Technical Information
Document

COMMUNITY
WATER SYSTEMS

RPS for INAC
TID-MS-01
October 2000

Table of Contents

LIST OF FIGURES

Foreword

This document is a general awareness publication. It is intended to provide an overview and general appreciation of community water systems including water supply, treatment, and distribution.

Policy and Standards

Policy and standards related to community water systems in First Nation communities are addressed in the DIAND Corporate Manuals System (CMS) policy document “Capital Facilities and Maintenance - Water and Sewage Systems.” The Levels of Service Standard and Design Standards established for community water systems are included in the CMS policy document.

Scope

This document presents information on community water systems including water supply, treatment and distribution. It is intended to provide information to Band Managers and DIAND Funding Services Officers on the various elements of community water systems including the following:

- Water Sources
- Water Demand
- Water Distribution
- Water Quality
- Water Treatment

Responsibilities

Community water systems should be designed by a qualified and experienced professional engineer. Drawings and reports should bear the stamp or seal of the licensed professional engineer who is responsible for the design. The engineer should be registered in the province where the project is located.

Part 1: Water Sources

1.1 General

When assessing a potential drinking water source, the following factors should be considered:

- Health - Is the water safe for human consumption?

  Water can be responsible for the transmission of human diseases such as typhoid fever and hepatitis. It is therefore important to choose a water supply that will be able to produce a drinking water free of bacteria, micro-organisms, or other compounds that could be hazardous for human consumption.

- Aesthetics - Is the water pleasing in taste, free of colour and odour, and clear in . . . appearance?

  Physical aesthetic tests do not measure the safety of a water supply, but they do give an indication of how acceptable the water will be to the user.

  Water supplies should be palatable. If the water is safe but not acceptable to sight, taste, or smell, the user will either drink amounts insufficient to meet physical needs or resort to other waters which, while pleasant to taste, may be unsafe.

- Quantity - Is there a sufficient quantity of water?

It is imperative that the water needs of all users are met when selecting a water source. An adequate quantity of water should be available for drinking, cooking, and personal hygiene.

In Canada, all water supplies come from two sources: surface water and groundwater. Surface water sources include lakes, rivers and streams, while groundwater sources include wells and springs and are located under the ground.

In selecting the source of water to be developed, it should be determined that an adequate quantity of water will be available and that the water which is to be delivered to the consumers will meet the latest edition of the “Guidelines for Canadian Drinking Water Quality” published by Health Canada.

Each water supply should take its raw water from the best available source for which development and treatment is technically possible and economically reasonable.

1.2 Surface Water Sources

1.2.1 General

Surface supplies of water are much less reliable than groundwater sources in terms of water quality and generally have to be treated in order to make the water safe for drinking. Surface water characteristics vary widely according to the season, local site conditions, and impacts of adjacent users. It is therefore important to test any potential water source to determine its suitability for drinking water.

1.2.2 Rivers

Rivers are commonly a good water source, especially in winter, when there is little surface run-off to lower water quality. The disadvantages of river water as a supply source include low water temperature and flowing ice during freeze-up and break-up periods. Ultimately, this may damage water intake structures.

However, in the summer, the quality of river water commonly decreases due to the receipt of sediments or silts from surface runoff.

1.2.3 Lakes

As a general rule, lakes offer surface water with the most consistent quality. However, they are subject to periods of considerable change in the spring and autumn. During these periods, rapid changes in water temperature cause the deeper layer of water to move towards the surface, bringing with it sediments which temporarily reduce water quality.

1.2.4 Surface Water Intakes

A surface water intake is a structure used to withdraw water from a river or lake. The intake usually consists of a pipe laid on the lake or river bottom with a grate or screen at the end to keep out debris that could clog the collector pipe or the pumps in the on-shore pump well. The surface water inlet is often located at an elevation above the lake or river bottom which provides access to the best available (usually least turbid) water. Depending on the turbidity of the water supply, raw water is pumped either directly to the water treatment plant, or into intermediate off-stream storage.

Designers should consult with authorities having jurisdiction over surface water sources. River intakes should be constructed well upstream from the community and any sewage discharge points to prevent drinking water contamination. The water system operator should be aware of the various maintenance problems that can be encountered with intake structures such as clogging with ice or debris. When clogging occurs, a **scuba** diver is usually required to clean the screen.

1.3 Groundwater Sources

1.3.1 General

Groundwater is generally a better quality source of water than surface water. It maintains a fairly consistent temperature year-round and usually contains fewer contaminants than surface water does. As a result, groundwater usually requires little or no treatment to meet drinking water quality standards, making it a more cost effective water source than surface water.

Since groundwater passes through various layers of earth, the suspended matter in the water is filtered out, therefore improving the water quality to levels beyond that of surface water. Conversely, groundwater is often "harder" than surface water, meaning it contains a greater quantity of dissolved minerals such as calcium and magnesium. Although hard water is not hazardous to human health, it does have an unpleasant taste, prevents the lathering of soap, and leads to scale build-up in kettles and other cooking utensils.

Groundwater may also contain other minerals such as sulphur and iron. Water containing high levels of sulphur may cause bowel disorders and diarrhea. Whereas, water containing high levels of iron will stain laundry and may also cause taste and odour problems. It is therefore important to test any potential water source to determine its suitability for drinking water. Water containing excessive dissolved minerals will require some type of treatment before it is suitable for human consumption.

1.3.2 Wells

A well is a vertical shaft or hole sunk into the ground by digging, boring, or drilling in order to obtain ground water. Figure 1 illustrates a drilled well.

The top of the well should be constructed to prevent surface water from entering. The ground near the well should be graded to divert surface drainage away from the well.

Casings are often used with drilled wells to prevent the walls of the well from collapsing. A cement grout is usually placed between the casing and the well hole to prevent surface water from draining into the well and possibly contaminating it. In addition, a watertight seal or cover is placed on top of the casing.

Shallow wells are generally more prone to contamination than deep wells. This is caused by groundwater in deeper wells travelling a greater distance through filtering soil layers.

1.3.3 Springs

Groundwater can appear at ground surface in the form of springs. There are two types of springs: gravity and artesian.

Gravity springs occur when the groundwater surface intercepts the ground surface. This can occur when there is a sharp drop in surface elevation below the groundwater table or when obstructions to flow, such as a rock surface, intercept the flow of groundwater and force it onto the ground surface.

