lbs would be needed for a 1600 ft section of 18 inch pipe?

23. A circular wet well measures 13 feet in diameter. If the pump lowers the water level 6.5 feet in 8 minutes, what is the pumping rate of the pump in gallons per minute? Assume no inflow.

24. A lift station is 30 feet by 20 feet and a depth of 100 feet. If the depth is now is at elevation of 69 feet. How many additional gallons can the lift station hold before it overflows?

25. A 120,000 gallon tank receives 670,000 gpd flow. A 495 gpm pump is attached to the tank, but it is broken. How long do they have to repair or replace the pump before the tank will overflow? Assume the tank is empty now.

26. The wet well at a lift station receives a flow of 600 gpm. The wet well has a diameter of 24 feet. How many minutes will it take to raise the water level 10 feet in the wet well?

27. An open topped rectangular tank is 80 feet wide, has a total depth of 25 feet and is 40 feet long. What would the cost be to coat the inside of the tank at 6.50 per square foot?

28. You have there lift stations, #1 has a 12 hp motor and runs for 30 minutes per hour, #2 has a 15 hp pump and it runs 45 minutes per hour; and #3 has a 25 hp pump that runs 30 minutes every 2 hrs. What is the yearly electrical cost to operate these three stations if each kilowatt hour cost $.09?

## Answers to Pump Review Questions

1. centrifugal pumps, propeller pumps, reciprocating or piston pumps, incline screw pumps, Progressive cavity pumps, pneumatic ejectors (Air Lift), metering pumps
2. lock out tag out
3. three phase current, equal distribution
4. lift station
5. Submersible
6. dry-well
7. flow meters
8. odors, noise
9. 12, 60
10. chemical addition, air injection, carbon adsorption, and biofilters
11. Pump performance curves
12. Force mains
13. always full
14. valves
15. Hazen-Williams
16. 58.91 hours
17. $164.12

18. 5.16 days
19. 1,090,584 gallons
20. 3.18 ft/s
21. 33.88 mg/L
22. 19.52 lbs
23. 806.27 gal/min
24. 139,128 gal
25. 4.3 hrs or 4 hrs 18 min
26. 56.37 minutes
27. $59,800
28. $13,820.66

# Chapter 7: INFLOW AND INFILTRATION

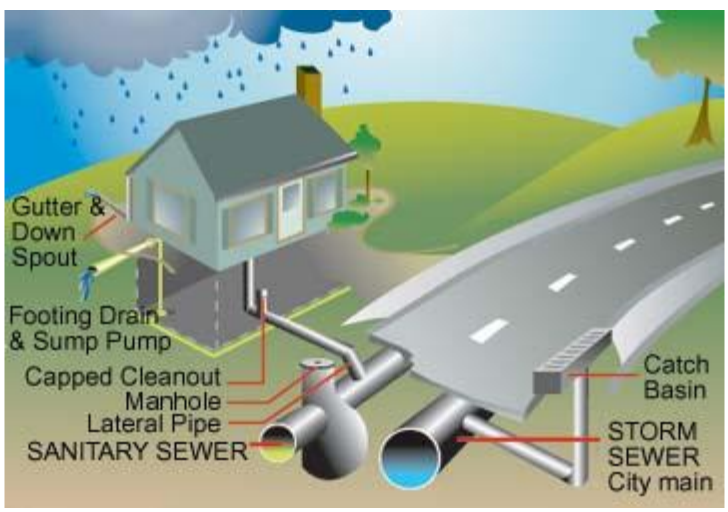
## Chapter 7 Objectives

1. Define inflow and infiltration and understand the techniques associated with infiltration and exfiltration.
2. Know, identify, and understand the techniques associated with inflow, infiltration, and sewer system evaluation studies.
3. Know, identify, and understand how to determine a monitoring and evaluation strategies to adequately measure the amount of inflow and infiltration in a sanitary sewer system and its importance.
4. Know, identify, and understand the sources of inflow and infiltration, the trouble spots in the collection system, and the importance of visual inspection of lines and manholes.
5. Know and understand the importance of smoke and dye testing and how to conduct them.
6. Know, identify, and understand inflow, infiltration, repair analysis, and cost estimates of sewer repairs given conditions and prices.
7. Know, identify, and understand the techniques used to reduce, fix, and repair inflow and infiltration.
8. Know the importance of cleaning and inspection in the collection system and the importance of keeping cleaning and inspection logs.
9. Know the importance of a successful collection system maintenance plan and its components.
10. Know, identify, and understand the advantages and disadvantages of each inspection technique used in collection system maintenance and preventive maintenance and when each technique is most effective.
11. Define a combined sewer system and sanitary sewer system and know what causes the overflows.
12. Know the environmental effects and principal pollutants of combined sewer overflows and sanitary sewer overflows.
13. Calculate
    a. velocity and flow rates.
    b. Calculations for inflow and infiltration repair analysis.
    c. Calculate operations and construction costs

Inflow and Infiltration is a major concern with most collection systems. Inflow is the excess rainwater that enters the system very soon after the rain begins and can normally be traced to unsealed manholes and an illegal connection such as roof down spouts, parking lot and yard drains. Infiltration is the excess water that continues to enter the system for three or four days after the rain has stopped and is the result of groundwater seeping into the system through breaks in the line and unsealed pipe joints. Inflow is usually more controllable and more easily eliminated.

Construction requirements limit the loss of waste from (or entrance of ground water into) a sewer system to 200 gallons per inch diameter per mile per day. This limitation is inclusive of manholes, sewer lines, and appurtenances. At least 30” of ground cover shall be provided for additional protection. As part of the construction, the integrity of a new system has to be verified by means of either the infiltration/exfiltration, or low-pressure air testing methods. An infiltration or exfiltration test shall be performed with a minimum positive head of two feet.

The infiltration test is generally preferred when the groundwater level is above the crown of the sewer. The upstream end of the section to be tested is plugged, and a flow-measuring device (weir, etc.) is installed in the manhole at the lower end. The rate of leakage can then be measured.




**Picture 7-1 Sources of inflow and infiltration**

In the exfiltration test when ground water levels are too low to use the infiltration test, both ends of the section of sewer to be tested, including a manhole at each end, are plugged, and all stoppers and plugs are braced or otherwise secured to resist the internal pressure resulting from the test. The section is then filled with water to a predetermined level above the crown of the sewer, and the rate of leakage is computed on the basis of the observed drop in water level over a reasonably long period of time or by metering the volume of water to be supplied to the system to maintain the original water level.

In the air pressure test, a section between manholes is plugged and the plugs secured to withstand the expected internal pressure. Air is then introduced at a pressure above the maximum pressure exerted by any groundwater that may be present outside the pipe. After the air is shut off, the time it takes the pressure in the pipe section to drop by a pre-designated amount is determined. Manholes should be tested separately.

Sewer lines, when flowing full, should have a mean velocity of not less than 2.0 fps (feet per second) to reduce the possibility of solids deposition in the collection system. A mean velocity of 10.0 fps or more may cause serious damage to manholes. The velocity may be calculated using the following equation.

$$\frac{\text{Distance in feet}}{\text{Time in seconds}} = \text{Velocity (feet per second)}$$

The numbers needed for the equation above may be obtained by measuring the distance between two manholes, in feet and then inserting a ping pong ball in the upstream manhole and measuring the amount of time, in minutes and seconds, it takes to reach the second manhole. Normally this requires at least two people with two way communication devices.

All well-run municipal public works department recognize the importance of having a <u>preventive maintenance program</u> for their sewers. Not only does it cut down on the number of customer service complaints, it reduces maintenance costs in the long term. A worthwhile maintenance program should include a good record keeping system, quick response to service requests, a cycle of regular televising of revolving parts of the sewer system each year, regular cleaning of the system, and regular attention to corrosion protection against hydrogen sulfide. Regular wet and dry weather <u>flow monitoring</u> can be used to see problems emerging, so corrections can be programmed in advance. In conjunction with water metering, this can be used to detect water main leakage and help with that system's maintenance.

Inflow and Infiltration or Sewer System Evaluation Studies (SSES) are performed to identify the specific causes and quantify the amounts of I/I entering the sewer system. This information allows the public works department to prescribe the most beneficial corrective actions and estimate their costs.

The techniques usually employed in the I/I or SSES study are:

- Flow monitoring
- Interviews of maintenance personnel and review of repair records
- Visual inspections of lines and manholes
- Smoke and dye testing
- Televising of the lines, usually with dyed water flooding of the surface

All have their place in the investigation process, and information from the least expensive techniques should be analyzed before going on to televising of the lines. Usually an adequate diagnosis can be made based on appropriate application of the cheaper techniques plus televising of about 20% of the system. We will now consider each of the major investigative techniques and their applications.

## *Flow Monitoring*

Flow monitoring is the least costly investigative technique for the amount of information gained. Generally one should start an investigation by monitoring flows throughout the system to identify which drainage basins have the most excess wet weather flows. Gravity sewer flows can be directly monitored. For force mains, you will have to calculate flows based on metering of pumping rates and times. Pressurized sewer cannot have I/I problems, but their flows may need to be known for the system-wide analysis.

**Picture 7-2 Flow meter**


**Picture 7-3 Flow meter**

To set up your monitoring locations, divide the system into drainage basins and locate the meters at the manholes where the drainage basin joins into a larger flow. If possible, establish drainage basins that have similar materials or age, even if this leads to big differences in flows among basins. The goal is to be able to determine from the flow data which basins have the most extraneous flow, and whether inflow or infiltration predominates. This will allow you to plan out the rest of your investigation more economically.

To determine how much I/I the system experiences in wet weather, first measure the dry weather flows. Check the measured dry weather flows by calculating what they should be, based on building occupancies and types of usage. If measured dry weather flows are significantly higher than calculated flows, there may be a cross connection with a potable or fire protection water line, a leak in one of these lines which is causing dry weather infiltration, an underground spring causing infiltration, or a perched or permanently high water table. Groundwater wells at a few key locations will help you determine if this is the case.

Wet weather monitoring data should be graphed as flow versus time on top of a rainfall versus time graph for the same period. Inflow will show up as elevated flows starting relatively close to the start of rain and dropping off soon after the rain stops. Infiltration may not show up right away, but will continue steadily after the rain stops and until the ground or trench around the sewer is no longer saturated.

Also, compare the total wet weather flows to the dry weather flow to see the magnitude of the problem for the various drainage basins. This way you will know in which basins to concentrate your efforts. Basins with high inflow should be investigated further using smoke and dye testing. Basins where infiltration is the predominant cause can be investigated using joint testing, visual inspections, and televising. First perform interviews and a record review.

The following "rules-of-thumb" may be used to determine a monitoring and evaluation strategy to adequately measure amount of inflow and infiltration in a sanitary sewer system. These parameters vary depending on the overall city or agency goals.

- One flow meter for every 30,000 – 50,000 feet of sanitary sewer pipe
- The flow meter recording should be set at 15-minute intervals
- Flow meter capable of measuring surcharges
- One rain gauge for every 2-4 flow meters

- Minimum monitoring period – 45 days with 60 days being optimal
- Measurement of between 6-8 separate rainfall events
- The system should be monitored during a period of high seasonal groundwater.

### *Interviews and Record Review*

Public works maintenance personnel and workers at the various industrial facilities should be interviewed to find out where the known trouble spots are. Information of particular use is:

- Where blockages usually occur
- Where there is flooding or sewer backups in conjunction with storm events
- Whether there are areas of the city which have buildings with down spouts going into the ground, but with no nearby storm sewers
- Which areas have had major repair work
- The quality of the drawings you are basing your work on
- Having the field drawings corrected

The record review should include sewer service requests, repair projects which have been completed or proposed, correspondence with regulators or the POTW about excess flows, internal facility plans, and drawings of the storm and sanitary sewers.

### *Visual Inspections of lines and Manholes*

A lot of infiltration and inflow enters the sewer through deteriorated manholes. Manhole defects are readily apparent upon visual inspection. The manhole can be physically entered if the steps are in good condition and confined space entry precautions are observed. The following are common sources of inflow and infiltration through manholes (all are exacerbated if ponding occurs over the manhole): holes in manhole covers, poor fit between manhole cover and rim, cracks and holes in the pavement around the manhole rim, cracks or misalignment between bricks in the manhole, and the loss or absence of mortar. between the bricks, cracks in the invert, and gaps or misalignment of connecting pipes.

The lines can be visually inspected through the manhole, by either lamping the lines and looking up them while in the manhole, or by using a remote halogen light and mirror while standing above the manhole.

**Picture 7-4 deteriorated manhole**

An important word of caution: Remember that even while working over an open manhole, you must observe confined space precautions. Sewer gases can render you unconscious before you detect them with your unaided senses, and many people have been killed by falling unconscious into manholes. In addition, methane gas, common in sewers, is very explosive, so sparks and open flames must always be kept away from sewers or manholes.

House-to house inspections are simple inspections of the exterior and interior of a property or residence. Inspectors check for illegally connected roof, yard, driveway, basement, and foundation drains, as well as sump pumps. Inspections usually take less than 10 minutes.

## *Smoke and Dye Testing*

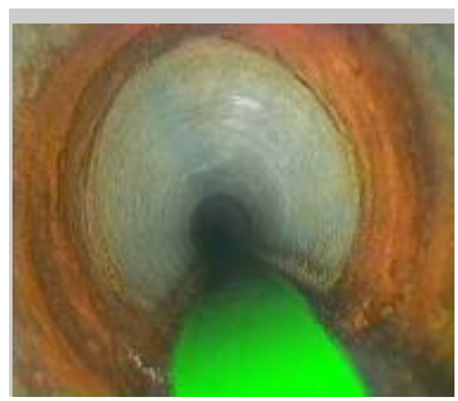
Smoke and dyed water testing can be used to identify inflow locations and cross connections, where inflow has been implicated as a problem in the results of the flow monitoring.

In smoke testing, a non-toxic "smoke bomb" is used to produce smoke. A blower is fitted over the top of the manhole for 15-20 minutes to purge the sewer of gases before the smoke is introduced. The pipes at the upstream and downstream manholes are blocked off to isolate a section of line. If there are any connections to the sewers, the smoke will travel up them. If there are any untrapped drains, the smoke will continue to travel until it gets to atmosphere.

Smoke testing is an effective way to detect storm connections to the sanitary sewer. Roof drains and catch basins connected to the smoked line will emit smoke. If there are significant cracks or holes in the pipeline, the smoke will come up through the ground above the pipe. To detect this, the smoke testing must be done during dry weather periods. Smoke testing is inexpensive. Sewer maintenance crews can easily carry it out. The engineer or technician in charge of the investigation should be on hand during the smoke test to observe and interpret the results. Pictures are usually taken to include in the report. Always inform the fire department and the nearby building occupants when you will be performing the testing, to prevent undue alarm.

Dyed water testing is like the reverse of smoke testing, in that dyed water is flooded on the surface or into potential sewer connections, and the nearest manhole is observed for signs of the dyed water. If the surface is flooded with dyed water and it gets into the pipe, it has entered through holes or cracks. If you suspect that a particular catch basin is connected to the sanitary sewer, you can dye running water from a hydrant or hose into the catch basin and look for it at the nearest downstream manhole. This is a very inexpensive technique and involves no equipment, just a bottle of dye and a water source.

**Picture 7-5 smoke testing**



**Picture 7-6 dye testing**

### Calculating velocity

A float is placed in a manhole. If the float travels 246 feet in 1 min 30 seconds. What is the estimated velocity in the channel in ft/sec?

The velocity is a direct calculation using the distance per time. Change the minutes into seconds to get the units of ft/sec

$$V = \frac{246 \text{ ft}}{90 \text{ sec}} = 2.73 \text{ ft/sec}$$

## *Cleaning and Televising the Lines*

Before lines are televised, they must be cleaned. This can be accomplished by pigging the lines, which is dragging a large rubber pig or plug through the lines, or jetting, which is sending a high pressure water jet through. Jets can also be used to pull a cable through the pipe, which will then be connected to the television camera to pull it through. While the lines are being cleaned, observe the debris which is removed. The contents of this debris will give you some indication of the condition of the sewer and the possible trouble sources. If there is grease, you may need to install or better maintain your grease traps. If there are roots, root intrusion may have caused cracks or joint separation. You may wish to regularly rod the lines or apply chemical root killers. If the removed debris includes dirt and pieces of broken pipe, you've probably got missing sections of pipe and may have to replace parts of the line.

**Using the lbs formula**

A sewer line is to be filled with a root control substance containing 500 mg/L of a specific chemical. How much chemical in lbs would be needed for a 300 ft section of 10 inch pipe?

Using the lbs formula find out the amount of liquid that will be in the pipe. The pipe is a cylinder so you will use .785 x D x D x L to get the flow.

Convert the diameter $D = \frac{10 \text{ in}}{12 \text{ in}} = .833 \text{ ft}$

Flow = volume = .785 x .833ft x .833ft x 300 ft = 163.47 $ft^3$
Convert to gallons 163.47 $ft^3$ x 7.48 = 1,222.75 gal = .0012MGD

Lbs = .0012MGD x 8.34 x 500 mg/L = 5 lbs

Televising must be done during wet weather or dyed water flooding of the surface. Wet weather is most effective, because it will also show sources of inflow. As the camera is drawn through the sewer, the film will record exact locations (in stations) of water entering the pipe. An expert can determine by watching the tapes how much water is entering in each defect in gallons per minute. The tape can also show the structural condition of the line. Also look for signs of hydrogen sulfide induced corrosion.

Televising is an expensive investigation technique--about $2 per linear foot, plus the cost of light or heavy cleaning which will add about another $1/ft. While televising rigs can be purchased for about $100K, most facilities find that it is more cost effective to hire a local sewer service company when this work is needed.

## *Analyzing the Results*

Once you have identified the quantities and sources of infiltration and inflow to your system, you will need to prioritize the defects in order of importance. The highest priority for rehabilitation is to maintain the structural integrity of your sewer system. Your biggest investment is the hole through the ground. So, if your investigation reveals places where your sewer is failing structurally, either experiencing collapses or where collapses are imminent, use these prescribed methods if the investigation showed signs that this was causing deterioration of your system. The next priority is the exclusion of extraneous clear water.

A fairly simple cost benefit analysis can be done to determine a cut off point for fixing infiltration or inflow sources. First determine the cost of transporting and treating a gallon of sewage in your system. Next determine the costs for repairing the various defects. Divide the cost of the repair by the amount of I/I the fix would remove from the system. If this cost is less than the cost to transport and treat, it is cost effective to do the repair, if this cost is higher, continue to allow the I/I from that source into the system.

There are some important exceptions to this simple analysis. You must also take into consideration why you are looking to get rid of the I/I in the first place. Are you violating your NPDES permit with hydraulic overloads? Is your sewer system under capacity for it's current demands. These issues could control your decision more than the economics.

For a system of average age and size, the following guidelines can be used to forecast the long-term costs that can be anticipated.

## Cost Estimating Guideline

An example of a Sewer System Evaluation Survey was conducted with the results found in Table 7-1.

**Table 7-1 Sewer System Evaluation Survey**

| Action Item | Cost |
|---|---|
| Flow Monitoring/Analysis | $0.15 - $0.30/lf |
| Physical Inspection | $0.75 - $1.50/lf |
| Cleaning/CCTV Inspection | $1.50 - $3.00/lf |
| Hydraulic Modeling | $0.10 - $0.20/lf |
| Plans and Specifications | 5.0 - 8.0% of Const. Est |
| Legal/Administration | 1.0 - 3.0% of Const. Est Construction |
| Pipeline Rehab (8-12") | $45.00 - $150.00/lf |
| Manhole Rehabilitation | $30.00 - $300.00/vf |
| Point Repairs (5-10') | $1,500 - $7,750/ea |

The above cost estimating guideline can vary depending on the size of the collection system and the actual rehabilitation requirements. (2009)

**Sewer System Infrastructure Analysis and Rehabilitation Manual**

http://nepis.epa.gov/EPA/html/DLwait.htm?url=/Exe/ZyNET.exe/30004DAX.PDF?ZyActionP=PDF&Client=EPA&Index=1991Thru1994&File=D%3A%5CZYFILES%5CINDEX%20DATA%5C91THRU94%5CTXT%5C00000002%5C30004DAX.txt&Query=625691030%20or%20sewer%20or%20system%20or%20survey%20or%20evaluation%20or%20costs&SearchMethod=1&FuzzyDegree=0&User=ANONYMOUS&Password=anonymous&QField=pubnumber%5E%22625691030%22&UseQField=pubnumber&IntQFieldOp=1&ExtQFieldOp=1&Docs=

The basic concepts for wastewater rates are as follows:

The cost per gallon for treatment involves (most systems will have performed this calculation to establish or check rates):

The cost to run a collection system is $28.8 million per year. The total flow through the collection system is 1.5 billion gallons. What is the wastewater cost per gallon of this system

$$\text{Wastewater cost per gallon} = \frac{\text{total collection system cost (\$ per year)}}{\text{total flow through the collection system (per year)}}$$

$$\text{Wastewater cost per gallon} \quad \frac{\$28{,}800{,}000}{1{,}500{,}000{,}000 \text{ gal}}$$

Wastewater cost per gallon $.02

The cost to run a collection system is $28.8 million per year. The total flow through the collection system is 1.5 billion gallons. What is the Collection System cost per equal resident unit for this system?

$$\text{Collection System Cost per Equal Residential Unit} = \frac{\text{collection system cost}}{\text{\# of gallons}} \times \frac{185}{\text{day}} \times \frac{30}{\text{month}}$$

$$\text{Collection System Cost per Equal Residential Unit} = \frac{\$28{,}800{,}000 \times 185 \times 30}{1{,}500{,}000{,}000 \text{ day month}}$$

Collection System Cost per Equal Residential Unit = $106.56

**Inflow and Infiltration Reduction**

There are many methods and technologies that are available to remove and reduce inflow and infiltration. Modern techniques allow for sewer lines to be inspected, cleaned, and even replaced without traditional open cut excavation. By utilizing Trenchless Technologies, rehabilitation and repair can often be performed without interruption of sewer service or traffic disruption.

Specific techniques that are available for fixing Infiltration sources are listed below:

Sewer Lines

- Manhole-to-Manhole Lining:
- Cured-in-place
- Fold & Form
- Slip Lining
- Pipe Bursting
- Dig and Replace
- Spot Repairs - sectional cured in place liner
- Spot Repairs - dig and replace

Manholes

- Exterior Coating or Grouting
- Interior Lining
- Replacement
- Inflow Dish
- Raise or Replace MH Covers and Frames

Inflow can also be removed by a variety of techniques, but these usually require a direct disconnection of the sanitary sewer system from the inflow source.

**Calculate the Percent Inflow and Infiltration**

The average flow to your facility is 2.88 MGD. When you receive a ½ inch rain your flow increases to 7.2 MGD. What is the percentage of inflow and infiltration?

The percent inflow and infiltration rate can be derived directly from the formula

$$\text{Percent inflow and infiltration} = \frac{\text{actual flow}}{\text{average flow}} \times 100$$

$$\text{Percent inflow and infiltration} = \frac{7.20 \text{ MGD}}{2.88 \text{ MGD}} \times 100 = 250\%$$

Below is a list of methods that may be used to remove inflow:

- Disconnect roof leaders, sump pumps, foundation drains, or other illegal or improper connection from the sanitary sewer system
- Encourage the removal of private inflow sources through enforcement of State,  Local Regulations or Incentive Programs
- Raise manhole covers that are located in low areas where storm water may pond
- Divert storm water that flows to manhole cover

## Review Questions for Inflow and Infiltration

1. _________ is the excess rainwater that enters the system very soon after the rain begins and can normally be traced to unsealed manholes and an ________ connection such as roof down spouts, parking lot and yard drains.

2. _________ is the excess water that continues to enter the system for three or four days after the rain has stopped and is the result of ___________ seeping into the system through breaks in the line and unsealed pipe joints.

3. A worthwhile maintenance program should include _____________, ___________, ________, ___________, and _____________.

4. Regular wet and dry weather ___________ ___________ can be used to see problems emerging, so corrections can be programmed in advance.

5. The techniques usually employed in the I/I or SSES study are _________, ___________, _________, _____________, and _____________.

6. Basins with high inflow should be investigated further using ______ and _____ _____________.

7. Basins where _________ is the predominant cause can be investigated using joint testing, visual inspections, and televising.

8. Common sources of inflow and infiltration through manholes are __________, ________, ___________, ___________, _______________.

9. If there are significant cracks or holes in the pipeline, the _____ will come up through the ground above the pipe; if roof drains and catch basins connected the smoked line will emit smoke. The smoke testing must be done during _____ ________ periods.

10. If the surface is flooded with ____ water and it gets into the pipe, it has entered through holes or cracks and signs of the _____ water will show up at the nearest manhole.

11. A fairly simple ________ _______ __________ can be done to determine a cut off point for fixing infiltration or inflow sources.

12. Before lines are televised, they must be _________.

13. The steps in performing a cost benefit analysis are _________, _________, __________, ____________and ______________.

14. By utilizing ___________ ______________, rehabilitation and repair can often be performed without interruption of sewer service or traffic disruption.

15. List of methods that may be used to remove inflow at residences include: ________, ____________, ___________, and ________________.

16. A float is placed in a manhole. If the float travels 600 feet in 3 min 30 seconds. What is the estimated velocity in the channel in ft/sec?

17. A sewer line is to be filled with a root control substance containing 268mg/L of a specific chemical. How much chemical in lbs would be needed for a 700 ft section of 10 inch pipe?

18. The cost to run a collection system is $2 million per year. The total flow through the collection system is 51 million gallons. What is the wastewater cost per gallon of this system?

19. The cost to run a collection system is $1.6 million per year. The total flow through the collection system is 12 million gallons. What is the Collection System cost per equal resident unit for this system?

20. The average flow to your facility is 9.88 MGD. When you receive a ½ inch rain your flow increases to 12.2 MGD. What is the percentage of inflow and infiltration?

## Answers to Inflow and Infiltration Review Questions

1. Inflow, illegal

2. Infiltration, groundwater

3. good record keeping system, quick response to service requests, a cycle of regular televising, regular cleaning of the system, and regular attention to corrosion protection

4. flow monitoring

5. flow monitoring, interviews of maintenance personnel and review of repair records, visual inspections of lines and manholes, smoke and dye testing, televising of the lines

6. smoke, dye testing

7. infiltration

8. holes in manhole covers, poor fit between manhole cover and rim, cracks and holes in the pavement around the manhole rim, cracks or misalignment between bricks in the manhole, and the loss or absence of mortar

9. smoke, dry weather

10. dyed, dyed

11. cost benefit analysis

12. cleaned

13. determine the cost of transporting and treating a gallon of sewage, determine the costs for repairing the various defects, determine the cost of the repair, determine the amount of I/I the fix would remove from the system, compare the cost of fixing the I/I problem to the cost to transport and treat

14. trenchless technologies

15. disconnecting roof leaders, sump pumps, foundation drains, or other illegal or improper connection from the sanitary sewer system

16. 2.86 ft/s

17. 6.37 lbs

18. $.04

19. $721.50

20. 123%

# Chapter 8: INSPECTION AND CLEANING

## Chapter 8 Objectives

1. Know the importance of sewer line cleaning.
2. Identify inspection and cleaning techniques pertaining to the collection system.
3. Identify purpose of a maintenance plan and the factors for the maintaining of pipes.
4. Differentiate between the advantages and disadvantages of inspection technique.
5. Differentiate between the limitations of cleaning methods.
6. Identify situations that cause environmental harm during inspections and cleanings.
7. Understand the importance of record keeping as it pertains to the cleaning and inspection process.
8. Calculate operations and construction costs

As sewer system networks age, the risk of deterioration, blockages, and collapses becomes a major concern. As a result, municipalities worldwide are taking proactive measures to improve performance levels of their sewer systems. Non-emergency sewer line cleaning and inspecting sewer lines are essential to maintaining the capacity of the sewer and maintaining a properly functioning system; these activities further a community's reinvestment into its wastewater infrastructure. In many systems the sewer lines have low flow between midnight and 5 AM, or many of the sewer lines can be temporarily plugged during this time frame.

## *Inspection Techniques*

Inspection programs are required to determine current sewer conditions and to aid in planning a maintenance strategy. Ideally, sewer line inspections need to take place during low flow conditions. If the flow conditions can potentially overtop the camera, then the inspection should be performed during low flow to reduce the flow.

