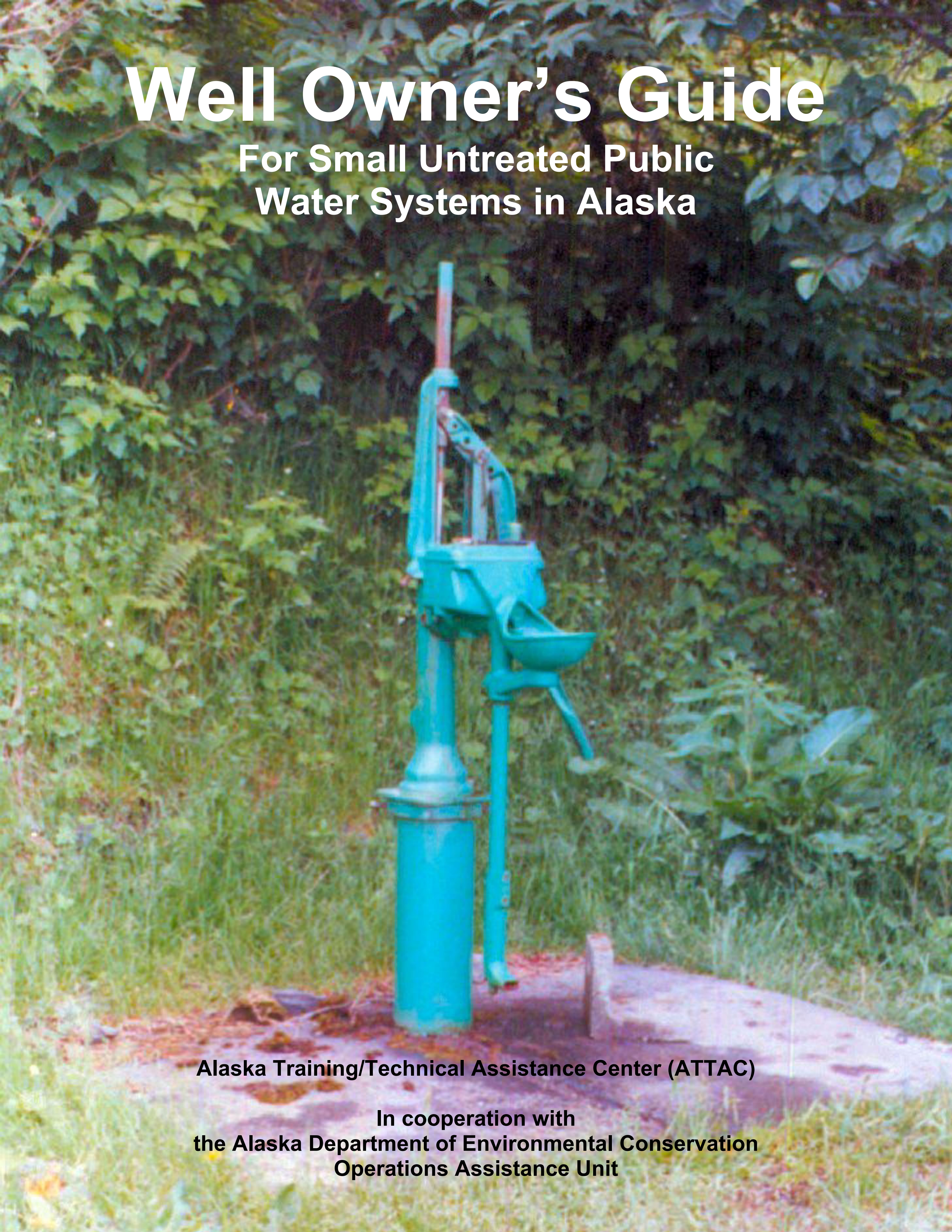
Well Owner's Guide

For Small Untreated Public Water Systems in Alaska



Alaska Training/Technical Assistance Center (ATTAC)

**In cooperation with
the Alaska Department of Environmental Conservation
Operations Assistance Unit**

Introduction

The **Safe Drinking Water Act (SDWA)** Amendments of 1996 require that all community and non-transient non-community water systems be operated by a 'certified individual'. These regulations require operators of very small public water systems to be certified according to federal guidelines. Approximately 300 water systems in Alaska are classified as small-untreated systems under the Alaska Department of Environmental Conservation (ADEC) operator certification regulations.

A small-untreated water system is a system serving less than 500 people per day and less than 100 service connections that adds no chemicals. Typically, these systems will be groundwater supplies. Groundwater is widely used throughout Alaska as the source of water for many public water supplies. In the State of Alaska 86 percent of community, non-transient non-community, and transient non-community water systems use groundwater and 14 percent use surface water. Almost half of the people in the United States obtain their public water supply from groundwater.

Small-untreated groundwater systems add *no chemicals* to the water. However, an operator of a very small groundwater system may periodically disinfect the well or employ some type of passive water treatment. Examples of passive water treatment include cartridge filtration, ion exchange softening, ion-exchange iron removal, and ultraviolet (UV) disinfection. These topics are included in this guide.

This guide is intended to provide information for owners and operators of small-untreated water systems and introduce them to some basic groundwater concepts. The concepts are important because they determine the quality and chemical characteristics of the source water used, the amount of water available, and how protected the water is from chemical or biological contamination.

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Chapter 1 - Introduction to Groundwater Basics

1.1 Background

Over the last ten years, public attention has been drawn to incidents of groundwater contamination. This has led to the development of groundwater protection programs at federal, state, and local levels. Because groundwater supplies and conditions vary from one area to another, the responsibility for protecting a groundwater supply rests substantially with you, the water system owners/operators.

Groundwater sources have advantages and disadvantages in comparison to surface water sources. Advantages of groundwater include:

- Groundwater is not as easily contaminated as surface water
- Groundwater may be available where surface waters are not
- Groundwater sources are generally lower in bacteriological count and turbidity than surface water sources

There are a number of disadvantages using groundwater. Disadvantages of using groundwater include:

- Groundwater wells that become polluted are extremely difficult to remedy, expensive to clean, and often have to be abandoned
- Pumping groundwater and treating it is expensive
- Groundwater normally contains more dissolved minerals than surface water

1.2 The Hydrologic Cycle

Groundwater occurs as part of what can be called the earth's oldest recycling program, the **hydrologic cycle**. Groundwater is water that fills spaces between rocks and soil particles underground, in much the same way as water fills a sponge. Groundwater begins as precipitation and soaks into the ground where it is stored underground in geological formations called **aquifers**. Sometimes groundwater feeds springs, lakes, and other surface waters, or is drawn out of the ground through wells. The water then can evaporate, form clouds, and return to the earth to begin the cycle over again. Figure 1.1 illustrates nature's method of continuously recycling the earth's renewable water supply.

The hydrologic cycle is an important concept because it shows how the amount of groundwater available to a water well is influenced by the amount of precipitation, infiltration, and underground water flow occurring in a given area.

In summary, groundwater begins as local precipitation that seeps into and through the ground. This water fills the pores and crevices of soil, and rock beneath the surface of the earth, much the way water fills open spaces and saturates a sponge. Water percolates, or moves down, through the soil until it reaches a level where all of the available space is completely filled with water. This is called the zone of saturation. The water contained in this zone is called **groundwater** and the upper most limit of this zone is known as the **water table**.

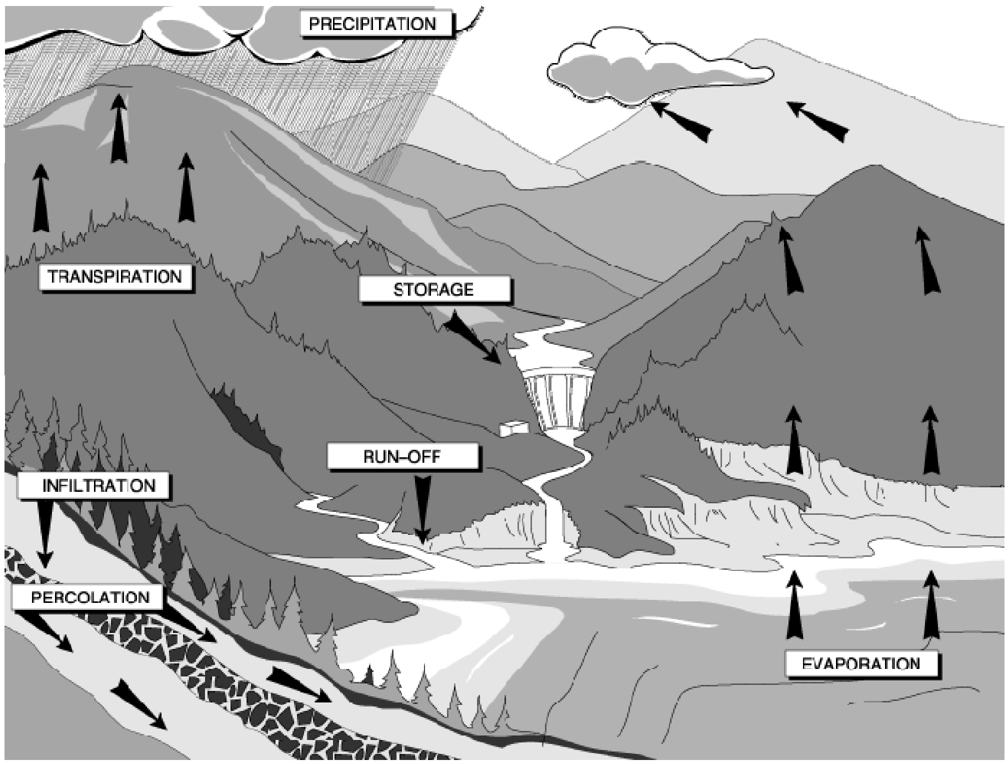


Figure 1.1: The Hydrologic Cycle

1.3 Aquifers

Underground formations where ground water exists in sufficient quantities to supply wells or springs are called aquifers, a term that literally means water bearer. Water that infiltrates the soil and is not picked up by plant roots, moves downward through spaces in the soil and subsurface material until it reaches an impervious layer of rock or clay.

An impervious layer is one that is difficult for the water to seep through. The porous layer of soil above the impervious layer becomes saturated with water forming an aquifer.

Wells obtain their water from aquifers. A common misconception is that groundwater is obtained from underground lakes. Actually, wells tap into voids containing water below the earth's surface. Most of the rocks near the earth's surface are composed of both solids and voids. The solid parts are more obvious than the voids, but without the voids there would be no water to supply wells and springs.

There are three types of aquifers:

1. Confined aquifers
2. Unconfined (or water table) aquifers
3. Springs

A **confined aquifer** is bound above and below by low-permeability material. The water-bearing materials are found between layers of impermeable material such as clay or **permafrost**. When water completely fills an aquifer that is overlain by a confining bed, the water in the aquifer is said to be confined. Confined aquifers are also known as **artesian** aquifers. Confined aquifers generally contain water that is under a pressure greater than atmospheric pressure. If a well is drilled into a confined aquifer, the water can rise above its level in the aquifer because of the pressure exerted on the fluid by the confining layers. This is called an artesian system.

An **unconfined aquifer** may have an impermeable layer below the water-bearing strata, but there is no confining layer on top. Permeable rocks and soil directly overlie the aquifer. An unconfined aquifer may be recharged by infiltration over the whole area underlain by that aquifer, because there is nothing to stop the downward flow of water from the surface to the aquifer. If a well is drilled into an unconfined aquifer, the water will rise in the well to the same height as the water table in the aquifer.

Consequently, the water-bearing material can fill up with water until the water level reaches the surface. The top of the water level in an unconfined aquifer is called the water table. Therefore, unconfined aquifers are sometimes called water-table aquifers.

An opening in the ground surface, from which groundwater flows, is a spring. Groundwater becomes surface water at springs or at intersections of a water body and a water table. Water may flow by force of gravity from water-table aquifers, or be forced out by artesian pressure. Figure 1.2 illustrates a confined and unconfined aquifer.

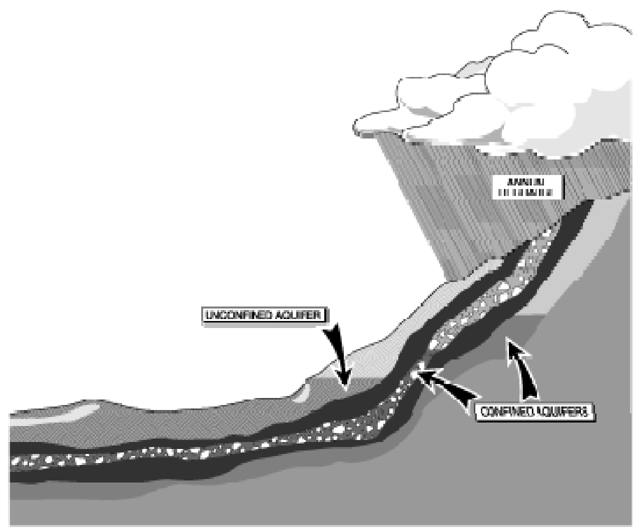


Figure 1.2: Aquifers

Chapter 2 - Groundwater Quality

2.1 Water - The Universal Solvent

You may have heard the phrase “water is the universal solvent.” Ultimately, any substance will dissolve to some extent when in contact with water. This is the reason why water can contain many impurities. Recall the hydrologic cycle, where precipitation falls upon the earth and percolates down through the soil and rock layers to become groundwater. As the water falls through the atmosphere and then percolates through the earth’s surface, it comes into contact with many substances.

Natural and man-made impurities are present in all groundwater. Some impurities, such as fluoride and calcium can be beneficial; others, like arsenic, disease-causing bacteria and pesticides, can be harmful. Still others, like iron, color and turbidity, although not harmful to your health, can make the water less desirable to the consumer.

A well supply may appear clear, have no odors and taste fine, yet may have a high level of dissolved substances or tiny organisms that are not visible to the naked eye. Since it is impossible to judge the quality of the water with the eye, it is necessary to analyze the water for physical and chemical properties. When it comes to drinking water, it’s what you cannot see, smell or taste that might hurt you!

2.2 Characteristics of Groundwater

In order for an operator of a small-untreated water system to understand the physical, chemical and biological characteristics of groundwater and the monitoring and reporting required, an understanding of basic groundwater quality and chemistry is needed. Since this manual is intended for untreated groundwater system operators, the following information is basic in nature and is oversimplified for purposes of illustration. There are numerous publications and textbooks that deal with water chemistry. Please contact the Operator Certification Program at ADEC if you are interested in obtaining more detailed information on water chemistry.

2.3 Physical Characteristics

There are a number of physical characteristics of groundwater that consumers tend to focus on because they can be seen, smelled or tasted. Generally, these physical characteristics are only important from an aesthetic standpoint, but are typically the basis for most consumer complaints. Interestingly enough, complaints regarding the aesthetic quality of the water are generally the driving force behind the installation of water treatment devices.

Turbidity - When water is cloudy, it is said to be turbid or have a high turbidity. Consumers will object to water that is highly turbid, even though it may be perfectly safe to drink. Turbidity can be measured with an instrument called a turbidimeter. Typically, groundwater is low in turbidity.

Color - If water is colored, it is less pleasing to the consumer and may be rejected in favor of a drinking water source that is less safe. Color can be measured in the laboratory; generally a measurement of 15 color units or higher is objectionable.

Tastes and odors - In groundwater, taste and odors result from the presence of hydrogen sulfide, organic matter and dissolved minerals like iron, manganese, zinc, and copper. Although these substances are generally not harmful in quantities typically encountered in most groundwater, their presence can lead to consumer rejection. Various taste-rating scales have been developed, but they are very subjective and do not mean much to the individual consumer. If water tastes bad, they will not drink it. An odor scale, the Threshold Odor Number (TON), has also been developed. Typically, a TON in excess of 3 is considered undesirable for drinking water.

2.4 Chemical Characteristics

Groundwater acquires its chemical characteristics in two ways:

1. from surface waters that find their way into an aquifer
2. from mineral deposits in the aquifer, some of which are dissolved by the groundwater

Surface waters that find their way into a groundwater aquifer may be polluted. For example, surface waters that percolate through areas where fertilizers have been applied could have nitrate concentrations or contain herbicides and pesticides.

Water that passes through the earth's crust and travels through aquifer material will dissolve some of the minerals and metals that it comes in contact with. Depending on the minerals that are present, the water may have high concentrations of iron and manganese, which can cause taste, odor and color problems. The water may be very hard due to dissolved calcium and magnesium. Often groundwater in areas having both high levels of iron and sulfur deposits will have the characteristic rotten egg odor of hydrogen sulfide.

Some common chemical constituents in groundwater are:

Iron	Manganese
Sodium	Fluoride
Chloride	Calcium
Sulfate	Magnesium
Arsenic	Hydrogen Sulfide
Nitrate	Radiological contaminants

The presence of many dissolved impurities often cannot be detected by sight, smell or taste. Consequently, laboratory testing is necessary. The importance of each substance depends on the kind and amount found in the water and also the use for which it is intended. For public health reasons, the strictest standards apply to groundwater, which is being used as a public water supply.

Some of the more troublesome chemical constituents found in Alaska are: calcium and magnesium (hardness), iron and manganese, and hydrogen sulfide.

The State Drinking Water Standards establish maximum amounts allowed in public drinking waters. These standards are discussed in Chapter 5.

2.4a pH

The acidic or basic nature of a solution is expressed as the **pH** (power of hydrogen). The pH scale ranges from 0 to 14, with 7 on the scale being neutral. Numbers below 7 indicate acidic conditions and numbers above 7 indicate basic conditions. Therefore, the more acidic the solution, the lower the pH. The more basic the solution, the higher the pH.

Table A shows the pH of some common liquids.

Fluid	**pH**
Milk	6.5
Soft drink (cola)	2.8
Drinking Water	6.5 - 8
Beer	4 - 5
Vinegar	3.0

Table A: pH of Common Liquids

2.4b Hardness

Hardness is caused by the presence of magnesium and calcium ions in water. The terms soft water and hard water are important terms. Water is said to be soft if it has a low concentration of calcium and magnesium ions in it, and said to be hard if it has a high concentration of calcium and magnesium (Table B).

Water that is difficult to make soap lather is called hard water and water that lathers soap easily is considered soft. If you have soft water, you might notice it takes a long time to rinse the soap off your hands. Soft water reacts with soap to produce a residue that feels like it is hard to wash off. Low hardness contributes to the corrosive tendencies of water.

Hard water leads to **calcium carbonate** $\mathbf{CaCO_3}$ scale in hot water heaters and boilers. Hardness is not considered a health hazard. However, water that contains hardness must often be softened by ion exchange or lime precipitation. Water hardness is commonly expressed in milligrams per liter (mg/L) of $CaCO_3$.

Soft water	0-75 mg/L
Moderately Hard	75-150 mg/L
Hard	150-300 mg/L
Very Hard	Over 300

Table B: Hardness Scale

Hardness can also be expressed in grains per gallon; 1 gpg = 17.1 mg/L.

2.4c Iron and Manganese

Iron and manganese are fairly common in groundwater. Iron may turn water reddish brown, while manganese can turn water black or very dark brown. Neither of the elements causes adverse health effects. However, water containing excessive amounts of iron and manganese can stain clothes, discolor plumbing fixtures, and sometimes add a rusty taste and look to the water resulting in aesthetic problems. These aesthetic problems may cause people that use your water to avoid what is otherwise a safe water supply in favor of water of unknown or questionable quality.

Iron and manganese in water promote the growth of **iron bacteria**. Iron bacteria are microorganisms that "eat" or metabolize iron. Iron bacteria will flourish when iron levels are high. If there is an excess of soluble iron in the water, the bacteria will utilize the soluble iron and produce by-products that give the water a metallic taste. Iron bacteria can cause red water, clog well screens and reduce water production.

Manganese creates problems similar to iron in groundwater. Manganese usually does not discolor the water but it will stain washed clothes and plumbing fixtures black, which is very unpopular with customers.

2.4d Hydrogen Sulfide

Hydrogen sulfide gas produces an offensive rotten egg or sulfur water odor and taste in water. In some cases, the odor may be noticeable only when the water is initially turned on or when the hot water is used. Heat forces the gas into the air that may cause the odor to be especially offensive in a shower.

Occasionally, a hot water heater is a source of hydrogen sulfide odor. The magnesium corrosion control rod present in many hot water heaters can chemically reduce naturally occurring sulfates to hydrogen sulfide.

A nuisance associated with hydrogen sulfide includes its corrosiveness to metals such as iron, steel, copper and brass. It can tarnish silverware and discolor copper and brass utensils. Hydrogen sulfide also can cause yellow or black stains on kitchen and bathroom fixtures. Coffee, tea and other beverages made with water containing hydrogen sulfide may be discolored and the appearance and taste of cooked foods can be affected.

High concentrations of dissolved hydrogen sulfide also can foul the resin bed of an ion exchange water softener. Hydrogen sulfide is often present in wells drilled in shale or sandstone, near coal, peat deposits or oil fields.

2.5 Biological Characteristics

Biology is defined as the study of living organisms. Microbiology is the study of **microorganisms** so small in size that they must be studied under a microscope. Most microorganisms cannot be seen with the naked eye.

Groundwater is typically less biologically active than surface water. This means that the numbers and types of microorganisms are lower. This is brought about by the natural filtration provided by the soil and rock particles that groundwater must pass through on its way to the aquifer. However, microorganisms may still be present that can cause disease or present nuisance problems for operators of well systems. Microorganisms of interest to a small-untreated groundwater system include bacteria, protozoa and viruses.

Diseases caused by **pathogenic** bacteria, protozoa and viruses can be transmitted through fecal contamination to humans. The presence of waterborne pathogens (disease-producing organisms) is often an indication of unsanitary conditions.

Bacteria are single-celled organisms ranging in size from 0.5 - 2 **microns** in diameter and about 1-10 microns long. A micron is a metric unit of measurement equal to 1 thousandth of a millimeter. To visualize the size of bacteria, consider that it would take approximately 1,000 bacteria lying side by side to reach across the head of a straight pin. They are among the most common microorganisms in water. Typhoid fever and cholera are examples of bacterial waterborne diseases.

Protozoa are single-celled organisms, several hundred times larger than bacteria. They range in size from 4 microns to 500 microns. Two species of protozoa, Cryptosporidium and *Giardia lamblia,* have been found to be the cause of waterborne gastrointestinal disease outbreaks in the United States. Protozoan cysts are extremely resistant structures that protect the organism from destruction when it encounters harsh environmental conditions, including chlorination.

Viruses are pathogens responsible for many human diseases such as viral gastroenteritis, smallpox, poliomyelitis (polio) and infectious hepatitis. They are intracellular parasitic particles considered to be the smallest living infectious materials known.

The presence or absence of living organisms in water can be one of the most useful **indicators** of its quality. Microscopic organisms are important in assessing the quality of water, particularly drinking water. A group of bacteria, called coliforms, are perhaps the most important of the biological indicators of water quality. Coliforms are a broadly defined group of bacteria. They occur naturally in the soil and on vegetation as well as in the digestive tract of warm-blooded animals, including humans. It is necessary to make a distinction between two groups of coliforms: **total coliforms** and **fecal coliforms**.

Total coliforms refer to all the members of the group regardless of origin. The total coliform group has been used for most of the twentieth century as an indicator of the possible presence of disease-causing microorganisms. These indicator organisms are used because the analytical methods available to detect them are inexpensive, they are present in large numbers in fecal matter of humans and other warm-blooded animals, and they survive outside the body longer than most pathogenic bacteria.

Fecal coliform provide stronger evidence of the possible presence of pathogens than do total coliform. This group indicates the presence of fecal matter, which could be of human or animal origin since fecal coliforms come from the intestines of all warm-blooded animals. Fecal coliforms do not include coliforms found naturally in the soil and on vegetation. *Eschericia coli (E. coli)* are fecal coliforms from humans.

The microbiological quality of water is determined by looking for the presence of bacteria indicative of fecal contamination - namely, total coliforms or *E coli. E. coli* will appear in water samples that may have been contaminated recently by human fecal matter; thus they indicate the possible presence of disease-causing bacteria, viruses or protozoa. **Water containing E. coli or fecal coliforms is not safe to drink.** Corrective action must be taken immediately. Procedures to follow are explained in Chapter 6 in the case of a laboratory report showing an unacceptable level of total coliforms or *E.coli*.

Water quality generally describes the composite chemical, biological, and physical characteristics of a water supply. Small water system owners/operators are not required nor expected to be chemists or biologists. However, a basic understanding of the chemical, biological, and physical properties of water will ensure that safe and aesthetically pleasing water is delivered to system customers.

Chapter 3 - Wells - Location, Construction, and Components

3.1 Source Assessment and Protection

Whether a well taps an aquifer just below the surface or hundreds of feet deep, its location on top of the ground is a crucial safety factor. Locating a well in a safe place takes careful planning and consideration of factors such as where the well is in relation to surface drainage and groundwater flow. A well downhill from a livestock yard, a leaking fuel tank or a septic system runs a greater risk of contamination than a well on the uphill side of those types of pollution sources.

A water right is a legal right to use surface or groundwater under the Alaska Water Use Act (AS 46.15). A water right establishes your right to use the groundwater resource and your use subsequent to any future water right applications. A water right allows a specific amount of water from a specific water source to be diverted, impounded, or withdrawn for a specific use. When a water right is granted, it becomes appurtenant (a right or privilege) to the land where the water is being used for as long as the water is used. If the land is sold, the water right transfers with the land to the new owner, unless the Department of Natural Resources (DNR) approves its separation from the land.

In Alaska, because water is a common property resource, landowners do not have automatic right to groundwater or surface water. For example, if a farmer has a creek running through his property, he will need a water right to protect his use. Using water without a permit or certificate does not give the user a legal right to use the water. To obtain water rights in Alaska, you should submit an application for water rights to the DNR office in your area before drilling. After your application is processed, you will be issued a permit to drill a well or divert the water. Once you have established the full amount of water that you use beneficially and have complied with all of the permit conditions, a certificate of appropriation will be issued. This is the legal document that establishes water rights. Retain this document in a safe place.

