Introduction to Water Sources

What is in this Lesson?

1. Definition of surface water
2. Examples of surface water
3. Surface water hydrology
4. Surface water intake structures
5. The types of pumps used to collect surface water
6. Transmission lines, materials and function
7. Types of flow meters used to record water use
8. Definition of ground water
9. Advantages & disadvantages of surface water and ground water sources
10. Groundwater hydrology
11. Well components

Key Words

- Aquifer
- Caisson
- Cone of depression
- Drawdown
- Flume
- Glycol
- Impermeable
- ntu
- Overland flow
- Permeability
- Polluted Water
- Raw water
- Riprap
- Stratum
- Surface runoff
- Transmissibility
- Unconfined aquifer
- Water table
- Baseline data
- Contamination
- Confined aquifer
- Drainage basin
- Groundwater
- Hydrology
- Microorganism
- Organic
- Parshall Flume
- Porosity
- Precipitation
- Recharge area
- Spring
- Static water level
- Surface water
- Turbidity
- Water rights
- Weir

Math Concepts Discussed

- cfs to gpm
- Percentage
- Million gallons per day
- Specific yield
- cfs to acre/feet
- Units for velocity
- Drawdown

Science Concepts Discussed

- Microbiology
- Evaporation
- DO
- Flow of ground water
- Chemistry
- Specific gravity
- pH
- Ground water hydraulics
- Chemical symbols for iron, manganese, calcium carbonate

Safety Considerations

- Amps required to kill a person
- Confined space
- Safe oxygen level
- Working over water

Mechanical Equipment Discussed

- Slide Gates
- Self cleaning screens
- End suction centrifugal pumps
- Screens
- Valves
- Flow meters
- Sanitary seal
- Motor controls
- Meters
- Check valve
- Shear gates
- Lineshaft turbine pumps
- Submersible turbine pumps
- Transmission piping
- Floats
- Boilers and heat exchangers
- Well screens
- Well casing
- Air/vacuum relief valve

Introduction to Water Sources

Introduction

This lesson is a discussion of the components associated with collecting water from its source and bringing it to the water treatment plant.

Not in This Lesson

The areas of operation and maintenance of the various components including pumps and their related components are not discussed in this lesson.

Lesson Content

This lesson will focus on **surface water**[1] and **groundwater**[2] **hydrology**[3] and the mechanical components associated with the collection and transmission of water to the water treatment plant.

Sources of Water

Three Classifications

The current federal drinking water regulations define three distinct and separate sources of water. They are, surface water, groundwater and groundwater under the direct influence of surface water (GUDISW). This last classification is a result of the Surface Water Treatment Rule. The definition of what conditions constitute GUDISW, while specific, are not obvious. This classification is discussed later in this lesson.

Surface Water

Definition

Surface water is that water that is open to the atmosphere and results from **overland flow**[4]. It is also said to be the result of **surface runoff**[5]. These are two ways of saying the same thing.

Examples of Surface Water

Specific sources that are classified as surface water include:

- Streams
- Lakes
- Man-made impoundments - lakes made by damming a stream or river
- Rivers
- **Springs**[6] that are affected by **precipitation**[7] that falls in the vicinity of the spring. Affected means a change in flow or quality.
- Shallow wells that are affected by precipitation. Affected means a change in level or quantity.
- Wells drilled next to or in a stream or river
- Rain catchments
- Muskeg and tundra ponds

[1] **Surface Water -** Water on the earth's surface as distinguished from water underground (groundwater).
[2] **Groundwater -** Subsurface water occupying a saturated geological formation from which wells and springs are fed.
[3] **Hydrology -** The applied science pertaining to properties, distribution, and behavior of water.
[4] **Overland Flow -** The movement of water on and just under the earths surface.
[5] **Surface Runoff -** The amount of rainfall which passes over the surface of the earth.
[6] **Spring -** A surface feature, where, without the help of man, water issues from rock or soil onto the land or into a body of water, the place of issuance being relatively restricted in size.
[7] **Precipitation -** The process by which atmospheric moisture is discharged onto the earths crust. Precipitation takes the form of rain, snow, hail and sleet.

ADVANTAGES AND DISADVANTAGES OF SURFACE WATER

Advantages

The primary advantages to using surface water as a water source are:

- It is easily located - It takes no sophisticated equipment to find a surface water source.
- In many parts of the US, considerable data is available on quantity and quality of existing surface water supplies.
- Surface water is generally softer than groundwater making treatment much simpler.

Disadvantages

The most common disadvantages to using surface water as a water source are:

- Surface waters are easily **polluted**[8] (or contaminated) with microorganisms that cause waterborne diseases and chemicals that enter the stream from surface runoff and upstream discharges.
- The **turbidity**[9] (measured as **NTU**[10]) of a surface water source often fluctuates with the amount of precipitation. Increases in turbidity increase treatment cost and operator time.
- The temperature of surface water fluctuates with the ambient temperature. This makes it difficult to produce consistent water quality at a water treatment plant.
- The intake structure may become clogged or damaged from winter ice or the source may be so shallow that it completely freezes in the winter. This is a common problem with surface water sources in the arctic.
- Removing surface water from a stream, lake or spring requires a legal right. This right is referred to as **Water rights**[11].
- Using surface water as a source means that the purveyor is obligated to meet the requirements of the Surface Water Treatment Rule (SWTR) of the State Drinking Water Regulations. Basically this rule requires that, in most instances, any surface water source must have a filtration system.
- Surface waters that are high in color, especially color that is the result of decaying vegetation, have the

[8] **Polluted Water** -Water than contains sewage, industrial wastewater, or other harmful or objectionable substances.
[9] **Turbidity** -A condition in water caused by the presence of suspended matter, resulting in the scattering and absorption of light rays.
[10] **ntu** - The units of measure of turbidity, Nephelometric Turbidity Units, the measurement as made with a nephelometric turbidimeter.
[11] **Water Rights** - The rights, acquired under the law, to use the water accruing in surface or groundwater, for a specified purpose in a given manner and usually within the limits of a given time period.

potential to produce high levels of Total Trihalomethanes (TTHM). These chemical compounds are formed when chlorine is added to the water. The problem with the TTHM is that some of them can cause cancer, (said to be carcinogenic).

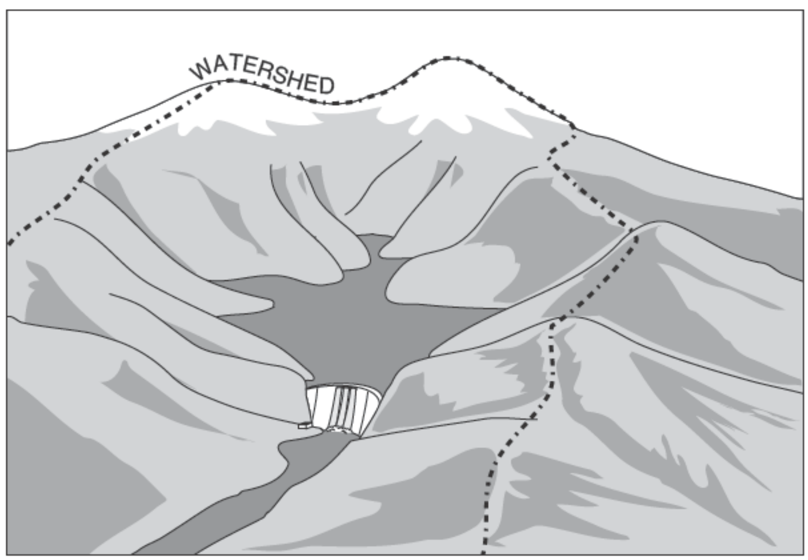
Hydrology

Introduction

A basic understanding of the movement of water and the things that affect water quality and quantity are important to those who manage and operate water systems. The study of these items is called hydrology. The components of hydrology include; the physical configuration of the watershed, the geology, soils, vegetation, nutrients, energy, wildlife and the water itself.

Drainage Basin

The area from which surface water flows is called a **drainage basin**[12]. With a surface water source this drainage basin is most often called the **watershed**[13]**.** When we are dealing with a groundwater supply this area is called the **recharge area**[14]. The drainage basin is difficult to identify when we are referring to a large river such as the Yukon. However, on a smaller river, stream or lake the area is defined by marking on a map an outline of the basin defined by the ridge of the mountains that surround the basin.



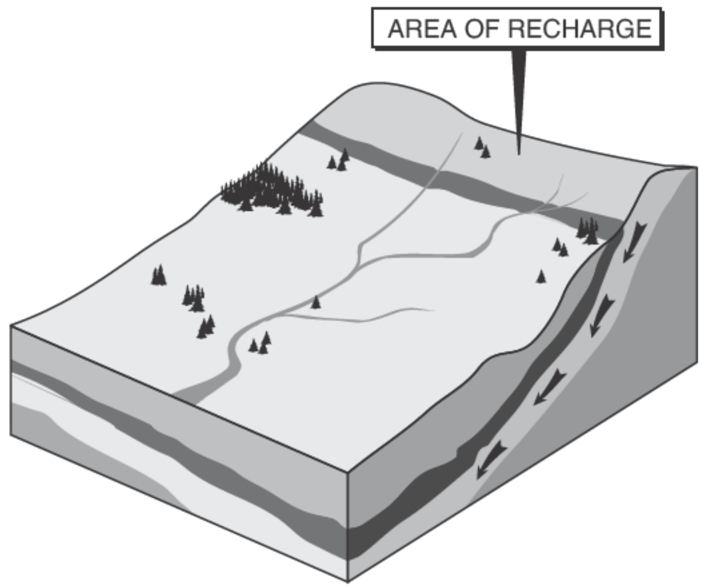
Area Measurements

The area of the basin is commonly measured in square miles, sections or acres. If you are taking water from a surface water source it is desirable to know the size of the watershed.

[12] **Drainage Basin** - An area from which surface runoff or groundwater recharge is carried into a single drainage system. Also called; catchment area, watershed, drainage area.
[13] **Watershed** - A drainage basin from which surface water is obtained.
[14] **Recharge Area** - One from which precipitation flows into the underground water sources.

Location of the Basin

A parcel of ground such as a drainage basin can be identified by and described by standard terms used in land descriptions and surveying. This description is based on a series of horizontal and vertical lines that form a rectangle system. The ability to describe properly the location of a drainage basin, well or surface water intake is important when communicating with state regulatory agencies.



Baseline Data

Gathering precipitation and flow data plus water quality data is called **baseline data**[15]. This data is essential for long term planning and determining the impact of activities in a drainage basin.

[15] **Baseline Data -** The water quality data, precipitation data and stream flow data that is accumulated from a drainage basin or groundwater supply when there was little or no activity in the area.

Raw Water Storage

Purpose

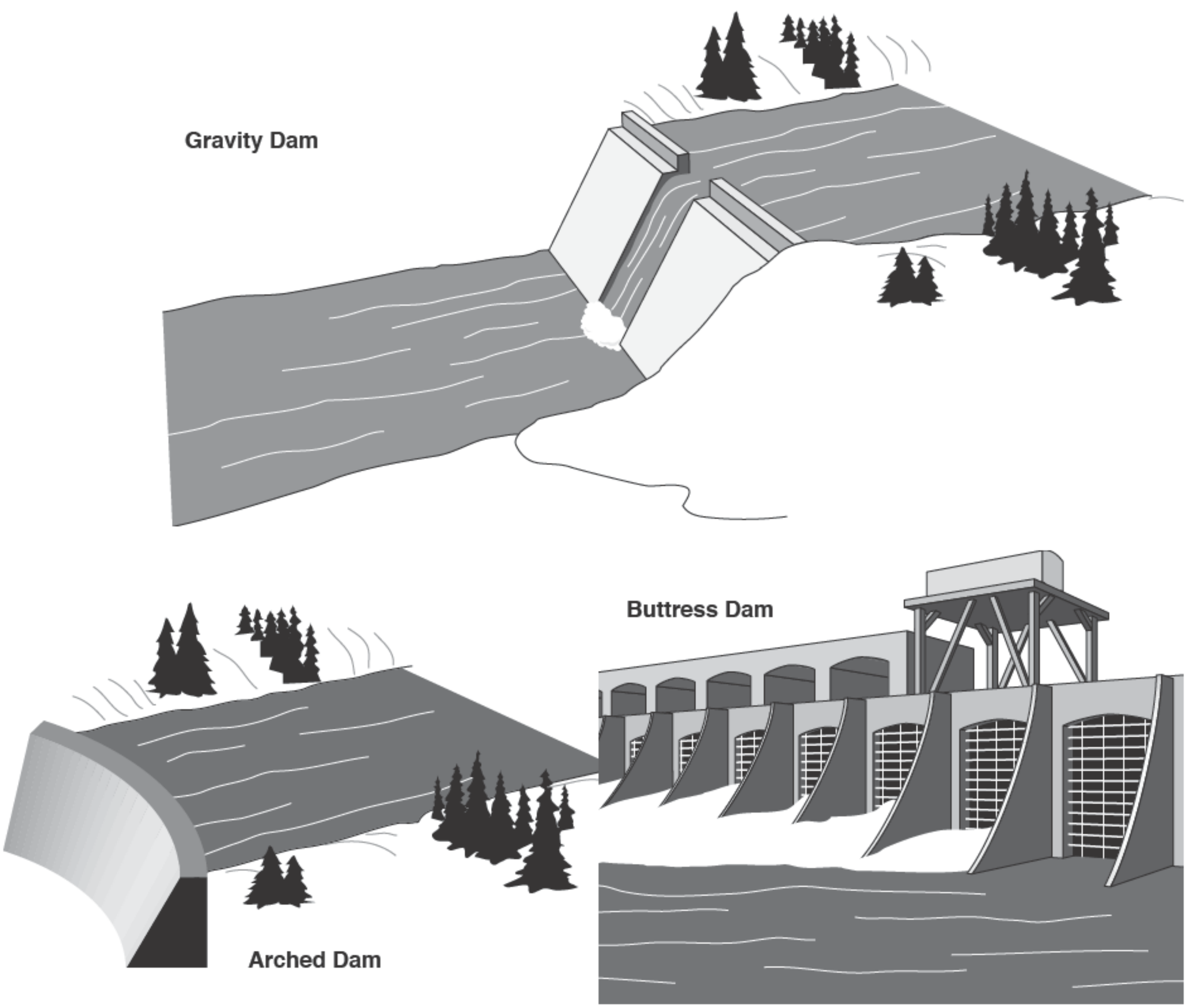
Raw water[16] storage areas are constructed to meet peak demands and/or to store water to meet demands when the flow of the source is below the demand.