Artesian springs are usually formed when groundwater enters a layer of porous material (such as sand) which is confined above and below by an impervious layer of material such as clay or rock. The flow of water from an artesian spring is under pressure because it is trapped or confined above the spring outlet.

Caution should be exercised in developing a spring as a water supply source because a spring may prove to be inconsistent in flow and may even stop during a prolonged spell of dry weather.

Springs developed as a water supply are usually housed in some type of permanent water-proof structure. Surface drainage should be diverted away from the spring outlet to prevent contamination.

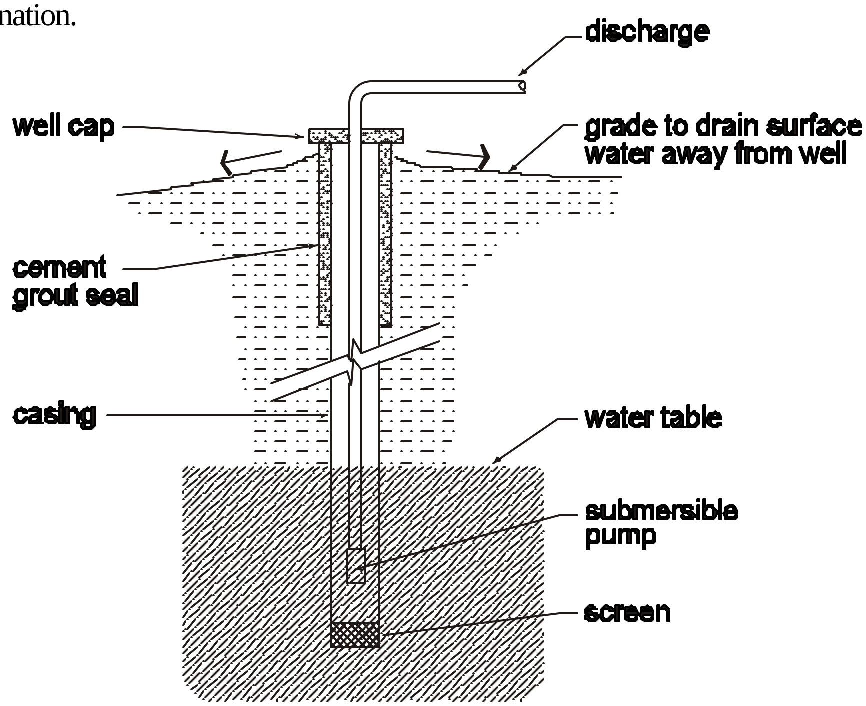

Figure 1: Drilled well.

Part 2: Community Water Demand

2.1 Daily Water Usage

For a small community, the daily water usage per person depends on the type of water distribution system being used, the presence of facilities requiring large amounts of water (such as nursing stations or industrial operations), and other factors such as community lifestyle.

Generally, the most practical system for a community is a fully piped water distribution system with individual house services, plumbing and a full sewer system. Unfortunately, the costs and technical problems associated with such a system can make this option impractical for small communities. In these cases, other systems such as watering points or truck delivery should be considered.

For figures on daily water demand per person for various levels of service, refer to the Corporate Manuals System (CMS) document “Capital Facilities and Maintenance - Water and Sewage Systems”.

2.2 Future Water Demand

To assess the future water demand of a small community, the projected future population must be estimated. A community plan is often a good starting point for estimating future populations as it can indicate any plans for industrial and commercial growth or fire protection. The information gathered on future population growth and fire flow along with data on daily consumption rates should provide a fairly accurate estimate of the community’s future water needs.

Although it is possible to estimate the quantity of water that should be made available to the community, it may not be possible to supply it. If the only acceptable source of water is a low capacity well or spring, the community will need to adapt its lifestyle to suit the water available. On the other hand, major improvements to the water supply system which increase the quantity of water supplied, may lead to an increased use of water. In both cases, it is important that the designer take into consideration any water conservation measures that are available to the community.

2.3 Daily Variations in Flow

The figures referenced in section 2.1 give the average daily water consumption per person. It should be noted that the rate at which water should be supplied will vary during the day with peaks typically occurring at mealtimes. The water source, treatment, and distribution system should be designed to cope with these variations. An operator should be aware of the community's peak usage times when planning repairs and maintenance. Refer to the Corporate Manuals System (CMS) document "Capital Facilities and Maintenance - Water and Sewage Systems" for peaking factors.

2.4 Reservoirs

Reservoirs are water storage tanks (either buried concrete or overhead steel) designed to accommodate the variations in flow described in section 2.3. Storage in a reservoir allows any excess water which is supplied and treated during a period of low demand to be captured and retained for use during a period of high demand. Reservoirs also provide additional water storage for fire protection, which requires a large quantity of water to be supplied over a relatively short period of time.

Elevated steel storage tanks may hold an advantage over buried concrete tanks due to the gravity head possessed by water at a high elevation. Since the water in the elevated steel tank is at a higher elevation than the rest of the distribution system, distribution pumping is not needed. However, elevated steel storage tanks are limited by their inflexibility to increase in storage volume. It may also be necessary to provide freeze protection for the water in an elevated steel storage tank, thereby increasing cost.

2.5 Fire Flow

In addition to the water demand for individual community members, an adequate and reliable water supply for fire fighting should be considered in a community having a piped distribution system. The amount of available water that is considered adequate for fighting fires varies between communities and depends on factors such as construction materials, the distance between buildings, and the water pressure available. Each community should be rated separately based on current fire protection standards. Refer to the Corporate Manuals System (CMS) document "Capital Facilities and Maintenance - Fire Protection Services" for levels of service standards.

Part 3: Water Distribution

3.1 Individual Systems

In these systems, individuals are responsible for finding their own source of water, whether it be by developing a private well or by collecting water from a nearby lake or stream. If properly constructed and maintained, a private well is usually a good source of water for individual residences. Frequently, a larger private well will become the water source for more than one residence.

Since treatment associated with individual systems is rare, any form of pollution is likely to pose a health problem. Generally, surface supplies are more prone to pollution from rainwater run-off than are properly constructed and maintained wells. This fact, combined with inadequate routine testing of individual systems, often places users unknowingly at risk.

3.2 Community Systems

3.2.1 General

A community system collects water at the source (typically from wells or rivers), provides the level of treatment required to make sure the water is safe, and then distributes it to the community. The following information describes the various types of community systems.

