Block A: Sewers

Block A: Sewers

Plumbing Apprenticeship Program Level 3

Industry Training Authority BC

BCCAMPUS

Sample APA-style citation (7th Edition):

Industry Training Authority BC. (2023). *Block a: Sewers*. BCcampus. https://opentextbc.ca/plumbing3a/

Cover image attribution:

HD photo (https://unsplash.com/photos/dRixo2BTeb8) by Eliobed Suarez (https://unsplash.com/@eliobedsuarez) is licensed under an Unsplash License (https://unsplash.com/license).

Ebook ISBN: 978-1-77420-177-0

Print ISBN: 978-1-77420-176-3

Visit BCcampus Open Education (http://open.bccampus.ca/) to learn about open education in British Columbia.

This book was produced with Pressbooks (https://pressbooks.com) and rendered with Prince.

Contents

Competency A2: Install Manholes and Catch Basins

Accessibility Statement

BCcampus Open Education believes that education must be available to everyone. This means supporting the creation of free, open, and accessible educational resources. We are actively committed to increasing the accessibility and usability of the resources we produce.

Accessibility of This Resource

The web version of *Block A: Sewers* (https://opentextbc.ca/plumbing3a/) has been designed to meet Web Content Accessibility Guidelines 2.0 (https://www.w3.org/TR/WCAG20/), level AA. In addition, it follows all guidelines in Appendix A: Checklist for Accessibility (https://opentextbc.ca/accessibilitytoolkit/back-matter/appendix-checklist-for-accessibility-toolkit/) of the *Accessibility Toolkit – 2nd Edition* (https://opentextbc.ca/accessibilitytoolkit/). It includes:

- **Easy navigation**. This resource has a linked table of contents and uses headings in each chapter to make navigation easy.
- **Accessible math equations**. Many of the equations in this resource have been written in LaTeX and rendered with MathJax, which makes them accessible to people using screen readers that are set up to read MathML. The rest of the equations are rendered as images with appropriate alternative text.
- **Accessible images**. All images in this resource that convey information have alternative text. Images that are decorative have empty alternative text.
- **Accessible links**. All links use descriptive link text.

Accessibility Checklist

Element	Requirements	Pass?
Headings	Content is organized under headings and subheadings that are used sequentially.	Yes
Images	Images that convey information include alternative text descriptions. These descriptions are provided in the alt text field, in the surrounding text, or linked to as a long description.	Yes
Images	Images and text do not rely on colour to convey information.	Yes
Images	Images that are purely decorative or are already described in the surrounding text contain empty alternative text descriptions. (Descriptive text is unnecessary if the image doesn't convey contextual content information.)	Yes
Tables	Tables include row and/or column headers that have the correct scope assigned.	Yes
Tables	Tables include a title or caption.	Yes
Tables	Tables do not have merged or split cells.	Yes
Tables	Tables have adequate cell padding.	Yes
Links	The link text describes the destination of the link.	Yes
Links	Links do not open new windows or tabs. If they do, a textual reference is included in the link text.	Yes
Links	Links to files include the file type in the link text.	Yes
Formulas	Formulas have been created using LaTeX and are rendered with MathJax.	Yes
Formulas	If LaTeX is not an option, formulas are images with alternative text descriptions.	Yes
Font	Font size is 12 point or higher for body text.	Yes
Font	Font size is 9 point for footnotes or endnotes.	Yes
Font	Font size can be zoomed to 200% in the webbook or eBook formats.	Yes

Known Accessibility Issues and Areas for Improvement

There are currently no known accessibility issues.

Let Us Know if You are Having Problems Accessing This Book

We are always looking for ways to make our resources more accessible. If you have problems accessing this resource, please contact us to let us know so we can fix the issue.

Please include the following information:

- The name of the resource

- The location of the problem by providing a web address or page description.
- A description of the problem
- The computer, software, browser, and any assistive technology you are using that can help us diagnose and solve your issue (e.g., Windows 10, Google Chrome (Version 65.0.3325.181), NVDA screen reader)

You can contact us one of the following ways:

- Web form: BCcampus Open Ed Help (https://collection.bccampus.ca/contact/)
- Web form: Report an Error (https://open.bccampus.ca/browse-our-collection/reporting-an-error/)

This statement was last updated on August 3, 2022.

The Accessibility Checklist table was adapted from one originally created by the Rebus Community (https://press.rebus.community/the-rebus-guide-to-publishing-open-textbooks/back-matter/accessibility-assessment/) and shared under a CC BY 4.0 License (https://creativecommons.org/licenses/by/4.0/).

For Students: How to Access and Use this Textbook

This textbook is available in the following formats:

- **Online webbook**. You can read this textbook online on a computer or mobile device in one of the following browsers: Chrome, Firefox, Edge, and Safari.
- **PDF**. You can download this book as a PDF to read on a computer (Digital PDF) or print it out (Print PDF).
- **Mobile**. If you want to read this textbook on your phone or tablet, you can use the EPUB (eReader) file.
- **HTML**. An HTML file can be opened in a browser. It has very little style so it doesn't look very nice, but some people might find it useful.

For more information about the accessibility of this textbook, see the Accessibility Statement.

You can access the online webbook and download any of the formats for free here: *Block A: Sewers* (https://opentextbc.ca/plumbing3a/). To download the book in a different format, look for the "Download this book" drop-down menu and select the file type you want.

How can I use the different formats?

Format	Internet required?	Device	Required apps	Accessibility Features	Screen reader compatible
Online webbook	Yes	Computer, tablet, phone	An Internet browser (Chrome, Firefox, Edge, or Safari)	WCAG 2.0 AA compliant, option to enlarge text, and compatible with browser text-to-speech tools	Yes
PDF	No	Computer, print copy	Adobe Reader (for reading on a computer) or a printer	Ability to highlight and annotate the text. If reading on the computer, you can zoom in.	Unsure
EPUB	No	Computer, tablet, phone	An eReader app	Option to enlarge text, change font style, size, and colour.	Unsure
HTML	No	Computer, tablet, phone	An Internet browser (Chrome, Firefox, Edge, or Safari)	WCAG 2.0 AA compliant and compatible with browser text-to-speech tools.	Yes

Tips for Using This Textbook

- **Search the textbook**.

    - If using the online webbook, you can use the search bar in the top right corner to search the entire book for a key word or phrase. To search a specific chapter, open that chapter and use your browser's search feature by hitting **[Cntr] + [f]** on your keyboard if using a Windows computer or **[Command] + [f]** if using a Mac computer.
    - The **[Cntr] + [f]** and **[Command] + [f]** keys will also allow you to search a PDF, HTML, and EPUB files if you are reading them on a computer.
    - If using an eBook app to read this textbook, the app should have a built-in search tool.
- **Navigate the textbook**.
    - This textbook has a table of contents to help you navigate through the book easier. If using the online webbook, you can find the full table of contents on the book's homepage or by selecting "Contents" from the top menu when you are in a chapter.
- **Annotate the textbook**.
    - If you like to highlight or write on your textbooks, you can do that by getting a print copy, using the Digital PDF in Adobe Reader, or using the highlighting tools in eReader apps.

About BCcampus Open Education

Block A: Sewers (https://opentextbc.ca/plumbing3a/) by Industry Training Authority BC was funded by Industry Training Authority BC.

BCcampus Open Education (https://open.bccampus.ca/) began in 2012 as the B.C. Open Textbook Project with the goal of making post-secondary education in British Columbia more accessible by reducing students' costs through the use of open textbooks and other OER. BCcampus (https://bccampus.ca/) supports the post-secondary institutions of British Columbia as they adapt and evolve their teaching and learning practices to enable powerful learning opportunities for the students of B.C. BCcampus Open Education is funded by the British Columbia Ministry of Advanced Education and Skills Training (https://www2.gov.bc.ca/gov/content/governments/organizational-structure/ministries-organizations/ministries/advanced-education-skills-training) and the Hewlett Foundation (http://www.hewlett.org/).

Open educational resources (OER) are teaching, learning, and research resources that, through permissions granted by the copyright holder, allow others to use, distribute, keep, or make changes to them. Our open textbooks are openly licensed using a Creative Commons licence (https://creativecommons.org/licenses/) and are offered in various eBook formats free of charge, or as printed books that are available at cost.

For more information about open education in British Columbia, please visit the BCcampus Open Education (https://open.bccampus.ca/) website. If you are an instructor who is using this book for a course, please fill out our Adoption of an Open Textbook (https://open.bccampus.ca/use-open-textbooks/tell-us-youre-using-an-open-textbook/) form.

This book was produced using the following styles: Plumbing Level Three Series Style Sheet [Word file] (https://opentextbc.ca/plumbing3e/wp-content/uploads/sites/408/2022/08/Plumbing-Level-Three-Series-Style-Sheet.docx).

Competency A1: Install Piping for Sewers

It is important that plumbers have a basic understanding of the sewer system conveying both sanitary waste and storm runoff. Although plumbers in some jurisdictions may not be involved in the design of sewer systems, they may be involved in the installation and maintenance. Competency A-1 will cover the sizing and installation of sewer systems.

Learning Objectives

After completing the learning tasks in this Competency, you will be able to:

- Describe sanitary and storm sewer systems.
- Determine pipe size for sewer systems.
- Describe the installation of piping for sewers.

Resources

You will be required to reference the most current National Plumbing Code.

Learning Task 1

Describe Sewers

A plumber’s responsibility for a drainage system on private property ends at the property line. The municipal or city system starts at the property line and ends at the eventual location where the treated effluent is returned to the earth. Although the materials and methods discussed in this learning task are overseen by engineers where they exist on public property, they are inherently like those encountered on private land. It is important to reinforce the fact that any work undertaken on drainage systems that exist beyond private property lines are not part of a plumber’s sphere of work; they are performed by municipal or city personnel and as such are not governed by the National Plumbing Code of Canada (NPC).

There are essentially three different types of sewer systems and they each have a unique purpose. They are:

- sanitary sewers
- storm sewers, and
- combined sewers.

All three of these sewer systems can be found in private and public systems. They play important roles in ensuring that the waste we produce is transported and treated properly. Although a sewer that exists on private property is correctly named a building sewer, for the purposes of explanation we will simply refer to them and those on public property collectively as sewers.

Sanitary Sewer System

The main purpose of a sanitary sewer is to carry liquid and solid waste away from homes and businesses and direct them to places of final treatment such as wastewater treatment plants. These systems are specifically designed to handle human solid waste and easily degradable manufactured solids such as toilet paper and tissues. They may consist of many kilometres of piping which are connected to manholes and pumping stations. The pumping stations, often known as lift stations, help to propel the waste through the system to the wastewater treatment plant. From the treatment plant, the treated effluent is returned safely to the environment.

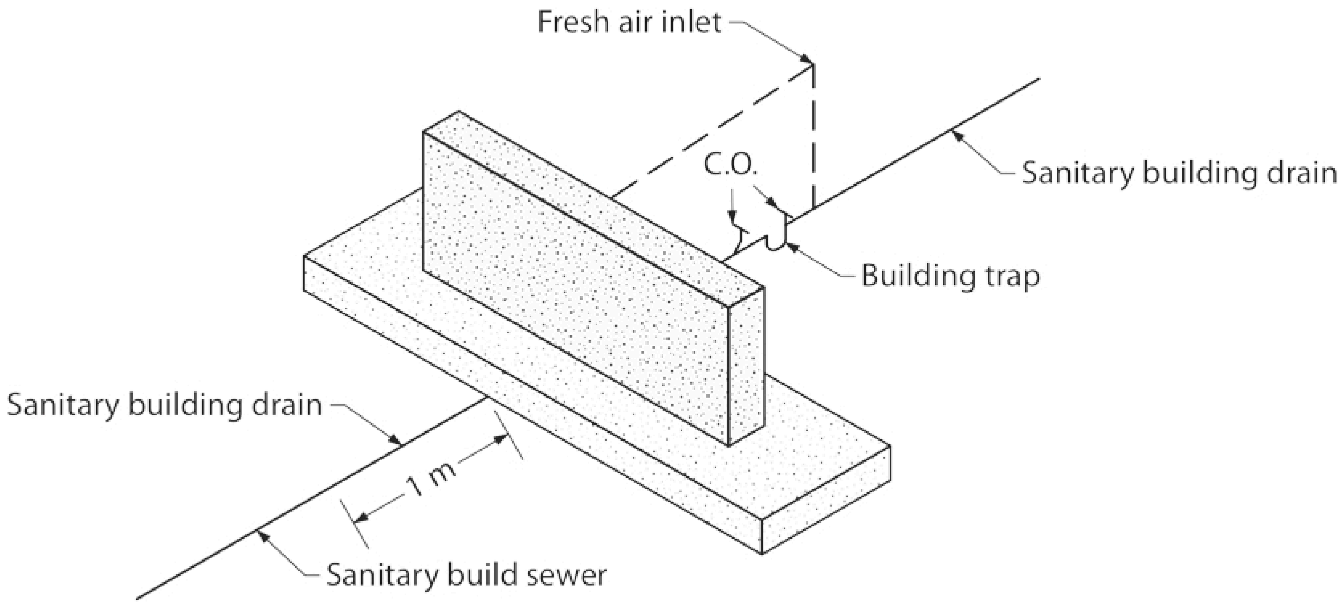

Figure 1 Sanitary building drain and sewer

Storm Sewer System

Storm sewer drainage systems are crucial in the prevention of flooding. They help to divert excess rain and groundwater which runs off impervious surfaces such as parking lots, roofs, paved streets, and sidewalks into nearby waterways through a system of drains and underground pipes. Unlike the sanitary sewers that carry waste to a treatment plant, the storm sewer system carries untreated runoff water directly into the environment.

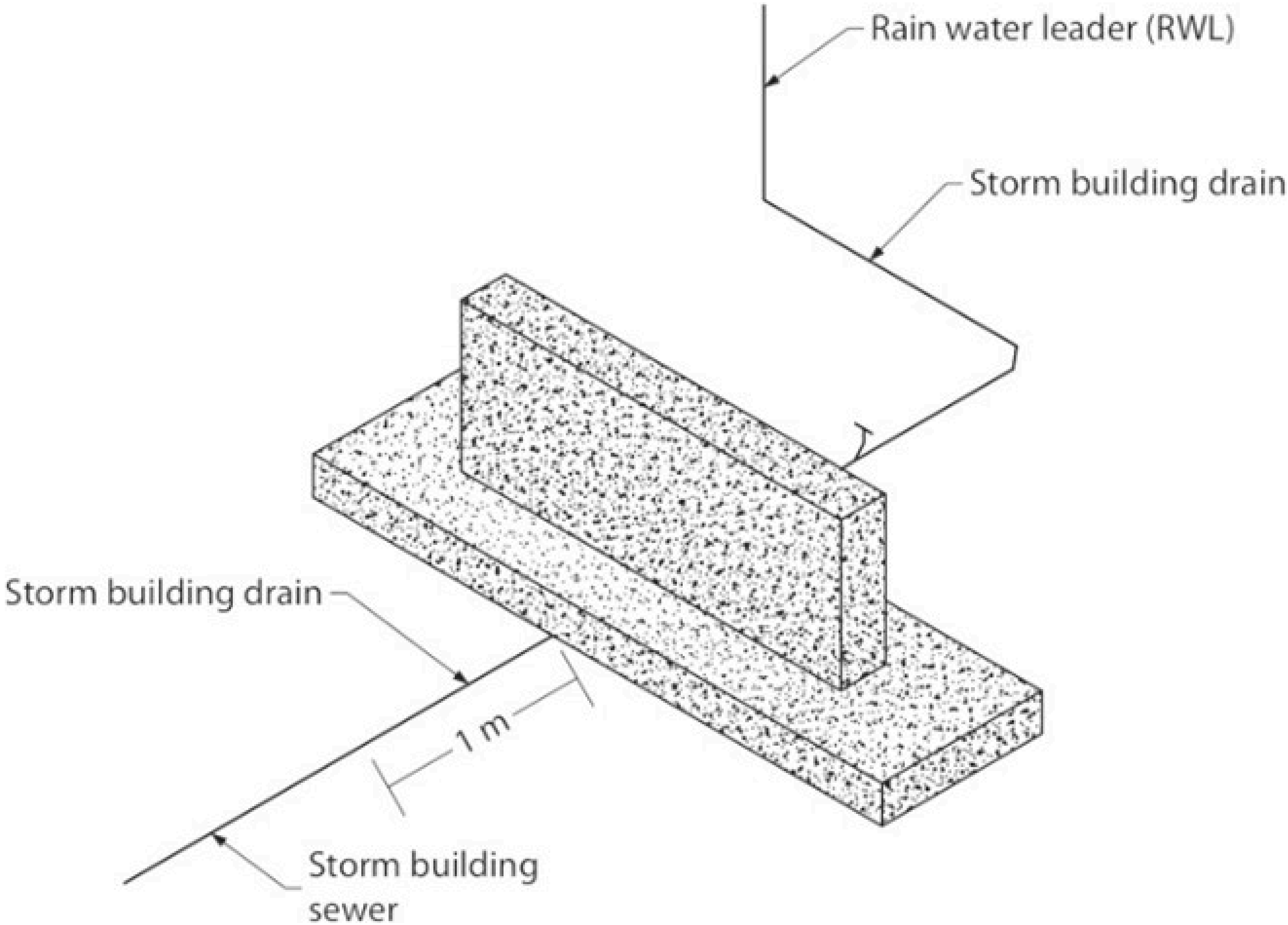

Figure 2 Storm building drain and sewer

Combined Sewer Systems

These types of sewer systems are exactly what they sound like, which is a combination of sanitary sewer systems and storm sewer systems. Sewage and storm water are channeled through the same pipe, eventually terminating in a sewage treatment plant, which can pose problems. In times of extreme rainfall or flooding, these systems can overload the capacity of the treatment plant. They can back up and overflow causing untreated wastewater to flow directly into the environment. This allows for dangerous pathogens and pollutants to make their way into surface and groundwater, posing a serious threat to people's health. Therefore, their use is very particular in that they are typically found in areas where it is very difficult or impossible to direct storm water to a safe disposal location such as a river or lake. Stormwater and sewage should never be introduced into common piping unless specifically mandated by the local Authority Having Jurisdiction.

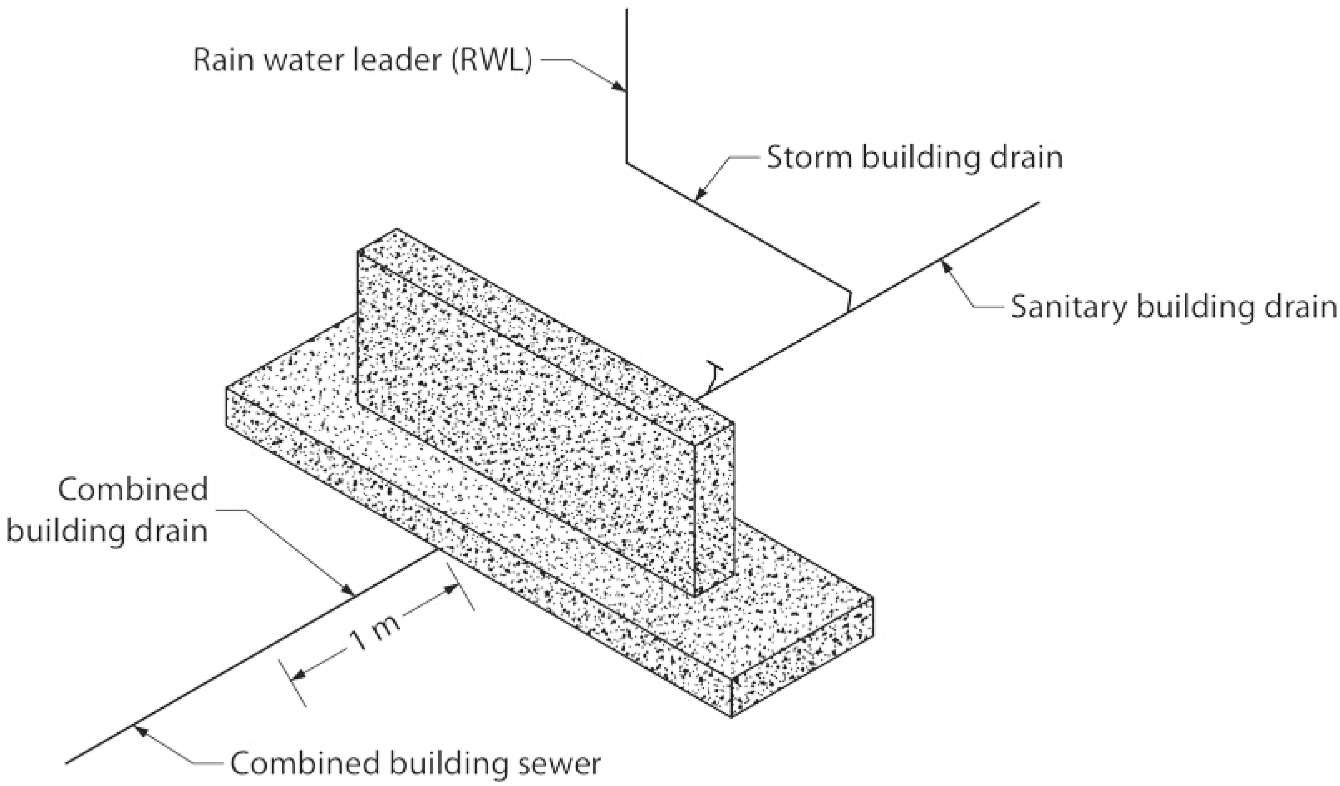

Figure 3 Combined building drain and sewer

Sewer Piping Material

The selection of piping material for use on private property is governed by the plumbing code in force in the area. Remember that the choice of pipe used in systems beyond the property line rests solely on the shoulders of the municipal engineers and staff.