Natural Storage

Natural storage includes lakes, muskeg and tundra ponds.

Man-made Storage

In many areas there is no natural storage areas and dams must be built. These dams can be either masonry or embankment dams. There are three different concrete masonry dam designs; the gravity dam, buttress dam and the arched dam.



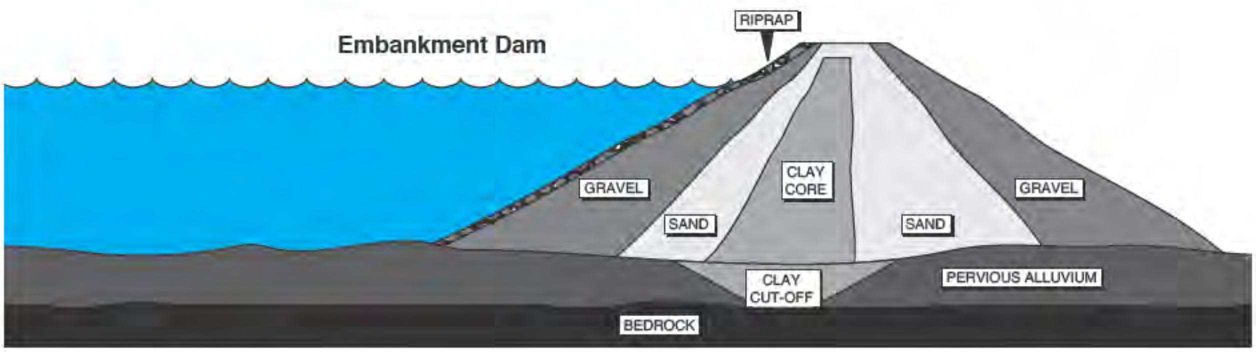
[16] **Raw Water -** Water that has not been treated and is to be used, after treatment, for drinking water.

Embankment Dams

The embankment dams are made from local materials. The key to the embankment dam is a tightly compacted **impermeable**[17] clay core. This core is held in place either by rock or earth. When rock is used the dam is called a rock fill embankment dam. **Riprap**[18] is placed on the face of the dam to prevent erosion by the water. The major advantage to this type of construction is its ability to give with small movements of the earth.

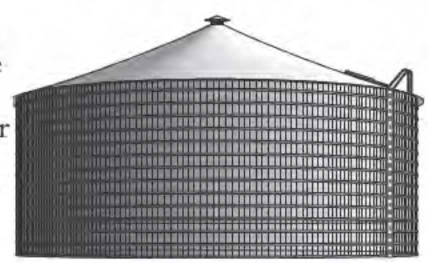
Man-made impoundment - resulting from an embankment dam

Embankment Dam



Raw Water Storage Tanks

In many locations in the arctic region it is common to use a large man-made storage tank to store raw water for use during the winter months. These structures normally hold one million gallons or more and are made of wood or steel.



[17] **Impermeable** -Not allowing, or allowing only with great difficulty, the movement of water.
[18] **Riprap** - Broken stones or boulders placed compactly or irregularly on dams, levees, dikes, etc., for protection of earth surfaces against the action of the water.

Flow Measurements

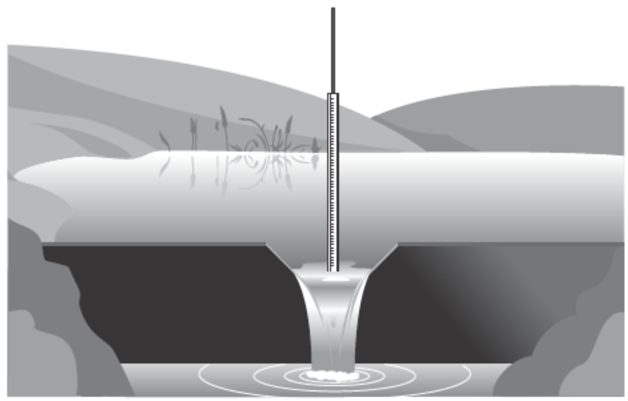
Introduction

The flow in a stream or river can be measured using primary devices such as **weirs**[19] and **flumes**[20] on small streams or secondary devices called current meters on larger streams.

Weirs

A weir is a plate made of wood or metal. These plates are placed in the stream plumb and level. They are identified by their shape, typical shapes are; rectangular, "V" notch and cipolletti. The "V" notch and the cipolletti are the most common.

"V" notch weir



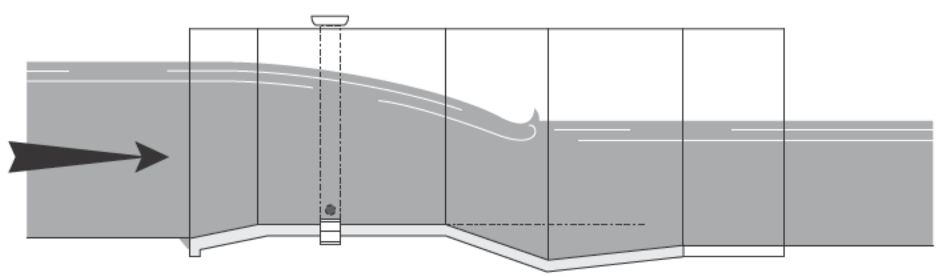
Flumes

Flumes are not as common as weirs. They are useful on very small streams, and in locations where the restriction caused by the weir would represent a problem to the habitat of the stream. Flumes must be installed perfectly level and plumb.

Flume types

There are two common types of flumes used to measure stream flow; rectangular and **Parshall**[21]. The Parshall flume is the most common and is also used in water and wastewater treatment plants to measure flow.

Parshall Flume



[19] **Weir** - A vertical obstruction, such as a wall, or plate, placed in an open channel and calibrated in order that a depth of flow over the weir (head) can easily be measured and converted into flow in cfs, gpm or MGD.

[20] **Flume** - A open conduit made of wood, masonry, or metal and constructed on grade, used to transport water or measure flow.

[21] **Parshall Flume** - A device used to measure flow in an open channel. The flume narrows to a throat of fixed dimension and then expands again. The flow is determined by measuring the difference between the head before the throat and at the throat.

Surface water Intake Structures

Location Criteria

Regulations & Standards

In order to protect high quality drinking water, the water works industry has developed standards and specifications for separation of the intake from potential sources of contamination. The following list includes industry standard practices as well as those items included in typical state regulations.

- There can be no wastewater disposal systems, including septic tanks and drain fields, within 200 feet of the intake.
- There should be no community sewer line, holding tanks, or other potential sources of contamination within 200 feet of the intake.
- Fuel not used for on-site emergency pumping equipment or heating can not be stored within 100 feet of the well.
- Fuel for on-site emergency generators or building heating system can be stored on-site if the total volume is less than 500 gallons.

Recommendations

The following are recommendations and not regulations:

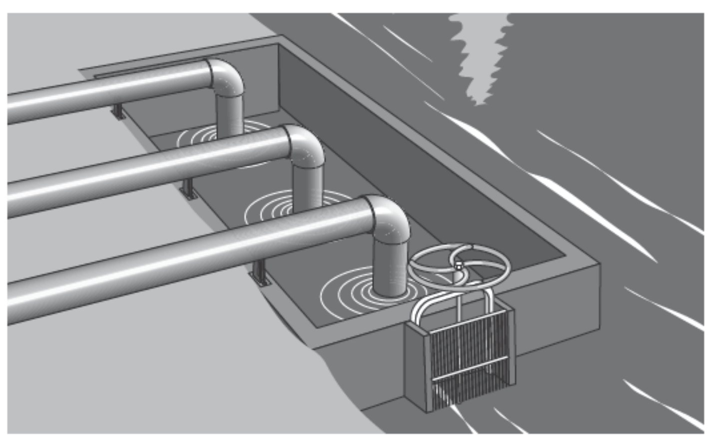
- The water purveyor should own or have a restricted area within 200 feet radius of the intake.
- There should be no roads within 100 feet of the intake.

Structures

Introduction

The intake structure is used to collect the raw water from the source and place it into the transmission line. The types of intake structures used in the water industry vary greatly to meet the specific needs and construction conditions of each site. The following discussion will explore a few of the most common types as they apply to small streams, lakes, rivers and reservoirs.

Submerged Intake



Small Streams

Small Dam

One of the most common intake structures on a small stream is a small gravity dam placed across the stream. Water behind the dam can be removed by a gravity line or pumps. This type of system is susceptible to ice damage in the winter.

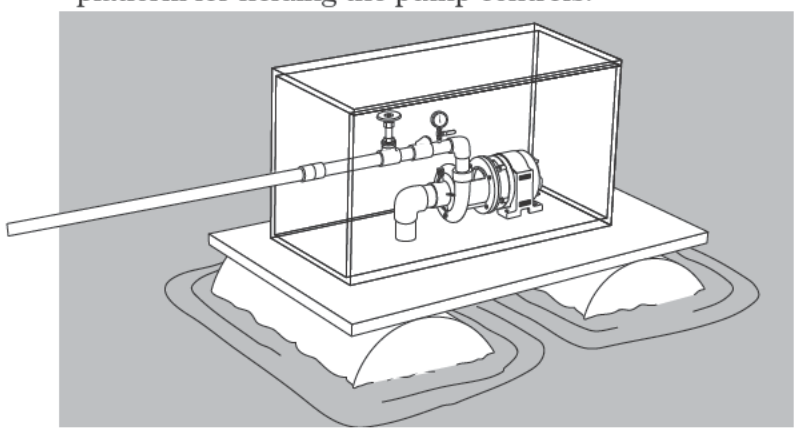
Diversion in Stream

A second common intake for a small stream is a diversion of some type built next to the stream. Water is collected in the diversion and either carried away by gravity or pumped from a caisson. This type of intake is sometimes called a *submerged intake*.

River Float

A common intake on small and large streams is to use an end-suction centrifugal pump or submersible pump placed on a float. The float is secured to the bank and water is pumped to a storage area. In the winter the float is replaced with a hole in the ice and a platform for holding the pump controls.

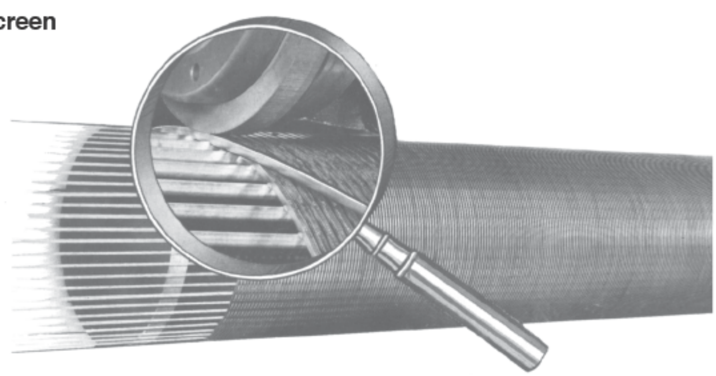
Floating Intake



Screens

One of the simple intake structures used on muskeg ponds, and small streams is a section of stainless steel screens placed on the end of a swing joint. The operator can select the best location of the pipe, raising and lowering it by a mechanical arm attached to the swing joint.

Stainless steel screen by Johnson Screen

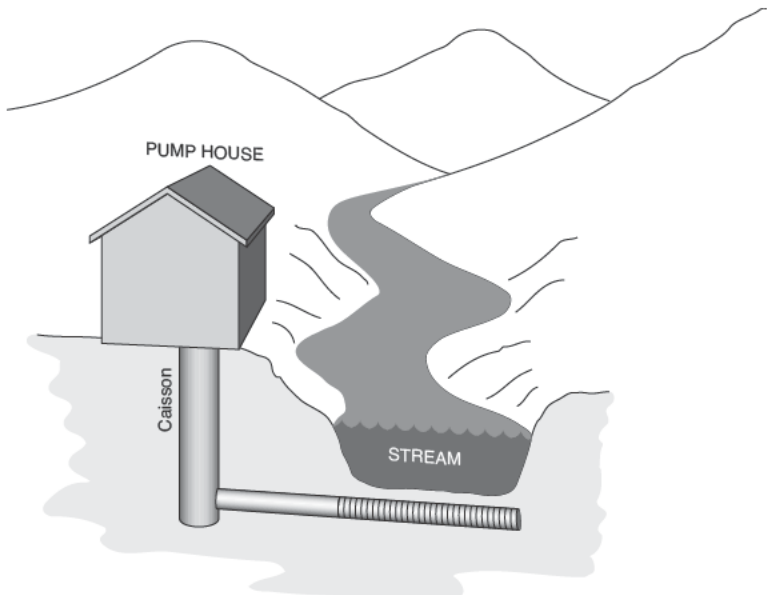


Infiltration Gallery

Description

There are several uses and designs for the infiltration gallery. These include intake structures for a spring and intake structures placed in the bed of a stream. The most common infiltration galleries are built by placing Johnson well screens or perforated pipe into the stream bed or water bearing strata. The pipe is covered with clean graded gravel. As water percolates through the gravel, a portion of the turbidity and **organic**[22] material is removed.