3.2.2 Watering Point (Self-Haul)

In this system, water is collected, treated as required, and then conveyed to one or more watering points in the community. A watering point is typically a small building that houses the pressure system and piping needed to provide water to a spout located on the building's exterior. Residents of the community simply fill portable water containers at the watering point spout and then carry it to their homes. Other than offering greater assurance of a safe water supply, the watering point (self-haul) system offers little advantage over the individual hauling system described in section 3.1.

3.2.3 Community Haul System

The community haul system transports water, usually by truck, to user destinations from a water treatment/storage facility equipped with a truck fill (refer to Figure 2). These systems may cater to either plumbed or unplumbed locations in which storage will consist of either outside cisterns or inside holding tanks. Truck haul delivery may be a cost effective option for assuring a relatively safe water supply in instances where housing is too spread out for a piped system to be viable. In evaluating the viability of a trucked system, the costs related to building and maintaining access roads and truck garages, hiring and training drivers and maintenance personnel, and even retrofitting unplumbed homes, need to be considered.

The size of the household water storage tank depends on such factors as the number of residents and frequency of delivery. Tanks and piping should be reliably protected against freezing.

Compared to the self-haul system, the community haul system is considerably more convenient and is potentially safer because the water is centrally treated. However, contamination can still occur through improper handling or failure to periodically clean trucks, hoses, and tanks. Storage tanks should be cleaned and disinfected on a regular basis. The frequency of cleaning and disinfection will depend on the quality of water stored.

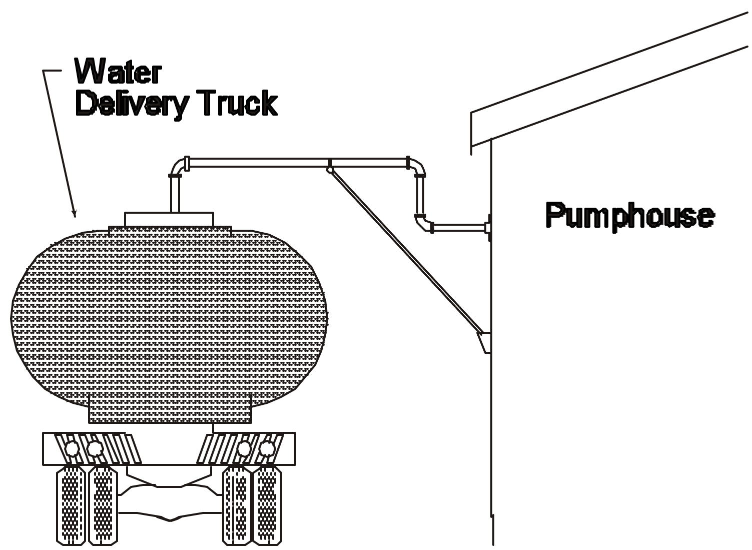

Figure 2: Overhead truck fill point.

3.2.4 Fully Piped Distribution System

In a fully piped system, finished water (cleaned and treated, as required) is delivered through service connections from a buried pipe distribution system into the homes of the users. A small conventional distribution system is shown in Figure 3. Although piped systems are usually the most efficient and safest means of distributing water, it may not be the most cost-effective option. In the instance of houses being widely spread, it becomes unfeasible to provide a conventional distribution system with mains sized to supply fire hydrants and carry fire flows. Alternative distribution methods such as a trucked system or small-diameter low-pressure distribution system should be considered. A small-diameter low-pressure system may provide the convenience and public health safety of a conventional system, but lacks the benefit of fire protection.

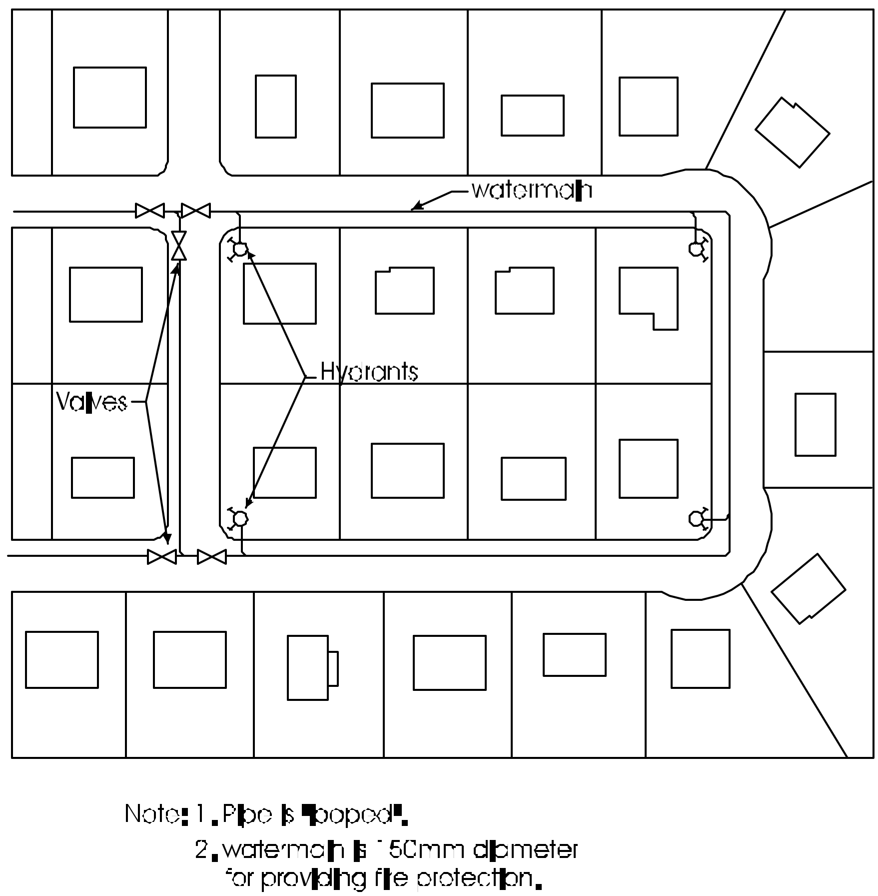

Figure 3: Small water distribution system.

The following sections describe the various components of a conventional piped distribution system and their functions.

3.2.4.1 Water Mains

The water main is the pipe through which the water flows as it is pumped from the source to the residences. The minimum size for water mains providing fire protection and serving fire hydrants is 150 mm diameter. The water main is an important component of the entire system and should be properly installed to prevent leakage or breakage that could disrupt service.

If possible, water mains should be installed in a loop as shown in Figure 3. If there is a break, the section of the line in which the break occurs can be isolated or separated by closing off valves on either side of the break. Water can still reach all residences outside the isolated section because the pipe "loops" around.