**Figure 8-1 dry weather wastewater flow example**

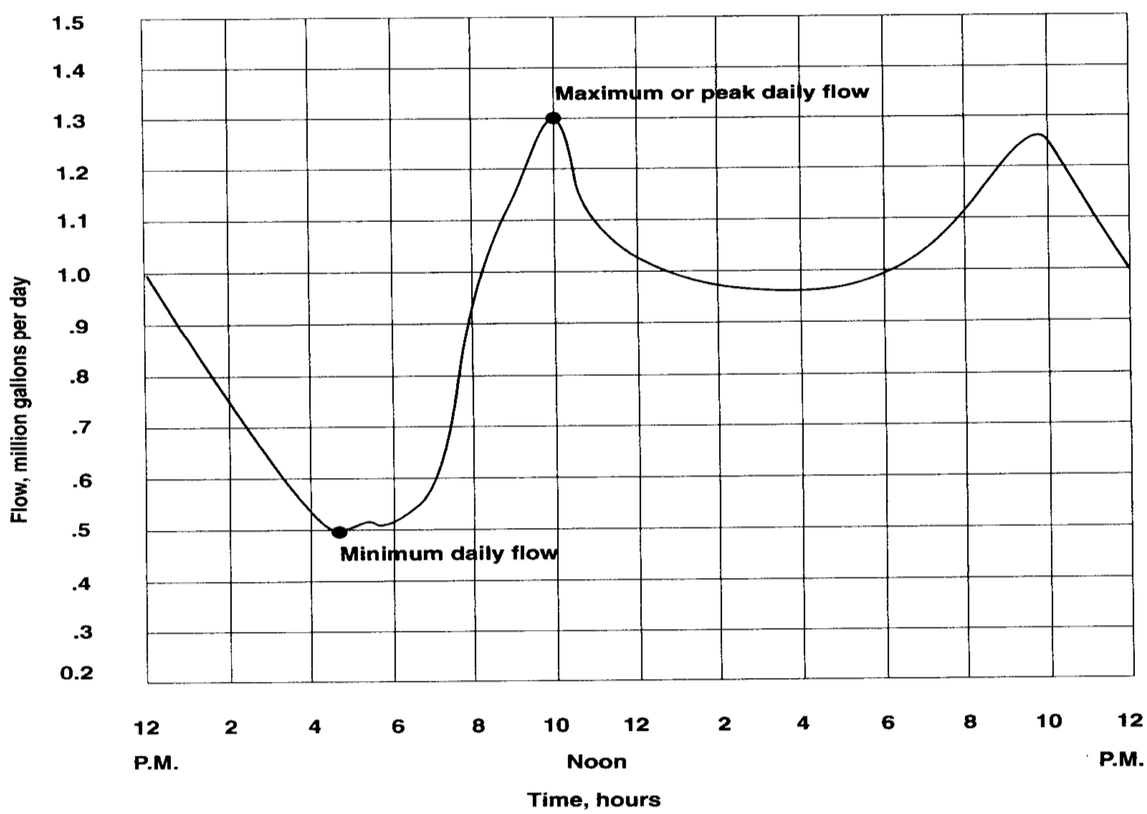



*Fig. 3.1 Variations of dry weather wastewater flow from a typical community*

Most sewer lines are inspected using one or more of the following techniques:

• Closed-circuit television (CCTV)
• Cameras
• Visual inspection
• Lamping inspection.

Television (TV) inspections are the most frequently used, most cost efficient in the long term, and most effective method to inspect the internal condition of a sewer.. CCTV inspections are recommended for sewer lines with diameters of 4 - 48 inches. The CCTV camera must be assembled to keep the lens as close as possible to the center of the pipe.

In larger sewers, the camera and lights are attached to a raft, which is floated through the sewer from one manhole to the next. To see details of the sewer walls, the camera and lights swivel both vertically and horizontally. In smaller sewers, the cable and camera are attached to a sled, to which a parachute or drogue is attached and floated from one manhole to the next.

Documentation of inspections is very critical to a successful operation and maintenance (O&M) program. CCTV inspections produce a video record of the inspection that can be used for future reference.

In larger sewers where the surface access points are more than1000 linear feet apart, camera inspections are commonly performed. This technique involves a raft-mounted film camera and strobe light. This method requires less power than the CCTV, so the power cable is smaller and more manageable. Inspections using a camera are documented on polaroid still photographs that are referenced in a log book according to date, time, and location.

Visual inspections are vital in fully understanding the condition of a sewer system. Visual inspections of manholes and pipelines are comprised of surface and internal inspections. Operators should pay specific attention to sunken areas in the groundcover above a sewer line and areas with ponding water. In addition, inspectors should thoroughly check the physical conditions of stream crossings, the conditions of manhole frames and covers or any exposed brickwork, and the visibility of manholes and other structures.

For large sewer lines, a walk-through or internal inspection is recommended. This inspection requires the operator to enter a manhole, the channel, and the pipeline, and assess the condition of the manhole frame, cover, and chimney, and the sewer walls above the flow line.

When entering a manhole or sewer line, it is very important to observe the latest Occupational Safety and Health Administration confined space regulations. If entering the manhole is not feasible, mirrors can be used. Mirrors are usually placed at two adjacent manholes to reflect the interior of the sewer line.

Lamping inspections may be used in low priority pipes, which tend to be pipes that are less than 20 years old. Lamping is used on projects where funds are extremely limited. In the lamping technique, a camera is inserted and lowered into a maintenance hole and then positioned at the center of the junction of a manhole frame and the sewer. This technique is very limited in the amount of pipe that can be inspected and is seldom used anymore.

## *Cleaning Techniques*

To maintain its proper function, a sewer system needs a cleaning schedule. There are several traditional cleaning techniques used to clear blockages and to act as preventative maintenance tools. When cleaning sewer lines, local communities need to be aware of EPA regulations on solid and hazardous waste as defined in 40 CFR 261. In order to comply with state guidelines on testing and disposal of hazardous waste, check with the local authorities.

**Picture 8-1 Dirty pipe/Clean pipe**

**Picture 8-2 Jetting a pipe**

Table 8-1 summarizes some of the most commonly used methods to clean sewer systems.

**Table 8-1 cleaning techniques**

| Technology | Uses and applications |
|---|---|
| **Mechanical** | |
| Rodding | • Uses an engine and a drive unit with continuous rods or sectional rods.<br>• As blades rotate they break up grease deposits, cut roots, and loosen debris.<br>• Rodders also help thread the cables used for TV inspections and bucket machines.<br>• Most effective in lines up to 300 mm (12 inches) in diameter. |
| Bucket Machine | • Cylindrical device, closed on one end with 2 opposing hinged jaws at the other.<br>• Jaws open and scrape off the material and deposit it in the bucket.<br>• Partially removes large deposits of silt, sand, gravel, and some types of solid waste |
| **Hydraulic** | |
| Balling | • A threaded rubber cleaning ball that spins and scrubs the pipe interior as flow increases in the sewer line.<br>• Removes deposits of settled inorganic material and grease build-up.<br>• Most effective in sewers ranging in size from 13-60 cm (5-24 inches). |
| Flushing | • Introduces a heavy flow of water into the line at a manhole.<br>• Removes floatables and some sand and grit.<br>• Most effective when used in combination with other mechanical operations, such as rodding or bucket machine cleaning. |
| Jetting | • Directs high velocities of water against pipe walls.<br>• Removes debris and grease build-up, clears blockages, and cuts roots within small diameter pipes.<br>• Efficient for routine cleaning of small diameter, low flow sewers. |
| Scooter | • Round, rubber-rimmed, hinged metal shield that is mounted on a steel framework on small wheels. The shield works as a plug to build a head of water.<br>• Scours the inner walls of the pipe lines.<br>• Effective in removing heavy debris and cleaning grease from line. |
| Kites, Bags, and Poly Pigs | • Similar in function to the ball.<br>• Rigid rims on bag and kite induce a scouring action.<br>• Effective in moving accumulations of decayed debris and grease downstream. |

| | |
|---|---|
| Silt Traps | • Collect sediments at convenient locations.<br>• Must be emptied on a regular basis as part of the maintenance program. |
| Grease Traps and Sand/Oil Interceptors | • The ultimate solution to grease build-up is to trap and remove it.<br>• These devices are required by some uniform building codes and/or sewer-use ordinances.<br>Typically sand/oil interceptors are required for automotive business discharge.<br>• Need to be thoroughly cleaned to function properly.<br>• Cleaning frequency varies from twice a month to<br>once every 6 months, depending on the amount of grease in the discharge.<br>• Need to educate restaurant and automobile businesses about the need to maintain these traps. |
| Chemicals [1] | • Used to control roots, grease, odors (H2S gas), concrete corrosion, rodents and insects.<br>• *Root Control* - longer lasting effects than power rodder (approximately 2-5 years).<br>• *H2S gas* - some common chemicals used are chlorine (Cl2), hydrogen peroxide (H2O2), pure oxygen (O2), air, lime (Ca(OH2)), sodium hydroxide (NaOH), and iron salts.<br>• *Grease and soap problems* - some common chemicals used are bioacids, digester, enzymes, bacteria cultures, catalysts, caustics, hydroxides, and neutralizers. |

[1] *Before using these chemicals review the Material Safety Data Sheets (MSDS) and consult the local authorities on the proper use of chemicals as per local ordinance and the proper disposal of the chemicals used in the operation. If assistance or guidance is needed regarding the application of certain chemicals, contact the U.S. EPA or state water pollution control agency.*

A jet rodder cleans 255,000 ft. of sewer line per month. If the operating costs of the rodder is $0.42 per 100ft. What is the monthly cost to use the rodder?

First calculate the number of 100 foot sections. Then calculate the monthly cost.

Number of 100 foot sections = $\frac{255,000 \text{ ft}}{100 \text{ ft}}$ = 2,550 sections

Cost per month = 2,550 x $.42 = $1,071.00

In recent years, new methodologies and accelerated programs have been developed to take advantage of the information obtained from sewer line maintenance operations. Such programs incorporate information gathered from various maintenance activities with basic sewer evaluations to create a system that can remedy and prevent future malfunctions and failures more effectively and efficiently. .

A study performed by the American Society of Civil Engineers reports that the most important maintenance activities are cleaning and CCTV inspections. Table 7-2 shows the average frequency of various maintenance activities.

**Table 8-2**

| Activity | Average ( % of system per year) |
|---|---|
| Cleaning | 29.9 |
| Root removal | 2.9 |
| Manhole inspection | 19.8 |
| CCTV inspection | 6.8 |
| Smoke testing | 7.8 |

A maintenance plan attempts to develop a strategy and priority for maintaining pipes based on several of the following factors:

- Problems- frequency and location; 80 percent of problems occur in 25 percent of the system (Hardin and Messer, 1997).
- Age- older systems have a greater risk of deterioration than newly constructed sewers.

- Construction material- pipes constructed of materials that are susceptible to corrosion have a greater potential of deterioration and potential collapse.
- Non-reinforced concrete pipes, brick pipes, and asbestos cement pipes are examples of pipes susceptible to corrosion.
- Pipe diameter/volume conveyed- pipes that carry larger volumes take precedence over pipes that carry a smaller volume.
- Location- pipes located on shallow slopes or in flood prone areas have a higher priority.
- Force main vs. gravity-force mains have a higher priority than gravity, size for size, due to the complexity of the cleaning and repairs.
- Subsurface conditions- depth to groundwater, depth to bedrock, soil properties (classification, strength, porosity, compressibility, frost susceptibility, erodibility, and pH
- Corrosion potential- Hydrogen Sulfide (H2S) is responsible for corroding sewers, structures, and equipment used in wastewater collection systems. The interior conditions of the pipes need to be monitored and treatment needs to be implemented to prevent the growth of slime bacteria and the production of H2S gases.

## Advantages And Disadvantages

There are many advantages and disadvantages to inspection techniques in the collection system. Below some of the limitations are listed.

The limitations of various inspection techniques used by sanitary sewer authorities are summarized in Table 8-3.

**TABLE 8-3**

| Inspection technique | Limitations |
|---|---|
| Visual Inspection | In smaller sewers, the scope of problems detected is minimal because the only portion of the sewer that can be seen in detail in near the manhole. Therefore, any definitive information on cracks or other structural problems is unlikely. However, this method does provide information needed to make decisions on rehabilitation. |
| Camera Inspection | When performing a camera inspection in a large diameter sewer, the inspection crew is essentially taking photographs haphazardly, and as a result, the photographs tend to be less comprehensive. |
| Closed Circuit Television (CCTV) | This method requires late night inspection and as a result the TV operators are vulnerable to lapses in concentration. CCTV inspections are also quite expensive and time consuming. |
| Lamping Inspection | The video camera does not fit into the pipe and during the inspection it remains only in the maintenance hole. As a result, only the first 10 feet of the pipe can be viewed or inspected using this method. |

**Table 8-4** cleaning methods used by sanitary sewer authorities.

| Cleaning methods | Limitations |
|---|---|
| 1. Balling<br><br>2. Jetting<br><br>3. Scooter | 1. Balling - Balling cannot be used effectively in pipes with bad offset joints or protruding service connections because the ball can become distorted.<br><br>2. Jetting - The main limitation of this technique is that cautions need to be used in areas with basement fixtures and in steep-grade hill areas<br><br>3. Scooter - When cleaning larger lines, the manholes need to be designed to a larger size in order to receive and retrieve the equipment. Otherwise, the scooter needs to be assembled in the manhole.<br><br>Caution also needs to be used in areas with basement fixtures and in steep-grade hill areas.<br><br>In general, these methods are only successful when necessary water pressure or head is maintained without flooding basements or houses at low elevations. |
| Bucket Machine | This device has been known to damage sewers.<br>The bucket machine cannot be used when the line is completely plugged because this prevents the cable from being threaded from one manhole to the next.<br><br>Set-up of this equipment is time-consuming. |
| Flushing | This method is not very effective in removing heavy solids. Flushing does not remedy this problem because it only achieves temporary movement of debris from one section to another in the system. |
| High Velocity Cleaner | The efficiency and effectiveness of removing debris by this method decreases as the cross-sectional areas of the pipe increase. Backups into residences have been known to occur when this method has been used by inexperienced operators. Even experienced operators require extra time to clear pipes of<br>roots and grease. |

| | |
|---|---|
| Kite or Bag | When using this method, use caution in locations with basement fixtures and steep-grade hill areas. |
| Rodding | Continuous rods are harder to retrieve and repair if broken and they are not useful in lines with a diameter of greater than 300 mm (0.984 feet) because the rods have a tendency to coil and bend. This device also does not effectively remove sand or grit, but may only loosen the material to be flushed out at a later time. |

**Picture 8-3 Bucket Machine**

The primary benefit of implementing a sewer maintenance program is the reduction of SSOs, basement backups, and other releases of wastewater from the collection system due to substandard sewer conditions. Improper handling of instruments and chemicals used in inspecting and maintaining sewer lines may cause environmental harm.

Examples include:

- Improperly disposing of collected materials and chemicals from cleaning operations.
- Improperly handling chemical powdered dyes.
- Inadequately maintaining inspection devices.
- Some instruments have a tendency to become coated with petroleum based residues and if not handled properly they can become a fire hazard.

## Performance

Table 7-5 defines the conditions under which certain cleaning methods are most effective. Cleaning is an important part of pipe maintenance. Sewer line cleaning is prioritized based on the age of the pipe and the frequency of the problems within it. The system may use rodding and pressurized cleaning methods to maintain the pipes. Bucket machines are rarely used because cleaning by this method tends to be time consuming. Every building or property should have a clean out placed in close proximity of the foundation or property line.

**Picture 8-4 Operator inspecting a sewer.**

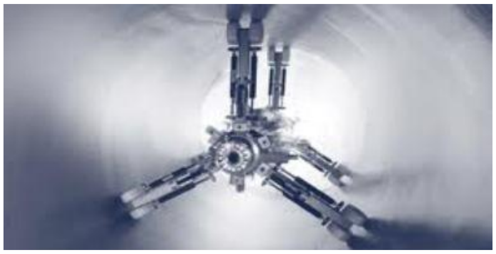
**Table 8-5**

***A = Best D = Not best***

| Solution | Emergency stoppage | Grease | Roots | Sand, grit, debris | Odors |
|---|---|---|---|---|---|
| Balling | | B | | B | C |
| High Velocity Cleaning | D | A | | B | C |
| Flushing | | | | | C |
| Sewer Scooter | | C | | C | |
| Bucket machine | | | | C | |
| Power Rodder | B | D | C | | |
| Hand Rodding | B | D | C | | |
| Chemicals | | C | B | | B |

The system may use mechanical, rather than chemical, methods to remove grease and roots. Introducing chemicals into the cleaning program requires hiring an expert crew, adopting a new program, and instituting a detention time to ensure the chemicals' effectiveness.

Record keeping is also vital to the success of such a maintenance program. The system may start tracking the number of times their sewer lines were inspected and cleaned and the number of overflows and backups a sewer line experienced. This information will help the utility reprioritize sewer line maintenance and adapt a more appropriate time schedule for cleaning and inspecting the sewer lines.



**Picture 8-5 CCTV camera in a new sewer line**

## Costs

The following shows gives an indication of cost parameters associated with cleaning and inspecting in the collection system.

Table 7-6 summarizes the annual maintenance costs per mile for cleaning and inspecting.

**Table 8-6**

| Identifier | Range of cost 2009$ | Average cost, 2009$ |
|---|---|---|
| Total O&M cost/mile/year | $1,263 - $62,474 | $3,755 |
| Labor (cost/mile/year) | $924 - $26,375 | $4,823 |
| Fringe Benefits (cost/mile/year) | $255 - $12,013 | $1,576 |
| Chemicals (cost/mile/year) | $.04 - $10,130 | $681 |
| Hydroflush Cleaning (cost/mile) | $631 - $6,956 | $2,261 |
| Television Inspection (cost/mile) | $1,330 - $15,228 | $6,118 |

**Picture 8-6 manual cleaning of a large sewer**

## Review Questions for Inspection and Cleaning

1. _____ sewer line cleaning and inspecting sewer lines are essential to maintaining the capacity of the sewer and maintaining a properly functioning system.

2. In many systems the sewer lines have low flow between ______ and _____, or many of the sewer lines can be temporarily plugged during this time frame.

3. 4 techniques used in sewer cleaning to inspection are ________, ________, _________, and __________.

4. To see details of the sewer walls in larger sewers, the camera and lights swivel both __________ and _____________.

5. Inspectors should thoroughly check the physical conditions of ______ _______, the conditions of ________ ______ and covers or any exposed brickwork, and the visibility of manholes and other structures.

6. 2 forms of mechanical cleaning are _____________ and use of a _____________.

7. The primary benefit of implementing a sewer maintenance program is the reduction of _______ ______ _______, ________ _______, and other ________ ______ _____________ from the collection system due to substandard sewer conditions.

8. CCTV should account for _________ % of the time used for inspection and cleaning.

9. The ultimate solution to ___________ __________ is to trap and remove it.

10. _________ ______ is also vital to the success of such a maintenance program.

11. A jet rodder cleans 500,000 ft. of sewer line per month. If the operating costs of the rodder is $0.42 per 100ft. What is the monthly cost to use the rodder?

## Answers to Review Questions for Inspection and Cleaning

1. Non-emergency
2. Midnight, 5 am
3. Closed-circuit television (CCTV), cameras, visual inspection, lamping inspection
4. vertically and horizontally
5. stream crossings, manhole frames
6. jetting, bucket truck
7. sanitary sewer overflows, basement backups, releases of wastewater
8. 6.8%
9. Grease build-up
10. Record keeping
11. $2,100

# Chapter 9: SEWER USE ORDINANCES, COMBINED AND SANITARY SEWER SYSTEMS

## Chapter 9 Objectives

1. Define sewer use ordinances, combined and sanitary sewer systems.
2. Identify parts of a sewer use ordinance and their applications.
3. Identify the items that make up CSO and SSO discharges.
4. Know the three major categories of pathogens.
5. Define toxins.
6. Identify potentially hazardous metals
7. Identify the effects that metals can have due to long term human exposure.
8. Define floatables and their affects in the collection system.
9. Identify the five designated uses that CSOs and SSOs can impact.
10. Identify the locations and causes of SSOs.

In the United States, two types of public sewer systems predominate: Combined sewer systems (CSS) and Sanitary Sewer Systems (SSS).

A combined sewer system is a wastewater collection system owned by a municipality that conveys domestic, commercial, and industrial wastewater and storm water runoff through a single pipe system to a publicly-owned treatment works. Combined sewer" or "combined sewer line" means a sewer or sewer line designed to carry storm water runoff as well as sanitary wastewater. Combined sewer overflow" or "CSO" means the flow from a combined sewer in excess of the interceptor or regulator capacity that is discharged into a receiving water without going to a POTW.

A sanitary sewer system is a wastewater collection system owned by a municipality that conveys domestic, commercial, and industrial wastewater, and limited amounts of infiltrated groundwater and storm water to a POTW. Areas served by Sanitary Sewer Systems often have a municipal separate storm sewer system to collect and convey runoff from rainfall and snowmelt.

A sewer use ordinance regulates the use of public and private sewers and drains, private wastewater disposal, the installation and connection of building sewers, and the discharge of waters and wastes into the public sewer system.

## *Sewer Use Ordinance*

A sewer use ordinance regulates the use of public and private sewers and drains, private wastewater disposal, the installation and connection of building sewers, and the discharge of waters and wastes into the public sewer system. A sewer use ordinance can help control several problematic situations that occasional occur in collection systems.

The following should be governed by a sewer use ordinance:

1. **Roof drains**
   a. Schools
   b. Churches
   c. Hospitals
   d. City hall

2. **Sump pumps/Floor drains** (can be 25 gpm)
   a. Schools
   b. Churches
   c. Hospitals
   d. Garages
   e. Residential

3. **Grease traps (ask for a manifest, proof of pumping)**
   a. Schools
   b. Churches
   c. Hospital
   d. Restaurants

Education and pollution prevention can also be addressed in a sewer use ordinance. The public should be informed of good sewer use principals, and other helpful ways to prolong the life of collection system infrastructure. Grease disposal methods and other techniques to keep grease and other unwanted debris out of collection system pipes are essential to maintaining and prolonging collection system life.

**Picture 9-1 grease interceptor**


**Picture 9-2 Pamphlet for FOG program**

Sewer Use Ordinances should have teeth. The enforcement of the ordinance is only as good as the terms included in the ordinance. The following should be thoroughly discussed and outlined in the ordinance.

**Factors that Should be Regulated in a Sewer Use Ordinance**

1. Designate who is responsible for enforcement
2. Define the area that the ordinance governs
3. Define what type of buildings are affected
4. Consequences for not following the ordinance
5. Give provisions for private wastewater disposal
6. Define policy for building sewers and connections
7. Give provisions for public usage of sewers
8. Define parameters for metals and other harmful contaminants
9. Define misuse and abuse
10. Define the authority of the inspectors of the sewers
11. Penalties associated with violations of the ordinance

The ordinance should then be validated and an effective date should be established in which enforcement of the ordinance is to begin.

## *CSOs*

The term "CSO" refers to a discharge from a point prior to the POTW treatment plant. CSOs generally occur in response to wet weather events; that is, during and following periods when rainfall or snowmelt drain to the combined sewer system. Most combined sewer systems are designed to discharge flows that exceed conveyance capacity directly to receiving water bodies, such as rivers, streams, estuaries, and coastal waters combined sewer systems can also back up into buildings, including private residences. When backups are caused by problems in the publicly owned portion of a combined sewer systems, they are considered unauthorized discharges. CSO discharges include a mix of domestic, commercial, and industrial wastewater, and storm water runoff. As such, CSO discharges contain human, commercial, and industrial wastes as well as pollutants washed from streets, parking lots, and other surfaces.

**Picture 9-1 Combined sewer overflow**


**Picture 9-2 Sign warning about possible combined sewer overflow potential**

## *SSOs*

The term <u>sanitary sewer overflow</u> (SSO) refers to untreated or partially treated sewage releases from a sanitary sewer system. SSOs have a variety of causes, including, but not limited to, severe weather, blockages, line breaks, power failures, lapses in sewer system operation and maintenance, inadequate sewer design and construction, and vandalism. SSO discharges typically contain a mix of domestic, commercial, and industrial waste. SSOs can pose challenging public health and environmental issues when they occur. SSOs include those overflows that reach waters of the United States, as well as overflows out of manholes and onto city streets, sidewalks, and other terrestrial locations. A limited number of municipalities have regular SSO discharges from fixed points within the sewer system.

Sanitary Sewer Systems can back up into buildings, including private residences. When backups are caused by problems in the publicly-owned portion of a sanitary sewer system, they are considered SSOs. SSOs that reach waters of the United States are point source discharges, and, like other point source discharges from municipal Sanitary Sewer Systems, are prohibited unless authorized by a National Pollutant Discharge Elimination System (NPDES) permit. Moreover, SSOs, including those that do not reach waters of the United States, may be indicative of improper operation and maintenance of the sewer system, and thus may violate NPDES permit conditions.

The principal pollutants present in CSO and SSO discharges include:

- Microbial pathogens
- Oxygen depleting substances (measured as BOD5)
- TSS
- Toxics
- Nutrients
- Floatables

The pollutants in CSOs and SSOs come from a variety of sources. Domestic wastewater contains microbial pathogens, BOD5, TSS, and nutrients. Wastewater from industrial facilities, commercial establishments, and institutions can contribute additional pollutants such as fats, oils, and grease (FOG), and toxic substances including metals and synthetic organic compounds. Fungi do not have a major presence in wastewater.

**Picture 9-3 Fish after a Sanitary Sewer Overflow**

## *Microbial Pathogens in CSOs and SSOs*

Microbial pathogens are microorganisms that can cause disease in aquatic biota and illness or even death in humans. The three major categories of microbial pathogens present in CSOs and SSOs are bacteria, viruses, and parasites. These microbial pathogens are, for the most part, easily transported by water

## *Environmental Effects of CSOs and SSOs*

The pollutants found in CSOs and SSOs can potentially impact five designated uses:

- Aquatic life support, meaning the water provides suitable habitat for the protection and propagation of desirable fish, shellfish, and other aquatic organisms.
- Drinking water supply, meaning the water can supply safe drinking water with conventional treatment.

- Fish consumption, meaning the water supports fish free from contamination that could pose a significant human health risk.
- Shellfish harvesting, meaning the water supports a population of shellfish free from toxics and pathogens that could pose a significant health risk to consumers.
- Recreation, meaning water based activities (e.g., swimming, boating) can be performed without risk of adverse human health effects.

**Picture 9-4 Sanitary Sewer Overflow from manhole**

**Picture 9-5 Sanitary Sewer Overflow from a grease trap**

## *Location of SSOs*

SSOs can occur at any location in the sanitary sewer systems, including: manholes, cracks and other defects in sewer lines, emergency relief outlets, and elsewhere. Reports of SSO events often include street addresses where the spill occurred. Because SSO events can occur at so many locations, gathering latitude and longitude for SSOs at a national level is impractical. Rather, it is more useful to look at the cause of the events, which is often linked to the type of location where it occurs.

## *Causes of SSOs*

In general, SSOs attributed to wet weather and I/I are caused by insufficient sewer system capacity, while the other types of spills are attributable to sewer system operation and maintenance.

**Table 9-1 EPA's five broad causes of SSO event occurrences**

| SSO Event | % of event occurrence |
|---|---|
| Blockages | 48 % |
| Wet weather and I/I | 26% |
| Power and mechanical failures | 11% |
| Line breaks | 10% |
| Miscellaneous (e.g., vandalism, contractor error) | 5% |

## Review Questions for CSOs, SSOs, and Sewer Use Ordinances

1. A _________ _______ _________ is a wastewater collection system owned by a municipality that conveys domestic, commercial, and industrial wastewater and storm water runoff through a single pipe system to a publicly-owned treatment works.

2. Flow from a combined sewer in excess of the interceptor or regulator capacity that is discharged into a receiving water without going to a POTW is ______________ ____________ ____________.

3. A __________ ___________ ___________ is a wastewater collection system owned by a municipality that conveys domestic, commercial, and industrial wastewater, and limited amounts of infiltrated groundwater and storm water to a POTW

4. A _________ __________ ___________ regulates the use of public and private sewers and drains, private wastewater disposal, the installation and connection of building sewers, and the discharge of waters and wastes into the public sewer system.

5. When backups are caused by problems in the publicly owned portion of a combined sewer systems, they are considered ___________ _________.

6. The term ____________ ___________ ___________ refers to untreated or partially treated sewage releases from a sanitary sewer system.

7. 6 causes of SSOs are ________, _______, ___________, ____________, ____________, and _____________.

8. Wastewater from industrial facilities, commercial establishments, and institutions can contribute additional pollutants such as ______, _________, and __________ and toxic substances including metals and synthetic organic compounds.

## Answers to Review Questions for CSOs, SSOs, and Sewer Use Ordinances

1. combined sewer system
2. combined sewer overflow
3. sanitary sewer system
4. sewer use ordinance
5. unauthorized discharges
6. sanitary sewer overflow
7. severe weather, blockages, line breaks, power failures, lapses in sewer system operation and maintenance, inadequate sewer design and construction, and vandalism
8. fats, oils, grease

# Chapter 10: HAZARDS

## Chapter 10 Objectives

1. Identify and understand bacterial hazards.
2. Recognize and comprehend the three steps in disease transmission.
3. Know, identify, and understand the three common routes used by pathogens to enter the human body.
4. Understand the importance of personal protective equipment.
5. Identify and understand the effect of chemical agents in the collection system.
6. Know, identify, and understand the chemical hazards of hydrogen sulfide ($H_2S$), ammonia gas ($NH_3$), carbon monoxide (CO), chlorine gas ($CL_2$), and methane gas ($CH_4$).
7. Know, identify, and understand the hazards associated with excavation, trenching, shoring, sloping and benching techniques.