Check for unused wells that may be in the area. Abandoned wells that are not properly decommissioned can cause groundwater contamination, waste, or loss of artesian pressure. An unplugged well casing serves as a direct conduit for surface contaminants to reach the aquifer. Alaska's well decommissioning standards are designed to prevent contamination of the well or aquifer by surface and subsurface leakage that may carry harmful chemicals or bacteria. ADEC has minimum standards that describe the acceptable methods for permanent well abandonment. Procedures for permanent well abandonment are discussed in detail in Chapter 4.

The SDWA attempts to protect drinking water resources. The act requires adherence to established drinking water standards and protection of underground sources of drinking water. As part of these goals, the act requires wellhead protection programs.

Wellhead protection areas are defined as the surface and subsurface areas surrounding a water well or well field supplying a public water system that may be contaminated through human activity. A wellhead protection program is designed to protect the wellhead from contamination.

Minimum Separation Distances Between Drinking Water Sources and Potential Sources of Contamination (measured horizontally in feet)	
Potential Sources of Contamination	**Community or Non-Transient Non-Community Public Water Systems**
Wastewater treatment works, wastewater disposal system, pit privy, sewer manhole, lift station, cleanout.	200 feet
Community sewer line, holding tank, other potential sources of contamination.	200 feet
Private sewer line, petroleum lines and storage tanks, drinking water treatment waste.	100 feet

Table C: Minimum Separation Distances

Water well drillers have local knowledge and experience with state regulations. They can help you select your well site.

Groundwater in its natural state is generally sanitary and safe to drink. The contractor must choose a well site so that potential contaminants from known nearby pollutant sources are avoided and construct the well in a way that surface pollutants cannot reach the aquifer.

One of the main considerations in locating your well is convenience. If conditions allow, try to locate the well close to where you will use the water and near a power source. The following standards apply to the siting and placement of wells:

- Locate the well away from septic tanks, sewage disposal area (such as drain field), and other sources of contamination such as stockyards, storm sewers, privies, or refuse dumps. The State of Alaska Drinking Water Regulations require a minimum distance of 200 feet from septic tanks and sewage disposal area (refer to Table C for minimum separation distances required between drinking water sources and potential sources of contamination).
- Identify potential contamination sources that are found in agricultural, commercial residential, industrial, or undeveloped areas.
- Provide for drainage away from the well on all sides; divert up-slope drainage away from hillside wells.
- Locate the well up gradient of disposal areas if possible.
- Locate the well far enough from buildings to allow easy access during maintenance, repair, testing, or redevelopment.

Remember to plan future well construction or repairs before building a shelter around the well.

- Locate the well in an area free from flooding or plan extra precautions to protect it.
- Site your well as far as possible from neighboring wells. When wells are close together, they can interfere with each other and may produce less water.

ADEC well construction standards are designed to protect the ground water resource and the public. The standards attempt to prevent contamination of the well or aquifer from surface and subsurface leakage that may carry harmful chemicals or bacteria to the water source, and they attempt to prevent physical injury and waste of water.

In some cases, due to site conditions, it may not be possible to construct or abandon a well in a manner that meets the minimum state standards. When the minimum construction standards cannot be met, the person responsible for drilling, altering, or abandoning the well must obtain a variance from ADEC. The variance, allowing exception from the standards, must be obtained before completing the work and must adequately protect the groundwater resource. The cost involved for well construction is not a compelling reason to grant a variance.

An important step in well construction is the development of the well to supply the amount of water that the aquifer is capable of producing. Factors related to development of a groundwater supply that must be considered include water system needs, the location of the well, the design and construction of the well, and well operation. These factors determine the success and the costs of using a well as a public water supply. Well construction is one of the most important aspects of system construction. Owners and operators need to have a basic understanding of well construction techniques, components, terminology and maintenance.

3.2 Well Types

There are three major types of wells: dug wells, sand point or driven wells, and drilled wells. A well is a hole in the ground that penetrates an aquifer. A pump and pipe are used to pull water out of the ground, and a screen filters out unwanted particles that could clog the pump and pipe.

A **dug well** is a large-diameter hole (usually more than 2 feet wide), which is often constructed by hand. Dug wells pose the highest risk of allowing drinking water supply contamination because they are shallow and often poorly protected from surface water. Driven-point (sand point) wells, which pose a moderate to high risk, are constructed by driving assembled lengths of pipe into the ground. These wells are normally smaller in diameter (two inches or less) and less than fifty feet deep. They can only be installed in areas of relatively loose soils, such as sand.

All other types of wells, including those constructed by a combination of jetting and driving, are considered drilled wells. Table D lists some problems and causes that can occur due to natural materials and their solutions.

Problems Due to Natural Material and Solutions		
Problem	**Cause**	**Solutions**
Hard water (scales/deposits in kettles and water heaters)	Excess calcium	Water softeners Reverse osmosis Distillation
Rusty (red to brown) staining of fixtures and laundry and/or metallic taste	Excess iron	Chlorination-filtration Greensand filtration Aeration-filtration Distillation
Black staining of fixtures and laundry and/or metallic taste	Excess manganese	Chlorination-filtration Greensand filtration Aeration-filtration Distillation
Rotten egg smell	Hydrogen sulfide	Chlorination-filtration Greensand filtration Aeration-filtration
Water has laxative effect	Excess sulfate	Reverse osmosis Distillation
Turbidity/grittiness	Mud/silt/clay/sediment in water	Sediment filters
Organic (tea) color	Tannins	Chlorination-filtration Ozonation-filtration

Table D: Problems Due to Natural Materials and Solutions

3.3 Well Log

A **well log** is a written report produced by the well driller that includes a description of the material (soil, rock, or ice) that was encountered during drilling, the depths at which they occurred, the depth to groundwater, and the well depth.

You should receive a copy of your well log report from the water well driller within 30 days. Alaska state law requires a copy of the well log be sent to DNR within 45 days. Also, when a well driller drills a well, they are required to file a copy with ADEC within 30 days after completion of the well. In order for ADEC to assess the vulnerability of each drinking water source in a public water system, evaluate significant existing and potential sources of man-made contaminants, and to establish protection areas for public water systems, the owner or operator of a community or non-transient non-community public water system shall submit to the department a copy of the driller's log for each well serving a community or non-transient non-community public water system.

The well log report also includes the length, diameter, wall thickness, and type of casing. A casing is the steel or plastic pipe installed to prevent borehole cave-in and to seal the upper portion of the well. Also included in the well log report is the location of casing perforations or screen location. Screens or slotted casings are installed in wells to permit sand-free water to flow from the aquifer into the well and to prevent cave-ins by providing support for unstable formations. The size of the slot for the screen or perforated pipe should be based on a sieve analysis of carefully selected samples of the water-bearing material in the aquifer. The screen manufacturer usually makes the sieve analysis. If the slot size is too large, the well may yield sand when pumped. If the slots are too small, they may become plugged with fine material and the well yield will be reduced. In a drilled well, the screens are normally placed after the casing has been installed; however, in a driven well, the screen is a part of the drive assembly and is sunk to its final position as the well is driven.

Finally, the well log report should include the yield and draw down test and the names of the water system owner and the well driller. This original information will be collected when the driller performs a pump test. Pumping tests, when properly performed, provide information about the performance and efficiency of the well and the pump. Measurements of static water level, pumping water level, well yield, and discharge pressure are recorded on the original well log report. At a minimum, the system operator should make measurements once quarterly. From these measurements the operator can determine draw down, specific capacity, and pump performance. These results may then be compared with the original well log and previous results to estimate changes in well and/or aquifer conditions and pump performance. Appendix 1 is an example of a Well Log Report. The following well production terms and well testing terminology is important:

Static water level - The level where water stands when the well is not being pumped. It is generally expressed as the distance in feet from the top of the well casing down to the water level in the well.

Pumping water level - The level at which water stands when the well is being pumped. Pumping level is measured the same as static water level.

Draw down - The difference in feet between the static and pumping water levels in a well.

Well capacity (Yield) - The volume of water per unit of time discharged from the well usually recorded as gallons per minute (gpm) or gallons per day (gpd).

Specific capacity - The well yield per unit of draw down. Commonly expressed as gpm/ft.

Well development - Involves vigorously pumping the well to help clean out drill cuttings and to maximize production of the well. Development should result in a well that produces sand-free water when operated properly.

Top terminal height - The casing head must extend twelve inches minimum above the finished ground surface or pump house floor, and twelve inches above the local surface runoff level.

Well depth can be measured by using a weighted line or by measuring the drill pipe in the hole when drilling is completed. Tie a heavy weight to a string and lower it into the well until it touches bottom and measure the length of the string used. The depth should be close to the depth recorded on the well log report.

A variety of methods are used to determine the static water level in a well, but all wells should have an access port or some feature that allows water level measurements to be easily taken.

Two common methods used to measure static water level are the electric tape method and the air line method. An electric well tape consists of a battery connected to a pair of insulated wires molded into a measuring tape. When the wires touch the water, the circuit is completed and a sensor (meter, light, or buzzer) indicates that the water surface has been reached and the depth can be read from the tape.

The air line method measures the water level depth by determining the air pressure required to push all the water out of a submerged tube of a known length. There is a direct correlation between pressure (pounds per square inch) and feet of water (0.433 psi = 1 foot of water).

To determine draw down, first determine the static water level. Then, after the well has been pumping at a constant rate for several minutes, or until you are confident that the pumping water level has stabilized, measure the depth to water again. The difference between these two readings is recorded as feet of draw down. Pumping water level is the level at which water stands when the well is being pumped. Pumping level is measured the same as static water level.

Specific capacity is calculated by dividing the well yield in gallons per minute (gpm) by the draw down. This data may be plotted on a chart so you may visually track the performance of the well. Industry standards suggest that a ten percent reduction in specific capacity signals that it is time to consider pump maintenance and/or well rehabilitation.

The frequency of well testing depends entirely upon the performance of your well. For example, a well that produces plenty of water, recovers quickly, has good water quality, and has a consistent draw down level may only need to be tested routinely. Other wells may need to be monitored constantly. Initially, you may want to test your wells weekly, monthly, or bimonthly to become comfortable with the procedures.

3.4 Well Components

The components that make up a well system include the well itself, the well house or building, the pump, and related piping system. Many components of a well cannot be observed. Components that make up the well are discussed in this section. Many of these components are shown in Figure 3.1.

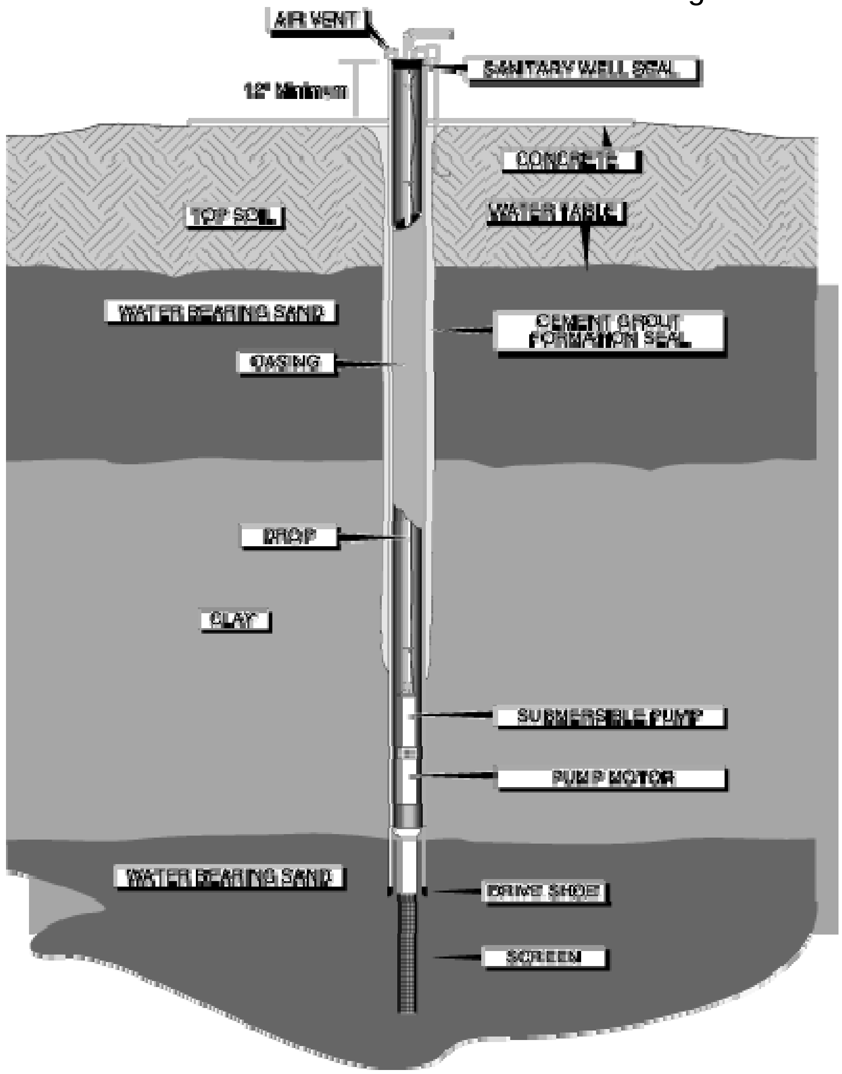


Figure 3.1: Well Components

3.4a Well Casing

The well begins as a hole in the ground called the borehole. During construction, the well driller installed a steel or plastic pipe called casing. The hole is protected from collapse by placing the casing inside the borehole. The well casing provides a column of stored water and a housing for the pump mechanisms and discharge pipe. The well casing also prevents contaminants (either surface or subsurface) from entering the water source. The well casing must extend a minimum of twelve inches above finished grade.

3.4b Grout

The **annular space**, the space between the borehole and well casing, or between an inner and an outer casing**,** presents a direct pathway for contaminants to enter a well and the groundwater. Sealing the space between the borehole and the casing with grout helps prevent contamination to the aquifer. Grout consists of cement or other watertight material that is pumped into the annular space.

Grouting is required by regulation. A cased well must be grouted with a water tight cement grout, sealing clay, bentonite, or an equivalent material with at least ten feet of continuous grouting within the first twenty feet below the ground surface, or an alternate method of grouting, per ADEC Drinking Water Regulations 18 AAC 80.

3.4c Well Pad

The well pad provides a ground seal around the casing. The pad is constructed of reinforced concrete 6 feet by 6 feet (6 in thick) with the wellhead located in the middle and sloped away from the wellhead. The well pad prevents contaminants from collecting around the well and seeping down into the ground along the casing.

3.4d Sanitary Seal

To prevent contamination of the well, a sanitary seal is placed at the top of the casing. The type of seal varies depending upon the type of pump used. The sanitary seal may have openings for power and control wires, pump support cables, a draw down gauge, discharge piping, pump shaft, and air vent, while providing a tight seal around them.

3.4e Well Screen (or filter pack)

Screens are installed at the intake point(s) on the end of a well casing or on the end of the inner casing on a gravel pack well. These screens perform two functions:

1. Supporting the borehole
2. Reducing the amount of sand that enters the casing and the pump

In an artificially gravel-packed well, the aquifer formation material around the well screen is removed. The removed materials are replaced by more coarse material of high uniformity, approximately five times the diameter of the native material, such as pea gravel. It is designed to:

- Increase the permeability of the formation and screen.
- Exclude virtually all of the formation material beyond the gravel pack.
- Stabilize the formation.

The filter pack material is poured down the annular space between the drill hole and casing prior to the installation of the grout.

3.4f Packers

Telescoped screen assemblies are equipped with one or more sand-tight seals between the top of the telescoped screen assembly and casing. Packers are made of material that will not impart taste, odor, toxic substances or bacterial contamination to the well water.

3.4g Lightning (Ground) Protection

Voltage and current surges produced in power lines by lightning discharges constitute a serious threat to electric motors. High voltage can easily perforate and burn the insulation between motor windings and motor frame. A submersible pump motor is highly vulnerable to voltage and current surges because it is submerged in groundwater. Groundwater serves as the natural ground sought by an electrical discharge. There are simple lightning arresters available to protect motors from near miss lightning strikes although arresters are seldom effective against direct hits.

Small water system operators unfamiliar with the basics of electricity and lacking hands-on experience should contact a local electrical firm or pump service company to install lightning protection or perform electrical maintenance or repairs.

3.4h Casing Vent

The well casing must have a vent to allow air to enter the casing as the water level drops. The vent typically terminates eighteen inches minimum above the floor/ground with a return bend pointing downward. The opening of the vent should be screened with #24 mesh stainless steel to prevent entry of insects, rodents, or debris.

3.4i Drop Pipe - Riser

The drop pipe or riser is the line leading from the pump to the wellhead. It assures adequate support so that an above ground pump does not move and so that a submersible pump is not lost down the well. The drop pipe serves as the distribution pipe from the pump carrying water from the well to the water system main distribution pipe.

3.4j Pitless Adapter

A pitless adapter is a unit or adapter designed to permit water service pipes to pass through the wall of the well casing below the frost line. It also prevents entrance of contaminants and provides full access to the water well components within the well.

Installation of a pitless adapter requires cutting a hole in the side of the well casing at a depth below frost line. A fitting to accommodate the discharge line from the pump is inserted into the opening in the well casing. The other part of the pitless adapter accommodates connection for the distribution pipe or service line. Watertight connections are accomplished by a system of rubber seals compressed by clamps or by the weight of the equipment itself. The top of the casing, which provides access to the well, must be sealed and vented as discussed above.

3.4k Electrical Cable

A waterproof electrical cable extends from the top of the unit down the inside of the casing to a submersible electric motor. The submersible electric motor is attached to the lower end of the pump assembly.

3.4l Foot Valve

A foot valve is a type of check valve. The foot valve is installed at the bottom, or foot, of the drop pipe. Water flow forces the valve open when the pump starts, and the valve acts as an automatic shutoff when the pump stops. For instance, when the pressure in a hydropneumatic tank drops to 30 psi, the pump starts. When the pump starts, the foot valve opens and water flows to the pressure tank until the shutoff pressure of 60 psi is attained. At 60 psi, the pump shuts down, and the foot valve then closes preventing the water from flowing back down into the well and keeping the drop pipe and water distribution lines full. Because of freezing concerns, some wells are completed with a weep hole in the riser so the riser pipe does not have standing water in it. Small particles of sand or foreign material may cause the foot valve not to seat tightly. As a result, a lineshaft turbine pump may lose its **prime**.

3.5 Well Pumps

Three common centrifugal pumps installed in groundwater systems are submersible turbines, lineshaft turbines, and jet-equipped centrifugals.

3.5a Submersible Turbines

A submersible pump is a vertical turbine pump with the motor **close-coupled** to it and placed in a watertight enclosure. The pump and motor are submersed in the well and are connected to the surface by the drop pipe and electrical connections. It is a pump that is usually designed to be multi-staged (the pump has more than one **impeller**). How far the water must be lifted and how much pressure is needed in the distribution system determines the number of stages. Since the pump is submerged, it requires no suction line and the motor is fitted on the lower end of the pump. The motor is designed to operate under water. The entire unit is lowered into the well on the end of the drop pipe. The drop pipe carries water from the well to the distribution main or service line. No external lubrication is required. The motor is completely enclosed and may be oil-filled, however, most new models are water-filled.

Submersible pumps (Figure 3.2) are extremely reliable and maintenance is minimal since there is no line shaft or oil tube requiring operator attention. However, if either the pump or motor needs to be repaired or replaced, the entire pump must be removed from the well. Removal of a submersible pump requires specialized equipment.

3.5b Lineshaft Turbine

The lineshaft turbine pump (Figure 3.3) is also a vertical turbine pump that consists of submerged bowls that contain the impellers, which are connected with each other through the pump shaft bearings. The motor is mounted above ground with a line shaft that connects to the pump at the bottom of the well column. A turbine pump will usually be staged with more than one bowl and impeller to overcome the head conditions that are encountered in the operation. The water from one stage will be discharged into the suction eye of the next stage, a process that will continue until the head is overcome. The size or diameter of the first impeller dictates the volume capacity of the pump in gallons per minute (gpm).

Vertical turbine pumps contain the following parts: power source, discharge head, pump column, pump shaft, shaft bearings, and the pump itself.

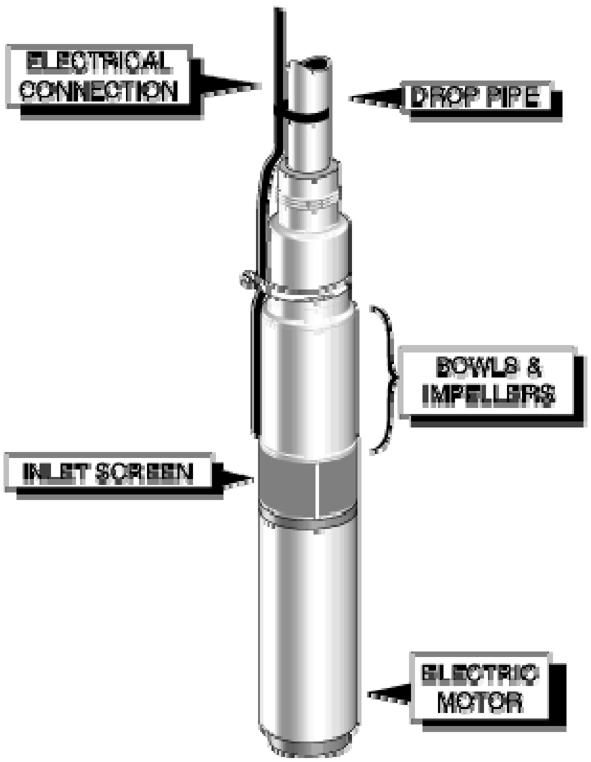


Figure 3.2: Submersible Pump

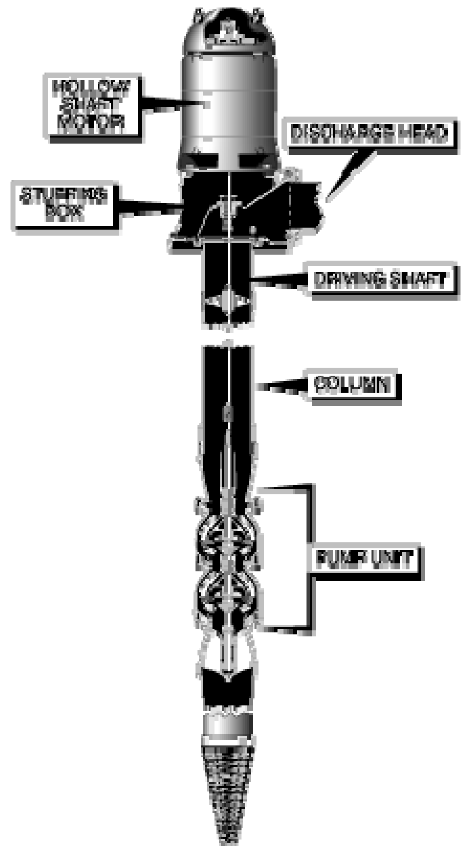


Figure 3.3: Lineshaft Turbine Pump

3.5c Jet Pumps

A jet pump uses a centrifugal pump, nozzle, and venturi tube to create a partial vacuum to pump water. A portion of the water is recycled to the nozzle and this makes jet pumps inherently inefficient. They are useful in small diameter domestic wells, but are also common to some water systems where the depth to water is relatively shallow.

3.6 Well System Components

Specialized equipment is required to meet the State of Alaska construction standards for drilling a well and installing the well casing, screen, and various components that make up a well system.

An understanding of the components that make up your well system will assist you with well maintenance and troubleshooting. Not every well component an owner/operator may encounter is covered in this section.

3.6a Check Valve

The check valve acts as an automatic shutoff when the pump stops. Water is prevented from draining back down the drop pipe providing the same reverse flow functions as the foot valve. The check valve is located on the discharge side of the pump.

3.6b Sample Tap

A spigot, referred to as the raw water sample tap, located before any storage or treatment is to permit sampling directly from the well. The raw water sample tap is normally located in the well house on the discharge side of the pump.

3.6c Flow Meter

A flow meter records the total amount of water produced by the well. By recording the gallons or cubic feet of water pumped, pump efficiency can be tracked. Total water usage must be known to establish fair rates for customers. Any unexplained increase of water usage may be the first indication of a water leak.

3.6d Blow-Off Valve

A blow off valve is normally located in the well house prior to the main control valve (isolation valve). The blow off valve is used to flush the well of sediment or chlorine.

3.6e Isolation Valve

In order to work on the pump, it must be isolated from the rest of the system. A gate valve or butterfly valve installed on the discharge line can serve as an isolation valve.

3.6f Pressure Gauge

The pressure gauge on a pump should be installed on the discharge piping as far from the pump as practical. If mounted on the pump casing directly, it will not give accurate readings, as the energy in the water has not yet been fully converted to pressure.

A properly operating gauge can be a handy tool to diagnose pump problems. If readings begin to show a steady increase in pressure, there may be an obstruction building downstream from the gauge. If gauge readings show a steady decrease in pressure, check for a leak or break in the piping downstream. If your system is not equipped with a flow meter, the flow rate can be estimated using the readings from the pressure gauge. However, a flow meter is recommended for more accurate flow readings.

3.7 Groundwater Withdrawal

As the well is pumped, groundwater flows toward the well and water is removed from the aquifer surrounding the well. The level of the water table in the vicinity of the well will be lowered. This lowering or draw down causes the water table or artesian pressure surface, depending on the type of aquifer, to take the shape of an inverted cone called a **cone of depression** (Figure 3.4).

The cone of depression, roughly conical in shape with the well at the apex (highest point), is produced by the extraction of water from a well. As a pump operates in a well, the depth of water will move up and down. If the pump were shut off for several hours and that water level allowed to recover and stabilize, the level would be called the static water level.

At increasing distances from the well, the drawdown of water decreases until the slope of the cone merges with the static water table. The distance from the well at which this occurs is called the **zone of influence**. The zone of influence is not constant but tends to continuously expand with continued pumping. At a given pumping rate, the shape of the cone of depression depends on the characteristics of the water-bearing formation. Shallow and wide cones will form in highly permeable aquifers composed of coarse sands or gravel. Steeper and narrower cones will form in less permeable aquifers. As the pumping rate increases, the draw down increases and consequently the slope of the cone steepens.