Two types of water main pipe commonly used are plastics (such as polyethylene (PE) and polyvinyl chloride (PVC)) and ductile iron. The plastics are lightweight, flexible, and easy to handle in the field. This makes water main installation with plastics simpler and easier because the pipe is easily carried by hand. Polyethylene is available in a pre-insulated heat traced jacket. The insulation provides protection from freezing (refer to Figure 4). Factory-insulated polyethylene pipe made to specification is preferred to field-insulated pipe. PVC pipe has the disadvantage of being susceptible to brittle fracture in cold conditions. Ductile iron pipe is very strong and very resistant to shock or impact loading. The disadvantage is its heavy weight.

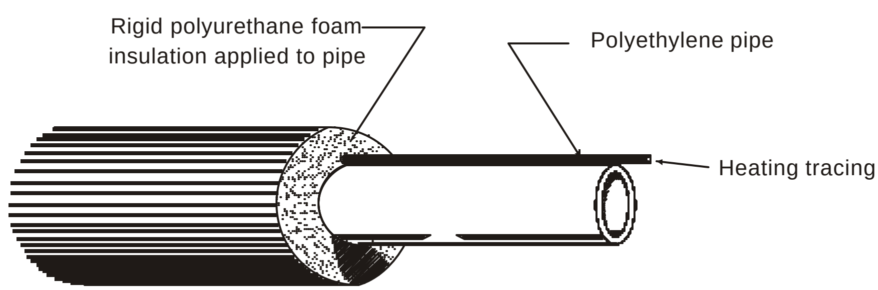

Figure 4: Pre-insulated and heat traced water main.

3.2.4.2 Valves

Valves should be used in pipe distribution systems to stop or start the flow of water in the main. They should be located in such a way that, in the event of a water main break, the broken section on the line can be isolated. This ensures that as few residences as possible experience interruptions in water service.

The most common type of valve used in water distribution systems is the gate valve (refer to Figure 5). It consists of a valve housing which contains a sliding metal disc that can be raised or lowered to turn the water flow off or on. The valve is activated by means of a valve shut-off key. To operate the valve, the lid is removed and the shut-off key is lowered into the valve box to turn the operating nut located on top of the valve housing or frame.

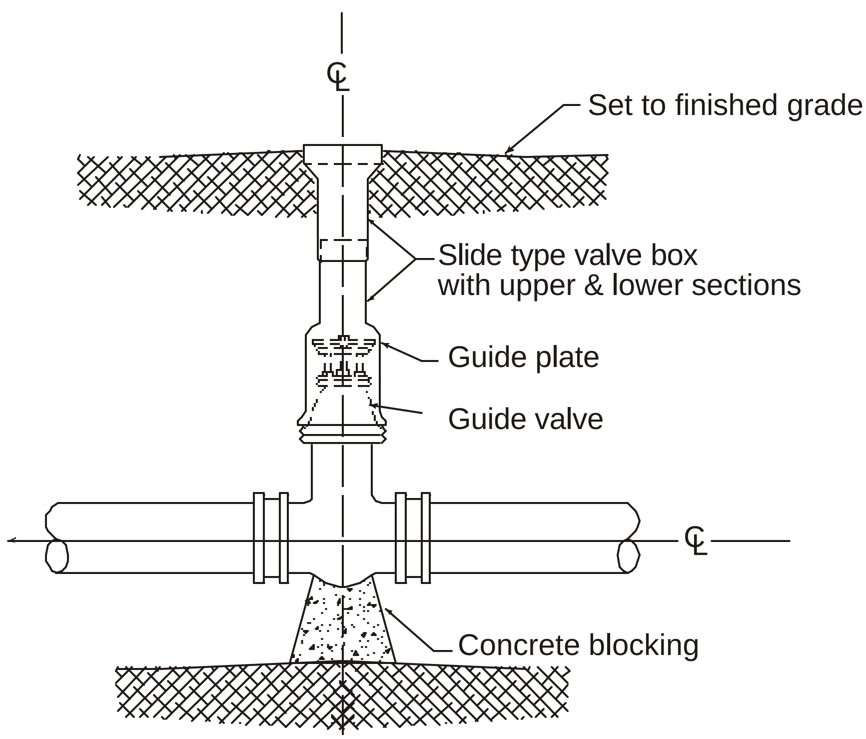

Figure 5: Water main gate valve.

3.2.4.3 *Fire Hydrants*

The primary purpose of fire hydrants is to make available large flows of water for fire suppression, most often by connection to the suction of the community fire truck. They are also used as a means of flushing water lines for maintenance purposes and as a convenient location from which to pressure test adjacent sections of water main or to test system pressure. For these reasons, proper operation and maintenance of hydrants is very important.

Fire hydrants are of either the off-line or on-line type. Figure 6 shows a typical off-line installation in which the hydrant is located at the end of a short branch line. The branch line leading to the hydrant is valved, permitting hydrant maintenance to be carried out without a disruption of water service. Since the branch line is prone to freezing, northern installations tend to use on-line hydrants. Where on-line hydrants are used, main line valving becomes critical to minimizing the number of users inconvenienced during hydrant maintenance.