## ***Bacterial Hazards***

Wastewater collection system operators are exposed daily to numerous health risks. These risks include exposure to gases, chemicals, endotoxins, exotoxins, and pathogens. Asphyxiating, irritating, and toxic gases produced through the anaerobic degradation of carbonaceous wastes include ammonia ($NH_3$), carbon dioxide ($CO_2$), carbon monoxide (CO), hydrogen sulfide ($H_2S$), and methane ($CH_4$). In addition to these gases, chemicals such as vaporized, volatile organic compounds (VOCs) from wastewater also represent a health risk. Biological activity in long sluggish flow flat grade sewer lines can cause oxygen deficiency in manholes, sewers and wet wells.

Dead and living bacterial cells release endotoxins and exotoxins, respectively. These toxins attack cells and tissues in the human body and cause gastrointestinal, respiratory tract, and nervous system diseases. Examples of several diseases caused by exotoxins include anthrax, food poisoning, and tetanus. Of all health risks associated with wastewater treatment facilities, perhaps disease transmission is of most concern to wastewater operators.

The two broad categories of bacteria associated with wastewater are indicator bacteria and pathogenic bacteria. Indicator bacteria are widely used as a surrogate for microbial pathogens in wastewater and water quality assessments. Indicator bacteria suggest the presence of disease-causing organisms, but generally are not pathogenic themselves. The principal indicator bacteria used to assess water quality are fecal coliform, *E. coli,* and enterococcus. All three are found in the intestines and feces of warm blooded animals.

Pathogenic bacteria are capable of causing disease. Examples of pathogenic bacteria associated with untreated wastewater, CSOs, and SSOs include *Campylobacter*, *Salmonella*, *Shigella*, *Vibrio cholerae*, and *Yersina*.

Pathogens include viruses, bacteria, fungi, protozoa, and helminthes (or worms). Exposure to pathogens and the potential for disease transmission through contact with pathogen contaminated wastewater, aerosols, compost, foam, sludge, and work surfaces are considered to be risks for wastewater personnel.

Pathogens enter wastewater treatment facilities from the bodily wastes of infected individuals, which may be human, domestic animals, or wild animals. Fecal waste and urine from cats and dogs enter wastewater treatment facilities through inflow and infiltration (I/I). Slaughterhouse waste from poultry, pork, and beef industries also contains many pathogens that are capable of infecting humans. Fecal waste and urine from rodents in the sanitary and combined sewers represent sources of pathogens.

Viruses are ultramicroscopic agents and are inert. They are not capable of independent growth or reproduction and are not considered to be living organisms. Viruses increase in number through replication. For replication to occur, a virus must enter a living cell (host) and cause disease. Although numerous viral groups are present in wastewater, the principle viruses of concern include the enteroviruses and the hepatitis viral group. Enteroviruses attack the gastrointestinal tract, while hepatitis viruses attack the liver.

More than 120 enteric (intestinal) viruses may be found in sewage. Concentrations of viruses reported in wastewater vary greatly and depend on the presence and amount of infection in the population served by a sewer system, season of the year, and the methods used for enumerating the virus counts. Examples of viruses associated with untreated wastewater, CSOs, and SSOs include poliovirus, infectious hepatitis virus, and coxsackie virus. These organisms may cause respiratory disease, gastroenteritis, pneumonia, hepatitis, respiratory infection and aseptic meningitis.

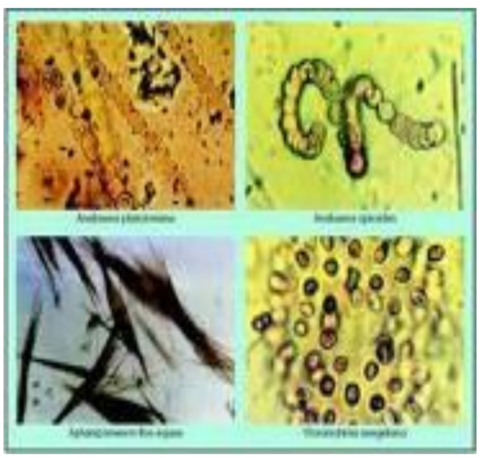
Bacteria are simple, unicellular organisms. Most bacteria range in size from 0.1 micrometers (µm) to 15 µm, and the shape of most bacteria is rod (bacillus), spherical (coccus), or spiral (sprillium). Bacteria are ubiquitous in nature, and most are harmless. They reproduce asexually, usually by splitting in half, and may be found as individual cells, clusters of cells, or chains of cells (filaments).

There are two types of pathogenic bacteria. "True" pathogens such as *Leptospira interrogans* are aggressive and cause disease. "Opportunistic" pathogens such as *Escherichia coli* are typically found on or in the human body and do not cause disease unless the body's immune system is weakened by injury, a "true" pathogen, or physiological disease

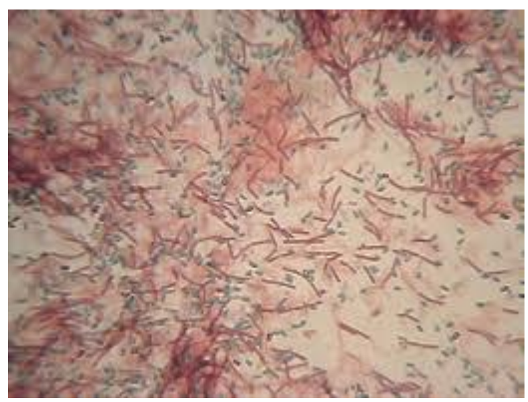
Fungi are a diverse group of organisms. Some fungi such as yeast are unicellular, while other fungi such as molds and mushrooms are multicellular. Fungi are saprophytes and obtain their nourishment from dead organic matter or living organisms. Although there are few pathogenic fungi, these fungi are not obligate parasites.

Protozoa are single-celled organisms that are animal-like, fungus-like, or plant-like. Protozoa often are grouped or identified by their ability or lack of ability for locomotion. Some protozoa move by the beating action of hair-like structures or cilia (ciliates) or whip-like structures or flagella (flagellates). Some protozoa (amoebae) move by a pseudopodia action, i.e., a streaming of the cytoplasm or intracellular content against the cell membrane.

Most protozoa are free-living, but several parasitic ciliated, flagellated, and amoeboid protozoa are found in wastewater. Of these parasitic protozoa, two protozoa are of concern to wastewater personnel. These protozoa are *Crytosporidium parvum* and *Giardia lamblia*. These organisms infest the intestinal tract and cause profuse and watery diarrhea.



**Picture 10-1 wastewater organisms**



**Picture 10-2 wastewater organisms**

**Table 10-1**

| Group | Pathogens |
|---|---|
| Viruses | Enterovirus, Hepatitis viral group |
| Bacteria | *Campylobacter jejuni, Leptospira interrogans* |
| Fungi | *Aspergillus fumigatus* |
| Protozoa | *Giardia lamblia* |

Pathogens that enter wastewater treatment facilities come from a variety of sources including infected community members, domestic animals, and wild animals. Infected community members may display acute or chronic symptoms of disease or may display no disease symptoms (asymptomatic). Regardless of disease manifestation (symptoms), infected individuals release pathogens in their bodily wastes. Travelers and military personnel, as well as migrant workers, represent an additional risk of the introduction of a new pathogen to the wastewater treatment facility.

In order for a wastewater worker to become infected with a pathogen, three steps in disease transmission must be satisfied. First, the pathogen must leave an infected individual within the community. Second, the pathogen must come in contact with a worker; and third, the pathogens must enter the worker.

There are three common routes of entrance or portals of entry for pathogens. These routes are ingestion (fecal-oral), inhalation, and invasion. The most common route of entrance is ingestion. For an infection to occur in a new individual, an adequate number of viable pathogens must enter the individual and overcome the individual's bodily defenses. Regardless of the risk assigned for disease transmission from any pathogen, that risk can be significantly decreased or eliminated through the use of proper hygiene measures, protective equipment, and common sense.

The use of proper hygiene measures, protective equipment, and common sense prevent contact with pathogens or block their portals of entry. These measures prevent infection. Measures available to wastewater personnel to prevent infection include the use of antimicrobial agents, automation, cleanliness and consumption precautions and restrictions, first aid, proper sampling practices, protective clothing, records, training, and ventilation. In addition to these measures, the use of immunobiologicals (vaccines and immunizations) also helps to prevent pathogen infection.

The common parasites of human health concern in untreated wastewater are parasitic protozoa and helminthes. Parasitic protozoa include *Giardia, Cryptosporidium*, and *Entamoeba*. *Giardia* is the most common protozoan infection in the United States These protozoa cause acute and chronic diarrhea.

Toxins are chemicals or chemical mixtures that, under certain circumstances of exposure, present an environmental or human health risk. Toxins include metals, hydrocarbons, and synthetic organic chemicals. Concentrations of toxins in wastewater can be a concern in industrialized areas or where monitoring data indicate potential toxicity.  Storm water contributions to CSOs in urbanized areas can also contain significant concentrations of hydrocarbons and metals. The metals most commonly identified in wastewater include cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc. Metals are a human health concern. First, metals are persistent in the environment. This creates an increased chance of long term human exposure once metals are introduced to a water body. Metals such as arsenic, cadmium, lead, and mercury, bioaccumulation in the human brain, liver, fat, and kidneys, causes detrimental effects. Other impacts that can be caused by metals include dermatitis, hair loss, gastrointestinal distress, bone disease, and developmental illnesses.

Floatables is the term used to describe the trash, debris, and other visible material discharged when sewers overflow. In sanitary sewer systems, floatables generally include sanitary products and other wastes commonly flushed down a toilet. In combined sewer systems, floatables include litter and detritus that accumulate on streets and other paved areas that wash into combined sewer systems during rainfall or snowmelt events. Floatables can have an adverse impact on wildlife, primarily through entanglement or ingestion. Floatables can also contribute to aesthetic impacts in recreation areas.

**Table 10-2**

| Cleanliness and Consumption Precautions and Restrictions |
|---|
| Avoid touching the ears, eyes, mouth, and nose with your hands, unless you have just washed. |
| Confine eating, drinking, smoking, and the use of smokeless tobacco products to designated areas. |
| Keep your fingernails short; use a stiff soapy brush to clean under your nails. |
| Wash your hands frequently and properly after contacting wastewater and before<br>eating, drinking, or smoking, use of smokeless tobacco products, and at the end of work. |
| Wear appropriate gloves where necessary, especially when hands are chapped, cut, or burned. |

Antimicrobial agents destroy pathogens by damaging cellular components. Antimicrobial agents can be used to disinfect the hands or hard surfaces such as lunch tables and laboratory counters. Automation, for example, automatic collection of wastewater samples and automatic cleaning of bar screens, reduces personnel contact with wastewater and pathogens. Cleanliness and consumption precautions and restrictions make use of good common sense, appropriate hygiene measures, and personal protective equipment where appropriate.

**Table 10-3 chemical agents and effects on wastewater**

| Chemical Agent | Action |
|---|---|
| Alcohols | Denature proteins |
| Alkalis (in soaps) | Denature proteins |
| Detergents and soaps | Lower surface tension of pathogens, making them susceptible to other chemical agents |
| Halogens | Oxidize cellular components |
| Heavy metals (in disinfectants) | Denature proteins |
| Oxidizing agents | Denature proteins |
| Phenol and phenolic compounds | Damage cell membrane and denature proteins |

Immediate first aid should be given to any cut or abrasion that occurs at a wastewater treatment facility. A physician should treat more serious injuries. Proper sampling techniques should prevent breakage and spillage. Sample bottles should have a wide mouth opening and, whenever possible, should be plastic. If glass containers are required, the glass should be coated with plastic. Lids for bottles should be tight fitting. Bottles and lids should be cleaned after each use with squirt bottles and paper towels. Carriers for sample bottles should be compartmentalized to prevent breakage, and sampling stations should be hosed down to wash away pathogens that may be present due to spillage or leaking bottles.

Protective clothing consists of uniforms, shoes or boots, masks, gloves, and goggles. Protective clothing remains at the wastewater treatment facility and prevents wastewater personnel from bringing pathogens home. Protective clothing should be washed, dried, and stored at the wastewater treatment plant or cleaned professionally. Separate lockers should be provided for work clothes and street clothes.

**Table 10-4 Protective equipment and their purpose**

| Clothing | Action or Item |
|---|---|
| Gloves | Wear appropriate gloves at each work site; elbow-length gloves may be necessary; never submerge top of glove; wash or dispose of gloves after use; wash hands immediately after work when gloves cannot be used. |
| Goggles | Protect eyes from pathogens in aerosols and dust; wash goggles after use. |
| Masks | Prevents inhalation of pathogens in aerosols and dust; ensure proper fit of masks; wash or dispose of masks as directed after use. |
| Uniforms | Leave uniforms at work; use separate lockers for work and street clothing; wash work uniforms at work or use professional service; use bleach on heavily soiled uniforms |

Safety records should be maintained for all wastewater personnel. The records should include information addressing accidents, immunobiologicals, major and minor illnesses, and training.

Training should provide information regarding the hazards of pathogens found in wastewater, areas of significant exposure to pathogens, and the use of appropriate hygiene measures and protective equipment. Training should also review significant pathogens that are present in wastewater, their transmission and portals of entry, clinical symptoms of gastrointestinal and respiratory tract infection, and available immunobiologicals

Proper ventilation helps to reduce the risk of infection from pathogenic agents including allergens and toxins by reducing their numbers. Pathogenic agents are present in higher concentration in poorly ventilated areas as compared with outside areas and properly ventilated areas. Areas of poor ventilation usually are bar screens, grit chambers, lift stations, sludge dewatering facilities, wet wells and manholes.

## *Chemical Hazards*

There are various chemical hazards that exist in the collection system. Some of these hazards are addressed below.

### Hydrogen Sulfide $H_2S$

Hydrogen Sulfide:

- Is explosive
- Most common odorant
- Produced by anaerobic bacteria
- Gaseous form of sulfuric acid ($H_2SO_4$)
- Specific gravity of 1.19
- More persistent gas
- Odor recognition at **10 PPB**
- Hydrogen sulfide and water mix to create sulfuric acid

**Table 10-5 Physiological Effect Of $H_2S$ On Humans**

| Less than 100 PPM | Greater than 100 PPM | Greater than 500 PPM |
|---|---|---|
| Eye and nose irritation | Destroys sense of smell | Brainstem toxicity |
| Cough | Confusion | Heart problems |
| Head ache | Vomiting | Seizure |
| Bronchial problems | Loss of conciseness | No treatment |
| | | **DEATH** in a single breath |

**Table 10-6 Gaseous ammonia effects at various concentrations**

| **Effects of exposure** | **gas in ppm/mg/l** |
|---|---|
| Time weighted Average | 25 ppm or less |
| Detectable odor; unlikely to experience adverse effects | 25-50 ppm |
| Mild eye, nose, and throat irritation | 50-100 ppm |
| Moderate eye irritation; no long-term problems | 140 ppm |
| Moderate throat irritation | 400 ppm |
| Immediately Dangerous to Life and Health | 500 ppm |
| Immediate eye injury | 700 ppm |
| Directly caustic to airway | 1000 ppm |
| Laryngospasm | 1700 ppm |
| **Fatality (after half-hour exposure)** | 2500 ppm |
| Sloughing and necrosis of airway mucosa, chest pain, pulmonary edema, and bronchospasm | 2500-6500 ppm |
| **Rapidly fatal exposure** | 5000 ppm |

## Carbon Dioxide $CO_2$

- At 1% concentration of carbon dioxide $CO_2$ (10,000 parts per million or ppm) and under continuous exposure at that level, such as in an auditorium filled with occupants and poor fresh air ventilation, some occupants are likely to feel drowsy.
- The concentration of carbon dioxide must be over about 2% (20,000 ppm) before most people are aware of its presence unless the odor of an associated material (auto exhaust or fermenting yeast, for instance) is present at lower concentrations.
- Above 2%, carbon dioxide may cause a feeling of heaviness in the chest and/or more frequent and deeper respirations.
- If exposure continues at that level for several hours, minimal "acidosis" (an acid condition of the blood) may occur but more frequently is absent.
- Breathing rate doubles at 3% $CO_2$ and is four times the normal rate at 5% $CO_2$.
- Toxic levels of carbon dioxide: at levels above 5%, concentration $CO_2$ is directly toxic. [At lower levels we may be seeing effects of a reduction in the relative amount of oxygen rather than direct toxicity of $CO_2$.]

Symptoms of high or prolonged exposure to carbon dioxide include:

- Headache
- Increased heart rate
- Dizziness
- Fatigue
- Rapid breathing
- Visual and hearing dysfunctions

Exposure to higher levels may cause unconsciousness or death within minutes of exposure.

**Picture 10-3 CO gas meter tester**

**Picture 10-4 Being fit for a respirator**

## Carbon Monoxide CO

The acute effects produced by carbon monoxide in relation to ambient concentration in parts per million are listed below:

**Table 10-7 concentration and symptoms of carbon monoxide**

| Concentration | Symptoms |
|---|---|
| 35 ppm (0.0035%) | Headache and dizziness within six to eight hours of constant exposure |
| 100 ppm (0.01%) | Slight headache in two to three hours |
| 200 ppm (0.02%) | Slight headache within two to three hours; loss of judgment |
| 400 ppm (0.04%) | Frontal headache within one to two hours |
| 800 ppm (0.08%) | Dizziness, nausea, and convulsions within 45 min; |
| 1,600 ppm (0.16%) | Headache, tachycardia, dizziness, and nausea within 20 min; death in less than 2 hours |
| 3,200 ppm (0.32%) | Headache, dizziness and nausea in five to ten minutes. Death within 30 minutes. |
| 6,400 ppm (0.64%) | Headache and dizziness in one to two minutes. Convulsions, respiratory arrest, and death in less than 20 minutes. |
| 12,800 ppm (1.28%) | Unconsciousness after 2-3 breaths. Death in less than three minutes. |

**Chlorine $CL_2$**

**Table 10-8 Physiological Effects of Breathing Air Chlorine Mixtures**

| Effects of exposure | $CL_2$ gas in ppm/mg/l |
|---|---|
| Slight symptoms after several hrs of exposure | 1 ppm |
| Irritates throat | 10-15 ppm |
| Causes coughing | 30 ppm |
| Dangerous in 30 minutes | 40-60 ppm |
| Fatal in a few breaths | 1000 ppm |

Chlorination Safety Precautions & Facts:

- If you have a leak in a cylinder, rotate the leak so gas and not liquid is escaping.
- One volume of liquid chlorine yields approximately 450 volumes of vapor.
- Never throw a leaking chlorine cylinder into water or hose it down. This will increase the size of the leak and worsen the situation.
- Use new lead gaskets when installing chlorine cylinders.
- Turn the chlorine valve on and right back off, test for leaks.
- Never open the cylinder valve more than one turn.
- Chlorine gas is about 2½ times heavier than air.

## Methane $CH_4$

- Is highly flammable and may form explosive mixtures with air.
- The explosive range of methane is 5-15%
- Methane is violently reactive with oxidizers, halogens, and some halogen-containing compounds.
- Methane is also an asphyxiant and may displace oxygen in an enclosed space.

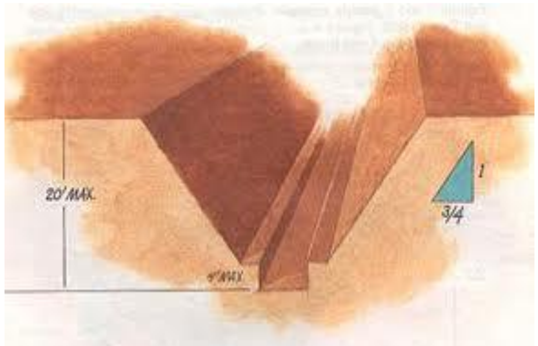
## *Excavation Hazards*

Several hazards exist when performing excavations in the collection system. Some of these are listed below.

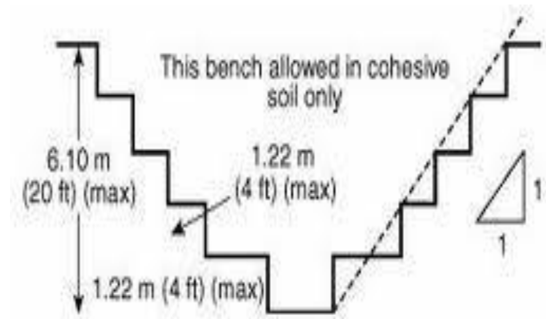
### Trench Shoring

- All work in an excavation must be supervised by a qualified person.
- Remove hazards to employees, trees, boulders, poles, etc
- Inspect excavation after rain, freeze/thaw or anytime you suspect a problem.
- Shoring or step-back any trench over 5 ft deep.
- Spoil pile: move spoil pile far enough away so it won't fall back in the hole. At least 2 ft away on one side only, for excavations over 5 ft.
- Use a ladder for access for trenches 4 ft + every 25 ft is required, don't climb on shoring.
- Don't jump across trenches install a crossing.
- Don't excavate under an existing structures foundation without shoring bracing or underpinning.
- Use no existing retaining walls or structure as a retaining wall for the excavation.
- Barricade or tape off all potentional hazardous areas.
- Use diversion ditches, dikes or other measures to keep water out of the excavations.
- Use additional bracing on the shoring if near a road, railroad or other sources of vibration or external load.

**Picture 10-5 Properly constructed Trench box**




**Picture 10-6 Benched excavation 1:3/4**




**Picture 10-7 Diagram of 1:1 benched excavation**

## Sloping and Benching

- If no shoring is used the side walls of the excavations should be sloped at ¾ horizontal to 1 vertical.
- Benching is used for deeper excavations, starting at 3.5 feet in depth the typical bench is 2 feet wide for each 2 feet of additional depth.

## Review Questions for Hazards

1. Wastewater collection system operators are exposed daily to numerous health risks. These risks include exposure to ________, __________, _________, __________, and ______________ .

2. Asphyxiating, irritating, and toxic gases produced through the anaerobic degradation of carbonaceous wastes include ___________, ___________, ___________, __________, and _____________.

3. Exposure to __________and the potential for disease transmission through contact with ______ ____________ ______________, __________, _________, _________, __________, and work surfaces are considered to be risks for wastewater personnel.

4. In order for a wastewater worker to become infected with a pathogen, the pathogen must ________________, __________________, and __________.

5. The principal indicator bacteria used to assess water quality are __________, ____________, and _______________.

6. ___________, ______________, and _____________ are toxins; chemicals or chemical mixtures that, under certain circumstances of exposure, present an environmental or human health risk.

7. The metals most commonly identified in wastewater include ________, __________, __________, ____________, ___________, _____________, ____________, and ____________.

8. Pollutants can potentially impact five designated uses: ___________, _________, ____________, ____________, and ____________.

9. Ammonia gas is rapidly fatal at ___________ mg/L or ppm.

10. $H_2S$ at greater than 100 ppm can _________, __________, _________, and ____________.

11. _______________ causes unconsciousness in 2-3 breaths and death in less than 3 minutes at 12,800 ppm.

12. Clorine is fatal in 2 breaths at _______________.

13. Never open the cylinder valve more than _______ turn.

14. The explosive range of methane is ______ to _______ %.

15. Shoring or step-back any trench over ________ deep.

16. Move spoil pile far enough away so it won't fall back in the hole. At least _________ away on one side only, for excavations over 5 ft.

## Answers to Hazards review Questions

1. gases, chemicals, endotoxins, exotoxins, and pathogens
2. ammonia ($NH_3$), carbon dioxide ($CO_2$), carbon monoxide (CO), hydrogen sulfide ($H_2S$), and methane ($CH_4$).
3. Pathogens, pathogen contaminated wastewater, aerosols, compost, foam, sludge
4. leave an infected individual, come in contact with a worker, enter the worker
5. fecal coliform, *E. coli,* and enterococcus
6. metals, hydrocarbons, and synthetic organic chemicals
7. cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc
8. aquatic life support, drinking water supply, fish consumption, shellfish harvesting, recreation
9. 5000 ppm
10. destroy the sense of smell, cause vomiting, confusion, and loss of consciousness
11. Carbon monoxide
12. 1000 ppm
13. one
14. 5-15
15. 5 ft
16. 2 ft

# Chapter 11: OPERATIONS AND REHABILITATION

## Chapter 11 Objectives

1. Know the importance of maintenance budgets and asset management plans and the parts that make up each.
2. Identify and define factors that are considered when predicting deterioration in the collection system.
3. Identify scenarios when a leaking, structural deterioration, and corrosion problems exists in the collection system.
4. Know the importance of inflow and infiltration as it pertains to rehabilitation in the collection system.
5. Know the importance of keeping rehabilitation maintenance records.
6. Know the importance of overflow information as it pertains to rehabilitation.
7. Know the importance of documenting information concerning unsewered areas.
8. Identify and understand the four actions that can be taken after a sewer rehabilitation assessment.
9. Identify and understand causes for deterioration and failure in the collection system.
10. Define and identify trenchless technologies and their importance in collection system rehabilitation.
11. Calculate volume..
12. Calculate the number of pipe sections needed for repairs.
13. Calculate the amount of seed to purchase to replace grass after a repair.
14. Calculate pump efficiency, horsepower, power costs, and pump rates.
15. Calculate operations and construction costs.

## *Important Operational Techniques and Information*

Maintenance budgets are important because those who manage the collection systems manage infrastructure, assets, and people. In many instances these are aging assets in need of rehabilitation or new infrastructure replacing the aged infrastructure. These managers must set priorities, consider their alternatives, and make the most efficient use of their available resources.

Asset management plans should also be considered to help with optimizing the collection system performance. Since collection system managers are responsible for planning, design, construction, operation and financing of the collection system an asset management program is essential to receive the following advantages

1. Makes decision making process clear to others
2. Provides consistent criteria for making those decisions, balancing critical needs and interests.
3. Minimize long term costs of system operation and maintenance
4. Define acceptable levels of customer service
5. Creates data and information processes to improve future decision making
6. Establishes roles, goals and metrics that can focus and motivate the organization toward more cost effective operation

Frequent system failures or lack of adequate performance and customer complaints may lead to unwanted political attention or regulatory enforcement issues. The asset management program will keep customers, decision makers, and employees in the know, and what the consequences may be if the mentioned issues are not done in a timely manner.

**Picture 11-1 sliplining of a pipe**

Maintenance and rehabilitation should occur based on predicted deterioration. There are several things that should be considered.

1. Conditions
2. Performance of Assets
3. Operating costs
4. Financial position; revenues, balance sheet, cash flows
5. Required and anticipated levels of service
6. Methods of monitoring and measuring system performance

## *Rehabilitation*

There are basically three scenarios in sewer collection systems which allow infiltration:

### Case 1: Leaking problem

In this case, the pipe is structurally sound and leakage is due to a problem with open or leaking joints. In this condition, chemical grouting provides the only cost-effective solution to the problem. Any other repair technique would be unnecessarily expensive since the only requirement is to stop the leaks, and no other method is less expensive than chemical grouting. A string line is often used in repair work on sewer sections to control the alignment of the sewer.

**Picture 11-2 Leakign sewer pipe**

**Picture 11-3 Corroded sewer pipe**

### Case 2: Leaking and corrosion problem

Corrosion is commonly encountered in wastewater systems. To be effective in this situation, the leakage should be eliminated using chemical grouting prior to any treatment of corrosion. However, grouting will not be an effective treatment to prevent further corrosion since it works outside the pipe. In this case, a combination of grouting the joints and lining, or coating, the pipe to prevent further corrosion would be the preferred engineering method of rehabilitation. If lining is chosen, the lateral reconnections should always be grouted to prevent water movement in the annulus and to seal the connection between the old pipe and the lateral.

### Case 3: Leaking and partially deteriorated structural problem

This is the most severe condition that could be encountered in the sewer system. Structural repair of the pipe or manhole is required. However, unless the leak is stopped prior to any structural repair (lining), the water will eventually find its way into the system at openings in the liner for each service connection and at manholes. Infiltration will flow through the annular space of the existing and newly installed pipe until if finds its way into the sewer line. If possible, the water leakage should be stopped or reduced using chemical grout prior to lining in the mainline and after lining at the service connections in order for the lining to be successful in stopping infiltration.

It is expected that city sewer systems in the United States will continue to be prone to infiltration problems due to deteriorated joints even though the pipes may remain structurally sound. The American Public Works Association's *National Statistical Survey* showed that rubber rings (used in the form of plastic and compression gaskets) were historically the most widely used joining materials throughout the United States and Canada. These rubber rings were used with concrete and vitrified clay pipes which were built in short lengths, thus requiring more joints, which are subject to infiltration. The problem arises from the fact that there was no standard introduced for the rubber rings and standard composition until 1970. Recycled rubber had been widely used and, since the rubber used had no anti-bacterial agents, it is now being slowly eaten away and deteriorating with time.

