Surface Water Operations

What is in this lesson?

1. Process of watershed management and the two common watershed management programs
2. Purpose and contents of a watershed or land use agreement
3. Four types of water rights doctrine and their application to utilities
4. Impact of fishers and minimum flows on water rights
5. Contents of a source protection plan
6. Contents of a spill response plan
7. Use of a map to indicate potential sources of pollution, land use, and watershed area
8. U.S. Forest Service stream condition evaluation tool
9. Methods of gathering stream flows and precipitation data
10. Types of weir plates used to measure small stream flow
11. Components of a weir installation
12. Conversion of cfs to gpm and MGD
13. How to evaluate water quality data on raw water
14. Value of testing total coliform levels in raw water supplies
15. Routine operations in a watershed
16. Components of a water quality survey
17. Routine water quality data collection recommendations for a surface water source
18. Common water quality testing associated with a surface water storage facility
19. How stored water deteriorates
20. Routine inspection and data collection for a surface water storage facility
21. Common techniques used to control algae problems in a surface water storage facility
22. Routine inspection process of surface water intakes
23. Components of a surface water intake
24. How to calculate acre feet of water

Key Words

- Algae
- Ambient
- Baseline Data
- Bed Load
- Benthic
- Discharge Measurement
- Dissolved Oxygen
- Doctrine
- Epilimnion
- Eutrophication
- Flume
- Hypolimnion

- Hydrograph
- Hydrological Event
- Infiltration Gallery
- Parshall Flume
- pH
- Raw Water
- Riparian
- Sanitary Survey
- Short Circuiting
- Stream Reach
- Thermocline
- Velocity
- Water Quality Survey
- Weir

Surface Water Operations

Introduction

Content

The operation of a a surface water source includes the operation and management of the watershed, storage reservoir (if used), and intake structure.

Springs & Roof Catchments

The operation of springs and roof catchments are included in this section because most springs and all roof catchments are surface water sources.

Importance

While operators may not be involved in setting watershed use policies and other water source management issues, they may be called upon to implement the policies. Therefore, it is important to understand all of the components that impact the operation of a surface water source, including watershed management issues.

Watershed Management Process

Introduction

The management of the watershed is the key to the maintenance of adequate and reliable water quality and quantity. Unfortunately, in some cases the watershed may be so large that direct management is not possible. For instance, it may be easy to manage a 200 acre watershed, but nearly impossible to manage the drainage basin of the Yukon River. When taking water from a river that drains a basin that is too large to reasonably manage, all that can be done is to make careful observations of the upstream events, activities, and water quality. Therefore, this lesson is focused on the watersheds that are small enough to be managed by a utility.

What is Watershed Management?

Watershed management requires the utility to conduct the following activities:

- Development and implementation of a watershed management policy.
- Development of a use agreement with the land owner(s).
- Obtaining and maintaining water rights.
- Gathering **baseline data**[1].
- Routinely gathering and evaluating physical, biological, and chemical data.
- Performing an annual **water quality survey**[2] as part of an internal **sanitary survey**[3].

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

[2] **Water Quality Survey** - The investigative process of observing, sampling, testing, evaluating, and reporting on the results of an investigation of a watershed and its associated streams. The process attempts to define the quality of the water and identify those items within the watershed, stream bottom, and riparian area that can adversely impact water quality.

[3] **Sanitary Survey** - An on-site review of the water source, facilities, equipment, operation and maintenance procedures, and management practices of a public water system for the purpose of evaluating the adequacy of each source, facility, equipment, operation and maintenance procedure, and management practice for producing and distributing safe drinking water.

Watershed Management Policy

There are two basic watershed use policies: multiple use and restricted (single) use. The watershed management policy is set by the utility policy-making body and may be included in the utility ordinance. It is the responsibility of the utility manager and operations personnel to implement the policy.

Multiple Use Policy

Description

The multiple use policy is the most popular because it places the least amount of restrictions on the types of activities allowed in the watershed. One of its major advantages is that it makes it easier to obtain support for funding to make improvements to intake structures and impoundments. Its major disadvantage is the difficulty it places on the utility in the protection of public health. Multiple use watersheds normally have a higher level of activity than single use and there there are more people in the watershed. People are the largest carrier of waterborne diseases.

Long Term Results

The U.S. Forest Service and BLM have historically practiced multiple use policies with watersheds. In many cases this policy has placed various uses, such as logging and maintaining drinking water quality, in conflict with one another. In recent years a restricted use policy with some watersheds has gained in popularity.

Restricted Use

Description

The restricted use policy is also called the single use policy. Under this policy the watershed is managed for water quality and quantity as the specific use. The major advantage of this policy is that it normally produces the highest quality of water and offers the best results in protecting public health. There are two major disadvantages. One is the increased cost and effort needed in surveillance of the access into the watershed as well as surveillance of the watershed itself. The second major disadvantage is the public relations problems associated with restricting recreational users and tourists that wish to use the watershed.