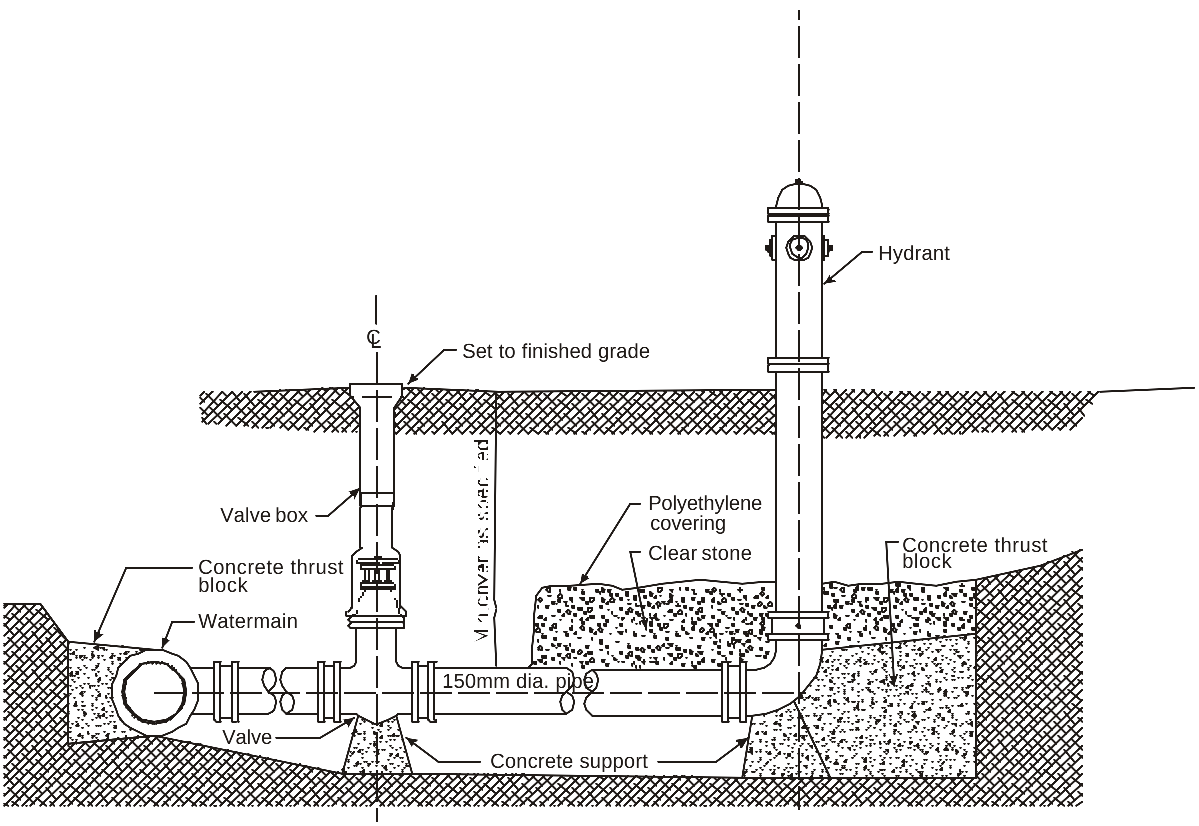

Figure 6: Fire hydrant.

3.2.4.4 Water Service Connections

The water service connection (often called the house or building connection) is the piping connecting the water main and the building being served (refer to Figure 7). House connections are usually only 19 mm in diameter -- a much smaller size than the water main -- because they only have to supply water to a single residence. The pipe used in house connections is typically made of either copper or plastic.

During winter and under certain conditions, a service line may freeze. Refer to the "Cold Regions Utilities Monograph" published by the American Society of Civil Engineers (ASCE) for the appropriate methods and procedures for thawing frozen pipe.

Service should normally be provided with a valve connecting the service line to the water main (known as a corporation stop), a shut-off valve (known as a curb stop) which is usually located near the property line, and a valve located in the basement just above the service entry point. The corporation stop enables a new service to be connected to a pressurized water main, and if necessary could be dug up and turned off to repair or discontinue use of the service connection. Unlike the corporation stop, the curb stop is equipped with a service box which extends to the ground surface. The service box allows the municipal authority to turn the valve off temporarily, should it be required to effect repairs on the owner's property or enforce payment of water billings.

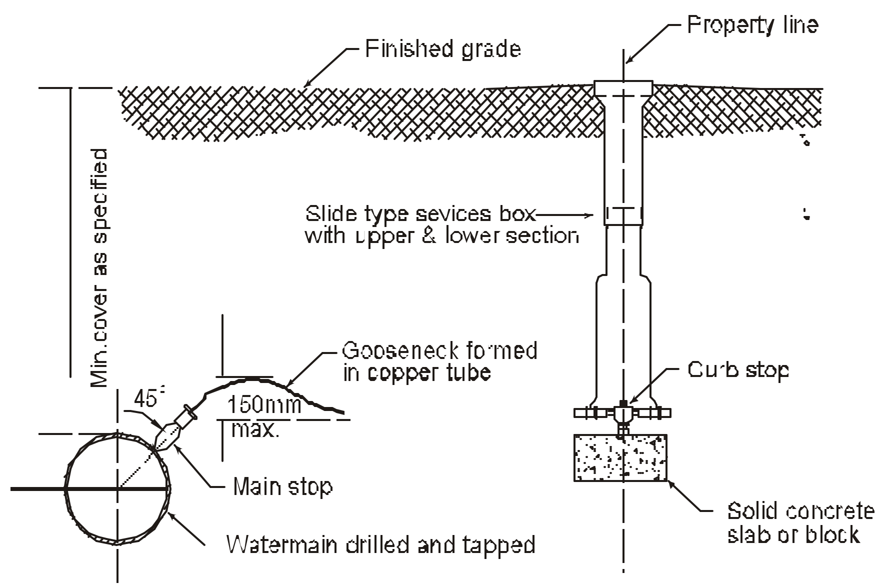

Figure 7: Water service connection.

Part 4: Water Quality

4.1 General

The type of treatment processes and devices employed should depend on an evaluation of the nature and quality of the particular water to be treated, the desired quality of the finished water, and the mode of operation planned.

Before reviewing the various available methods of treatment, it is necessary to discuss some of the common characteristics of water and how they affect the suitability of water for human consumption. These characteristics are divided into three categories: biological, physical and chemical.

Water which is delivered to customers should meet the guidelines listed in the latest edition of the "Guidelines for Canadian Drinking Water Quality" published by Health Canada.

4.2 Biological Characteristics

Biological characteristics refer to the various types of aquatic life, bacteria, and viruses found in water. It should be noted that of the almost countless types of bacteria, the vast majority are harmless. Bacteria that cause disease in humans are known as pathogenic bacteria.

Some very serious diseases such as cholera, hepatitis, and typhoid fever can be transmitted by human waste. For this reason, care should be taken to ensure that rivers and lakes do not become polluted by dumping human waste into them.

In order to determine if water contains disease causing organisms, one of the most important tests to be conducted in a laboratory is a test for fecal coliforms. Fecal coliforms are a particular type of bacteria found in humans and animals. When this type of bacteria shows up in a water test, it indicates that the water is being polluted with human or animal wastes and that disease-causing organisms may be present. If fecal coliforms do show up in a test, the water should be treated and disinfected accordingly to make certain that any possible diseases are not spread by drinking the water.

Parasites in drinking water can also affect human health. *Giardia* and *Cryptosporidium* are microscopic parasites that can be found in water and can cause intestinal illness. Drinking water can become contaminated with these parasites if it is being polluted with human or animal wastes.