Continued improvements in the collection system should be on going. It is important for municipalities to continue to move forward with inflow and infiltration projects as well as upgrade and maintain the existing systems. Grants are not as plentiful as they once were with tighter budgets on the state and federal levels and more cities and towns now have to fund the projects locally or borrow funds from various agencies to make the necessary repairs.

With the current state of aging infrastructure it is important to consider rehabilitation. Operation and maintenance logs should be kept to help make sure the collection system is working optimally.  Maintenance records allow operators and managers to keep track of repair/replacement work for equipment. These records also allow supervisors to develop more accurate maintenance budgets.

Sewer system rehabilitation is intended to reduce the flow of extraneous storm water into wastewater collection facilities. In order to determine the economic feasibility of sewer system rehabilitation, infiltration/inflow studies are conducted to quantify and locate sources of infiltration and inflow. Since these types of projects involves the rehabilitation and replacement of a collection system, it is important to characterize the activities usually undertaken to maintain the collection system. Information related to financing the rehabilitation of the collection system maintenance should be in the form of an annual budget or an asset management plan. It is important to consider a few things before starting a rehabilitation project. If you plan to hire contractors to do any of the work establish a municipal sewer construction contract. This will ensure that you will be covered on some very important issues. Things that should be included in the mainteneance contract are:

1. Material performance clause
2. Performance test
3. Presence of a qualified inspector on-site

## *Provide Information about Maintenance Activities*

Maintenance activities include flushing and cleaning activities, CCTV analyses, air testing, and control and erosion repairs. Provide summary information that shows the maintenance activities undertaken for the entire collection system. This could include the miles of pipe cleaned; pump station operation and maintenance program description, etc. All of this should be provided in order for a full assessment to be conducted. All events that lead to any problems in the system should be mentioned in the assessment. A thorough system description of the current conditions is very important. The following describes the factors that are important in making rehabilitation assessments.

### System Size Description

Identify the length and/or inch-miles of gravity sewers/interceptors only in the entire area where the work will occur. If force mains are included, distinguish between gravity sewers and force mains. Provide a map for sewer lines; utilize the following definitions for Good, Fair, and Poor:

- **Good.** The gravity sewer lines have adequate capacity to pass peak flows and have good structural integrity with minimal obstructions such as root intrusions. Force mains have adequate capacity to pass peak flows and good structural integrity with no cracking or other signs of age.
- **Fair.** The gravity sewer lines allow flow but have some structural integrity issues such as cracks and some intrusions such as roots. Force mains show some signs of wear.
- **Poor.** Flow within gravity sewer lines is limited due to structural issues (e.g. offset joints) or imminent structural failure. Intrusions such as roots are high. Force mains show signs of current or impending structural failures such as cracking. Lines do not have adequate capacity to pass peak flows (e.g., surcharging, SSOs, etc.).

**Calculate the number of sections of pipe needed for repairs**

A sewer pipe has failed and 94 feet of 12 in vitrified clay pipe must be replaced. How many 4 foot sections are required?

Since the pipe comes in four foot sections, divide the total number of feet by 4 which represents the section length.

$$\text{Sections required} = \frac{94\text{feet}}{4\text{ feet}} = 23.5 \text{ or 24 sections of pipe}$$

## Lift Stations

Provide a description of the lift stations in the sewershed where the project will occur. For lift stations, utilize the following example definitions for Good, Fair, and Poor:

- **Good.** Pumps within the lift station show little signs of wear and function in an efficient manner with only routine maintenance. Equipment/appurtenances show minimal signs of corrosion. Lift station has needed reliability (e.g., standby power).
- **Fair.** Pumps within the lift station show some signs of wear and fail periodically. Some repair outside of routine maintenance is required to keep the pump functioning. Equipment/appurtenances show signs of corrosion. Lift station may need minor upgrades to provide reliability.
- **Poor.** Pumps within the lift station show signs of wear and fail on a regular basis. Repairs outside of routine maintenance occur frequently. Equipment/appurtenances

show excessive signs of corrosion that limit functionality. Lift station needs upgrades to provide reliability.

## Discussion Of Collection System Issues

Describe in more details the issues associated with the assessments discussed above for gravity sewers and/or pump stations and force mains Include a description of the specific problems with the portion of the collection system to be rehabilitated or replaced. Additionally, describe the method used to ascertain the condition of the collection system to be rehabilitated or replaced (e.g., smoke testing, CCTV, direct observation, alarms on SCADA system).

### Overflows

For overflows, describe if any overflows have happened within the sewershed where the project will occur. Attach any information such as reported sanitary sewer overflows (SSOs) that show where these SSOs occurred. Discuss whether the local government is under a Special Order of Consent (SOC) or is currently negotiating one. The location of any sanitary sewer overflows should be shown on a map.

### Unsewered Areas

Identify any locations within the sewershed that contain unsewered areas. Additionally, discuss any water quality or public health problems associated with failing septic systems or whether there are single-family residence discharges, or single-family residence spray/drip irrigation systems within the sewershed. For failing septic tanks, include a letter from the county Health Department. The letter must clearly state that the area contains failing septic systems. For single-family residence discharges, or single-family residence spray/drip irrigation systems, provide permit numbers and locations. Additionally, show the location of any sanitary sewer overflows and unsewered areas on a map. Sanitary sewer overflow reports and backup information should also be reported.

**Picture 11-4 Unsewered areas should be identified and monitored**

Provide a discussion of current flows in the sewer lines that are being rehabilitated. Include in the discussion of flow measurements (monitored, estimated, anecdotal, etc.), capacity provided after rehabilitation compared with flow measurements, and the need for line size increases due to growth. If population growth will result in capacity issues for the collection system, then determine what improvements, adjustments or additions should be made in order to correct the issues. Include a discussion about the potential for future growth in the service area for the project. If future growth leads to capacity issues and line size increases due to growth after the rehabilitation project, be sure to include this concern. The future flow evaluation method should be sufficiently documented.

**Calculate Operation and Construction Costs**

You have to excavate a trench around the bypass to lay a 36 inch diameter interceptor storm sewer 2.3 miles. The average depth is 9 feet and the trench is 3 feet wide. If the backhoe operator can remove 400 $yd^3$ of material per hour and you assume a constant removal rate, what would the removal cost be if the rate for the backhoe and operator is \$530 per hour?

First convert the miles into feet. Next you will calculate the volume of the trench. Convert the $ft^3$ into $yd^3$. Then determine how many hours it will take to complete the excavation. Then multiply it by the cost per hour to find the total cost.

2.3 miles = 12,144 ft
Volume of trench = 3ft x 9 ft x 12,144 ft = 327,888 $ft^3$
327,888 $ft^3$ = 12,144 $yd^3$

$$\text{Removal time} = \frac{12{,}144\,yd^3}{400\,yd^3/hr} = 30.36\text{ hrs}$$

Cost = 30.36 hrs x \$530 = \$16,090.80

Four actions that can be taken after a sewer rehabilitation assessment has been made are:

1. No-Action Alternative
2. Rehabilitation
3. Replacement
4. Preferred Alternative

A description of each action should be documented and reviewed prior to deciding on rehabilitation recourse. Where appropriate, include figures and maps, preliminary design criteria, pipe diameter, pipe length, capital cost and present worth. The capital cost and present worth should be derived from the present worth analysis. For all alternatives, a discussion regarding why the alternative was accepted or rejected, including capital cost, present worth, and environmental impacts should occur.

**No-Action Alternative**

For this alternative, discuss what would happen if the project were not built. In answering this question, describe the social, economic, and environmental impacts that would occur from not building the project. In the rationale, describe why this alternative was not chosen, including whether it was feasible or not.

**Rehabilitation**

Discuss whether or not rehabilitation is a feasible alternative. Describe the various methods that could be used to rehabilitate the collection system (piping and/or pump stations and force mains). In a figure, show where the rehabilitation for each alternative considered would occur. Each practicable alternative for rehabilitation should be a separate alternative. Provide the rationale as to whether the alternative by itself would be accepted or rejected.

**Replacement**

In this alternative, describe whether replacement is a feasible alternative. Discuss the various methods that could be use to replace portions of the collection system (piping and/or pump stations and force mains). In a figure, show where the replacement for each alternative considered would occur. Each practicable alternative for replacement should be a separate alternative. Provide the rationale as to whether the alternative by itself would be accepted or rejected.

**Preferred Alternative**

The project selected as the preferred alternative may be a combination of the above alternatives. Describe the preferred alternative by summarizing and referring back to any other alternative descriptions as necessary. Provide the rationale as to why this alternative is the preferred alternative. For example, the project may consist of a series of different rehabilitation methods as well as areas of replacement. These rehabilitation methods and replacement would be combined into the Preferred Alternative.

**Present Worth Analysis**

**Present value** is the value on a given date of a future payment or series of future payments, discounted to reflect the time value of money and other factors such as investment risk. Present value calculations are widely used in business and economics to provide a means to compare cash flows at different times on a meaningful "like to like" basis. Calculating a total project cost for a sewer system improvement project that includes initial cost, annual operation costs, and maintenance and replacement costs over the life of the project is called the life cycle cost.

**Present Cost vs Future Cost………. How does it stack up?**

Most economic analyses consider alternatives for “permanent” solutions lasting the commonly accepted design life of 20 years. However, in high growth areas it may be necessary to consider multiple improvements within the conventional 20 year time frame. Depending upon the long-term consequences of immediate actions, it might be discovered that the first, short-term decision may not have been the most cost effective long-term decision. Also consider when the next investment that will likely be required will occur if growth projections hold true. Present worth analyses must also consider operation and maintenance costs over the economic period. Sometimes the least cost capital investment loses its appeal when it's discovered the costs to operate the solution are more than for other, higher capital cost alternatives. The goal is to make the economic comparison as close to a same variety "apples to apples" comparison as can reasonably be assumed. Determine if additional full time staff will result form the rehabilitation, and if so will it just be for construction or if it will extend to the future operations and maintenance.

Current Rehabilitation Issues includes a range of approaches that return the system to near-original condition and performance. For example, repair techniques are used when the existing sewer is structurally sound. But when the existing sewer is severely deteriorated or collapsed, or when its flow capacity should be increased, the system is usually replaced.

**Calculate the Amount of Seed to Purchase After a Construction Project**

After installing a main through a park, a strip that is 1900 feet long and 8 feet wide that must be reseeded with grass.3 men are in charge of planting the seed. If one bag of grass seed covers 1,000 $ft^2$. How many bags of seed do you need to buy?

First calculate the area to be seeded. Calculate the number of 1000 ft sections.
Area of plot = 1924 ft x 8 ft = 15,392 $ft^2$

Number of 1000 $ft^2$ sections = $\frac{15,392\ ft^2}{1,000\ ft^2}$ = 15.39 or 16 bags

## *Wastewater Collection System Deterioration and Failure*

There are many causes for wastewater collection system deterioration and failure:

1. Poor design and installation
2. Inadequate or improper bedding material
3. Chemical attack
4. Traffic loadings
5. Soil movements
6. Root intrusion
7. Compromised joint integrity
8. Subsequent construction damage
9. Ground water fluctuation
10. Inadequate maintenance

Deposition of material and sewer blockages that occur because of flat grades along with high ambient temperatures and poor ventilation can lead to the development of sulfuric acid and resulting crown corrosion. This reduces the structural integrity of concrete and its reinforcing steel. In addition, inadequate inspections and quality assurance, and poor workmanship during sewer installation, can result in long-term problems. Other issues include:

1. Pipe defects can cause blockages that lead to dry-weather sewer overflow and backups into buildings.
2. Water that flows into sewer pipes through defects (e.g., holes, cracks, and failed pipe joints) can weaken the critical soil-pipe structure.
3. Fine soil particles carried into the sewer can eventually reduce soil support and cause pipe deformation or subsidence.
4. Exfiltration of water from the sewer into the surrounding soil can weaken support provided by the soil.
5. Soil movement due to traffic can exceed design assumptions and result in soil support problems.

Collection system rehabilitation includes many repair and replacement options, each of which could return the system to acceptable levels of performance. Options include repairing the pipeline using common methods, such as chemical and cement grouting, to address ground water movement, washouts, soil settlements, collapses, and soil voids.

## Calculate Operation and Construction Costs

Estimate the construction cost of a sanitary sewer project. The project consists of 9,500 feet of 24-inch sewer and 19 manholes. Costs are estimated below:

Excavation and backfill $16.45 per linear foot
Pipe cost (delivered)$ 5.89 per linear foot
Manhole, complete $2,236.00 each

First calculate the amount of the cost of pipe material, excavation, and backfill. Then calculate the manhole cost and add them together.

Excavation and backfill cost = 9,500 ft x $16.45 = $156,275.00
Pipe material cost = 9,500 x $5.89 = $55,955.00
Manhole Cost = 19 x $2,236.00 = $42,484.00

Total project cost = $156,275.00 + $55,955.00 + $42,484.00 = $254,714.00

**Picture 11-5 Engineer working on rehab project**

You are constructing a sewer in a subdivision which will contain 6-inch and 10 inch sewer lines. Using the following information, determine the total cost of the project?

Total in-place cost of 6-inch pipe - $80.00 per linear foot
Total in-place cost of 10-inch pipe - $105.00 per linear foot
Pipe cost is 33% of in-place cost
Manpower is 19% of in place cost
Backfill and compaction is 52% of the in-place cost
3.9 miles of 6-inch pipe and 2.8 miles of 10-inch pipe

First calculate the number of feet of pipe to be laid for each size. The price is the total in place cost. To calculate the cost, multiply the number of feet of pipe by the cost per foot. Add them together to get the total project cost.

Convert miles to feet 3.9 miles x $\frac{5,280 \text{ ft}}{\text{mile}}$ = 20,592 ft 2.8 miles x $\frac{5,280 \text{ ft}}{\text{mile}}$ = 14,784 ft

Cost of project 20,592 ft x $80.00 = $1,647,360.00
14,784 x $105.00 = $1,552,320.00

Total cost of project = $1,647,360.00 + $1,552,320.00 = $3,199,680.00

1. In the problem above what is the cost for manpower?

To calculate the manpower cost multiply the total cost by the percent of manpower cost.

Manpower cost = $3,199,680 x .19 = $607,939.20

Trenchless technologies have moved to the forefront of sewer system rehabilitation. These techniques enable workers to install new pipe in the location of the old pipe without total surface digging and its accompanying traffic and business disruptions.

Selection of rehabilitation materials is an important factor. New materials are emerging; the application of plastic pipe (as opposed to more traditional sewer pipes made of concrete, clay, or ductile iron) is becoming standard practice. The most commonly used for wastewater applications are glass-reinforced plastic, polyvinyl chloride, and polyethylene. Innovations using plastic include structured wall pipe and composite pipe that use different materials to address both structural and corrosion issues. However, long-term performance testing is needed to understand the capabilities of new materials under field conditions and to determine life-cycle cost. In addition, raw materials and formulations can vary widely, resulting in different quality pipe from the same plastic.

Studies have shown that sewer rehabilitation at the street alone does not completely solve the infiltration problem for various reasons, including those involving private ownership of service laterals. It is at these service laterals (the pipe that conveys wastewater from the property line or easement to the public sanitary sewer) where entry can occur when successive rainfalls elevate the ground water table. Rehabilitation of service laterals is generally done by point repair or replacement; cured-in-place lining, slip lining, and pipe bursting are also used. However, these approaches do not resolve the private ownership problem or the problems associated with the location and configuration of the line (e.g., sharp bends and transitions) or the line condition (e.g., nearby massive roots that can cause line damage).

**Picture 11-6 collection system rehab in progress**

## Table 11-1. Trenchless Rehabilitation Methods in Sewer Collection Systems and Underground Structures

| Options | Type/Description | Advantages | Disadvantages | Areas of Application |
|---|---|---|---|---|
| Chemical Grout | Impregnation of the soil surrounding the pipe with a curable compound, thus effectively sealing the soil. Chemical grout can be used to stop leaks in pipe joints and cracks, as well as leaks around lateral connections and leaks in manholes. | • No excavation<br>• Very flexible<br>• Repair limited to damage area<br>• Quick<br>• Economical<br>• Longevity<br>• Stops I/I<br>• Stabilizes soil outside the pipe | • No structural repair to the pipe itself, except for stabilization of the supporting soils outside the pipe. | • Repair of sewer line joints<br>• Manhole infiltration<br>• Lateral infiltration<br>• Underground structures<br>• Tunnels<br>• Parking structures<br>• Subways |
| CIPP Lining | Flexible tube externally coated with a polyurethane membrane and internally with resin, is inverted on site by air/water pressure. The tube turns inside out and travels down the pipe and is later cured by hot water. | • No excavation<br>• Economic compared to manhole-to-manmade replacement<br>• New pipe within old pipe | • Tightness of liner to pipe is questionable; and annular space exists<br>• Does not stop I/I<br>• Expensive | • Repair of holes and areas of extensive cracking |
| Fold and Form Liner | A folded thermoplastic pipe is pulled into place through a manhole and then rounded, using heat or steam and pressure to conform to the internal diameter of the existing pipe. | • No excavation<br>• New pipe within old pipe | • Reduction of pipe diameter<br>• Long-term buckling strength may be an issue<br>• Does not stop I/I<br>• Expensive<br>• Limited to small diameter pipes | • Repair of holes and areas of extensive cracking |
| Slip Lining | Insertion by pulling or pushing a new pipe into the old one. The remaining annular space may be filled with granular material. | • New pipe within pipe | • Reduction of pipe diameter<br>• Full length of pipe has to be lined<br>• Lateral connection is difficult to reconnect<br>• Does not stop I/I<br>• A large annular space exists in slip lining unless the annular space is grouted<br>• Expensive | • From manhole-to-manmade<br>• Medium level of damage |
| Pipe Bursting | Technique which uses radial forces to break out and push away the pieces of the existing pipe and permit a new pipe to be simultaneously installed. | • New pipe inserted<br>• Limited surface disruption | • Excavation required<br>• Laterals reconnected by digging<br>• Expensive | • Replacement of badly damaged sewers<br>• Runs with few laterals<br>• Can result in a new pipe with larger diameter |
| New Pipe Installation | Soil is excavated and new pipe is installed. | • Completely new pipe<br>• Longer lifetime<br>• Modification is possible<br>• Simple and well-known technology | • Large surface area disturbed<br>• Risk of damaging other pipes and cables during excavation<br>• Disturbance of traffic<br>• Expensive<br>• Time consuming | • General repair of complete structural damage<br>• Pipelines close to the surface<br>• Open areas with no obstacles |

## Chemical Grouting

Chemical grouting is the injection of grout into the soil surrounding the pipe. This is the most common method of sealing leaking sewer joints. It is a type of permeation grouting in which water in the soil voids is replaced with grout to reduce the permeability of the grouted soil around the leaking joint. The intent of grouting is to seal sewer pipe joints which fail to pass joint tests or have leakage rates of ¼ gallon per minute or more. The grout is remotely applied under pressure to leaking joints or laterals and small cracks in sewers and manholes to seal the voids within the soil surrounding the exterior of the pipe at the point of leakage. Chemical grout is a two-part solution that changes to a solid in a predictable period of time. Grouts used in sealing of sewer pipes must have the following characteristics:

1. While being injected, the chemical grout must be able to react/perform in the presence of water (groundwater)
2. The cured material must withstand submergence in water without degradation and must re-hydrate after each dry-out cycle
3. The resulting grouted soil formation must prevent the passage of water (infiltration) through the sewer pipe joint
4. The cured grout material must be flexible as opposed to brittle
5. The cured grout material must not be biodegradable
6. Residual grout materials must be easily removable from the sewer line to prevent reduction or blockage of sewage flow.
7. The cured grout should be chemically stable and resistant to the mild concentrations of acids, alkalis and organics found in the soil and in normal sewage. Organic solids in wastewater are normally of animal and vegetable origin.

**Picture 11-7 Grouting on the exterior of a pipe**

To date, the only proven method of stopping infiltration is the application of chemical grout. Based on its cost-effectiveness, durability and method of leak repair for sewer pipe joints, manholes and laterals, chemical grouting has proven to be the least expensive remediation alternative for stopping leaks and infiltration. Thus, chemical grout will provide significant reductions in infiltration and, when combined with other methods that provide structural integrity, will prove to be an effective and reliable long-term solution for the rehabilitation of sewer collection systems.

Rehabilitation methods to control infiltration in the sewer collection system can be summarized as follows:

**Internal Pipe Seals**

a) Internal mechanical seals are well suited to applications where vibration or shifting of the pipe can be anticipated. Typically made of impervious, flexible rubber gaskets and stainless steel bands, internal pipe seals are installed at leaking pipe joints or as a preventative measure. In cases of harsh environment, several bands can be linked together to act as sheathing of the pipe.
b) Banding material can be custom manufactured to suit environmental conditions. Odd shaped pipes including egg and square can be accommodated. New, low profile designs reduce historical problems concerning loss of flow area and build-up of debris. Due to the nature of their installation, internal pipe seals require manned entry into pipes and therefore are available only for pipes 16 inch and larger. No excavation is required but by-pass pumping may be necessary. A bulkhead can be used during sewer maintenance as a temporary obstruction to stop or divide the flow of wastewater while working on rehabilitation projects.

**Picture 11-8  Internal pipe seal being constructed**

**Sliplining**

Sliplining is a method by which a pipe is inserted into an existing line by either pulling or pushing continuous or short-length pipes, frequently HDPE pipe. An access pit is excavated adjacent to an existing sewer and a liner pipe of slightly smaller diameter is slid into the existing pipe to create a continuous, watertight liner between the two manholes.

It is a relatively cost efficient method where existing capacity is sufficient, as a significant amount of internal area is lost during the slip lining process. The pipe is inserted in a variety of methods, depending upon both the length of pipe and its material. With traditional slip lining, a lead-in trench must be excavated for installation. Pipes are butt-welded on the surface of the ground before being winched or jacked into the existing pipe. Additional pipe lengths are added as needed. For short sections of pipe, the pipes can be joined together by special gasketed joints and jacked into place. Both flexible and rigid mechanical gaskets can be used to join the short sections together. Depending upon pipe size and access, an excavation trench may not be required for slip lining using short sections of pipe.

Grouting the annular space between the lining and the original pipe is recommended, both to stop infiltration from migrating down the annular space between the pipes and to provide additional strength. Significantly dropped joints, roots and other impediments to the insertion of the pipe must be repaired or removed prior to installation. Laterals must be reconnected by excavation. Bypass pumping is required during installation for conventional slip lining methods but may not be necessary for segmental slip lining.

**Picture 11-9 sliplining of a pipe**

While relatively cost efficient in most instances, the installation can be disruptive due to the excavation required for the installation trench and lateral re-connection. Especially deep installation may make the method less desirable due to increased costs. In some instances, lack of access may make traditional slip lining impractical.

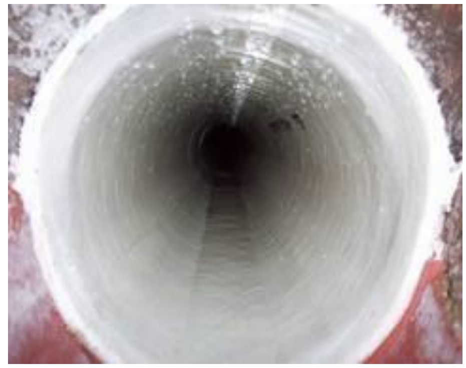
**Cured-in-Place Pipe (CIPP)**

An internal liner is formed by inserting aresin-impregnated felt tube through the manhole into the sewer. The liner is then expanded against the inner wall of the existing pipe and allowed to cure. Considered a trenchless repair, CIPP liners use a polyester flexible sock or sleeve impregnated with resin that is inverted or winched into the pipe. The sock is inverted using either winch inversion, water inversion or air (steam) inversion. Inversion allows the liner to conform to the existing pipe contours providing for minor irregularities or slight changes of pipe direction. The thickness of the pipe can be increased by increasing the thickness of the polyester sock.

Both ambient cure and thermal cure products are available. Ambient cure relies on a chemical reaction to harden the resin and may be better suited to short sections of pipe due to its quick cure time and relatively simple installation setup. A four to eight foot section of 12'' ambient cure CIPP may cure in as little as two to four hours. However, this quick cure time may make the method inconvenient for longer stretches of pipe. Thermal cure CIPP uses hot water or steam to activate the hardening of the resins in the sock, so setting time is dictated by the installer. However, curing times are longer. Bypass pumping usually is required for either method.

Because the lining is designed to fit closely to the existing pipe, grouting of the annular space usually is not required. Both methods require no, or very limited, excavation; and lateral connections can be reconnected internally, making the process ideally suited for crowded urban environments or locations with restricted access. The sealing or lining of laterals using internal robotics often is required to curtail leak migration in lines where I/I reduction is one of the rehabilitation objectives.

**Picture 11-10 Cured in plaxce pipe installation**



**Picture 11-11 Cured in place pipe after installation**

**Fold and Formed Pipe**

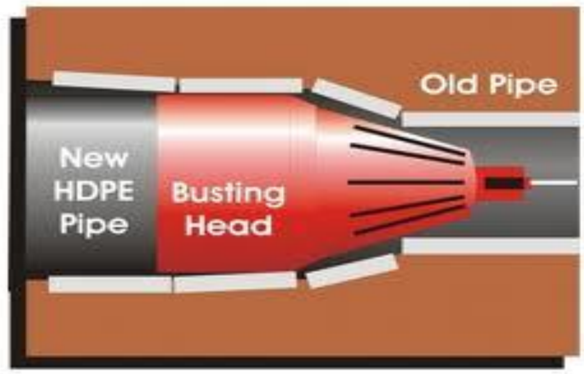
A folded thermoplastic pipe is pulled into place through a manhole and then rounded, using heat, steam and air pressure to conform to the internal diameter of the existing pipe. Another trenchless repair, the fold-and-formed method uses deformation to reduce the pipe diameter of conventionally formed pipe. Deformation of the pipe can be done either during fabrication or on site, depending on the product. The pipe is either rolled down from a continuous roll or fusion welded together before installation. In both cases, the new pipe then is pulled into the existing pipe in the manner of traditional slip lining. Once winched into place, the pipe is expanded back into its original shape, forming a close fit with the existing pipe. The process of the pipe expansion may be accelerated by air pressure and heat. As with CIPP, because the close fit of the new pipe to the old, grouting of the annular space usually is not required. Laterals may be reconnected internally or by excavation. As with CIPP, laterals may require sealing or lining in order to eliminate migration of I/I. By-pass pumping usually is required.

**Picture 11- 12 fold and formed manhole rehabilitation**

**Pipe Bursting**

An access pit is excavated adjacent to an existing sewer and the pipe is broken outward by means of an expansion tool. A flexible liner pipe of equal or larger diameter is pulled behind the bursting device as a replacement sewer. A strong misconception exists about how to stop infiltration. While liners, when properly designed and constructed, will stabilize the structural integrity of the host pipe, even close-fit liners will not eliminate the problem of infiltration and will not stabilize the soil surrounding the pipes. Tests have shown that infiltration from joints and cracks will enter in the annular space between the liner and the host pipe and migrate through this space until an opening is found for it to join the sewage flow. Such openings are regularly found in collection lines where holes are cut into the liner to permit reconnection of the house services to the mainline sewer. These tests reveal the exact flow along the annulus of the close-fit liner will vary, depending on the location and magnitude of the defect in the host pipe, with respect to the location and continuity of that space. The use of various types of liners also presents a problem when it is necessary to connect, or adhere, a lateral liner to the mainline. The greasy surface of the mainline makes it virtually impossible to obtain a tight, leak-proof seal at the lateral connection. The only method of sealing these openings is to grout the service line connection after lining or to grout the mainline. This stops the infiltration around and through the connection to the lateral. When lining is used, grouting the connection also prevents water movement in the annular space between the liner and the old pipe.

The most effective repair technique to eliminate infiltration uses chemical grout and an inflatable packer guided by a CCTV. Chemical grouting has been used successfully for more than 40 years. This method to control leaks reduces the permeability of the soil outside the leaking joints, but does not reduce the capacity of the system. It provides a long-term solution to the leaking problem, while stabilizing the soil outside the joint.




**Picture 11-13 Pipe bursting**

Pipe bursting works by using a pneumatic or hydraulic bursting mandrel to crush the existing pipeline while at the same time a new pipe can be pulled into place. The crushed pipe is forced into surrounding soils, acting as bedding material for the new pipe. A sleeve pipe is pulled immediately behind the bursting mandrel during the process. Following completion, the sleeve pipe is lined with a new pipe, typically HDPE. Pipe bursting is well suited to brittle pipes and allows for the size-for-size or increased size replacement of the existing pipe

Pipe bursting typically can be performed on distances as great as 300 feet or more, depending on surrounding soils and ground conditions. Offset joints and short or minor line swags can be eliminated during the process. Excavation of an insertion trench is required, usually at a manhole, and laterals must be reconnected by excavation. Some ground upheaval may occur where pipes are close to the ground service or where surrounding soils are not easily compressed. Bypass pumping is required during the process.