Infiltration Gallery



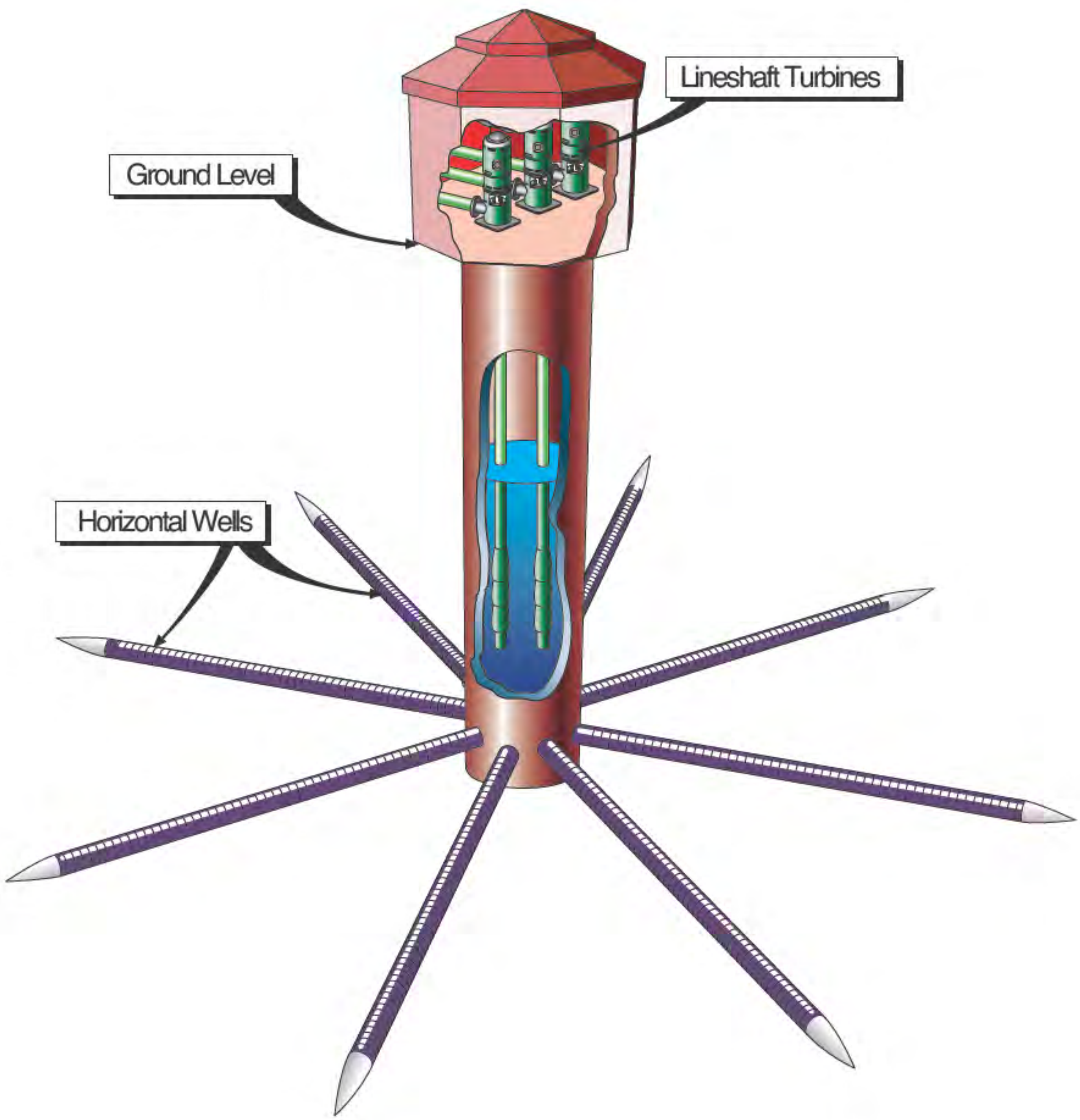
Infiltration - Caisson

The water collected by the perforated pipe flows to a caisson placed next to the stream. The water is removed from the **caisson**[23] by gravity or pumping.

Ranney Well Collector

A special type of infiltration gallery is the Ranney well. This is a commercial system utilizing a large caisson and a series of horizontal wells. The caisson is installed and the horizontal wells drilled from inside the caisson. The system is typically located in the flood plain to draw water from the riverbed water table. Water is pumped from the caisson to the treatment plant. A diagram of a Ranney collector is shown on the next page.

22 **Organic** - Chemical substances of animal or vegetable origin, usually containing carbon.
23 **Caisson** - Large pipe placed in a vertical position.

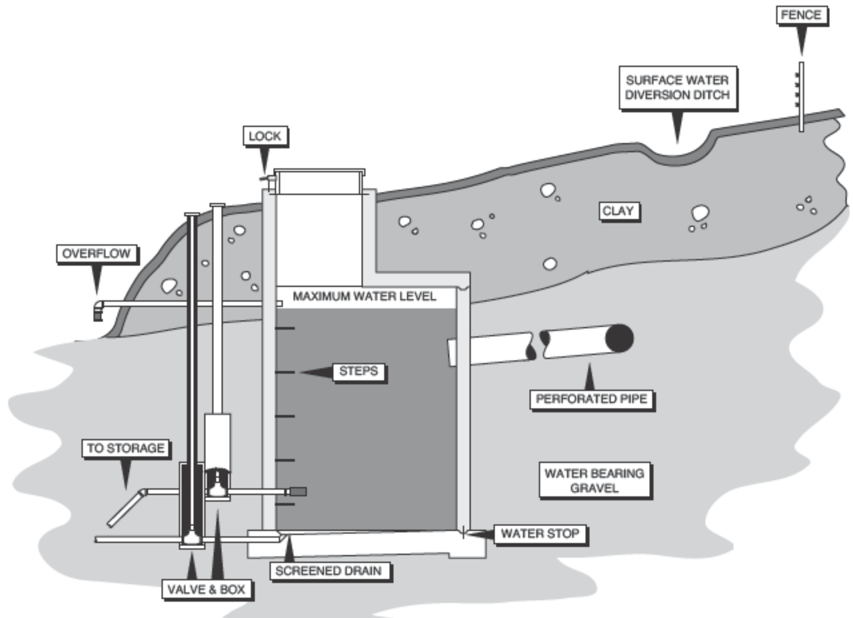

Lineshaft Turbines
Ground Level
Horizontal Wells

Other Intakes

Springs

A common method of collecting water from a spring is to dig back into the mountain and place Johnson screens or perforated pipe into the water bearing strata. This is then covered with clean washed rock and sealed with clay. The outlet is piped into a spring box.

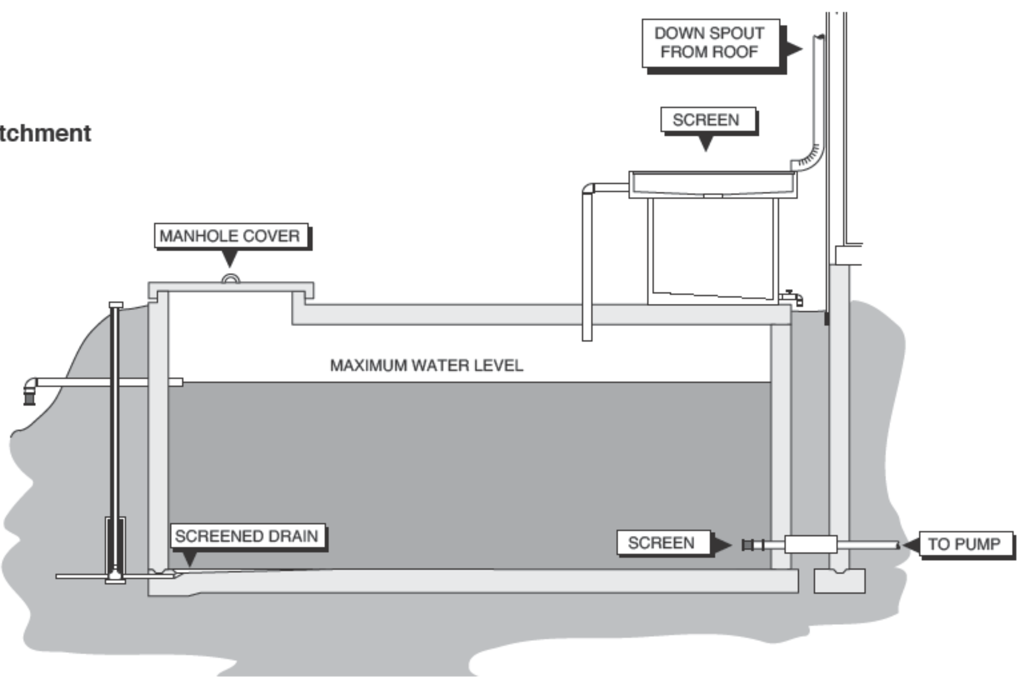
Spring Box

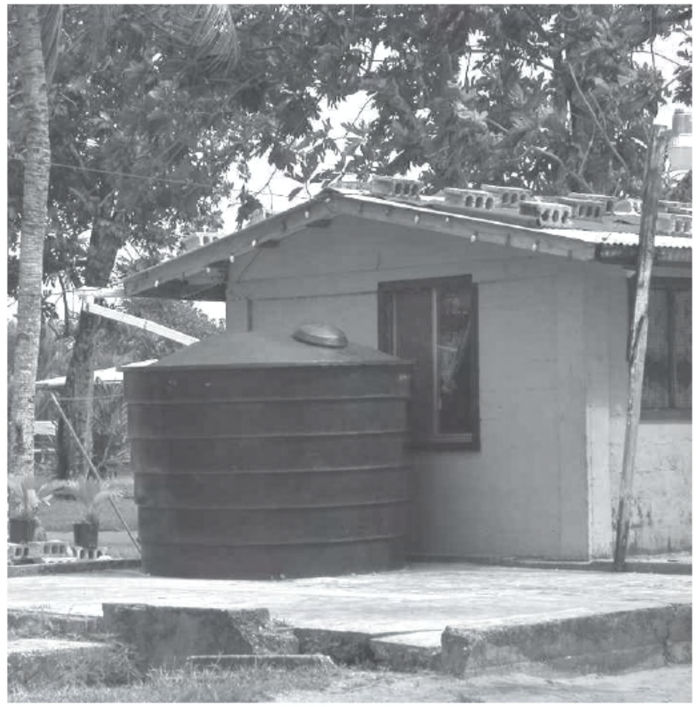


Roof Catchments

In various parts of the world including Southeast Alaska, British Columbia, the islands of the Pacific, and the Caribbean, a primary source of water is rain water. Rain water is collected from the roof of buildings with a device called a roof catchment.

Roof Catchment



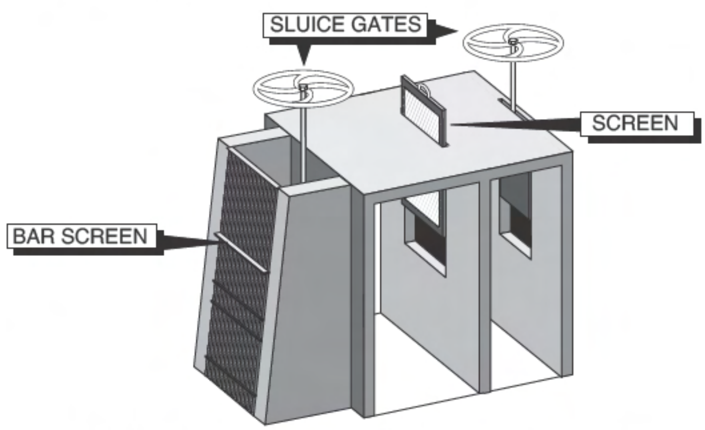


Typical Roof catchment system in the Pacific Islands. Majuro Island in the Republic of the Marshalls

Screens

Bar Screens

The intake pumps, valves and piping need to be protected from debris that would normally be drawn into the intake. One of the primary protection devices are large steel or concrete bars set vertically in the flow. This is called a bar screen and is designed to protect against large material.



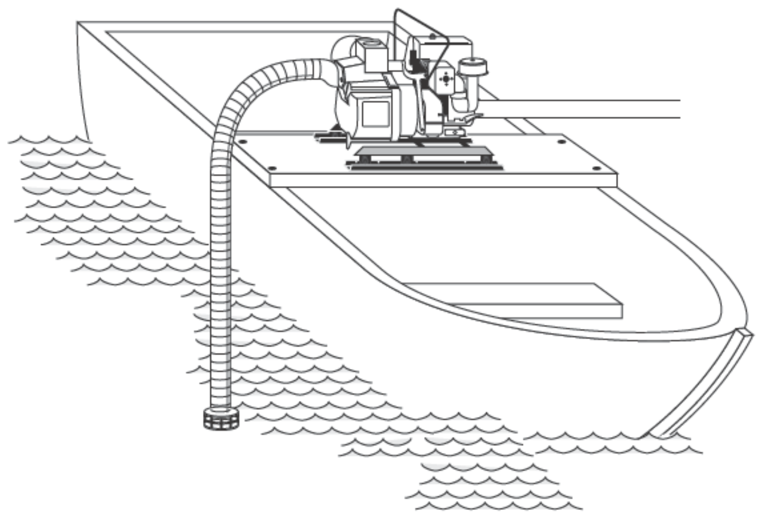
Screens

After the bar screens is usually a smaller screen, designed to remove leaves and other small material that could clog the pumps and valves. The screens can be either self-cleaning or manually cleaned. The manually cleaned screens often require daily cleaning during certain times of the year.