4.3 Physical Characteristics

4.3.1 Colour

Although the presence of colour in drinking water is not directly linked to health, consumers will often turn to alternate, and possibly unsafe, water sources when drinking water exhibits high colour levels. Colour is primarily caused by decaying vegetation and metals such as iron and manganese dissolved in the water.

4.3.2 Temperature

In addition to cool water tasting better than warm water, temperatures above 15 degrees Celsius can speed up the growth of nuisance organisms such as algae which can intensify taste, odour, and colour problems. Temperature also affects water treatment. Low water temperature tends to decrease the efficiency of water treatment because chemicals cannot mix as easily and settling cannot be as thorough.

4.3.3 Turbidity

Turbidity is a measure of the amount of very fine matter suspended in water. Water with high turbidity will appear cloudy or murky. Turbidity occurs because insoluble materials such as clays and silts are present in the water. The clay and silt particles are not heavy enough to settle to the bottom and not light enough to float; thus, they remain “suspended” in the water.

Excess turbidity is displeasing to the user for aesthetic reasons and can also be a health problem because turbidity can shield microorganisms (such as bacteria) from chlorine disinfection. Essentially, because clear water is so much more attractive to drink, treated water should be as clear as possible.

4.3.4 Taste and Odour

Taste and odour problems in water can be caused by a variety of factors such as algae, dissolved materials, and biological activity. Taste and odour problems are the most common reason for user complaints. Changes in the taste of water can also be a warning of inadequate treatment or contamination of the water distribution system. The objective of a good water treatment system should be to produce contaminant free water with no offensive taste or odour.

4.4 Chemical Characteristics

4.4.1 pH

The term pH is a measure of the acidity or alkalinity of a liquid. The pH scale ranges from 0 to 14, with the acceptable range for drinking water being 6.5 to 8.5.

Although not normally a health problem, water which lies outside the normal pH range will taste unpleasant and can be an inconvenience. Acidic water will tend to corrode equipment while alkaline water will deposit scale in pipelines and home appliances such as kettles.

Many water treatment processes operate most efficiently at a fairly neutral pH. It is sometimes necessary for the operator to add chemicals such as soda ash to raise the pH level.

4.4.2 Hardness

Hardness measures the amount of the minerals calcium and magnesium that are in the water. “Hard water” denotes a high concentration of these minerals.

Hard water will cause scale to form on pipes and appliances. It also has an unpleasant taste and necessitates a greater amount of soap in washing.

4.4.3 Dissolved Solids

Both surface water and groundwater contain dissolved minerals which are picked up from the soil and rock which they come into contact with.

Some substances such as arsenic, cyanide, lead, and mercury are toxic. Others do not present a health problem but can cause inconvenience if present in excessive amounts. Examples include:

- Iron and Manganese: stain laundry and plumbing fixtures and causes objectionable tastes.
- Chloride: causes unpleasant tastes.
- Copper: causes taste and staining problems. Intake of large amounts can cause . . . health problems.
- Sulphur: causes taste and odour problems and can. Also causes bowel disorders.
- Zinc: causes taste problems. Causes water to develop a greasy film when boiled.

4.5 Guidelines for Canadian Drinking Water Quality (Health Canada)

The latest edition of the "Guidelines for Canadian Drinking Water Quality" produced by Health Canada sets out the respective limit or level of acceptability for the key characteristics, under each of the three categories (biological, physical or chemical) mentioned in the above sections. These limits are deemed essential to ensuring the suitability of water for drinking purposes.

Maximum acceptable concentrations (MACs) have been established for certain substances that are known or suspected to cause adverse effects on health.

Aesthetic objectives (AOs) apply to certain substances or characteristics of drinking water that can affect its acceptance by consumers or interfere with practices for supplying good quality water.

There is a two-step process for determining whether a given water is acceptable or not:

(1) Have a sample of the water analyzed by a qualified laboratory to determine the concentration of key substances.

(2) Compare the laboratory results for each substance to the respective limit given in the latest edition of the guidelines.

If concentrations of one or more of the substances exceed the guideline limits, it should first be noted whether the variance relates to an issue of health or aesthetics. If it is a health issue, treatment will be needed to render the water suitable; if it is an aesthetic issue only, some variance may be acceptable.

Since water supplies vary widely in biological, physical, and chemical characteristics, each proposed water source should be tested individually and evaluated as to the type of treatment required in order to meet the Health Canada Guidelines.

Part 5: Water Treatment

5.1 General

The primary purpose of water treatment is to produce water that is safe to drink. This means that the water is free from all disease causing organisms and any toxic or poisonous substances.

The secondary purpose of water treatment is to produce water that is aesthetically acceptable. This means that it looks, tastes, and smells acceptable to the user.

Depending on the raw water quality, treatment techniques may include one or more of the following:

- Disinfection
- Coagulation/Flocculation
- Sedimentation
- Filtration
- Softening
- Iron and/or Manganese Control

Water which is delivered to customers should meet the requirements listed in the latest edition of the "Guidelines for Canadian Drinking Water Quality" published by Health Canada.

5.2 Disinfection

Disinfection means the ultimate destruction of disease causing organisms. By disinfecting the water, the spread of disease by drinking water is prevented.

Continuous disinfection is recommended for all community water supplies. Disinfection should be provided for any groundwater supply of questionable sanitary quality or where other treatment is provided. Disinfection should be provided for all surface water supplies.

Of the several methods of water disinfection available, the most commonly used is chlorination. Chlorination by means of sodium hypochlorite should be considered for small community water systems. One of the advantages of having chlorine as a disinfectant is that the portion of chlorine that is not used up in destroying or disinfecting bacteria remains in the water as residual chlorine. The residual chlorine is needed to react with any bacteria that might enter the water supply after treatment. It is important for the operator to check on a daily basis whether the appropriate amount of residual chlorine is in the water being distributed to the community.

A disadvantage of chlorination is the fact that by-products such as Trihalomethanes (THMs) may be formed in the drinking water as a result of chlorine reacting with the organic matter naturally present in raw water supplies. The "Guidelines for Canadian Drinking Water Quality" suggests a maximum acceptable concentration for Trihalomethanes, based on health reasons.

When handling potentially dangerous chemicals, such as chlorine, the operator should always wear the necessary protective equipment and clothing.

5.3 Coagulation/Flocculation

The coagulation and flocculation processes may be used to condition or prepare the untreated water for the sedimentation process. Depending on the settling characteristics of the suspended material in the raw water, chemicals may be used to help the suspended materials stick together and form larger particles. In this process, a chemical called coagulant is rapidly mixed into the water. The coagulant helps the small suspended particles group together. Some of the types of coagulants typically used are alum, ferrous sulphate, ferric chloride, and ferric sulphate.