In the NPC, subsections 2.2.5, 2.2.6. and 2.2.7 specify uses and conditions for pipes meant to be used in building sewers. For ease of use, Table A-2.2.5., 2.2.6. and 2.2.7 in the "Notes to Part 2 Plumbing Systems" lists, in tabular form, the pipe types acceptable for this use. The general material types listed there are:

- asbestos cement
- concrete
- vitrified clay
- polyethylene
- plastic
- ABS
- PVC
- polyolefin
- cast iron

- ductile iron
- stainless steel
- corrugated galvanized
- copper, and
- brass

Although this list is quite extensive, many of the materials are specific in their purpose and so are not commonly used for sewers that progress beyond the property line to become part of a city or municipal system. Therefore, we will restrict our study to only the most common pipe types that may be newly installed as building sewers or under public streets as part of a new storm, sanitary or combined drainage system.

ABS Pipe

Acrylonitrile-butadiene styrene (ABS) pipe has been the most common replacement option for old cast iron and copper drainage pipe in residential use since the early 1970's. It is the most predominant type of pipe used for residential drainage systems in British Columbia. Although weaker and less resistant to acids than PVC pipe, it is easier to handle, cut and connect. The cellular core variety of ABS is most common due to its light weight and cost.

Figure 4 Cellular core ABS pipe

Readily available diameters for building sewer purposes range from 75 to 150 mm (3 to 6") with larger sizes available by special order. The most common pipe length is 3.67m (12 ft) although lengths of 3m (10 ft) and 6m (20 ft) are also available. Because of its fairly small available diameters when compared to those of PVC and concrete piping, it is rarely seen as a component of a municipal system.

PVC Pipe

PVC (polyvinyl chloride) is one of the oldest synthetic piping materials. PVC is a thermoplastic, meaning it can be softened and reformed, and a fusible version is now available, which competes with HDPE in trenchless construction. This pipe is very corrosion resistant and is often used to coat other materials that are affected by acidic conditions. Cost and longevity are large reasons why municipalities are drawn to PVC. Even when including backfill and labor expenses, PVC is typically a less expensive replacement option than other materials. An AWWA (American Water Works Association) Research Foundation study estimates the life expectancy of PVC to be more than 110 years. Pipe sizes range from 100 mm to 1.5m (4 to 60 inches) for sewer applications with common lengths of 6m (20 feet). Its light weight, longevity, and options of joining methods (mechanical, gasketed or glued) make PVC a popular choice of municipal engineers.

Figure 5 PVC sewer pipe

HDPE pipe

HDPE (high-density polyethylene) pipe has also become a popular choice for wastewater applications because of its noncorrosive, highly flexible characteristics. Joints are either heat-fused (common for pressure systems) or bell-and-spigot and mechanical (for drainage use). Pipe interiors and exteriors can be either corrugated (ribbed) or smooth depending on the pipe's intended function. Like PVC, HDPE is highly resistant to corrosion and has a low failure rate, which further decreases life span costs. The pipe is offered in diameters from 100 mm to 1.5m (4″ through 60″), in nominal 6m (20 ft) lengths.

Figure 6 HDPE sewer pipe

Concrete pipe

RCP (reinforced concrete) pipe is mainly used in municipal gravity systems. Its high strength offers protection from crushing loads primarily when used at shallow depths. Precast gravity-flow pipe is manufactured in several shapes, including round, elliptical, arched and box, and is used in sanitary sewers, storm drains and culverts. Despite its durability, concrete is susceptible to H2S (hydrogen sulphide) attacks, and in extremely acidic soil, it can corrode. To combat these problems, concrete pipe can be coated with a plastic lining, and special measures can be used to prevent exterior corrosion in acidic soils. Depending on manufacturer, sizes can range from 300 mm (10 inches) to 3m (10 feet) in diameter, with lengths of 1.25m (4 feet) to 2.45m (8 feet).

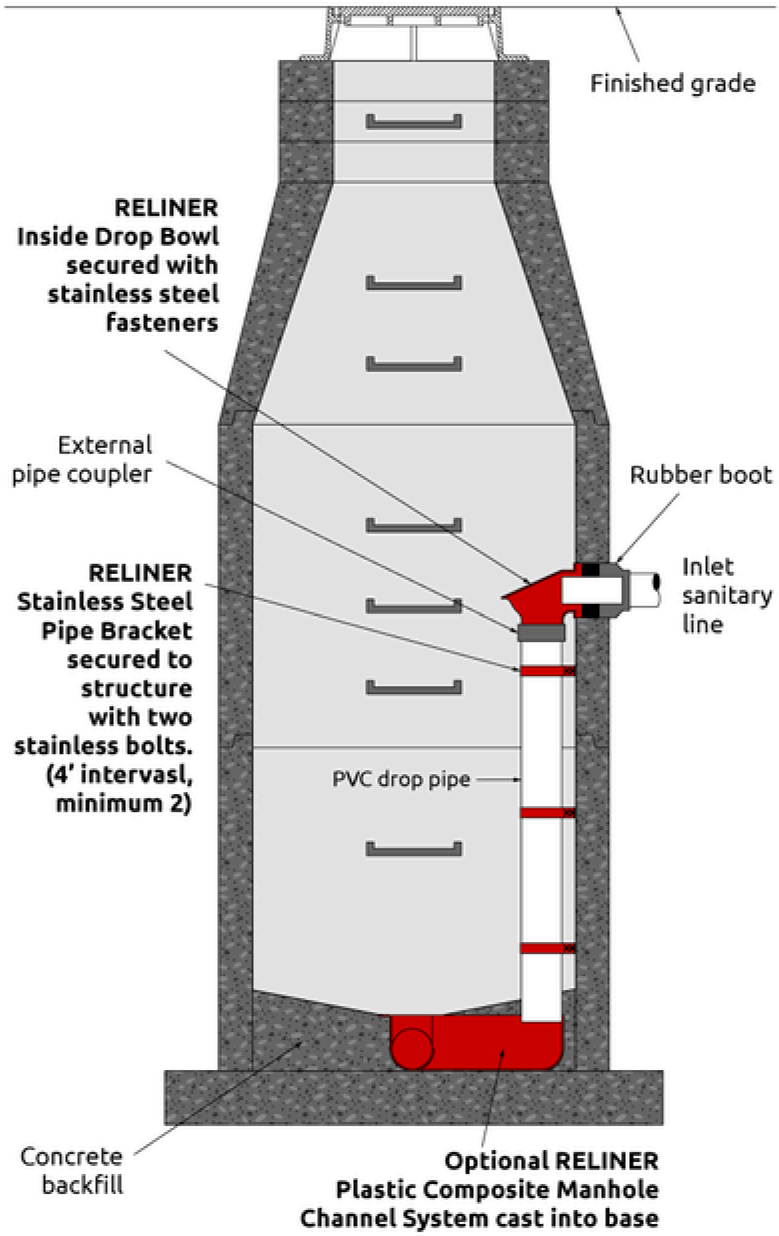

Figure 7 Manhole components

Its weight dictates the pipe's short lengths which increases the number of joints needed and necessitates the use of large equipment for handling and placing.

Hazards Associated with Sewer Work

Workers face conditions that may be immediately dangerous to life or health when entering sewer systems for repair or maintenance. Knowledge of the dangers involved, training in safe work procedures, and the correct use of safety equipment are essential to ensure that workers are protected from injury.

Responsibilities

Where the employer is operating under contract (contractor), the owner of the sewer system (or prime contractor if one is appointed) is required to ensure that the employer carries out their responsibilities under the local OHS legislation. The employer is responsible to develop safe work practices, ensure that workers are provided with adequate training on the practices and ensure that these practices are followed. The employer must assess hazards at the work site and ensure appropriate controls are in place to protect workers. The following are the most common workplace hazards involved with work on sewers.

Trenches

Cave-ins pose the greatest risk to workers and are much more likely than other sewer-related accidents to result in worker fatalities. Other potential hazards include material handling, falls, unstable loads, and incidents of contact involving mobile equipment.

An unprotected trench can be considered an early grave, in that one cubic meter of soil can weigh as much as a car. Unprotected trenches cause dozens of fatalities and hundreds of injuries each year. Trench failures occur more often in winter and early spring when ground moisture content is higher, as additional pressure from water in the soil contributes to trench failure. No one should ever enter an unprotected trench. Trenches and excavations over a certain depth (e.g., 1.2m (4 ft) in British Columbia) require a protective system such as sloping or shoring unless the excavation is made entirely in stable rock.

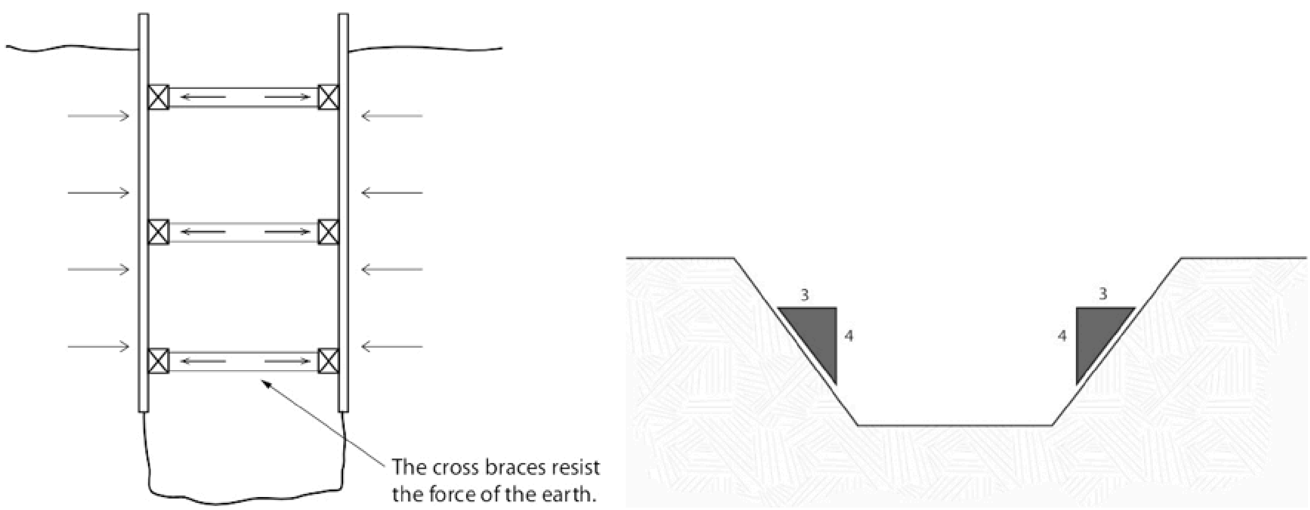

Figure 8 Trench shoring and sloping examples

Hazards still exist at shallow depths, and a competent person is needed to determine if a protective system is warranted. Examples of trenching and shoring methods are covered in the Level 1 Plumber Apprenticeship Learning Guides.

Confined Spaces

WorkSafeBC's OSH Regulation: Part 9 includes this definition of a confined space:

"confined space", except as otherwise determined by the Board, means an area, other than an underground working, that

a. is enclosed or partially enclosed,
b. is not designed or intended for continuous human occupancy,
c. has limited or restricted means for entry or exit that may complicate the provision of first aid, evacuation, rescue or other emergency response service, and
d. is large enough and so configured that a worker could enter to perform assigned work.

A space may also be a permit-required confined space if it has a hazardous atmosphere, the potential for engulfment or suffocation, a layout that might trap a worker through converging walls or a sloped floor, or any other serious safety or health hazard.

The current Confined Spaces standard is a component of provincial Worker Compensation Board (WCB) legislation. The following are examples of some of those requirements for safe entry of confined spaces.

- Preparation: Before workers can enter a confined space, employers must provide pre-entry planning. This includes:
  - Having a competent person evaluate the work site for the presence of confined spaces, including permit-required confined spaces.
  - Once the space is classified as a permit-required confined space, identifying the means of entry and exit, proper ventilation methods, and elimination or control of all potential hazards in the space.
  - Ensuring that the air in a confined space is tested before workers enter, and at specified intervals thereafter, for oxygen levels, flammable and toxic substances, and stratified atmospheres.
  - If a permit is required for the space, removing or controlling hazards in the space and determining rescue procedures and necessary equipment.
  - If the air in a space is not safe for workers, ventilating or using whatever controls or protections are necessary so that employees can safely work in the space.
- The employer must implement additional specific requirements in the OHS legislation regarding hazard assessment.
- Workers are responsible for carrying out their work in a manner that does not endanger them or their fellow workers. Workers must cooperate with their employer by following safe work procedures and using the equipment provided to complete the job safely.

Confined Spaces Air Quality Hazards

Air quality hazards are the most immediate of the concerns regarding confined space entry. Those concerns can originate from:

- insufficient amount of oxygen for the worker to breathe.
- toxic gases that could make the worker ill or cause the worker to lose consciousness.
- The presence of asphyxiants. Simple asphyxiants are gases which can displace oxygen in the air. Low oxygen levels (19.5 percent or less) can cause symptoms such as rapid breathing, rapid heart rate, clumsiness, emotional upset, and fatigue. As less oxygen becomes available, nausea and vomiting, collapse, convulsions, coma and death can occur. Unconsciousness or death could result within minutes following exposure to a simple asphyxiant. Asphyxiants include argon, nitrogen, or carbon monoxide. It is important to note that wherever there is ferrous piping present, the rusting process can use up the available oxygen in a confined space, contributing to the likelihood of asphyxiation.

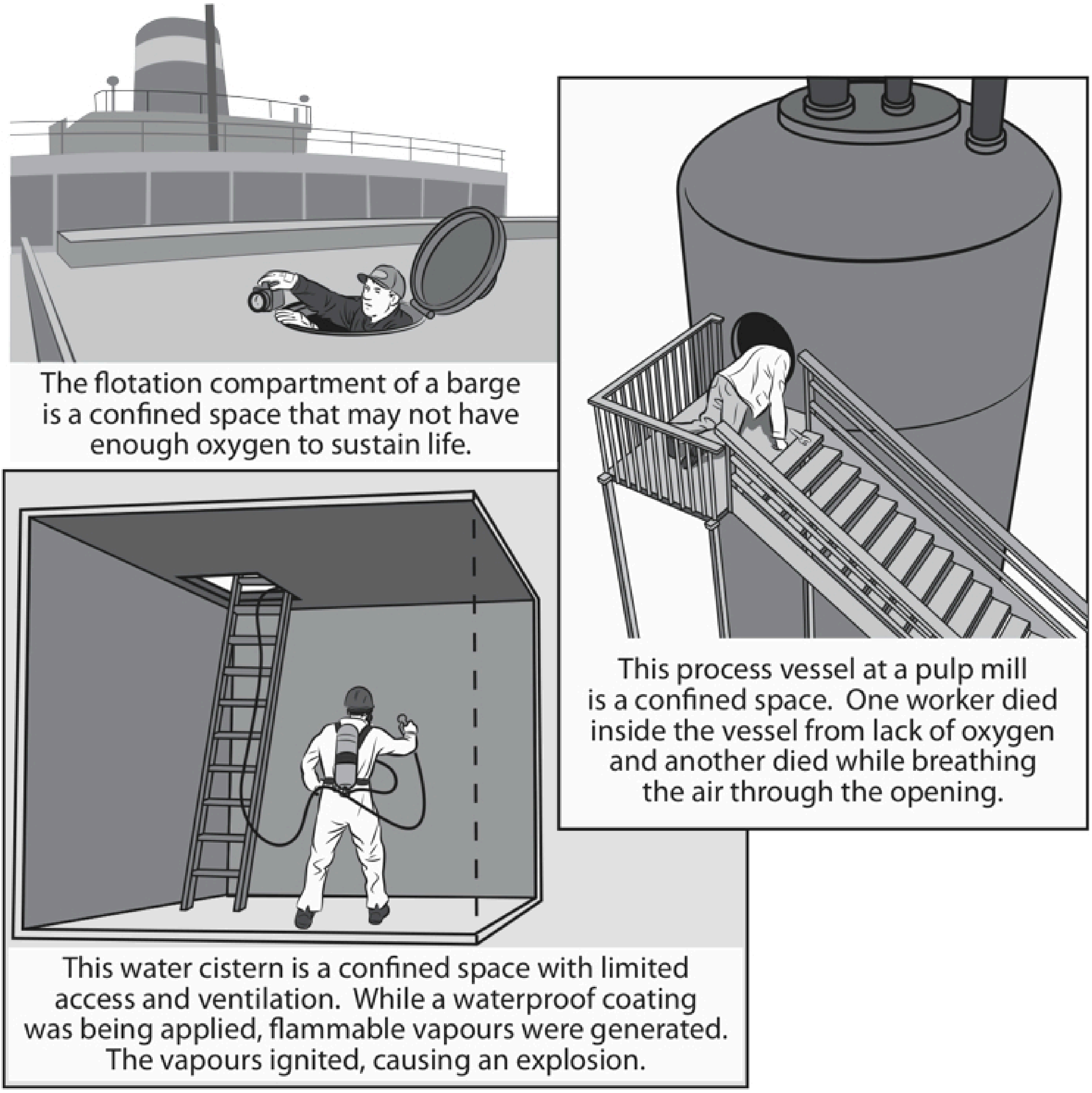

Figure 9 Examples of confined space air quality hazards

Other hazards of confined spaces include:

- Chemical exposures due to skin contact or ingestion (as well as inhalation of toxic gases).
- Fire hazard – An explosive or flammable atmosphere due to flammable liquids and gases and combustible dusts which, if ignited, would lead to fire or explosion.
- Process-related hazards – such as residual chemicals, or release of contents of a supply line.
- Biological hazards – viruses, bacteria from fecal matter and sludge, fungi, or molds.
- In warmer climates, the presence of dangerous animals and insects

Pinch Points

A pinch point is produced when two objects come together and there is a possibility that a person could be caught or injured when entering that area. Pinch points commonly impact fingers and/or hands but can involve any area of the body. The injury resulting from a pinch point could be as minor as a blister or as severe as amputation or death. Conveyors, gears, loaders, compactors and other moving equipment are examples of machinery with pinch points.

Common causes of injuries from pinch points are:

- Not paying attention to the location of hands and feet
- Walking or working in areas with mobile equipment and fixed structures
- Loose clothing, hair or jewelry getting caught in rotating parts of equipment
- Poor condition of equipment and guarding
- Dropping or carelessly handling materials or suspended loads
- Not using the proper work procedures or tools
- Reaching into moving equipment and machinery

Hoists

When lifting and hoisting sewer piping materials on site, incidents may occur for a variety of reasons. The main causes include but are not limited to the following:

- Unintentional contact with a moving load will often result in serious or fatal consequences due the masses involved. Examples include workers that are responsible for landing and stacking loads getting caught between a solid surface and the moving load, or loads being moved before all workers have moved clear of the lifting zone, and workers getting crushed by the load. This latter situation can also be exacerbated if the load’s centre of gravity is unsafe, causing it to start swinging unexpectedly and uncontrollably.
- Lifting equipment can overturn for a variety of reasons. A common cause involves not using or fully extending the outriggers to provide a solid platform or setting up a crane on non-compacted/disturbed ground. The ground underneath may appear to be solid, but it can be deceptive. As a load is moved and weight transfers over the outriggers, they can start to sink into the soil.

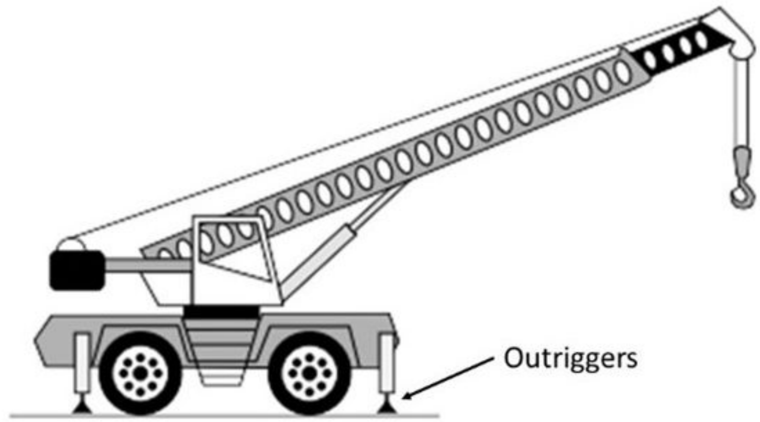

Figure 10 Mobile Crane

- Proximity to overhead power lines is one major factor that is either overlooked or not understood. The crane boom/forklift truck does not actually have to come into direct contact with the power line for a dangerous condition to occur. The electric current in the lines can "arc" through the air when a grounded point is within a certain distance. This distance is determined largely by the voltage – the higher the voltage the greater the arc distance. Therefore the available voltage in the lines will determine the safe "limits of approach" as shown below.

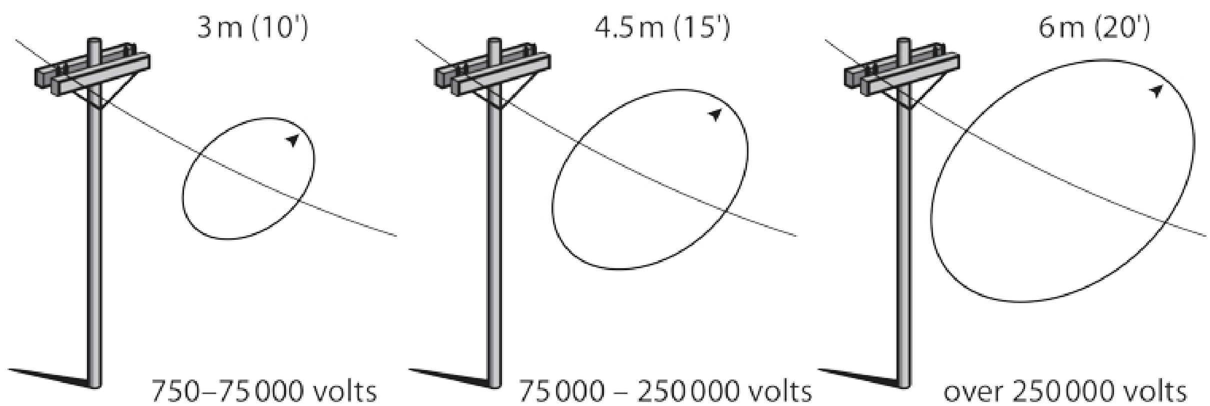

Figure 11 Limits of approach

- In many cases the operator sitting in the cab may be isolated from the current and will not typically feel anything, but they are at significant risk if they attempt to leave the lifting equipment while the current is still flowing, as once they grab the structure and place a foot on the ground the current may then pass through their body to earth.
- Mechanical failure doesn't occur as frequently as do some of the events described previously but is still relevant. Installed safety devices such as a safe working load indicator can fail. Braking systems, hydraulic systems and electrical systems are all vulnerable to failure. The very nature of the way that lifting devices are typically used, moving between locations, working in a wide variety of environmental conditions all add significantly to the wear and tear on this equipment. The key factor here for prevention is the systematic inspection, testing and certification of lifting and hoisting equipment. Whilst a slightly different mechanism of failure, it is also worth considering the condition and integrity of lifting accessories such as slings, shackles and hooks. These devices can also fail with catastrophic results.