Pumps

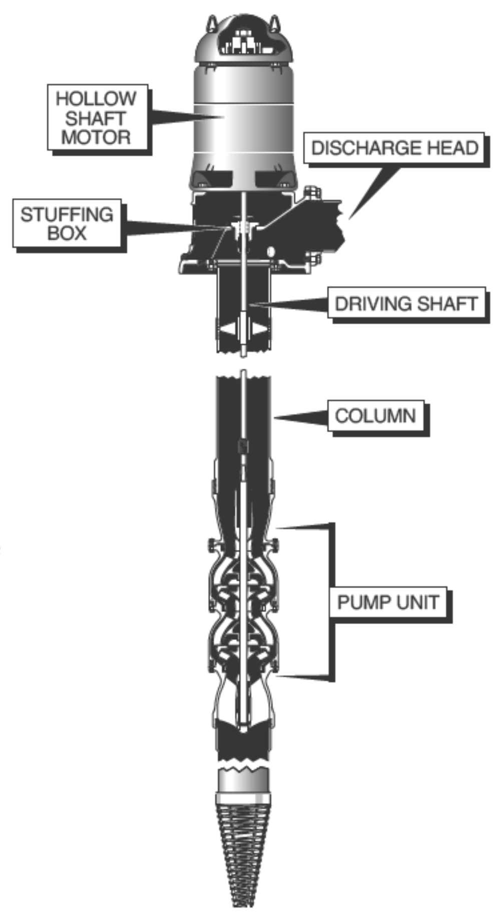
Gas Powered Units

In many small Alaska villages that use the fill and draw process a gas powered, end-suction centrifugal, a self priming pump is used to remove the water from the stream, muskeg or tundra pond.



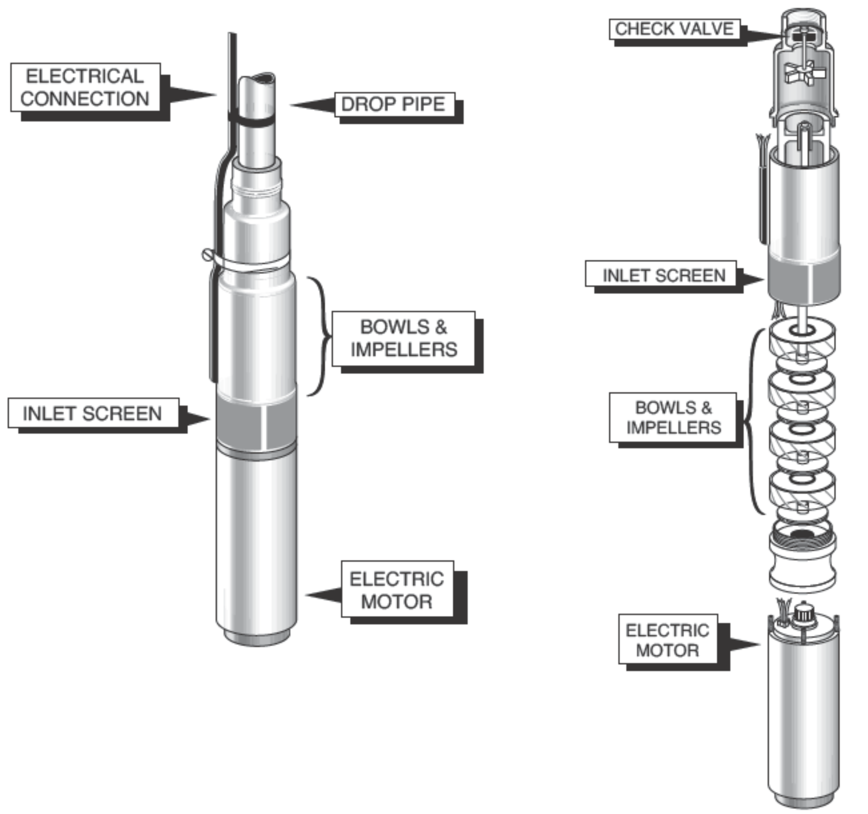
Lineshaft Turbines

One of the most common surface water intake pumps is the lineshaft turbine. They are frequently used in larger facilities and are installed inside a protective caisson. This type of pump cannot be used as a portable device, because it must remain in a perfectly plumb, vertical position when it is in operation.



Submersible Turbine

The submersible turbine is used in caisson on small streams, in river floats, and set through the ice in the winter. The pump will operate best and have the longest life if it can be kept in a nearly vertical, plumb position when it is operating.



Safety Concerns

Electrical

Anytime you are working with electricity there is a safety concern. A 200 milliamp shock from arm to arm is enough to kill an average person. This current is less than what would run through your body if shocked by 120 volts. To prevent shock, always wear insulated gloves, never wear metal jewelry or metal eye glass frames when working with electricity. Latch the panel door open when working inside the panel. Turn the power off when making repairs and always STOP AND THINK TWICE BEFORE TOUCHING AN ELECTRICAL COMPONENT.

Lock-Out

When working on a pump be sure to shut the power off and "lock-out" the breaker with a padlock. Place a tag on the padlock with a note indicating when and why the unit is turned off.

Noise

When using gas or diesel powered equipment you should be aware of the noise level. If the noise in the area in which you are working is above 85 db you should wear hearing protection. Damaged hearing cannot normally be repaired. For instance, a gas powered pump installed in a caisson or on a boat would require hearing protection anytime you were in or directly above the caisson when the pump was running.

Confined Spaces

Most all of the caisson and valve boxes that are found associated with intake structures are confined spaces and therefore require:

- A written permit before you enter
- The use of an air ventilation system, and
- Monitoring the air quality with a oxygen and combustible gas meter every 15 minutes.

Carbon Monoxide

When running the gas powered pump in a caisson, special care must be taken to ensure that the exhaust is out of the caisson. However, the wind could easily blow carbon monoxide back into the caisson. Check for oxygen and combustible gases before entering the caisson.

Records & Data Collection

Records

In order to properly operate and maintain a surface water system you should keep the following records:

- As-built drawings of all facilities
- Copy of the water rights certificate
- Copy of the watershed management use agreement
- Map of drainage basin showing land ownership, potential or existing **contamination**[24] sites, activity sites, and location of any water system structures.
- Baseline quality and quantity data
- Water quality survey reports
- Water monitoring reports

Recommended Activities

In order to properly operate and maintain a surface water system you should routinely obtain the following data and/or perform the following tasks:

- Test turbidity, pH and temperature - daily.
- If there is color in the water - test daily.
- Test chloride levels at lense wells - weekly
- Test for bacteriological quality - monthly.
- Collect a sample and have it tested for inorganic contaminants - yearly.
- Collect a sample and have it tested for organic contaminants - yearly.
- Inspect the intake structure - frequency depends on type of structure, but at least weekly.
- Make an on-site investigation of the drainage basin and waterway each year, looking for existing or potential contamination. This contamination could be natural or man-made. This process is called a water quality survey.
- Collect stream flow and precipitation data - weekly.

[24] **Contamination -** The introduction into water of toxic materials, bacteria, or other deleterious agents that make the water unfit for its intended use.

Groundwater

Definition

Groundwater is considered to be water that is below the earth's crust, but not more than 2500 feet below the crust. Water between the earth's crust and the 2500 foot level is considered usable fresh water.

Examples of Groundwater

Groundwater is obtained from wells, and springs that are not influenced by surface water or a local hydrologic event.

Under the Influence

When a well or spring is influenced by an adjacent surface water source or by a local hydrological event the supply is said to be groundwater under the direct influence of surface water (GUDISW).

Advantages and disadvantages of groundwater

Advantages

The advantages of groundwater sources in relationship to surface water are:

- Groundwater is not as easily contaminated as surface water.
- The quality of groundwater, while not always as much as is preferred, is stable throughout the year.
- Groundwater sources are generally lower in bacteriological count than surface water sources.
- With the exception of atolls and other low islands, groundwater is available in most locations..

Disadvantages

When comparing groundwater sources with surface water the following are disadvantages to using groundwater:

- Once a groundwater source is contaminated it is difficult for it to recover. There is no easy way to remove the contaminants.
- Groundwater usually contains more minerals than surface water including increased levels of hardness. Because groundwater is in contact longer with minerals, there is more time to bring them into solution.
- Removal of groundwater normally requires a pump thus increasing operation cost.
- Groundwater is more susceptible to long term contamination from fuel spills.
- Groundwater supplies often have high levels of iron and manganese thus increasing treatment cost and/or causing stains on plumbing and clothing of the customers.
- Wells in the coastal areas are subject to salt water intrusion into the **aquifer**[25] and well. This contamination is difficult to predict and costly to treat.
- Sources of contamination can be hidden from sight.

[25] **Aquifer** - A porous, water-bearing geologic formation.

Groundwater Hydrology

Source

Groundwater, like surface water, is part of the hydrologic cycle. Groundwater is found in saturated layers under the earth's surface called aquifer. There are different names given to aquifer depending upon their type.

Types of aquifer

Three Types

There are three types of aquifer; unconfined, confined and springs. The following is a brief description of the differences between these types of aquifer.

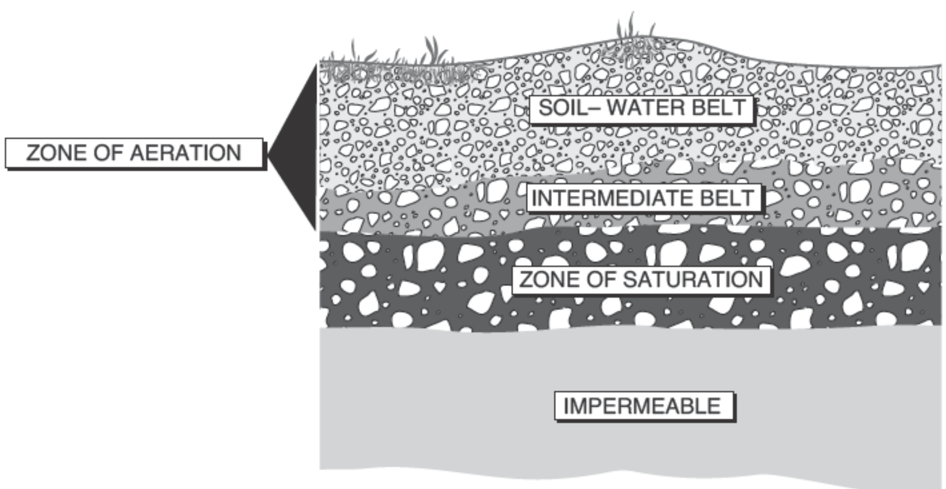
Unconfined aquifer

Definition

The zone of saturation is an **unconfined aquifer**[26]. It is not contained, except on the bottom. An unconfined aquifer is dependent on local precipitation for recharge. This type of aquifer is often called a water table aquifer.

Zones & Belts

Unconfined aquifer are composed of unconsolidated strata that is divided into two zones, the zone of aeration and the zone of saturation. The zone of aeration contains two belts; the soil water belt where plants obtain their water and the intermediate belt where there is a mixture of air and water. The zone of saturation is an unconfined or water table aquifer. The top of this zone of saturation is called the **water table**[27].



Unconfined Aquifer Wells

Wells drilled in an unconfined aquifer are normally called shallow wells and are subject to local contamination from: hazardous and toxic material such as fuel and oil, agricultural runoff containing nitrates and **microorganisms**[28], and septic tanks that discharge increased levels of nitrates and microorganisms.

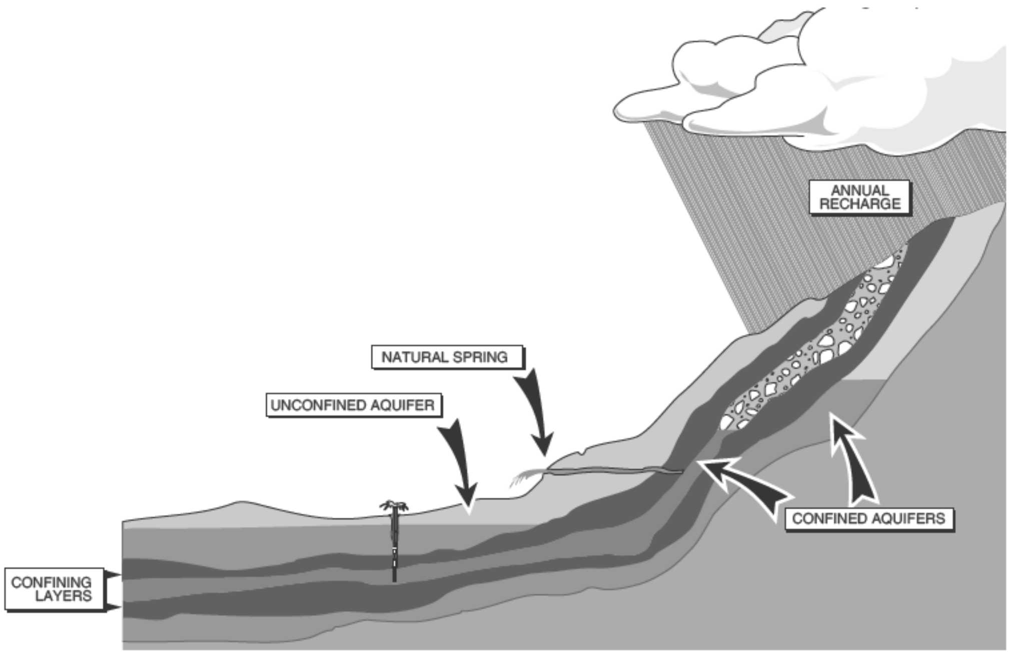
[26] **Unconfined Aquifer -** An aquifer that is sitting on an impervious layer but is open on the top to local infiltration. The recharge for a unconfined aquifer is local. Also called a water table aquifer.
[27] **Water Table -** The average depth or elevation of the groundwater over a selected area. The upper surface of the zone of saturation, except where that surface is formed by an impermeable body.
[28] **Microorganisms** - Minute organisms, either plant or animal, invisible or barely visible to the naked eye.