After the coagulant has been thoroughly mixed, the particles in suspension are ready to clump together into larger sized particles called floc. Flocculation is the slow gentle mixing of the water to allow the particles to collide and stick together to form larger particles with better settling properties. The operator should determine the proper coagulant dosage through regular testing.

5.4 Sedimentation

This is the process of retaining water in a settling basin to remove suspended solids. Particles that are heavier than the water will settle to the bottom forming a sludge which is later removed. It is important that the water pass through the tank with minimum turbulence.

The operator should check that the sludge draw-off mechanism works properly, that no excessive accumulation occurs, and that it is not creating too much turbulence to allow for proper settling.

Since particles settle more slowly in cold water than in warm water, the operator may have to adjust the flow through the tank during the winter months.

Tube settlers or plate settlers can also be added to the sedimentation tank. These are steeply inclined tubes or plates that allow the suspended matter to settle in a shallow depth as the water passes through them. Tube settlers are frequently installed in package treatment plants.

5.5 Filtration

Filtration removes most of the suspended matter remaining in the water by passing it through **a** porous filter media such as sand or anthracite (a type of hard coal). Filtering or passing water through a very fine material will remove dirt and turbidity.

5.5.1 Rapid Rate Gravity Filter

The rapid rate gravity filter (refer to Figure 8) is commonly used in the treatment of surface water supplies. It consists of a structure to house the unit, the filter media, an under-drain system, a surface washer, and a waste disposal system. The filter area should be divided into at least two separate units to allow operation flexibility. Some form of pre-treatment of the raw water, such as sedimentation, is usually needed.

In the filtering process, water flows onto the top of the filter media and is driven through it by gravity. In passing through the small spaces between the filter's grains, impurities are removed. The water continues its way through the support gravel, enters the under-drain system, and then flows to the reservoir. It is the filter media, composed of sand or anthracite, which actually removes the particles from the water. The filter media is routinely cleaned by means of a backwashing process.

Problems with filters are caused mainly by filter or media breakthrough which refers to water passing through the filter without adequate treatment. The turbidity of the filtered water is one of the best indicators of filter performance and should be checked regularly. Inadequate flocculation, filter clogging, mudball formation, and filter cracking can all lead to media breakthrough. In light of these problems, the filter top should be visually inspected for loss in depth, mudball formation, surface cracks, and bacterial growth. The operator should also check that the backwash cycle is operating normally.

Adequate emphasis should be placed on operation and maintenance procedures to ensure that all equipment is operating properly. A qualified operator should be available to monitor the processes and make the necessary treatment adjustments. A filtration plant requires regular maintenance, repairs, and process control changes.

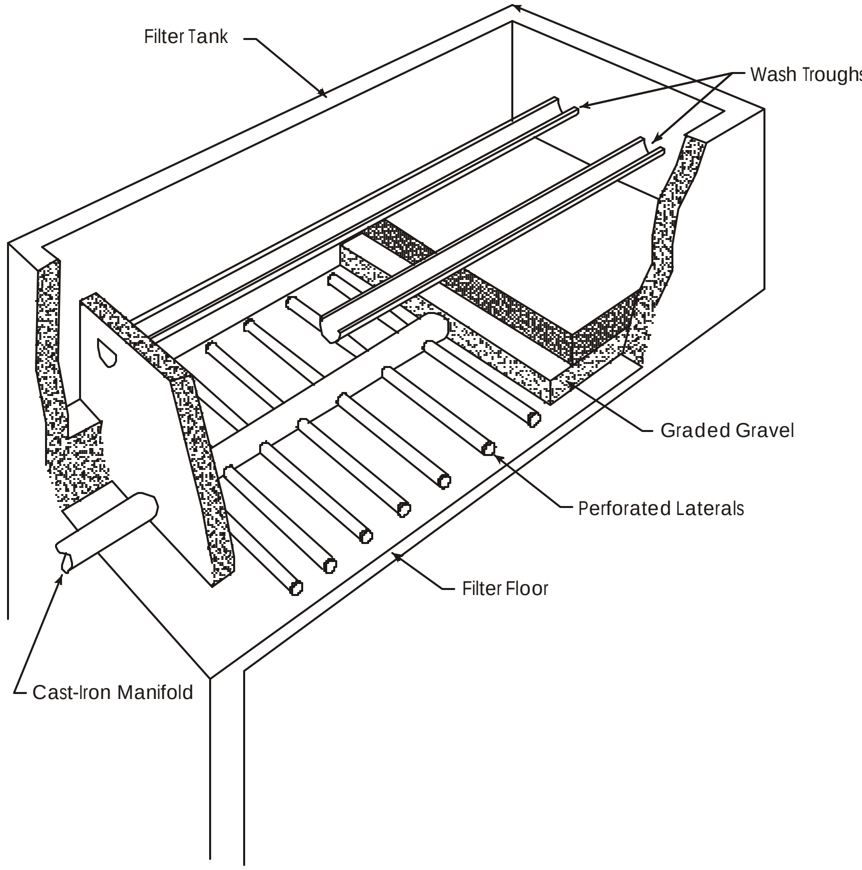

Figure 8: Rapid rate gravity filter.

5.5.2 Slow Sand Filter

Due to the amount of land area necessary to house slow sand filters and their relative inefficiency in removing high levels of turbidity and colour from water, the rapid gravity filter discussed in section 5.5.1 was developed. For many years, slow sand filtration has been considered old-fashioned. However, the water industry has recently shown some renewed interest in slow sand filtration as a simple and reliable means of treatment, particularly for small communities. The approach has been to evaluate the slow sand filtration method through a lengthy pilot study and, if treatment problems occur, revert to a rapid gravity filter approach.

Slow sand filtration consists of a structure to house the unit, the filter media, an under-drain system, and inlet and outlet piping. The filter area should be divided into at least two separate units to allow operation flexibility. In the filtering process, water flows onto the top of the filter media and is allowed to drain or filter down through the media, thus removing particles in the water. Whenever the head loss indicates that the filter has accumulated a high concentration of impurities, the media should be cleaned.

In order to clean the filter unit, the top layer of sand must be removed from the filter. This process will undoubtedly require some physical effort. This is because the slow sand filter lacks the backwashing components which are available in the rapid sand filter. To avoid contaminating the filters during scraping, operators should always use clean boots and equipment dedicated to the task.