- Dropped objects is a hazard that can occur in several ways. Objects may fall off the crane, the load or parts of it could fall or objects hidden within it may fall. If not secured properly, it is quite common for items to shift once the load is raised and then fall to the ground. For example, where items are left on a load by mistake (e.g., hand tools) or are hidden from view (e.g., rocks or other solid materials in pallet pockets), once the load is airborne these objects may be dislodged and fall.
- Climbing onto a load as it is being lifting or set in place such as when riggers/slingers have to climb on top of loads to either attach a sling to a hook or vice versa. Climbing on top of the load can be problematic as there is normally no safe access and no fall protection in place.

Sewer System Types, Applications and Operations

Sewer system design and application date back to ancient times, and many of the technologies used in past centuries are still seen in today's sewer systems. The development of better sewer systems that can meet a variety of community and municipal needs has been ongoing. Demand for advanced scientific innovations and techniques in sewer systems continues to increase as the urban population increases, new contaminants emerge, and effluent standard requirements become more stringent. Some of these alternatives for sewer system designs are in full operation, while others are still evolving. New innovative sewer systems, commonly referred to as alternative wastewater collection system designs, include pressure sewer systems, vacuum sewer systems, and small diameter gravity sewer systems.

Gravity Sewer Systems

Gravity sewer systems, small and large, are by far the most used of any sewer system worldwide. In a gravity sewer system, pipes are installed on a slope that allows sewage and wastewater to flow by gravity from the household to lift stations and finally to the wastewater treatment plant. They are sized with as straight an alignment as possible and a uniform gradient to maintain self-cleansing velocities. Gravity sewers are typically installed at a depth of one meter (3 ft) or more and to a maximum of approximately 7.6 meters (25 ft).

Figure 12 PVC gravity sewer piping at substantial depth

Materials used for a gravity sewer conveyance system include but are not limited to reinforced concrete pipes (RCP), specialty plastic pipes, polyvinyl chloride pipes (PVC), and Centrifugally Cast Fiberglass Reinforced Polymer Mortar (CCFRPM) pipes.

Manholes are installed at various locations along sewer systems. Spacing of municipal sewer manholes ranges from 400-900 ft. (122 – 275m). Manhole spacing on private property is mandated by clauses in the NPC. Manholes are required under the following conditions:

- at both ends of horizontal curves
- at the intermediate point of a curve with angle greater than 90°
- at the point of reverse curve
- at abrupt change in vertical alignment
- at changes in pipe size, and
- at the confluence of three or more pipes.

More information regarding manholes will be covered further in a later section of this learning guide.

Pressure Sewer Systems

A pressure sewer system is commonly used when a gravity system is impractical, such as in rocky areas, areas with high groundwater table, around lake areas where homes are built fronting the lake, and in flat terrains over long distances. It is also commonly used within buildings where the building sewer elevation is higher than that of the gravity drainage piping feeding into it. It is comprised of a small diameter pipeline under pressure head generated by a grinder pump. The pump is located in a tank either inside the building basement or buried outside the building. The pump pushes a sewage slurry into a municipal or district system which may itself operate by gravity or be pressurized. Typical main pipe diameters range between 50 to 150 mm (2 in to 6 in). Solvent welded polyvinyl chloride (PVC) is the most-used piping material. For more detailed information, including a video, visit E/One Sewer Systems in Canada (https://www.johnbrooks.ca/product/eone-sewer-systems/).

Vacuum Sewer System

The vacuum sewer system consists of three major components: a service holding tank/valve pit, a collection piping/vacuum main and a vacuum station. In vacuum sewer systems, wastewater flows by gravity away from the building through a small diameter pipe to a sump and valve pit. A vacuum valve located inside the valve pit provides the interface between the collection main (vacuum main) and the sump, which is under atmospheric pressure. When a certain amount of sewage accumulates in the sump, the interface valve opens automatically, and the sewage is immediately sucked into the collection main which is under a light negative pressure of between 16 – 20 in of Hg created at the vacuum station. This negative pressure provides the energy that moves the sewage at a velocity of 15-18 fps. The collection system pipes, which are typically solvent welded PVC, HDPE, and O-ring rubber gasketed pipes, range in size between 3 and 10 inches. This system, like the pressure systems, can be used in areas with unstable soils, flat terrain, high water table, semi-urban/rural areas, rocky ground, and when the wastewater is of higher solids concentration. Like the pressure systems, these systems can be installed closer to ground level than gravity piping, requiring minimal slope.

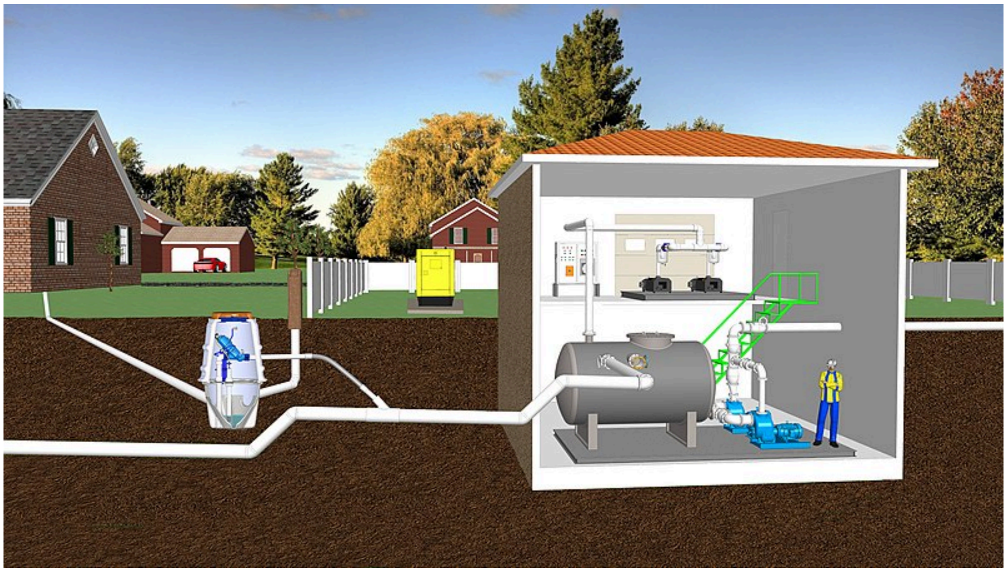

Figure 13 Vacuum sewer system

Small Diameter Gravity Sewer

The small diameter gravity sewer is another advanced sewer system that provides primary treatment of the wastewater at each connection and releases pretreated wastewater to the collection main. This system consists of a house connection, interceptor tank, service laterals, collection mains, cleanouts, manholes, vents and lift stations. An interceptor tank or septic tank, with a detention time of 12-24 hours, collects the suspended solids from the house connection and then releases the pretreated wastewater to the service lateral which connects to the collection main. A well-designed interceptor or septic tank can remove up to 50% of biological oxygen demand (BOD5), 75% of suspended solids, 90% of grease, and all grit. This allows the municipal main to be laid at minimal slopes due to the relative absence of solids, while also allowing smaller main sizes. The typical diameter of service main pipes is three to four inches, with a slope of two percent. The collection main is also three to four inches in diameter, and it maintains a 1.5 fps velocity compared to a 2.5 fps velocity requirement for conventional gravity sewers. However, like a standard gravity system, there would have to be lift stations at intervals along the mains to prevent the mains from being buried too deep in the ground.

Hybrid Sewer System

The hybrid sewer system is a design that combines two or more of the above sewer system designs into one functional system. Examples of hybrid sewer systems are a combination of pressure sewer and gravity sewer, vacuum sewer and gravity sewer or a combination of vacuum sewer, pressure sewer and gravity sewer.

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

1. Where does a plumber’s responsibility for a drainage system on private property end?
    a. At the property line
    b. At the end of the building drain
    c. At the cleanout for the main drain
    d. At the connection of the sewer to the street main
2. Which one of the following is *not* a type of sewer system?
    a. Storm
    b. Sanitary
    c. Drainage

  d. Combined

3. Which one of the following is a system that contains both sewage from toilets and rainwater from roofs and parking lots?
  a. Storm
  b. Sanitary
  c. Drainage
  d. Combined
4. Which one of the following choices is a type of pipe that was used in the earliest form of municipal waste systems and that may still be used where corrosive wastes may be expected?
  a. Vitrified clay
  b. Ductile iron
  c. Steel
  d. ABS
5. Which one of the following choices is a type of pipe that is limited to use on private property, mainly due to its fairly small available diameters?
  a. PVC
  b. ABS
  c. HDPE
  d. Concrete
6. Which one of the following is listed as being the most likely cause of worker fatalities associated with the installation of sewers?
  a. Pinch points
  b. Trench cave-ins
  c. Hoisting operations
  d. Confined space work
7. Which one of the following choices is of the most immediate concern when entering a confined space?
  a. Air quality
  b. Fire hazard
  c. Biological hazards
  d. Chemical exposure
8. A worker tries to walk around the back of an excavator and gets crushed between the counterweight and a pile of dirt. Which one of the following hazards would this be categorized as?
  a. Confined space hazard

b. Confined space hazard
c. Pinch point hazard
d. Hoisting hazard

9. What is the purpose of a lift station in a municipal sewer system?
   a. It is the location of the crane used for lifting
   b. It is a place where materials are readied for hoisting
   c. It pumps sewage from a deep sewer to a higher elevation
   d. It is the place where the sewage is disposed of into the environment
10. Which one of the following choices is the most common type of sewer system in both private and municipal use?
   a. Hybrid
   b. Gravity
   c. Vacuum
   d. Pressure

Check your answers using the Self-Test Answer Keys in Appendix 1.

Media Attributions

- Figure 1 Sanitary building drain and sewer by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 2 Storm building drain and sewer by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 3 Combined building drain and sewer by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 4 Cellular core ABS pipe by Greg Wirachowsky is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 5 PVC sewer pipe by Greg Wirachowsky is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 6 HDPE sewer pipe by Greg Wirachowsky is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 7 Manhole components (https://reliner.com/) © Reliner (https://reliner.com/), used with permission.
- Figure 8 Trench shoring and sloping examples by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 9 Examples of confined space air quality hazards by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 10 Mobile Crane was adapted from work by ITA is licensed under a CC BY-NC-SA

Learning Task 2

Size Pipe for Sewers

The following explanations are a synopsis of the sizing steps for sanitary, storm and combined sewers. These steps were originally covered in greater detail in Learning Modules D-1: “Install Sanitary Drain, Waste and Vent Systems” and D-3: “Install Storm Drainage Systems” of the BC Apprenticeship Learning Guides for Plumber.

Code Requirements for Sewerage Systems

Most provinces and territories in Canada have adopted the National Plumbing Code of Canada (NPC) as the accepted code for that jurisdiction. Provinces such as British Columbia and Ontario have chosen to create their own code by using the NPC as the base document and adding supplements to satisfy regional needs. For the purposes of explanations within this literature we will reference tables and clauses from the NPC; the same tables and clauses can be found in the BCPC, however the prefix “2” will be replaced by the prefix “7” where the BCPC is used.

Both codes have established a minimum acceptable standard for the design and installation of sanitary, storm and combined drainage systems on private property. The size of sewer is dependent on the hydraulic load on the pipe, the grade on the pipe and the Code table used for sizing. It is important to note that the NPC has no application on public property, although its clauses and tables can be used as guidelines. All aspects of sewer installations on public property are determined by engineers and their “good engineering practices”.

Sanitary Building Sewer Sizing

Sanitary sewers systems use fixture units (FU) to determine the hydraulic load imposed on the sewer system by the upstream fixtures or appurtenances. A fixture unit is not a flow rate unit but rather a design factor based on the rate of discharge, time of operation and frequency of use of a fixture. In original calculations arrived at by PDI (Plumbing and Drainage Institute) a fixture unit was equal to one cubic foot of water drained through a 1 ¼” OD pipe over one minute.

The fixture unit values of individual fixtures can be found in NPC tables 2.4.9.3 and 2.4.10.2.

The sizing procedure for a sanitary sewer is fairly simple:

1. Determine the total number of fixture units from fixtures found in tables 2.4.9.3 and 2.4.10.2
2. Add the flow from any semi-continuous or continuous flow appurtenances draining into it. These loads are normally expressed in L/sec, so they have to be converted into FU by applying the conversion number given in 2.4.10.3 (1) of the NPC, which is **31.7 fixture units per litre/second**.

3. Once a total flow rate of fixture units has been calculated, it is applied to Table 2.4.10.6.-C to establish the minimum size of sanitary building sewer required at the chosen grade.

Note: See the explanation and illustrations in A-2.4.10 of the NPC for an example of these sizing methods.

Additional loads to be added when sizing a storm drainage system include:

- If a clear-water waste appliance or fixture discharges a semi or continuous flow to the storm system, multiply its load in litres per second by 900 (the number of seconds in 15 minutes) to obtain the hydraulic load in L/15 min.
- If flow control roof drains are used, compute the discharge rate based on rainfall intensity, retention duration, accumulation height and roof area from the roof drain manufacturer's data.

Add all the contributing hydraulic loads listed above to obtain the total hydraulic load on the storm building sewer in L/15 min. Using the appropriate pipe grade, consult table 2.4.10.9 of the NPC to select the sewer's minimum size.

Shown below is a comparison example involving the introduction of a semi or continuous flow fixture into a sanitary system versus a storm system.

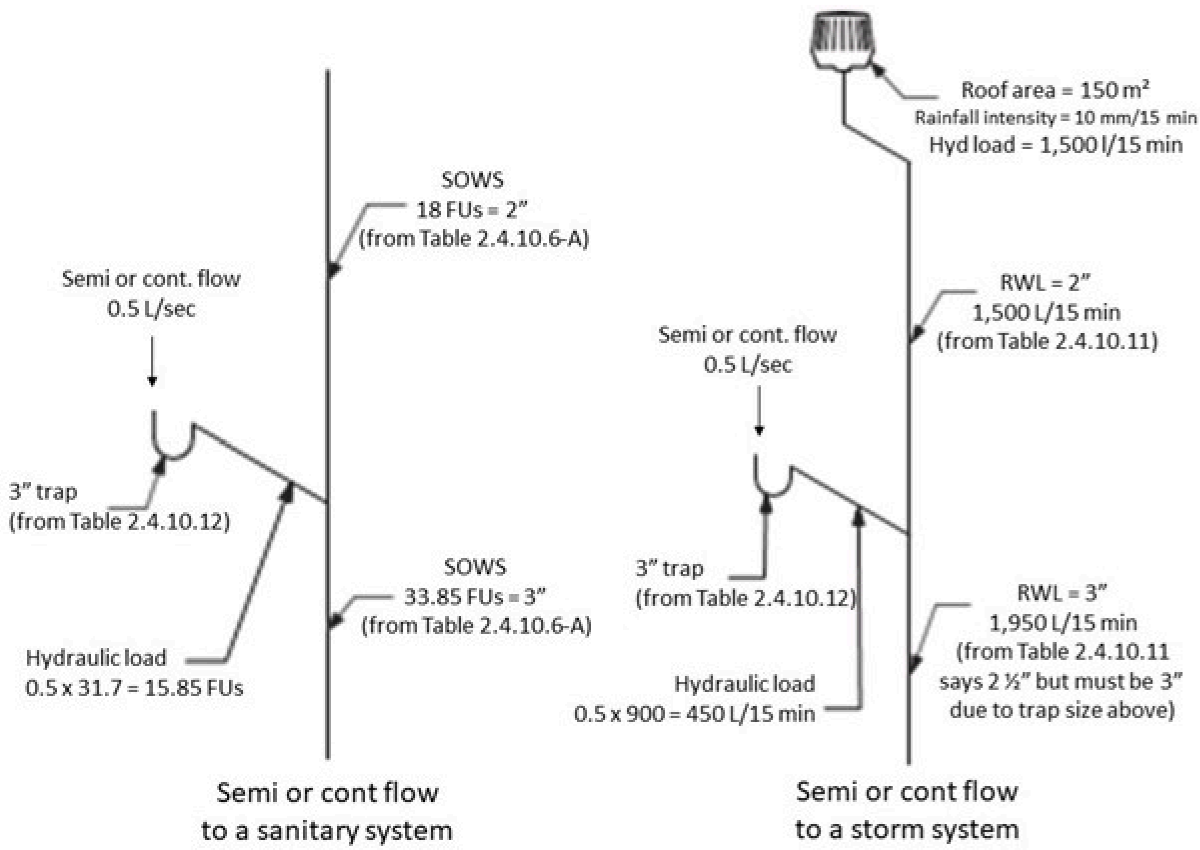

Figure 1 Semi or continuous flow fixture into a sanitary system vs a storm system

Note that, for the purposes of sizing the sanitary system downstream of the trap, the load must be expressed in fixture units. In the storm system, the load from the trap is expressed in L/15 minutes to be compatible with the tables used to size storm drainage.

Combined Building Sewer Sizing

This process is more complex than the procedures used in the above explanations. When sanitary drainage is connected to a combined building drain or sewer, the hydraulic load from only the plumbing fixtures must be converted from fixture units to litres/15 min or, in the case of semi or continuous flow, from litres per second to litres/15 min so that these loads can be added to the hydraulic loads from roofs and paved surfaces. Unfortunately, the relationship between fixture units and litres per second and, consequently, the relationship between fixture units and litres, is not easily calculated. To make the sizing process easier to navigate, the NPC has adopted an approximate conversion factor.

The conversion factor is detailed in Sentence 2.4.10.5.(1) of the NPC, which says to apply a hydraulic load of 9.1 L/15 min for each fixture unit drained to the combined drainage system.

This holds true only when the total sanitary drainage load draining to the pipe section being sized is *greater than* 260 FU. When the load is *260 FU or fewer*, a round figure of 2,360 L is to be used instead of the aforementioned 9.1 L/15 min. Consider this an "either/or" situation; never apply both.

As stated earlier, when semi or continuous flow appurtenances or fixtures drain to combined sewers or storm sewers, the factor for converting flow from the fixture from L/15 min to L/sec is 900 [given in Sentence 2.4.10.3.(2)]. This conversion factor is not an approximation but an exact calculation.

The sizing process for combined drainage systems requires you to determine the load on the section of pipe you are sizing and to find the pipe size from Table 2.4.10.9 in the NPC. To determine the load on any section of a combined drainage system requires the following four distinct steps.

1. Determine the total load in fixture units from all upstream plumbing fixtures, excluding the flow from any semi or continuous flow appurtenances or fixtures. If the fixture unit load is 260 FU or less, use 2,360 L/15 min to represent them. However, if there are more than 260 FU, multiply the fixture units by 9.1 to determine the equivalent hydraulic load in litres/15 min.
2. Add up the total flow rate in L/sec from any semi or continuous flow appurtenances or fixtures that are draining through the section of combined piping being sized. Multiply this by 900 (the number of seconds in 15 minutes) to get a hydraulic load in L/15 min; this is the same procedure used when sizing storm sewer pipes.
3. Determine the hydraulic load, in L/15 min, from roofs and paved surfaces using the same procedure employed when sizing storm drainage pipes [effective area (m2) × rainfall intensity (mm/15 min)].
4. Add the hydraulic loads calculated in Steps 1 through 3 to obtain the total hydraulic load on the combined drainage pipe in L/15 min and then consult Table 2.4.10.9 to select the pipe size at the chosen grade.

We'll use the diagram shown below as an example to illustrate the correct use of the load conversions given in Articles 2.4.10.3 and 2.4.10.5. Remember that this is a refresher of the learning from Level 2 Apprenticeship training. Consult the Level 2 learning guides if more clarity is required.