Groundwater Under the Influence

Water taken from wells drilled in an unconfined aquifer are not considered desirable as a public drinking water source. This type of well may be classified as groundwater under the direct influence of surface water (GUDISW) and therefore, require treatment for control of microorganisms.

Confined Aquifer
Definition

At various locations in the earths crust are layers of saturated material that are contained between two layers of impermeable material such as rock, clay or permafrost. This type of aquifer is called a **confined aquifer**[29].



Artesian Aquifer

Confined aquifer are also called artesian aquifer. Naturally a well drilled in an artesian aquifer would be called a artesian well. An artesian well is described as any well where the water in the well casing would rise above the saturated strata. There are two types of artesian wells; flowing and non-flowing.

Water Quality - Confined aquifer

Confined aquifer commonly yield large quantities of high quality water. One exception is water confined by permafrost layers. This water is very poor quality. The aquifer may be relatively short or may extend several hundred miles into the mountains.

Recharge of Confined aquifer

A confined aquifer is recharged by snow or rain in the mountains where it is close to the surface of the earth. Because the recharge area is away from the area of contamination, the possibility of contamination of a confined aquifer is very low. However, once contaminated, it may take hundreds of years before it recovers.

[29] **Confined Aquifer -** An aquifer which is surrounded by formations of less permeable or impermeable material.

Wells in Confined Aquifer

A well in a confined aquifer is normally referred to as a deep well. If the well is properly installed the water quality is not impacted by local hydrological events.

Springs

Types

Water that naturally exits the crust of the earth is called a spring. The water in a spring can originate from a water table aquifer or from a confined aquifer. When a spring comes from a confined aquifer it is commonly the result of a geological fault (a break in the confining layer.) Only water from a confined aquifer spring is considered desirable for a public water system.

Water Movement Through an Aquifer

Composition of an Aquifer

An aquifer is made up of a combination of solid material such as rock and gravel, and open spaces called pores. Regardless of the type of aquifer the water in the aquifer is in motion. This motion is caused by gravity or by pumping. The flow of water through the aquifer is influenced by the size of the material, the number of pores and the connection between the pores.

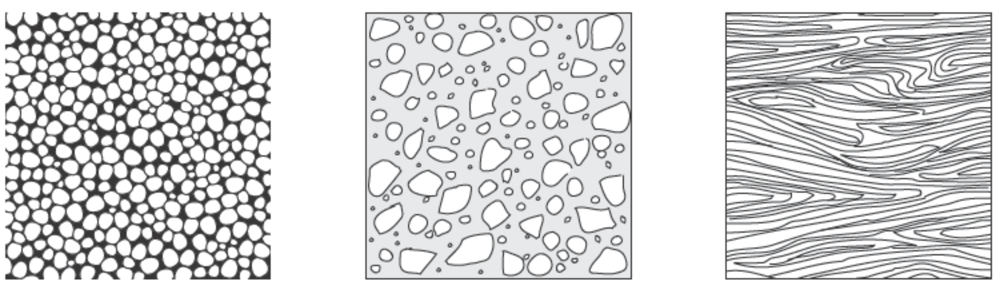
Volume of Water

The volume of water in a aquifer is dependent upon the amount of space available between the various grains of material that make up the aquifer. The amount of space available is called **porosity**[30].

All grains approximately the same size.
High Porosity

Mixed grain sizes.
Low Porosity

Interconnecting pores
High Porosity

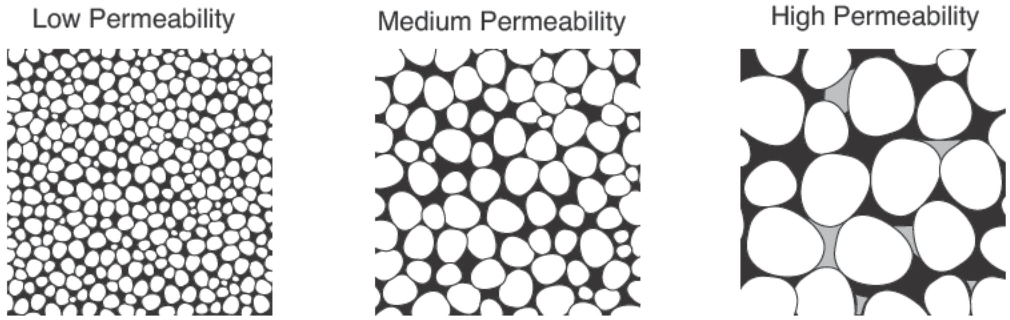


Ease of Movement

Some material, such as clay, can hold a lot of water, has a high porosity, but the pores are not connected. It is therefore difficult for the water to move through the clay. The ease of movement through an aquifer is dependent upon how well the pores are connected. Below are three sections of different aquifer. The porosity of all three is the same. Section three (3) offers far less friction to the water and thus allows greater flow. The ability of an aquifer to pass water is called **permeability**[31].

30 **Porosity** - The ratio of pore space to total volume. That portion of a cubic foot of soil that is air space and therefore could contain moisture.

31 **Permeability** - The property of a material that permits appreciable movement of water through it when it is saturated and the movement is actuated by hydrostatic pressure of the magnitude normally encountered in natural subsurface water.



Water Quality

The most ideal aquifer for a public water system is the one that offers high quality and high quantity. This is commonly an aquifer composed of a mixture of sand and gravel. This provides adequate quantity and filters out unwanted material.

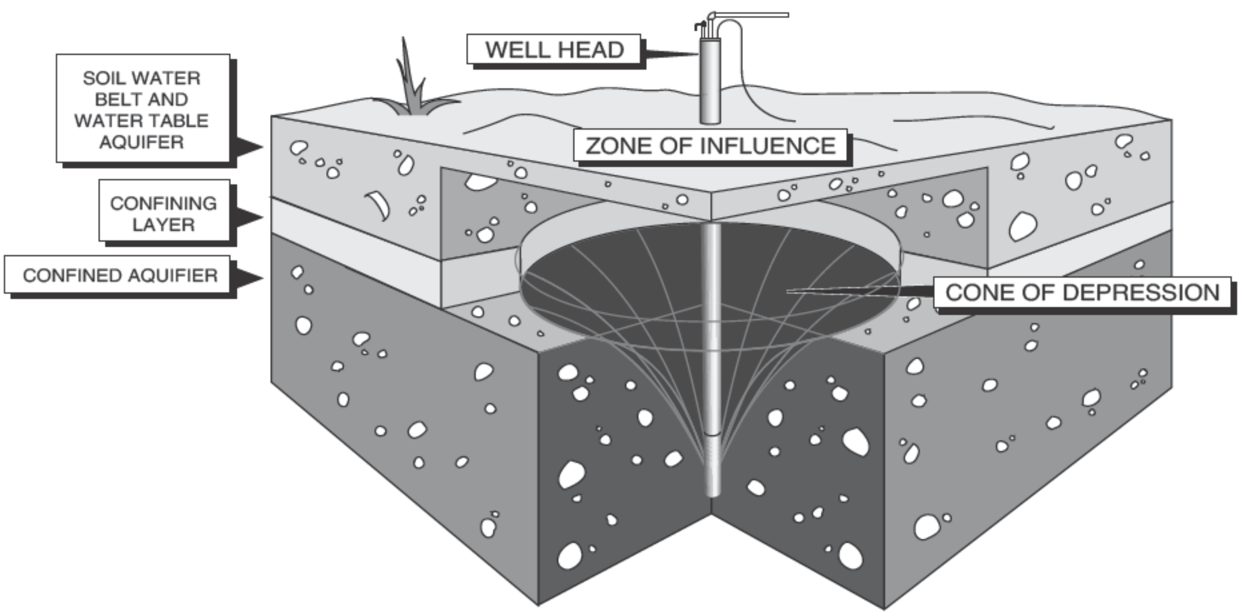
Results of Pumping

Cone of Depression

Whenever a well is placed in a water-bearing **stratum**[32] and pumped, water will flow towards the center of the well. In a water table aquifer this movement will cause the water table to sag towards the well. This sag is called the **cone of depression**[33].

Shape of the Cone

The shape and size of the cone is dependent on the relationship between the pumping rate and the rate at which water can move toward the well. If the rate is high the cone will be shallow and its growth will stabilize. If the rate is low the cone will be sharp and continue to grow in size.



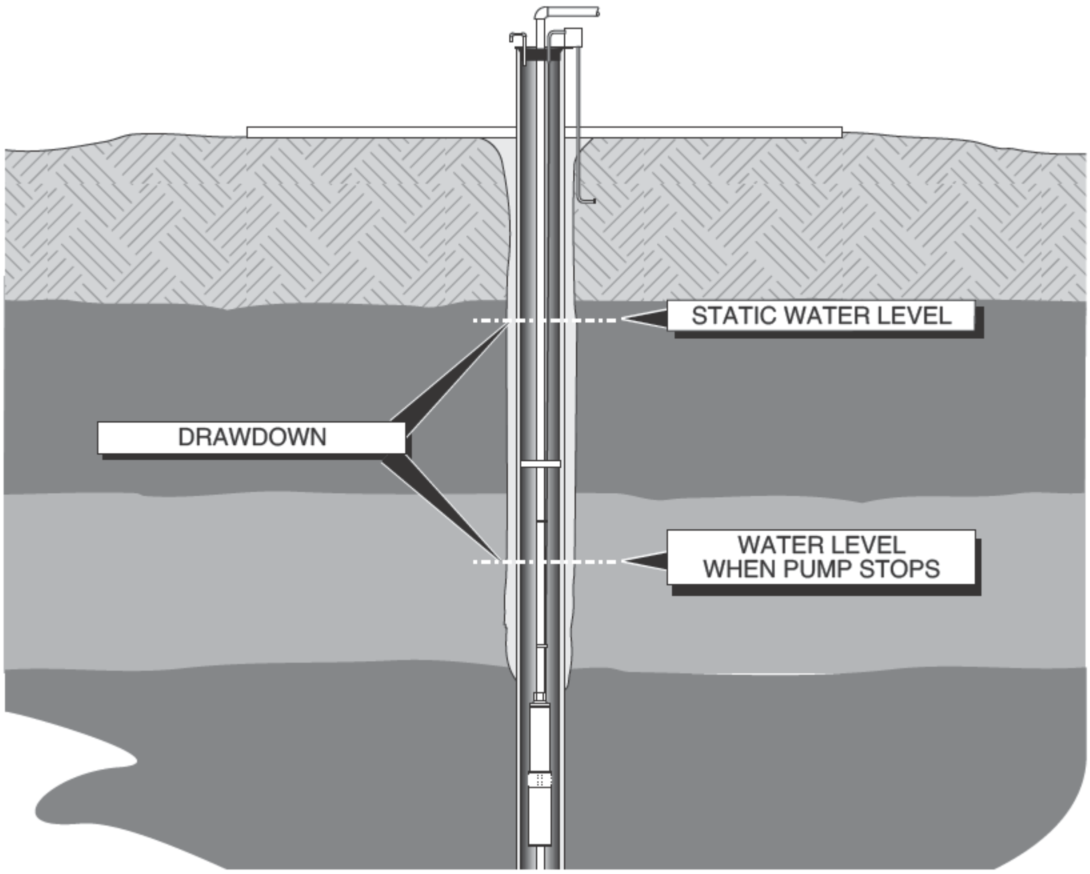
Zone of Influence

The area that is included in the cone of depression is called the zone of influence. Any contamination in this zone will be drawn into the well.

32 **Stratum** - A layer of the earth's crust.
33 **Cone of Depression** - The depression, roughly conical in shape, produced in a water table or other piezometer surface by the extraction of water from a well at a given rate.

Static Water Level

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.



Drawdown

When the well pump is operating the level of water in the well drops. The difference between the static level and the level that the pump is operating to is called the **drawdown**[34].

Specific Yield

The drawdown level is dependent on the pumping rate and the transmissibility of the aquifer. One standard test that is used to compare the performance of a well from year to year is to determine the specific yield of the well. This is done by pumping the well at a set rate for a specific period of time and measuring the drawdown. The flow is then divided by the drawdown to give a value in gpm/ft of drawdown.

[34] **Drawdown -** The distance between the static level and the pumping level.