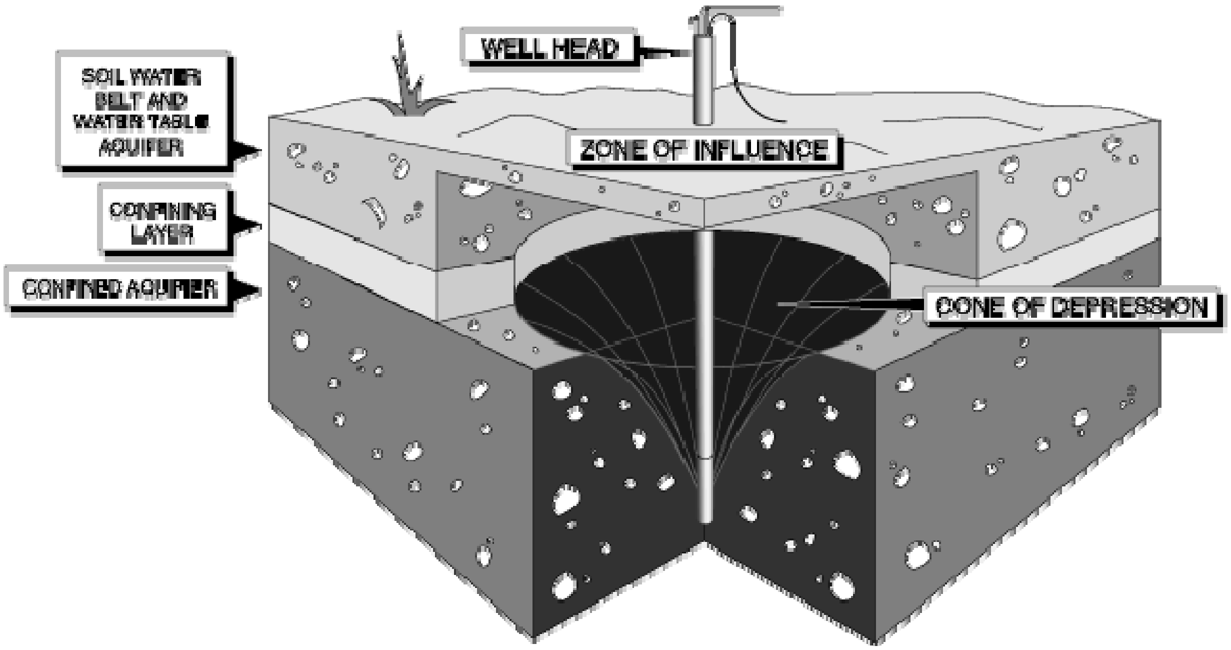


Figure 3.4: Cone of Depression

Chapter 4 - Water System O&M

4.1 Operation and Maintenance of Wells

Proper siting, location, construction and maintenance of your well will minimize the likelihood of contamination. Check the well cap frequently to ensure it is secure and watertight. Joints, cracks and connections in the well casing should be sealed. Pumps, pipes, and valves should also be checked on a regular basis, and any changes in water quality should be investigated.

Surface drainage should be sloped away from the well casing in order to prevent surface water from collecting (pooling) near the well. Prevention, planning, and protection are the keys to properly operating a well/water system. Although not all-inclusive, a list of sanitary procedures to help protect your well are listed below:

- Do not store or use hazardous substances such as gas, oil, pesticides, or paints in or around the well house.
- Check the casing vent monthly. A properly functioning and vented sanitary seal on top of your well casing keeps potential contaminants from entering.
- If your well has a pitless adapter (water pipe exits the well casing below ground surface rather than through the top of the well casing) make sure there is an adequate seal present to prevent bacteria from entering the well. The pitless adapter may be visually inspected when the well cap is removed by shining a light into the casing. You can also use a mirror to reflect sunlight into the well casing and inspect some of the well casing internal components.
- Keep vegetation from growing around the immediate area of the wellhead and well house.
- Protect well/water system from freezing. Insulate the pipes; locate a lamp, heat lamp, or heater (with proper electrical connections) in the well house. Be aware that lamps burn out and cause freeze-ups. Check lamps frequently.

Well components do not last forever. Every ten to twenty years, a well may require mechanical service from a qualified pump service company or well pump installer. However, regular inspection and preventative maintenance will help ensure continued, reliable operation of the entire water system. Owners/operators agree that well maintenance is important, but it is often delayed because the well and well components are out-of-sight and out-of-mind.

As discussed earlier, protecting the well from possible contamination cannot be over emphasized. Shallow wells draw water from near the land surface and may be directly affected by activities around the well. Rain and surface water that soak into the soil may carry nearby pollutants to the aquifer.

Each year wells are threatened, damaged, and destroyed by accidents that occur near the wellhead: fuel tank leaks, fertilizer tank leaks, or a pesticide truck spill. These are a few of the types of accidents that threaten the safety of the aquifer on a regular basis. Diligent management of activities allowed near your well can minimize the impact of these activities. By monitoring and moving sources of potential accidents away from the well, any adverse impact to the well may be avoided or delayed. Anticipating possible accidents and taking precautions takes a small amount of time compared to the cost of cleanup or environmental damage. An ample supply of safe drinking water is absolutely necessary for living. Permanent contamination of a well ultimately means loss of property value and may involve liability.

Local geological conditions determine how long it takes for pollutants to be carried to an aquifer. In some places, the process happens quickly, in weeks, days or even hours. Areas with thin soil over fractured bedrock or sand and gravel aquifers are particularly vulnerable. Even thick sand over fractured bedrock represents a site vulnerable to contamination. On the other hand, thick clay soils do not allow contaminants to reach the water table, and may prevent contamination or delay the day when a well turns bad. If you have a **deep well** (more than several hundred feet below the water table), the well may be less vulnerable to pollutants carried to the aquifer if it is properly sealed and constructed. Once again, be diligent monitoring the types of activities you allow around your well.

4.1a Well House Inspection

An operator's senses are the best tools available for detecting abnormal water system conditions. Look, listen, smell, and touch are the main troubleshooting tools that warn operators of potential or existing problems. Look for water, air, or lubricant leaks. Listen for unusual sounds coming from the pump, motor, valves, or controls. Feel the motor casing and pump casing for vibration or excessive heat.

Frequent inspection of the well house and maintaining written records should be routine activities. In the well house, check the motor temperature if the motor is mounted above ground. Check the motor temperature by placing the back of your hand on the motor casing. The casing will normally be warm to the touch. If you must remove your hand quickly because the heat is intense, the motor may be overheating and the reason should be investigated.

The well house, pumps, and water system operating equipment should be inspected daily. Check the well house for vandalism or damage. Verify that containers of poisons, pesticides, petroleum products, or other hazardous materials have not been moved into the pump house or near the well. Do not use the pump house to shelter animals. Check for exposed and bare electrical wires. All wires should be cased in conduit and wire-splices contained within a junction box.

A daily operational log sheet should be created and tailored to record data for the well house and water system being operated. Record the date and time of the visit to the well house and any maintenance or operational changes made. Record pressure gauge readings, water meter readings, and **pump hour meter** readings. Pay special attention to the pump discharge pressure gauge. This reading is used to monitor the efficiency of the well pump. Similarly, the suction and discharge pressure gauge readings are useful for monitoring performance on end-suction centrifugal booster pumps. Observe the on-off pressures from the hydropneumatic tank if possible.

Record the pump hour meter reading. The pump hour meter is normally located in the control panel and records the amount of time that power was delivered to the pump (the length of time water was pumped is recorded). Record the **pump cycles counter** reading. The pump cycles counter tallies the number of times the pump motor cycles (turns) on and off. If cycles are too frequent, the storage tank level controls are improperly set or the hydropneumatic tank may have lost its air cushion and is waterlogged. Make certain the well house access door is locked after completing the routine maintenance and inspection visit.

At least once per year check to see that the wellhead casing is free of cracks or other leaks. Check that the sanitary seal is secure and watertight, and make sure the ground slopes away from the wellhead for at least ten feet in all directions. Check electrical wiring at the well casing to make sure it is enclosed in conduit, and check the conduit to make sure it is flush against the well cap. The conduit should not be pulled away from the well cap creating an entryway into the well casing for insects and rodents. Review water monitoring data and analyses, and compare to past results, on a regular basis. Find and fix the cause of any change in water color, taste, or odor. Shock-chlorinate the well only when necessary.

Keep a permanent record of the static water level from a reference point such as the top of the well casing. These measurements provide early warning of pump and well capacity problems. Measure the static water level at least twice per year and record the measurement, time, and date. Measurements should be made on approximately the same dates each year, usually in the spring and fall. The well should be allowed to sit without pumping for one to two hours before measuring the static water level.

4.2 Operation and Maintenance of Pumps

Pumps transfer water out of the well to a pressure tank, storage tank, and distribution system or to a combination of water system pipes and storage facilities.

Always refer to the manufacturer's service manual supplied with your pump when performing pump installation and maintenance procedures. Manufacturers' service manuals should be available for all water system equipment. Manufacturers' service manuals provide detailed instructions for the replacement of impellers, seals, and **bearings**. Follow the manufacturer's instructions for the particular pump being serviced. Service manuals should be carefully read, filed, and consulted whenever servicing is required.

Consult with a reputable pump manufacturer or local pump service company before purchasing a pump. Purchasing a pump that is oversized in anticipation of future system requirements can lead to problems. When pumps are operated against a **throttled** (partially closed) discharge valve, the pump operates under capacity. This arrangement not only wastes **horsepower**, it also creates internal vibration and pressure surges that can damage your pump.

Vibration may also be the result of **cavitation**. Cavitation produces distinctive erosion marks on the volute and impellers similar to those left by hitting a hard surface with a ballpeen hammer. A cavitating pump may sound like someone is inside the pump casing pounding on the impeller with a hammer creating a loud pinging noise.

Inspecting submersible pumps on a daily, semiannual, or even an annual basis is unreasonable. Therefore, recording the amount of water produced by the well, recording the pressure gauge reading on the pump discharge pipe, and the electrical meter reading (submersible pump usage) are crucial indicators that determine when a submersible pump should be pulled for service or replacement.

Declining well yield *may* indicate pump service or replacement is required. A declining well yield may also indicate an incrustation problem. Incrustation occurs when clogging of the well screen and water-bearing formation occurs. Incrustations, on screens and adjacent aquifer materials, result from chemical or biological reactions at the air-water interface in the well. The main encrusting agent is calcium carbonate, which cements the gravel and sand grains together. Treatment involves pulling the screen and removing the incrusted material, replacing the screen, or treating the screen and water-bearing formation with acids. However, removing well screens may not be practical. Do it in place with acid if you know for sure they are plugged. Once again, consult with a reputable pump manufacturer or local pump service company for the proper procedure to clean screens with acid. If severe, treatment may involve redeveloping the well. Incrustation could also be a result of carbonates of magnesium, clays and silts, or iron bacteria.

Iron bacteria occur naturally in the soil and may be introduced into the groundwater during the well drilling process. These bacteria use soluble iron in their life processes and as a by-product form a gelatinous slime or mat. This mat can be found as a reddish, slippery substance on the inside surfaces and parts of a toilet tank. Once established on steel pipes, such as the well casing, this mat will provide a haven for sulfur bacteria.

Some sulfur bacteria convert sulfides to elemental sulfur, which combine with bacterial filaments that can clog pipes. Another group of sulfur bacteria generate **hydrogen sulfide gas**, which is corrosive to pipes and has a foul smell like rotten eggs. Some sulfur bacteria may produce sulfuric acid as a by-product that can also cause corrosion of pipes. As mentioned above, the slime mat produced by the iron bacteria provides a favorable environment for the sulfur bacteria. This slime mat also encloses and supports sites of corrosion, which may be the cause of the odor, taste, and staining problems commonly encountered with wells.

Never assume declining well yield is caused by failure of the pump or incrustation. Has the static water level decreased? The static water level and pumping water level should be compared to previous records. Regular inspection, record keeping, and preventive maintenance ensure continued reliable operation of the entire submersible pumping system.

Operators have more control and maintenance responsibilities with line shaft turbine pumps or above surface pumps and motors. Operators should check daily for irregularities of motor and pump performance. Irregularities that must be noted include:

- Changes in sound of a running pump
- Unexplained temperature changes on bearings
- Seal chamber leakage
- Sudden pressure gauge drops
- Increased motor or pump vibration or heat

Any irregularities should be investigated and corrected. **Pressure gauge(s)** should be observed and reading(s) recorded daily. Also, the well house flow meter and electrical meter readings should be observed and recorded.

Bearings requiring lubrication should be checked to see that they contain the correct amount of grease. Maintenance of grease-lubed bearings is a matter of flushing old grease out with new. Old grease must have a place to go. For instance, out relief plugs. If not removed, the old grease builds up inside the machine and may lead to future problems.

Pump bearings are designed to have a minimum service life of more than thirty years when properly installed, operated, and maintained. Contamination of bearing lubricant is a far greater danger to bearing life than overloading, overuse, or fatigue. Grease according to manufacturer's recommendations, which will be approximately twice per year (semiannually). *Do not over-grease bearings. More grease is not better*. Semiannual maintenance should also include:

- Inspect shaft packing
- Replace packing if necessary
- Observe mechanical seals for signs of leaking
- Check stuffing box packing glands for free movement
- Clean and lubricate packing gland bolts
- Check pump and driver alignment, if applicable

A centrifugal pump should never be started unless it is primed. Priming a pump means that the volute is completely filled with water and all air removed.

A spare parts inventory should be kept. Pump usage, past repairs, and maintenance records will determine the minimum number or spare parts that should be stocked. Spare parts should be purchased when the pump is purchased as insurance against delays receiving parts that may result in downtime. Consult with the pump installer and pump manufacturer to determine what critical spare parts should be kept on hand. Rather than waiting for a failure to start overhauling a pump, small water systems may be better off having a spare pump on hand ready to run. Remote water systems in Alaska must factor shipping time into the creation of a spare parts inventory. Delivery may take three to five days or more in many parts of the state.

4.2a Well Pumps

The two most common well pumps are the centrifugal pump and jet pump. Use extra precautions when working on pumps or other water system equipment. Contamination may enter into the water system through transmission of bacteria from your hands, the ground, or tools.

A centrifugal pump is the simplest of all pumps. It consists of one moving part (a rotary impeller) and a stationary casing (the volute or diffuser). The volute (case) captures the water that is thrown from the impeller (Figure 4.1) and directs it in a single direction. Operation of a centrifugal pump is very simple. The pump body is filled with liquid and the impeller is rotated, causing the liquid to flow outward by centrifugal force, creating a high velocity to the water. The outward flow of the liquid through the impeller reduces the pressure at the eye of the impeller, causing more liquid to be forced into the impeller eye by external or atmospheric pressure.

The liquid is collected in the volute, or diffuser, and converted to pressure. The pressure a centrifugal pump develops is in direct relation to the velocity created by the impeller. The larger the diameter of the impeller or the faster the impeller is rotated the more pressure the pump will develop. The width of the impeller vanes will determine how much liquid the pump will deliver. Pump speed and impeller size both affect the horsepower size of the motor. The more water you pump, or the higher pressures you develop, the more horsepower you will need. Horsepower is defined as a measurement of work. One foot-pound of work is the amount of energy required to lift one pound of water one foot in elevation. One horsepower is 33,000 foot-pounds per minute of work.

Figure 4.1: Semi-open Impeller

Jet pumps are seldom used in Alaska public water systems because of their low efficiency. However, they are commonly used for private wells because of their initial low cost and low maintenance. Jet pumps are used successfully in shallow wells and small diameter domestic wells. A jet pump includes a jet. A jet is a nozzle that receives water at high pressure. As water passes through the jet, water speed (velocity), increases and pressure drops. The action is comparable to the squirting action achieved through a garden hose when the nozzle starts to be closed. The velocity of the water coupled with the pressure drop allows water around the jet to be sucked in along with the suction flow of the pump.

4.3 Motor Maintenance (Non-submersible)

Check the oil quantity and condition on oil-filled motors on a regular basis. Check the oil in the motor housing through the oil inspection sight window or inspection plug. The oil may be low or emulsified (cream-like appearance), which indicates that water has entered the cavity and a water leak is present. If there has been leakage, or whatever the problem, correct it and make certain that the oil is refilled to the proper level with manufacturer's recommended oil.

Temperature, moisture, altitude, power source, and wire size are all factors that could impact the performance and longevity of the motor and pump.

4.4 Operation and Maintenance of Valves

Valves
Valves are used to regulate water flows, reduce pressure, provide air and vacuum relief, and blow off or drain water from the system. Valves are also used to prevent **backflow** and to isolate sections of the piping system for repair and maintenance. Many types of valves are used in the water industry, but all have basically the same function, to control or stop the flow of water in pipes.

Valve inspection program
A well-organized valve inspection program is essential for proper system maintenance. Valves normally suffer from a lack of operation, not wear. Valves four inches and larger should be **exercised** semi-annually. Exercising valves means to open and close the valve manually to assure they operate properly and easily. When exercising valves, they must be opened and closed slowly. If they are closed quickly **water hammer** may occur. The rise and fall in pressures, or water hammer, can cause serious damage to the distribution pipes and components.

Valves in a distribution system allow small sections of the distribution lines to be isolated for emergency maintenance.

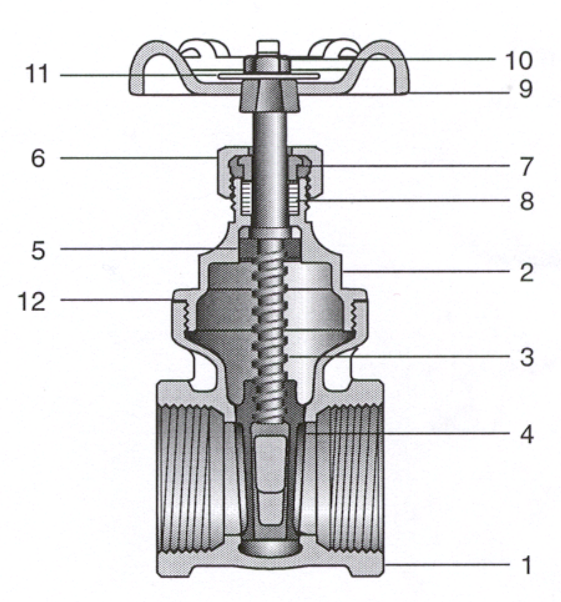
Inspection items
A good valve inspection program includes:

- Check the location of each valve as well as the measurements to established reference points, such as poles, trees, hydrants or buildings.
- Exercise valves in both directions; fully closed and fully open. Record the number of turns required to close the valve. Any valves that operate in the opposite direction from normal (normal: "righty-tighty; lefty-loosey") should be noted. Leave valves in a position one-half turn from the fully opened or fully closed position.
- Most valves should be left in the open position, but valves that normally remain closed should be noted.
- Valve boxes should be checked, debris removed, raised or lowered to grade, or replaced as necessary to accommodate current local conditions.

Small valves should be inspected annually and checked to make sure the handle and valve stem move freely. Tightening the packing nut, located on the top of valves, one-half to one full turn to stop leakage around the valve stem.

Gate Valves
The most common type of valve used in the water distribution system is the gate valve (Figure 4.2). It receives its name because of its gate-like operation. The most common gate valve is one with a non-rising stem; a valve in which the stem does not rise as the valve is opened.

The valve is reasonably dependable, has an almost unobstructed waterway when open, is very economical in smaller sizes, and can be installed underground with a minimum cost. A gate valve should not be used for throttling flow or for infrequent operation. It should be operated in the full-open position or left in a full-closed position.

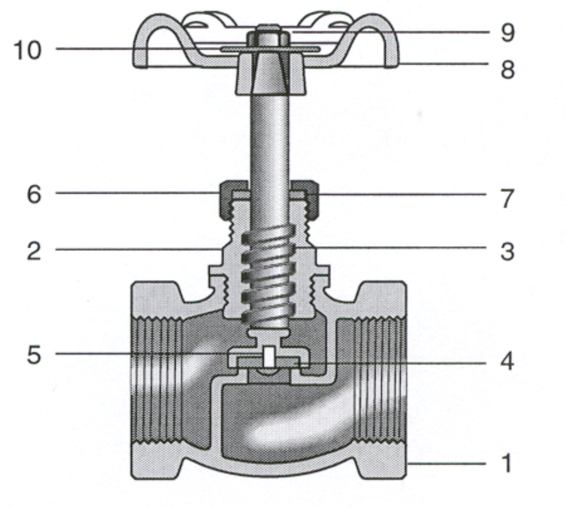


1 – Body	7 – Gland
2 – Bonnet	8 – Gland packing
3 – Stem	9 – Handwheel
4 – Disc	10 – Wheel nut
5 – Lock nut	11 – Name plate
6 – Packing nut	12 – Bonnet gasket

Figure 4.2: Gate Valve

Globe Valve
Globe valves are installed where there is to be a frequent change of operation. It receives its name because the main body is globelike in shape (Figure 4.3). Because of its design, this type of valve offers a significant resistance to the flow of liquids but does provide a more positive shutoff. Globe-type valves would not be used if the flow rates are important to the installation. The design of the valve is such that it must be installed in the correct position with the flow of liquid. Oftentimes, this direction

is indicated by an arrow on the valve itself.



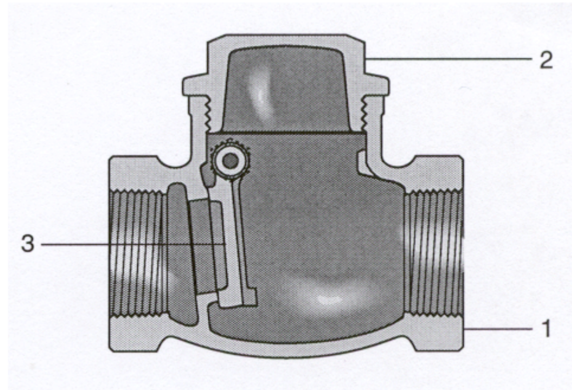
1 – Body	6 – Packing nut
2 – Bonnet	7 – Gland packing
3 – Stem	8 – Handwheel
4 – Disc	9 – Wheel nut
5 – Disc bolt	10 – Name plate

Figure 4.3: Globe Valve

Check Valve

A check valve is designed to allow flow in only one direction. The most common use of check valves in a water system is on the discharge side of pumps to prevent backflow when pumps shut down. A foot valve is a special type of check valve installed at the bottom of the pump suction so the pump will not lose its prime when power is shutoff.

The most common type of check valve is a swing check (Figure 4.4). Installed in the correct position, the flow of the liquid opens the disc allowing the fluid to pass. Should the flow reverse, the pressure and the disc's weight close the disc against the seat, stopping backflow.

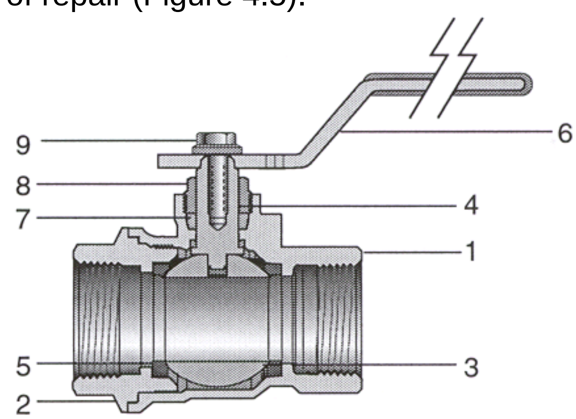


1 – Body
2 – Cap
3 – Disc

Figure 4.4: Check Valve

Ball Valve

Ball valves offer little or no resistance to the flow of liquids. One of its features is that a 90^{o} turn quickly opens or closes the valve completely. The handle position also indicates whether or not the valve is in the opened or closed position. Its simple design allows the valve to operate easily and offers ease of repair (Figure 4.5).



1 – Body	6 – Lever handle
2 – Body end piece	7 – Gland packing
3 – Ball	8 – Packing nut
4 – Stem	9 – Handle bolt
5 – Seat	

Figure 4.5: Ball Valve

4.5 Pressure Tanks

Hydropneumatic or pressure tanks are frequently used to maintain water system distribution pressure for small systems. Generally, when service to more than 50 houses is anticipated, other storage should be provided. Tanks are constructed of steel or fiberglass. The most common types of pressure tanks in use are the diaphragm, the bladder, and plain galvanized pressure tanks. They are not a good storage vessel for fire protection purposes due to the small volume of water within the vessel.

Water systems using hydropneumatic tanks operate in the following general manner:

- The water supply pump starts when the pressure drops to a predetermined low pressure (cut-in pressure). The energy from the pump pressurizes the pocket of air at the top of the pressure tank.
- When the pressure builds to a predetermined high pressure (cut-out pressure), the pump stops and compressed air forces the water into the distribution system.
- When the pressure falls to the cut-in pressure (often 30 to 40 psi), the pump starts up again, and the cycle is repeated. The cycle rate is the number of times the pump starts and stops in one hour. Six to eight pump cycles/hour with a minimum pump run time of one minute is the standard recommendation.

The pressure tank prevents frequent start/stop cycling that can be extremely hard on the pump. Water is incompressible for all practical purposes. Therefore, it is necessary to provide a pressure tank with storable energy (air under pressure). The pressurized air acts upon the water to force it from the tank into the water system pipes.

A pressurized storage tank must have provisions to replenish the air since another characteristic of water (the universal solvent) is its ability to absorb air. The tanks are pressurized with an air compressor that pumps air into the tank. Bladder tanks or tanks with optimum air volume controls generally are set up for one-third water and two-thirds air. Although, off-the-shelf galvanized tanks have an even ratio; one-half water and one-half air.

4.5a Diaphragm and Bladder Pressure Tanks

Diaphragm and bladder type tanks use a mechanically locked-in flexible separator that completely isolates the air from the water. The tank is pre-charged at the factory and has an air charging valve installed on the top of the tank to allow the installer to change the tank pressure in the field to accommodate different system pressures. Table E lists the recommended recharge pressure for different systems.

If the pressure switch is set to start the pump when the pressure drops to 30 psi, the air pre-charge pressure in the tank should be 28 psi. A water system may use pump cycle counters to tally the times that pump motor cycles on and off. If cycles are too frequent it is an indication that the storage tank level controls are improperly adjusted or that the hydropneumatic tank has lost its air cushion and is waterlogged.