The main advantage of the slow sand filter is that it is relatively simple to operate and maintain. The main disadvantage is its inefficiency with waters having high turbidity. In addition to adequate emphasis being placed on operation and maintenance procedures, a qualified operator should always be available.

5.5.3 Pressure Sand Filter

This type of filter is contained in a closed steel jacket and the water is pumped through the filter under pressure rather than by gravity. The pressure sand filter usually has the same type of filter media as the rapid rate gravity filter. The difficulty in providing adequate pretreatment limits the application of pressure sand filters. Pressure sand filters should not be used in the filtration of surface or other polluted waters.

Their main disadvantage lies in the fact that they are enclosed in a steel tank. The operator is therefore unable to observe the filter operations or determine the condition of the media.

5.5.4 Greensand Filter

The Greensand filter is used when it is necessary to remove dissolved iron and manganese which is often found in groundwater. In this process, a special chemical is used on the media which causes a reaction with the iron and manganese and allows them to be filtered out. This type of filter has to be periodically regenerated with a chemical known as potassium permanganate.

5.6 Water Softening Unit

A water softening unit is used to treat hard water that contains large amounts of calcium or magnesium. Hard water is frequently found in wells. A water softening unit has the same general principles as the Greensand filter but in this case, the filter is an exchange media where the calcium and magnesium ions in the water are replaced with sodium ions, thereby softening the water. The exchange media is periodically regenerated using salt.

5.7 Other Treatment Technologies

It is not possible to cover all types of treatment processes in this type of publication. Examples of other technologies include: Granulated Activated Carbon (GAC) Adsorption and Membrane Processes. Their omission from this technical information document does not, however, preclude their use.

For the application of any type of treatment, it is important to establish the adequacy of proposed processes and unit parameters for the treatment of the specific water under consideration. The need for pilot studies should also be assessed.

Where two or more solutions exist for providing water treatment, each of which is feasible and practical, the options should be analyzed and financial considerations (capital costs, operation and maintenance costs) assessed. All treatment system designs should satisfy the requirements of the provincial and federal regulatory authorities.

5.8 Package Water Treatment Plants

In a small treatment plant, the process units are often combined in a complete pre-assembled unit, called a package plant. For example, the processes of coagulation, flocculation, sedimentation, and filtration are often packaged in a single treatment plant. Usually the package plant includes all the treatment equipment, pumps, chemical feeders, and controls. The operator of such a package plant should be aware that although the plant may operate automatically, it requires maintenance, repairs, and process control changes.

Generally, package plants are pre-engineered for treatment of raw water which is of relatively constant quality. However, many such plants are currently being considered for application on waters of variable quality. Accordingly, it is necessary to demonstrate to the satisfaction of the reviewing authority that the desired water quality can be produced under all water conditions and system flow demands.

Proper attention should be given to regular maintenance if all equipment is to operate properly and adequate treatment is to be achieved. Highly sophisticated automation may put proper maintenance beyond the plant operators' capability and lead to expensive servicing or equipment breakdown.

A qualified operator should be available at all times in order to make the necessary treatment adjustments.

5.9 Waste Handling and Disposal (Backwash and other wastes)

Provisions should be made for proper disposal of water treatment plant waste such as sanitary waste, laboratory waste, coagulation/sedimentation sludge, softening sludge, filter backwash water, and brines. All such waste discharges should be disposed of in an environmentally acceptable manner subject to the requirements of regulatory authorities.

5.10 Operation and Maintenance Procedures

Appropriate emphasis should be given to operation and maintenance for any treatment plant to operate properly. A qualified operator should be available in order to make the necessary treatment adjustments. A treatment plant requires maintenance, repairs, and process control changes to maintain it in proper condition. The operator should follow the manufacturer's recommendations on regular maintenance and lubrication. The name, address and phone number of the service representative should be kept on file at the site. Copies of the operation manuals, maintenance manuals, and applicable drawings should be available for use as required.

It is good practice to keep written records of all testing and work carried out on the treatment plant. This would include any maintenance tasks performed. This not only provides a record of the last check or maintenance task but also enables the operator to detect any changes in the operating characteristics of the plant. In addition, a spare parts inventory should be kept so that if a critical part breaks down, there is a replacement available. This is especially important in remote sites where the breakdown of a key part can result in the treatment plant being out of operation for an inconveniently long time while the replacement part is obtained.

5.11 Process Control

In order to make appropriate adjustments to the treatment plant, the operator should be able to perform the tests required to monitor and control the quality of its treatment processes. These tests will depend on the type of treatment plant serving a particular community. It is recommended that the operator of a water treatment plant be given sufficient training in the operation and maintenance of the facility.

In certain regions, the "circuit rider" program is available to address these training needs. This is a practical, hands-on training method that takes place at the operator's facility.

5.12 Safety

Safety is one of the most important aspects of a water treatment and distribution system's operation. The operator and personnel should use safety equipment as directed and follow all safety procedures. Good housekeeping is important. The operator and other personnel should be protected from hazards.

Some safety procedures include the following:

- install handrails and guards where necessary;
- provide first-aid equipment; and
- provide protective clothing and equipment such as hard hats and rubber gloves.

Special attention should be made to the storage and handling of chemicals. The operator should be familiar with the supplier's recommendations for each individual chemical. In general, chemicals should be stored in a clean, dry, and well ventilated area.

When handling potentially dangerous chemicals, such as chlorine, protective equipment and clothing should be worn.

Glossary

Adsorption	The adherence of a gas, liquid or dissolved substance on the surface of another material.
Aquifer	A natural underground layer of porous, water-bearing materials (sand, gravel) usually capable of yielding a large amount or supply of water.
Backwashing	The process of reversing the flow of water back through the filter media to remove entrapped solids.
Groundwater surface	The upper surface of the groundwater in an aquifer.
Head loss	The head or pressure lost by water flowing in a pipe or channel, caused by the roughness of the pipe or channel walls.
Mudballs	Material that is round in shape and forms in filters, gradually increasing in size when not removed by backwashing process.
Palatable	Water at a desired temperature that is free from objectionable tastes, odours, colours and turbidity.
Run-off	Water that flows over the ground surface into streams, rivers or lakes.
Residual chlorine	The amount of free and/or available chlorine remaining after a given contact time under specified conditions.
Turbidity	The cloudy appearance of water caused by the presence of suspended matter.
Water table	The upper surface of the zone of saturation in an unconfined aquifer.