**Coatings**

Frequently used for manhole rehabilitation, coatings have evolved over the years into specialized compounds designed for a variety of environmental and site conditions. Broad categories include cementitious and polymer coatings. Both types either are sprayed or hand applied to cleaned and prepped manhole interiors. Preparation is critical to the success of application, with a clean, sound substrate necessary for either type. Before application, high pressure washing, usually from 3500 psi to 5000 psi, is necessary to adequately etch brick, remove loose materials, grease or other foreign matter from the manhole walls, bench and invert.

All active groundwater infiltration must be eliminated by using chemical grouts, high early strength repair mortars, resin impregnated materials or other appropriate water stopping compounds. During preparation, manhole benches and inverts should be repaired or rebuilt as necessary.


**Picture 11-14 manhole being lined using spray trenchless technology**

Coatings can be used to cover the entire manhole including bench and inverts. In each application, the coating material is applied in one or more layers depending upon desired final thickness. The profile of the substrate dictates the minimum thickness required for pin-hole, or "holiday" free application. The industry standard for holiday free application of material is 1/2 inch for cementitious and 65 mm for polymer coatings. A 2:1 safety factor often is employed resulting in a typical minimum application of 1 inch for cementitious and 100 mm for polymers on structurally sound existing manholes or new construction. Structural integrity can be improved with applications of two inch to four inch for cementitious and up to 125 mm for polymers on rehabilitation.

Cementitious coatings are typically the most cost effective and with sufficient reinforcing and thickness can provide structural integrity. However, they provide limited corrosion resistance unless additives are included in the mix. Polymers provide excellent corrosion resistance, but are more expensive. Used in combination, a balance can be reached between economy and functionality.

In either case, care should be taken during the application and inspection process to ensure holiday-free application. Vacuum testing and/or pull tests should be performed to assess the success of the application. Pull tests of 300 psi should be a standard for either process.

## Meeting the Challenge

The above discussion of rehabilitation methods is by no means a comprehensive listing. Traditional open-cut, point repairs and a multitude of exotic methods all have their place in the arsenal of collection system managers as they strive to meet the challenges of maintaining today's aging infrastructure.

As collection systems continue to deteriorate and funding remains limited, new, economical methods will continue to be developed. Setting priorities, accurately evaluating existing conditions and proper selection of the appropriate technique still will be the keys to a successful rehabilitation program.

## Calculate Operation and Construction Costs

You have found out that you are losing 80% of the sewage on a 2 mile stretch of pipe. You have been tasked to see if it will be best to search for the leak and fix it or just replace the entire line. EPA is fining you $2,000 per day until the leak is fixed. It will cost you $11 per hour per man to search for and repair the leak. There will be 2 operators searching for and repairing the broken pipe. It will cost you $15 per hour for the back hoe operator and $1.00 per foot to dig to find the broken pipe, and $500 per day for back hoe rental. Assume that you will have to dig up 3,747 linear ft of 18 inch diameter pipe to make the repair and take 33 hours to make sure that all of the leaks on the stretch of pipe are found, the pipe is sold in 20 foot sections, and the workers will work a 12 hour workday (4 hrs of OT). The cost for the 18 inch pipe is $2.48 and additional fittings will cost $17.00 each. The 18 inch pipe cost and all the fittings from a contractor is $4.75 per linear foot and bedding is $1.85 per linear foot. They will charge a clean up fee of $3,100. It will take the contractor 9 days to complete the entire installation and they will work on weekends for a fee of $600 per day. Today is Friday and the contractor will start in the morning if you give them the go ahead. The weekend work is considered OT as well for the municipal employees. What is the total cost of the contractor installing the pipe? Include All costs that will be associated with the contractor. The contractor will replace the entire 2 mile stretch?

First convert miles into feet. Calculate the cost of the fittings, bedding, clean-up fee, fine and weekend fee costs. Ignore all of the municipal costs because you only want to know the contractor fees.

2 miles = 10,560 feet

Clean Up Fee = $3,100.00
Cost of Pipes = 10,560 ft x $4.75 = $50,160.00
Cost of Bedding = 10,560 x $1.85 = $19,536.00
4 weekend days = $2,400
Fine = $2,000 per day x 9 days = $18,000

Total Cost of Project = pipe cost + bedding cost + fine + weekend cost = $93,196.00

A new chemical plant is moving into town. It will bring in 2,700 jobs into the community paying an average of $19 per hour. There is a 2% city tax for anyone who works in the city. The mayor has done everything in his power to accommodate the business because the city is hurting for jobs. The taxes that the business will end up paying will be $125,000 per month. The company will sign a contract to pay taxes for a minimum of 30 years regardless of how long the business remains there. They will be tax exempt for the first year of operation. The problem is that the company will require special water treatment that they do not have in their start-up budget to pay for in a pre-treatment process. You can not run this water directly to the treatment plant. You will have to go into your emergency funds to complete the pre-treatment plant. Right now you have 1.8 million dollars in the fund. 10% of the taxes paid in by the business is earmarked for the wastewater emergency fund to pay for construction, expenses, and any other wastewater expansion that will occur due to the chemical plant's existence. There is also a $40,000 per month stipend that is paid into the emergency fund from the city's general tax fund and sewer revenue. It will take 90 12 hour days to complete the project, with no weekend work. How long will it take to build the emergency funds back to the 1.8 million dollars once the project is completed? Any hours worked over 8 in a day are at time and a half.

9 pumps at $4,500
8 inch pipe $2.77 per linear foot
9,345 linear ft of pipe
170 X 140 x 90 foot treatment tank at $1.27 per cubic foot
8 operators at $12 per hour

Cost of the pumps = 9 x $4,500 = $40,500.00

Volume of tank = 170ft x 140 ft x 90 ft = 2,142,000 $ft^3$

Pipe cost = 9,345 ft x $2.77 = $25,885.65

Operator cost straight time =
6 operators x $12 per hour x 90 days x 8 hrs per day = $51,840.00

Operator overtime cost = 6 operators x $18 per hour x 90 days x 4 hours = $38,880.00

Tank cost = 2,142,000 x $1.27 = $2,720,340.00

Project cost = pump cost + pipe cost + operator cost + tank cost =
$40,500.00 + $25,885.65 + $51,840.00 + 438,880.00 + 42,720,340.00 = $2,877,445.65

A loan or financing in the amount of $1,077,445.65 is needed.

Year 1 income = $480,000.00

Year 2 and beyond income = $600,000.00

Total owed after year 1 = $597,445.65

Total to rebuild account after 1 year = $1,8000,000 + $597,445.65 = $2,397,445.65

$$\text{\# of years to rebuild to \$1.8 million} = \frac{\$2,397,445.65}{\$600,000.00} + 1$$

# of years to rebuild to $1.8 million = 5 years

## Rehabilition Charts and Information

### *Manhole Inspection*

# MANHOLE INSPECTION

**City of ---------,**

Project No.:________ Date: ___/___/___ Manhole No.: ( ) ____________________

Address: ______________________ Location: ______________________

Precipitation: ________ 1= None, 2 = Light Rain, 3 = Heavy Rain, 4 = Snow Downstream Pipe Length:________ (ft.)

Ground Conditions:________ 1 = Dry, 2 = Damp, 3 = Wet, 4 = Standing Water Crew: ________

☐ Inspected

Not inspected: _____
1 - C.N.L.
2 - D.N.E.
3 - Buried
4 - Haz/Atmos.
5 - Unsafe
6 - Sealed Lid
7 - Traffic
8 - Dog
9 - Other

Location: _____
1 - Paved Street
2 - Unpaved Street
3 - Paved Intersection
4 - Unpaved Intersection
5 - Alley
6 - Sidewalk
7 - Parking Lot
8 - Backyard
9 - Ditch
10 - Curb/Gutter
11 - Easement
12 - Private Residence

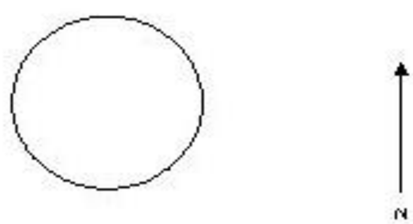
Manhole Diameter:______ (ft.) Depth: ______ (ft.)
☐ Subject to Ponding Ponding Depth: ______ (ft.)
Grade Elevation:______
1 - Even 2 - Above ______ (in.)
3 - Below ______ (in.)
Tributary Area:__________ (sq.ft.)

| | | Condition | I/I (gpm) | General Observations | Comments |
|---|---|---|---|---|---|
| Cover: diameter ________ (in.)<br>thickness ________ (in.)<br>Type:____ ☐ Vented #___ Dia.___(in.)<br>1 - Light Duty 3 - Bolt Down<br>2 - Heavy Duty 4 - Locking | | G F P | | ___,___,___ | ________ |
| Cover-to-Frame Fit | | G F P | ______ | ___,___,___ | ________ |
| Frame | | G F P | ______ | ___,___,___ | ________ |
| a. Inside dia. (in.)________ b. Outside dia. (in.)________ c. Dwell (in.)________ d. Height (in.)________ | | | | | |
| Frame-to-Chimney Seal | Type____ | G F P | ______ | ___,___,___ | ________ |
| Chimney<br>Height (in.) _____ | Type____ | G F P | ______ | ___,___,___ | ________ |
| Corbel | Type____ | G F P | ______ | ___,___,___ | ________ |
| Wall | Type____ | G F P | ______ | ___,___,___ | ________ |
| Bench | Type____ | G F P | ______ | ___,___,___ | ________ |
| Invert | Type____ | G F P | ______ | ___,___,___ | ________ |
| Steps (No. Missing) _____ | Type____ | G F P | | ___,___,___ | ________ |

Pipe Seal
1. G F P I/I____ gpm
2. G F P I/I____ gpm
3. G F P I/I____ gpm
4. G F P I/I____ gpm
5. G F P I/I____ gpm
6. G F P I/I____ gpm

☐ Evidence of Surcharge Depth: ________ (ft.)

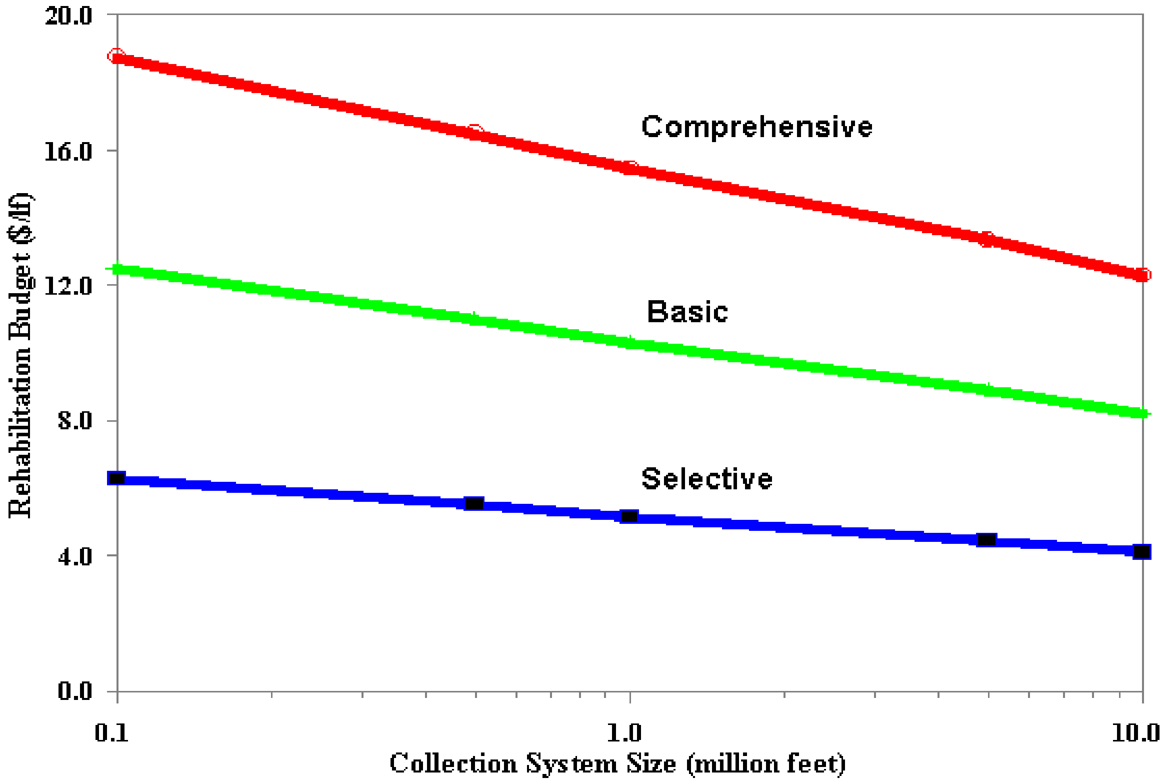
Structure Type:
1 - Brick
2 - Precast
3 - Block
4 - Clay Pipe
5 - Concrete Pipe
6 - Poured
7 - Mortar Mask
8 - Cast Iron
9 - PVC
10 - PVC-coated
11 - Rebar
12 - None
13 - Bituminous
14 - Grout
15 - Other




See Attachment "A" for General Observation Codes.

Form 3 04/94

## *Rehabilitation Budget*



## Review Questions for Rehabilitation

1. _____________ ____________ are important because those who manage the collection systems manage infrastructure, assets, and people.

2. ___________ ____________ ___________should also be considered to help with optimizing the collection system performance, since collection system managers are responsible for planning, design, construction, operation and financing of the collection system.

3. City sewer systems will continue to be prone to infiltration problems due to __________ __________even though the pipes may remain structurally sound.

4. Records that allow supervisors to develop more accurate maintenance budgets called __________ _____ __________ _________should be kept to help make sure the collection system is working optimally.

5. _____________ _________ allow operators and managers to keep track of repair/replacement work for equipment.

6. ___________ ___________ ____________ is intended to reduce the flow of extraneous storm water into wastewater collection facilities.

7. Four actions that can be taken after a sewer rehabilitation assessment has been made are __________ ___________ _____________ _____________.

8. __________ ___________is the value on a given date of a future payment or series of future payments, discounted to reflect the time value of money and other factors such as investment risk.

9. __________ ____________ ____________ must also consider operation and maintenance costs over the economic period.

10. _____________ ____________ enable workers to install new pipe in the location of the old pipe without total surface digging and its accompanying traffic and business disruptions.

11. _____________ __________works by using a pneumatic or hydraulic bursting mandrel to crush the existing pipeline while at the same time a new pipe can be pulled into place.

12. ______________is a method by which a pipe is inserted into an existing line by either pulling or pushing continuous

13. Estimate the construction cost of a sanitary sewer project. The project consists of 11,500 feet of 24-inch sewer and 25 manholes. Costs are estimated below:

| | |
|---|---|
| Excavation and backfill | $19.45 per linear foot |
| Pipe cost (delivered) | $ 8.89 per linear foot |
| Manhole, complete | $3000.00 each |

14. A sewer pipe has failed and 174 feet of 36 in vitrified clay pipe must be replaced. How many 4 foot sections are required?

## Answers to Rehabilitation Review Questions

1. Maintenance budgets
2. Asset management plans
3. deteriorated joints
4. operation and maintenance logs
5. maintenance records
6. sewer system rehabilitation
7. no-action alternative, rehabilitation, replacement, preferred alternative
8. Present value
9. Present worth analysis
10. Trenchless technologies
11. Pipe bursting
12. Sliplining
13. $400,910
14. 44 ft

# GLOSSARY AND ACRONYMS

**(ABS) Acrylonitrile-butadiene-styrene**

**Anthropogenic** Relating to the science of man.

**Amino acids** Compounds, containing within their structure at least one amino group (NHy) and one carboxylic group (-COOH)). Sub-units of amino acids make up proteins.

**Amplitude** The magnitude of the maximum displacement of an oscillating sound wave.

**Anaerobic digestion** Digestion of organic matter by anaerobic microbial action, resulting in the production of methane gas.

**Anaerobiosis** The presence of life in an anaerobic environment.

**Anion** A negatively charged ion.

**Anion exchange capacity** The ability to exchange positively charged particles of two or more compounds, measured in milliequivalents per 100 grams.

**Aquaclude** Rocks and soils which transmit water with difficulty, e.g. clay, shale and unfractured granite.

**Aquifer** Rocks and soils which transmit water with ease through their pores and fractures, e.g. limestone, sandstone and fractured granite.

**(ASTM) American Society of Testing Materials**

**Attached growth** Fixed microbial growth on the media surface in a trickling filter.

**Attentuate and disperse landfill sites** The traditional type of landfill site from which the leachate produced seeps through soil assures and pores into the underlying saturated zone, where it is diluted.

**Autotrophic** A term applied to organisms which produce their own organic constituents from inorganic compounds utilizing energy from sunlight or oxidation processes.

**Available water content** The water available in the soil for plant use, i.e. the difference between the permanent wilting point and the field capacity.

**(AWWA)** American Water Works Association

**Baseflow** Water which enters streams from persistent, slowly varying sources and maintains streamflow between water-input events.

**(BOD) Biochemical oxygen demand** A measure of the amount of oxygen used by bacteria in the wastewater. Measures the organic strength of the water.

**($BOD_5$) Five-day biochemical oxygen demand -** A measure of the amount of oxygen used by bacteria to degrade organic matter in a sample of wastewater over a 5 day period at 20 ºC, expressed in mg $1^{-1}$.

**Biocide** A chemical toxic or lethal to living organisms.

**Biodegradable** Capable of decomposition by living matter.

**Biosolids** The semi-solid end product of wastewater treatment.

**Bound water** A thin film of water held by adhesion to the surface of soil particles.

**Buoyancy** The upward force that acts on a body which is totally immersed in a fluid and is equal to the weight of the fluid displaced by the body.

**Buffer** A solution which undergoes only a slight change in pH when $H^+$ or $OH^-$ ions are added to it.

**Bulking agent** A low density material, usually domestic refuse, straw or woodchips which is mixed with compost to permit air circulation while the compost is digesting.

**Catalyst** A substance which alters the rate of a chemical reaction but which is not used up and is unchanged chemically at the end of the reaction.

**Catchment** A natural drainage basin which channels rainfall into a single outflow.

**Cation** A positively charged ion.

**Cavity zone** A region within which there is little mixing of air.

**(CCTV) closed-circuit television**

**Cell wall** The outer supporting layer of a plant cell made by the protoplast and consisting largely of cellulose.

**(COD) Chemical oxygen demand** A quick chemical test to measure the oxygen equivalent of the organic matter content of wastewater that is susceptible to oxidation by a strong chemical.

**Chemisorption** Adsorption involving very strong bonding forces

**Chemotrophic** A term applied to organisms which produce their own organic constituents from inorganic compounds utilizing the energy obtained from the oxidation of hydrogen sulphide.

**Chloramine** A compound composed of chlorine and ammonia.

**Chlorination** A disinfection technique used in water treatment, involving the addition of $Cl_2$ gas, chlorine dioxide, sodium hypochlorite or calcium hypochlorite.

**Chlorofluorocarbons (CFCs)** Compounds containing chlorine, fluorine or bromine, used as aerosol propellants, refrigerants, foaming agents and solvents and which, on decomposition by sunlight, produce oxides of chlorine responsible for the removal of ozone from the stratosphere.

**Circulating bed** Recovery of solids from the gas phase of a fluidized bed combustion reactor, followed by reinjection into the sand bed.

**Closed loop recycling** The remanufacture of a new product from a retired product of the same type.

**Coagulation** The water/wastewater treatment process of destabilizing colloidal particles to facilitate particle growth during flocculation by either double-layer compression, charge neturalization, interparticle bridging or precipitate enmeshment.

**Conductivity** A measure of the ability of a solution to conduct an electrical current and is proportional to the concentration of ions in the solution.

**Coliforms** Non-pathogenic bacteria present in the intestines of warm-blooded animals, water and wastewater, whose numbers indicate contamination.

**Colloids** Very small particles in suspension, e.g. clays.

**Combustion** A high temperature process involving the decomposition of organics in an excess of air.

**Completely mixed reactor** An aeration tank in which, on entering, the influent wastewater is dispersed immediately throughout the reactor volume.

**Composting** The biological stabilization of wastes of biological origin under controlled conditions.

**Compound** A substance, the molecules of which consist of two or more different kinds of atoms.

**Compression settling** Particles are present in such a high concentration that they touch each other and settling can occur only by compression of the particle mass.

**Constructed wetland** A biological wastewater treatment system which utilizes plants for the degradation of organic waste.

**Contact stabilization** A wastewater treatment plant in which there are two tanks, one for the adsorption of organic matter onto the suspended solids and another for oxidation of the adsorbed materials.

**Containment landfill sites** The modern landfill site, in which the leachate generated is contained by bottom liners, collected and treated.

**Contaminated site** A landfill into which hazardous polluting waste has been dumped.

**Convection** Transport of heat by vertical movement of a heated body.

**Cryogenic** Producing very low temperatures.

**Cyanide** A highly poisonous salt of hydrocyanic acid, used frequently in the extraction of gold and silver.

**Cyclone separator** A means of purifying an air stream by using both gravitational and centrifugal forces.

**Denitrification** The chemical reduction of nitrate and nitrite to gaseous forms: nitric oxide, nitrous oxide and dinitrogen: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

**Detritivores** Organisms which feed on fragmented particulate organic matter.

**Dewatering of sludge** A mechanical unit operation which increases the dry solids concentration of the sludge from 3.9 percent after digestion to 25 – 30 percent thereby ensuring that the sludge effectively behaves as a solid for handling purposes.

**Diffusion** The process by which gases and liquids spread themselves throughout any space into which they are put.

**(DIP) Ductile Iron Pipe** outgrowth of the cast iron pipe industry. Improvements in the metallurgy of cast iron in the 1940's increased the strength of cast iron pipe and added ductility, an ability to slightly deform without cracking

**Discrete settling** Particles settle as independent units, without interaction of flocs.

**Disinfection** The removal or inactivation of pathogenic organisms.

**(DO) Dissolved oxygen** A measure of the amount of oxygen dissolved in water, expressed as either:
(i) mg/1 – which is the absolute amount of oxygen dissolved in the water mass
(ii) as percentage saturation of the water with $O_2$ (% sat)

**Dissolved solids** The total colloidal and suspended solids in a liquid. Any particle passing a 1.2 µm filter is defined as dissolved.

**Dry weather flow** The combination of wastewater and dry weather infiltration flowing in a sanitary sewer during times of low precipitation.

**Ecology** That branch of science dealing with living organisms and their surroundings.

**Ecosystem** A community of interdependent organisms together with the environment which they inhabit and with which they interact, e.g. a pond.

**Effluent** The outflow from a sewage treatment plant.

**Element** A substance, the molecules of which have all the same atoms.

**Endotoxin** An environmental toxin which attacks the endocrine glands, i.e. kidney, liver, etc.

**(EIA) Environmental impact assessment** A review to which all commencing projects must be subjected with regard to their impact on the environment.

**Enzyme** A substance produced by living cells which acts like a catalyst in promoting reactions within the organism.

**Equilization basin** A holding tank within which variations in sewage inflow rate and liquid nutrient concentrations are averaged.

**Eurotrophic** A term describing freshwater bodies which are rich in plant nutrients and therefore highly productive.

**Eutrophication** An increase in the concentration of nutrients in an aquatic ecosystem, causing:
(i) the increased productivity of autotrophic green plants, leading to the blocking out of sunlight
(ii) elevated temperatures within the water body
(iii) depletion of the world's oxygen resources
(iv) increased agal growth
(v) reduction in the level of and variety of fish and animal

**Evaporation** The changing of liquid water from rivers, lakes, bare soil and vegetative surfaces into water vapor.

**Exothermic reaction** A chemical reaction during which heat is liberated.

**Extended aeration** Involves an aeration period of more than 24 hours and a high rate of return sludge to allow cell decay during the endogenous respiration phase of the growth curve.

**Facultative aerobes/anaerobes** Having the ability to live either with or without oxygen.

**Filtration** A process whereby suspended and colloidal matter is removed from water and wastewater by passage through a granular medium.

**Flash point** The lowest temperature at which a flammable vapor/air mixture exists at the surface of a combustible liquid.

**Flocculation** The water treatment process in which particle collisions are induced in order to encourage the growth of larger particles.

**Flotation** A process by which suspended matter is lifted to the surface of a liquid to facilitate its removal. Frequently done by the bubbling of air through the liquid.

**Flow duration curve** A means of summarizing temporal variability by averaging precipitation over a selected time period.

**Flowing well** When the groundwater is flowing in a confined aquifer, it is under hydrostatic pressure. Should a standpipe be inserted into the aquifer, the water will rise in the standpipe.

**Fluoridation** The addition of fluoride to drinking water within the limits 0.7 – 1.2 $mg/1^{-1}$ to help prevent the occurrence of tooth decay.

**Foaming agent** Anti-foaming chemicals added to wastewater in the aeration tank to disperse the contaminating foam caused by the action of the surface aerators and the presence of detergents in the wastewater.

**Food/micro-organism ratio (F/M)** A measure of the organic loading rate of a wastewater treatment system, i.e. the ratio between the daily BOD load and the quantity of activated sludge in the system (microbes).

**(FRP) Fiberglass Reinforced Plastic Pipe** basic class of pipes; another word for RTR or RFRP

**(FRPM) Fiberglass Reinforced Polymer Mortar** basic class of pipes; another word for RFRP or RTR

**Groundwater** Water under a pressure greater than atmospheric pressure which is present in the saturated zone of the soil.

**($H_2S$) Hydrogen Sulfide Gas** inhalation hazard and causes corrosion of collection system equipment

**Hardness in water** The sum of the calcium and magnesium ion concentrations. A hard water will leave a scale on the inside of kettles and will form a scum rather than a lather with soap.

**Hazardous waste** A substance which exhibits ignitability, reactivity, corrosivity, and/or toxicity.

**(HPDE)** High- Density Polyethylene commonly used with pipe bursting

**Heavy metal** Inorganic species of large atomic weight. Usually chromium ($Cr^{3+}$), lead ($Pb^{2+}$), mercury ($Hg^{2+}$ ), zinc ($Zn^{2+}$), cadmium ($Cd^{2+}$) and barium ($Ba^{2+}$).

**High rate aeration** An increased rate of aeration of MLSS in an activated sludge system requiring less activated sludge and shorter aeration periods.

**Homogenous** Consisting of only one phase.

**Hydrophilic** Displaying an affinity for water.

**Hydrophobic** Displaying an aversion for water.

**Hydrological cycle** The endless recirculatory transport process of the earth's water resources, linking the atmosphere, the land and the oceans.

**(I/I or I&I) Inflow and Infiltration Inflow** is excess rainwater that enters the system very soon after the rain begins and can normally be traced to unsealed manholes and illegal connections such as roof down spouts, parking lot and yard drains. **Infiltration** is the excess water that continues to enter the system for three or four day s after the rain has stopped and is the result of groundwater seeping into the system through breaks in the line and unsealed pipe joints

**Ion** Atoms or groups of atoms which have either lost or gained electrons and so have become either positively or negatively charged.

**Ion exchange** Ion exchange can be illustrated by the following reaction: $Ca^{2+} + Na_2 Z \rightarrow CaZ + 2Na^+$.

**Irrigation requirement** The difference in volume between effective precipitation and evapotranspiration.

**Isohyet** A line on a map connecting areas of equal precipitation.

**Karst** Landforms of chemically weathered limestone, characterized by underground channels and caverns, swallow holes and open joints.

**Landfill** A repository in the ground for unwanted waste.

**Landfill liner** Used to limit the movement of leachate and landfill gases from the landfill site. Can be made of natural clay material or composite geomembrane and clay materials.

**Leachate** Liquid, composed of external rainfall, groundwater, etc. which has percolated through solid waste and has extracted both biological and chemical, dissolved or suspended materials.

**Life cycle assessment (LCA)** The assessment of the steps in a product life cycle, including: raw materials acquisition, bulk material processing, materials production, manufacture, assembly, use, retirement and disposal.

**Magnetic separation** A process which utilizes the magnetic properties of ferrous metals to extract them from the waste stream.

**Masking agent** A substance which will remove an offending odor from an air stream by decomposition or conversion to an organic salt.

**Materials recovery facility (MRF)** Depots where reusable waste material is recovered.

**Mean cell residence time (MCRT)** The average time a single microbe will remain in an activated sludge system and is calculated by: Total mass of cells/Rate of cell wastage

**Membrane process** The removal of dissolved solids from water by passage through a membrane of minute pore diameter ($3*10^{-10}$ m).