Pressure switch setting	Tank discharge (psi)
20 – 40 psi	18
30 – 50 psi	28
40 – 60 psi	38

Table E: Recommended Recharge Pressures

Waterlogged Tank

- Shut off electrical power to pump
- Lockout/Tagout breaker box
- Locate and remove the 1½” or 2” pipe plug that is located about 1/3 of the way down from the top of the tank
- Water will drain from the tank when the pipe plug is removed
- Drain the tank completely if possible
- When the water stops draining out, replace the pipe plug, using Teflon tape or thread sealer on the male threads
- Reconnect electrical power to the pump and run through a normal cycle
- Check for leaks
- Determine reason for the air-add system failure and correct it

The air-add system used by a submersible pump/galvanized tank setup has 3 critical parts:

- Air volume control (air release type)
- Check valve with snifter valve at tank
- Bleed-back valve in the well

Note that failure of any one of the listed critical parts will cause the tank to become waterlogged.

To check pressure tank air charge:

- Disconnect electrical power to pump
- Lockout/Tagout breaker box
- Open nearest faucet and completely drain tank
- Check pressure with a regular tire gauge using the air charging valve located on the top of the tank
- If air pressure is more than 2 psi below pump cut-in pressure, add air with tire pump or air compressor

  Note: If pre-charge pressure is low you will generally find that the tank feels heavier than it should when you rock it, indicating water remains inside the tank on top of the bladder. Seldom does adding air successfully restore proper operation. If air pressure is too high, remove air as necessary.

- Use a soap solution to ensure air charging valve is not leaking before replacing cap

To test for bladder leakage:

- Disconnect power to pump
- Lockout/Tagout breaker box
- Drain all water from tank bladder by opening a faucet closest to the tank
- Remove valve cap from air charging valve and release all pressure possible by depressing valve core
- When air stops coming out of valve, remove the valve core to release remaining air
- Disconnect all piping to tank
- Carefully turn tank upside down or lay the tank on its side
- Retained water in the tank may cause sudden weight shift when lowering. Each gallon of water remaining in the tank weighs 8.34 pounds. Support tank so tank cannot fall when being lowered or inverted.
- Water will run out of the air charge valve if bladder has a leak

Some bladders can be replaced, but it may be cheaper to replace the tank. If you decide to replace the bladder yourself, be sure to follow manufacturer's instructions and recommendations.

Air Charge Valve Replacement

- Disconnect power to pump
- Lockout/Tagout breaker box
- Drain all water in system by opening faucet closest to tank
- Depress valve core to release all air pressure in tank. When air stops coming out of valve, remove core from inside of valve to release remaining air.
- Remove air charge valve
- Use Teflon tape on male threads of new valve. Thread valve into tank and tighten.
- Do not over tighten!
- Recharge the tank with air pressure according to Table E above

4.5b Galvanized Pressure Tanks

Galvanized pressure tanks can be mounted in either a horizontal or vertical position. The tank discharge should always be near the bottom of the tank. The principle of how this tank operates is similar to the diaphragm and bladder tanks, with the exception that these tanks have no barrier between the water and the air cushion (air-water interface).

To maintain the proper air pressure inside the tank, a special valve known as an air volume control valve is mounted to the tank at the level where the water will be when the pump starts. When the pump starts, the diaphragm is drawn to the right by pump suction. Air enters through the snifter valve if the water level in the tank is above the air control. When the pump shuts off, the pressure equalizes, and the diaphragm moves to the left by spring pressure and forces air into the tank.

Galvanized pressure tanks are usually low maintenance. Every so often the air volume control valve will fail. Water will start dripping from the valve and indicates the valve should be replaced. Over time, galvanized tanks will rust and may begin to leak. It is not a good idea to weld the tank to stop the leak. Welding on the tank will actually accelerate the corrosion and cause the tank to deteriorate within a short period of time and the tank may become waterlogged. A tank may be waterlogged if the pump begins to cycle rapidly.

Air Volume Control Replacement

- Shut off electrical power to pump
- Lockout/Tagout breaker box
- Partially drain the tank until the water level is below the air volume control connection
- Remove the small line from the pump suction line to the air control valve
- Remove the old air control valve with a wrench
- Use Teflon tape on the male threads of the pipe nipple
- Install the new air volume control
- Do not over tighten!
- Install small line from pump suction to new air control valve
- Reconnect electrical power to pump and run through normal cycle
- Check for leaks

Most pumps and systems come from the manufacturer with the pressure switch preset. Many small water system deliver about 40 psi to each house. Pressure switches are set to start the pump when the pressure drops close to 20 psi, and shut off the pump near 40 psi. Due to back-siphonage concerns, some system may be preset at 30/50. Keep a good operational pressure gauge on the pump and check it periodically as the pump goes through its cycle. A pump cycle check will confirm if the system is operating at the preset pressures, and at its most efficient cycle. To determine if the size of the pressure tank is adequate refer to Table F.

Pump Capacity (gpm)	**Pressure-Switch Range Setting (psi)**				
	20-40 psi	30-50 psi	40-60 psi	50-70 psi	60-80 psi
4	*42	82	82	120	120
8	82	120	180	220	315
12	120	180	220	315	315
15	144	220	315	525	525
18	180	315	315	525	525
24	220	315	525	525	1000
32	315	525	525	1000	1000

Table F: Pressure Tank Selection Chart

* Number denotes pressure tank size in gallons

Example: If the pump puts out 18 gpm, and the water system pressure is between 30-50 psi, a 315-gallon pressure tank is recommended.

Water storage facilities located on water distribution systems are primarily used to provide for fluctuating demands of water usage (to provide sufficient amount of water to average or equalize daily demands on the water supply system).

Other functions of water storage facilities include increasing operating convenience, leveling pumping requirement (to keep pumps from running 24 hours a day), decreasing power costs, providing water during power source or pump failure, providing large quantities of water to meet fire demands, and providing surge relief (to reduce the surge associate with stopping and starting pumps).

4.6 Leak Detection

Leak detection should be conducted throughout the entire distribution system once per week. The distribution system consists of the network of pipes, valves, fire hydrants, service lines, meters, and well house plumbing. Water can be lost from any of these water system components.

Check and record the master flow meter readings on a daily basis. If the customers have individual meters, residential water use can be compared to the master flow meter reading. Lost water equals lost revenue. Patrol the distribution system and observe for obvious leaks. Look for wet spots on the ground that may indicate a leak. Small leaks never get smaller.

Early detection and leak repair will help to keep operating and maintenance costs down. Also, water pooled around a leak in the pipe is an indirect **cross connection**. Non-potable water may back siphon into the water pipe if a pressure drop caused by a leaking line or power failure occurs and creates a vacuum.

4.7 Cross Connection

The greatest potential hazard in the piping or distribution system is associated with cross-connections to non-potable waters. It is the systems owner’s responsibility to ensure that their system is free of cross-connections. If you have any questions about a potential cross connections situation, a cross-connection control specialist should by consulted. A cross connection is defined as any direct or indirect connection between a public water supply and any other source of non-potable liquid.

A direct connection is a physical connection between the piping arrangements of a potable and non-potable system. An indirect connection occurs when the water completes the connection such as a hose from a potable supply submerged in contaminated water, or a leaking pipeline that pools water around the break.

Backflow is defined as an undesired, reversed flow of liquid in a piping system. Backflows, due to cross-connections, are serious plumbing problems that can cause sickness or death. Backflow can be caused by **back-siphonage**, **backpressure**, or a combination of the two. The minimum pressure that should be maintained in the distribution system is 20 psi. At 20 psi a positive pressure is kept in the distribution, and the chance of back-siphonage is reduced.

Cross connections can occur in a variety of locations, including the pump house, hospitals, farms, houses, and apartment complexes. The following are examples of cross connections:

- A prevalent type of cross connection is made when a hose is connected to a sink faucet with the other end of the hose lying in a pool or sink full of polluted or contaminated water. In this case backflow occurs by back-siphonage. If a partial vacuum is set up in the water distribution system, water can be drawn from the sink by suction when the faucet is opened.
- Direct cross connections to a pressurized system, such as a hot water boiler, are not uncommon. In this case backflow can occur by backpressure and by back-siphonage. Backpressure backflow can occur when the water pressure in the boiler or pressurized tank exceeds the positive pressure in the water distribution lines.
- A cross connection to an elevated tank containing a non-potable substance can cause backflow by backpressure. Backflow can occur if the valve is left open and the pressure caused by the water elevation in the tank exceeds the line pressure.
- A cross connection to a pressurized pipe carrying contaminated water can cause backflow. When the valve is opened, backflow by backpressure can occur if the pressure in the non-potable lines is higher than the positive pressure in the potable system.
- A cross connection can be created when a hose connection from a water line is used to fill a tanker truck. Backflow can occur by back-siphonage if a partial vacuum is developed in the water system.
- A cross connection can be created when a hose connection from a water line is used to operate a paint sprayer or a herbicide applicator.

4.7a Backflow Preventers

There are five basic devices or methods used to prevent or reduce the possibility of backflow in cross connections. Each device must be installed properly and tested annually by a certified backflow device tester to ensure satisfactory performance. If you have any questions regarding the suitability of a particular device in a specific application, an experienced backflow-device technician should be consulted.

1. Air Gap
An air gap (Figure 4.6) is a physical separation of the potable and non-potable water system by an air space. The air gap is the most reliable backflow prevention measure. The vertical distance between the supply pipe and the flood-level rim should be at least two times the diameter of the supply pipe, but *never less than two inches*. This type of backflow prevention technique can be used in situations in which potable water runs into a tank, sink, or any source that is under atmospheric pressure.

Figure 4.6: Air Gap

2. Atmospheric Vacuum Breaker (AVB)
Atmospheric vacuum breaker devices (Figure 4.7) do not prevent backflow due to backpressure, but they can control back-siphonage. They must be installed on the discharge side of the last control valve. In addition, they cannot be used under continuous pressure for a period of eight hours or more. AVB's are usually used with hose bibs or spigots in situations in which a hose is attached to a sprinkler system or is draining into a tank.

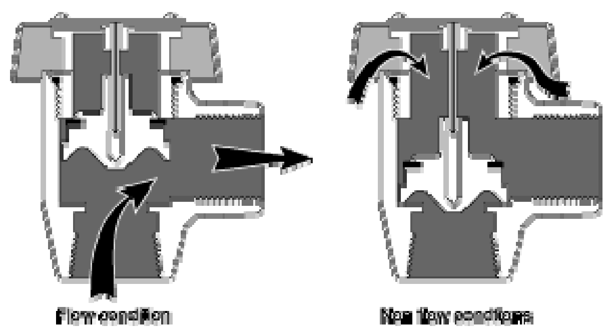


Figure 4.7: Atmospheric Vacuum Breaker

3. Pressure Vacuum Breaker Assembly (PVB)
Pressure vacuum breaker assemblies are similar to atmospheric vacuum breakers except that these devices can be used under continuous pressure. They cannot prevent backflow due to backpressure and must be installed above the usage point to prevent back-siphonage. The PVB is spring loaded to allow air to enter the device. Under normal conditions, water pressure compresses the spring, closing the air opening with the plunger. If a partial vacuum in the assembly is obtained, air is allowed to enter the assembly, forming an air gap.

4. Double Check Valve Assembly
Double check valve assemblies (Figure 4.8) are used for a direct connection between two potable water systems. Under continuous pressure they cannot

be used to connect a potable water supply to a contaminated or high-hazard water system. They offer only partial degree of protection because particles can prevent proper seating of the valves causing them to leak.

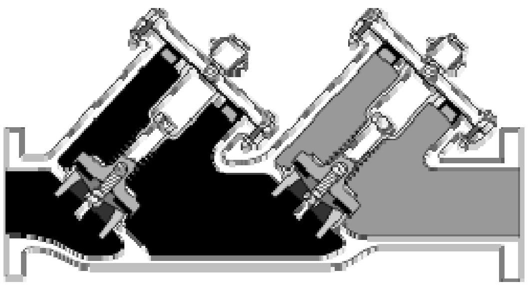


Figure 4.8: Double Check Valve

5. Reduced Pressure Zone Assembly (RPZ)
The reduced pressure zone assembly (Figure 4.9) provides the greatest protection against backpressure and back-siphonage. The RPZ can be used under continuous pressure and in high-hazard conditions. The RPZ is designed so it will operate even if both check valves become fouled.

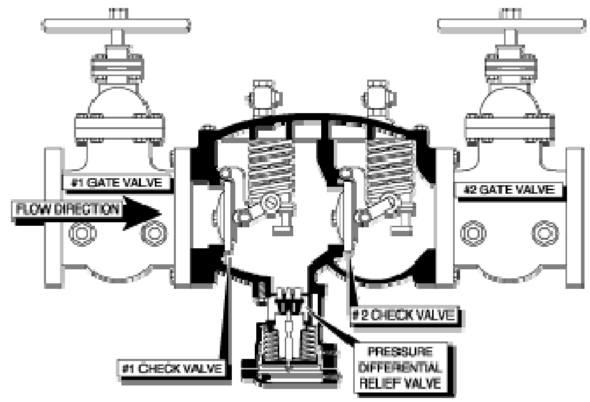


Figure 4.9: Reduced Pressure Zone Assembly

4.7b Cross Connection Control Program

The main function of the cross connection control program is to eliminate the possibility of cross connections in the water system. Creating an effective cross connection control program is an important and challenging responsibility.

Establishing a cross connection control program for a small water system can be a daunting task. As a water system owner or operator, the last thing you want is someone getting sick or possibly dying due to a cross connection in your system.

To prevent this from happening, you need to survey your system for cross connections. *Every time* a new connection is made to the potable water system, you must ask yourself, “am I creating a cross connection?” If the answer is yes, the proper backflow device must be installed and maintained. If you have backflow devices already installed in your system, you must make sure a qualified tester tests them annually and records of the tests are retained.

4.7c Summary

Small water systems in Alaska may be more susceptible to backflow and backpressure problems than larger water systems throughout the state. When the well pump shuts down due to a power outage or mechanical failure, consumers continue to use water and negative pressure is created throughout the distribution system. Non-potable water may back siphon into the potable drinking water supplies.

Owners/operators must be able to recognize cross connections and take the appropriate actions to remove indirect cross connections if possible or install approved backflow prevention devices on direct cross connections.

4.8 Well Decommissioning (Abandonment)

A well is considered temporarily abandoned when it is taken out of service but still exists. Owners of a temporarily abandoned well intend to bring them back into service at a future date. A watertight cap or seal that prevents any materials from entering the well must cover temporarily abandoned wells.

A well is considered permanently decommissioned (abandoned) when it is completely filled so that movement of water within the well is permanently stopped. The appropriate permanent abandonment method depends on information obtained from an examination of the well log and an onsite investigation of the well. However, the method for abandonment must conform to ANSI/AWWA Standard A100-97. Contact the local ADEC office for abandonment procedures. Generally, a drilled well with steel or plastic casing will be abandoned by either removing or ripping the casing and filling the borehole with cement from the bottom up. Any pump, wiring, or debris in the well must be removed before the cement is placed. Proper plugging accomplishes these purposes:

- Restores barriers to contamination
- Removes safety hazards by closing off tempting openings for children and animals
- Restores stability to the land surface
- Removes liability and improves or protects property values

4.9 Basic Electricity

Small water system owners/operators may fit the definition of being the Jack of all Trades. They are expected to have knowledge of microbiology, chemistry, mathematics, hydraulics, supervisory skills, administrative ability, accounting experience, mechanics, and serve as part-time electrician in some instances.

All the knowledge is then tailored to keep their water system running and providing safe water on a daily basis. Seventy-five percent of well pumps and control problems are reported to be electrical-related; therefore, an owner/operator will likely encounter an electrical problem at some point.

The following basic electrical information will help an operator prepare for the certification exam and provide an understanding of electrical fundamentals.

NOTE: Electricity is dangerous and can kill you. The information covers electrical theory in very basic terms and *does not* attempt to prepare an owner/operator for troubleshooting electrical problems, electrical circuits, or wiring water system instrumentation nor machinery. An owner/operator should not attempt servicing or troubleshooting water system electrical components unless he/she has received appropriate training.

Electricity is the flow of invisible particles called electrons, through a conductor. That flow is controlled in an electric circuit. The knowledge that electricity is created by the flow of electrons, and the knowledge of how to capture electrons, makes electricity a convenient and convertible form of energy.

Most electricity used in the United States is produced at power plants. Various energy sources are used to turn turbines. The spinning turbine shafts turn electromagnets that are surrounded by heavy coils of copper wire inside generators. This creates a magnetic field, which causes the electrons in the copper wire to flow.

Electricity travels fast at 186,000 miles per second. If you traveled that fast, you could travel around the world eight times in the time it takes to turn on a light! And if you had a lamp on the moon wired to a switch in your bedroom, it would take only 1.26 seconds after you flipped the switch for electricity to light the lamp 238,857 miles away!

Electrons flow better in some things than in others. Conductors are substances in which electrons flow freely. Metals are excellent conductors. Water is a fair conductor. Since the human body is mostly water, it can conduct electricity fairly well, too. This is why it is important to be very careful when working around electricity.

Insulators are substances that electrons cannot flow freely in. Glass, plastic, and rubber are good insulators. Electrical wiring is always enclosed in a protective covering of plastic or rubber that serve as insulators.

In order to make electrons do useful work, the electrons must have a source of pressure to push on them and cause them to move. Also, the electrons must have a complete path or circuit to follow.

The basic components of an electric circuit (Figure 4.10) include the following:

Source
The part that provides the electric force to move the electrons as pressure; such as a battery or generator

Load
The part that does the work, or part that uses the electricity; such as light bulb, heater, or motor

Conductor
The part that carries the electricity around the circuit such as wire, cable, or power line

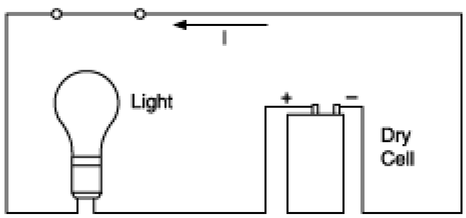


Figure 4.10: Simple Circuit

The battery pushes electrons through the metal wire, through the light bulb and back to the other terminal of the battery, completing the circuit.

4.9a Current Flow

The following section lists electrical terms and gives a brief discussion of electrical theory.

Current is the flow of electrons. To understand current, imagine an electric circuit as a chain. When all three components (source, load, and conductor) exist in the circuit, the electrical force causes the electrons to move down the chain. This forced movement of electrons is called current and is measured in amperes. Current is measured with a test instrument called an **ammeter**.

Two types of current flow are:

1. **Direct Current (DC)**
   The electrons flow in one direction.

2. **Alternating Current (AC)**
   The AC you use at home changes direction 60 times per second. This means it moves back and forth 60 times per second. This flow in one direction, reversing, and flowing in the other direction is called a cycle. The term 60 cycles AC or 60 Hertz means 60 of these cycles occur each second.

4.9b Electrical Pressure

Electrical pressure is the force that causes electrons to move in a closed electric circuit. It is also referred to as voltage. The pressure or force is measured in volts by a test instrument called a voltmeter. In a DC circuit, a battery produces voltage and in AC circuit a generator produces voltage.

A car battery is typically 12 volts. That means that the difference in electron pressure between the two terminals is 12 volts. The electric outlets in your well house are 120 volts or 240 volts. The voltage difference between the two prongs of the outlet is 120 V or 240 V.

4.9c Resistance

Electrons do not flow freely in a conductor. There is a certain amount of resistance or friction to oppose the electron flow. This resistance is called **ohms** and is measured by a test instrument called an **ohmmeter**. Factors that determine amount of resistance are:

- **Type of material**
  A conductor has low resistance permitting the flow of electrons - copper, aluminum. An insulator has high resistance restricting the flow of electrons - rubber, glass.
- **Size** (diameter)
  Large diameter, less resistance
  Small diameter, higher resistance
- **Length**
  Longer the length, more resistance
- **Temperature**
  Higher temperature, more resistance

If something has a high resistance, it takes a lot of voltage (pressure) to get the current to flow.

4.9d Water Flow Analogy of Electrical Circuit

The flow of electrons in an electric circuit can be compared to the flow of water through a closed loop piping system. Volts, amps, and watts measure electricity. Volts measure the pressure under which electricity flows. Amps measure the amount of electric current. Watts measure the amount of work done by a certain amount of current at a certain pressure or voltage.

To simplify the relationship, think of water in a hose. Turning on the faucet supplies the force, which is like the voltage. The amount of water flowing (gallons per minute) through the hose is like the amperage. You would use a lot of water that comes out fast (more watts) to wash off a muddy car. You would use less water that comes out more slowly (less watts) to fill a glass.

Water circuit vs. Electric circuit

Source
- Water circuit - water pump produces water pressures (psi) to cause water to flow (gpm)
- Electric circuit - generator produces electrical force (volts) to cause electrons to flow (amps)

Flow measurement
- Water circuit - flow meter measures water flow in gpm
- Electric circuit - ammeter measures current in amperes (amps)

Load
- Water circuit - water wheel does work by rotating
- Electric circuit - light bulb does work by producing light and heat

Pressure loss
- To determine the loss of energy, pressure gauges installed before and after the water wheel can

measure the loss of water pressure.

- A voltmeter measures voltage drop as the current goes through the light bulb (conversion of electrical energy to light and heat energy).

Conductor

- Water circuit - pipe that carries the flow of water
- Electric circuit - wire that carries the electrons

4.9e Ohms Law

You have learned that the flow of electrons (current) is measured in amperes or amps. Also, electrical pressure, measured in volts, is required to cause current to flow. In addition, there is always resistance to this flow and the unit of resistance is the ohm.

The relationship between these electrical terms can be expressed very simply as Ohm's Law. Known as Ohm's Law because German physicist Georg Simon Ohm, discovered the relationship between voltage, current and resistance. It is one of the basic laws of electricity and can be expressed by the following equation:

$$Amps = \frac{Volts}{Ohms}$$

or

$$Volts = Amps \times Volts$$

or

$$Ohms = \frac{Volts}{Amps}$$

4.9f Electric Power

When a charge moves in a circuit, *the rate* at which work is done is called electric power. Electric power is equal to the product of current and voltage:

Power = Voltage x Current
You must have voltage and current to generate power. Power is *the rate* at which electrical work is done, measured in Watts (W).

Watts (Power) = Volts x Amperes
A more powerful pump motor can pump water faster than a less powerful one. Many electrical devices (heater, light bulbs, etc.) are rated in watts, but electric motors used to drive pumps are usually rated in horsepower (hp).

Although theoretically one horsepower equals 746 watts, this does not include the loss of energy in the motor through heat and friction. Consequently, for practical purposes, if a motor is ½ hp or larger each hp is equivalent to approximately 1000 watts. Motors smaller than ½ hp, use 1200 watts per hp. A 5-hp motor will use about 5,000 watts at full load and a ¼ hp motor will use about 300 watts at full load. However, watts and horsepower do not tell you how much electrical energy a piece of equipment is using. Remember, since power is a rate, you need to include the time that the equipment is running. The unit most commonly used to measure power is the kilowatt-hour or Kw-h.

If we can figure out how much energy an electrical device uses and we know how long the equipment is in operation each day, we should be able to figure out how much it costs to operate that device. For instance, let us calculate the cost of running a 1 ½ hp pump for 10 hours a day if electricity costs 15 cents per kilowatt-hour:

1. Since a horsepower is roughly equivalent to 1000 watts for this size pump, the power consumed by the pump would be 1,500 watts or 1.5 kilowatts;
2. Next find the energy consumed:
   Energy = Power x Time
   = 1.5 Kw x 10 hours
   = 15 Kw-hours
3. Next find cost:
   Cost = 15 Kw-hours x $0.15/Kw-hour = $2.25

The cost is about $2.25 to run this pump for 10 hours a day.

4.10 Emergency Generator (Power)

An extended power outage may shut off the pump, as well as other electricity needed to run the water system. To prevent this problem, a water system owner/operator may want to purchase an emergency generator to keep the pump operating and maintain minimal electrical service to the system. The generator should be powerful enough to operate the pump. Also, because of the electrical hazard, a qualified electrician should make the installation

Chapter 5 - Public Water Supply Regulations

5.1 Introduction

The SDWA was passed into law in 1974 as an attempt to ensure the quality of drinking water throughout the United States. Major amendments that greatly expanded the scope and impact of the Act on water suppliers were made in 1986 and 1996. The 1986 amendments to the SDWA significantly increased the number of contaminants public water supply systems must monitor. It tightened the requirements for systems that use surface water, and defined public notification requirements when monitoring is not performed or when a contaminant exceeds the maximum allowable limit.

The 1996 amendments to the SDWA added some flexibility for state implementation of the federal requirements but also included new items for certified operators and system **capacity**. Capacity as it is used here, refers to the financial, managerial, and technical abilities to operate and manage a public water supply system.

New public water supply systems cannot begin operating unless they can demonstrate capacity. Also, existing public water supply systems will be evaluated for capacity by the State.

Consumer Confidence Reports (CCRs) also became a requirement through the 1996 amendments.

CCRs (Chapter 8) require all community or non-transient non-community water systems to prepare annual reports summarizing the quality of their drinking water supplies. The information contained in consumer confidence reports are designed to raise consumers' awareness of where their water comes from and help them understand the process by which safe drinking water is delivered to their homes. Public water systems must also ensure that copies of these annual reports are made available to their customers.

The federal government, through the United States Environmental Protection Agency (USEPA), sets standards for drinking water quality and establishes the frequency at which water samples must be collected and analyzed. Individual states, like Alaska, have the option to carry out and enforce regulations for their public water supply systems. In return for federal grant money, the states administer and enforce safe drinking water regulations in their jurisdictions.

The term **primacy** is used to identify states that have taken over responsibility for administering and enforcing safe drinking water regulations. ADEC obtained primacy in 1978 and since then has administered and enforced the State Drinking Water Regulations. To maintain the role of primacy, Alaska was required to adopt regulations no less stringent than federal requirements.

5.2 Standards

There are two types of standards: primary and secondary. **Primary standards** are health based and are enforceable. **Secondary standards** are also health based but were set more for aesthetic reasons (how the water looks and tastes). Secondary standards, once imposed, are enforceable.

5.2a Primary Standards

Primary standards are designed to protect public health by setting maximum permissible levels of potentially harmful substances in the drinking water.