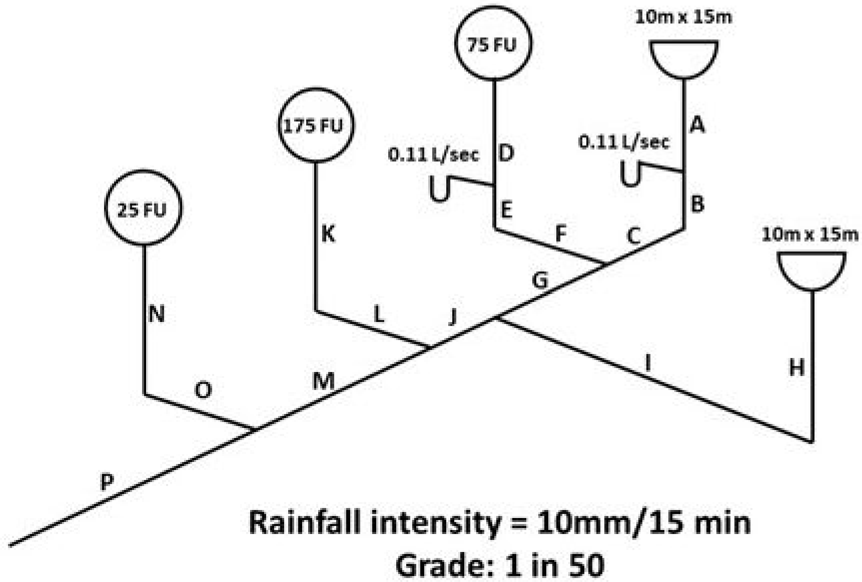

Figure 2 Sample load conversion

A (Leader)	10m × 15m = 150 m² 150m² × 10 mm/15 min = 1,500L/15 min 1,500L/15 min on Table 2.4.10.11 = **2″ leader**
B (Leader)	Trap size: 0.11 L/sec on Table 2.4.10.12 = **2″ trap** Load from trap = 0.11 L/sec × 900 = 99 L/15 min 99 L/15 min + 1,500 L/15 min = 1,599 L/15 min 1,599 L/15 min on Table 2.4.10.11 = **2″ leader**
C (Storm building drain)	1,599 L/15 min @ 1/50 grade on Table 2.4.10.9 = **3″ ST.BD**
D (SOWS)	75 FU on Table 2.4.10.6.-A (centre column) = 3″
E (SOWS)	Trap size: 0.11 L/sec on Table 2.4.10.12 = **2″ trap** Load from trap = 0.11 L/sec × 31.7 = 3.5 FU (rounded up to one decimal) 3.5 FU + 75 FU = 78.5 FU 78.5 FU on Table 2.4.10.6.-A (centre column) = **3″ SOWS**
F (Sanitary building drain)	78.5 FU on Table 2.4.10.6.-C @ 1/50 grade = **4″ SBD**
G (Combined building drain)	Stormwater: 1,500 L/15 min (from “A”) “Unconverted” FU = 75 (from “D”); use 2,360 L/15 min Semi or cont flow from traps: 0.22 L/sec × 900 = 198 L/15 min Total flow: 1,500 + 2,360 + 198 = 4,058 L/15 min 4,058 L/15 min on Table 2.4.10.9 @ 1/50 grade = **4″ CBD**
H (Leader)	10m × 15m = 150 m² 150 m² × 10 mm/15 min = 1,500 L/15 min 1,500 L/15 min on Table 2.4.10.11 = **2″ leader**
I (Storm building drain)	1,500 L/15 min on Table 2.4.10.9 @ 1/50 grade = **3″ St. BD**
J (Combined building drain)	Stormwater: 3,000 L/15 min (from “A” and “H”) “Unconverted” FU = 75 (from “D”); use 2,360 L/15 min Semi or cont flow from traps: 0.22 L/sec × 900 = 198 L/15 min Total flow: 3,000 + 2,360 + 198 = 5,558 L/15 min 5,558 L/15 min on Table 2.4.10.9. @ 1/50 grade = **4″ CBD**
K (SOWS)	175 FU on Table 2.4.10.6.-A (centre column) = **4″ SOWS**
L (Sanitary building drain)	175 FU on Table 2.4.10.6.-C @ 1/50 grade = **4″ SBD**
M (Combined building drain)	Stormwater: 3,000 L/15 min (from “A” and “H”) “Unconverted FU = 250 (from “D” and “K”); use 2,360 L/15 min Semi or cont flow from traps” 0.22 L/sec × 900 = 198 L/15 min Total flow: 3,000 + 2,360 + 198 = 5,558 L/15 min 5,558 L/15 min on Table 2.4.10.9 @ 1/50 grade = **4″ CBD**
N (SOWS)	25 FU on Table 2.4.10.6.-A (centre column) = **3″ SOWS**
O (Sanitary building drain)	25 FU on Table 2.4.10.6.-C @ 1/50 grade = **3″ SBD**

P (Combined building drain)	Stormwater: 3,000 L/15 min (from “A” and “H”) “Unconverted” FU = 275 FU; 275 x 9.1 = 2,502.5 L/15 min Semi or cont flow from traps: 0.22 L/sec x 900 = 198 L/15 min Total flow: 3,000 + 2,502.5 + 198 = 5,700.5 L/15 min 5,700.5 L/15 min on Table 2.4.10.9 @ 1/50 grade = **4″ CBD**

The steps to take note of in the example above are:

- Although the two traps have the same flow rate into them in L/sec and are sized from the same table using that flow rate, the load from them is dependent upon the pipe that they are draining through, which is expressed in L/15 min for storm or combined pipes and in FU for sanitary pipes
- The loads at “J” and “M” are the same, even though there are 175 FU more at “M” than at “J”. This is because we look for the *total* number of FU going through a combined building drain. At “G”, “J” and “M” the load from “unconverted” (original) FU had not yet reached or exceeded 260, so at those points the single conversion number of 2,360 L/15 min was used to represent them. At “P”, there were now *more than* 260 FU in that piece of combined building drain, so *instead of* using 2,360 L/15 min we now multiply the “unconverted” FU by 9.1 and use that number. It is an “either/or” situation when considering the load presented on a piece of combined building drain by fixture units; either 2,360 L/15 min *or* FU x 9.1, *never both*.
- *Never* include the converted FU from any semi or cont flow trap in the calculation for a combined building drain. Instead use the calculation “L/sec x 900 = L/15 min”
- *Don’t take shortcuts in calculations of load on combined building drains!* Whenever a new piece of combined building drain is to be sized, always look for the totals of the three possible types of flow going through it, which are:
  - Stormwater from roof drains and parking lot drains
  - “Unconverted” (original) FU, and
  - Semi or continuous flow from traps serving pumps or clear water waste

Also remember that a clearwater waste fixture or appurtenance can drain into either a sanitary pipe or a stormwater pipe, and that pipe will still retain its name. A combined building drain or sewer is only so named because stormwater and sewage exist within the same pipe.

The table below shows the three varieties of building sewers, the NPC table used to size them and the units of measurement of flow within them.

National Plumbing Code Sizing Tables

Sewer Type	**Table**	**Units of Measure**
Sanitary	2.4.10.6.C	Drainage Fixture Units
Storm	2.4.10.9	L/15 minutes
Combined	2.4.10.9	L/15 minutes

Grades

Proper slope of gravity sewer pipes is important so that liquids flow smoothly, which helps transport solids away without clogging. A pipe that is installed at too shallow a grade will prevent waste from being carried along, which will no doubt result in blockages. It is also commonly thought that pipes that are too steep will allow liquids to flow so quickly that solids will not be carried away at that same velocity, also contributing to blockages. This concept has endured much debate over many decades, and the resulting train of thought has been that, for optimum performance, installers should strive to provide a minimum grade of 2% (approximately ¼"/ft) on any horizontal drainage pipe, regardless of its designated name (e.g "branch" or "sanitary building drain") or function. Short sections of nominally vertical pipe are unavoidable in most installations but maintaining all nominally horizontal pipe as close to this grade as possible appears to work best.

Now complete Self-Test 2 and check your answers.

Self-Test 2

Self-Test 2

1. Where do the National and BC Plumbing Codes have application jurisdiction?
    a. On all properties everywhere in Canada
    b. On public property underground only
    c. On private property only
    d. On public property only
2. What were the original calculations for a fixture unit based on?
    a. 1 ft^3 of water through a 1 ¼″ ID pipe in 1 minute
    b. 1 ft^3 of water through a 1 ¼″ OD pipe in 1 minute
    c. 1 ft^3 of water through a 1 ½″ OD pipe in 1 minute
    d. 1 ft^3 of water through a 1 ½″ ID pipe in 1 minute
3. What are the units of measure used to size pipes in a storm or combined system?
    a. Fixture units
    b. Litres per 15 minutes
    c. Fixture units per second
    d. Fixture units per 15 minutes
4. Where would one look to find the local rainfall intensity for a city or area?

a. BC Plumbing Code
b. The Weather Channel
c. National Building Code of Canada
d. National Plumbing Code of Canada

5. What information would one consult if calculating the discharge rate from flow control roof drains?
   a. The NPC
   b. The NBC
   c. The CBC
   d. The manufacturer
6. What are the units of measure used to size pipes in a sanitary system?
   a. Fixture units
   b. Litres per 15 minutes
   c. Fixture units per second
   d. Fixture units per 15 minutes
7. What is the conversion factor to be used to represent the flow through a combined building drain from not more than 260 fixture units?
   a. 9.1 litres per 15 minutes
   b. 900 litres per 15 minutes
   c. 9.1 litres/15 min per L/sec
   d. 2,360 litres per 15 minutes
8. Which one of the following choices would be the correct conversion of 300 FU flowing through a combined building drain?
   a. 900 L/15 min
   b. 2,360 L/15 min
   c. 2,730 L/15 min
   d. 9,510 L/15 min
9. If a fixture discharging clearwater waste drains into a sanitary building drain, what is that pipe now called?
   a. A branch
   b. A fixture drain
   c. A sanitary building drain
   d. A combined building drain
10. What is the most common grade for above ground and below ground nominally horizontal drainage pipes, which helps ensure that solid waste will be carried away by the liquid flow?

a. 0.5%
b. 1%
c. 2%
d. Greater than 2%

Check your answers using the Self-Test Answer Keys in Appendix 1.

Media Attributions

- Figure 1 Semi or continuous flow fixture into a sanitary system vs a storm system adapted from image by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 2 Sample load conversion by Greg Wirachowsky is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).

Learning Task 3

Describe The Installation of Piping for Sewers

As noted in Learning Task 1, different piping materials are used in the construction of sewer systems. The best pipe material for the project depends on the type of system being designed, the type of waste being carried through it, the depth of installation, the pipe's surroundings, the loads being exerted on the pipe, the available handling equipment and the pipe's cost. All these factors must be considered before choosing the appropriate pipe. The installation methods may differ slightly due to the materials being used but overall, the procedures will be similar.

Sewer Installation Procedures

Determine the Elevations

The first main step of a sewer pipe installation is to determine the elevations of the upstream and downstream ends. For a residential installation, the building sewer pipe typically starts where the home's building drain exits the house foundation. The line then slopes downhill to where it connects to the city's connection at the property line or to where it connects to the inlet to a septic tank. Elevations can be measured and laid out using various tools such as a laser level, GPS, or traditional surveying equipment.

Figure 1 Builders level on tripod

Pipe Path and Grade

In some cases, the installer must adhere to the elevations given on an engineered drawing. These often include installing the pipe at a particular grade and meeting elevations at specific points on the site. A benchmark (starting point) elevation may be used that is a true geodetic one (elevation above sea level) or an assumed one (e.g., using 100.00’ for the roadway or sidewalk). In any case, the installer must establish the elevations required and select a pipe path that meets those requirements.

Figure 2 Geodetic benchmark

The elevations and the length of the pipe run are used to make the initial slope calculations. Subtracting the ending elevation from the starting elevation yields the total drop in elevation. Dividing the drop by the total run (length) of the pipe yields the grade. For example, if the grade is to be consistent throughout the installation of a 75m long run of sewer pipe, the downstream elevation (e.g. 92.376m) would be subtracted from the upstream elevation (e.g. 93.501m) to arrive at a total fall of 1.125m between the two points. If that total fall is then divided into the length, in this case 1.125m ÷ 75m, a grade of 1.5% is the result. This can be thought of as, for every metre of run, the pipe will drop by 15mm.

The grade to which the pipe is to be laid is generally specified on the project drawings and may vary depending on the sewer pipe material. For instance, some PVC sewer pipe manufacturers require a grade that is sufficient to provide a minimum flow velocity of 0.6 m/s (2.0 fps). This will ensure that the flow is always self-cleansing inside the pipe. Laser levels, as picture below, are available that help to ensure that pipes are laid straight and at a consistent grade.

Figure 3 Pipe laser and target for pipe interior

The standard minimum slope for most sizes and varieties of nominally horizontal pipe is 2 percent, or 2 feet of drop per 100 feet of run. Although not exact, this grade is so close to ¼" per foot that the two are considered the same. The actual slope between the two ends of the sewer can be slightly steeper than this target but must meet the requirements of the local code. However, a slope that is too steep may cause the liquids to run faster than the solids, leading to clogs. A slope that is too shallow does not create enough velocity for proper drainage. The NPC and BCPC allow slopes as shallow as 1 in 400 but in this case the pipe has to be at least 12 inches (300 mm) in diameter.

Sewers are expected to be installed in as straight and direct a path as possible. According to the NPC and BCPC, manholes are commonly required whenever abrupt directional changes of 45 degrees or more for horizontal building sewers of 8 inches (200 mm) or larger occur or where cleanouts are required for those pipe sizes. Pipes smaller than 8 inches do not require manholes; they only require acceptable pipe configurations, such as a wye and 1/8th bend, for cleanouts or excessive changes of direction.

Excavation

As a rule, do not excavate too far ahead of pipe laying. Avoiding long stretches of opened trench will often minimize costly and dangerous problems such as:

- the possibility of flooding the trench
- cave-ins/sloughing caused by ground water
- frozen trench bottoms and backfill
- safety hazard risks to workers and traffic

Obviously, keeping open trench lengths to a minimum will necessitate very careful planning and layout. Problems can occur when pipe is installed and backfilled prior to meeting up with the intended destination. If too much grade has been used, the pipe will need to be removed and regraded, whereas if installed with insufficient slope, the installation may not meet minimum requirements and may be rejected by the Authority Having Jurisdiction.

Trench Width

The width of the trench at the top of the pipe should allow for proper placement and compaction of the haunching materials (the aggregate that surrounds the part of the pipe above the compacted trench bottom). Generally, the minimum trench width should be 450 mm (18 inches) or 300 mm (12″) greater than the outside diameter of the pipe, whichever is the lesser. The trench width must also allow compacting machinery enough room to properly prepare the trench bottom. For even the smallest compactor, this is usually at least 300 mm (12 inches) in width. As well, consideration must also be given for workers to be able to handle the pipe by standing or kneeling beside it. On the other hand, keeping the trench width narrow is important since the load imposed upon the pipe is a function of the trench width. Over-excavating also increases costs and takes away the stability that un-excavated “native” soil provides.

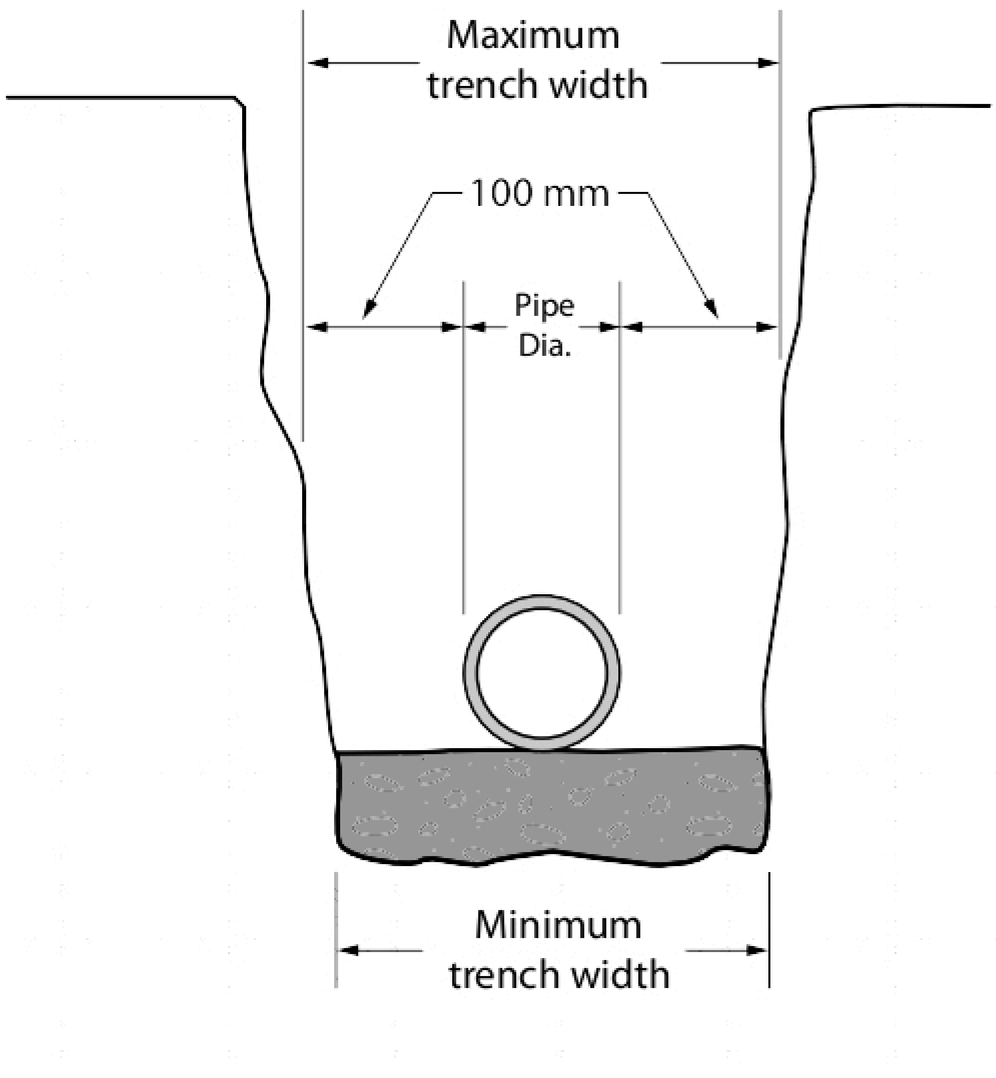

Figure 4 Example of trench for pipe

Preparation of Trench Bottom

Preparation of the trench bottom is the starting point for a satisfactory and safe sewer pipe installation. The trench bottom should be compacted to a smooth and properly graded finish, free from large stones, clumps of dirt, and any frozen material as approved by the engineer. It is economical on most sewer installations to slightly undercut the trench bottom by machine and bring it up to grade using granular bedding material such as sand. If the bedding is hard and compacted, excavation for the pipe hubs, known as “bells” should be provided. Creating “bell holes” ensures that bell-and-spigot pipe is uniformly supported along its entire length.

Install the Pipe

Sewer pipe is installed one section at a time. When installing a building sewer, it is often customary to start at the upstream end near the building and trench toward the property line. This is the normal practice, but site conditions may dictate starting at the downstream end and working back upstream.

Regardless of the pipe material chosen, if using bell and spigot type pipe, the bell (female) end of each pipe section must be at the upstream end to conform to code as well as to minimize the chances of blockages caused by material coming up against the blunt spigot end of pipe. Pipe gasket lubricant is spread on both the inside of the rubber gasket and the outside of the beveled spigot end before pushing the spigot into the bell. On smaller pipe, the back side of a shovel driven into the soil and placed against the bell end of the upstream pipe will allow a worker to exert enough force to push the pipes together by hand. On larger pipes, slings and a come-along or cable puller may be needed. Some installers use the excavator bucket to gently push the sections together. This practice requires a machine operator with a delicate touch to avoid damaging the piping and should only be considered if the use of slings and pulling equipment is not feasible.

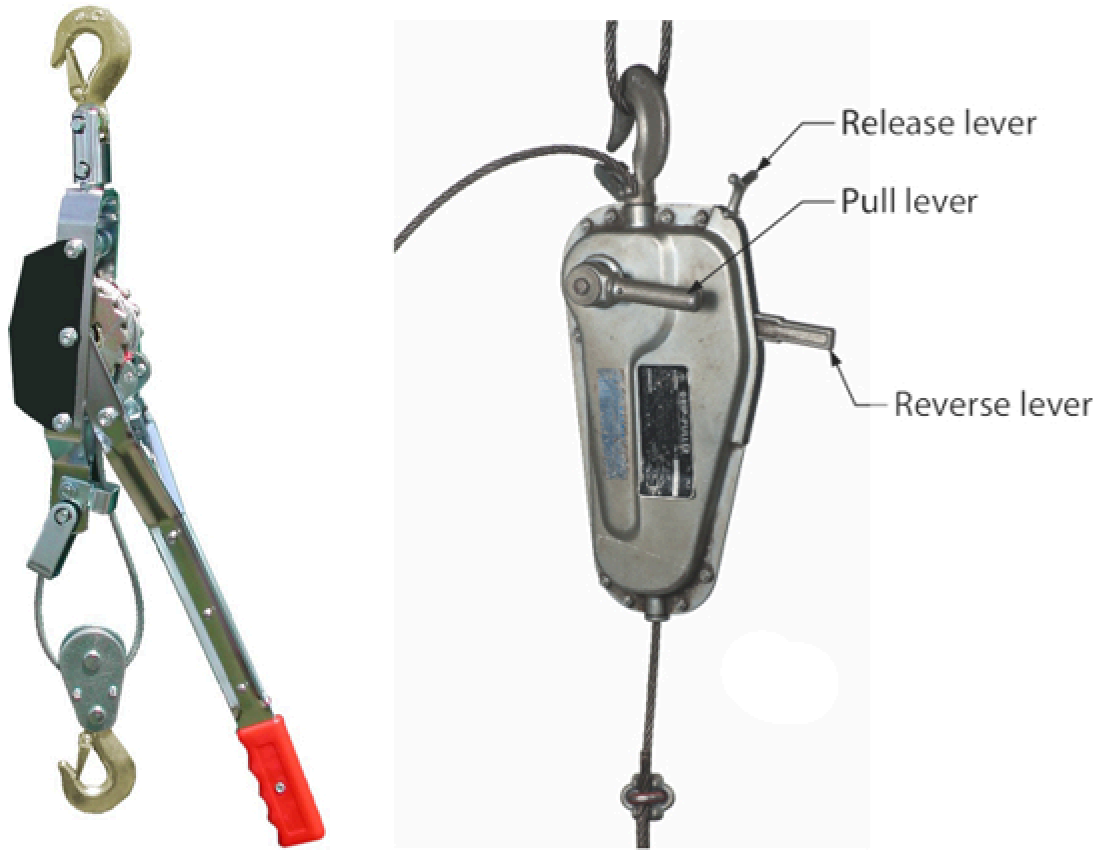

Figure 5 Cable puller and "Tirfor"®

PVC sewer pipe in sizes up to 375 mm (15″) diameter are capable of being handled and lowered into the trench by hand. Larger PVC and concrete sewer pipe should be lowered using hoisting equipment with slings. Pipe and fittings should be inspected for defects or damage prior to lowering into the trench. Any defective or damaged pipe or fittings should be repaired or replaced.