**Mesotrophic** A term to describe waters having intermediate levels of the minerals required by green plants.

**Methanogenic bacteria** Obligate anaerobes and methanobacteria (e.g. methanosarcina, methanobacilli) which produce methane gas from the decomposition of acids and alcohols:
$CH_3COOH$ ? $CH_4 + CO_2$
$CO_2 + H_2O + NH_3$? $NH_4HCO_3$

**(MGD) million gallons per day**

**Micro-organisms** Neither plant nor animal, these are small, simple organisms which are either unicellular or multicellular, consisting of protozoa, algae, fungi, ricettsiae, viruses and bacteria.

**Mineralization** The process by which organic N is reconverted to mineral form by a wide variety of heterotrophic organisms – bacteria, fungi and actinomycetes.

**Mixed liquor suspended solids (MLSS)** The microbial suspension in the aeration tank containing living and dead micro-organisms and inert biodegradable matter, the operating concentration of which may vary in the range 1500 to 4000 mg/1

**Mole** A mole of any substance is that amount of it which contains the Avogadro Constant number of particles. A mole of any substance is equal to its molecular mass or atomic mass expressed in grams.

**Mouse system** Software for the hydrodynamic and hydrochemical design of a wastewater collection system from the Danish Hydraulic Institute.

**Neutrality** An ion or ion group which has an equal number of electrons and protons, i.e. neither a positive nor negative overall change.

**Nitrification** The conversion of the ammonium ion, $NH_4^+$, into the nitrite ion, $NO_3^+$. It occurs in two steps:
(i) $2NH_4^+ + 3O_2 = 2NO_2^- + 2H_2O + 4H^+$ by the bacteria genus *Nitrosomonas*
(ii) $2NO_2 + O_2 = 2NO_3^-$ by the bacteria genus *Nitrobacter.*

**Non-point source pollution** Pollution from diffuse and not easily identifiable sources, e.g. a field.

**Normality** A concentration unit which is defined as: number of equivalents of solute/number of liters of solution.

**Nutrient removal** Tertiary treatment introduced to remove some of the trace compounds and elements contained in most domestic wastewaters, e.g. inorganic ammonia, nitrates, phosphates and sulfates, which are little affected by conventional treatment processes.

**Odor threshold** The minimum level or value of an odor necessary to elicit a public response.

**Open loop recycling** The manufacture of a new and simpler product from a retired, downcycled, more complex product.

**Overflow rate** The rate at which water is drawn off from the surface of primary and secondary clarification tanks. It is an important tank design parameter and is derived from the analysis of settling particles.

**Overland flow** The lateral movement of water over the ground surface due to gravitational forces.

**Oxidation** A process in which there is loss of electrons from an element or ion.

**Oxidation ditch** A ring-shaped channel, 1 – 1.5 m deep, around which wastewater circulates at 0.3-0.6 $m/s^{-1}$, is aerated by mechanical rotors and undergoes biological treatment by the resident microbes.

**Oxidation number** The charge which an atom of an element has, or appears to have, in a compound, e.g. chlorine has an oxidation number of – 1.

**Ozone** A triatomic gas, particularly prevalent in the stratosphere, formed by the reaction:
$O + O_2$ + energy  $O_3$ + energy.

**Ozone-depleting gases** Gases (e.g. oxides of nitrates, chlorine nitrate, halocarbons and water vapor) which cause destruction of the ozone layer, thereby allowing increased amounts of sunlight to reach the earth.

**(PAH)** Polycyclic aromatic hydrocarbons.

**(PAN)** Peroxyacetyl-nitrate.

**Parasite** An organism which lives on or in another living organism of a different species (the host), from which it obtains food and protection, e.g. tapeworms, greenflies.

**(PB) Polybutylene**

**(PCCP) Prestressed Concrete Cylinder Pipe** used for force mains. PCCP may be of either embedded cylinder or lined-cylinder construction

**(PE) Polyethylene**

**Permeability** The rate at which a fluid flows through a porous medium under the hydraulic head operating within the medium. Usually, the greater the porosity, the greater the permeability.

**pH** A measure of the acidity or basicity of a solution i.e. the negative of the logarithm of the hydrogen ion concentration.

**Photo-oxidation** Oxidation initiated by sunlight.

**Point-source pollution** Pollution from sources which are easily identified, e.g. slurry tank.

**Polymer** Giant molecules built up from thousands of smaller molecules, combined together to form a repetitive structure.

**Positive project** A commencing project for which an Environmental Impact Assessment is considered essential.

**Precipitation** The depth of rainfall plus the water equivalent of snow, sleet and hail falling during a given measurement period.

**Precipitation reaction** A physical or chemical reaction which results in the precipitation of one of the products formed.

**Primary pollutant** Air pollutants which are emitted from an identifiable source, e.g. carbon monoxide from the car engine.

**Primary producer** Organisms which are capable of using solar energy to make food by the process of photosynthesis, e.g. plants.

**Procaryotic cell** A cell which lacks a distinct nucleus, e.g. bacteria.

**Proteins** Substances containing the elements carbon, hydrogen, oxygen, nitrogen and occasionally sulfur, whose main function is cell growth and repair.

**Proton** Positively charged particle contained within the nucleus of an atom.

**(PVC) Polyvinyl Chloride** strong, lightweight, and somewhat flexible pipe. PVC pipe is the most widely used plastic pipe material.

**Rapid gravity filter** A filter used in water treatment which removes suspended solids from water by passing it through a sand bed, where the solids collect as a surface mat and in the sand interstices. The water should previously have been treated by coagulation, flocculation and sedimentation.

**(RCP) Reinforced Concrete Pipe** used primarily for gravity lines

**Recharge** The process of renewing underground water by infiltration.

**Reduced groundwater** Groundwater which contains no oxygen.

**Regeneration rate** The rate of reproduction of bacteria, the method of which is usually by binary fission.

**Retention time** The length of time a wastewater remains in a clarification tank, an important design parameter in the optimization of settling of suspended solids.

**Return activated sludge** Settled activated sludge from the clarifier which is returned to the aeration tank to ensure an active population of microbes will be mixed with the incoming wastewater.

**Reverse osmosis** A membrane process in which solutions of two different concentrations are separated by a semi-permeable membrane. An applied pressure gradient greater than the osmotic pressure ensures flow from the more concentrated to the less concentrated solution.

**Roughing filter** A high-rate trickling filter of depth 1 – 2m, hydraulic loading 10-40$m^3/m^2/d$ and organic loading 0.32 – 1.0 kgBOD/$m^3$/d through which wastewater may be passed prior to an activated sludge treatment.

**(RPM) Reinforced Plastic Mortar** class of pipes

**(RTR) Reinforced Thermosetting Resin** class of pipes; another name for FRP or RFRP

**Schmutzdeck** The surface mat of suspended particles which forms on the surface of a slow sand filter.

**Screening** (i) The final sorting stage necessary for high-quality compost, during which uncomposted particles such as wood, glass or plastic are removed by passing through a fine mesh.
(ii) The first stage of an Environmental Impact Assessment (EIA) in which the projects to be subjected to an EIA are chosen.

**Scrubbing** A process by which suspended particles and acid gases are removed from a flue gas stream, the former by absorption onto liquid droplets and the latter by diffusion into the liquid phase.

**Scum well** A box used to store the scum which forms on the surface of a wastewater in a clarification tank. Scum is usually drawn off by a horizontal, slotted pipe that can be rotated by a lever or a screw.

**Secondary pollutant** Air pollutants which are formed in the atmosphere by chemical reactions, e.g. ozone.

**(SCR) Selective catalytic reduction** A pre-combustion method of decomposition of NO, in an ajar stream to nitrogen and water by injection of ammonia into the catalytic bed of a combustion chamber.

**(NSCR)** S**elective non-catalytic reduction (NSCR)** A post-combustion method of decomposition of $NO_x$ in an air stream to nitrogen and water by injection of ammonia downstream of a combustion chamber.

**Sensitive area** A water body which may intermittently suffer eutrophication.

(**STEP) Septic tank effluent pump** systems that require pump-out of septic tanks at two to three year intervals.

**Sequencing batch reactor** A time-stepped batch process for the biological treatment of liquid hazardous waste.

**Settling tank** A rectangular or circular tank in which particle velocities within the liquid are sufficiently reduced to allow the suspended material to be removed from the liquid by gravity settling.

**Settling velocity** This is the velocity at which a particle will fall to the bottom of a settling tank and is equal to the surface overflow rate for a rectangular tank.

**Sewage** Wastewater and other refuse such as feces, carried away in sewers.

**Sewerage** System of pipes and treatment plants which collect and dispose of sewage in a town.

**Sloughing** A term which describes the falling off of the slime layer of micro-organisms on the media of a trickling filter due to the development of anaerobic conditions and lack of food caused by an increase in slime thickness.

**Slow sand filter** A filter which removes suspended solids from raw water by passing it through a sand bed, where the solids collect as a surface mat and in the sand interstices. Filtration rates are in the order of 2 – 51/m$^2$/min.

**Sludge** The accumulation of solids resulting from chemical coagulation, flocculation and sedimentation after water or wastewater treatment.

**Sludge bulking** A phenomenon caused when a large number of filamentous micro-organisms present in the mixed liquor interferes with the compaction of the floe and produces a sludge with a poor settling rate.

**Sludge conditioning** Addition of chemicals, polyelectrolytes or heat treatment to improve the rate of dewatering.

**Sludge dewatering** The mechanical unit operation used to reduce the moisture content of sludge to 70 – 75 percent and thus ensure that the remaining sludge residue effectively behaves as a solid for handling purposes.

**Sludge stabilization** The process of destroying or inactivating pathogens.

**(SVI) Sludge volume index** A measure of the ability of sludge to settle, coalesce and compact on settlement.

**Solid waste** All the wastes arising from human and animal activities which are normally solid and are discarded as useless or unwanted.

**Solubility product** The equilibrium constant for a reaction involving a precipitate and its constituent ions, e.g. for magnesium sulfate $MgSO_4 = Mg^{+2} + SO_4^{-2}$, the solubility product = $[Mg^{+2}][SO_4^{-2}]$

**Solute** A substance dissolved in a fluid.

**Solution** The conversion of a solid or gas into liquid form by mixing with a solvent.

**Solvent** A liquid capable of or used for dissolving something.

**(SEL) Sound exposure level** Used to express the energy of isolated noise events, the SEL is that constant level in decibels lasting for one second which has the same amount of acoustic energy as a transient noise.

**(SRF) Specific resistance to filtration** A laboratory-determinable wastewater sludge parameter.

**Stabilization pond** A quiescent, diked pond in which wastewater undergoes biological treatment under microbial action.

**Step feed aeration** An aeration system in which a portion of the sewage load is added at each of several inlets, thus spreading out the oxygen demand over the length of the tank so that oxygen utilization is more efficient.

**Supernatant** The partially purified water, high in suspended solids and ammoniacal nitrogen, which is released during the digestion process and whose quality and amount is dependent on the type and settling quality of the waste and on the digester system efficiency.

**Surface tension** The minimization of the surface of a free body of liquid due to the unbalanced attractions exerted by the liquid and the air on the liquid surface molecules.

**Surge channel** A channel or basin designed to take excess flow.

**Suspended growth** The free-moving, aerobic, microbial culture used in the biological treatment of wastewater by the activated sludge process.

**Suspended solids** Solids in suspension in a water or wastewater which can be removed by filtration.

**Suspension** A substance consisting of particles suspended in a medium.

**Sustainable development** Projects undertaken with care to preserve and manage resources, use genetic engineering with responsibility, search for technical alternatives to existing energy sources and control land, water and air pollution.

**Synoptic storm** A storm covering several hundred miles, associated with frontal activity and/or intense low pressure centers.

**Synthetic organics** Man-made, organic compounds, some of which are carcinogenic, including surfactants pesticides, cleaning solvents and trihalomethanes.

**Tapered aeration** An aeration system which equalizes the quantity of air supplied to the demand for air exerted by the micro-organisms as the liquor flows through the aeration tank.

**Thermal drying** An operation which involves reducing the water content of sludge by vaporization of water to air, resulting in a granular dried product of 92 – 95 per cent dry solids concentration.

**Thermal plume** Heated effluent from an outfall, usually less dense than the receiving water, causing increased growth rates and species changes due to local warming.

**Thickening of sludge** A process which facilitates disposal of sludge by increasing the solids content to approximately 4 per cent.

**(TSS) Total Suspended Solids** the solids captured on the special filter when performing the TSS test as specified by Standard Methods For The Examination Of Water and Wastewater.

**Toxin** A specific poison of biological organic origin.

**Transfer station** A location to accomplish transfer of solid wastes from collection and other small vehicles to larger transport equipment, with the aim of economizing on waste transportation.

**Transmissivity** A measure of the rate of flow of water through a water-bearing rock.

**Trickling flter** A biological reactor in which micro-organisms, growing as a slime on the surface of fixed media, oxidize the colloidal and dissolved organic matter in wastewater using atmospheric oxygen which diffuses into the thin film of liquid as the wastewater is trickled over the slimed surfaces at regular intervals.

**Transpiration** The loss of water vapor from the surface of the plant due to evaporation.

**Trommel** A rotary screen used to separate out the various size fractions of municipal solid waste.

**Turbidity** The clarity of water, i.e. a measure of the accumulation of collidal particles, determined by light transmission through the water.

**Turbulent mixing** When a flow of liquid or air becomes large, the streamlines become irregular and parcels of the flowing substance begin to move in a highly irregular path while maintaining a net downstream velocity.

**Ultrafiltration** Filtration technique used in water treatment to separate out bacteria larger than 1 - 100 µm.

**Upflow column** Where the water/wastewater flows upward under pressure through a column or tank, instead of downward by gravity. When used in water filtration, it is akin to the backwashing process in rapid gravity filters. Also used in aerobic digestion of industrial wastewaters where the column is packed with aggregate or synthetic material.

**Vadose zone** The entire zone of negative water pressures above the water table, the lowest portion of which is permanently saturated by capilliary rise.

**Vibrating screen** Used to remove undersized components of municipal solid waste.

**(VOC) volatile organic compounds**

**Waste minimization** The general trend in developed countries to reduce the quantities of waste material **produced.**

**(WW) Wastewater**

**(WWT) Wastewater Treatment**

**Watershed** Line between the headstreams of river systems, dividing one catchment from another.

**Water table** The level of water within the soil at which the pore water pressure is equal to the atmospheric pressure.

**Zone settling** Particles are so close together that interparticle forces hinder the settling of neighboring particles, causing all the particles to remain in a fixed position relative to each other and to settle at a constant velocity.

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# APPENDIX A - Regulations

Regulations

## *401 KAR 11:001. Definitions for 401 KAR Chapter 11.*

RELATES TO: KRS 223.160-220, 224.01-010(9), 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.200, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of wastewater operators. KRS 223.200 requires the cabinet to promulgate administrative regulations concerning the certification of water treatment and distribution system operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes definitions applicable to the certification of wastewater and water operators.

### Section 1. Definitions.

(1) "Applicant" means a person who has submitted an application to take an examination for certification.
(2) "Board" means:
(a) The Kentucky Board of Certification of Wastewater System Operators; or
(b) The Kentucky Board of Certification of Water Treatment and Distribution System Operators.
(3) "Cabinet" is defined by KRS 224.01-010(9).
(4) "Certificate" means a certificate of competency issued by the cabinet stating that the operator has met the requirements for the specified operator classification as established by 401 KAR Chapter 11.
(5) "Certified operator" means an individual that holds an active certified operator's certificate issued in accordance with 401 KAR 11:050.
(6) "Core content" means the information identified as essential by the board for purposes of certification examination and continuing education training.
(7) "Direct responsible charge" means personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the drinking

water treatment plant or distribution system is operated in accordance with accepted practices and with KRS Chapters 223 and 224 and 401 KAR Chapters 8 and 11.
(8) "Operator" means a person involved in the operation of a wastewater treatment plant, wastewater collection system, drinking water treatment plant, or drinking water distribution system.
(9) "Primary responsibility" means personal, first-hand responsibility to conduct or actively oversee and direct procedures and practices necessary to ensure that the wastewater treatment plant or wastewater collection system is operated in accordance with accepted practices and with KRS Chapter 224 and 401 KAR Chapters 5 and 11. (35 Ky.R. 473; Am. 1210; eff. 3-6-2009; 36 Ky.R. 449; 1047; eff. 2-5-2010.)

## *401 Kar 11:010. Boards Of Certification.*

RELATES TO: KRS 223.160-220, 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-200, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the board of certification of wastewater system operators and the certification of wastewater operators. KRS 223.160-220 authorizes the cabinet to promulgate administrative regulations concerning the board of certification for water treatment and distribution operators and the certification of water treatment and distribution system operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes the duties of the Kentucky Board of Certification of Wastewater System Operators and the Kentucky Board of Certification of Water Treatment and Distribution System Operators.

### Section 1. Duties of the Board. The board shall:

(1) Evaluate the qualifications of applicants and recommend qualified applicants to the cabinet for certification examination;
(2) Review and provide comments to the cabinet on proposed administrative regulations regarding operator certification;
(3) Review and make recommendations to the cabinet on core content for certification examinations and continuing education training for certification renewal;
(4) Review and make recommendations to the cabinet on training proposed to provide continuing education to certified operators. During the evaluation of training courses and seminars, the board shall consider:
(a) The consistency of training material with the core content;

(b) The ability of the training to provide information that supports effective water conveyance, treatment, and quality; and

(c) The ability of the instructor to properly present the training;

(5) Assist the cabinet in drafting examinations for the certification of operators;

(6) Review and provide comments to the cabinet on proposed fees for the training and certification of operators;

(7) Review applications for reciprocity and recommend to the cabinet the acceptance or denial of the application based on the criteria established in 401 KAR 11:050, Section 1(8); and

(8) Review evidence and advise the cabinet regarding disciplinary actions for certified operators who fail to comply with KRS Chapters 223 and 224 or 401 KAR Chapter 5, 8, or 11. (35 Ky.R. 474; Am. 1211; 1746; eff. 3-6-2009; 36 Ky.R. 450; 1049; eff. 2-5-2010.)

## *401 Kar 11:020. Standards Of Professional Conduct For Certified Operators.*

RELATES TO: KRS 223.160-220, 224.73-110, EO 2009-538

STATUTORY AUTHORITY: KRS 224.10-100, 224.10-110, 224.73-110, EO 2009-538

NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of water and wastewater operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes standards for the performance of certified water and wastewater operator duties.

### Section 1. Standards of Professional Conduct.

(1) In order to safeguard the life, health, and welfare of the public and the environment and to establish and maintain a high standard of integrity in the certified operator profession, the following standards of professional conduct apply to persons certified in accordance with 401 KAR Chapter 11:

(a) A certified operator shall, during the performance of operational duties, protect the safety, health, and welfare of the public and the environment;

(b) A certified operator shall use reasonable care and judgment in the performance of operational duties;

(c) If a certified operator’s judgment is overruled by an employer under circumstances in which the safety, health, and welfare of the public or the environment are endangered, the certified operator shall inform the employer of the possible consequences;

(d) A certified operator shall be objective, truthful, and complete in applications, reports, statements, and testimony provided to the cabinet; and

(e) A certified operator shall ensure the integrity of the samples that the operator collects, prepares, or analyzes so that results shall be a true representation of water quality.
(2) Proof of certification. While on duty, a certified operator shall carry the cabinet-issued wallet card showing the operator's current certification status.
(3) Maintenance of records. If information related to the operator's employment or mailing address changes from that provided in the application for certification, the certified operator shall provide written notification to the cabinet within thirty (30) days. (35 Ky.R. 475; Am. 1212; 1747; eff. 3-6-2009; 36 Ky.R. 452; 1051; eff. 2-5-2010.)

## *401 Kar 11:030. Wastewater Treatment And Collection System Operators; Classification And Qualifications.*

RELATES TO: KRS 224.73-110

STATUTORY AUTHORITY: KRS 224.10-100, 224.10-110, 224.73-110

NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of wastewater. This administrative regulation establishes classification of wastewater treatment and collection operator certifications and establishes the qualifications for certification.

### Section 1. Classification of Wastewater Operator Certifications.

(1) Wastewater treatment certifications.

(a) Limited certification. As provided in KRS 224.73-110(5), an operator issued a limited certificate may have primary responsibility for a school wastewater treatment plant and collection system.

(b) Class I Treatment certification.

1. A Class I treatment operator may have primary responsibility for a wastewater treatment plant with a design capacity less than or equal to 50,000 gallons per day.

2. A Class I Treatment operator shall not have primary responsibility for a wastewater treatment plant with a larger design capacity.

(c) Class II Treatment certification.

1. A Class II Treatment operator may have primary responsibility for a wastewater treatment plant with a design capacity less than or equal to two (2) million gallons per day.

2. A Class II Treatment operator shall not have primary responsibility for a wastewater treatment plant with a larger design capacity.

(d) Class III Treatment certification.

1. A Class III Treatment operator may have primary responsibility for a wastewater treatment plant with a design capacity less than or equal to seven and one-half (7 1/2) million gallons per day.

2. A Class III Treatment operator shall not have primary responsibility for a wastewater treatment plant with a larger design capacity.

(e) Class IV Treatment certification. A Class IV Treatment operator may have primary responsibility for a wastewater treatment plant of any design capacity.

(2) Wastewater collection certifications.

(a) Class I Collection certification.

1. A Class I Collection operator may have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a design capacity of less than or equal to 50,000 gallons per day.

2. A Class I Collection operator shall not have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a larger design capacity.

(b) Class II Collection certification.

1. A Class II Collection operator may have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a design capacity of less than or equal to two (2) million gallons per day.

2. A Class II Collection operator shall not have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a larger design capacity.

(c) Class III Collection certification.

1. A Class III Collection operator may have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a

design capacity of less than or equal to seven and one-half (71/2) million gallons per day.

2. A Class III Collection operator shall not have primary responsibility for a wastewater collection system that transports wastewater to a treatment plant with a larger design capacity.

(d) Class IV Collection certification. A Class IV Collection operator may have primary responsibility for any wastewater collection system.

(3) Operator in Training designations.

(a) Except as provided in paragraphs (c) and (d) of this subsection, a certified operator with an Operator in Training designation shall not have primary responsibility of a wastewater treatment plant or wastewater collection system.

(b) A certified operator with an Operator in Training designation shall work under the direct supervision of a certified operator who works at the same facility and has obtained a certification level that is equal to or greater than the certification level required to serve in primary responsibility of the facility.

(c) A wastewater Class I Treatment operator with an Operator in Training designation who operates a wastewater treatment plant owned by the operator that serves only one (1) residence:

1. May have primary responsibility for that system; and

2. Shall be exempt from paragraph (b) of this subsection and 401 KAR 11:050, Section 1*(2)(b) and (9)(a)3.

(d) If a certified operator also has been issued a wastewater treatment or collection certification without an Operator in Training designation, the operator may have primary responsibility for a wastewater treatment plant or collection system as provided by this section for the certifications that do not have an Operator in Training designation.

## Section 2. Wastewater Operator Qualifications: Experience, Education, and Equivalencies.

An individual desiring to become a certified operator shall meet the following minimum qualifications prior to the cabinet approving the individual to take a certification examination as provided in 401 KAR 11:050.

(1) The education and experience requirement for each class of wastewater treatment certifications shall be as follows:

(a) Limited certification.

1. Education. A minimum level of education shall not be required.

2. Experience. A minimum level of experience shall not be required.

(b) Class I Treatment certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a wastewater treatment plant shall be required.

(c) Class II Treatment certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a wastewater treatment plant shall be required.

(d) Class III Treatment certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a wastewater treatment plant with one (1) year of that experience in a wastewater treatment plant with a design capacity greater than 50,000 gallons per day shall be required.

(e) Class IV Treatment certification.

1. Education. A baccalaureate degree in engineering, science, or equivalent shall be required; and

2. Experience. At least five (5) years of acceptable operation of a wastewater treatment plant shall be required.

a. Three (3) years of the required experience in a wastewater treatment plant with a design capacity greater than two (2) million gallons per day shall be required; and

b. At least two (2) years of primary responsibility in a wastewater treatment plant with a design capacity greater than two (2) million gallons per day shall be required.

(2) The educational and experience qualifications for wastewater collection certifications shall be as follows:

(a) Class I Collection certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. One (1) year of acceptable operation of a wastewater collection system shall be required.

(b) Class II Collection certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Two (2) years of acceptable operation of a wastewater collection system shall be required.

(c) Class III Collection certification.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Three (3) years of acceptable operation of a wastewater collection system with one (1) year of that experience in a wastewater collection system that transports wastewater to a treatment plant with a design capacity of greater than 50,000 gallons per day shall be required.

(d) Class IV Collection certification.

1. Education. A baccalaureate degree in engineering; environmental technology; biological, physical, or chemical sciences; or equivalent shall be required; and

2. Experience. At least five (5) years of acceptable operation of a wastewater collection system shall be required.

a. Three (3) years of the required experience in a wastewater collection system that transports wastewater to a treatment plant with a design capacity of greater than two (2) million gallons per day shall be required; and

b. At least two (2) years of primary responsibility in a wastewater collection system that transports wastewater to a treatment plant with a design capacity of greater than two (2) million gallons per day shall be required.

(3) The educational and experience qualifications for Operator in Training designations shall be as follows:

(a) Class I Treatment and Class I Collection certifications.

1. Education. A high school diploma or general education development (GED) certificate shall be required; and

2. Experience. Experience shall not be required.

(b) All other applicants for the classifications identified in Section 1(1) and (2) of this administrative regulation:

1. Shall have successfully qualified for and passed the certification exam of the same type classification at one (1) level lower than the Operator in Training designation being pursued; and

2. Shall not have been subject to disciplinary action as provided by 401 KAR 11:050, Section 4.

(4) Substitutions. The cabinet shall allow the following substitutions for the qualifications specified in subsections (1) and (2) of this section:

(a) Education in environmental engineering; environmental technology; and biological, physical, or chemical sciences shall be substituted if the substitution does not exceed fifty (50) percent of the required experience.

1. An associate degree may substitute for two (2) years of experience.

2. A baccalaureate degree may substitute for four (4) years of experience.

3. Education that did not result in a degree in a related field shall be substituted for the required experience as follows:

a. Ten (10) contact hours, one (1) Continuing Education Unit, or one (1) postsecondary education quarter hour with a passing grade shall substitute for 0.022 years of experience.

b. One (1) postsecondary education semester hour with a passing grade shall substitute for 0.033 years of experience.

4. Education applied to the experience requirements established in subsections (1) and (2) of this section shall not be applied to the education requirement.

(b) Experience shall be substituted for the educational requirement as follows:

1. One (1) year of operational experience at a treatment plant shall substitute for one (1) year of education.

2. One (1) year of collection system experience shall substitute for one (1) year of education.

3. The cabinet may allow partial substitution of the education requirement by experience in maintenance, laboratory analysis, or other work related to the collection, treatment or distribution of drinking water or wastewater. To establish how much experience shall be accepted, the cabinet shall determine the degree of technical knowledge needed to perform the work and the degree of responsibility the applicant had in the operation of the system.

4. Experience applied to the education requirement established in subsections (1) and (2) of this section shall not be applied to the experience requirement.

(c) Collection system and treatment experience may be substituted as follows:

1.a. Four (4) years of collection system experience shall be considered equivalent to one (1) year of treatment experience.

b. This substitution shall not account for more than fifty (50) percent of the experience required by subsection (1) of this section.

2. One (1) year of treatment experience shall be considered equivalent to one (1) year of collection system experience. (35 Ky.R. 476; Am. 1213; eff. 3-6-2009; 36 Ky.R. 454; 1052; 1456; eff. 2-5-2010; 36 Ky.R. 2105-A; 37 Ky.R. 51; eff. 8-5-2010.)

## *401 Kar 11:050. Operator Certification.*

RELATES TO: KRS 223.160-220, 224.10-420(2), 224.73-110, EO 2009-538
STATUTORY AUTHORITY: KRS 223.160-220, 224.10-100, 224.10-110, 224.73-110, EO 2009-538
NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of water and wastewater operators. EO 2009-538, effective June 12, 2009, establishes the new Energy and Environment Cabinet. This administrative regulation establishes application and examination procedures; provisions relating to certificate issuance, renewal, and termination; reciprocity; training; and disciplinary actions.

## Section 1. Application and Examination for Certification.

(1) An individual desiring to become a certified operator shall first meet the qualifications established in 401 KAR 11:030 or 11:040 and then pass an examination administered by the cabinet.

(2) (a) An applicant for certification shall complete the Registration Form for Exams and Training and Education and Experience Documentation Form and shall submit them and the certification application fee to the cabinet.