Primary Standards may be either **Maximum Contaminant Levels (MCLs)** or Treatment Technique Requirements (TTRs). The MCL is the number against which the water samples from your system are judged for compliance with the regulations.

Where the USEPA is unable to establish an MCL, it must establish a TTR in lieu of an MCL. **Public water systems (PWS)** must comply with these treatment requirements. Currently, there are surface water filtration and corrosion control requirements in lieu of MCLs for several microorganisms and lead and copper, respectively.

5.2b Secondary Standards

Secondary standards are guidelines that apply to the aesthetic qualities of drinking water, which do not pose a health risk (for example, color and odor). The Secondary Maximum Contaminant Level (SMCL) is a number associated with the aesthetic quality of the water, such as taste, odor, or color. Water with contaminants above the SMCL may not be pleasant to drink but will not cause health problems. Yet, secondary standards can be important from a customer acceptability standpoint. Perfectly safe drinking water may be rejected based upon how it looks, tastes, or smells.

5.3 Public Water System Monitoring

Alaska's Safe Drinking Water Regulations establish rules that all Public Water Systems in Alaska must comply with. Monitoring requirements, MCLs, public notice requirements, and plan review for all public water systems, large and small, are described in the State's Drinking Water Regulations. However, since this manual is designed as a guide for small-untreated groundwater systems, the focus will be on the primary contaminants of concern to community or non-transient non-community groundwater systems. System owners/operators are encouraged to obtain the most recent version of the State Drinking Water Regulations from their local ADEC office.

A **Community Water System** (CWS) is a public water system that serves at least 15 service connections used by year-round residents or regularly serves at least 25 year-round residents. A **Non-Transient Non-Community Water System** (NTNCWS) is a public water system that is not a community water system and that regularly serves at least 25 of the same individuals over six months per year. Community and non-transient non-community water systems serve cities, villages, schools, apartment buildings, and mobile home parks.

Since community and non-transient non-community water systems, in general, provide water to people where they permanently reside, most of the MCLs for organic and inorganic chemicals in water are based on the potential health effects from chronic (long-term) exposure.

5.4 Primary MCLs

MCLs for potentially toxic or harmful substances reflect levels that can be safely consumed in water, taking into account exposure to substances from other sources. The MCLs are based on the consumption of approximately 2 quarts of water-based fluids every day for a lifetime. The State of Alaska must establish MCLs that are equivalent or more stringent than those set by the USEPA.

The primary contaminant list that applies to groundwater systems includes microorganisms, nitrate/nitrite, organic chemicals, inorganic chemicals, and radionuclides. With the exception of nitrate and microorganisms, water that exceeds the MCL for inorganic and organic chemicals and radionuclides poses no immediate threat to consumers. The substances are monitored for and controlled because drinking water that exceeds the standards over long periods of time may be harmful to consumers.

5.4a Microorganisms

The microorganism group of contaminants includes bacteria, viruses, and protozoa. The total coliform group of bacteria is used to indicate the possible presence of pathogenic organisms. The coliform group of bacteria is covered in depth under the Total Coliform Rule in Chapter 6.

5.5 Organic Chemicals

Many synthetic organic chemicals (SOCs) are included in the primary regulations. Some of these (benzene and carbon tetrachloride) readily become airborne and are known as volatile organic compounds (VOCs). Public drinking water supplies must be sampled and analyzed for organic chemicals at least every three years. VOC monitoring must be performed quarterly for one year. If sample results show Non-Detects (NDs), the monitoring frequency may be reduced to once every three years.

SOC monitoring must be performed quarterly for one year. If sample results show NDs, the system qualifies to monitor once every three years.

5.6 Inorganic Chemicals

Inorganic substances at high levels in drinking water, particularly heavy metals, are of public health importance. Inorganic substances have been shown to damage the brain, lungs, kidneys, heart, and intestines of laboratory animals. Sources of inorganic contaminants are natural soils, groundwater, and industrial activities.

Groundwater systems must monitor for inorganic contaminants every three years. However, nitrate, nitrite, lead, copper and asbestos monitoring are the exceptions to inorganic contaminant monitoring because monitoring timeframes are different and monitoring frequency may be reduced or increased depending on contaminant levels.

A limited number of inorganic substances are discussed in this section. For a complete list of inorganic substances and monitoring requirements for your system, contact your local ADEC office.

5.6a Nitrate

Nitrate must be monitored annually (one sample per year) for groundwater sources. Nitrates are inorganic chemicals found in both surface and groundwater. They originate from many sources such as animal and human wastes, soil, fertilizers and crop residues. Nitrates enter the water either directly or by percolation through the soil. The presence of nitrates may indicate pollution.

Nitrate levels above 10 mg/L pose an immediate threat to children less than six months of age because their digestive systems are more likely to allow conversion of nitrates to nitrites. The nitrite is absorbed into the blood stream and prevents the blood from carrying oxygen and the child suffocates. This disease is called methemoglobinemia or 'blue baby' syndrome and can be fatal.

5.6b Nitrite

Nitrite must be sampled for once. If the results of the nitrite sample are less than 50% of the MCL no further sampling is required. The current MCL for nitrite is 1.0 mg/L. Therefore, if the nitrite result is greater than 0.5 mg/L, the water system must monitor quarterly until the results are reliably and consistently less than the nitrite MCL.

5.6c Lead & Copper

Lead and copper are inorganic contaminants that have specific "at the tap" monitoring requirements. A small number of natural groundwaters contain significant levels of lead or copper. Most lead and copper contamination results from the corrosion of piping and fixtures containing lead and copper or alloys such as bronze.

Lead in the body is dangerous because it interferes with normal body functions. It can change the way the blood-forming cells work, alter the way nerve cells signal each other, and lead can disturb or destroy the way the brain makes connections for thinking. Because children are still developing, the potential damage to their development from lead exposure is very important to their future health and well-being. Lead pipe and lead solder or flux for installation or repair of public water system piping is no longer allowed. The Lead and Copper Rule (LCR) specifies sampling procedures, actions to be taken if an **action level** is exceeded and acceptable treatment techniques a water system may employ to address distribution system corrosion problems. Treatment techniques have been set for lead and copper because the occurrence of these chemicals in drinking water usually results from corrosion of plumbing materials.

Most inorganic samples are taken before the water is distributed to the consumer but lead and copper samples are taken directly from consumer's taps.

Systems that exceed the action level at the tap are required to install corrosion control treatment to reduce the levels of lead and copper. The action level for lead is 0.015 mg/L, and for copper it is 1.3 mg/L. The LCR requires first draw samples be taken from customers taps. The population served by the system determines the number of samples required. The lead and copper results determine if a water system must take further action to determine if the water source is aggressive (corrosive).

Lead and copper monitoring is required for all community or non-transient non-community water systems for two initial (consecutive) six-month monitoring periods. If the results of the two monitoring periods are below the action level, the water system may reduce the number of samples collected and perform the monitoring annually. After three consecutive years of monitoring with results below the action levels, monitoring may be reduced (per ADEC approval) to a three-year cycle.

5.6d Radionuclides

Water may have a long residence time in the ground. Therefore, the potential exists for radioactive contamination. Many groundwater aquifers in the United States have naturally occurring radium. Radium is the main radionuclide in groundwater that produces a health threat. Community or non-transient non-community water systems are required to sample for gross alpha radioactivity at least once every four years.

5.6e Asbestos

Asbestos is a naturally occurring mineral and a component of asbestos pipe. Because there is a risk of developing stomach cancer from ingesting water containing asbestos, an MCL of 7 million fibers per liter has been established. Asbestos monitoring is required once during the first three years after the system begins to provide potable water. Subsequent sample requirements depend on the results of the initial sampling.

5.6f Arsenic

Arsenic is an element that occurs naturally in rocks and soil, water, air, plants and animals. The erosion of rocks and minerals, volcanic activity and forest fires are natural events that can release arsenic into the environment.

Arsenic in drinking water causes bladder, lung and skin cancer, and may cause kidney and liver cancer according to a 1999 study by the National Academy of Sciences. The study also found that arsenic harms the central and peripheral nervous systems, as well as heart and blood vessels, and causes serious skin problems. It also may cause birth defects and reproductive problems.

Community or non-transient non-community water systems currently monitor for arsenic. The USEPA recently approved a final rule lowering the allowable levels of arsenic in drinking water from 50 parts per billion (ppb) to 10 ppb. Monitoring for arsenic will be on an annual basis unless reduced monitoring is granted.

5.7 Specific Monitoring Information

Appendix 2 lists the compliance monitoring requirements for community or non-transient non-community groundwater systems. For specific monitoring information and variances that may apply to the water system you own/operate, call ADEC in Anchorage, Fairbanks or Juneau (Appendix 3).

Chapter 6 - Total Coliform Rule (TCR)

6.1 Monitoring and Reporting

The State Drinking Water Regulations establish microbiological standards and monitoring requirements that apply to all community or non-transient non-community public water systems. Regulations require owners of public water supplies to collect total coliform samples and deliver them to a certified laboratory (Appendix 4) for bacteriological examination at least monthly.

The number of routine coliform monitoring samples a water system is required to collect is established by federal standards. Small-untreated groundwater systems are required to take one sample per month unless **repeat samples** are required.

Under certain conditions a waiver may be granted to small systems, reducing the sampling requirement to once per quarter. State drinking water officials grant waivers only after a review.

The State's (TCR) requires:

- Routine total coliform monitoring
- Repeat sample collection
- Fecal coliform testing of positive total coliform samples
- A **sample site plan**, and if necessary
- Public notification

Routine coliform samples are collected monthly unless a quarterly waiver was granted by State officials. Routine samples should be collected early in the month to provide enough time to collect **replacement samples** if the original samples are damaged in transit or cannot be analyzed by the lab. Rotate sample collection sites monthly so that samples are representative of the entire distribution system. Collection sites for bacteriologic samples must be designated on the sample site plan.

Repeat samples must be collected if coliform bacteria were detected in the routine sample. Repeat samples must be collected within 24 hours after being notified by the lab that the routine sample was unsatisfactory. Do not disinfect or change any treatment process prior to taking repeat samples.

If coliform organisms were detected in a routine sample, the owner/operator must collect four repeat samples (based on a water system serving a population between 25 and 1000) for each routine coliform-positive sample found. One repeat sample shall be taken from the site of the original positive, one repeat sample within five service connections upstream, one from within five service connections downstream, and one from another representative site in the distribution system. Small systems with few service connections will need to adjust the location of repeat samples per instructions from their ADEC Drinking Water Program contact person. Any routine or repeat sample that is total coliform positive must also be analyzed for fecal coliforms or for *E. coli.*

Note: After a total coliform-positive routine or repeat sample, a different monitoring and repeat sample frequency protocol must be followed (Table G). The water system owner/operator must collect a set of five routine samples the next month if coliforms were detected in any routine or repeat samples.

Monitoring and Repeat Sample Protocol Following a Total Coliform-Positive Routine Sample		
Routine samples required per month	Number of **repeat** samples required	Number of **routine** samples *next month*
1	4	5
2	3	5
3	3	5

Table G: Monitoring and Repeat Sample Protocol (for a total coliform positive routine sample)

When **total coliform bacteria** levels are exceeded, the water owner/operator must notify the public served by the water system. The MCL is exceeded if:

- The limits given in Table H are exceeded.
- Any repeat sample is positive for fecal coliforms or *E. coli*.
- A routine sample which is positive for fecal coliforms or *E. coli* is followed by a total coliform positive repeat sample.
- Fecal coliforms or *E. coli* are detected in any total coliform positive sample, the system must notify ADEC immediately.

ADEC may allow a water system to forgo fecal coliform or *E. coli* testing on a case-by-case basis if the system responds to every total coliform positive sample as if it contained fecal coliforms.

Routine Samples Required per Month	**Limits for Total Coliform Positive Samples Each Month**
Less than 40 samples per month	No more than one sample
More than 40 samples per month	No more than five percent of all monthly samples

Table H: Coliform MCLs

If an MCL is exceeded, the operator will be required to perform emergency chlorination (Chapter 10) and to issue a Boil Order. A boil order notifies customers that water should be boiled vigorously at a rolling boil for at least 5 minutes before drinking it. Public notification requirements are discussed in depth in Chapter 8.

A sample site plan must be filed with, and approved by ADEC. Each public water system must sample according to a written sample site plan. Sample sites must be rotated throughout the distribution system. The sample site plan should include:

- A map of the water distribution system
- Sample locations marked on the distribution map
- A list and identification of

distribution system pressure zones
- The addresses or identification numbers/names of buildings used as primary and backup sampling sites at each location
- The number of samples required by the system per month
- Distribution system rotation frequency
- Repeat sample procedure to address an unsatisfactory (positive) sample

6.2 Significance of the Coliform Test

Coliform bacteria detected in any water sample warn of possible contamination from a warm-blooded animal. One test does not prove that contamination exists; more tests must be taken. Samples may have been contaminated from external sources or there may have been other problems such as non-sterile bottles, contamination of the sample bottle, or laboratory error. Another common problem, however, involve errors in sampling. The current regulations require that if a sample is positive (shows the presence of coliforms), the water supplier must take four repeat samples.

6.3 Collecting a Bacteriological (BacT) Sample

- Obtain sterile bottles from the lab.
- Do not open a sample bottle until ready to fill.
- Select a sample tap. Always collect the sample from the cold-water tap. Select a faucet that is not leaking, non-swivel, and non-mixing.
- Do not sample from drinking fountains or outside hydrants.
- Avoid sample points located after water softeners, carbon filters, or cisterns serving single homes.
- Remove any faucet attachments (aeration screens, hoses, etc.).
- Remove screen from inside faucet and disinfect mouth of faucet with a chlorous bleach solution. If rubbing alcohol is used, remember alcohol requires contact time (optional).
- Do not use a butane lighter to flame faucet. A propane torch is acceptable.
- Open tap fully. Let water run to waste for two or three minutes (sufficient time to allow flushing of the service line).
- If you must use a mixing faucet, run the hot water tap for two minutes and then run the cold water tap for two or three minutes (always collect cold water sample).
- Reduce the flow (to about the diameter of a pencil), and fill the bottle. If the water dribbles to the faucet edge and contacts the metal (lips) before entering the bottle, the sample may be contaminated; readjust the flow or locate a different sampling tap.
- Collect the sample.

- Open container by pushing up cap where indicated (do not use if seal is broken and do not take the pill out of the container). Fill the bottle to the top of the label, or base of the neck. Leave an airspace that allows mixing by shaking at the lab.
- Close the container by pressing cap from hinge side until it securely snaps shut. Put the tie through the round hole on lid and pull through. Be sure to complete the information on the sample bottle label.

Do not rinse the bottle before filling (the tablet or white powder inside is **sodium thiosulfate** which neutralizes any chlorine in the water). Sample should be shipped to the lab using the shortest transit possible. Try to maintain sample at normal water temperature. Regulations requires that analysis for coliform bacteria begin within 30 hours of collection.

If repeat samples show unacceptable levels of total coliforms or *E.coli,* it is necessary to shock disinfect the well. If possible, find and eliminate the source of contamination. Chapter 10 discusses well disinfection.

6.4 Positive (Hot) BacT Sample

If a sample is positive the following questions must be addressed:

Was the sample properly taken?

Was the aerator removed, tap flushed full flow for 5 minutes and the sample bottle filled without touching the interior of container, etc.?

Was work done on the water system that was not followed by adequate disinfection when the work was completed?

Is there a new pump, pipe, or have there been any distribution system repairs?

Was a new well or backup well brought on line that was not disinfected?
Was the sample site location the same or was a different or vacant building sampled?

Is the well still properly sealed?

Are there cartridge type filters in use on the water system?

How long has it been since the cartridge has been changed?

Disinfection of the water system may solve the problem if the source of the contamination is not due to an ongoing situation such as a cross connection, bad groundwater source, or influence of the well by surface water. Follow the emergency disinfection of a well procedure in Chapter 10.

6.4a Invalid Sample

Owners/operators are primarily concerned with bacterial pathogens responsible for disease. However, not every bacterial organism causes disease. Bacteria are found on our skin, in our intestines and on plants and animals as well as in soil.

Some harmless bacteria interfere with the coliform test and make the results invalid. This happens when non-coliform bacteria are too numerous in the water and interfere with the test method. This prevents coliforms from growing and is often reported in the sample result as:

- Too numerous to count non-coliforms (TNTC)
- Heavy growth non-coliforms

The non-coliform interference is caused by heterotrophic bacteria. When non-coliform bacteria interference occurs a replacement sample is required. It must be collected during the same calendar month in which the routine sample was due.

6.5 Well Disinfection Evaluation

If the repeat samples are satisfactory after disinfection, attempt to determine if the contamination was due to operator error or caused by a bacteriological growth in the distribution system due to a distribution repair or plumbing change. If so, disinfecting probably corrected the problem.

If the contamination was caused by a persistent source of contamination, disinfection treatment can appear to correct the problem by killing off bacteria but the problem can and probably will reoccur.

If the contamination is from a major source, with a high bacteria count, repeated disinfection and testing of the well may yield inconsistent results, sometimes satisfactory results, and sometimes not. If shock disinfection due to positive samples is necessary more than twice per year, serious well contamination or distribution system problems may be indicated.

If repeat samples are unsatisfactory after disinfecting, it is likely there is a persistent source of contamination. Common sources of contamination include a loose or damaged sanitary seal, a loose or damaged pitless adapter (where the buried water line enters the well casing), a bad plumbing connection in piping between the well and the building, a cross connection, spiders living in the wellhead, or a dead animal in the well. Rodents can gain entry into a well that was not properly capped or has a damaged well casing.

A detergent test may determine if the well is being influenced by a septic system. Bacteria can be filtered out of water that passes through several feet of soil. Therefore, BacT results may start to be intermittently satisfactory then unsatisfactory. Any water that reaches a well from a septic system will have detergent present. Have the lab run a detergent test if a septic system is suspected as the source of contamination.

Correcting the source of contamination is naturally preferred, but installing continuous disinfecting equipment such as a chlorinator or ultra-violet light system may be required to protect the health of water system customers. The disinfecting equipment will depend on the type of chemical to be used.

In addition to required tests, well water should be tested immediately if there is any change in its clarity, color, odor or taste, or if there has been a change in the surrounding land use. Through regular assessment and testing of drinking water, the microbial and chemical safety of well water can be verified so that it will be both safe to drink and aesthetically pleasing.

Chapter 7 - Safety

7.1 Safety Conditions

This section will introduce the topic of safety to the reader, but is not intended to provide detailed information on all the safety topics that owners/operators need to be aware of.

The water/wastewater industry is an extremely hazardous occupational field. An operator of a small water system encounters potentially hazardous conditions on a daily basis.

Accident prevention is everyone's duty, but it is the employer that is ultimately responsible for providing a safe workplace. Some of the hazards an operator may encounter include but are not limited to:

- Lifting injuries
- Excavation accidents (cave-ins)
- Construction accidents
- Eye injuries
- Slips and falls
- Chemical burns
- Inhalation accidents (toxic gases and vapors)
- Electric shock
- Oxygen deficient confined spaces (less than 19.5% oxygen)

Accidents are the result of unsafe actions by employees or unsafe conditions that exist at the water system. Unsafe actions include but are not limited to:

- Removing or disabling machinery safety devices
- Failure to wear personal protective equipment
- Using equipment or tools not designed for the job
- Using defective equipment or tools
- Standing on or riding outside moving equipment
- Failure to secure or tie down heavy loads
- Operating vehicles, including heavy equipment, at an unsafe speed

Unsafe conditions found in a small water system may include but are not limited to:

- Improper storage of chemicals
- Machinery guards or safety devices missing
- Fire and explosion hazards
- Low clearance hazards
- Protruding objects hazards
- Poor housekeeping
- Inadequate lighting
- Noise above safe decibel levels
- Lack of warning placards
- Confined spaces

A safe water system facility is uncluttered, clean and orderly. Emergency equipment and doorways are kept clear, and machine guards are kept in place. The door to the pump house should open outward. Any volume of water built up against the door would make opening the door inward difficult. Remember, water weighs 8.34 pounds per gallon.

Abnormal machine or equipment operation, electrical hazards or other unsafe conditions should be corrected promptly. Do not let unsafe conditions become commonplace.

A couple of the old adages still apply when thinking about injury prevention:

- An ounce of prevention is worth a pound of cure.
- Hindsight is 20/20.

The five-minute task unfortunately is the task that causes many injuries. Quick fixes promote unsafe acts. Do not let five-minute tasks result in an injury to yourself or employee.

Employee knowledge of unsafe conditions and unsafe acts gives an operator foresight to correct a hazardous situation before an accident happens. Materials handling, falls, falling objects and machinery accidents cause more than two out of three workplace injuries.

7.2 Lifting

Operators are required to lift and move various materials on the job. One-third of all injuries result from improper lifting and handling of heavy objects. Nearly a half million disabling job injuries are reported industry wide annually and most are back injuries. Of every one hundred workers hurt, thirty-three are injured handling materials.

Water system owners/operators should know the proper methods for lifting heavy objects. Steps for safe lifting include:

- Get a good footing
- Place feet about shoulder width apart
- Bend at the knees to grasp the weight
- Keep the back straight and vertical
- Get a firm hold
- Keep the load close to the body
- Keep the back as straight and vertical as possible
- Lift gradually by straightening the legs
- Do not twist your body while lifting
- Get help when the load is too heavy or bulky for you to lift comfortably
- Reverse the procedure when putting the load down

Carrying heavy, bulky or long objects may result in a fall. Check your path beforehand, noting slipping or tripping hazards that should be picked up or avoided. Make sure the object is balanced and your grasp secure before walking. Take your time, particularly on steps and through tight places. Make sure large objects do not bump or catch on anything and throw you off balance. Carry objects so you can see where you are going. Get help if you need it or save the job until help is available. Do not risk straining your back or falling.

7.3 Lockout/Tagout

Plant machinery and equipment must be de-energized and isolated before maintaining or servicing equipment. Isolation and de-energizing equipment is required to protect yourself and workers from unexpected start-up of the equipment or machinery or release of energy. This Lockout/Tagout procedure is covered under OSHA's 29 CFR 1910.147 Standard. Placement of a lockout device or an energy-isolating device is the most effective means to protect an operator or maintenance personnel from being injured.

Tagout means placement of a warning tag on or near the energy-isolating device. The tag must include the name of the person applying the tag, date and reason the equipment is locked out.

7.4 Material Safety Data Sheets (MSDS)

A material safety data sheet is a compilation of the information known about a chemical that relates to assessing the hazards of the chemical. Chemical manufacturers are required by the Occupational Safety and Health Administration (OSHA) to provide MSDSs for all hazardous chemicals.

7.5 Personal Protective Equipment (PPE)

PPE may be uncomfortable and increase stress. When wearing PPE, the body's ability to cool is usually diminished. Nevertheless, PPE is frequently required to reduce the risk of injury. PPE includes steel-toed boots, safety glasses or goggles, face shields, earplugs, gloves or chemical protective clothing.

Respiratory protection equipment is commonly used because inhalation provides a rapid entry for volatile chemicals into the blood stream.

There are two general types of respiratory protection devices, called respirators: air purifying and air supplying. Both consist of a face piece connected to either an air source or an air-purifying device. The air-purifying respirator uses cartridges with filters to purify air before it is inhaled. This type of protection is not adequate in an oxygen deficient atmosphere.

A respirator with its own air source is called a supplied-air respirator or SCBA (Self Contained Breathing Apparatus). It consists of either a self-contained unit that the worker wears or a hose connecting a worker to a remote air source. The SCBA provides continuous positive air pressure into a facemask.

7.6 Confined Spaces

A confined space means a space that:

- Is large enough and configured so that an employee can bodily enter and perform assigned work.
- Has limited or restricted means for entry or exit (for example; tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry and exit).
- Is not designed for continuous occupancy.

Some examples of confined spaces include manholes, sewers, boilers, pipelines, dug wells, fuel tanks, storage tanks, tanks on haul -trucks, septic tanks, sewage lift stations, and valve vaults. A confined space may have an oxygen-deficient atmosphere or an explosive atmosphere. Air monitoring should be conducted before entering a confined space.

The buddy system should be used when working in a confined space, with one person *always* remaining outside the confined space. In the event of an accident, the person on the outside of the confined space should *never* enter the space to attempt a rescue. That person should immediately call for help. In the event that the confined space is oxygen deficient, under no circumstances should an air-purifying respirator be used. Always use a SCBA.

Chapter 8 - Public Water System Management

8.1 Introduction

The drinking water industry, like any other, operates under a set of guidelines. Based on the most current and best available knowledge, rules and recommended standards have been established to ensure safe and reliable drinking water is delivered to the public.

In Alaska, ADEC enforces drinking water regulations. Regulations affecting public water supply systems cover a wide range of subjects. The following are the main areas that concern drinking water:

- Monitoring and reporting requirements deal with water quality, treatment, and public communication
- Operator certification requirements pertain to individuals in responsible charge of a water system
- Minimum design standards and the plan review and approval process ensure water system components are adequately sized and properly installed
- Other regulations address such issues as safety during system repair or construction, fire codes, and cross-connection control programs

General information on each of these subjects will be presented in this chapter. Some items are covered in more detail throughout the manual.

The manual was written as a guide for small-untreated groundwater systems serving less than 500 people. Therefore, specific monitoring and reporting requirements have intentionally been left out of this manual because they differ by system size, system complexity, and population served by the water system.

8.2 Record Keeping

The recording of data is an everyday task at a water system. In fact, certain water system records are required by State regulation (Table I).

Some records are maintained to assist owner/operators with operational decisions. For example, operational records establish historical data that will indicate when a pump or motor may need to be replaced. Operational decisions based on historical data, through good record keeping, will save time trying to solve problems, save money through proactive operations rather than reactive (crisis) operating, and free-up time for monitoring and maintenance of the water system.