Fresh Water Lens Wells

Description

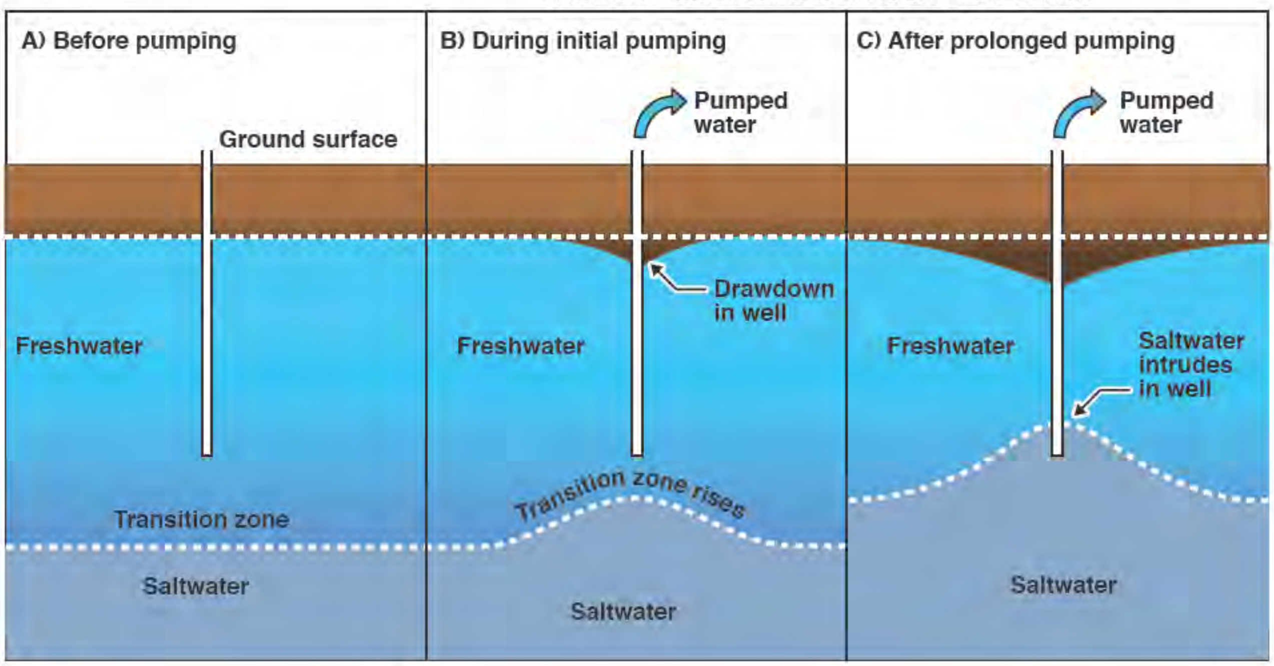
A special type of aquifer found in many of the islands of the Pacific and the Caribbean is the fresh water lens. This is a layer of fresh water sitting on top of the salt water. On high volcanic islands these lenses could be 40 to 100 feet below the ground surface. On low islands such as atolls they may only be a few feet below the surface. The well construction and pumping systems used on volcanic islands are standard submersible and lineshaft turbine pump installations. On low islands the well often utilizes horizontally placed perforated pipe that feeds water to a cassion. A end-suction or small submersible turbine pump is used to extract water from the cassion.

Salt Water Location

The separation between fresh and salt water is gradual. That is, the water on top of the lens is 100% fresh water. As you move down through the lens the concentration of fresh water decreases and the concentration of salt water increases.

Pumping Results

Pumping water from a fresh water lens creates an inverted cone of depression. The center of the inverted cone can contain salt water. Thus, pumping at high rates can deplete the fresh water supply near the well, allow salt water to enter the system. Normal pumping operations requires routine measurement of chlorides in the raw water. An increase in chloride levels is an indication of saltwater intrusion into the lens. Typically, the pumping rate should be adjusted to keep the chloride level below 400 mg/L. Once salt water is allowed to inter into the fresh water lens, it may take an extended period of non-pumping before the fresh water lens will return to normal.



Well Location Criteria

Regulations & Standards

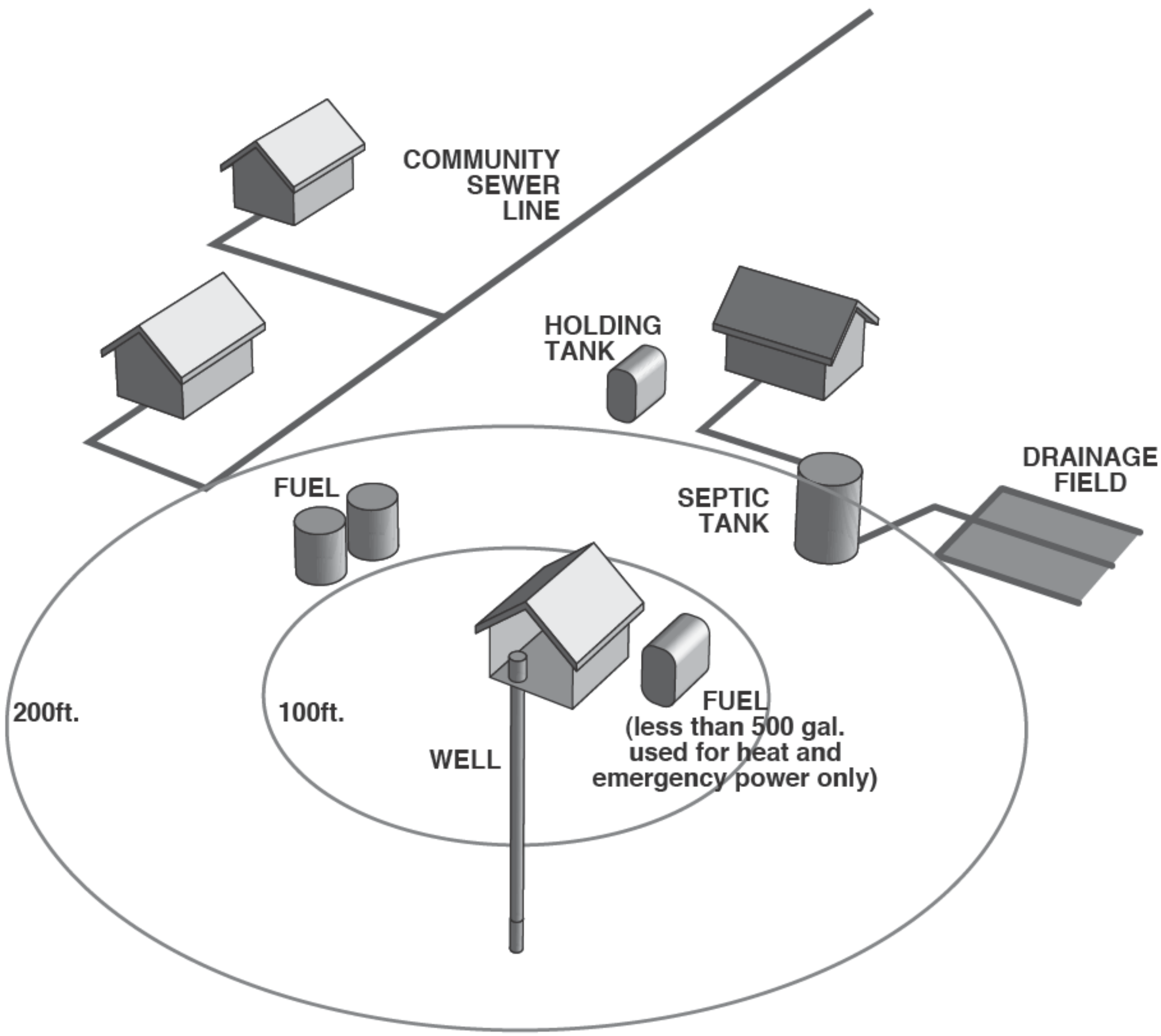
In order to protect the groundwater source and provide high quality safe water, the water works industry has developed standards and specifications for wells. In addition most states have established minimum construction criteria for municipal wells. The following listing includes industry standard practices as well as those items included in many state regulations.

- There can be no wastewater disposal systems including septic tanks and drain fields within 200 feet of the well.
- There should be no community sewer line, holding tanks, or other potential sources of contamination within 200 feet of the well.
- Fuel not used for on-site emergency pumping equipment or heating can not be stored within 100 feet of the well.
- Fuel for on-site emergency generators or building heating system can be stored on-site if the total volume is less than 500 gallons.
- The well casing must extend one-foot above the ground.
- The top of the well casing must extend 12 inches above the well house slab.
- The ground around the well must be sloped away from the well 10 feet in all directions.
- The well must have a sanitary seal.
- The well casing must be grouted for at least 10 feet within the first 20 feet below the surface.
- The well head must be protected against flooding.
- Well pits are prohibited.

Recommendations

The following are recommendations and not regulations:

- To reduce the possibility of the well being classified as being under the influence of surface water it should not be located within 200 feet of a surface water source.
- The water purveyor should own or have a restricted area within 200 feet radius of the well.
- There should be no roads within 100 feet of the well.
- If the well is drilled within 100 feet of a road, the well must be protected against contamination from runoff from the road.
- To avoid the well being classified as GUDISW review the determination criteria and discuss the location with the state regulatory agency.


COMMUNITY
SEWER
LINE
HOLDING
TANK
DRAINAGE
FIELD
FUEL
SEPTIC
TANK
200ft.
100ft.
WELL
FUEL
(less than 500 gal.
used for heat and
emergency power only)

Well Components

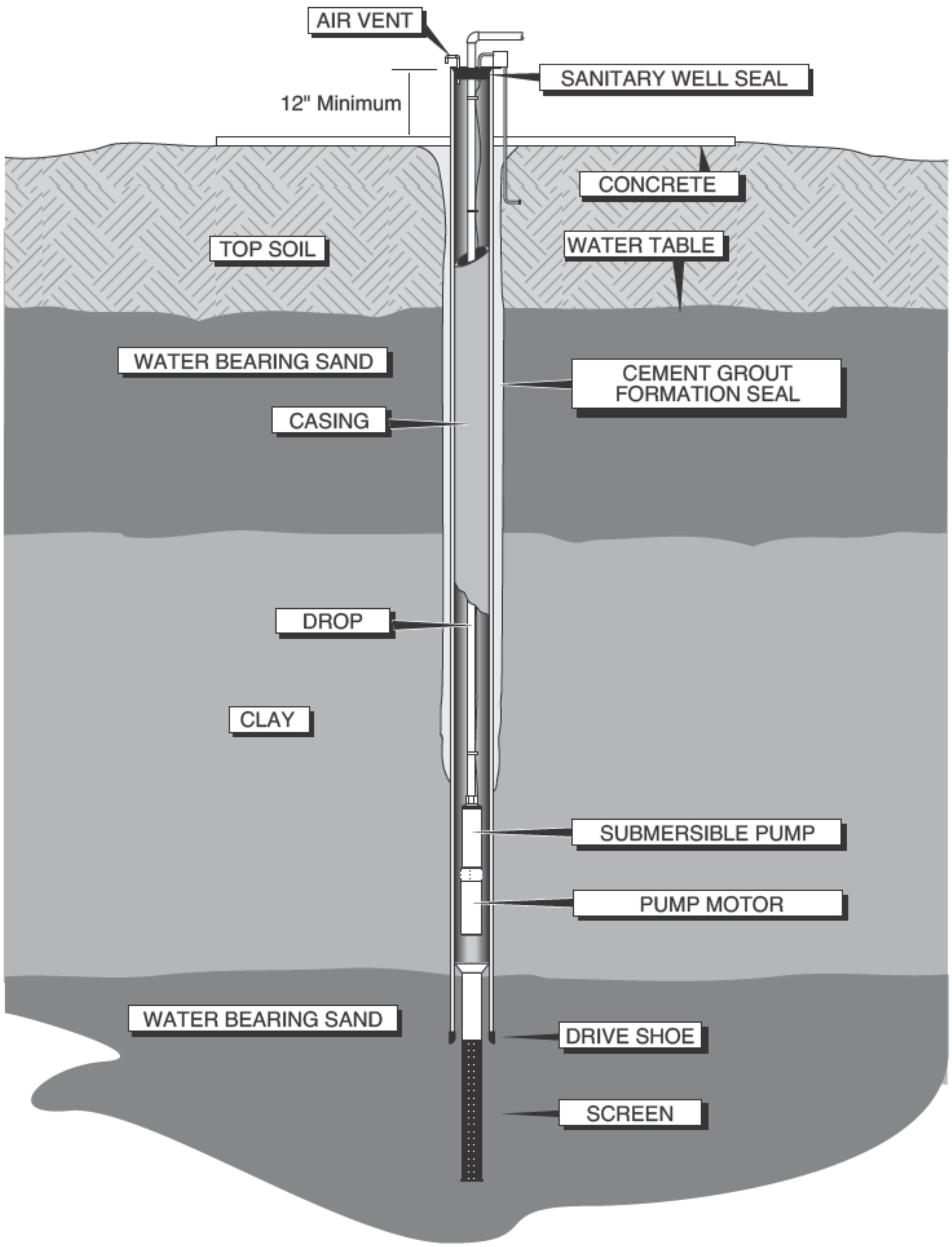
Overview

The components that make up a well system can be divided into three categories; the well itself, the building and the pump, and related piping system.

Well

Casing

A well is a hole in the ground called the bore hole. The hole is protected from collapsing by placing a casing inside the bore hole and securing the casing to the bore hole in a way that protects the aquifer from contamination. The most common casing material is steel. The casing should extend 1 foot above the ground and down into the impermeable layer above the aquifer.