Pipe Terminations

At the downstream end, the pipe connects to the city main per the city's specifications, and at the upstream end, most codes require cleanouts to provide easy access to the pipe for maintenance or for cleaning with a sewer auger. Once installed, the pipe must be tested and inspected as per the requirements of the AHJ.

Backflow Prevention

A backwater valve (sometimes called a backflow or sewer backup valve) is a check valve installed on a gravity drainage line and is designed to allow water or sewage to flow in only one direction. In certain instances, such as when there is a sudden heavy rainfall, the city sewer lines can become overwhelmed, causing water or sewage to flow back towards the buildings. If there is a sewer system backup, and there is a backwater valve in place, the likelihood that sewage will flow back into a building will be greatly minimized or negated.

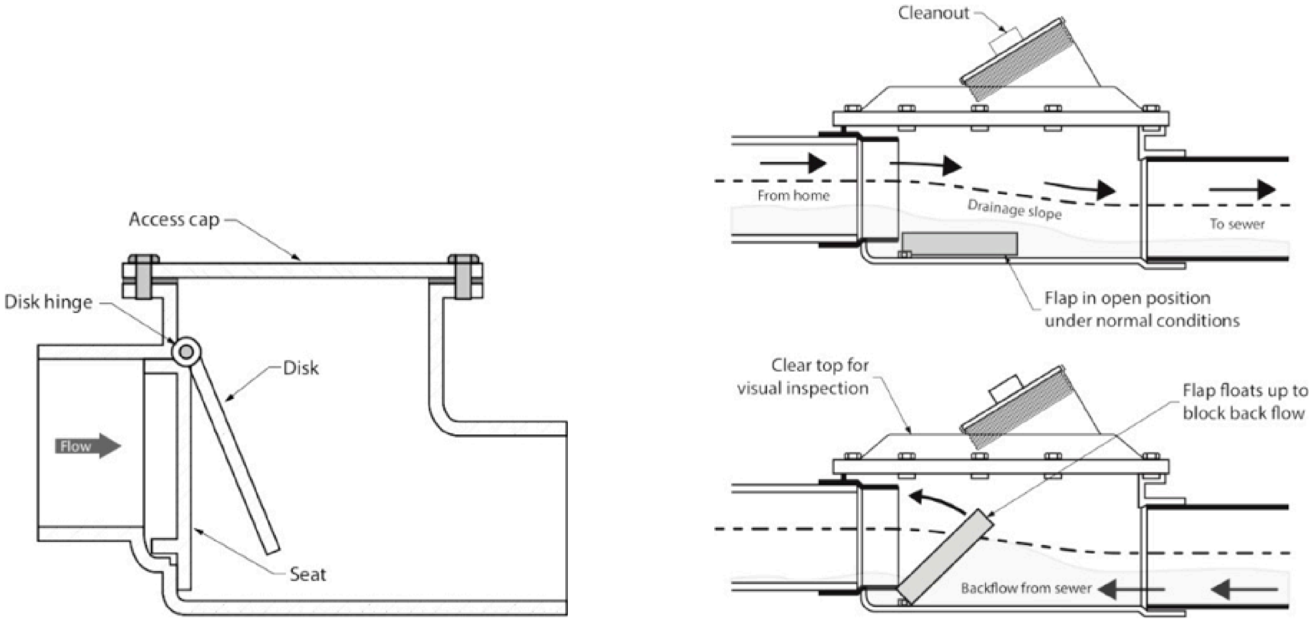

Figure 6 N.C. backwater valve (left) and N.O. backwater valve (right)

Backwater valves are required by some municipalities and recommended by others. They can be installed as part of new construction or can be retrofitted into existing lines. Installing during the initial construction is naturally much less costly. The risk of sewer backup increases if there is a basement in the building and the basement is very close in elevation to the elevation of the city sewer. If a new building has any fixtures located lower than the street level, it is a requirement of most prevailing plumbing codes to have a backwater valve installed. According to those codes, the backwater valve must not be installed on the building drain or sewer unless it is of the “normally open” variety and is allowable by the AHJ. Installing a “normally closed” backwater valve on a building drain or sewer can interfere with the venting of the city’s sewer through the building’s venting system.

If a backwater valve is installed, it must be accessible for periodic inspection and maintenance. They can become inoperative due to items damaging or becoming lodged against the internal components. They are best installed within the building, on branches that drain the lowest fixtures.

Backfill the Trench

After the sewer is completely installed and passes final inspection, the trench is backfilled to complete the project. The backfilling process often involves using sand or other fine haunching material that will not damage the pipe. It is installed in layers known as “lifts” and each lift is compacted. Once there is a reasonable thickness of fine compacted bedding material covering the pipe, the excavated soil can be placed over the bedding, doing so again in lifts. Compacting each lift ensures the amount of settlement will be minimized and helps keep water from penetrating the trench.

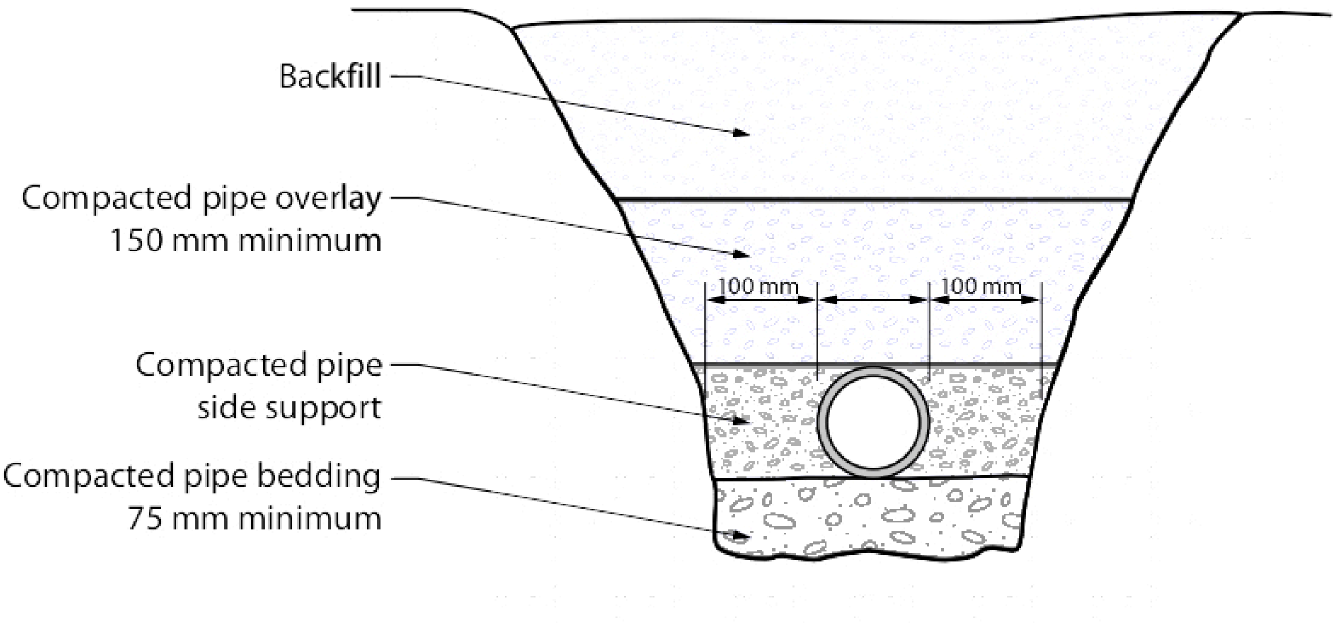

Figure 7 Proper trench construction

The presence of fine bedding material over the top of the pipe is a visual indicator for any future excavations that there may be a buried pipe nearby. To further avoid future mishaps involving unintentional contact with buried pipe, it is a good idea, and often a requirement, to lay a plastic warning tape over the top of the first compacted layer of "spoils" (previously excavated earth) being replaced into the trench. This alerts crews to the presence of the pipe buried below.

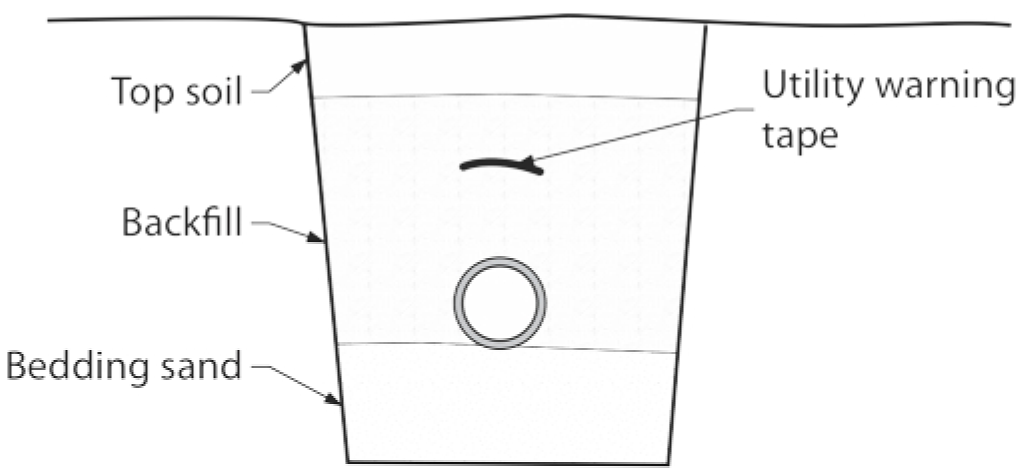

Figure 8 Trench with warning tape above pipe

Trench Boxes (Trench Shields or Shoring)

It is good safety practice, and mandated by provincial Workers' Compensation Board regulations, to use movable trench boxes whenever possible while installing pipe in a below ground trench that is over 1.2m (4 ft) deep. The trench box serves as a lateral support to protect workers from possible cave-ins in areas where proper sloping is not an option.

How to Install Reinforced Concrete Pipe (RCP)

Reinforced concrete pipe, or RCP, is one of the standard materials used in storm sewer systems, sanitary systems, and large irrigation projects. RCP offers high strength and durability at competitive costs and is the primary alternative to high-density polyethylene (HDPE) plastic pipe in many applications. One benefit of concrete is its inherent strength, which simplifies installation and backfilling procedures. It is capable of withstanding very heavy loads which may occur where it is buried at shallow depths under public roadways. On the other hand, RCP is very heavy and must be handled carefully during transportation and installation.

Handling Reinforced Concrete Pipe

RCP must be handled and moved carefully to prevent damaging the bell (the flared end of the pipe sections), the spigot (the narrow end that is inserted into the bell of an adjoining pipe) and any bells of pipes that are cemented into short sections of RCP to create a wye fitting. RCP should never be dragged to the site. It is best if the pipes are unloaded with the use of a nylon sling or other certified material that can support the weight of the pipe. The pipe must be balanced precisely in the sling for safety and to prevent damage.

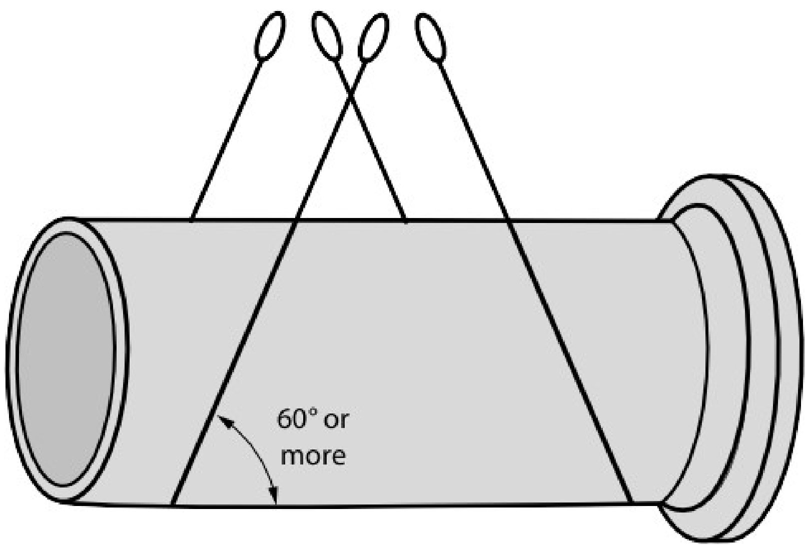

Figure 9 Lifting reinforced concrete pipe section

When storing pipes prior to their installation, set the pipe sections on dunnage on the ground to both protect the pipe ends from being damaged by the pipe's sheer weight and to allow easier access for re-slinging.

Excavating for Reinforced Concrete Pipe

Trenches for RCP should be wide enough to accommodate at least two pipes. This provides sufficient room to verify the required slope, and it helps ensure that any subsequent trenching will not impact the pipe installation or compromise worker safety. The grade (pipe slope) is established during trenching, followed by laying down a bedding material. The bedding should be free of debris and must provide a uniformly level surface. When setting RCP into the trench prior to installation, the pipes should not be supported on their bells, as this can damage them. As previously mentioned, dig bell holes wherever necessary.

Figure 10 Installing two pipes in one trench

Preparing Joining Surfaces of RCP

Just before installation, each RCP section is cleaned to remove all dirt from the pipe's bell. If the surface is not properly cleaned, it may prevent proper homing of the pipe. After cleaning, workers apply a lubricant to the pipe bell, using a brush or gloves. Lubricant should be sufficient to prevent the gasket from rolling away and damaging the bell end. Next, the spigot or tongue end of the adjoining pipe is also cleaned and lubricated to ensure a good seal with the joint gasket.

Installing RCP

Installing each section of RCP requires at least two workers to manage the pipe. The pipe is lowered into the trench with a crane or backhoe, while the workers guide the pipe section into place. Typically, the spigot end of the new pipe is inserted into the bell of the pipe at the end of the installed pipeline, then the new section is pushed into place with a crowbar, pipe pullers, or other means.

Some RCP must have its bell gasket stretched, using a rounding device. The device is passed several times along the circumference of the gasket to make sure everything is in place. If the gasket is not stretched, the pipe could leak at the joint or the bell can crack.

Once the new section is fully seated, workers make sure it is properly aligned, using surveying or leveling instruments.

Backfilling Reinforced Concrete Pipe

The final step of installing RCP is to add bedding and backfill material and compact it thoroughly. The bedding material is placed evenly in lifts on both sides of the pipe until the trench is filled about one foot above the top of the pipe. The spoils may then be replaced into the trench.

It is important that the spoils are not bulldozed into the trench or dropped directly onto the pipe. The backfill material must not contain large boulders, which do not compact and could damage the pipe. The material also should be free of roots and other organic material.

Once the pipe is adequately backfilled and compacted, the trench can be filled up to grade, per the project specifications. At any stage during the backfilling process, heavy construction equipment should not drive over the pipe until adequate backfill is in place or the pipe is deep enough that it will not be damaged.

Now complete Self-Test 3 and check your answers.

Self-Test 3

Self-Test 3

1. What is the point known as that is the basis for determining any elevations surrounding a sewer pipe installation?
    a. A geodetic elevation
    b. A necessary elevation
    c. An assumed elevation
    d. A benchmark elevation
2. What would be the grade on a sanitary sewer that is 60m long if the starting and ending elevations were 72.875m and 71.350m?
    a. 1%
    b. 1.5%
    c. 2%
    d. 2.5%
3. Generally, what is the minimum width of a trench if a small “jumping jack” compactor is meant to be used in it?
    a. 18 inches
    b. 12 inches

    c. 10 inches
    d. 6 inches

4. What trenching feature allows bell and spigot pipe to be installed so that it is uniformly supported along its length?
    a. Bell holes
    b. Pipe stands
    c. Piers and blocks
    d. Spigot supports
5. If a backwater valve is required to protect a building from sewer backup, what are the two main points to be considered?
    a. It is accessible and normally closed
    b. It is accessible and installed on a branch
    c. It is at least 6″ diameter and normally open
    d. It is normally closed and installed on a building sewer
6. Which one of the following would likely be the best choice for ensuring that buried pipe is not accidently contacted when digging in that area?
    a. Lay warning tape on the trench bottom
    b. Pour concrete on top of the buried pipe
    c. Lay warning tape on top of the first lift of compacted spoils
    d. Provide at least 600 mm (2 ft) of fine bedding material over the top of the pipe
7. Which one of the following choices would be preferred where heavy loads may occur on top of pipe that is shallow in its burial depth, such as under public roadways?
    a. PVC
    b. RCP
    c. ABS
    d. HDPE
8. Which one of the following would *not* be a good choice for trenching operations?
    a. Grade and compact the trench bottom before installing any pipe
    b. Bulldoze the spoils back into the trench once haunching has been compacted
    c. Lay the pipe sections on dunnage beside the trench near the installation point
    d. Compact the bedding and backfill in lifts of approximately 300 mm (1 ft) depths

Check your answers using the Self-Test Answer Keys in Appendix 1.

Media Attributions

- Figure 1 Builders level on tripod by Greg Wirachowsky is licensed under a CC BY-NC-SA

Competency A2: Install Manholes and Catch Basins

It is important that plumbers have a basic understanding of the sewer system conveying both sanitary waste and storm runoff. Although plumbers in some jurisdictions may not be involved in the design of manholes and catch basins, they may be involved in the installation and maintenance. Competency A-2 will cover the types, applications, and installation of manholes and catch basins.

Learning Objectives

After completing the learning tasks in this Competency, you will be able to:

- Describe manholes for storm and sanitary systems.
- Describe special types of covers and applications of manholes for storm and sanitary systems.
- Describe the installation of manholes and catch basins.

Resources

You will be required to reference the most current National Plumbing Code.

Learning Task 1

Describe Manholes

A manhole is a composite or concrete chamber installed at specific intervals along sewer lines, that allow access to the pipes entering and exiting them. Sometimes referred to as inspection chambers, manholes allow inspection, cleaning, and maintenance of sewers without needing to dig them up. They are normally installed at every bend, junction, change of gradient or change of diameter of the sewer. The sewer line between any two manholes is normally laid straight with consistent gradient to minimize the chance of blockages forming at any point between manholes.

Types of Manholes

Manhole types are mainly classified into two categories, which are:

- Based on depth
- Based on construction material

Manholes based on depth

Using overall depth as the factor, manholes are further classified into three categories, these being:

- shallow manholes
- normal manholes, and
- deep manholes

Shallow manholes

Manholes with a depth of 0.75m to 0.9m (2.5 to 3 ft) are called shallow manholes. They are used where the expected amount of traffic over them is low and, consequently, the piping between them is at relatively shallow depths. These manholes can be either round or rectangular in shape and are sometimes referred to as inspection chambers.

Normal manholes

A manhole with an overall depth greater than 0.9m (3 ft) but not more than 2m (6 ft) is called a normal manhole. These manholes typically have a thick cover to support heavy loads over them and, similar to the shallow variety, are either round or square in shape.

Deep manholes

Deep manholes are those with an overall depth of more than 2m (6 ft). These types of manholes are mainly circular in shape and consist of multiple "stacked" sections rather than being one-piece like the shallow or normal manholes.

Manholes based on construction material

Depending on the construction material used, manholes fall into three categories, which are:

- precast concrete manholes
- plastic manholes, and
- fiberglass manholes

Precast concrete manholes

This type of manhole is precast (constructed off-site) and is the predominant style that is used worldwide. It has two steel cable loops embedded in the concrete and protruding out of opposite sides of each section, used for lifting it. They may also have anodized steel rungs embedded to form a self-contained ladder for easier access and egress. Runged sections are rotated so that the rungs are aligned vertically. Precast concrete manholes are available with or without a poured bottom.

Plastic manholes

Plastic manholes are made of polyethene material, which makes them lighter than the concrete versions, allowing for possible placement by hand. They come in various thicknesses and the walls can be either smooth or ribbed. They normally have a bottom to them for structural integrity. Once buried, they normally won't be affected by ultraviolet rays from the sun and so should last many years. Plastic manholes do not require much maintenance and are highly resistant to the effects of corrosive liquids and soils.

Fiberglass manholes

Like plastic manholes, fiberglass manholes are lightweight, durable, and easier to handle than the concrete versions. Also like the plastic varieties, they commonly have a bottom built into them and generally have more strength than the plastic versions but also tend to be more expensive than plastic. Pipe penetrations are accomplished in a similar fashion to that of the plastic manholes.

Manhole covers

Manholes have lids that normally have a smaller opening built into them for access to the manhole. If the lid is flat, the smaller opening is cast eccentrically into the lid, allowing the lid to be rotated to align the smaller opening with the self-contained ladder below it. Tapered precast sections are also available for the same purpose, as seen below.