(b) In addition to the requirements of paragraph (a) of this subsection, an applicant desiring to obtain an Operator in Training designation shall submit a signed letter for a certified operator located at the facility where the applicant will work. The letter shall include:

1. A statement from the certified operator indicating that the certified operator shall oversee the work of the applicant seeking an Operator in Training designation;

2. A commitment that the certified operator shall serve as a mentor to the applicant seeking an Operator in Training designation as long as the applicant is under the certified operator's direct responsible charge;

3. Verification that the certified operator is not currently the mentor for any other individuals with an Operator in Training designation; and

4. Confirmation that the certified operator has obtained a certification level that is equal to or greater than the certification level required to serve in primary responsibility of the facility.

(c) An application shall not be submitted to the cabinet unless the applicant has met the qualifications for examination.

(3) (a) After receipt of the application items established in subsection (2) of this section, the cabinet, considering the recommendation of the board, shall determine if the applicant meets the qualifications established in 401 KAR 11:030 or 11:040.

(b) If the applicant meets the qualifications, the cabinet shall approve the application and notify the applicant of the scheduled exam date.

(4) (a) Upon the applicant's completion of the examination, the cabinet shall notify the applicant of the applicant's examination score.

(b) A score of at least seventy (70) percent shall be required to pass the examination.

(5) (a) The cabinet shall issue a certificate and a wallet card to an applicant who successfully passes the certification examination.

(b) The certificate and wallet card shall designate the certification classification for which the operator has demonstrated competency.

(6) An applicant who fails to pass an examination may apply to take the examination again by resubmitting the Registration Form for Exams and Training and the application fee to the cabinet.

(7) (a) An examination shall not be returned to the applicant, but results may be reviewed by the applicant with a member of the cabinet.

(b) A request for a review shall be submitted to the cabinet in writing.

(8) A certificate shall be issued in a comparable classification, without examination, to a person who holds a valid certificate in a state, territory, or possession of the U.S. if:

(a) The requirements for certification under which the certificate was issued are not less stringent than the requirements for certification established in KRS 223.160-220, 224.73-110, and 401 KAR Chapter 11; and

(b) The applicant submits an Application for Reciprocity form and the reciprocity fee to the cabinet.

(9) (a) A certified operator who holds an Operator in Training designation may upgrade the certification by removing the Operator in Training Designation without examination if the operator:

1. Has satisfied the requirements of Section 3(1)(a) and (b) of this administrative regulation;

2. Has acquired the minimum experience required for the certification being pursued as required by 401 KAR 11:030 or 11:040; and

3. Submits a letter from the certified operator who has served as the applicant’s mentor during the Operator in Training period that recommends the removal of the Operator in Training designation.

(b) A certified operator with an Operator in Training designation who is unable to comply with the requirements established in paragraph (a) of this subsection shall apply for and retake the certification exam to upgrade the operator’s certification.

## Section 2. Duration of Certification.

(1) (a) Wastewater certifications shall expire on June 30 of an odd-numbered year unless suspended, revoked, or replaced by a higher classification certificate before that date.

(b) Wastewater certifications issued on or after January 1 and on or before June 30 of an odd-numbered year shall expire on June 30 of the next odd-numbered year.

(2) (a) Water certifications shall expire on June 30 of an even-numbered year unless suspended, revoked, or replaced by a higher classification certificate before that date.

(b) Water certifications issued on or after January 1 and on or before June 30 of an even-numbered year shall expire on June 30 of the next even-numbered year.

(3) (a) An expired certification shall continue in force pending the administrative processing of a renewal if the certified operator has complied with the renewal requirements of Section 3 of this administrative regulation.

(b) A certification continued in accordance with this subsection shall remain fully effective and enforceable.

(4) A certification shall terminate if not renewed on or before December 31 of the year the certification expired.

## Section 3. Continuing Education and Certification Renewal.

(1) A certified operator who is not designated an Operator in Training may renew a certification without examination if the operator has:

(a) Accumulated the training hours required in subsection (5) of this section; and

(b) Submitted a completed Application for Certification Renewal form and the renewal fee to the cabinet or has renewed the certification electronically on the cabinet's Web site.

(2) (a) A certified operator seeking to renew a certification with an Operator in Training designation shall apply for and retake the certification exam as provided in Section 1 of this administrative regulation.

(b) The cabinet shall not approve an operator to take an exam to renew a certification with Operator in Training designation unless the applicant has accumulated the training hours required in subsection (5) of this section.

(3) If the Application for Certification Renewal form and the renewal fee are not received by the cabinet or submitted electronically by June 30 of the year the certification expires, a late renewal fee as established in 401 KAR 8:050, Section 3 or 11:060, Section 1 shall be paid.

(4) (a) A terminated certification shall not be renewed.

(b) An operator whose certification is terminated and who wishes to become recertified shall reapply for and pass an examination in accordance with Section 1 of this administrative regulation.

(5) (a) Prior to applying for certification renewal, a certified operator shall complete the required number of cabinet-approved training hours.

(b) A certified operator holding multiple wastewater certifications issued in accordance with this administrative regulation shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for each certificate.

(c) A certified operator holding multiple water certifications issued in accordance with this administrative regulation shall complete the required number of cabinet-approved training hours for the highest certificate held in lieu of completing the required number of continuing education hours required for each certificate.

(d) Hours earned prior to initial certification shall not count toward certification renewal.

(e) Wastewater training hours shall expire two (2) years from the date earned.

(f) Water training hours shall be completed for each renewal during the two (2) year period immediately prior to the certificate expiration date.

1. Certified operators with a Bottled Water, Limited, Class I or II Treatment, Collection, or Distribution certification shall complete twelve (12) hours of approved training; or

2. Certified operators with a Class III or IV Treatment, Collection, or Distribution certification shall complete twenty-four (24) hours of approved training.

(6) (a) A training provider seeking approval of certified operator training shall submit to the cabinet a completed Application for Approval of Courses for Continuing Education Credit form.

(b) Upon completion of the approved training, the provider shall submit to the cabinet a completed Continuing Education Activity Report form.

(c) A certified operator who has attended training that has not been submitted to the cabinet for approval may apply for training approval as established in paragraph (a) of this subsection.

(d) A certified operator who provides approved training shall receive hour-for-hour credit for actual instruction time.

(7) (a) Cabinet approval of training shall expire two (2) years following the date of approval.

(b) The cabinet, in consultation with the board, shall extend the approval expiration date if:

1. The provider requests the extension in writing; and

2. The training has not changed from the previous approval.

## Section 4. Disciplinary Action.

(1) A certified operator shall be subject to disciplinary action if the cabinet, in consultation with the board, determines that the certified operator has not satisfactorily performed the operator's duties in accordance with 401 KAR 11:020.

(2) (a) A written complaint received by the board or cabinet regarding a certified operator, unless duplicitous or frivolous, and violations of 401 KAR 11:020 that are identified by the cabinet shall be evaluated by the board.

(b) The certified operator shall appear before the board if requested by the board

(3) The board shall make a recommendation to the cabinet regarding disciplinary action. The board may recommend that disciplinary action not taken or recommend that a disciplinary action be taken if the board determines that the certified operator has not satisfactorily performed operator duties in compliance with 401 KAR 11:020.

(4) (a) Upon receiving a recommendation from the board, the cabinet shall review the available evidence.

(b) After completing the review, the cabinet shall initiate the recommended disciplinary action or notify the board as to why an alternative disciplinary action was taken.

(5) A disciplinary action shall be commensurate with the severity, duration, and number of the violations. Disciplinary actions may include:

(a) Probation of the operator's certification for a specified period of time, not to exceed one (1) year;

(b) Suspension of the operator's certification for a specified period of time, not to exceed four (4) years, during which the certification shall be considered void;

(c) Revocation of the operator's certification;

(d) Civil or criminal penalties; or

(e) A combination of the disciplinary actions established in paragraphs (a) through (d) of this subsection.

(6) If disciplinary action is taken, the cabinet shall notify the certified operator and the operator's employer by certified mail of the action, the reasons outlined for the action, and the length of time for which the disciplinary action shall apply.

(7) (a) A certified operator whose certification has been suspended shall not have primary responsibility during the period that the suspension remains in effect.

(b) Experience gained during a suspension shall not be included toward meeting the requirements of 401 KAR 11:030 or 11:040.

(8) If a certification is revoked, the operator shall be ineligible for future certification.

(9) A certified operator who is aggrieved by a disciplinary action may file a petition for hearing with the cabinet pursuant to KRS 224.10-420(2).

## Section 5. Incorporation by Reference.

(1) The following material is incorporated by reference:

(a) "Registration Form for Exams and Training", August 2009;

(b) "Education and Experience Documentation Form", July 2009;

(c) "Application for Certification Renewal", August 2009;

(d) "Application for Approval of Courses for Continuing Education Credit", August 2009;

(e) "Continuing Education Activity Report", August 2009; and

(f) "Application for Reciprocity", July 2009.

(2) This material may be inspected, copied, or obtained, subject to applicable copyright law, at the Division of Compliance Assistance, 300 Fair Oaks Lane, Frankfort, Kentucky 40601, Monday through Friday, 8 a.m. to 4:30 p.m. (35 Ky.R. 479; Am. 1216; eff. 3-6-2009; eff. 2-5-2010.)

## *401 KAR 11:060. Certification Fees.*

RELATES TO: KRS 224.10-110, 224.73-110

STATUTORY AUTHORITY: KRS 224.10-100, 224.10-110, 224.73-110

NECESSITY, FUNCTION, AND CONFORMITY: KRS 224.10-110 authorizes the cabinet to promulgate administrative regulations concerning the certification of wastewater operators. This administrative regulation establishes a fee schedule for wastewater operator certification and for training of wastewater operators that is provided by the cabinet.

## Section 1. Fees.

(1) Fees for certification of wastewater operators shall be:

(a) Certification application fee: $100.

(b) Renewal application fee:

1. Fifty (50) dollars if renewed through the cabinet Web site.
2. $100 if not renewed through the cabinet Web site.

(c) Renewal late fee: $250.

(d) Reciprocity fee: $500.

(2) Each year the cabinet, in consultation with the board, shall set fees for operator training conducted by the cabinet.

(3) (a) The fees in subsection (1) of this section of this administrative regulation are nonrefundable.

(b) Fifty (50) percent of the fees in subsection (2) of this section are refundable if registration is canceled at least two (2) business days prior to the beginning of the training event.

(c) The fees in subsection (2) of this section shall be fully refunded if the training event is cancelled by the cabinet. (35 Ky.R. 481; Am. 1219; eff. 3-6-09.)

## *Bypass in the Collection System*

Bypass is when waste is intentionally diverted from the collection system or waste treatment facility. Examples of bypass are:

- Discharge from a sewer line causing sewage release to the ground surface storm sewer, surface water
- Back-ups into basements on private property
- Overflow or bypass of sewage at a pumping station or at a Water Pollution Control Facility (WPCF)
- Bypassing any portion of the WPCF treatment or collection system that would normally be online
- Whenever sewage leaves a containment vessel, planned or unplanned even if it does not reach a body of water; this includes but is not limited to tanks, pipes, pumps, hoses, channels, etc.

The following are guidelines for the collection system as listed in CFR 40 .

### CFR 40 122.41 Conditions Applicable To All Permits (*This Does Not Contain The Full Content Of This CFR*)

(m) Bypass—(1) Definitions. (i) Bypass means the intentional diversion of waste streams from any portion of a treatment facility.

(ii) Severe property damage means substantial physical damage to property, damage to the treatment facilities which causes them to become inoperable, or substantial and permanent loss of natural resources which can reasonably be expected to occur in the absence of a bypass. Severe property damage does not mean economic loss caused by delays in production.

(2) Bypass not exceeding limitations. The permittee may allow any bypass to occur which does not cause effluent limitations to be exceeded, but only if it also is for essential maintenance to assure efficient operation. These bypasses are not subject to the provisions of paragraphs (m)(3) and (m)(4) of this section.

(3) Notice—(i) Anticipated bypass. If the permittee knows in advance of the need for a bypass, it shall submit prior notice, if possible at least ten days before the date of the bypass.

(ii) Unanticipated bypass. The permittee shall submit notice of an unanticipated bypass as required in paragraph (l)(6) of this section (24-hour notice).

(4) Prohibition of bypass. (i) Bypass is prohibited, and the Director may take enforcement action against a permittee for bypass, unless:

(A) Bypass was unavoidable to prevent loss of life, personal injury, or severe property damage;

(B) There were no feasible alternatives to the bypass, such as the use of auxiliary treatment facilities, retention of untreated wastes, or maintenance during normal periods of equipment downtime. This condition is not satisfied if adequate back-up equipment should have been installed in the exercise of reasonable engineering judgment to prevent a bypass which occurred during normal periods of equipment downtime or preventive maintenance; and
(C) The permittee submitted notices as required under paragraph (m)(3) of this section.

(ii) The Director may approve an anticipated bypass, after considering its adverse effects, if the Director determines that it will meet the three conditions listed above in paragraph (m)(4)(i) of this section.

(n) Upset—(1) Definition. Upset means an exceptional incident in which there is unintentional and temporary noncompliance with technology based permit effluent limitations because of factors beyond the reasonable control of the permittee. An upset does not include noncompliance to the extent caused by operational error, improperly

designed treatment facilities, inadequate treatment facilities, lack of preventive maintenance, or careless or improper operation.

(2) Effect of an upset. An upset constitutes an affirmative defense to an action brought for noncompliance with such technology based permit effluent limitations if the requirements of paragraph (n)(3) of this section are met. No determination made during administrative review of claims that noncompliance was caused by upset, and before an action for noncompliance, is final administrative action subject to judicial review.

(3) Conditions necessary for a demonstration of upset. A permittee who wishes to establish the affirmative defense of upset shall demonstrate, through properly signed, contemporaneous operating logs, or other relevant evidence that:

(i) An upset occurred and that the permittee can identify the cause(s) of the upset;

(ii) The permitted facility was at the time being properly operated; and

(iii) The permittee submitted notice of the upset as required in paragraph (1)(6)(ii)(B) of this section (24 hour notice).

(iv) The permittee complied with any remedial measures required under paragraph (d) of this section.

(4) Burden of proof. In any enforcement proceeding the permittee seeking to establish the occurrence of an upset has the burden of proof.

Bypasses can be reported by public, city personnel, and contractors

### 401 Kar 5:015. Spills And Bypasses To Be Reported To Division.

RELATES TO: KRS Chapter 224

STATUTORY AUTHORITY: KRS 224.10-100(17)

NECESSITY, FUNCTION, AND CONFORMITY: This administrative regulation requires that spills and bypasses from sewage systems as defined in KRS 224.01-010(25) be reported to the division. Such reports enable the division to determine what action it need initiate to protect public safety and mitigate or reduce the effect of such spill or bypass.

Section 1. Any person having knowledge in advance of the necessity to bypass a sewage system shall notify the Division of Water before such bypass is commenced. Notification shall be given as far in advance as possible.

Section 2. Whenever by reason of emergency or accident a spill or discharge occurs from a sewage system or from a container or pipeline used to transport or store substances which would result in or contribute to the pollution of the waters, the person in charge of such activity shall immediately notify the Division of Water by the most rapid means available.

Section 3. Any person notifying the division pursuant to Sections 1 and 2 of this administrative regulation shall report the point of discharge, the nature of the material discharged the quantity of the material discharged and an assessment of probable environmental impact.

Section 4. Notification required under Section 1 of this administrative regulation may be made by any mode of communication. Notification required by Section 2 of this administrative regulation shall be made by the most rapid means of communication available. If notification is not initially made in writing, it shall be confirmed by written notification within ten (10) days if requested by the division director or his appointed representative.

Section 5. Persons failing to report as required in Sections 1, 2, 3 and 4 of this administrative regulation are subject to the penalties provided by KRS 224.99-010. (WP-3; 1 KY.R. 761; Am. 1382; eff. 7-2-75; Tam eff. 6-6-2008.)

## *Inflow and Infiltration*

### 401 Kar 5:005. Permits To Construct, Modify, Or Operate A Facility.

### Section 9 Municipal Water Pollution Prevention Program.

This section applies to owners of regional WWTPs, sewer systems served by regional WWTPs, and political subdivision facilities with KISOPs.

(1) For each regional WWTP, the cabinet shall review the WWTP's reported monthly flows and organic loads for the most recent twelve (12) months. If the annual average flow or organic load, or for systems with combined sewer lines the lowest monthly flow and associated organic load, exceed the following values, the cabinet shall advise the owner of the WWTP of the need to address the potential overload condition pursuant to subsection (2) of this section:

(a) For a regional WWTP with a design capacity of ten (10) MGD or less, ninety (90) percent of the WWTP's average daily design capacity; or

(b) For a regional WWTP with a design capacity of more than ten (10) MGD, ninety-five (95) percent of the WWTP's average daily design capacity.

(2) The cabinet shall deny the approval of a sewer line extension until the owner of the WWTP agrees to address the potential overload condition identified in subsection (1) of this section. The owner shall address the condition by:

(a)1. Demonstrating, with supporting documentation, that the average daily design capacity of the plant is greater than the permitted amount.

2. The cabinet shall review the request and if justified, shall issue a revised average daily design capacity for the WWTP by issuing a modification to the KPDES permit;

(b) Expanding the WWTP to a size sufficient to handle the anticipated flows and loads; or

(c) Performing other remedial measures that address the condition.

(3) The cabinet shall deny a sewer line extension that is of sufficient flow or adds load sufficient to exceed the remaining design capacity of the WWTP or exacerbate

water quality problems until the owner of the WWTP agrees to address the design capacity or water quality problem.

(4) The owners of the following facilities shall conduct a study of the sewer system or the affected portion of the sewer system that complies with subsections (5) and (6) of this section:

(a) A regional WWTP with a reported average flow or organic load that exceeds the percent identified in subsection (1)(a) or (b) of this section, as applicable, or a political subdivision KISOP facility that either:

1. Receives more than 275 gallons per capita per day of sewage flow based on the maximum flow received during a twenty-four (24) hour period exclusive of industrial flow; or

2. Receives more than 120 gallons per capita per day of sewage flow based on the annual average of daily flows exclusive of industrial flow; or

(b) If subject to excessive infiltration or excessive inflow, a regional WWTP, sewer system served by a regional WWTP, or a political subdivision facility with a KISOP.

(5) The study shall determine if the infiltration-inflow can be removed in a cost-effective manner by using a twenty (20) year present worth cost analysis and if it cannot be, shall identify the modifications to the sewer system, affected portion of the sewer system, or affected portion of the WWTP necessary to transport and treat the infiltration-inflow.

(a) A schedule for completion of the necessary modifications shall also be prepared.

(b)1. The study and schedule shall be submitted to the cabinet for review and approval.

2. Approval shall be based on cost and length of time required to correct the infiltration-inflow.

(6) For the infiltration-inflow study of the sewer system or the affected portion of the sewer system, the owner shall:

(a) Use a map of the sewer system or the affected portion of the sewer system to select manholes for the installation of flow monitoring equipment;

(b) Install equipment to monitor flow at the key manholes, groundwater levels, and rainfall volume and duration for a period of thirty (30) to ninety (90) days;

(c) Conduct physical surveys, smoke tests, and dye water studies of the affected portion of the sewer system;

(d) Evaluate the cost-effectiveness of transportation and treatment versus correction of the infiltration-inflow sources by using a twenty (20) year present worth cost analysis;

(e) Internally inspect the sewer lines in the affected portion of the sewer system to determine the rehabilitation locations and methods if the rehabilitation locations and methods cannot be established by other analysis;

(f) Develop plans for rehabilitation of the affected portion of the sewer system or modifications to the affected portion of the facility necessary to transport and treat all flows; and

(g) Develop a schedule for completion of the rehabilitation or modifications.

(7)(a) The owner of the facility shall complete the necessary rehabilitation or modifications in accordance with the schedule to which the applicant and cabinet agree.

(b) The cabinet may deny a further sewer line extension if the owner is not meeting the schedule or is not making progress that follows the schedule.

## *Combined Sewers, Combined Sewer Overflow and Sanitary Sewer Overflow*

Combined sewer" or "combined sewer line" means a sewer or sewer line designed to carry storm water runoff as well as sanitary wastewater. Combined sewer overflow" or "CSO" means the flow from a combined sewer in excess of the interceptor or regulator capacity that is discharged into receiving water without going to a POTW.

The following information regarding CSOs and SSOs was provided by the Division of Water.

### 6.2 SSO Permits

Kentucky Department of Environmental Protection (KY DEP) does not issue permits for SSOs.

### 6.3 SSO Enforcement: Discretion, Standards, Requirements

KY DEP does exercise enforcement discretion, but it is associated with frequency, duration, volume, and number of overflows rather than a storm event of a certain magnitude. SSOs are illegal under the Clean Water Act; any SSO constitutes an illegal discharge. Enforcement standards are determined on a case by case basis. Communities with a small number of less voluminous SSOs will be addressed with less stringent enforcement than communities with a large number of recurring wet weather SSOs.

## 6.4 SSO Elimination

KY DEP requires elimination of SSOs and it is not associated with a specific storm event. SSO elimination schedule varies by community and is based on several factors, including “frequency, duration, volume, human health and environmental impacts.

## 6.5 Inflow/Infiltration (I/I) Identification & Reduction

KY DEP established standards for identifying excessive I/I in Kentucky Administrative Regulations, 401 KAR5:005, Sections 8 & 9 (reference 55). These regulations require the integrity of newly constructed gravity sewer lines to be verified using either the infiltration-exfiltration test method with a positive head of two feet or the low pressure air testing method. Exfiltration is when groundwater that enters the collection system through cracks or imperfect joints in lines or manholes Also, new gravity sewer lines must not allow groundwater to enter the system or waste to exit the system at a rate greater than 200 gallons per day (gpd) per inch of diameter per mile of sewer line. Owners of treatment plants must study the conveyance system to evaluate “the cost effectiveness of transportation and treatment versus correction of the infiltration-inflow sources by using a twenty year present worth cost analysis.

## 6.6 SSO Funding Sources

Special appropriation grants, state infrastructure authority low interest loans, conventional funds (e.g., bonds).

## 6.7 Blending Policies

KY DEP allows the blending of secondary effluent with partially treated effluent during wet weather events in several of its discharge permits. In each permit, blending operates with a temporary authorization, with each permit addressing the elimination schedule and/or plan on a case-by-case basis.

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# APPENDIX B – Sample Sewer Use Ordinance

The following is a sample sewer use ordinance. This sample includes many factors that should be regulated in a sewer use ordinance.

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*Sample Ordinance*
*ORDINANCE NO. 200*
*AN ORDINANCE ESTABLISHING*
*SEWER USE REGULATIONS*

*An ordinance regulating the use of public and private sewers and drains, private wastewater disposal, the installation and connection of building sewers, and the discharge of waters and wastes into the public sewer system(s); and providing penalties for violations thereof.*

*Be it ordained and enacted by the Council of the City of _______, Kentucky as follows:*

*ARTICLE I*
*Definitions*

*Unless the context specifically indicates otherwise, the meaning of terms used in this ordinance shall have the meanings hereinafter designated:*

*Sec. 1 "Act" - The Federal Water Pollution Control Act also referred to as the Clean Water Act, as amended, 33. U.S.C. 1251, et seq.*

*Sec. 2 "ASTM" - American Society for Testing Materials.*

*Sec. 3 "Authority" - The City, Minnesota or its representative thereof.*

*Sec. 4 "BOD5 or Biochemical Oxygen Demand" - The quantity of oxygen utilized in the biochemical oxidation of organic matter under standard laboratory procedure in five (5) days at 20 degrees Centigrade in terms of milligrams per liter (mg/l).*

*Sec. 5 "Building Drain" — that part of the lowest horizontal piping of a drainage system which receives the discharge from waste and other drainage pipes inside the walls of the building and conveys it to the building sewer, beginning five (5) feet outside the building wall.*

*Sec. 6 "Building Sewer" - the extension from the building drain to the public sewer or other place of disposal, also referred to as a house connection or service connection.*

*Sec. 7 "City" — the area within the corporate boundaries of the City as presently established or as amended by ordinance or other legal actions at a future time. The term "City" when used herein may also be used to refer to the City Council and its authorized representative.*

*Sec. 8 "Chemical Oxygen Demand (COD)" - the quantity of oxygen utilized in the chemical oxidation of organic matter as determined by standard laboratory procedures, and as expressed in terms of milligrams per liter (mg/l).*

*Sec. 9 "Compatible Pollutant" - biochemical oxygen demand, suspended solids, pH, and fecal coliform bacteria, plus additional pollutants identified in the NPDES/SDS Permit if the treatment facilities are designed to treat such pollutants to a degree which complies with effluent concentration limits imposed by the permit.*

*Sec. 10 "Control Manhole" — a structure specially constructed for the purpose of measuring flow and sampling of wastes.*

*Sec. 11 "Easement" — an acquired legal right for the specific use of land owned by others.*

*Sec. 12 "Fecal Coliform" — any number of organisms common to the intestinal tract of man and animals whose presence in sanitary sewage is an indicator of pollution.*

*Sec. 13 "Floatable Oil" - Oil, fat, or grease in a physical state, such that it will separate by gravity from wastewater.*

*Sec. 14 "Garbage" - animal and vegetable waste resulting from the handling, preparation, cooking, and serving of food.*

*Sec. 15 "Incompatible Pollutant" — any pollutant that is not defined as a compatible pollutant (Sec. 9) including non-biodegradable dissolved solids.*

*Sec. 16 "Industry" - any nongovernmental or nonresidential user of a publicly owned treatment works which is identified in the Standard Industrial Classification Manual, latest edition, which is categorized in Divisions A, B, D, E and I.*

*Sec. 17 "Industrial Waste" — gaseous, liquid, and solid wastes resulting from industrial or manufacturing processes, trade or business, or from the development, recovery, and processing of natural resources, as distinct from residential or domestic strength wastes.*

*Sec. 18 "Infiltration" — water entering the sewage system (including building drains and pipes) from the ground through such means as defective pipes, pipe joints, connections, and manhole walls.*

*Sec. 19 "Infiltration/Inflow (I/I)" - the total quantity of water from both infiltration and inflow.*

*Sec. 20 "Inflow" - water other than wastewater that enters a sewer system (including building drains) from sources such as, but not limited to, roof leaders, cellar* *drains, yard and area drains, foundation drains, drains from springs and swampy areas, manhole covers, cross-connections from storm sewers, catch basins, surface runoff, street wash waters or drainage.*

*Sec. 21 "Interference" - the inhibition or disruption of the City's wastewater disposal system processes or operations which causes or significantly contributes to a violation of any requirement of the City's NPDES and/or SDS Permit. The term includes of sewage sludge use or disposal by the City in accordance with published regulations providing guidelines under Section 405 of the Act or any regulations developed pursuant to the Solid Waste Disposal Act, the Clean Air Act, the Toxic Substances Control Act, or more stringent State criteria applicable to the method of disposal or use employed by the City.*

*Sec. 22 "KPCA" — Kentucky Pollution Control Agency.*

*Sec. 23 "National Categorical Pretreatment Standards" - federal regulations establishing pretreatment standards for introduction of pollutants in publicly-owned wastewater treatment facilities which are determined to be not susceptible to treatment by such treatment facilities or would interfere with the operation of such treatment facilities, pursuant to Section 307(b) of the Act.*

*Sec. 24 "National Pollutant Discharge Elimination System (NPDES) Permit" — a permit issued by the MPCA, setting limits on pollutants that a permittee may legally discharge into navigable waters of the United States pursuant to Sections 402 and 405 of the Act.*

*Sec. 25 "Natural Outlet" - any outlet, including storm sewers and combined sewers, which overflow into a watercourse, pond, ditch, lake or other body of surface water or ground water.*

*Sec. 26 "Non-contact Cooling Water" — the water discharged from any use such as air conditioning, cooling or refrigeration, or during which the only pollutant added, is heat.*

*Sec. 27 "Normal Domestic Strength Waste" — wastewater that is primarily introduced by residential users with a BOD5 concentration not greater than 200 mg/l and a suspended solids (TSS) concentration not greater than 250 mg/l.*

*Sec. 28 "Person" — any individual, firm, company, association, society, corporation, or group.*

*Sec. 29 "pH" - the logarithm of the reciprocal of the concentration of hydrogen ions in terms of grams per liter of solution.*

*Sec. 30 "Pretreatment" - the treatment of wastewater from industrial sources prior to the introduction of the waste effluent into a publicly-owned treatment works (See Sec. 23).*

*Sec. 31 "Properly Shredded Garbage" - the wastes from the preparation, cooking and dispensing of food that have been shredded to such a degree that all particles will be carried freely under the flow conditions normally prevailing in public sewers with no particle greater than 1/2 inch (1.27 cm) in any dimension.*

*Sec. 32 "Sewage" - the spent water of a community. The preferred term is wastewater.*

*Sec. 33 "Sewer" - a pipe or conduit that carries wastewater or drainage water.*

*a. "Collection Sewer" - a sewer whose primary purpose is to collect wastewaters from individual point source discharges and connections.*

*b. "Combined Sewer" - a sewer intended to serve as a sanitary sewer and a storm sewer.*