Grout

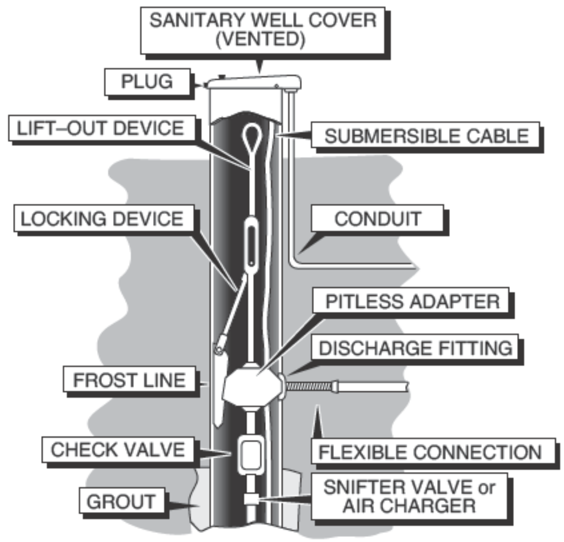
To protect the aquifer from contamination the casing is sealed to the bore hole near the surface and near the bottom where it passes into the impermeable layer.

Ground Seal

The ground around the casing is sealed with a reinforced concrete slab. This concrete is usually connected to the grout that extends down the well.

Pitless Adapter

In some instances it is desirable to have the discharge from the well exit below ground level. This reduces the possibility of freezing and allows more flexibility in the location of the pump house. The device that allows the line to pass through the casing wall is called a pitless adapter. The casing vent is an internal part of the pitless adapter cover.



Grouting a Pitless Adapter

Wells with pitless adapters are also required to be grouted at the top. This grouting should start just below the pitless adapter and extend down at least 10 feet.

Well Head

The well head is merely the top of the well casing.

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 being used.

Sanitary Seal - Submersible Pump

For submersible turbines this seal is typically composed of a rubber like material placed between two pieces of metal. By tightening the bolts on the sanitary seal the rubber is compressed and expands to seal against the casing and the pump discharge pipe.

Drop Pipe - Riser

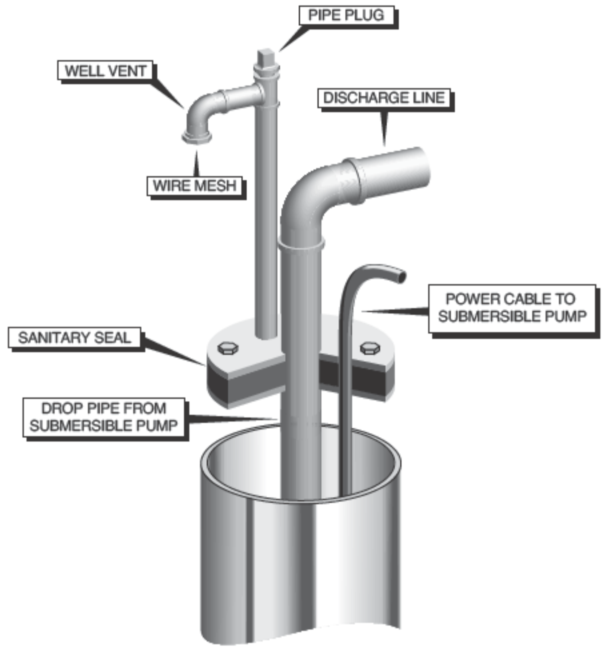
The line leading from the pump to the well head is called a drop pipe or riser pipe. This pipe is either steel or PVC. Steel is the most desirable.

Well Screen

Screens can be installed on the end of a well casing or on the end of the inner casing on a gravel packed well. These screens perform two functions, one is the support of the bore hole and the second it to reduce the amount of sand that enters the casing and the pump.

Casing Vent

The well casing must have a vent. On a typical casing this vent is a double 90° Ell that is pointed toward the ground. The opening of the vent should be screened with a #24 mesh stainless steel screen.

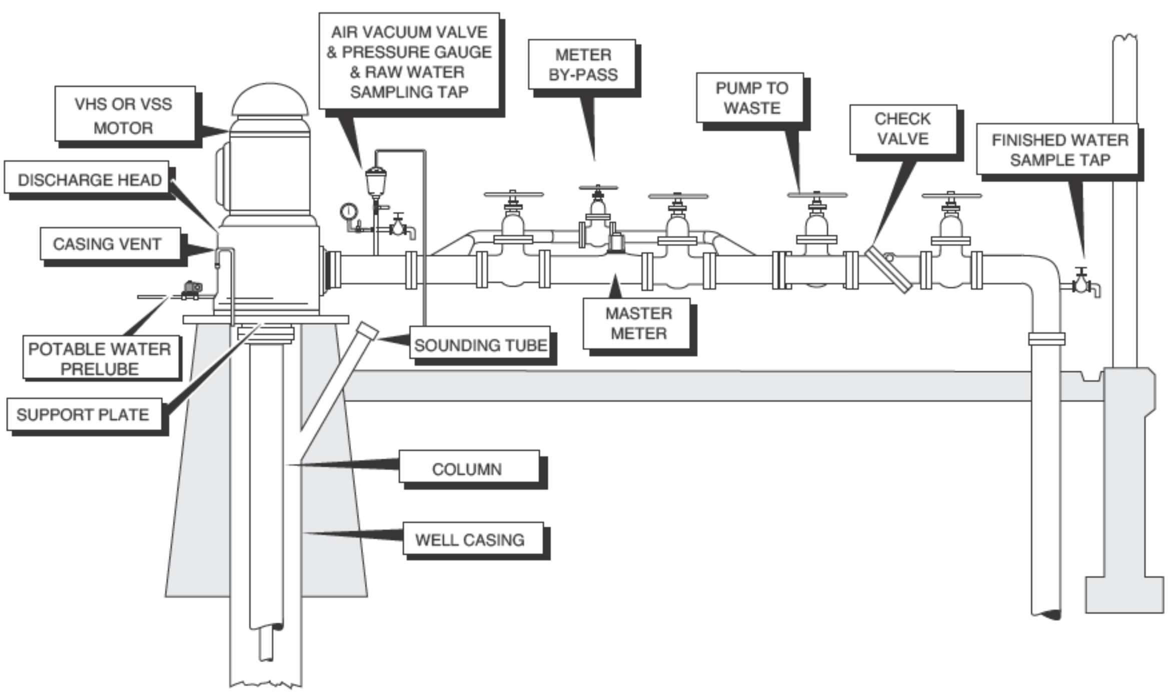


Sampling Tap

A sampling tap or valve should be installed to allow for sampling of raw water. This tap must be far enough from any chemical injection point so that the chemicals do not contaminate the sample.

Master Meter

A master meter should be installed on the discharge from the well. The meter is the only reliable means of determining the production of the well.



Check Valves

On lineshaft turbines there is commonly a check valve assembly on the discharge of the pump. The check valve prevents water from running back into the well. On small submersible pumps there is usually a check valve at the top of the pump. On deep well submersibles there may be additional check valves in the riser pipe. These check valves prevent water from running back through the pump and causing it to be turned in the opposite direction which could damage the pump.

Air Vacuum Relief Valve

A air vacuum relief valve is installed on the discharge line to reduce water hammer and prevent air in the column from being forced into the water. The casing is protected from collapse by a double ninety vent with #24 mesh stainless steel screen.

Check Valves & Freezing

In some cases it may be desirable to allow a portion of the water to run back down the riser pipe on a submersible pump installation. This is accomplished by drilling a “weep hole” in the side of the pipe or in the disk of the check valve. This is done in order to remove the water from the top of the drop pipe and thus reduce the possibility of freezing.

Building

Function of Building

The building is designed to protect the pump and piping from freezing. Protection from freezing may require the installation of heat trace tape on the drop pipe. The building should also be designed to allow easy removal and replacement of the pump and pump motor.

Electrical Equipment

All electrical components should be protected from weather damage.

Heat & Lights

The building must be heated and contain proper lighting to allow for maintenance.

Chlorine

The chlorine and fluoride systems should not be in the same room with electric motors and control panels. If they must be housed with the electrical system all the electrical fixtures and motors must be corrosion resistant.

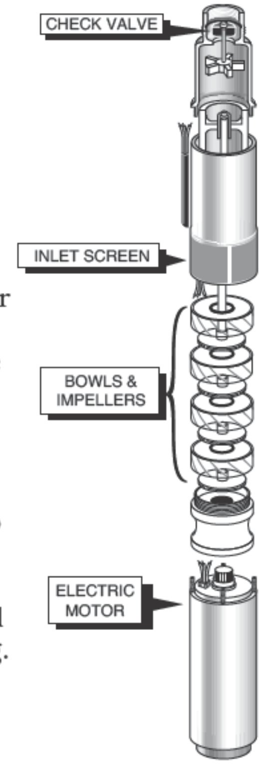
Pumps

Two Types

There are two types of pumps that are commonly installed in groundwater systems. They are the lineshaft turbine and the submersible turbine.

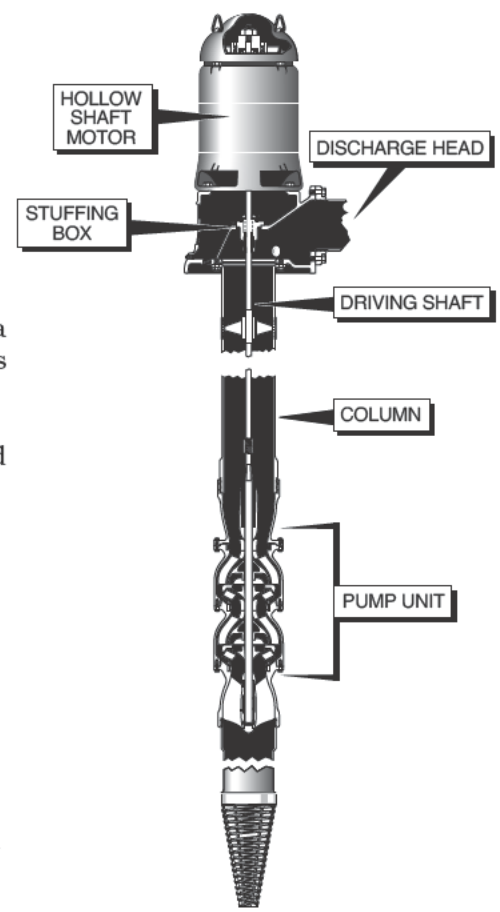
Submersible Turbine Components

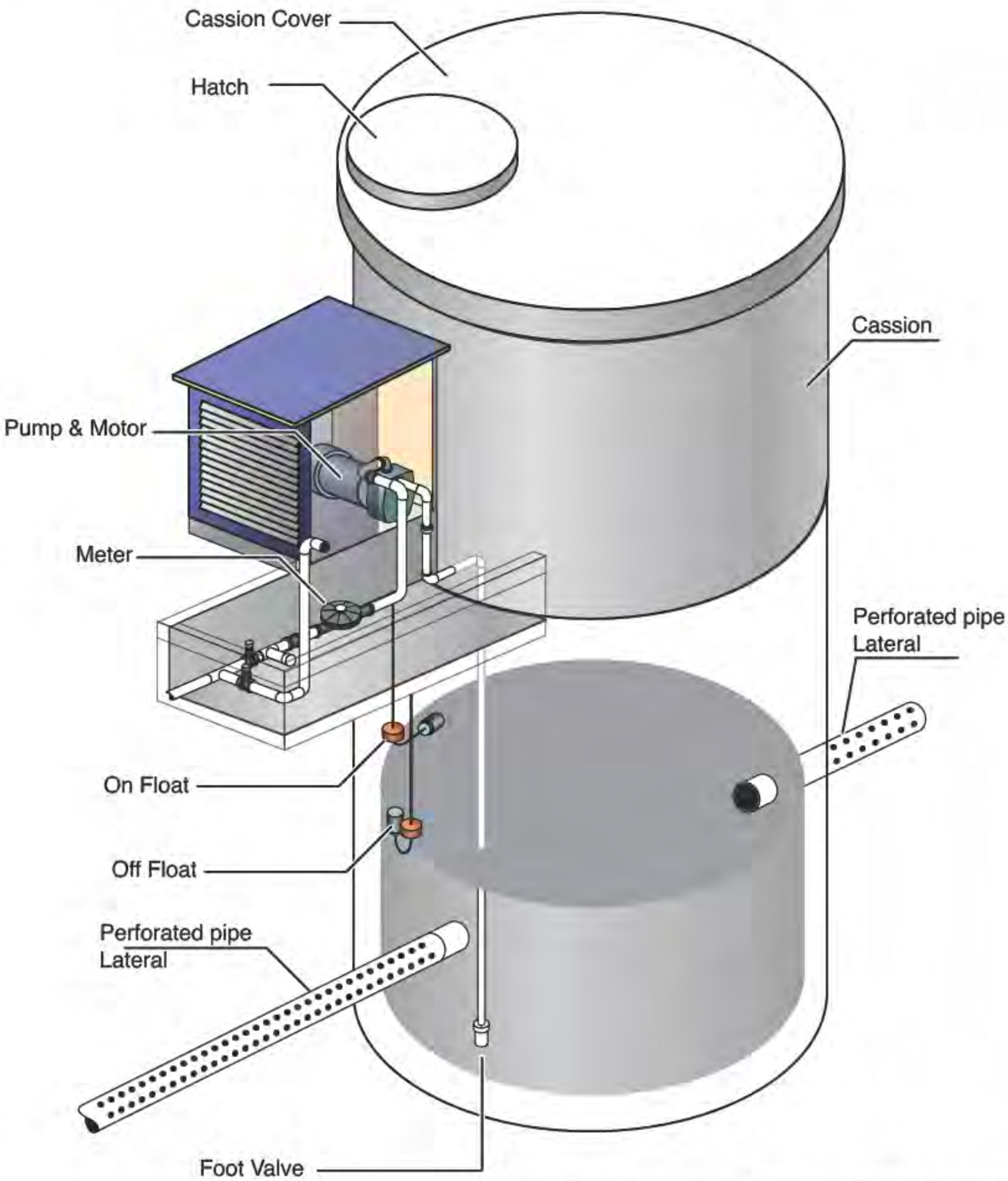
With the submersible turbine pumping installation the pump motor is below the pump. The water intake is between the motor and the pump. The pump is a series of impellers called stages. Water moves from stage to stage up through the pump and into the riser pipe. Water exits the casing through the discharge head at the top of the well casing. Electrical connections are made above the casing in an electrical box. As with other types of wells there is a casing vent installed in the sanitary seal.