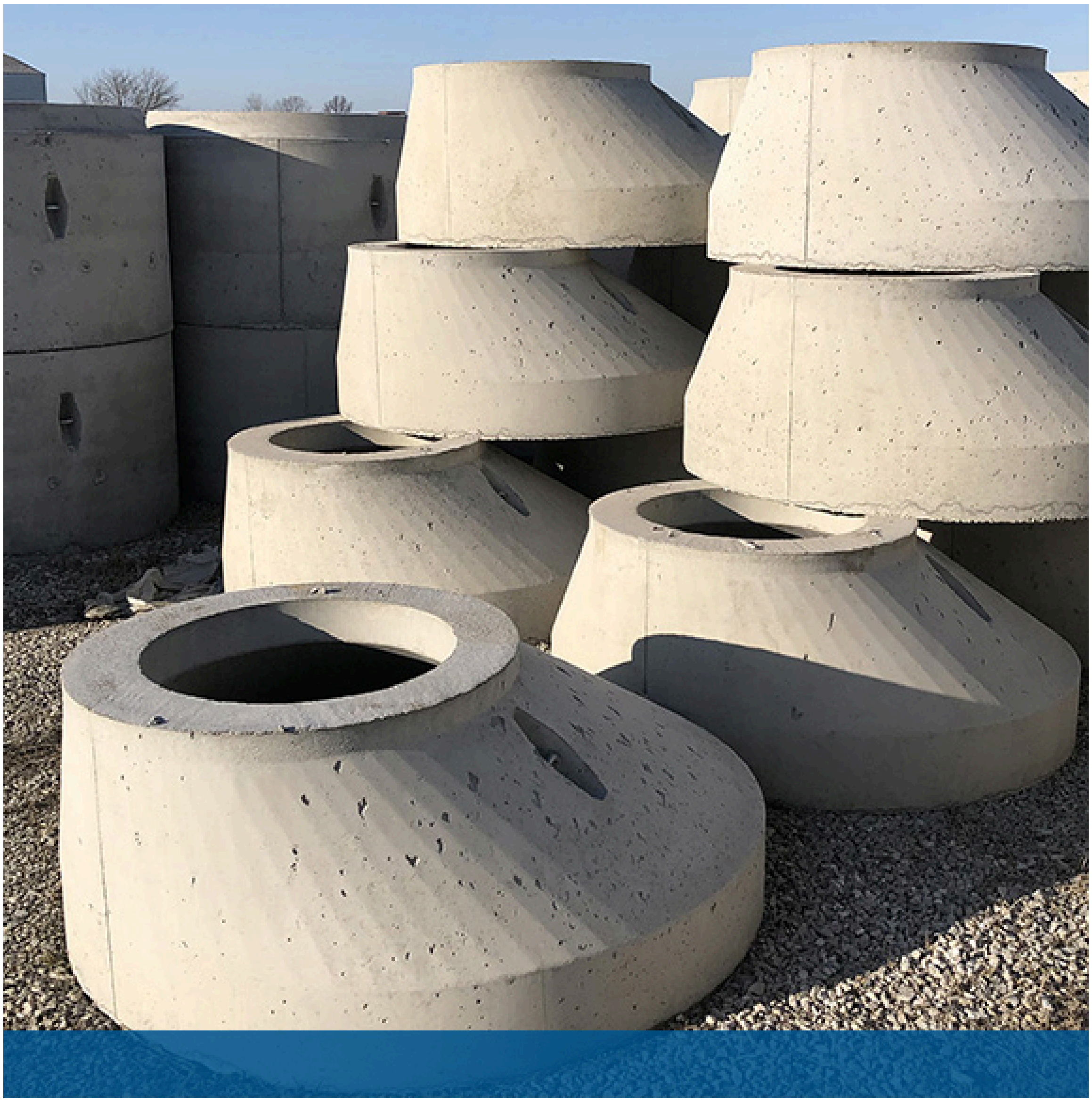

Figure 1 Tapered precast concrete barrel sections

Traditionally, manhole covers are constructed of cast iron, concrete, or even a combination of the two. These materials are preferred due to specific qualities like durability, cost, and being heavy enough to stay in place without needing a locking mechanism. However, technology has led to various alternative manhole cover materials like composites, fiberglass, and plastic. Recessed type covers are used for residential projects and service industry projects like hospitals, hotels, malls, etc. Ductile iron covers are often used for airports, docks, roads, and pedestrian walkways where long lifespans in heavy traffic areas is required. Solid top covers are preferred in industrial areas and heavy-duty manufacturing workshops.

Figure 2 Manhole lid and cover

Figure 3 Plastic manhole cover

Applications

While manholes were initially meant to provide workers with access to pipes and other underground utilities, they are often used for equipment access as well. They can be an access point for an underground public utility such as an underground storm reservoir or lift station, allowing inspection, maintenance, and system upgrades. Most underground services utilize manholes, including water, sewers, telephone, electricity, storm drains, district heating, and gas. Work crews can lower inspection cameras into manholes to gather CCTV footage to assist in determining the need for cleaning and routine maintenance. Manholes also allow the placement and use of remotely controlled equipment. This keeps people above ground and immune from the possible safety and cost implications of entering a confined space that may contain fumes, bacteria, debris, and sewage flows.

Manhole Locations

Indoor Manholes

Although mainly used outdoors, manholes are sometimes installed inside commercial buildings to allow access to services such as underground electrical cables. Using this type of manhole, sometimes referred to as a work chamber, cable chamber or vault, an electrician can enter it to inspect and service existing circuits or to add more cables to service new equipment.

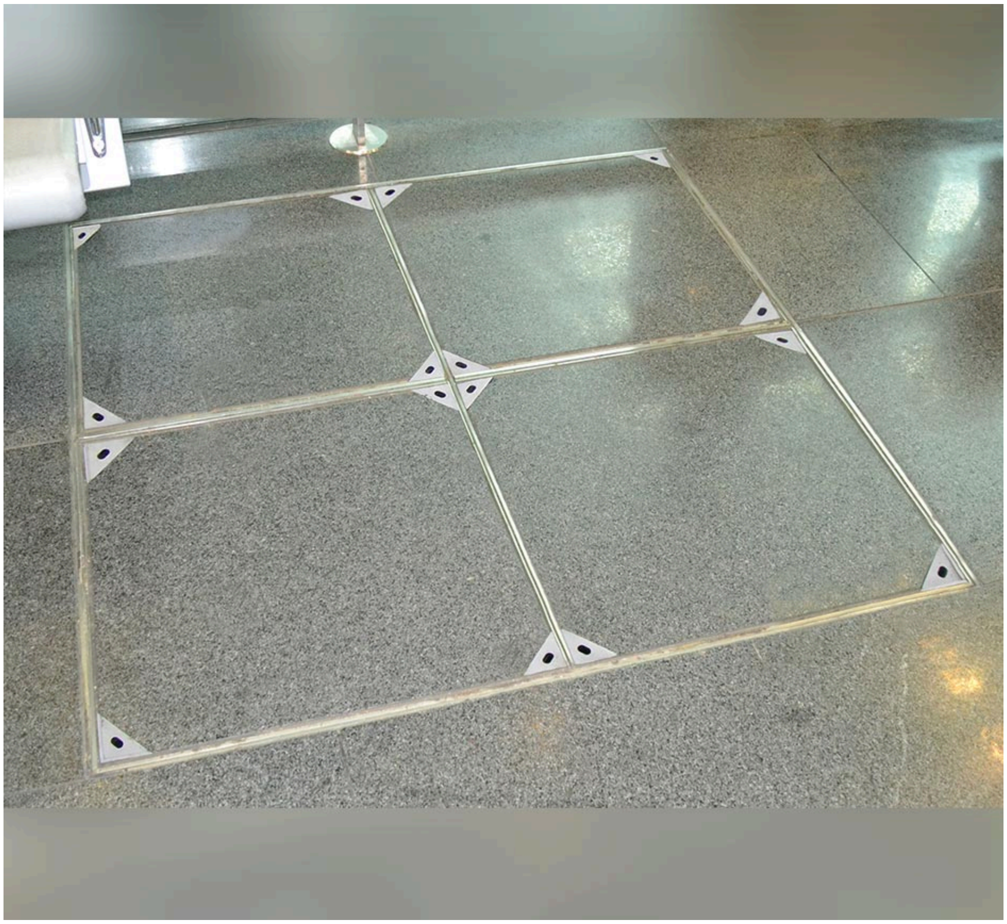

Figure 4 Triple-sealed access cover for interior manhole

Clause 2.4.7.3. (1) (c) of the NPC requires that a manhole installed inside a building needs a vent to the exterior, with Sentence 2.5.7.6. (1) stating that the vent must be a minimum size of 2 inches. The codes don’t specify what the manhole is used for, only that a vent is required if it is indoors.

Storm Manholes

Storm manholes are used in conjunction with catch basins to move untreated stormwater to disposal areas such as ditches or larger bodies of water. Storm manholes can have multiple inlet pipes at varying elevations and usually have only one outlet pipe. Because storm manholes are usually installed with a sealed bottom, there will be a standing water level within it. At the outlet, a hood or a downturned 90-degree elbow with its inlet below the standing water level prevents floating material from entering the outlet pipe. A backwater valve is sometimes installed at the outlet as well. The backwater valve prevents reverse flow back into the manhole caused by downstream drainage issues such as overloading.

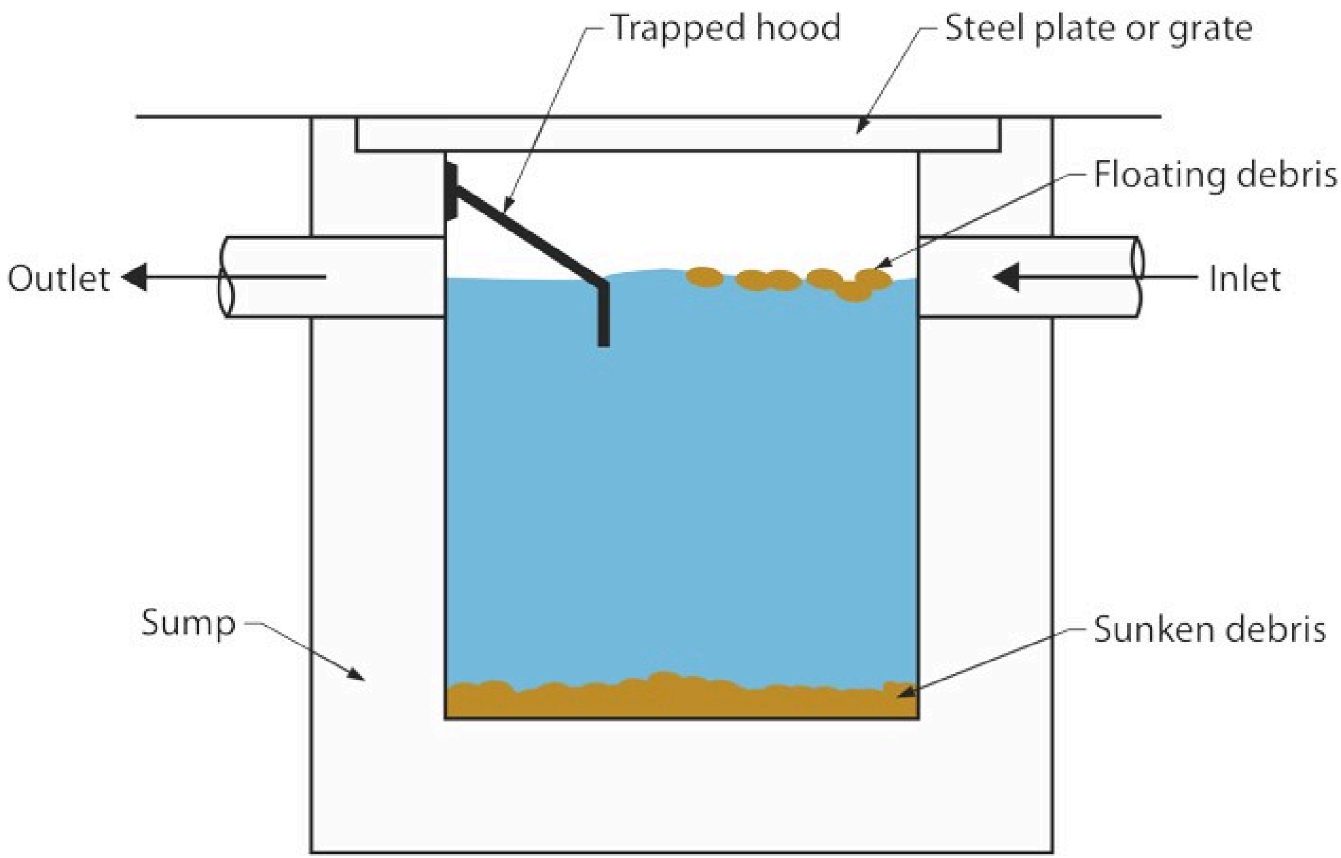

Figure 5 Storm manhole

Sanitary Manholes

Sanitary manholes are used in conjunction with gravity or pressure fed piping systems engineered to move raw sewage to treatment plants. Manholes are commonly placed every 100 – 120m (300-400 ft) in sewer collecting lines, but this may vary depending on municipalities, engineers, codes, and design standards. Sanitary sewer manholes are most commonly made of precast concrete. They have concrete bottoms into which are sculpted channels for moving raw sewage, containing solids, from multiple inlets into a single outlet. The inlets and outlet are at elevations that differ only by the amount of grade required to allow flow by gravity between them.

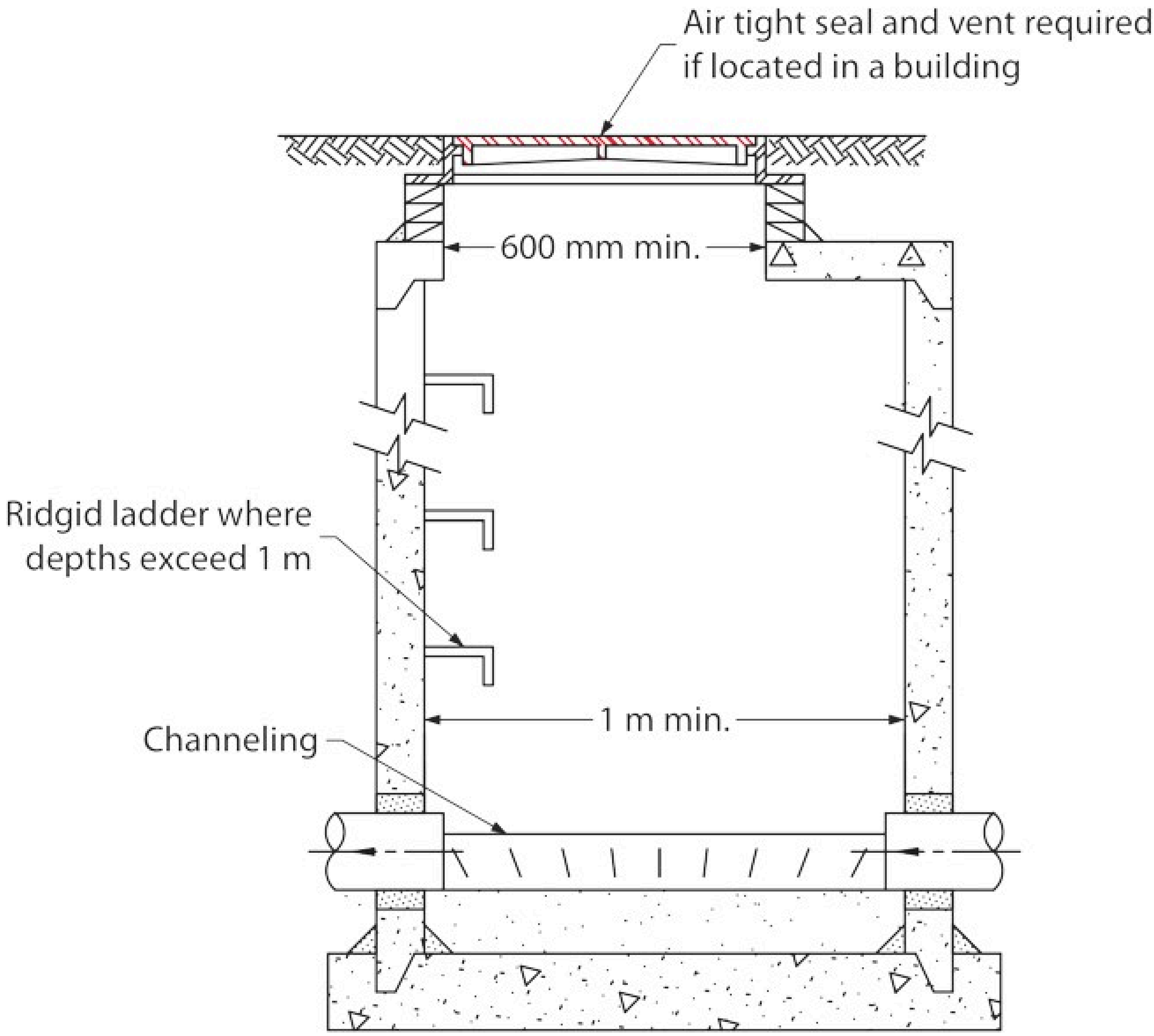

Figure 6 Sanitary manhole

Specialty Manhole Types

Drop Manhole

As previously stated, the flow through a sanitary manhole must be channeled, which means the entry and exit pipe elevations must be almost the same. A drop manhole describes the piping arrangement sometimes provided at the junction point of a high-level sewer inlet and a low-level main sewer outlet. The use of a drop manhole avoids an unnecessary steep gradient of the sewer piping feeding into it and thus reduces the quantity of earthwork required, while it also negates the possibilities of sewage being thrown onto personnel entering the working chamber of the manhole.

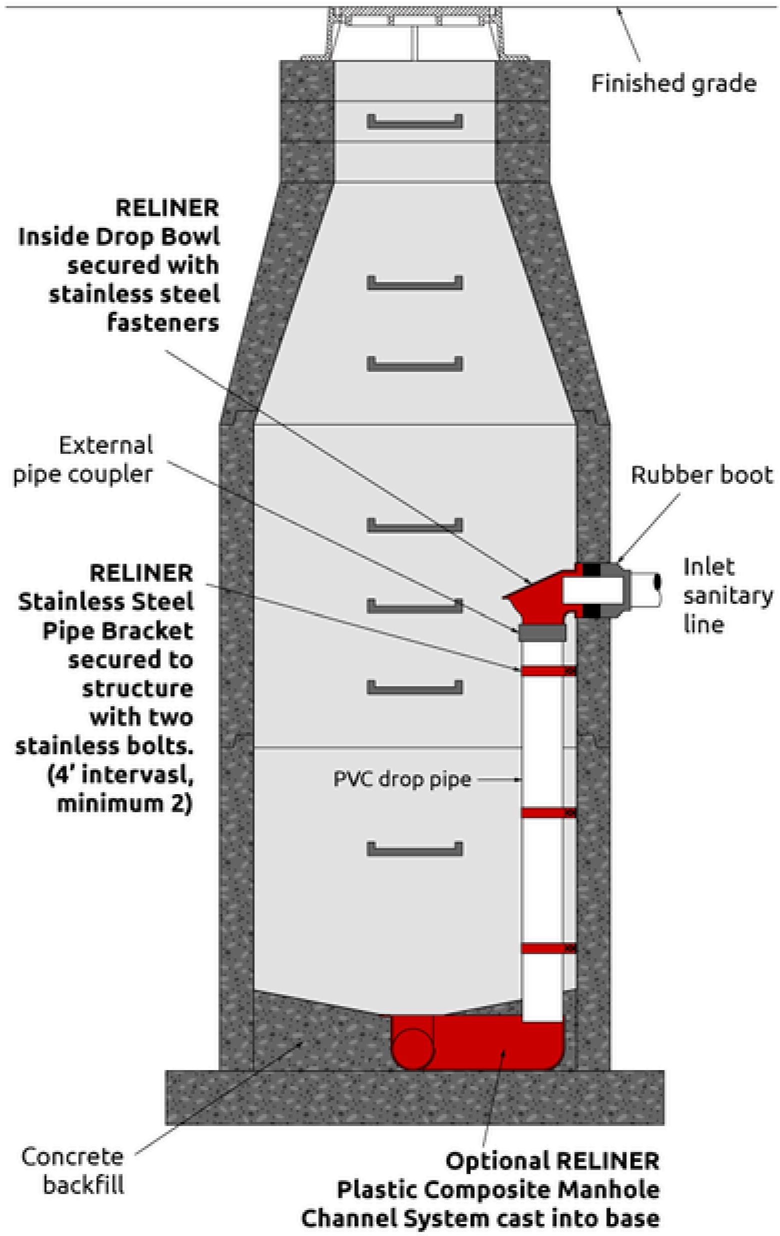

Figure 7 Manhole components

Lamp Manhole

A lamp manhole is a small opening on a sewer that is extended vertically to the ground's surface for the purpose of lowering a lamp or light inside it. The lamp holes were provided at places where inspection of the flow through the sewer was necessary due to bends in the sewer or where there was greater length between manholes than desired due to difficulty in installing or locating a "standard" manhole. A lamp hole could also be used as a flushing point if needed, and if its top cover was perforated, it could assist in the ventilation of the sewer.

Although existing lamp manholes can be found in some jurisdictions, they are not referenced in either the NPC nor the BCPC as such and their allowable use is debatable. Sentence 2.2.6.2. (1) of the NPC alludes to the existence of “maintenance holes” and if a lamp manhole could be categorized as such, it might be allowable by code.

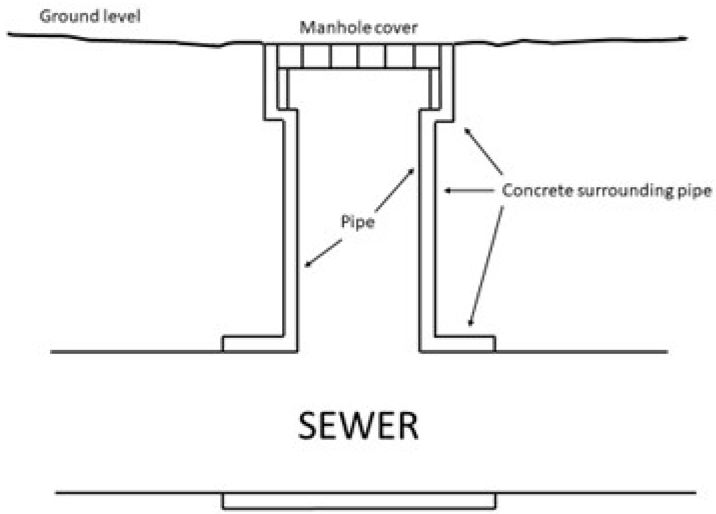

Figure 8 Lamp manhole

Media Attributions

- Figure 1 Tapered precast concrete barrel sections (https://kohnenconcrete.com/wp-content/uploads/2020/03/2-MH-Cones_Feature.jpg) © Kohnen Concrete Products, Inc (https://kohnenconcrete.com/). Used with permission.
- Figure 2 Manhole lid and cover (https://www.flickr.com/photos/gtzecosan/4427168758/in/photostream/) by SuSanA Secretariat (https://www.flickr.com/photos/gtzecosan/) is licensed under a CC BY 2.0 licence (https://creativecommons.org/licenses/by/2.0/).
- Figure 3 Plastic manhole cover by Greg Wirachowsky is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 4 Triple-sealed access cover for interior manhole (https://kentstainless1.b-cdn.net/wp-content/uploads/2020/09/STAINL2-2.jpg) © Kent Stainless (https://kentstainless1.b-cdn.net/). Used with permission.
- Figure 5 Storm manhole by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 6 Sanitary manhole by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 7 Manhole components (https://reliner.com/) © Reliner (https://reliner.com/), used with permission.
- Figure 8 Lamp manhole by Greg Wirachowsky is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).