*c. "Force Main" - a pipe in which wastewater is carried under pressure.*

*d. "Interceptor Sewer" - a sewer whose primary purpose is to transport wastewater from collection sewers to a treatment facility.*

*e. "Private Sewer" - a sewer which is not owned and maintained by a public authority.*

*f. "Public Sewer" - a sewer owned, maintained and controlled by a public authority.*

*g. "Sanitary Sewer" - a sewer intended to carry only liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions together with minor quantities of ground, storm, and surface waters which are not admitted intentionally.*

*h. "Storm Sewer or Storm Drain" - a drain or sewer intended to carry storm waters, surface runoff, ground water, sub-surface water, street wash water, drainage, and unpolluted water from any source.*

*Sec. 34 "Shall" is mandatory; "May" is permissive.*

*Sec. 35 "Significant Industrial User" — any industrial user of the wastewater treatment facility which has a discharge flow (1) in excess of 25,000 gallons per average work day, or (2) has exceeded five percent (5%) of the total flow received at the treatment facility, or (3) whose waste contains a toxic pollutant in toxic amounts pursuant to Section 307(a) of the Act, or (4) whose discharge has a significant effect, either singly or in combination with other contributing industries, on the wastewater disposal system, the quality of sludge, the system's effluent quality, or emissions generated by the treatment system.*

*Sec. 36 "Slug" - any discharge of water or wastewater which in concentration of any given constituent, or in quantity of flow, exceeds for any period of duration longer than fifteen (15) minutes, more than five (5) times the average 24-hour concentration of flows during normal operation, and shall adversely affect the collection and/or performance of the wastewater treatment works.*

*Sec. 37 "State Disposal System (SDS) Permit" - any permit (including any terms, conditions and requirements thereof) issued by the MPCA pursuant to Minnesota Statutes 115.07 for a disposal system as defined by Minnesota Statutes 115.01, Subdivision 8.*

*Sec. 38 "Superintendent" — the utilities superintendent or a deputy, agent or representative thereof.*

*Sec. 39 "Suspended Solids (SS) or Total Suspended Solids (TSS)" - the total suspended matter that either floats on the surface of, or is in suspension in water, wastewater or other liquids, and is removable by laboratory filtering as prescribed in "Standard Methods for the Examination of Water and Wastewater", latest edition, and referred to as non-filterable residue.*

*Sec. 40 "Toxic Pollutant" — the concentration of any pollutant or combination of pollutants which upon exposure to or assimilation into any organism will cause adverse effects as defined in standards issued pursuant to Section 307(a) of the Act.*

*Sec. 41 "Unpolluted Water" - water of quality equal to or better than the effluent criteria in effect, or water that would not cause violation of receiving water quality standards, and would not be benefited by discharge to the sanitary sewers and wastewater treatment facilities. (See "Non-contact Cooling Water", Sec. 26.)*

*Sec. 42 "User" - any person who discharges or causes or permits the discharge of wastewater into the City's wastewater disposal system.*

*Sec. 43 "Wastewater" — the spent water of a community and referred to as sewage. From the standpoint of source, it may be a combination of the liquid and water-carried wastes from residences, commercial buildings, industrial plants, and institutions together with any ground water, surface water and storm water that may be present.*

*Sec. 44 "Wastewater Treatment Works or Treatment Works" - an arrangement of any devices, facilities, structures, equipment, or processes owned or used by the City for the purpose of the transmission, storage, treatment, recycling, and reclamation of municipal sewage, domestic sewage or industrial wastewater, or structures necessary to recycle or reuse water including interceptor sewers, outfall sewers, collection sewers, pumping, power, and other equipment and their appurtenances; extensions, improvements, remodeling, additions, and alterations thereof; elements essential to provide a reliable recycled water supply such as standby treatment units and clearwell facilities; and any works including land which is an integral part of the treatment process or is used for ultimate disposal of residues resulting from such treatment.*

*Sec. 45 "Watercourse" - a natural or artificial channel for the passage of water, either continuously or intermittently.*

*Sec. 46 "WPCF" - the Water Pollution Control Federation.*

*ARTICLE II*

*Control by the Utilities Superintendent*

*Sec. 1 The Utilities Superintendent shall have control and general supervision of all public sewers and service connections in the City, and shall be responsible for administering the provisions of this ordinance to the end that a proper and efficient public sewer is maintained.*

*ARTICLE III*

*Sec. 1 It shall be unlawful for any person to place, deposit, or permit to be deposited in any unsanitary manner on public or private property within the City, or in any area under jurisdiction, any human or animal excrement, garbage or objectionable waste.*

*Sec. 2 It shall be unlawful to discharge to any natural outlet any wastewater or other polluted waters, except where suitable treatment has been provided in accordance with subsequent provisions of this ordinance and the City's NPDES/SDS Permit.*

*Sec. 3 Except as provided hereinafter, it shall be unlawful to construct or maintain any privy, privy vault, septic tank, cesspool, or other facility intended or used for the disposal of wastewater.*

*Sec. 4 The owner(s) of all houses, buildings, or properties used for human occupancy, employment, recreation or other purposes from which wastewater is discharged, and which is situated within the City and adjacent to any street, alley, or right-of-way in which there is now located, or may in the future be located, a public sanitary sewer of the City, shall be required at the owner(s) expense to install a suitable service connection to the public sewer in accordance with provisions of this Code, within 90 days of the date said public sewer is operational, provided said public sewer is within 200 feet of the structure generating the wastewater. All future buildings constructed on property adjacent to the public sewer shall be required to immediately connect to the public sewer. If sewer connections are not made pursuant to this section, an official 30-day notice shall be served instructing the affected property owner to make said connection.*

*Sec. 5 In the event an owner shall fail to connect to a public sewer in compliance with a notice given under Article II, Section 4 of the Ordinance, the City must undertake to have said connection made and shall assess the cost thereof against the benefited property. Such assessment, when levied, shall bear interest at the rate determined by the City Council and shall be certified to the Auditor of the County of __________, Minnesota and shall be collected and remitted to the City in the same manner as assessments for local improvements. The rights of the City shall be in addition to any remedial or enforcement provisions of this ordinance.*

*ARTICLE IV*

*Private Wastewater Disposal*

*Sec. 1 Where a public sewer is not available under the provisions of Article III, Section 4; the building sewer shall be connected to a private wastewater disposal system complying with the provisions of this Article.*

*Sec. 2 Prior to commencement of construction of a private wastewater disposal system, the owner(s) shall first obtain a written permit signed by the City. The application for such permit shall be made on a form furnished by the City, which the applicant shall supplement by any plans, specifications, and other information as are deemed necessary to the City.*

*Sec. 3 A permit for a private wastewater disposal system shall not become effective until the installation is completed to the satisfaction of the City or its authorized representative. The City or its representative shall be allowed to inspect the work at any stage of construction, and, in any event, the applicant for the permit shall notify the City when work is ready for final inspection, and before any underground portions are covered. The inspection shall be made within eight (8) hours of the receipt of notice.*

*Sec. 4 The type, capacities, location, and layout of a private wastewater disposal system shall comply with all requirements of entitled, "Individual Sewage Treatment System Standards". No septic tank or cesspool shall be permitted to discharge to any natural outlet.*

*Sec. 5 At such time as a public sewer becomes available to a property serviced by a private wastewater disposal system, a direct connection shall be made to the public sewer within 90 days in compliance with the Ordinance, and within 30 days any septic tanks, cesspools, and similar private wastewater disposal systems shall be cleaned of sludge. The bottom shall be broken to permit drainage, and the tank or pit filled with suitable material.*

*Sec. 6 The owner(s) shall operate and maintain the private wastewater disposal facilities in a sanitary manner at all times at no expense to the City.*

*Sec. 7 No statement contained in this article shall be construed to interfere with any additional requirements that may be imposed by the MPCA or the Department of Health of the State of Minnesota.*

*ARTICLE V*

*Building Sewers and Connections*

*Sec. 1 Any new connection(s) to the sanitary sewer system shall be prohibited unless sufficient capacity is available in all downstream facilities including, but not limited to capacity for flow, BOD5, and suspended solids, as determined by the Superintendent.*

*Sec. 2 No unauthorized person(s) shall uncover, make any connections with or opening into, use, alter, or disturb any public sewer or appurtenance thereof without first obtaining a written permit from the City.*
*Sec. 3 Applications for permits shall be made agent and the party employed to do the location, name of owner, street number connected, and how occupied. No person building drain beyond the limits of the which the service connection permit has by the owner or authorized work, and shall state the of the building to be shall extend any private building or property for been given.*
*Sec. 4 There shall be two (2) classes of building sewer permits: (a) for residential and commercial service, and (b) for service to establishments producing industrial wastes. In either case, the application shall be supplemented by any plans, specifications, or any other information considered pertinent in the judgment of the City. The industry, as a condition of permit authorization, must provide information describing its wastewater constituents, characteristics, and type of activity.*
*Sec. 5 All costs and expenses incidental to the installation and connection of the building sewer shall be borne by the owner(s). The owner(s) shall indemnify the City from any loss or damage that may be directly or indirectly occasioned by the installation building of the sewer.*
*Sec. 6 A separate and independent building sewer shall be provided for every building, except where one building stands at the rear of another on an interior lot and no private sewer is available or can be constructed to the rear building through an adjoining alley, court, yard, or driveway. The building sewer from the front building may be extended to the rear building and the whole considered one building sewer. The City does not and will not assume any obligation or responsibility for damage caused by or resulting from any such connection aforementioned.*
*Sec. 7 Old building sewers may be used in connection with new buildings only when they are found, on examination and test by the superintendent or his representative, to meet all requirements of this ordinance.*
*Sec. 8 The size, slopes, alignment, materials of construction of a building sewer, and the methods to be used in excavating, placing of the pipe, jointing, testing, and backfilling of the trench, shall all conform to the requirements of the State of Minnesota Building and Plumbing Code or other applicable rules and regulations of the City. In the absence of code provisions or in the amplification thereof, the materials and procedures set forth in appropriate specifications of the ASTM and WPCF Manual of Practice No. 9, shall apply.*
*Sec. 9 Whenever possible, the building sewer shall be brought to the building at an elevation below the basement floor. In all buildings in which any building drain is too low*

*to permit gravity flow to the public sewer, sanitary sewage carried by such building drain shall be lifted by an approved means and discharged to the building sewer.*

*Sec. 10 No person(s) shall make connection of roof downspouts, foundation drains, areaway drains, or other sources of surface runoff or groundwater to a building sewer or indirectly to the wastewater disposal system.*

*Sec. 11 The connection of the building sewer into the public sewer shall conform to the requirements of the State of Minnesota Building and Plumbing Code or other applicable rules and regulations of the City, or the procedures set forth in appropriate specifications of the ASTM and the WPCF Manual of Practice No. 9. All such connections shall be made gastight and watertight, and verified by proper testing to prevent the inclusion of infiltration/inflow. Any deviation from the prescribed procedures and materials must be approved by the City prior to installation.*

*Sec. 12 The applicant for the building sewer permit shall notify the City when the building sewer is ready for inspection and connection to the public sewer. The connection and inspection shall be made under the supervision of the superintendent or authorized representative thereof.*

*Sec. 13 All excavations for building sewer installation shall be adequately guarded with barricades and lights so as to protect the public from hazard. Streets, sidewalks, parkways, and other public property disturbed in the course of the work, shall be restored in a manner satisfactory to the City.*

*Sec. 14 No person shall make a service connection with any public sewer unless regularly licensed under this chapter to perform such work, and no permit shall be granted to any person except such regularly licensed person.*

*Sec. 15 Any person desiring a license to make a service connection with public sewers, shall apply in writing to the City Council with satisfactory evidence that the applicant or employer is trained or skilled in the business and qualified to receive a license. All applications shall be referred to the Superintendent for recommendations to the Council. If approved by the Council, such license shall be issued by the City Clerk upon the filing of a bond as hereinafter provided.*

*Sec. 16 No license shall be issued to any person until a $_____ bond to the City, approved by the Council, is filed with the City Clerk conditioned that the licensee will indemnify and save harmless the City from all suits, accidents, and damage that may arise by reason of any opening in any street, alley, or public ground, made by the licensee or by those in the licensee's employment for any purpose whatever, and that the licensee will replace and restore the street and alley over such opening to the condition existing prior to installation, adequately guard with barricades and lights and will keep and maintain the same to the satisfaction of the Superintendent, and shall conform in all* *respects to the rules and regulations of the Council relative thereto, and pay all fines that may be imposed on the licensee by law.*

*Sec. 17 The license fee for making service connections is $_________. All licenses shall expire on ____________________ of the license year unless the license is suspended or revoked by the Council for cause. Upon failure to apply for a license renewal prior to the expiration date thereof, the license fee for the ensuing year shall be $____________.*

*Sec. 18 The Council may suspend or revoke any license issued under this article for any of the following causes:*

*a. Giving false information in connection with the application for a license.*

*b. Incompetence of the licensee.*

*c. Willful violation of any provisions of this article or any rule or regulation pertaining to the making of service connections.*

*ARTICLE VI*

*Use of Public Services*

*Sec. 1 No person(s) shall discharge or cause to be discharged any unpolluted water such as stormwater, ground water, roof runoff, surface drainage, or non-contact cooling water to any sanitary sewer.*

*Sec. 2 Stormwater and all other unpolluted drainage shall be discharged to such sewers as are specifically designed as storm sewers or to a natural outlet approved by the City and other regulatory agencies. Industrial cooling water or unpolluted process waters may be discharged to a storm sewer or natural outlet on approval of the City and upon approval and the issuance of a discharge permit by the KPCA.*

*Sec. 3 No person(s) shall discharge or cause to be discharged any of the following described waters or wastes to any public sewers:*

*a. Any liquids, solids, or gases which by reason of their nature or quantity are, or may be, sufficient either alone or by interaction with other substances to cause fire or explosion or be injurious in any other way to the wastewater disposal system or to the operation of the system. Prohibited materials include, but are not limited to, gasoline, kerosene, naptha, benzene, toluene, xylene, ethers, alcohols, ketones, aldehydes, peroxides, chlorates, perchlorates, bromates, carbides, hydrides, and sulfide.*

*b. Solid or viscous substances which will cause obstruction to the flow in a sewer or other interference with the operation of the wastewater treatment facilities such as, but not limited to, grease, garbage with particles greater than one-half (1/2) inch in any dimension, animal guts or tissues, paunch manure, bones, hair, hides or fleshings, entrails, whole blood, feathers, ashes, cinders, sand, spent lime, stone or marble dust, metal, glass, straw, shavings, grass clippings, rags, spent grains, spent hops, waste* *paper, wood, plastic, asphalt residues, residues from refining or processing of fuel or lubricating oil, mud or glass grinding or polishing wastes.*

*c. Any wastewater having a pH of less than 5.0 or greater than 9.5 or having any other corrosive property capable of causing damage or hazard to structures, equipment, and personnel of the wastewater disposal system.*

*d. Any wastewater containing toxic pollutants in sufficient quantity, either singly or by interaction with other pollutants, to inhibit or disrupt any wastewater treatment process, constitute a hazard to humans or animals, or create a toxic effect in the receiving waters of the wastewater disposal system. A toxic pollutant shall include but not be limited to any pollutant identified pursuant to Section 307(a) of the Act.*

*Sec. 4 The following described substances, materials, water, or wastes shall be limited in discharges to municipal systems to concentrations or quantities which will not harm either sewers, the wastewater treatment works treatment process or equipment, will not have an adverse effect on the receiving stream and/or soil, vegetation and ground water, or will not otherwise endanger lives, limb, public property, or constitute a nuisance. The Superintendent may set limitations lower than limitations established in the regulations below if, in his opinion, such more severe limitations are necessary to meet the above objections. In forming his opinion as to the acceptability of wastes, the Superintendent will give consideration to such factors as the quantity of subject waste in reaction to flows and velocities in the sewers. materials of construction of the sewers, nature of the sewage treatment process, the City's NPDES and/or SOS permit, capacity of the sewage treatment plant, degree of treat ability of wastes in the sewage treatment plant, and other pertinent factors. The limitations or restrictions on materials or characteristics of waste or wastewaters discharged to the sanitary sewer which shall not be violated without approval of the Superintendent are as follows:*

*a. Any wastewater having a temperature greater than 150 degrees F (65.6 degrees C), or causing, individually or in combination with other wastewater, the influent at the wastewater treatment plant to have a temperature exceeding 104 degrees F (40 degrees C), or having heat in amounts which will inhibit biological activity in the wastewater treatment works resulting in interference therein.*

*b. Any wastewater containing fats, wax, grease, or oils, whether emulsified or not, in excess of 100 mg/l or containing substances which may solidify or become viscous at temperatures between 32 degrees F and 150 degrees F (0 degrees C and 65.6 degrees C); and any wastewater containing oil and grease concentrations of mineral origin of greater than 100 mg/l, whether emulsified or not.*

*c. Any quantities or flow, concentrations, or both which constitute a "slug" as defined herein. (See Article I, Section 33.)*

*d. Any garbage not properly shredded, as defined in Article I. Section 28. Garbage grinders may be connected to sanitary sewers from homes, hotels, institutions, restaurants, hospitals, catering establishments, or similar places where garbage originates from the preparation of food on the premises or when served by caterers.*
*e. Any noxious or malodorous liquids, gases, or solids which either singly or by interaction with other wastes are capable of creating a public nuisance or hazard to life, or are sufficient to prevent entry into the sewers for their maintenance and repair.*
*f. Any wastewater with objectionable color not removed in the treatment process, such as, but not limited to dye wastes and vegetable tanning solutions.*
*g. Non-contact cooling water or unpolluted storm. drainage, or ground water.*
*h. Wastewater containing inert suspended solids (such as, but not limited to, Fullers earth, lime slurries, and lime residues) or of dissolved solids (such as, but not limited to, sodium chloride and sodium sulfate) in such quantities that would cause disruption with the wastewater disposal system.*
*i. Any radioactive wastes or isotopes of such half-life or concentration as may exceed limits established by the superintendent in compliance with applicable state or federal regulations.*
*j. Any waters or wastes containing the following substances to such degree that any such material received in the composite wastewater at the wastewater treatment works in excess of the following limits for such materials:*

| *Waste or Chemical* | *Daily Maximum Concentration (mg/l)* | *30-Day Average Concentration (mg/l)* |
|---|---|---|
| *Arsenic* | | |
| *Cadmium* | *1.2* | *0.5* |
| *Copper* | *4.5* | *1.8* |
| *Cyanide* | *0.8* | *0.23* |
| *Lead* | *0.6* | *0.3* |
| *Mercury* | | |
| *Nickel* | *4.1* | *1.8* |
| *Silver* | | |
| *Total Chromium* | *7.0* | *2.5* |
| *Zinc* | *4.2* | *1.8* |
| *Total Heavy Metals (Copper, Chromium, Nickel, Zinc)* | *10.5* | *5.0* |

*Phenolic compounds which cannot be removed by City's wastewater treatment system.*

*k. Any wastewater which creates conditions at or near the wastewater disposal system which violates any statute, rule, regulation, or ordinance of any regulatory agency, or state or federal regulatory body.*

*l. Any waters or wastes containing $BOD_5$ or suspended solids of such character and quantity that unusual attention or expense is required to handle such materials at the wastewater treatment works, except as may be permitted by specific written agreement subject to the provisions of Section 16 of this Article.*

*Sec. 5 If any waters or wastes are discharged or are proposed to be discharged to the public sewers which contain substances or possess the characteristics enumerated in Section 4 of this Article, and/or which in the judgment of the Superintendent, may have a deleterious effect upon the wastewater treatment facilities, processes, or equipment; receiving water and/or soil, vegetation, and ground water; or which otherwise create a hazard to life or constitute a public nuisance, the City may:*

*a. Reject the wastes,*

*b. Require pretreatment to an acceptable condition for discharge to the public sewers, pursuant to Section 307(b) of the Act and all addendums thereof,*

*c. Require control over the quantities and rates of discharge, and/or,*

*d. Require payment to cover the added costs of handling, treating, and disposing of wastes not covered by existing taxes or sewer service charges.*

*If the City permits the pretreatment or equalization of waste flows, the design, installation, and maintenance of the facilities and equipment shall be made at the owner's expense, and shall be subject to the review and approval of the City pursuant to the requirements of the KPCA.*

*Sec. 6 No user shall increase the use of process water or, in any manner, attempt to dilute a discharge as a partial or complete substitute for adequate treatment to achieve compliance with the limitations contained in Sections 3 and 4 of this Article, or contained in the National Categorical Pretreatment Standards or any state requirements.*

*Sec. 7 Where pretreatment or flow-equalizing facilities are provided or required for any waters or wastes, they shall be maintained continuously in satisfactory and effective operation at the expense of the owner(s).*

*Sec. 8 Grease, oil, and sand interceptors shall be provided when, in the opinion of the Superintendent, they are necessary for the proper handling of liquid wastes containing floatable grease in excessive amounts, as specified in Section 4(b), any flammable wastes as specified in Section 3(a), sand or other harmful ingredients; except that such interceptors shall not be required for private living quarters or dwelling units. All interceptors shall be of the type to be readily and easily accessible for cleaning and* *inspection. In the maintaining of these interceptors, the owner(s) shall be responsible for the proper removal and disposal of the captured materials by appropriate means, and shall maintain a record of dates and means of disposal which are subject to review by the Superintendent. Any removal and hauling of the collected materials not performed by the owner's personnel, must be performed by a currently licensed waste disposal firm.*

*Sec. 9 Where required by the City, the owner of any property serviced by a building sewer carrying industrial wastes shall install a suitable structure, or control manhole, with such necessary meters and other appurtenances in the building sewer to facilitate observation, sampling, and measurement of wastes. Such structure shall be accessible and safely located, and shall be constructed in accordance with plans approved by the City. The structure shall be installed by the owner at his expense and shall be maintained by the owner to be safe and accessible at all times.*

*Sec. 10 The owner of any property serviced by a building sewer carrying industrial wastes may, at the discretion of the City, be required to provide laboratory measurements, tests, or analyses of waters or wastes to illustrate compliance with this Ordinance and any special conditions for discharge established by the City or regulatory agencies having jurisdiction over the discharge. The number, type, and frequency of sampling and laboratory analyses to be performed by the owner shall be as stipulated by the City. The industry must supply a complete analysis of the constituents of the wastewater discharge to assure that compliance with Federal, State and local standards are being met. The owner shall report the results of measurements and laboratory analyses to the City at such times and in such manner as prescribed by the City. The owner shall bear the expense of all measurements, analyses, and reporting required by the City. At such times as deemed necessary, the City reserves the right to take measurements and samples for analysis by an independent laboratory.*

*Sec. 11 All measurements, tests, and analyses of the characteristics of waters and wastes to which reference is made in this ordinance shall be determined in accordance with the latest edition of Standard Methods for the Examination of Water and Wastewater, published by the American Public Health Association. Sampling methods, location, times, duration and frequencies are to be determined on an individual basis subject to approval by the Superintendent.*

*Sec. 12 Where required by the City, the owner of any property serviced by a sanitary sewer shall provide protection from an accidental discharge of prohibited materials or other substances regulated by this ordinance. Where necessary, facilities to prevent accidental discharges of prohibited materials shall be provided and maintained at the owner's expense. Detailed plans showing facilities and operating procedures to provide this protection shall be submitted to the Superintendent for review and approval* *prior to construction of the facility. Review and approval of such plans and operating procedures shall not relieve any user from the responsibility to modify the user's facility as necessary to meet the requirements of this ordinance. Users shall notify the Superintendent immediately upon having a slug or accidental discharge of substances of wastewater in violation of this ordinance to enable countermeasures to be taken by the Superintendent to minimize damage to the wastewater treatment works. Such notification will not relieve any user of any liability for any expense, loss or damage to the wastewater treatment system or treatment process, or for any fines imposed on the City on account thereof under any State and Federal law. Employees shall insure that all employees who may cause or discover such a discharge, are advised of the emergency notification procedure.*

*Sec. 13 No person, having charge of any building or other premises which drains into the public sewer, shall permit any substance or matter which may form a deposit or obstruction to flow or pass into the public sewer. Within 90 days after receipt of written notice from the City, the owner shall install a suitable and sufficient catch basin or waste trap, or if one already exists, shall clean out, repair or alter the same, and perform such other work as the Superintendent may deem necessary. Upon the owner's refusal or neglect to install a catch basin or waste trap or to clean out, repair, or alter the same after the period of 120 days, the Superintendent may cause such work to be completed at the expense of the owner or representative thereof.*

*Sec. 14 Whenever any service connection becomes clogged, obstructed, broken or out of order, or detrimental to the use of the public sewer, or unfit for the purpose of drainage, the owner shall repair or cause such work to be done as the Superintendent may direct. Each day after seven (7) days that a person neglects or fails to so act shall constitute a separate violation of this section, and the Superintendent may then cause the work to be done, and recover from such owner or agent the expense thereof by an action in the name of the City.*

*Sec. 15 The owner or operator of any motor vehicle washing or servicing facility shall provide and maintain in serviceable condition at all times, a catch basin or waste trap in the building drain system to prevent grease, oil, dirt or any mineral deposit from entering the public sewer system.*

*Sec. 16 In addition to any penalties that may be imposed for violation of any provision of this chapter, the City may assess against any person the cost of repairing or restoring sewers or associated facilities damaged as a result of the discharge of prohibited wastes by such person, and may collect such assessment as an additional charge for the use of the public sewer system or in any other manner deemed appropriate by the City.*

*Sec. 17 No statement contained in this Article shall be construed as preventing any special agreement or arrangement between the City and any industrial concern whereby an industrial waste of unusual strength or character may be accepted by the City for treatment, subject to payment therefore by the industrial concern, providing that National Categorical Pretreatment Standards and the City's NPDES and/or State Disposal System Permit limitations are not violated.*

*ARTICLE VII*

*Sec. 1 No person(s) shall maliciously, willfully, or negligently break, damage, destroy, uncover, deface or tamper with any structure, appurtenance, or equipment which is part of the wastewater facilities. Any person violating this provision shall be subject to immediate arrest under the charge of a misdemeanor.*

*ARTICLE VIII*

*User Rate Schedule for Charges*

*Sec. 1 Each user of sewer service shall pay the charge(s) applicable to the type of service, and in accordance with the provisions set forth in Ordinance No. ______.*

*ARTICLE IX*

*Powers and Authority of Inspectors*

*Sec. 1 The superintendent or other duly authorized employees of the City, bearing proper credentials and identification, shall be permitted to enter all properties for the purpose of inspection, observations, measurement, sampling, and testing pertinent to the discharges to the City's sewer system in accordance with the provisions of this ordinance.*

*Sec. 2 The superintendent or other duly authorized employees are authorized to obtain information concerning industrial processes which have a direct bearing on the type and source of discharge to the wastewater collection system. An industry may withhold information considered confidential however, the industry must establish that the revelation to the public of the information in question, might result in an advantage to competitors.*

*Sec. 3 While performing necessary work on private properties, the superintendent or duly authorized employees of the City shall observe all safety rules applicable to the premises established by the company, and the company shall be held harmless for injury or death to the City employees and the City shall indemnify the company against loss or damage to its property by City employees and against liability claims and demands for personal injury or property damage asserted against the company and growing out of the gauging and sampling operation, except as such may be caused by negligence or failure of the company to maintain safe conditions as required in Article VI, Section 9 of this ordinance.*

*Sec. 4 The superintendent or other duly authorized employees of the City bearing proper credentials and identification shall be permitted to enter all private properties through which the City holds a duly negotiated easement for the purposes of, but not limited to, inspection, observation, measurement, sampling, repair, and maintenance of any portion of the wastewater facilities lying within said easement. All entry and subsequent work, if any, on said easement, shall be done in full accordance with the terms of the duly negotiated easement pertaining to the private property involved.*

*ARTICLE X*

*Penalties*

*Sec. 1 Any person found to be violating any provision of this ordinance, shall be served by the City with written notice stating the nature of the violation and providing a reasonable time limit for the satisfactory correction thereof. The offender shall, within the period of time stated in such notice, permanently cease all violations.*

*Sec. 2 Any person who shall continue any violation beyond the time limit provided for in Section 1 of this Article, shall be guilty of a misdemeanor, and on conviction thereof, shall be fined in the amount not exceeding $50 for each violation. Each day in which any such violation occurs shall be deemed as a separate offense.*

*Sec. 3 Any person violating any of the provisions of this ordinance shall become liable to the City for any expense, loss, or damage occasioned by the City by reason of such violation.*

*ARTICLE XI*

*Validity*

*Sec.1 This ordinance shall be in full force and take effect from and after its passage and approval and publication as provided by law.*

*Sec. 2 All other ordinances and parts of other ordinances inconsistent or in conflict with any part of this ordinance, are hereby repealed to the extent of such inconsistency or conflict.*

# Acknowledgements

Mitchell and Stapp, 1992; KanCRN website

Qasim 1994

Watershed Protection Plan Development Guidebook Northeast Georgia Regional Development Center

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