Record retention should include:

- Source records:
  Well log

Total water produced
Total water used
Static water level measurements
Pumping water level measurements
Raw water temperature

- System Maps:
  As-Builts
  Maps of all existing facilities
- Distribution system maps:
  Valve locations
  Fire and yard hydrants locations
  Pipe locations and sizes
  Distribution leak locations and dates
  Distribution pipe replacements and dates
  Sampling site plan

Required Monitoring Records	
Records to Keep	**Required Record Retention (Years)**
Actions to correct violations	3
Bacteriological (BacT) analyses	5
Variance or exemptions	5
Sanitary survey reports	10
Chemical analyses (SOC's, VOC's, IOC's)	10
All lead and copper analyses & data	12

Table I: Required monitoring records

8.3 Consumer Confidence Reports (CCR's)

A Consumer Confidence Report (CCR) is an annual drinking water quality report issued to consumers of each community or non-transient non-community public water supply system. The CCR describes the source of their water and the levels of contaminants found in the drinking water. The first reports were due October 1, 1999, and the reports are to be available to consumers by July 1 each year thereafter. Alaska's small water systems, systems serving less than 500 people per day and less than 100 service connections, may distribute their CCR's by mail, door-to-door delivery or by posting in an appropriate location. Also, the report must be available upon request.

Public water systems are free to enhance their reports in any useful way, but each report must provide consumers with the following fundamental information about their drinking water:

- Identification of the aquifer, lake, river, or other source of the drinking water
- A brief summary of the susceptibility to contamination of the local drinking water source, based on the source water assessments that states are completing over the next five years
- How to get a copy of the water system's complete source water assessment
- The level (or a range of levels) of any contaminant found in local drinking water as well as

USEPA's health-based standard (MCL) for comparison
- The likely source of that contaminant in the local drinking water supply
- The potential health effects of any contaminant detected in violation of an USEPA health standard, and an accounting of the systems actions to restore safe drinking water
- The educational statement for vulnerable populations about avoiding *Cryptosporidium*
- Educational information on nitrate, arsenic, or lead in areas where these contaminants are detected above 50% of USEPA's standard
- Phone numbers of additional sources of information, including the water system and USEPA's Safe Drinking Water Hotline (1-800-426-4791)

CCRs are the centerpiece of the right-to-know provisions in the 1996 Amendments to the Safe Drinking Water Act. The Amendments contain several other provisions aimed at improving public information about drinking water, including the annual public water system compliance report and improved public notification in cases where a water supplier is not meeting a contaminant standard. The Amendments also call for increased public participation in the protection and delivery of safe drinking water. For example, citizen advisory committees are helping states to implement their source water assessment activities and are involved in decisions about allocating the state revolving loan fund that provides funding for drinking water infrastructure improvements.

8.4 Public Notification

The primary purpose of public notification is to keep the public informed of incidents that may affect drinking water quality. Public notification serves to advise consumers of the potential health hazards and to educate them about the importance of adequate financing and support for drinking water systems.

Public water systems must notify their customers when they violate state drinking water regulations. Please consult with your local ADEC local drinking water program representative if your system:

- Violates a maximum contaminant level or treatment technique
- Fails to report or monitor a contaminant
- Fails to comply with the requirements of a compliance schedule prescribed under a variance or exemption

Your ADEC Drinking Water Program can help you develop a public notice that:

- Provides a clear and readily understandable explanation of the violation.
- Describes potential adverse health effects, if any.

- Identifies the population at risk.
- Outlines the steps that the owner or operator is taking to correct the violation, explain the necessity, if any, for seeking alternative water supplies.
- Describes preventive measures, if any, that the consumer should take until the violation is corrected.
- Contains mandatory language required by State Drinking Water Regulations.

The system owner or operator must notify the public of an MCL violation by publication in a daily newspaper circulated in the affected area as soon as possible, and no later than 14 days after the violation or failure. If a daily newspaper of general circulation does not serve the area, the owner or operator shall give notice by publication in a weekly newspaper of general circulation in the area served. If the area does not have a daily or weekly newspaper, the owner or operator shall give notice within 14 days after the violation or failure by hand delivery, by continuous posting in conspicuous places within the area served by the system or by both methods. Posting must continue for as long as the violation or failure exists. Notice by hand delivery must be repeated at least every three months for as long as the violation or failure exists.

Notification may be by mail delivery, direct mailing, included with the water bill or hand delivered within 45 days of the violation or failure. If ADEC finds that the owner or operator has corrected the violation or failure within the 45 day time period, the department will issue a written waiver of the requirement for mail or hand delivery.

MCL violations for contaminants that may pose an acute risk to human health must be publicized through each radio and television station that provides service to the area served by the public water system as soon as possible, and not later than 24 hours after the violation. For a community that is not served by a radio or television station, public notice of the violation must be hand delivered to persons served by the system and must be posted in conspicuous places in the community as soon as possible no later than 24 hours after the violation. Notice of the violation must continue for as long as the violation exists or for 10 days, whichever is longer. An acute violation is defined as the failure of a water system to meet a SDWA regulation, resulting in an immediate public health risk. The following violations are considered acute violations:

- A violation specified by ADEC as posing an acute risk to human health
- A violation of the MCL for nitrate or nitrite
- An occurrence of a waterborne disease outbreak in an unfiltered system
- A violation of the MCL for total coliforms if fecal coliforms or *E. coli* are detected in the distribution system

Chapter 9 - Passive Treatment

9.1 Introduction

For purposes of this guide, passive treatment methods are water treatment methods that do not rely on chemical additions to accomplish the treatment goal for which they are intended. Generally, passive treatment requires no daily operator interaction. Only periodic attention from the operator is required for proper operation of passive treatment methods. Examples of passive treatment include cartridge filtration, ion-exchange softening or ion-exchange iron removal devices, and ultraviolet disinfection.

9.2 Passive Filtration

Passive filtration means no chemicals are required to condition the water before it is filtered. The filtration mechanism is solely physical; straining water through a filter or series of filters to remove contaminants. The only routine maintenance required is periodic replacement of the filtration element.

9.2a Filters

The basic concept behind nearly all filters is similar. The contaminants are physically prevented from moving through a filter either by screening them out with very small pores and/or, in the case of carbon filters, by trapping them within the filter matrix by attracting them to the surface of carbon particles.

Micron or sub-micron filtration refers to a measure of how good the filter is at removing particles from the water - smaller is better. A micron is a unit of measure. One micron is 1/1,000,000 of a meter or about 1/100 the diameter of a human hair. A filter that removes particles down to 5 microns will produce fairly clean-looking water, but most of the water parasites; bacteria, cryptosporidia, giardia, etc. will pass through the pores. A filter must trap particles one micron or smaller to be effective at removing cryptosporidia or giardia cysts. Viruses cannot be physically removed by any of the water filtration methods.

9.2b Cartridge Filter

A cartridge filter (Figure 9.1) is made up of a housing (sump and cover) and a removable cartridge (element). The cartridge is a disposable item. These devices are suitable for filtering water with small amounts of suspended material or if the volume of water required is small.

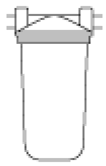


Figure 9.1: Cartridge Filter

In cartridge filtration the replaceable inner package, which is similar to an automobile oil or air filter, consists of a membrane folded in accordion fashion with a molded retaining device. The package is sealed into a pressure vessel. As the membrane becomes soiled, raw water will pass further down the pleat until the whole surface is soiled.

When you start to experience low water pressure, the filter is probably full and needs replacement. Replace the filter cartridge and remember to put a quarter teaspoon of household bleach into the filter sump to kill any bacteria introduced from changing the filter. Remember to handle the replacement filter aseptically (wash your hands and use clean latex gloves). Do not use the water for 10 minutes. Chlorine in the bleach does not kill immediately upon contact. Give the chlorine time to disinfect the bacteria. Filter to waste if this option is available. If the filter cartridge has a by-pass valve in the assembly, remember to put it back into the service position.

Bag filters (Figure 9.2) can be used to filter larger microorganisms such as *Giardia* and certain types of protozoa. In the bag filter, one or more layers of fabric are formed as a seamless bag that can be sealed into a pressure vessel. The membrane for this type of filtration may be woven or non-woven, and fibers may be either natural or synthetic.

One type of bag filter made by 3M has many layers of fine fabric interwoven with a more porous fabric. The small cartridge filters are available with stainless steel or plastic housings. The bag filters are typically installed using stainless steel housings. As in sand filtration, particle removal occurs deep in the fabric, leading to longer filter runs and less pressure loss through the filter.

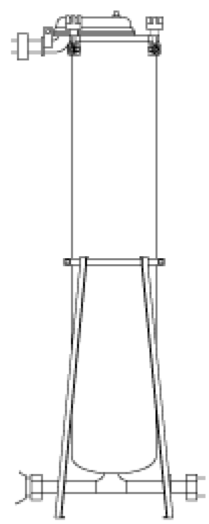


Figure 9.2: Bag Filter

In both the bag and cartridge filter designs, excessive pressure loss indicates that the cartridge must be replaced. The following sequence can be used as a guide for changing the media in a cartridge or bag filter:

- Shut off the inlet and outlet isolation valves
- Drain the pressure from the system. This can be accomplished by opening the filter to waste valve.

- Put on latex gloves
- Remove the housing cover
- Remove the filter element. Place the filter element in a sealed bag for disposal.
- Using a chlorine solution of 1 to 5 percent (household bleach is approximately 5% chlorine) disinfect the interior of the housing
- Install the filter element
- Inspect the seal on the housing and replace if damaged
- Replace and tighten the housing or housing bolts. Do not over tighten the housing.
- If not already open - open the filter to waste valve
- Slowly return flow to ½ of normal
- After 5 to 10 min. close the filter to waste valve and open the inlet valve
- Record initial pressure gauge reading across each stage and flow through the filters

Unlike traditional filtration technologies, backwashing is usually not used to clean the bag or the cartridge filter. Instead, the whole bag or cartridge is replaced with a new one. The old bag is disposed of along with the accumulated sludge and debris. However, some cartridge filters can be cleaned by backwashing, but will still need periodic replacement. Because operators spend less time cleaning equipment, a saving in labor costs offsets the expense of replacing the filter element. Another benefit is the absence of wash water with a high sediment load. Without having to dispose of this waste, costs are cut even further.

Some small systems use a combined cartridge/bag filter design to increase the effectiveness of Giardia removal. There is no set standard cartridge/bag filter design. Typical, installations include a Giardia filter preceded by 1 or more pre-filters and/or basket strainers. The pre-filters extend the life of the Giardia filter by removing excessive debris and they are less expensive to replace than a Giardia filter. Typical combinations of filter and pre-filters (Figure 9.3) are:

- 50 and 25 micron pre-filters followed by a 5 micron Giardia filter
- 50 and 5 micron pre-filters followed by a 2.5 or 1 micron Giardia filter
- 25 and 5 micron pre-filters followed by a 2.5 or 1 micron Giardia filter
- Back washable basket strainers or mixed media filters with 50, 25, or 10 micron effective size and 95% removal efficiency, followed by a 5, 1.5 or 1 micron Giardia filter

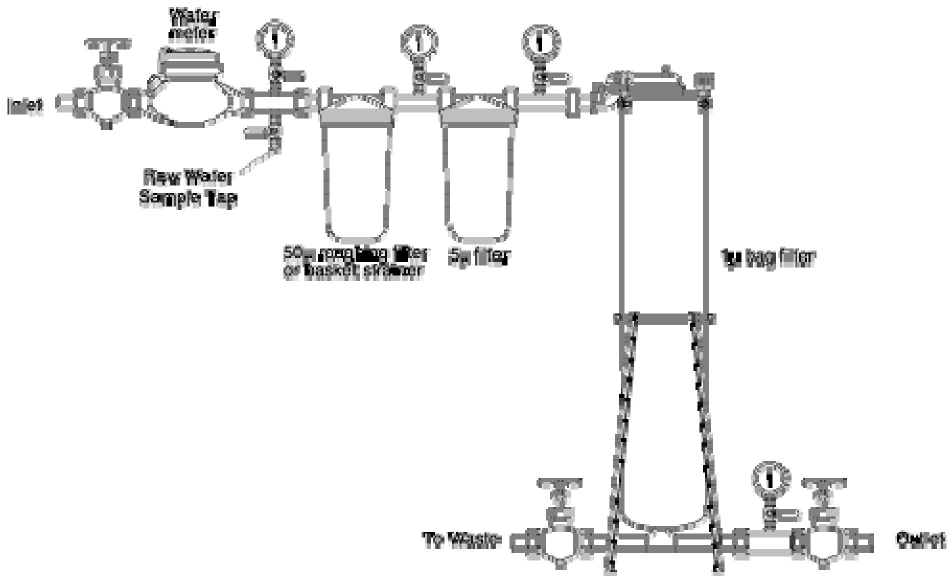


Figure 9.3: Cartridge Bag Filtration

9.2c Sand Traps

Most wells produce some sand. If sand is excessive, a sand trap can be installed to prevent sand from entering the piping system. Normally, sand traps are a large tank with a series of internal baffles or chambers. The tank is placed on the discharge side of the pump. The baffles or chambers slow the velocity of the water so that gravity will cause the sand and heavier silt particles to settle to the bottom of the tank. Sand and silt are removed from the tank by a blow-off valve located on the bottom of the tank.

9.3 Water Softening

Water containing dissolved salts of calcium and magnesium at elevated levels is known as hard water. The process of removing these minerals is called water softening. Water softening involves exchanging calcium and magnesium minerals present in water (which causes the hardness) with sodium. Two common methods of softening are the ion exchange method and the lime-soda method. Typically water softeners (conditioners) are not by themselves water purification systems. Their sole function is to reduce the hardness of water by replacing calcium and magnesium ions with another ion, frequently sodium.

To understand the operation of a water softener, one must first understand the concept of ions. Many chemical elements from compounds dissolved in water separate and form electrically charged particles called ions. Because opposite charges attract each other, these ions move to and attach themselves to objects with opposite charges. A common compound that demonstrates this property is NaCl (sodium chloride or common table salt). The ions formed in water from this compound are Na^+ and Cl^-. The small + and - signs indicate these elements have formed ions and that their charges are either positive (+) or negative (-). There are many elements that form ions when dissolved in water that have undesirable characteristics. Some common ones are listed in Table J.

Ion	**Characteristics**
Ca^{++} (calcium) Mg^{++}(magnesium)	Gives water the characteristics we call hard. It causes damage to heating appliances and fixtures because of scaling, excessive soap usage, dry skin and premature deterioration of fabrics washed in water containing it.
Fe^{++} (iron)	When exposed to air turns red/orange and causes staining.
Mn^{++} (manganese)	When exposed to air turns black and causes staining.

Table J: Ion characteristics

Softening by ion exchange involves passing the water through a column containing a special ion exchange material. Several different types of ion exchange materials are in use, including natural substances called zeolites and synthetic resins.

Exchange resins are placed in a pressure vessel, and a salt brine is flushed through the resin. The sodium ions in the salt brine attach to the resin, which are now charged. Once charged, water is passed through the resin and the resin exchanges the sodium ions attached to the resin for calcium and magnesium ions, thus removing them from the water. When water containing calcium or magnesium ions is in contact with these materials, an exchange or trade of ions takes place. The calcium and magnesium ions are taken up by the resin, whereas sodium ions, Na^+ are released into the water.

A common water softener consists of two tanks, a resin tank and the brine (salt) tank. The resin tank is filled with a resin that consists of small plastic beads. The resin is call cation (“cat” “ion”) resin. The beads have a permanent negative charge. The charge causes the beads to attract positively charged ions. The resin is placed into service with the Na^+ ions on the beads. When the hardness ions (Ca^{++} and Mg^{++}) come into contact with the Na^+ they remove the Ca^{++} and Mg^{++} and take the Na^+’s place on the beads. The Na^+ is now dissolved in the water. The Na+ leaves the resin tank and is delivered to the tap with the water. When most of the Na^+ is removed from the resin beads the softener head starts the regeneration process (cycle). A control is set that allows raw water into the house for regeneration. This is done so none of the salt used during regeneration can enter the house plumbing. Drawing in a high concentration salt (NaCl) solution from the brine tank then regenerates the resin. This salt solution is washed over the depleted resin. The salt solution contains Na^+ and Cl^- ions. The Na^+ is placed back onto the beads and the Ca^{++}, Mg^{++} and Cl^- are washed down the drain. The media is then rinsed with fresh water to remove all the remaining salt.

Softening by ion exchange can produce water with almost zero levels of hardness, but that is not really desirable. Very soft water may be aggressive, or corrosive, causing damage to metal pipes and plumbing. Hardness levels of about 100 mg/L are considered optimum for drinking water. Consequently, it may be wise to consider “blending” water from the softener with raw water before sending your water to the distribution system. Also, a factor that must be considered is that softened water from an ion exchanger contains sodium, which may be harmful to persons who must limit their intake of sodium.

9.4 Iron and Manganese Removal

Ion exchange is used mostly to soften hard water but will also remove soluble iron and manganese. Iron and manganese removal by ion exchange is similar to eliminating calcium and magnesium by softening. This process uses a sodium-form strong acid cation resin. The method is used for low flow applications where manganese is the primary metal ion to be removed because the resin exchanges the manganese ion easier than the iron ion. In addition, softening occurs during the process with the exchange of calcium and magnesium. Sodium chloride is particularly effective at removing the manganese ion from groundwater. There must be no oxygen in either the influent or regenerate water. Otherwise, ion exchange units experience media fouling.

9.5 Ultraviolet (UV) Light Disinfection

Ultraviolet (UV) light is also used at some small water systems for disinfection. Water passes through a clear chamber where it is exposed to UV light. UV light kills bacteria and deactivates viruses, but the tough cryptosporidia cyst is resistant to UV light unless the UV equipment is specifically designed for cyst inactivation. If designed properly, a system with UV light can provide a very safe and user friendly disinfecting system.

UV light is generated by a variety of lamps; low-pressure mercury lamps are best suited for use in disinfection systems because they generate a large fraction of UV energy that gets absorbed. Any turbidity in the water can hide pathogens, protecting them from the light. UV light is not effective against any non-living contaminant, lead, asbestos, organic chemicals, chlorine, etc. UV is typically used as a final purification stage on some filtration systems.

UV light does not, however, provide any residual in the distribution system. The lack of residual means that extra care must be taken in installation to make sure the distribution system is thoroughly disinfected during the installation process. UV lights alone should not be used on any system that there is a potential for contamination in the distribution system such as leaking underground lines or cross connections with other supplies.

Water treated by UV must be relatively clear and colorless to allow the light to pass through to kill bacteria and viruses. The water should be free of any materials that might build up on the surface of the bulb and could decrease the output from the bulb. Iron, manganese, and hardness are the most common materials that could cause this problem.

There are three levels of safety that should be provided with UV lights:

1. UV light with an inspection hole to determine if the light is on
2. UV light with a photo sensor that will automatically determine if the light is on or off. If the light is not on, an alarm will sound and or the water will be shut off with a solenoid valve.
3. UV light with a transmittance detector that will not only determine if the light is on but will also measure the intensity of the light after it has passed through the water. If the light that transmitted through the water is not sufficient, the detector will shut the water off to the system until the problem is corrected.

Consult ADEC to determine the level of safety that should be provided when using UV for disinfection. If a UV light is used by itself (no other disinfection), the type described in #3 above should be used. If chlorination is used with retention then the UV light system described in #2 above would be satisfactory because it is used as part of a redundant system. The combination of chlorination and UV light would be a good choice for any situation where residual is needed and or redundancy is required.

Chapter 10 - Troubleshooting

10.1 Introduction

During water system operations, various problems may develop. Problems with pumps will usually be hydraulic or mechanical. Hydraulic problems may include a pump that will not deliver water at all, delivers an insufficient amount of water, or loses prime after start up. Mechanical problems may include excessive use of power to operate the pump, excessive vibration or noise, or bearings failure.

Well problems may be caused by a combination mechanical and hydraulic problem. For example, the well may pump sand or mud. When this occurs, the well screen may have collapsed or corroded, causing the screen's slot openings to become enlarged (allowing debris, sand, and mud to enter). If the well screen is not the problem, the pumping rate should be checked. The pumping rate may be too high. Excessive sand may require the installation of a sand trap.

Approximately 75 percent of well pump and control problems are associated with electricity as noted in Chapter 4. The operator should have a good working knowledge of electrical circuits and circuit-testing instruments before attempting to service or troubleshoot the electrical circuits and components commonly used in well pump operations.

Small water systems operators unfamiliar with well pump or electrical circuit troubleshooting should arrange with a local electrical firm or pump service company to perform this service.

NOTE: Never attempt to service, troubleshoot, or repair a motor without disconnecting the motor breaker from the main power source. Many motors also use capacitors which maintain an electrical charge until they are properly discharged!! Do not attempt to service electrical equipment without appropriate training and licensing.

This trouble-shooting guide is not intended to be all-inclusive, but rather a starting point for recognizing and identifying well problems. A list of well problems, probable causes, and possible solutions are listed in Table K.

Troubleshooting Guide

Symptom	Probable Cause	Corrective Action
Pump Will Not Start	Circuit breaker or overload relay tripped, motor cold	Reset breaker or reset manual overload relay.
	Fuses burned out	Check for cause and correct, replace fuses.
	No power to switch box	Confirm with voltmeter by checking incoming power source, notify power company.
	Motor is hot and overload relay has tripped	Allow motor to cool. Check supply voltage. If low, notify power company. If normal, reset overload relay, start motor, check amperage; if above normal, call electrician.
	Loose or broken wire, or short	Tighten wiring terminal, replace any broken wires, check for shorts and correct.
	Low line voltage	Check incoming power, use voltmeter; if low, notify power company.
	Defective motor	*MEG* out motor; if bad, replace.
	Defective pressure switch	With contact points closed, check for voltage through switch; if no voltage, replace switch; if low voltage, clean contact points; if full voltage, proceed to next item.
	Line to pressure switch is plugged or valve in line has accidentally been shut off	Open valve if closed. Clean or replace line.
	Pump control valve malfunctioning	Check limit switch for proper travel and contact. Adjust or replace as required.
	Defective time delay relay or pump start timer	Check for voltage through relay or timer – replace as necessary – check for loose linkage.
	Float switch or transducer malfunctioning	If pump is activated by float switch or pressure transducer on storage tank, check for incoming signal; if no signal, check out switch or transducer with voltmeter. If okay, look for broken cable between storage tank and pump station.
Pump Will Not Shut Off	Defective pressure switch	Points in switch stuck or mechanical linkage broken, replace switch.
	Line to pressure switch is plugged or valve in line has been accidentally shut off	Open valve if closed. Clean or replace plugged line.
	Cutoff pressure setting too high	Adjust setting.
	Pump control valve malfunctioning	Check limit switch for proper travel and contact. Adjust or replace as required.
	Float switch or transducer malfunctioning	Defective incoming signal, check and replace components as required. Check cable.
	Defective timer in pump stop mode	Check for voltage through pump stop timer, replace if defective.
Pump Starts Too Frequently	Pressure switch cut-in and cutoff settings too close	Adjust settings, maintain minimum 20 psi (138 kPa or 1.4 kg/sq cm) differential.
	Waterlogged tank	Add air to tank. Check air charging system and air release valve. Also check tank and connections for air leaks.
	Leaking foot valve	Check for backflow into well; if excessive or if pump shaft is turning backward, correct problem as soon as possible.
	Time delay relay or pump start/stop timers are malfunctioning	Check relay or timers for proper operation, replace defective components.

MEG: A procedure used for checking the insulation resistance on motors, feeders, bus bar systems, grounds, and branch circuit wiring

Symptom	Probable Cause	Corrective Action
Fuses Blow, Circuit Breaker or Overload Relays Trip When Pump is in Operation	Switch box or control not properly vented, or in full sunshine or dead air location, overload relay may be tripping due to external heat	Provide adequate ventilation (may require small fan). Provide shelter from sun. Paint box or panel with heat reflective paint, preferably white.
	Incorrect voltage	Check incoming power source. If not within prescribed limits, notify power company.
	Overload relays tripped	Check motor running amperage; verify that thermal relay components are correctly sized to operating conditions. Repeated tripping will weaken units, replace if necessary.
	Motor overloaded and running very hot	Modern motors are designed to run hot and if the hand can be held on the motor for 10 seconds without extreme discomfort, the temperature is not damaging. Motor current should not exceed *NAMEPLATE* rating. Fifteen percent overload reduces motor life by 50 percent.
Pump Will Not Deliver Normal Amount of Water	Pump breaking suction	Check water level to be certain water is above pump bowls when operating. If not, lower bowls.
	Pump impeller improperly adjusted	Check adjustment and lower impellers (qualified personnel only).
	Rotation incorrect	Check rotation.
	Impellers worn	If well pumps sand, impeller could be excessively worn thus reducing amount of water pump can deliver. Evaluate and recondition pump bowls if required.
	Pump control valve malfunctioning	Check limit switch for proper travel and contact. Adjust or replace as required.
	Impeller or bowls partially plugged	Wash down pump by forcing water back through discharge pipe. Evaluate sand production from well.
	Drawdown more than anticipated	Check pumping water level. Reduce production from pump or lower bowls.
	Pump motor speed too slow	Check speed and compare with performance curves. Also check lift and discharge pressure for power requirements.
Pump Takes Too Much Power	Impellers not properly adjusted	Refer to manufacturer's bulletin for adjustment of open or closed impellers.
	Well is pumping sand	Check water being pumped for presence of sand. Restrict discharge until water is clean. Care should be taken not to shut down pump if it is pumping very much sand.
	Crooked well, pump shaft binding	Reshim between pump base and pump head to center shaft in motor quill. Never shim between pump head and motor.
	Worn bearing or bent shaft	Check and replace as necessary.
Excessive Operating Noise	Motor bearing worn	Replace as necessary.
	Bent line shaft or head shaft	Check and replace.
	Line shaft bearings not receiving oil	Make sure there is oil in the oil reservoir and the oiler solenoid is opening. Check sight gage drip rate, adjust drip feed oiler for 5 drops per minute plus 1 drop per minute for each 40 feet (12 m) of column.

NAMEPLATE: A durable metal plate found on equipment which lists critical installation and operating conditions for the equipment.

Table K: Troubleshooting Guide

10.2 Emergency Well Disinfection

Disease-causing organisms can enter wells, tanks and distribution piping during the construction process, or during maintenance or repair. Special care must be taken to prevent contaminated soils or water from getting into the water source or distribution system resulting in a hot BacT sample.