Learning Task 2

Describe Catch Basins

Catch basins are storm sewer inlets that have a specific function. Their main purpose is to collect or catch surface water from an area and direct it into a storm sewer system. Catch basins are typically found on streets, highways, parking lots, driveways, and landscape areas. They are used in areas which experience significant amounts of storm runoff, helping to collect water before it gets the chance to pool and present flooding issues. Another purpose for a catch basin is to trap or retain debris such as leaves, trash, and dirt so it doesn't make its way into the downstream piping system, which in turn can cause pipes to clog. In this way, it acts as a form of interceptor.

Catch basins can be located on public or private property and can be found next to street curbs, in parking lots, at the bottom of sloping driveways or in the low points of residential and commercial lawn areas. Catch basins also significantly reduce the number of pollutants that enter the storm sewers.

When a catch basin become clogged, it can cause water to pool along streets, yards, and parking lots. In the minimum, this type of flooding can be an annoyance; in a worst-case scenario, the pools of water will increase to the point that they completely flood the surrounding area.

Residential drainage catch basins are usually installed at the lowest point of any area where water gathers. Properties that have uneven terrain may require multiple catch basins. Some of the benefits of having a catch basin are:

- Prevents water pooling
- Protects lawn and landscaping from water damage
- Helps route water away from a home's foundation and driveway
- Lessens mosquito infestation and unpleasant odors from stagnant water

There are two main types of catch basins, which are curb inlet and area inlet. The curb inlet type are normally found on public roads where the roadway abuts the sidewalk. They are usually constructed of concrete and have a cast iron grate at the inlet.

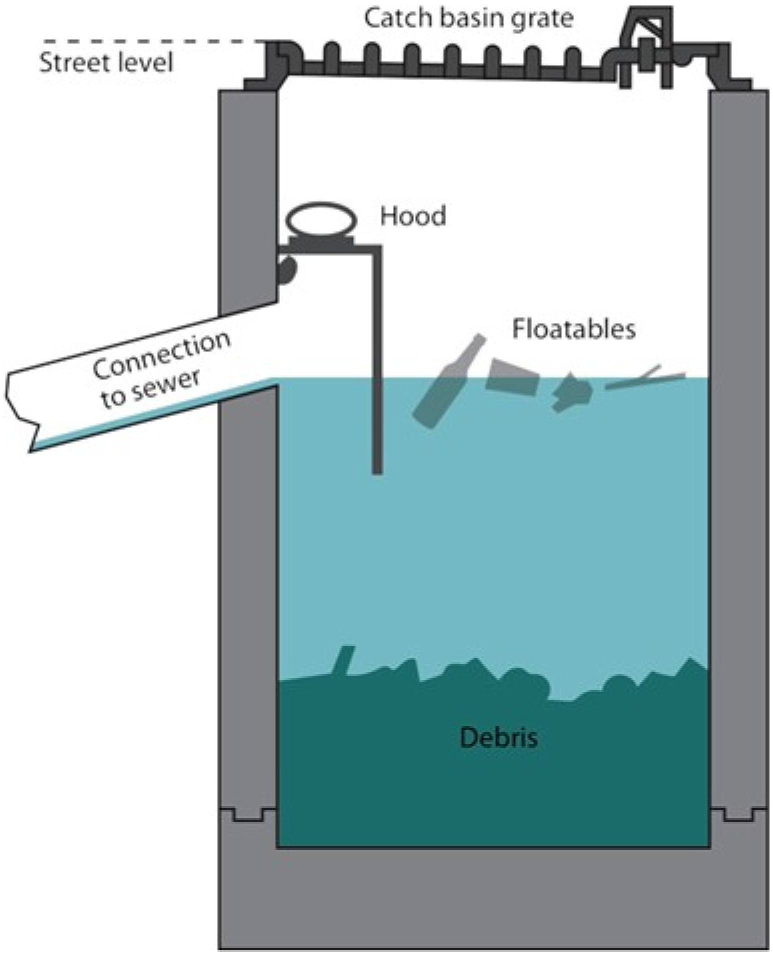

Figure 1 Curb inlet catch basin

Area inlet catch basins are found on both public and private property and are normally installed at low points in paved driveways, parking areas or landscaping. Both the inlet grate and the body of residential area catch basins are normally constructed of high impact plastic, whereas the inlet grate of commercial catch basins is cast iron, with the body constructed of concrete.

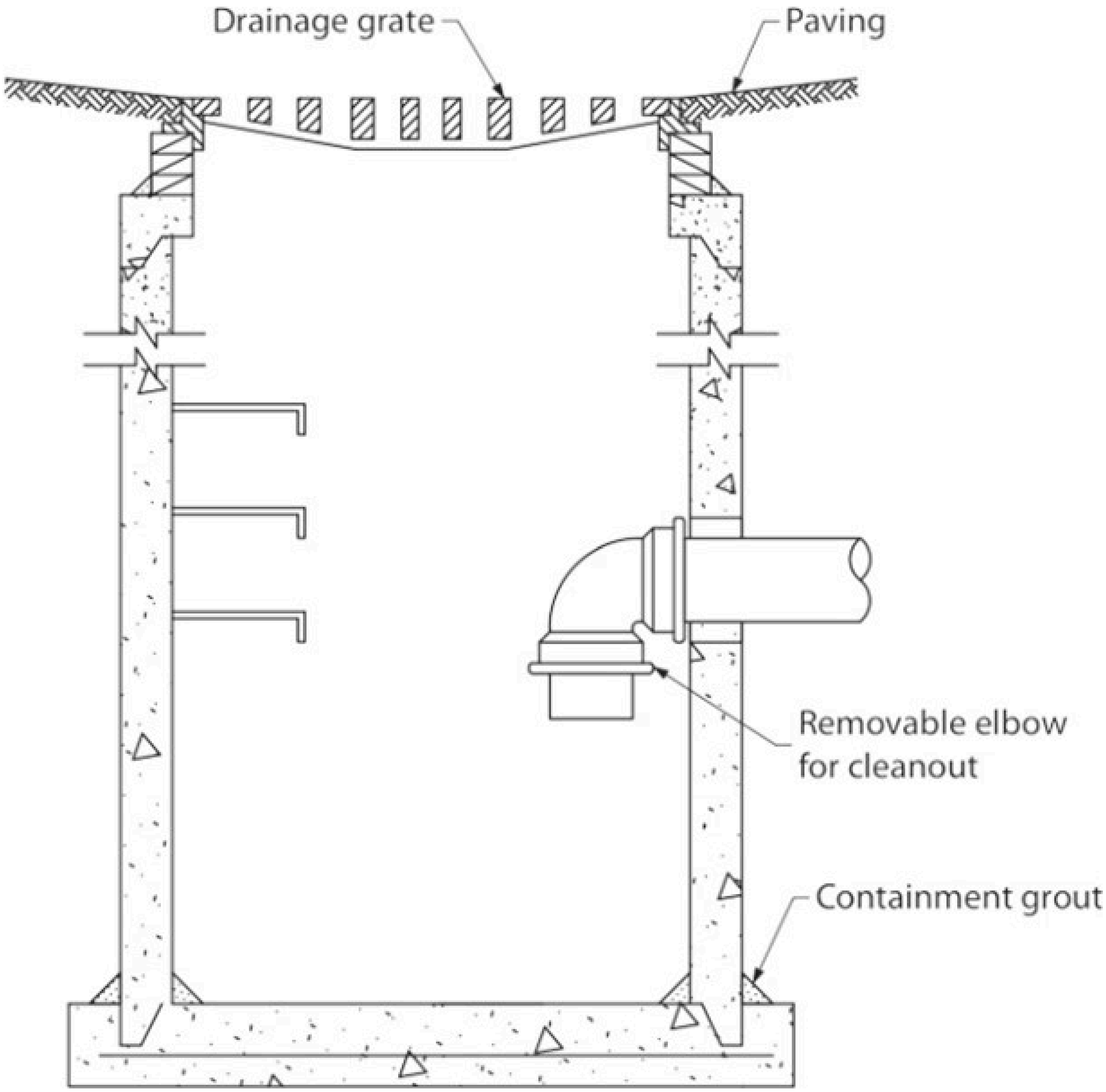

Figure 2 Area inlet catch basin

The flow from catch basins on residential properties is sometimes directed to a dry well as a point of disposal. A dry well is a large hole in the ground, usually filled with large diameter aggregate such as drain rock or “overs” (rock of > 2″ diameter) which is open to native soil on the bottom. They are an outlet for water rather than an inlet. A piping arrangement carries stormwater runoff from roofs or ground areas to the dry well, where it collects and seeps into the soil over time. Other setups use French drains to direct runoff along a natural drainage path to the dry well. The use of dry wells for storm water disposal can ease the burden on municipal storm drains, and some communities now require them. Local area regulations must be consulted before contemplating their use.

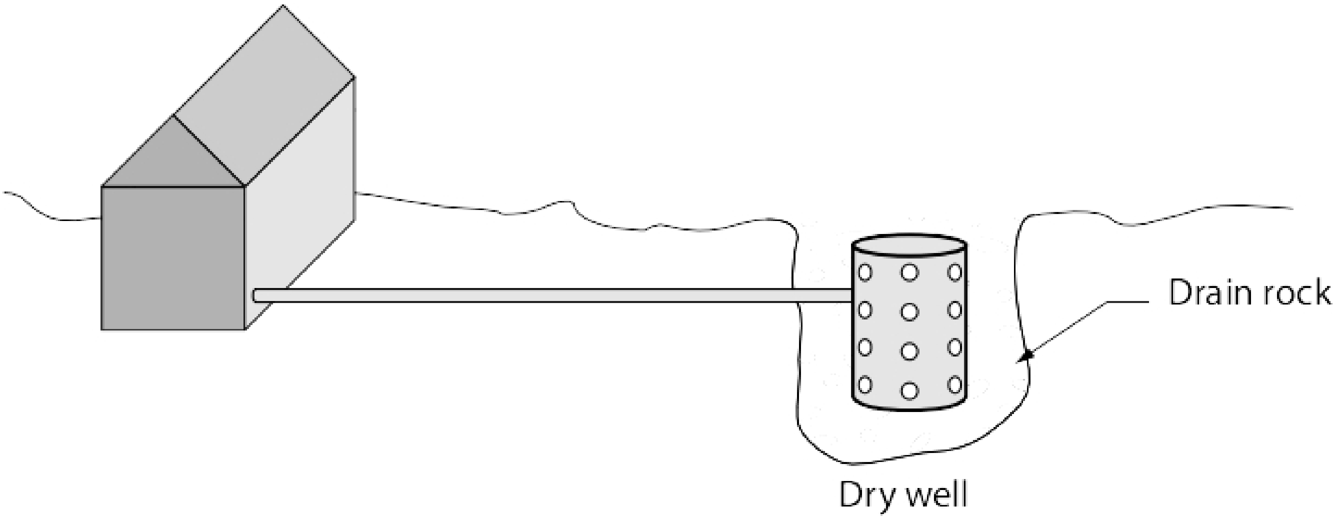

Figure 3 Dry well

Types of Residential Catch Basins

Lawn Catch Basins

If a low point in a lawn area has poor natural drainage, a catch basin can be used to drain water away while intercepting leaves and debris. They come in various sizes of square, rectangular or round bodies and are normally made of plastic, which will normally withstand the weight of a lawnmower or lawn tractor.

Water and solids enter the box through the grate. Solids settle to the bottom while water drains out of the side through a pipe that typically connects to the larger local plumbing system and directs the water to a disposal point such as a dry well, ditch, stream, or sewage plant.

Figure 4 Residential area catch basins

Patio and Driveway Catch Basins

Residential catch basin construction and design is similar in all the above applications, with the size and shape of the inlet grate and basin body being the differing features. Driveway catch basins and grates tend to need a more robust design than the others due to the loads imposed upon them by vehicles, however high impact plastic is the material most often used. Driveway catch basins are normally long and narrow while those meant for patios are round or square.

Figure 5 Driveway area catch basins

Now complete Self-Test 1 and check your answers.

Self-Test 1

Self-Test 1

1. What would a manhole with a depth of 1.5m (5 ft) be classified as?
    a. A shallow manhole
    b. A normal manhole
    c. A deep manhole
    d. An extra deep manhole
2. What is imbedded into pre-cast concrete manholes that are meant to allow for their lifting?
    a. An eccentric lid
    b. A cast iron grate

   c. Steel cable loops
   d. Anodized steel rungs

3. What aspect of a manhole cover allows it to be used without needing a locking mechanism?
   a. Its weight
   b. Its shape
   c. Its colour
   d. Its size
4. According to the NPC and regardless of its use, a manhole installed within a building must have what also installed?
   a. A vent
   b. A drain
   c. A locking access
   d. An automatic high-level alarm
5. What feature of a storm manhole ensures that floating material doesn't enter the downstream piping?
   a. A screen
   b. A trapping hood
   c. A backwater valve
   d. A very deep overall depth
6. What feature of a concrete sanitary manhole is not usually found in a storm manhole?
   a. A ladder
   b. An inlet grate
   c. A downturned 90
   d. Sculpted channels
7. What type of sanitary manhole may be used when its inlet and outlet piping elevations differ greatly?
   a. A drop manhole
   b. A lamp manhole
   c. A concrete manhole
   d. A composite manhole
8. Besides they function to keep leaves and debris from passing into downstream piping, what are most catch basins also considered to be?
   a. A fixture
   b. An interceptor

c. An appurtenance
d. An unnecessary component

9. What is often used on residential properties to dispose of runoff from roofs and that helps ease the burden on a municipal storm drainage system?
    a. A sump
    b. A drywell
    c. A catch basin
    d. A septic tank
10. What type of catch basin has a shape that is usually long and narrow?
    a. A curb catch basin
    b. A lawn catch basin
    c. An area catch basin
    d. A driveway catch basin

Media Attributions

Learning Task 3

Describe the Installation of Manholes

NPC Code Requirements for Manholes

The following are references from the NPC regarding manholes:

- 2.2.5.2.(5) – Concrete Pipe and Fittings: Precast reinforced circular concrete manhole sections, catch basins and fittings shall conform to CSA A257.4, "Precast Reinforced Circular Concrete Manhole Sections, Catch Basins and Fittings"
- 2.4.7.1.(4) – Where a cleanout is required on a building sewer 8 inches or larger in size, it shall be a manhole.
- 2.4.7.3 "Manholes":
    1. A manhole, including the cover, shall be designed to support all loads imposed upon it.
    2. A manhole shall be provided with
        a. a cover that provides an airtight seal if located within a building
        b. a rigid ladder of a corrosion-resistant material where the depth exceeds 1m, and
        c. a vent to the exterior if the manhole is located within a building
    3. A manhole shall have a minimum horizontal dimension of 1m, except that the top 1.5m may be tapered from 1m down to a minimum of 600 mm at the top.
    4. A manhole in a sanitary drainage system shall be channeled to direct the flow of effluent.

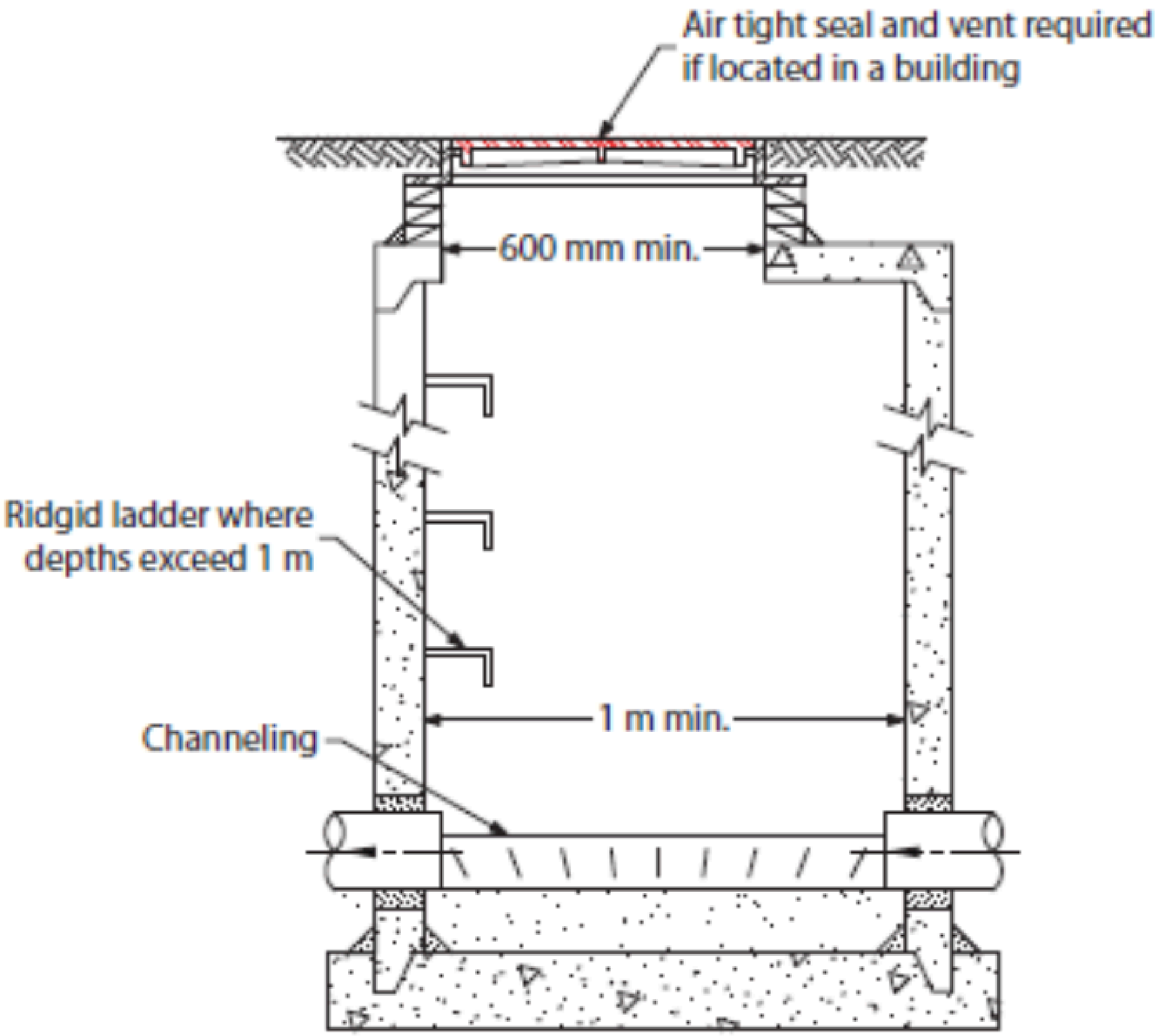

Figure 1 Concrete sanitary manhole

Manhole Installation

The following instruction points are typical of those found in contract documents that apply to a general or mechanical contractor installing manholes and catch basins onsite.

Delivery, Handling, and Storage

- Once the concrete sections have been delivered to site the installer must inspect the components for damage during shipping and unloading, and any non-compliance to approved shop drawings.
- Manhole components shall only be handled with appropriately rated handling equipment from the safe lift points designated by the manufacturer of the precast manhole sections. Manhole ladders, steps or appurtenances are *not* to be used as lifting points.

- When lifting manhole bases and risers, make sure the chain or cable lengths are long enough to prevent contact with the manhole joint area and are kept at appropriate lifting angles. Where safe lifting angles cannot be achieved, use appropriately rated spreader bars.
- If manhole product(s) need to be stored onsite, it is the installer's responsibility to ensure the product is placed on level ground and free from unnecessary mud or debris to prevent damage to the manhole components.
- If any damage or non-compliance is identified, the installer shall take corrective action by notifying the manufacturer. Upon inspection if the damage may affect the performance of the manhole structure, the area shall be repaired. If the damaged manhole component cannot be repaired that component shall not be installed.
- If furnished, special joint materials, such as gaskets, lubricant, and mastic shall be stored securely and in accordance with manufacturer's recommendations.

Excavation and Bedding Preparation

- Shoring if utilized for construction shall be in accordance with all national, regional, and local regulations.
- If shoring is to be removed, the installer shall use the appropriate lifting equipment to safely remove the shoring and to prevent any disturbance or damage to the manhole.
- The manhole foundation should be moderately firm to hard stabilized soil, or compacted fill material with adequate bearing capacity to support the manhole structure.
- A minimum 3 inches [75 mm] thick leveling course shall cover an area not less than manhole base area but preferably 6 inches [150mm] beyond the outside radius of the manhole base. The nominal maximum aggregate size within the leveling course shall not be greater than 1 inch.
- The soil foundation area or bedding under incoming and outgoing pipes should be treated the same as the manhole base section to prevent settlement or shearing of pipes and to provide proper alignment for the watertight connector/pipe interface if resilient rubber connectors are being used.