Lineshaft Turbine Components

With the lineshaft turbine installation only the pump is placed into the water. The pump is similar to the submersible pump. There are a series of impellers called stages or bowls. The water flows from stage to stage up through the pump and into the column and exits the well through the discharge head. The discharge head is mounted to the base plate and sealed with a rubber like sanitary seal. The pump is driven by a drive shaft that extends from the pump to the motor. The drive shaft is supported by bearings approximately every 20 feet. These bearings can be lubricated with water or with a food-grade oil.





Lense well and pumping system in a shallow lens on the island of Majuro in the Republic of the Marshall Islands.

Data and Record Keeping Requirements

Records

A properly operated and managed water works facility keeps the following records concerning their well.

- Well log - A documentation of what materials were found in the bore hole and at what depth. The well log should include the depths at which water was found, the casing length and type, the depth and type of soils, testing procedure well development techniques and well production.
- Pump and motor name plate data, as well as maintenance history.
- Water quality data on the physical, chemical, and bacteriological testing results.
- Quantity of water pumped from the well.
- Static and drawdown water levels.

Data Collection & Testing

The raw water should be tested for:

- Temperature - daily
- pH - daily
- Amount of water pumped - daily.
- Pumping hours - daily.
- Pump discharge pressure - daily.
- Iron or manganese, if a problem - daily.
- Conductivity - weekly
- Total coliform - monthly.
- Gallons per minute that pump produces - monthly.
- Raw water fluoride, if feeding fluoride - quarterly.
- Depth of water in well - quarterly.
- Motor amperage and voltage - quarterly.
- Specific yield - Twice a year - winter and summer.
- Collect sample and have it tested for Nitrate - annually.
- Collect sample and have it tested for inorganics - every three years.
- Collect and sample for pesticides - every 3 years.
- Collect sample and have it tested for radioactivity - every 3 years.
- Collect sample and have it tested for VOCs - every five years.

Transmission Lines

Function

Transmission lines are installed in order to move the water between the well or intake and the treatment plant or storage tank. A transmission line is used to transfer raw water only and should have no service connections. Transmission lines can serve as a chlorine contact chamber.

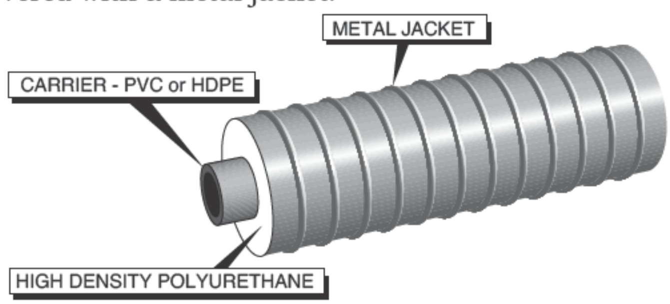
Types of Transmission Lines

Piped

The most popular type of transmission line is the buried pipe. These lines are commonly DCIP or HDPE, although in the past PVC, wood and steel pipe have also been used. The City of Craig uses 12 inch DCIP from their surface water reservoir to their treatment plant seven miles away.

Arctic Pipe

In the arctic regions a special piping material called arctic pipe is commonly buried instead of the standard piping material. Arctic pipe is composed of three components. The line that carries the water is called the carrier pipe and is commonly made of PVC or HDPE. HDPE is the most common in new installations. The carrier is protected with several inches of high density polyurethane insulation and covered with a metal jacket.



Above Ground Utilidor

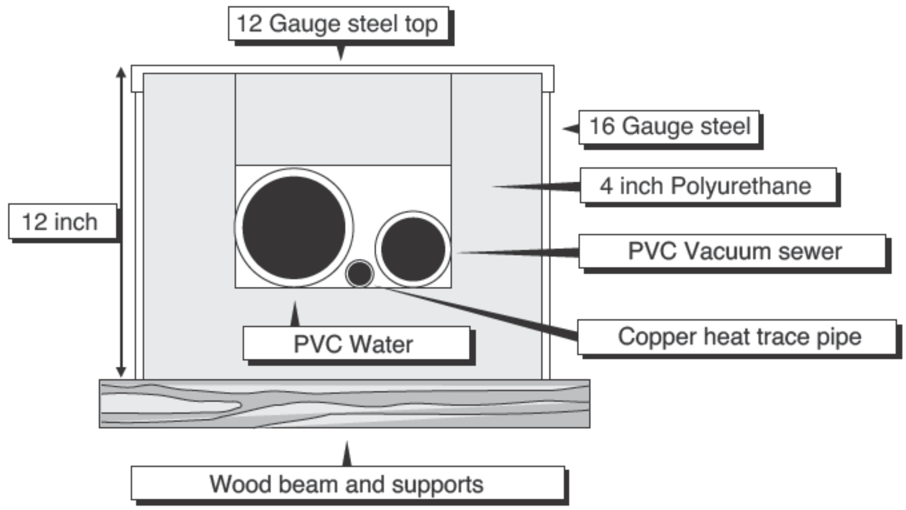
Utilidors have been used in the arctic for a number of years. The older utilidors were made of insulated plywood. The newer installations are made of large diameter arctic pipe, insulated with high density polyurethane or polystyrene and covered with 16 & 12 gauge steel. The carrier pipe on new utilidors is PVC or HDPE. The above ground utilidors are commonly heated using a HDPE pipe loop of heated **glycol**[35]. The glycol is heated with a low pressure water boiler and circulated with a pump through the loop.

Below Ground Utilidors

Due to cost, below ground, walk through utilidors are not very common. They can be found in a number of arctic communities including the Alaska communities of; Barrow, Nome and Fairbanks. The most common below ground utilidors are made of wood or concrete insulated with a polystyrene foam. The water, sewer and electrical utilities are placed on racks in the utilidors. Heat is provided by a glycol heating loop or electric heaters.

35 **Glycol** - Common name for propylene glycol, a colorless, thick, sweet liquid used as an antifreeze.

Above Ground Utilidor



Flow Meters

Purpose

A flow meter placed in the raw water line is the only method of tracking daily use, monthly average and peak demands. These meters can also be useful in evaluating the amount of leakage in a water system.

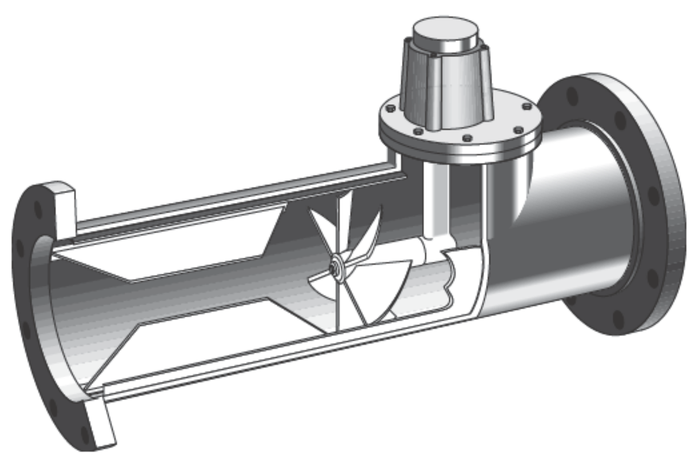
Types

There are six types of meters used in raw water lines. They are; propeller, turbine, magnetic, displacement, orifice and venturi meters. The turbine and displacement meters are the most common in the small systems.

Turbine

On lines three inches to 12 inches in diameter turbine meters are common and practical. These meters use a bypass technique to divert a portion of the flow through a turbine wheel. The turbine is connected via a magnet to the register. This type of meter is quite accurate over a wide flow range and offers low headloss to the flow.

Turbine Meter



Displacement Meters

Displacement meters are used on pipes from 3/4 inch through four inch. They are the most accurate over a wide range of flows. There are two common types of displacement meters; the rotating piston and the nutating disc. In each case the flow of water causes a device to move in a chamber with a fixed volume. As the device moves it rotates. The rotating device is connected by a magnet to a register that records the flow.

Groundwater Under Direct Influence of Surface Water (GUDISW)

Background

When surface water can infiltrate a groundwater supply there is a high possibility that the groundwater could be contaminated with Giardia, viruses, turbidity and organic material from the surface water source. As a result, the Surface Water Treatment Rule of the Safe Drinking Water Act requires that each state determine which groundwater supplies are influenced by surface water. When a groundwater supply is identified as being under the direct influence of surface water it is no longer called a groundwater supply but is referred to as groundwater under the direct influence of surface water (GUDISW). When a supply is designated as GUDISW the state's surface water rules apply to the source rather than the groundwater rules.

Involvement of State Agency

It is the responsibility of state regulatory agency to identify and categorize all groundwater supplies into either groundwater or GUDISW. It is the responsibility of the utility to perform the analysis required for this determination.

Evaluation Process

General Explanation

To determine if a groundwater supply is under the direct influence of surface water, EPA has developed procedures which focus on significant and relatively rapid shifts in water quality characteristics such as turbidity, temperature and pH. When these shifts can be closely correlated with rainfall, breakup, or other surface water conditions or when certain indicator organisms associated with surface water are found, the source is said to be under the direct influence of surface water.

Procedure - More Details

The procedure for springs, infiltration galleries and wells includes the following steps:

1. Review of records to determine the method of well construction and water quality conditions, distance from well to nearby surface water, coliform contamination history and history of known or suspected waterborne disease outbreaks associated with organisms normally found in surface water.
2. An on-site inspection to look for evidence that surface water can enter through defects with the well head, casing or underground connections with the aquifer.
3. An analysis of the well water to identify organisms that normally occur in surface waters but are not normally found in groundwater sources.

When Evaluation is Not Required

Utilities are not required to perform extensive evaluations if the system meets the following criteria:

- Well is deeper than 50 feet
- Well is more than 200 feet from a surface water source
- Well was constructed properly with screens or perforated intake below a confining layer
- There is no history of significant shifts in water quality
- There is no history of coliform contamination or waterborne disease outbreaks in the system.

Importance of Organisms

Although a significant and relatively rapid shift in groundwater quality can indicate the influence of surface water, it is the analysis for surface water organisms that determines if the supply falls under the requirements of the SWTR. The intent of the analysis is to identify organisms that are likely to occur only in surface waters. The presence of such organisms in groundwater indicates that at least some surface water has been mixed with the groundwater.

Sampling

The sampling for surface water organisms generally involves filtering 1,000 gallons of water through a 1 micron cartridge filter over a 4 to 8 hour period. At least two samples must be collected during the time the source is most susceptible to surface water influence (during heavy rainfall or runoff).

The Results

There is no standardized method for interpreting the results of this test. The recommendation is to look for Giardia cysts, Helminths, chlorophyll-bearing algae, Coccidia and other microorganisms that are larger than 7 microns and are normally found in surface water.

Introduction to Water Sources

Worksheet

1. What are the three sources of drinking water?
   a. ________________________
   b. ________________________
   c. ________________________

2. What do the letters GUDISW mean?

3. A muskeg pond is an example of what type of water source?

4. Two of the advantages of surface water sources are:
   a. ______________________________
   b. ______________________________

5. Two of the advantages of groundwater sources are:
   a. _______________________________
   b. _______________________________

6. The study of the properties of water, its distribution and behavior is called?

7. What is the area called that directly influences the quantity and quality of surface water?

8. What is the area called that directly influences the quantity of groundwater?

9. The area inside the cone of depression is called the zone of _______________.

10. The ___________ __________ prevents an embankment dam from leaking.

11. A spring and a shallow well are examples of what type of water source?

12. What is the function of the bar screen at a surface water intake?

13. The two most common pumps found in small water system surface water and groundwater intakes are the _____________ _____________ _________________ and the submersible _____________.

14. An artesian well is found in a_____________________ aquifer.

15. The water table is found at the top of the _________________ of _________________.

16. When water is drawn out of a well a _________ of ___________ will develop.

17. For each of the following items give the proper separation from a well for a community water system.

    ______ a. Community sewer

    ______ b. Fuel oil, less than 500 gallons used for heating

    ______ c. Septic tank

18. The well casing should extend _______ above the ground or well house floor.

19. A well casing should be grouted for at least ___________ feet, within the first ________ feet with ____.

20. What are the two most common arctic pipe carriers?

    a. ________________________________

    b. ________________________________

21. Identify the items indicated.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

i. ____________________