Proper disinfection kills disease-causing microorganisms and other bacteria that may be present in drinking water. Poorly constructed wells may also allow contaminated ground water or surface water runoff to enter the well. The State of Alaska Drinking Water Regulations require that before use, a newly constructed or reworked well must be flushed of sediment and disinfected as specified in ANSI/AWWA Standard A100-97. A copy of the ANSI/AWWA Standard may be obtained from ADEC, ATTAC or AWWA.

Water supply wells must be disinfected and sampled after their initial construction to assure that the water produced is safe for human consumption. Additionally, wells should be disinfected and sampled after repairs are made to the well or well equipment.

Whenever periodic or emergency disinfection is required, only chlorine products approved by the National Sanitation Foundation (NSF) or AWWA for use in potable water should be used. When system disinfection is performed with non-NSF approved products, such as household bleach, it is critical to flush ALL chlorine from the system prior to human consumption. High-test hypochlorite (HTH), or **calcium hypochlorite**, is used to disinfect swimming pools and is readily found at hardware stores and outlets for swimming pool equipment. HTH is NSF approved at a maximum dosage of 4.0 mg/L. Therefore, it must be thoroughly flushed from the system prior to human consumption. When working with chlorine, the operator must be in a well-ventilated place. The powder or strong liquid should not come in contact with skin or clothing. Chlorine solutions are best handled in plastic or crockery containers because metals are corroded by strong chlorine solutions.

10.3 Disinfection

The chemical or physical process used to control waterborne pathogenic organisms and prevent waterborne disease is called **disinfection**. Organisms that cause disease are referred to as pathogenic organisms.

The goal of disinfection in a water system is to destroy all disease-causing organisms.

Chlorine (Cl_2) is the most common substance used for disinfection of potable water in the United States. Chlorine deactivates microorganism through several mechanisms, assuring that it can destroy most biological contaminants.

Two forms of chlorine commonly used for disinfection by small water systems are **sodium hypochlorite** (bleach) solution and calcium hypochlorite granules or tablets.

Sodium hypochlorite is available in liquid form in glass, rubber-lined, or plastic containers typically ranging in size from one quart to five gallons. Containers of sodium hypochlorite of thirty gallons or larger size may be available in some areas. Sodium hypochlorite contains approximately five percent to fifteen percent available chlorine. Common household bleach normally contains 5% chlorine.

Calcium hypochlorite is available in granular form or small tablets, and contains approximately 65% available chlorine by weight. The material should be stored in a cool, dry, and dark environment to minimize deterioration.

Note carefully the precautions listed on the container label.

Disinfection of a groundwater source should be performed under any of the following conditions:

- After completing construction of a new well or spring supply
- When repair or reconstruction of a well or spring, pumps or attached piping is completed
- If the well or spring has been temporarily flooded or subjected to another temporary source of bacteriological contamination
- Receipt of a laboratory report indicating an unsatisfactory bacteriological analysis of the well or spring supply.

10.3a Disinfection Procedure for Coliform and Non-Coliform Bacteria

Appendix 5 shows the required amount of liquid household bleach or calcium hypochlorite to be added to five or ten gallons of water to achieve the proper chlorine concentration in the well (approximately 100 mg/L).

The procedure involves calculating the volume of water standing in the well and then applying enough chlorine powder, tablets or liquid to achieve a 100 mg/L chlorine concentration (50 mg/L for new wells). The chlorine is mixed with five to ten gallons of water then poured down the well.

Chlorine products must be handled in accordance with the manufacturer's directions. Failure to follow instructions could cause bodily injury. Wear eye protection, gloves, and protective clothing.

Once the chlorine solution has been added to the well, a hose is then connected to the discharge side of the pump with the outlet of the hose pointed back down into the well casing or access pipe. The well pump is started so that water from the well is circulated back down into the casing. Circulation should continue until a strong chlorine odor is detected coming from the hose. A chlorine colorimetric comparator may also be used to measure chlorine residual.

As a rule of thumb, wells of six inches in diameter require 0.5 ounces of sodium hypochlorite (household bleach) or

0.033 ounces of calcium hypochlorite per foot of water for disinfection. The following steps outline a simplified procedure for disinfecting a well.

1. Calculate the depth of water in the well by subtracting the non-pumping (static) water level in the well from the well depth. Then calculate the volume of water in the well.
2. A solution of approximately 100 mg/L chlorine is recommended for disinfection of wells containing coliform or non-coliform bacteria. Using Appendix 5 determine the amount of bleach or calcium hypochlorite needed to disinfect the well. Mix this calculated dosage with five to ten gallons of water.
3. Remove the well cap. Carefully pour the chlorine solution down the well. Replace the cap securely. Start the well pump and circulate the well water until the chlorine odor is present.
4. Turn on each service tap and allow the water to run until the chlorine odor is present at each tap. Shut the tap off. Do this at each tap if possible. *Customers must not be allowed to drink the chlorinated water*.
5. Leave the chlorine in the well and system at least twelve to twenty-four hours to allow contact time with the bacteria. Do not use the water during this time. Never drink well water containing high levels of chlorine.
6. After 12 - 24 hours, pump the chlorinated water out of the system until its odor is no longer detected, or the residual measures 0.5 or below with the color comparator. Water with a chlorine residual above 1 mg/L should not be discharged to any lake, stream or other surface water body because chlorine is extremely toxic to fish and other aquatic life. Complete removal of the chlorinated water may take several hours depending on the capacity of the pump. Flush all taps inside the buildings.
7. Wait 72 hours and then collect a water sample to test for coliform bacteria. The sample should be taken to determine if the disinfection process was effective and should be labeled a special sample when submitted to the laboratory. It will not be used for Coliform Rule compliance purposes.

Chlorine may also be used as a continuous disinfectant for groundwater. Various chlorine equipment must be installed for continuous system disinfecting. Ultraviolet light (UV) may also be used for continuous disinfection.

Chapter 11 - Math

11.1 Introduction

Someone once asked Albert Einstein how many feet were in a mile. "I don't know," he replied, "Why should I fill my head with information I can look up in a reference guide within two minutes?"

A math formula sheet is included as Appendix 6. Use the formula sheet as your reference guide. The formula sheet is similar to the formula sheet provided by ADEC when an operator takes his/her certification exam. Learn to identify what a math problem is asking, then use the formula sheet to plug in the numbers to solve math problems. Using Albert Einstein's logic, why try to memorize mathematical formulas when you can look them up on the formula sheet?

Also, an approved calculator can be used during certification exams. So practice and be familiar with the calculator you will use when taking the certification exam.

This math section is intended to be an aid to the operator solving everyday problems in the operation of a small-untreated ground water system. The section is very basic. However, an operator must know how to do certain calculations. The section attempts to present basic math problems that would be required for an operator to accomplish his/her everyday work, and prepare for the certification exam.

Solving math problems is not any different than solving any type of problem. It requires practice in manipulation and knowledge of what manipulations to make. Below is an approach to solving math problems:

- Decide what the problem is asking
- List the information given
- Make a drawing of the information in the problem if appropriate
- Pay attention to the units given and required
- If the calculation calls for an equation, write it down
- Refer to the formula sheet, and fill in the data in the equation
- Look to see what is missing in the equation – what to solve for
- Perform the calculations necessary to solve the problem
- Label the answer

11.2 Averages

An average is a way of representing several different measurements as a single number. The average is the total values of a series divided by the total number in the series.

Problem*:*
Find the average of the following series of numbers:
90, 120, 75, 250, 150

Solution*:*
Add the five numbers together:
90 +120 + 75 + 250 + 150 = 685

Next, divide the total by the number in the series: 685/5 = 137

Problem*:*
Flow measurements were taken twice a week for a month. Find the average daily flow for the month.
1200 gpd; 2250 gpd; 2600 gpd; 1800 gpd; 1900 gpd; 2200 gpd; 2500 gpd; 1100 gpd;

Solution*:*
Add the eight numbers together:
1200 gpd + 2250 gpd + 2600 gpd + 1800 gpd + 1900 gpd + 2200 gpd + 2500 gpd + 1100 gpd = 15,550 gpd

Next divide the total by the number in the series: 15,550 gpd/8 = 1943.75 gpd

11.3 Fractions

Fractions are used when you want to express a portion of the whole. If you have a pizza that is cut into five pieces and you eat one, you have eaten 1/5th of the pizza (1 divided by 5). If you eat two pieces, you have eaten 2/5th of the pizza (two divided by five).

The top number of the fraction is called the numerator and represents how many parts you have and the bottom number is called the denominator that represents the number in the whole.

The bar or slash (/) in the fraction separates the two numbers and is read “divided by”. Divided by means that the top number (numerator) is divided by the bottom number (denominator). This means that another way to say 1/5 is to say 1 divided by 5.

11.4 Decimals

Another method of representing a fraction is by using decimals of tenths, hundredths, etc. This is a much better method to use with a calculator. If you have a fraction, and need to express the fraction as a decimal, you can convert the fraction to a decimal by dividing the numerator by the denominator. A decimal is composed of two sets of numbers. The numbers to the left of the decimal are whole numbers and numbers to the right of the decimal are parts of whole numbers, or a fraction of a whole number.

Whole number → 157.658 ←Fraction of a number

The term used to denote the fraction component is dependent on the number of characters to the right of the decimal. The first character after the decimal point is tenths; the second character is hundredths; the third is thousandths; the fourth is ten thousandths; and the fifth is hundred thousandths.

1	2	3	.	4	5	6
Hundreds	Tens	Units	Decimal	Tenths	Hundredths	Thousandths

We can convert a fraction to a decimal by dividing the numerator by the denominator. Using a calculator to divide the fraction, simplifies the process. For example, to convert 3/4 to a decimal, we divide 3 by 4. Using a calculator, enter the following keystrokes:

$$3 \div 4 =$$

The display will show the answer, 0.75.

11.4a Subtracting Decimals

If a calculator is unavailable, some basic rules apply to solving decimal problems.

Problem:
Subtract 15.21 from 64.26

Solution:
Line up the numbers at their decimal points and subtract.

```
   64.26
-  15.21
   49.05
```

Problem:
Subtract 15.602 from 165.900

Solution:
Line up the numbers at their decimal points and subtract.

```
  165.900
-  15.602
  150.298
```

11.4b Adding Decimals

Problem:
Add 25.34 and 62.46

Solution:
Line up the numbers at their decimal points and add.

```
   62.46
+  25.35
   87.81
```

Problem:
Add .721 and 409.731

Solution:
Line up the numbers at their decimal points and add.

```
  409.731
+   0.721
  410.452
```

11.4c Multiplying Decimals

When multiplying two or more numbers containing decimals, follow these basic rules:

- Multiply the numbers as whole numbers; do not worry about the decimals
- Write down the answer
- Count the total number of digits (numbers) to the right of the decimal in all numbers multiplied
- Place the decimal that many places from the right hand end of your answer

Problem:
Multiply 2.48 x 4.6

Solution:
248 x 46 = 11408 (multiplied as whole numbers)

A total of three digits fall to the right of the decimal point (2 for the number 2.*48* and 1 for the number 4.*6*)

Place the decimal point three places to the left from the right of the 8; (11.408)

Answer: 2.48 x 4.6 = 11.408

11.4d Dividing Decimals

To divide a number by a number containing a decimal, the divisor must be made into a whole number by moving the decimal point to the right until a whole number remains. Follow these basic rules:

- Count the number of places the decimal needed to be moved
- Move the decimal in the dividend by the same number of places

Problem:
Divide 288.8 by 21.6

Solution:
Divisor → 21.6)$\overline{288.8}$← Dividend

Move the decimal in the divisor 1 place to the right changing the divisor to the whole number 216. Moving the dividend decimal 1 place to the right changes the dividend to the whole number 2888.

Note the sum of decimal places moved equals two. Place the decimal two places from the right of the 1; (13.37037). Answer rounded to two decimal places for convenience.

Divisor → 216)$\overline{2888}$ ← Dividend

Using a calculator, this problem would be set up as follows:

$$\frac{288.8}{21.6} = 13.37037$$

11.5 Rounding Numbers

Rounding is the process of taking a number and reducing the number to one with fewer digits. Digits are rounded for convenience, not accuracy. If you have a number like the calculation above (13.37037) and you wanted to round to two significant digits, you look at the third number to the right of the decimal (13.37<u>0</u>37). If the number is greater than 5 raise the second digit up one, if the number is less than 5 leave the number as is. The solution to rounding the above number would be 13.37.

11.6 Powers

Powers are used, for example, to identify area in square feet (ft^2), and volume in cubic feet (ft^3). Powers indicate when a number should be squared, cubed, etc. The power of a number indicates the number of times a number must be multiplied by itself.

Rather than writing 5 x 5 x 5 x 5, it is convenient to use an exponent to indicate that the factor 5 is used as a factor four times. Specifically, when several numbers are multiplied together as above, 5 x 5 x 5 x 5 = 625, the 5s are the factors; 625 is the product. Since the factors are alike, the product is called a power. Thus, 625 is a power of 5, and 5 is the base of the power. A power is a product obtained by using a base a certain number of times as a factor.

The exponent is a small number placed above and to the right of the base number and indicates how many times the base is to be used as a factor. Using this system of notation, the multiplication 5 x 5 x 5 x 5 is written 5^4. The 4 is the exponent showing the 5 is to be used as a factor four times.

Problem:
Rewrite 8 x 8 x 8 and calculate the product.

Solution:
$8 \times 8 \times 8 = 8^3 = 512$

Problem:
Rewrite 4 x 4 x 4 x 4 x 4 and calculate the product.

Solution:
$4 \times 4 \times 4 \times 4 \times 4 = 4^5 = 1024$

11.7 Ratios

This is a comparison of two numbers with the same units, such as 2 : 1. For instance if the units are parts per million (ppm), this represents 2 parts per million parts.

11.8 Unit Conversions

Unit conversion represents a method of converting from one unit to another, such as cubic feet (ft^3) to gallons. Conversions are a process of changing the units of a number to make the number usable in a specific instance. Conversions are accomplished by multiplying or dividing into another number to change the units of the number. If the units are incorrect the number that you calculate is incorrect as well.

Most calculations used for water related problems have units connected with them. Unit conversions appear to be one of the most difficult tasks for water system operators. You must always write the units down with each number. The number tell us how many, the units tell us what we have. All units must be checked prior to your calculations to make sure your answer will be in correct units.

When converting one unit to another, the following method determines units (but it does not solve the equation):

- Write down the number and units you wish to convert from on the left
- Write down the unit you wish to convert to on the right
- Draw a line under both of these (this line means "divided by" and allows you to use a conversion factor)
- Below the division line (on the right) write down the same unit as you wrote on the left
- Write the appropriate conversion number associated with the two units on the right
- Cancel out the same units (this will leave you with the units you wish to convert to)
- Perform the appropriate multiplication and division

Example A:
200 cubic feet (ft^3) is how many gallons?

$$\frac{200\ (\cancel{ft^3})\qquad 7.48\ \text{gallons}}{1\ (\cancel{ft^3})}$$

$$\frac{200\ (\cancel{ft^3}) \times 7.48\ \text{gallons}}{1\ (\cancel{ft^3})} = 1486\ \text{gals}$$

Example B:
How many gallons are contained in 2400 ft^3?

$$\frac{2400\ (\cancel{ft^3})\qquad \text{gallons}}{1\ (\cancel{ft^3})}$$

$$\frac{2400\ (\cancel{ft^3}) \times 7.48\ \text{gallons}}{1\ (\cancel{ft^3})} = 17{,}952\ \text{gals}$$

Units must be the same to make calculations. For instance, when numbers are added or subtracted, the units must be the same. 6 *feet* + 6 *feet* = 12 *feet*

Now, add 4 feet + 6 yards. The answer cannot be determined unless yards are converted to feet or feet are converted to yards. Converting the larger units is easiest when possible, but the conversion may depend on the answer desired:

6 ~~yards~~ feet
1 ~~yard~~

6 ~~yards~~ x 3 feet = 18 feet
1 ~~yard~~

Yards have now been converted to feet. Complete the problem:

3 feet + 18 feet = 22 feet

Refer to the formula sheet (Appendix 6) when the conversion factor is not known. Some operators probably memorize formulas because they use them daily. However, most water system operators have a formula sheet nearby to look up conversion factors when needed. Caution: Most formulas require specific units. You may need to convert your units before plugging them into a formula.

Practice:
If your pressure tank holds 100 gallons of water, how many cubic inches are contained in the tank? Ans. (23,155 in^3)

11.9 Solving Word Problems

1. Read the problem
2. Circle what is being asked for, underline pertinent information, draw a picture and label with information given in the question
3. Stop and think about what the question asks for
4. Check the units; many times the units of the item being asked for will tell you how to do the problem
5. Do not proceed until you understand what is being asked and you know how to proceed
6. Select the proper formula from the formula sheet
7. Write down the formula
8. Plug numbers from the question into the formula; if you don't have enough numbers to plug into the formula or too many numbers for the formula, you probably are trying to use the wrong formula
9. Solve the formula
10. Check if the answer is reasonable (makes sense). If not, go back and check your work and the formula you used.

11.10 Area

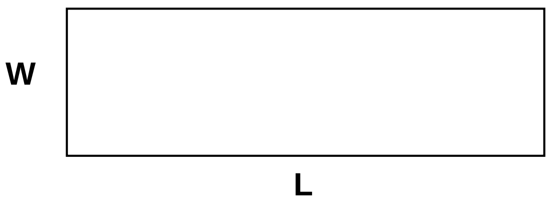
Area represents the surface of an object. Area of any figure is measured in the two dimensions or in square units. The units in the English system are usually square inches (in^2), square feet (ft^2), etc. Once again, remember units must be the same to solve math equations.

Area is found by multiplying two length measurements, so the result is square measurement.

(6 feet) x (6 feet) = 36 $feet^2$

11.10a Rectangle

The area of any rectangle is equal to the product to the length multiplied by the width of the figure.



Example:
Find the area of a rectangle that has a length of 8 feet and width of 4.5 feet.

$A = L \times W$
$A = 8 \text{ ft} \times 4.5 \text{ ft}$
$A = 36 \text{ ft}^2$

Remember: The units must be the same (both feet or both inches, etc.)

Practice:

1. What is the area of a sand filter 32 feet wide by 46 feet long? Ans. (1472 ft^2)

2. A sheet of wall paneling is 4 ft wide by 8 ft tall. How many square feet is a sheet of wall paneling? Ans. (32 ft^2)

3. You decide to panel a wall in your house. The wall measures 14 ft long and 8 ft high.

How many square feet is the wall? Ans. (112 ft^2)

How many sheets of paneling do you need? Ans. (3.5 sheets)

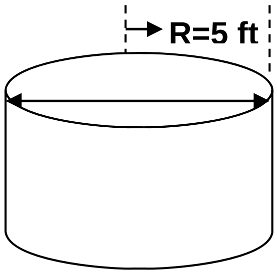
11.10b Circle

The area of a circle is found in a different manner because a circle does not have a base and height measurements. A circle is defined as a figure that has an arc that is equidistant in all areas from a center point. A line drawn from the center point to any point on the arc is called the radius (r). A straight line drawn through the center from arc to arc is called the diameter (D) of the circle. The distance around the outside of the circle is called the circumference (C).

The area of a circle is found by squaring either the radius (multiplying it by itself) or squaring the diameter. By doing this operation the units will become squared and at that point the units are right for finding area.

When making calculations involving circular objects, a special number is required, referred to as the Greek letter pi (pronounced pie), the symbol for pi is π. Pi (π) always has the value 3.1416 (many calculators include a button for π, since it is used so often). Pi is usually rounded to 3.14. The circular shape below shows the diameter and the radius.

D=10 ft



Example:
What is the area in square feet of the circular shape above?

$A = \pi \times r^2$
$A = \pi \times 5 \text{ ft} \times 5 \text{ ft}$
$A = 3.14 \times 5 \text{ ft} \times 5 \text{ ft}$
$A = 78.5 \text{ ft}^2$

or

$A = \pi/4 \times D^2$
$A = \pi/4 = 3.14/4 = 0.785;$

therefore,

$A = 0.785 \times D^2$
$A = 0.785 \times 10 \text{ ft} \times 10 \text{ ft}$
$A = 78.5 \text{ ft}^2$

Practice:

1. What is the area in square feet of a circular tank with a diameter of 40 ft.? Ans. (1256 ft^2)

2. How many gallons of paint will be needed to paint the roof of a circular storage tank that is 20 feet in diameter? A gallon of paint covers 110 square feet. Ans. (2.85 gallons)

11.11 Volume

Operators are usually interested in how many gallons a container, tank, or pipe can hold. Volume is measured in the three dimensions where a depth or height of the figure is known. Units are generally cubic feet (ft^3), cubic inches (in^3), acre-feet and gallons. In the water field, the volumes of most tanks are measured in gallons.

11.11a Volume of a Rectangle

The volume of a rectangular object like a clear well is calculated by multiplying together the length, width, and the depth. To calculate volume, remember the length times the width is the surface area. Then, surface area is multiplied by the depth to find the volume.

Volume = L x W x H

L = Length
W = Width
H = Height (or) Depth

Example:

What is the volume in cubic ft (ft^3) of a tank 45 feet long, 20 feet wide and 10 feet deep?

Volume = L x W x H

= 45 ft x 20 ft x 10 ft
= 900 ft^2 x 10 ft
= 9000 ft^3

Most problems involving storage tanks require the volume of the tank be known in gallons rather than cubic feet. One of the most common conversions used in the water industry is converting cubic feet (ft^3) to gallons. One cubic foot (ft^3) will hold 7.48 gallons. To calculate gallons the tank above will hold:

Volume = L x W x H

= 45 ft x 20 ft x 10 ft
= 900 ft^2 x 10 ft
= 9000 ft^3

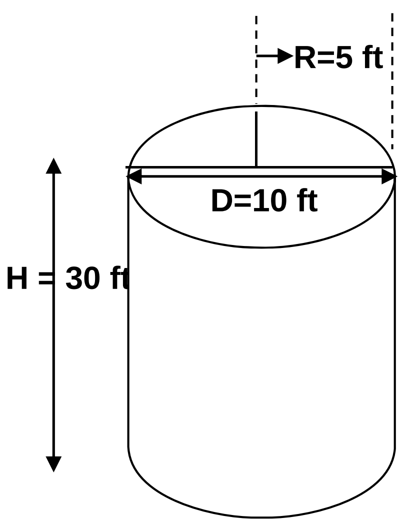
$\frac{9000\ \cancel{ft^3}\ \times\ 7.48\ gallons}{\cancel{ft^3}}$ = 67, 320 gals

Practice:
What is the volume of a tank 50 feet long, 32 feet wide and 15 feet deep in gallons? Ans. (179,520 gallons)

A tank holds 240,000 gallons and is 160 feet long and is 35 feet wide. What is the depth of the tank in feet? Ans. (5.7 feet)

11.11b Volume of a Cylinder

The volume of a cylinder is equal to the surface area times the height of the cylinder. The volume of a cylindrical tank is calculated by multiplying the surface area times the height of the tank walls.



When working with the area of a circular shape, you must select one of two formulas for finding the surface area:

$A = \pi \times r^2$

or

$A = 0.785 \times D^2$

Example:
The tank above is 10 feet in diameter and 30 feet deep, how many gallons of water will it hold?

Calculate the surface area first, multiply by height, and then convert to gallons.

A = $\pi \times r^2$
= 3.14 x 5 ft x 5 ft

$= 78.5\ ft^2$
$V = A \times H$
$= 78.5\ ft^2 \times 30\ ft$
$= 2355\ ft^3$

$= 2355\ ft^3 \times 7.48\ gal/ft^3 = 17615.4$ gallons

or

$A = \pi/4 \times D^2$
$= 0.785 \times 10\ ft \times 10\ ft$
$= 78.5\ ft^2$
$V = A \times H$
$= 78.5\ ft^2 \times 30\ ft$
$= 2355\ ft^3$
$= 2355\ ft^3 \times 7.48\ gal/ft^3$

= 17615.4 gallons

Practice:

How many gallons does a tank that measures 60 feet in diameter and 40 feet deep hold? Ans. (845539.2 gallons)

If a cylinder holds 40,000 gallons of liquid, what is the depth of the container when the radius is 12 feet? Ans. (11.8 feet)

Practice:
The static water level is measured to be 40 feet below ground level. The well casing is 250 feet long. How many gallons of water are in the casing? Ans. (308 gallons)

If a cylinder holds 40,000 gallons of liquid, what is the depth of the container when the radius is 12 feet? Ans. (11.8 feet)

11.12 Pressure

Pressure is expressed as pounds per square inch (psi), but it can be expressed as feet of head. Pressure in the water system makes the system work. It is caused by the weight of water above a given point in the system.

To convert from feet of head multiply the head times 0.433 psi/foot of head. When you know the pressure on a given point you can calculate the head in feet by multiplying the pressure times 2.31 feet/psi.

Example:
Find the pressure on a gauge when the water level above a point is 35 feet?

PSI = 35 feet x 0.433
= 15.2 psi

Find the feet of head when a pressure gauge reads 30 psi?
HEAD = 30 psi x 2.31 feet/psi
= 69.3 feet

Practice:
A pressure gauge at the base of a water tank reads 29 psi. What is the elevation of the water above the gauge? Ans. (67 feet)

A water tank is 35 feet high. If the tank is filled to the 30-foot level, what is the pressure at the base? Ans. (13 psi)

11.13 Dosage Calculations

An operator must understand the importance of calculating the amount of chemical that he/she adds to the water. Units are expressed as either parts per million (ppm) or milligrams per liter (mg/L). Milligrams per liter and parts per million are considered to be equal (mg/L = ppm).

A calculation using the pounds formula shows the number of pounds of chemical being added to the water per million pounds of water. The loadings are calculated by multiplying the following:

- The volume expressed in million gallons (MG)
- The weight of one gallon of water (8.34 lbs/gal)
- The amount of chemical added in parts per million

Pounds = Million gallons x 8.34 lbs/gal x parts per million

Example:
How many pounds of chlorine must be added to 1.5 MG to obtain 2.5 ppm of chlorine residual?

lbs of chlorine = 1.5 MG x 8.34 lbs/gal x 2.5 ppm
= 12.51 M lbs/day x 2.5 ppm
= 31.3 lbs/Cl_2/day

Practice:
How many pounds of chlorine must be added to a 1.2 million-gallon tower to raise the residual 50 ppm? Ans. (500.4 lbs)

Note: If the gallons aren't in million gallons, divide the gallons by one million.