Installing and Joining

- During installation, set the manhole base on the leveling course making sure the manhole base section is firmly in place and the connectors or pipe openings match design orientation. Verify the top of the manhole base is level in two directions perpendicular to each other.
- Verify the manhole base section pipe openings and/or connectors are at proper grade for pipe inverts to match design elevations.
- Assemble multi-section manhole structures by lowering each section into the excavation. As they are installed, verify each additional riser section is plumb and the joint homed before installing the next riser, conical top or flat slab top.
- Ensure any seals or gaskets are installed correctly. The graphic below shows three common types of manhole rubber seals.

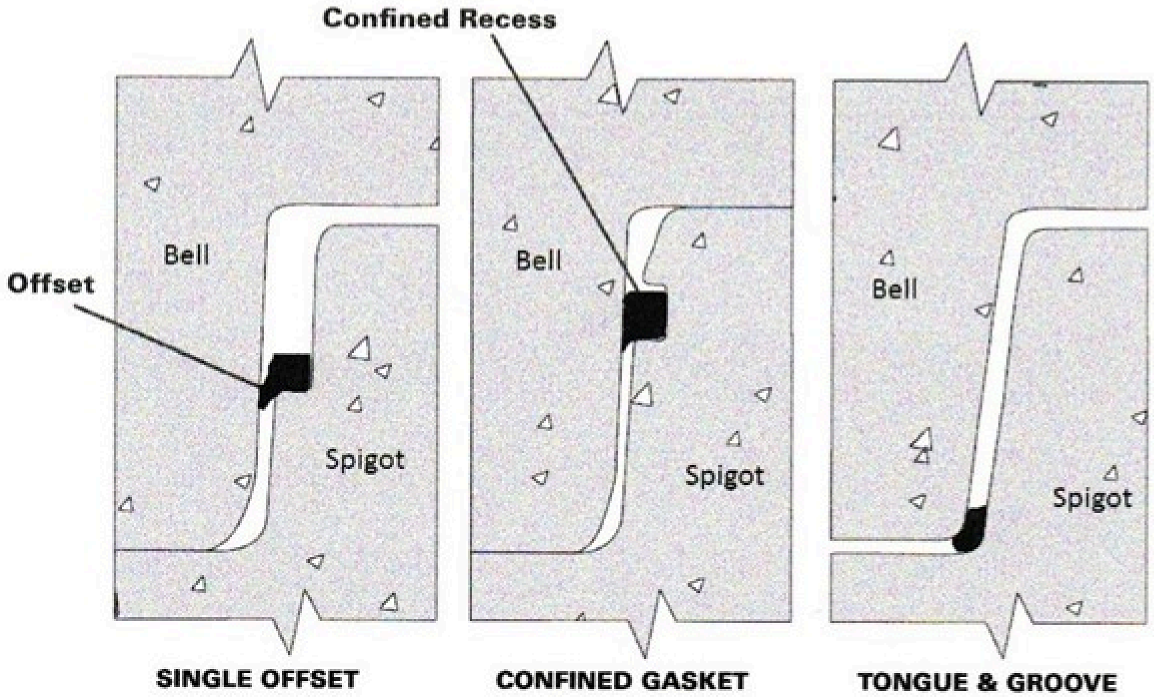

Figure 2 Manhole section seals

- Adjacently placed manhole sections shall be aligned to match the step placement of the preceding section if steps are provided.
- To ensure joint integrity when assembling the manhole structure, the installation contractor is responsible to maintain clean joint surfaces, removing all foreign materials that could damage or impair the jointing surfaces or gasket materials.

Connecting Pipes to Manholes and Field Cutting or Coring

- Any field cut of the manhole structure required for a pipe opening shall be approved by the engineer
- Lifting holes (full penetration "see through") shall be sealed by inserting into the hole a rubber or plastic plug, precast plug with mastic sealant or with an approved cementitious material (or filling the opening with non-shrink grout from inside or outside or both).
- Embedded or cast-in lift anchors ("non-see through") shall have the exposed small pocket volumes filled with non-shrink grout or with an impervious mastic material.

Channeling and Benching

Channels are created at the base of sanitary manholes to eliminate free-fall conditions resulting from invert elevation differentials between incoming and outgoing pipes. The areas surrounding the channels are called benches. There are several methods used by precast manufacturers or contractors to create invert channels in precast concrete manholes. They include installation at the plant and field installation. To ensure the best quality product, inverts should be manufactured in the precast plant along with the manhole section, cured, and then delivered to the site. However, there are specific instances when pouring of inverts must be done in the field, and this situation is the norm. The following precautions should be followed.

Field-Poured Manhole Benching

- For precast manhole bases, the area underneath the manhole base must be excavated to the required elevation. The soil below the base should not be disturbed, or if fill is required it should be properly compacted. The manhole base is then lowered into the trench and checked for proper bearing on the sub-grade, proper elevation, and orientation to receive the incoming and outgoing sewers at the designated invert elevation. The base should be set to the invert elevations specified on the plans. If the base is not set within plan specifications, it may have to be removed and reset.
- The concrete inverts will be formed after connecting the sewer pipes to the manhole. The invert must be true to the sewer pipe invert elevations, with smooth channels of uniform cross section and slope, either straight or with a continuous curve between the inlet and outlet of the pipes. The concrete invert should be placed based on the dimensions and details of the contract plans and specifications. Some installers use dirt, brick, and other loose material as the foundation of the invert and then add a thin coat of concrete on the surface. This method should *not* be used because it does not produce a durable invert, which could lead to future maintenance problems.
- As with invert channels manufactured at the plant, field-poured channels and benching must be constructed only with high-quality concrete. The channels should then be consolidated, finished, cured, and properly placed. The minimum concrete thickness must be 2 inches.
- For onsite-constructed channeling, some installers use pipe of the same dimensions as the intended channel as the form for the channel. The pipe is coated with form oil and pressed halfway into the concrete benching to create a uniform path. The pipe is then removed, and the channel is troweled to a smooth finish.

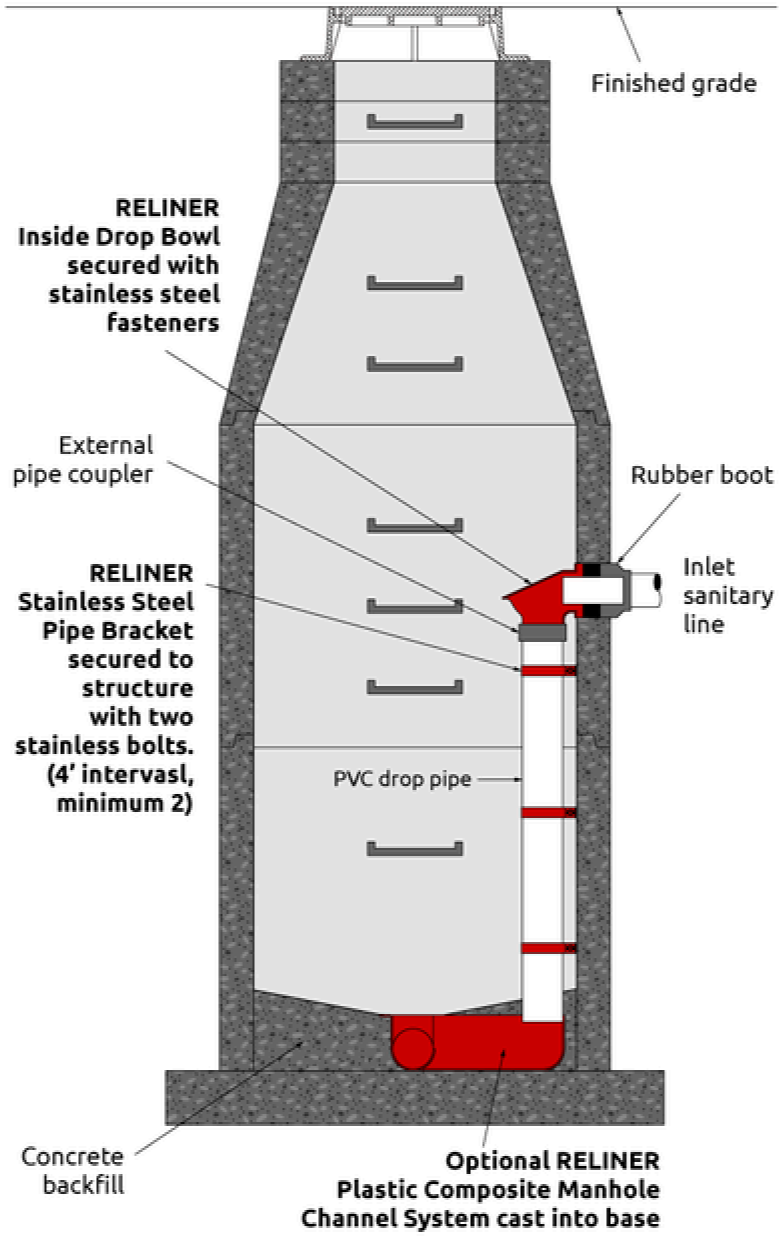

Figure 3 Manhole components

Figure 4 Precast channeling

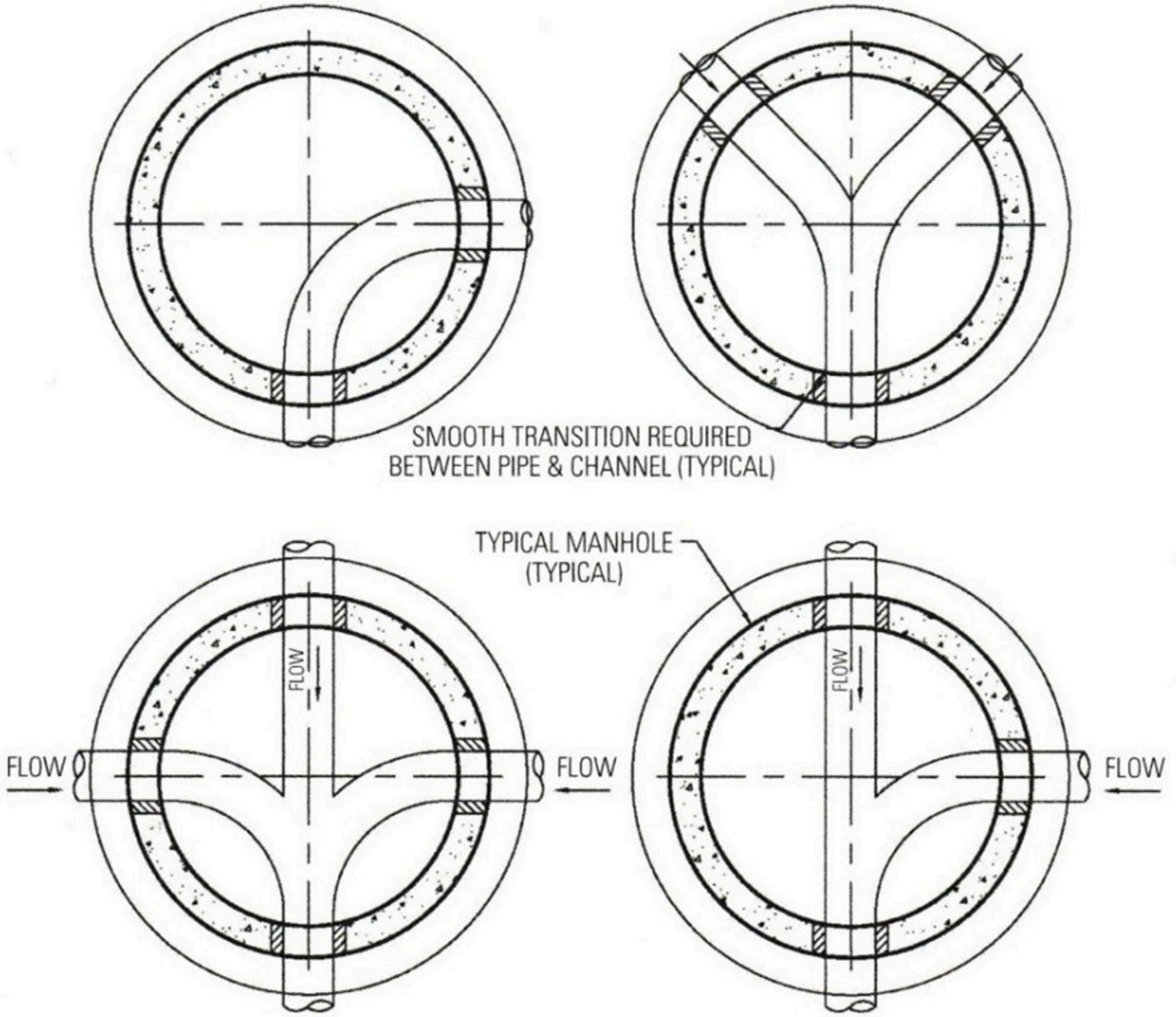

Figure 5 Examples of suggested directional changes through a manhole

Backfilling and Restoration

- Excavations shall be backfilled with an approved or specified soil material free from large stones, rocks, pavement, and other items that could damage the installed manhole structure. Expansive soil material shall not be used as backfill around the structure.
- When a precast concrete manhole structure is placed in an unpaved area, slope the area around the entrance frame and cover to provide drainage away from the entrance cover. Slope the final grading upward to within 1 inch (25 mm) of the top surface of the frame and cover.
- Backfilling shall be achieved by using lifts (layers) and compaction efforts or flooding (jetting) the excavation to meet the required soil density requirements.
- The installer must take special care and placement of bedding and backfill material under and

surrounding pipe connections to manholes to provide firm, uniform support of the pipe at these junctions. This compaction effort is to reduce the potential of pipe shear at the manhole interface due to differential settlement of the surrounding soil.

Media Attributions

- Figure 1 Concrete sanitary manhole by ITA is licensed under a CC BY-NC-SA licence (https://creativecommons.org/licenses/by-nc-sa/4.0/).
- Figure 2 Manhole section seals © photo courtesy of the National Precast Concrete Association (https://precast.org/).
- Figure 3 Manhole components (https://reliner.com/) © Reliner (https://reliner.com/), used with permission.
- Figure 4 Precast channeling (https://kohnenconcrete.com/manhole-utility-structures/) © Kohnen Concrete Products, Inc (https://kohnenconcrete.com/). Used with permission.
- Figure 5 Examples of suggested directional changes through a manhole © photo courtesy of the National Precast Concrete Association (https://precast.org/).

Learning Task 4

Describe the Installation of Catch Basins

The following is the lone reference to catch basins within the within the NPC:

> 2.2.6.2. (1) Cast iron frames and covers used with manholes shall conform to CSA B70.1 (Frames and Covers for Maintenance Holes and Catch Basins)

Catch Basin Location and Layout

Catch basins are strategically placed to capture excess water and move it into a wastewater system or other underground system. While many residential properties do not require catch basins, the mandate for those that do will have come from either the architect during the drafting process, the AHJ through the plan approval process, or the general contractor in recognition of specific site conditions that require them. The need for a catch basin "after the fact" should be avoided at all costs because it is much more difficult to install remedial equipment after the site has been landscaped.

Here are some points to consider in determining where a catch basin may be needed, and points to help in its installation.

Pick the Location

If it's already clear where the drain needs to be, start by planning the material and height that will be needed for optimal water handling and capture. If necessary, it's helpful to wait until a heavy rain to observe where water and debris tend to flow and gather, provided possible damage from flooding during the process doesn't occur. Having a slight slope of at least 1% (approx. $\frac{1}{8}$″/ft) toward that area will be ideal for directing water there.

Install the Catch Basin

A hole slightly deeper and larger than the catch basin itself should be dug. This will allow the placement, compaction and leveling of bedding material under the basin. This is especially important if there is to be any vehicular traffic on top of it. Make sure the construction of the catch basin will support those potential loads. The catch basin can be bedded and backfilled enough to allow the attachment of the piping without dislodging the basin.

Create the Trenches

Trenches should be wide enough to contain the pipes, with about 3 inches of clearance on either side for working room and bedding. Make sure to grade the trenches to a minimum of 1% (approx. $\frac{1}{8}$″/ft) or to the grades specified in the plans. Trenches should start at the catch basin and be dug straight towards the junction of other drainage pipes or its destination. Any changes in direction should be accomplished by using manufactured fittings. If not using sand or other fine bedding material, make sure there are no large rocks or boulders left in the trench that may damage the pipe. If the ground is made of aggregate that allows good drainage through it, it is sometimes a good idea to line the trench bottom with drain rock and use perforated sewer pipe which creates a “French drain”; if not wishing to let any water seep out into the surrounding soil, sewer pipe with tight joints should be used and the trench bottom should be compacted.

Lay the Pipe

Now it’s time to lay the pipes in the trench. Start by connecting the first pipe to the catch basin, bedding and backfilling it just enough so that the pipe doesn’t shift when the next section downstream is attached to it. “Flow-through” type catch basins have an inlet and an outlet so they can be installed inline on a run of pipe. This only works if the top of the catch basin grate is exactly at the desired elevation; if it isn’t, subsequent downstream catch basins are installed and connected to the piping through a wye fitting.

Testing and Back-Fill

Using water from a hose, test out the system. Get a good flow of water going through the most upstream catch basin and look for leaks or problem areas that should be fixed before the back-filling process. Make sure the flow into the catch basin is smooth. Once satisfied there are no issues, back-fill the trenches and holes with sand, gravel or whatever material has been specified. If inspection is required, it should be done at this step. Once tested and inspected, the backfilling can be completed and the final grade can be met.

Now complete Self-Test 2 and check your answers.

Self-Test 2

Self-Test 2

1. According to the NPC and BCPC, what is the minimum horizontal dimension of a manhole?
    a. 1 m
    b. 1.5 m
    c. 2 m

d. 3 m

2. According to the NPC and BCPC, a ladder is required to be provided with a manhole if it is over what minimum depth?

    a. 600 mm
    b. 1 m
    c. 1.5 m
    d. 2 m

3. What is the minimum suggested thickness of a leveling course of compacted fill used to set a manhole onto?

    a. 1 inch (25 mm)
    b. 3 inches (75 mm)
    c. 6 inches (150 mm)
    d. 12 inches (300 mm)

4. How far beyond the outside edge of a manhole should the leveling course from the previous question extend?

    a. 1 inch (25 mm)
    b. 3 inches (75 mm)
    c. 6 inches (150 mm)
    d. 12 inches (300 mm)

5. What is the area surrounding the channels in a sanitary manhole called?

    a. Slurry
    b. Seating
    c. Flat area
    d. Benching

6. What do some installers use as a form for the channels in a sanitary manhole, if they are not pre-cast into the base?

    a. Pipe that is the same diameter as the channel
    b. Treated wood sawn into a semi-circular shape
    c. Pipe that is one diameter larger than the channel
    d. Large, smooth river rock that is then removed before troweling

7. What should be the minimum thickness of the high quality concrete used for benching and channeling?

    a. 1 inch (25 mm)
    b. 2 inches (50 mm)
    c. 3 inches (75 mm)

d. 4 inches (100 mm)

8. To effectively direct surface runoff water to a catch basin, what should be the minimum amount of slope for the ground area surrounding it|?

   a. 0.5% ($\frac{1}{16}$″/ft)
   b. 1% ($\frac{1}{8}$″/ft)
   c. 1.5% ($\frac{3}{16}$″/ft)
   d. 2% ($\frac{1}{4}$″/ft)

9. The use of drain rock and perforated sewer pipe to collect or disperse water is known as what?

   a. A “French” drain
   b. An “English” drain
   c. A “European” drain
   d. A “North American” drain

10. What type of catch basin has a grate as well as a pipe inlet and a pipe outlet?

   a. A concrete type
   b. A prohibited type
   c. A double pipe type
   d. A flow-through type

Check your answers using the Self-Test Answer Keys in Appendix 1.

Appendix 1: Self-Test Answer Keys

Competency A1

Self-Test 1

1. a. At the property line
2. c. Drainage
3. d. Combined
4. a. Vitrified clay
5. b. ABS
6. b. Trench cave-ins
7. a. Air quality
8. c. Pinch point hazard
9. c. It pumps sewage from a deep sewer to a higher elevation
10. b. Gravity

Self-Test 2

1. c. On private property only
2. b. 1 ft^3 of water through a 1 ¼″ OD pipe in 1 minute
3. b. Litres per 15 minutes
4. c. National Building Code of Canada
5. d. The manufacturer
6. a. Fixture units
7. d. 2,360 litres per 15 minutes
8. c. 2,730 L/15 min
9. c. A sanitary building drain
10. c. 2%

Self-Test 3

1. d. A benchmark elevation

2. d. 2.5% 72.875 – 71.350 = 1.525m 1.525m ÷ 60m = 0.025m/m = 2.5%
3. b. 12 inches
4. a. Bell holes
5. b. It is accessible and installed on a branch
6. c. Lay warning tape on top of the first lift of compacted spoils
7. b. RCP
8. b. Bulldoze the spoils back into the trench once haunching has been compacted

Competency A2

Self-Test 1

1. b. A normal manhole
2. c. Steel cable loops
3. a. Its weight
4. a. A vent
5. b. A trapping hood
6. d. Sculpted channels
7. a. A drop manhole
8. b. An interceptor
9. b. A drywell
10. d. A driveway catch basin

Self-Test 2

1. a. 1 m
2. b. 1 m
3. b. 3 inches (75 mm)
4. c. 6 inches (150 mm)
5. d. Benching
6. a. Pipe that is the same diameter as the channel
7. b. 2 inches (50 mm)
8. b. 1% ($\frac{1}{8}$″/ft)
9. a. A “French” drain

10. d. A flow-through type

Versioning History

This page provides a record of edits and changes made to this book since its initial publication. Whenever edits or updates are made in the text, we provide a record and description of those changes here. If the change is minor, the version number increases by 0.01. If the edits involve substantial updates, the version number increases to the next full number.

The files posted by this book always reflect the most recent version. If you find an error in this book, please fill out the Report an Error (https://collection.bccampus.ca/report-error/) form.

Version	Date	Change	Details
1.00	Jan 11, 2023	Book published.	
1.01	April 5, 2023	Added content.	Added introductory text and “Learning Objectives” in each competency.