Example:
Change 6500 gallons into million gallons (MG).

6500 gallons/1,000,000 gallons = 0.006500 MG

Practice:
Change 750,000 gallons into million gallons. (Ans. 0.75 MG)

Chlorine products used to disinfect the well will not be pure elemental chlorine (with the exception of liquid/chlorine gas), but contain some other chemical in combination with the one that your will use to disinfect. An example of this is sodium hypochlorite (HTH), which may be 65 percent available chlorine. In this case: Lbs/day = pounds pure chemical/percent purity

Example:
How many pounds of HTH would be required to raise the chlorine residual to 50 ppm if a tank contains 0.5 MG? HTH is 65 percent pure.

$$\text{lbs HTH} = \frac{\text{MG x 8.34 lbs/gal x PPM}}{\text{Percent Purity}}$$

$$\frac{\text{0.5 MG x 8.34 lbs/gal x 50 PPM}}{0.65}$$

$$= \frac{\text{208.5 lbs.HTH}}{0.65}$$

= 320.8 lbs HTH

Example:
The static level of a well is measured to be 55 feet below ground level. While pumping, the level is lowered to 95 feet.

The flowmeter indicates that 120 gpm is pumped. What is the specific capacity of the well?

Static Water Level (SWL) = 55 feet

Pumping Water Level (PWL) = 95 feet
95 feet – 55 feet = 40 feet draw down

Specific Capacity (SC) $= \frac{120 \text{ gpm}}{40 \text{ feet}}$

= 3 gpm/feet

Practice:
A well is 250 feet deep with a 6-inch casing. After a flood it is necessary to disinfect the well. If the static water level is 100 feet below the ground surface, how many ounces HTH (65% available chlorine by weight) will be required to disinfect the well at a 100-ppm chlorine dosage? (Ans. 4.5 ounces)

Glossary

A

Action level - The concentration of lead or copper in water that determines, in some cases, the treatment requirements for source water or corrosion control.
Ammeter - A device for measuring electric current
Annular space - The ring-shaped space located between the borehole of a well and the well casing.
Aquifers - Underground formations where groundwater exists in sufficient quantities to supply wells or springs. These saturated underground formations will yield water to a well or spring. The water in an aquifer is called groundwater and the two terms often are used interchangeably. A saturated formation that will not yield water in usable quantities is not considered an aquifer.
Artesian - Water held under pressure in porous rock or soil confined by impermeable geologic formations.

B

Backflow - An undesired, reversed flow of liquid into a piping system.
Back-pressure - Back-pressure occurs when normal flow in the distribution system is reversed due to an increase in the downstream pressure above the supply pressure.
Back-siphonage - Back-siphonage can occur when a negative pressure (below atmospheric pressure, or a vacuum) develops in the distribution system that can allow pollutants or contaminants to be siphoned into the water system.
Bearings - Devices that supports, guides, and reduces the friction of motion between fixed and moving machine parts.

C

Calcium carbonate - A colorless or white crystalline compound, $CaC0_3$, occurring naturally as chalk, limestone, marble, and other forms.
Calcium hypochlorite - A chlorine compound available in granular form or small tablets, containing approximately 65% available chlorine by weight.
Capacity (viability) - Refers to the financial, managerial, and technical abilities to operate and manage a public water supply system.
Capacity (well design) - Volume of water per unit time.
Cavitation - The formation and collapse of a gas pocket or bubble on the blade of an impeller or the gate of a valve. The collapse of the pocket or bubble drives water into the valve or impeller with enough force to cause pitting. It is accompanied by loud noises that sound like someone pounding on the impeller or gate with a hammer.

Close-coupled pumps - End suction centrifugal pumps in which the pump shaft and motor shaft are the same shaft. The pump bearings and motor bearings are also the same. The impeller is attached directly onto the end of the motor shaft.
Color - A physical characteristics describing the appearance of water (different from turbidity, which is the cloudiness of water).
Community Water System (CWS) - A public water system that serves at least 15 service connections used by year-round residents or regularly serves water to the same 25 or more people year-round.
Cone of depression - A depression in the water table around a well or group of wells in response to groundwater withdrawal.
Confined aquifer - Bounded on the top by materials (clay, shale, etc.) through which water moves very slowly. Groundwater in a confined aquifer is under pressure and rises in a well above the top of the aquifer.
Consumer Confidence Reports - An annual report to consumers of each community or non-transient non-community public water supply system on the source of their water and the levels of contaminants found in the drinking water.
Cross-connection - A physical arrangement by which a public water system is connected, directly or indirectly, with an unapproved water system, sewer, drain, conduit, pool, storage reservoir, plumbing fixture, or other device that contains, or might contain, wastewater or other substances of unknown or unsafe quality that might be capable of contaminating the water supply through backflow; "cross-connection" includes a bypass arrangement, jumper connection, removable section, swivel or change-over device, and other temporary, permanent, or potential connection through which, or because of which, backflow or back-pressure could occur.

D

Disinfection - The process designed to inactivate most microorganisms in water, including all pathogenic bacteria and viruses.
Draw down - The difference in feet between the static and pumping water levels in a well.

F

Fecal Coliform – Members of the total coliform group of bacteria that are characterized by their ability to ferment lactose at 112.1º F (44.5º C). Fecal coliform provide stronger evidence of the possible presence of pathogens than do total coliform. This group indicates the presence of fecal matter, which could be of human or animal origin since fecal coliforms come from the intestines of all warm-blooded animals. Fecal coliforms do not include coliforms found naturally in the soil and on vegetation. *Eschericia coli (E. coli)* are fecal coliforms from humans.

G

Groundwater - Water that occupies voids, cracks or other pore spaces in clay, silt, sand, gravel, or rock beneath the surface of the earth.

H

Horsepower - A measurement of work. One foot-pound of work is the amount of energy required to lift one pound of water one foot in elevation. In pumping situations the amount of work done will be in the thousands of foot-pounds. Because we do not like to use large numbers we have defined another term for work. When 33,000 foot-pounds of work is performed in one minute we call it one horsepower.
Hydrologic cycle - Describes the constant movement of water above, on, or below the earth's surface. Water changes states between liquid, solid, and gas during the cycle. Condensation, evaporation, and freezing of water occur in the cycle in response to the earth and its climactic conditions.

I

Impeller - A rotating device in a pump for forcing water in a given direction under pressure.
Indicators - Bacteria that serve as a surrogate indicator for the potential presence of pathogens in drinking water.
Iron bacteria - Microorganisms that metabolize iron. This specialized group of bacteria is capable of using iron for metabolic processes and commonly causes red-water, slime, or encrustation in well water systems.

M

Maximum Contaminant Level - The maximum permissible level of a contaminant in a public water supply system.
Micron - A unit of length equal to one millionth (10^{-6}) of a meter.
Microorganism - An animal or plant of microscopic size that includes bacteria, viruses, and protozoa.

N

Nitrates and Nitrites - Inorganic chemical contaminants found in some drinking water. At elevated levels pose an immediate threat to infants less than six months of age because they may lead to a condition known as methemoglobinemia. Nitrate reverts to nitrite in the human body, which causes the condition. They originate from many sources such as animal and human wastes, soil, fertilizers and crop residues.

Non-Transient Non-Community Water System (NTNCWS) – A public water system that is not a community water system and that regularly serves at least 25 of the same individuals over six months per year.

O

Ohmmeter - A test instrument that measures the resistance of a conductor in Ohms.
Ohm - A unit of electrical resistance equal to that of a conductor in which a current of one ampere is produced by a potential of one volt across its terminals.

P

Pathogen - An organism that is capable of causing disease.
Permafrost – Ground that is below freezing for 2 or more years.
pH - The power of Hydrogen. The numerical measure of hydrogen ion activity with a scale of 0 -14. Neutral is pH 7; values below 7 are acid, and values above 7 are alkaline (basic).
Pressure gauge - A device for measuring fluid pressure.
Primacy - Primary enforcement authority granted to states for implementation and enforcement of federal regulations.
Primary standard - Designed to protect public health by setting maximum permissible levels of potentially harmful substances in the drinking water. An enforceable drinking water standard.
Prime - To prepare for operation by or pouring water into a pump.
Pump cycles counter - Tallies the times that the pump motor cycles on and off.
Pump hour meter - Normally located in the control panel and records the amount of time that power was delivered to the pump (the length of time water was pumped is recorded).
Pumping water level - The level at which water stands when the well is being pumped. Pumping level is measured the same as static water level.

R

Repeat samples - Bacteriological quality samples collected after receiving results that routine samples were unsatisfactory. These are often referred to as check samples.
Replacement sample - A bacteriological quality sample collected to replace a routine sample which was late arriving at the lab (verify with ADEC sample analysis time requirement) or had interference from heterotrophic bacteria.
Routine coliform sample - Monthly or quarterly bacteriological quality monitoring required of all public water supply systems.

S

Safe Drinking Water Act - *The Safe Drinking Water Act* (SDWA) was enacted by Congress in 1974 and amended several times since then, establishes minimum drinking water standards in the United States.
Sample site plan - Bacteriological sample collection location plans required of all community public water supply systems identifying locations for routine monitoring and repeat monitoring.
Secondary standards - An USEPA regulation for a contaminant that may adversely affect the taste, odor, or appearance of water. These effects may cause an undesirable impact on the public welfare, e.g. by a substantial number of people discontinuing use of the water provided by a public water system.
Sodium hypochlorite - One of several liquid forms of chlorine commonly used to disinfect public water supply systems. Sodium hypochlorite is usually available in 5%, 12%, and 35% chlorine solution.
Sodium thiosulfate - A white translucent crystalline compound, in tablet or powder form, used to neutralize chlorine in bacteriological sample bottles.
Specific capacity - A measure of well yield per foot of drawdown expressed as gallons per minute per foot (gpm/ft) of drawdown.
Static water level - The level where water stands when the well is not being pumped. It is generally expressed as the distance in feet from the top of the well casing down to the water level in the well.

T

Throttle - To regulate the flow of water by partially opening/closing a valve.
Top terminal height - The casing head must extend twelve inches above the finished ground surface or pump house floor, and twelve inches minimum above the local surface runoff level.
Total coliform bacteria - A group of indicator bacteria used to detect the possible contamination of water by pathogenic organisms.
Turbidity - The cloudy appearance of water caused by the presence of suspended and colloidal matter.

U

Unconfined aquifer - The uppermost aquifer located immediately beneath the unsaturated zone. Groundwater in this aquifer is not pressurized. Because the unconfined aquifer is nearest to the surface, it is generally more susceptible to contamination than a confined aquifer.

V

Viruses - Pathogens responsible for many human diseases such as viral gastroenteritis, smallpox, poliomyelitis (polio) and infectious hepatitis. They are intracellular parasitic particles considered to be the smallest living infectious materials known.

W

Water hammer - Opening or closing a valve rapidly may cause a quick rise and fall of water pressure throughout the distribution piping system. The sound, like someone hammering on the pipe, occurs because the pressure in the pipe will increase and decrease back and forth very quickly.
Water table - The level in the geologic formation below which all voids or cracks are saturated. The water table also can be thought of as the upper surface of the groundwater and top of the saturated zone for an unconfined aquifer.
Well capacity (yield) - The volume of water per unit of time discharged from the well usually recorded as gallons per minute (gpm) or gallons per day (gpd).
Well development - Involves vigorously pumping the well to help clean out drill cuttings and to maximize production of the well. Development should result in a well that produces sand-free water when operated properly.
Well log - A written report produced by the well driller that includes a description of the material (soil, rock, or ice) that was encountered during drilling, the depths at which they occurred, the depth to groundwater, and the well depth.

Appendix 1 - **Water Well Log** Example

City/Borough:	Subdivision:	BLOCK	LOT	Property Owner Name & Address:

Meridian ____________ Township ________ Range ________ Section ______ ______ ¼ of ______ ¼ of ______ ¼ of ______ ¼

BOREHOLE DATA: (from ground surface) Material: Type, color & wetness	Depth From	To

Drilling method: ( ) Air rotary, ( ) Cable tool, Other ____________________
Well use: ( ) Public supply, ( ) Domestic, Other ______________________

Depth of hole: ____________ ft, Casing stickup: ____________ ft

Casing type: ____________ Thickness: ____________ inches

Casing diameter: ____________ inches Casing depth: ____________ ft

Liner type: ____________ Diameter: ______ inches Depth: ______ ft

Static water (from top of casing): ___________ ft on ____/____/_______

Pumping level & yield: _____feet after _______ hours at __________ gpm

Recovery rate: __________gpm, Method of testing: ___________________

Development method: ________________ Duration: __________________

Well intake opening type: ( ) Open end, ( ) Open hole, Other ___________

Screen: Start: _________________ ft, Stopped: _________________ ft

Screen type: _________________ Slot/mesh size: ________________

Perforated: Start: _________________ ft, Stopped: _________________ ft

Start: _________________ ft, Stopped: _________________ ft

Note: ____

Grout type: ________________________ Volume: _______________________

Depth; from _________________________ ft, to _________________________ ft

Pump intake depth: ___________________________ ft

Pump size: _________________ hp, Brand name: ________________________

Was well disinfected upon completion? ( ) Yes, ( ) No

Method of disinfection: ____

Driller comments/disclaimers: ____

____

____

____

Well driller name: ____

Company name: ____

Mailing address: ____

City: _____________________________________State: AK Zip:_____________

Phone number: (_________)_________ - _________

Drillers signature:

Alaska state law requires that a copy of this well log be sent to the Department of Natural Resources within 45 days: faxes are acceptable. (AK statues 38.05.020, 38.05.035, 41.08.020, 46.15.020 and AK regulations 11 AAC 93.140).
DNR/ Division of Mining, Land and Water,
550 W 7th Avenue, Suite 900A
Anchorage, AK 99501-3577
Phone (907)269-8639 and fax (907)269-8947

Within the City of Anchorage, it is required that a copy of the well log be sent to the appropriate city office within 60 days and that another copy of the well log be sent to the well/property owner within 30 days.
Permit Number: ____
Date of Issue: _______/______/_______
Parcel Identification Number: _________ - _________ - _________
Is well located at approved permit location? ( ) Yes or ( ) No

Appendix 2 - Groundwater Systems Monitoring Requirements

Test	Frequency	PWS Class CWS or NTNC	TNC	This summary does not replace the current drinking water regulations.
TCR				
Sanitary Survey	Every 5 years	√	√	Sanitary Survey must be performed by ADEC staff or an ADEC approved third party sanitary surveyor
Total Coliform Bacteria	Every Month	√		If the water system serves more than 1,000 people per day, see 18 AAC 80.405, Table D for the increased number of test required.
	Every Quarter		√	
Nitrate	Annually	√	√	If nitrate test result exceeds 5.0 mg/l, begin testing quarterly. Contact ADEC to discuss how long quarterly sampling is required.
Nitrite	One Sample on Record	√	√	Only a single Nitrite test is required if the results are below 0.5 mg/l. Otherwise, repeat quarterly for one year. Contact ADEC to discuss how long quarterly sampling is required.
Inorganic Chemicals				
7 Old Inorganics (Phase II)	Every Period or Cycle*	√		**Arsenic, Barium, Cadmium, Chromium, Fluoride, Mercury, Selenium.** After three test results are below the MCLs, a waiver is available to reduce sampling frequency from once per period to once per cycle*. (At least one of the three test must be since 1990.)
5 New Inorganics (Phase V)	Every Period or Cycle*	√		**Antimony, Beryllium, Cyanide, Nickel, Thallium.** After three sample results are below the MCL, a waiver is available to reduce sampling frequency from one sample per period to one sample per cycle*. (At least one of the three tests must be since 1990.)
Asbestos	Once per Cycle* (unless waived)	√		No asbestos sampling is required if a waiver is approved. New systems contact ADEC for requirements.
Lead and Copper	Every 6 Months	√		The number of lead/copper samples is based on population. See 18 AAC 80.545, Table E. After 90th percentile test results from two consecutive six months are below the Action Levels, annual sampling is allowed. After two additional years of test results below Action Level, sample once every three years.
	Annually	√		
	Every 3 Years	√		
Organic				
Pesticides (SOCs), & Other Organics	Every Quarter (unless waived)	√		No SOC sampling is required if a waiver is approved. If waiver is denied, four quarters of testing is required each compliance period. Contact ADEC for more information.
Volatile Organic Chemicals (VOCs)	Every Quarter	√		After four quarterly tests detect no regulated compound over 0.5 ug/l, sample annually. After three years of tests detect no volatile organic chemicals, a groundwater system can sample once per period*.
	Annually	√		
	Every Period	√		
Rads				
Gross Alpha Radioactivity	Every 4 Years	√		First time compliance is based on either the test result from the composite of four consecutive quarterly samples, or on the average of the test results from four samples taken at consecutive quarterly intervals. Test one sample every 4 years thereafter.
Reporting				
Consumer Confidence Report	Annually	√		Community Water Systems (CWS) distribute to ADEC and deliver to all customers by July 1 for the previous year. A CWS serves at least 25 residents or 15 residential service connections year round.

NOTE: *Period = 3 years (1999-2001, 2002-2005, 2006-2008, etc.)*Cycle = 9 years (1993-2001, 2002-2010, etc.)

This Appendix was adapted from ADEC's PWS Testing Schedule at http://www.state.ak.us/local/akpages/ENV.CONSERV/deh/water/testing.pdf

Appendix 3 - Technical Assistance and Training Contacts

Agency/Organizations	Phone	Fax
Alaska Department of Environmental Conservation (ADEC) Anchorage Office 555 Cordova Anchorage, AK 99501 Juneau Office Drinking Water Program 410 Willoughby Avenue, Suite 303 Juneau, AK 99801-1795 Fairbanks Office 610 University Avenue Fairbanks, AK 99709 Operator Certification Program 410 Willoughby Avenue, Suite 303 P.O. Box 111800 Juneau, AK 99811-1800	269-7633 465-5350 451-2360 465-1139	 465-5362 451-2188 465-5177
Alaska Department of Natural Resources Public Information Centers Anchorage Office 550 W. 7th Ave Ste. 1260 Anchorage, AK 99501-3557 Fairbanks Office 3700 Airport Way Fairbanks, AK 99709-4699 Juneau Office 400 Willoughby Ave 4th Floor Juneau, AK 99801	269-8400 451-2705 465-3400	269-8901 451-2706 586-2954
Alaska Rural Water Association 1075 Check St., Suite 106 Wasilla, AK 99654-8067	357-1155	357-1400
Safe Drinking Water Hotline	800-426-4791	

Appendix 4 - Certified Laboratories

The list of laboratories certified for Microbiological Analyses of Drinking Water is available at http://dec.alaska.gov/applications/eh/ehllabreports/certmicrolabs.aspx.

The list of laboratories certified to perform Chemical Analyses of Drinking Water is available at http://dec.alaska.gov/applications/eh/ehllabreports/certchemlabs.aspx.

Appendix 5 - Quantities of Calcium Hypochlorite

65% (rows A) and liquid household bleach, 5.25% (rows B) required for water well disinfection

Depth of Water in Well (ft.)		Well Diameter (In.)															
		2	3	4	5	6	8	10	12	16	20	24	28	32	36	42	48
5	A	1T	1T	1T	1T	1T	1T	2T	3T	5T	6T	3 oz	4 oz	5 oz	7 oz	9 oz	12 oz
	B	1C	1C	1C	1C	1C	1C	1C	1C	2C	4C	1 Q	2 Q	3 Q	3 Q	4 Q	5 Q
10	A	1T	1T	1T	1T	1T	2 T	3 T	5 T	8 T	4 oz	6 oz	8 oz	10 oz	13 oz	1 1/2 lb	1 1/2 lb
	B	1C	1C	1C	1C	1C	1 C	2 C	2 C	1 Q	2 Q	3 Q	4 Q	4 Q	6 Q	8 Q	2 1/2 G
15	A	1T	1T	1T	1T	2 T	3 T	5 T	8 T	4 oz	6 oz	9 oz	12 oz	1 lb	1 1/2 lb	1 1/2 lb	2 lb
	B	1C	1C	1C	1C	1 C	2 C	3 C	4 C	2 Q	2 1/2 Q	4 Q	5 Q	6 Q	2 G	3G	4 G
20	A	1T	1T	1T	2 T	3 T	4 T	6 T	3 oz	5 oz	8 oz						
	B	1C	1C	1C	1 C	1 C	2 C	4 C	1 Q	2 1/2 Q	3 1/2 Q						
30	A	1T	1T	2 T	3 T	4 T	6 T	3 oz	4 oz	8 oz	12 oz						
	B	1C	1C	1 C	1 C	2 C	4 C	1 1/2 Q	2 Q	4 Q	5 Q						
40	A	1T	1T	2 T	4 T	6 T	8 T	4 oz	6 oz	10 oz	1 lb						
	B	1C	1C	1 C	2 C	2 C	1 Q	2 Q	2 1/2 Q	4 1/2 Q	7 Q						
60	A	1T	2 T	3 T	5 T	8 T	4 oz	6 oz	9 oz								
	B	1C	1 C	2 C	3 C	4 C	2 Q	3 Q	4 Q								
80	A	1T	3 T	4 T	7 T	9 T	5 oz	8 oz	12 oz								
	B	1C	1 C	2 C	4 C	1 Q	2 Q	3 1/2 Q	5 Q								
100	A	2 T	3 T	5 T	8 T	4 oz	7 oz	10 oz	1 lb								
	B	1 C	2 C	3 C	1 Q	1 1/2 Q	2 1/2 Q	4 Q	6 Q								
150	A	3 T	5 T	8 T	4 oz	6 oz	10 oz	1 lb	1 1/2 lb								
	B	2 C	2 C	4 C	2 Q	2 1/2 Q	4 Q	6 Q	2 1/2 G								

*Quantities are indicated as: T = tablespoon; oz = ounces (by weight); C = cups; lb = pounds; Q = quarts; G = gallons

NOTE: Figures corresponding to rows A are amount of solid calcium hypochlorite required; those corresponding to rows B are amounts of liquid household bleach. For shock chlorination of iron bacteria the amounts of either compound should by multiplied by 10 to obtain the necessary chlorine concentration. For cases lying to the left of the dark line, add 5 gallons of chlorinated water as final step. For those cases to the right of the dark line, add 10 gallons of chlorinated water as final step.

Appendix 6 - Formula Sheet

Abbreviations:

in	inches
ft	feet
in^2	square inches (sq. in.)
ft^2	square feet (sq. ft.)
ft^3	cubic feet (cu. ft.)
hr	hours
min	minutes
sec	seconds
d	days
lb	pounds
gal	gallons
MG	million gallons
gpm	gallons per minute (gal/min)
gpd	gallons per day (gal/d)
MGD	million gallons per day
cfs	cubic feet per second (ft^3/sec)
ppm	parts per million
mg/L	milligrams per liter
hp	horsepower
psi	pounds per square inch
kWh	kilowatt hours
kW	kilowatts
mL	milliliter

Conversion Factors:

Length:

12 in = 1 ft
5280 ft = 1 mile

Area:

1 ft^2 = 144 in^2
1 acre = 43,560 ft^2

Volume:

1 ft^3 = 7.48 gal

Time:

1 min = 60 sec
1 hr = 60 min = 3600 sec
1 d = 24 hr = 1440 min
1440 min = 86,400 sec

Flowrate:

1 MGD = 1.55 cfs = 694.4 gpm
1 gpm = 60 ga/hr = 1440 gal/d
1 gal/hr = 24 gal/d

Power & Energy:

1 kW = 1.341 hp
1 kW-hr = 2.655 x 10^6 ft lbs
1 hp = 33,000 ft-lb/min
= 550 ft-lb/sec

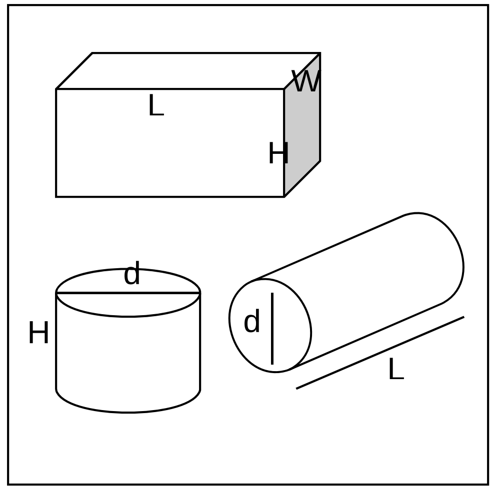
Force & Pressure:

1 psi = 2.31 ft (pressurehead)

Temperature:

$T(^0F) = T(^0C) \times 1.8 + 32$
$T(^0C) = [T(^0F) – 32.2] / 1.8$

Geometry:



Rectangular tank:

Area = length x width (top)
= height x width (vertical cross-section)

Volume = length x width x height

Circular tank: (note: $\pi/4$ = to 0.785)

Circumference = π x d or 3.14 x d

Area = $(\pi/4) \times d^2$

Volume = $(\pi/4) \times d^2 \times H$ (tank)
= $(\pi/4) \times d^2 \times L$ (pipe)

NOTE: If all dimensions are in feet, area will be in ft^2 and volume in ft^3. For pipes, convert pipe diameter to dimensions of *feet* before using the above formula.

Basic Hydraulics:

Detention and Delivery Times:

Detention time (min) = $\frac{\text{tank capacity (gal)}}{\text{flowrate (gpm)}}$

Detention time (days) = $\frac{\text{tank capacity (Mgal)}}{\text{flowrate (MGD)}}$

Force, Pressure and Water:

Water weighs 8.34 lbs/gal or 62.4 lb/ft^3.
A column of water 2.31 feet high exerts a pressure of 1.0 psi at its base.
A column of water 1.0 feet high exerts a pressure of 0.433 psi or 62.4 lb/ft^3 at its base.

Concentration, Dose and Volume (Note: ppm = mg/L)

Dosage (lb) = concentration (mg/L) x volume (MG) x 8.34
Lb/day = mg/L x gpm x 0.012

Mg/L = $\frac{\text{lbs}}{\text{MG} \times 8.34}$ MG = $\frac{\text{lbs}}{\text{mg/L} \times 8.34}$

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The valve figures in Chapter 4 were used by permission from the Red-White Valve Corp., 20600 Regency Lane, Lake Forest, CA 92630. http://www.redwhitevalveusa.co