Alterations

In most cases where a restricted use policy is in effect, there has been some alteration of the policy to allow limited use of the area for recreation and thus reduce the negative public relations associated with total restriction. One example is a community that gives a set number of access permits to the watershed during hunting season.

Use Agreements

Results

If the utility does not own the watershed, it must have a use agreement with the owner(s). Failure to have a written use agreement places the utility at risk of having the watershed damaged by activities such as road building, logging, or mining. These activities can have a significant negative impact on water quality, resulting in increased treatment costs.

Content

A watershed use agreement should provide details about the types of allowed activities, road building standards, and other standards that must be followed for those activities that may be carried on in the watershed. The agreement must spell out how notification of activities is to be done and within what time frame. The use agreement should be reviewed at least every three years.

Water Rights

Four Doctrines

In the U.S. there are four **doctrines**[4] governing the right to use surface water:

- **Riparian**[5] Doctrine
- Appropriation Doctrine
- Doctrine of Correlative Rights
- Pueblo Rights

Application

The riparian doctrine is found in the states east of the Mississippi River and the appropriation doctrine in the states west of the Mississippi. Pueblo and Correlative Rights are limited to specific communities and states in the western U.S.

Individual States

The descriptions below are general in nature, as each state has specific laws governing the use of water. To be complete this text would have to provide 50 individual discussions. This is beyond the scope of the text. However, an operator should be able to utilize the general information provided below in developing an understanding of the water rights in an individual state or U.S. territory.

Riparian Doctrine

Source

The riparian doctrine is limited to the states east of the Mississippi River and was introduced into Anglo-American law from the French *Code Napoleon* through the writings of Justice Story of the Supreme Court of the U.S. and Chancellor Kent of New York.

Natural Flow

This doctrine is based on the “natural flow” rule. Under this rule only the owners of land next to a stream or lake (called riparian owners) could use water from the stream. However, the water flowing out of their property could not be changed in quantity or quality from what flowed into their property. While this protected water quality, it prevented a riparian

[4] **Doctrine** – A legal doctrine is a body of inter-related rules (usually of common law and built over a long period of time) associated with a legal concept or principle

[5] **Riparian** – An adjective pertaining to anything connected with or adjacent to the banks of a stream or other bodies of water.

owner from removing significant amounts of water from the source, thus limiting its beneficial use.

Reasonable Doctrine

Because the "natural flow" rule makes it impossible to obtain beneficial use of the water, most jurisdictions have adopted what is called the "reasonable use doctrine." Under this doctrine the lower riparian owner is entitled to protection from diversions by upper riparian owners that could adversely interfere with the lower owner's use of the water. This doctrine provides flexibility in water allocation and provides more water for beneficial use.

The Downside

Once an owner begins using water, there is no guarantee water will be available in the future. If upper riparian owners begin using more water for beneficial use, the lower owners are limited in what is available. The major drawback to this doctrine is the inability of anyone, other than riparian owners, to obtain water for beneficial use.

Appropriation Doctrine

Source of Doctrine

The pioneers of the west needed vast amounts of water for mining, farming, and logging. As a result they would at times use force to "appropriate" the water they needed. The current appropriation doctrine used by most western states utilizes a first-in-time, first-in-line appropriation of the water from a lake or stream. That is, anyone may obtain all the water they need for a beneficial use as long as they do not prevent users whose right is dated prior to theirs from obtaining all the water they need.

Quantity Assigned

In most of the western states the quantity of water an individual or organization can take from a water course is based on their ability to show they will use the quantity stated for a beneficial use. What constitutes a beneficial use varies from state to state, but can include recreation, domestic use, farming, municipal use, mining, fisheries, etc.

Correlative Rights

Origin

When some of the western states were admitted to the Union, they adapted the common law of England which included the riparian doctrine. This doctrine so severely limited the ability of the pioneers to put water to a beneficial use, especially for irrigation in California, the water rights for irrigation were changed to correlative rights, which is similar to the reasonable use doctrine.

Structure

Under the correlative rights doctrine, the amount of water a user may take from the stream is dependent upon the needs of all the users. This system considers riparian and non-riparian land that can be served by the watercourse.

Pueblo Rights

Spanish Law

Several of the western states were under Spanish or Mexican control prior to becoming part of the United States. In these areas early settlers established pueblos (municipalities) and adopted Spanish water rights laws. Under these laws the pueblo has a right to any and all water it needs that is “adjacent” to the pueblo. The only constraints on the distance the pueblo can go from the pueblo to obtain water is based on practical engineering. San Diego and Los Angeles have such water rights. These rights, because they existed prior to state hood, take priority over riparian and appropriation rights.

Application of Rights to Utilities

Domestic Use

Except in very few cases, domestic use of water takes precedence over all other beneficial uses throughout the United States, its territories, and protectorates. In many cases the states have made it easy for an individual to protect the water they need for domestic use.

Obtaining a Water Right

In most states, the state has set specific procedures for obtaining and holding a water right. Obtaining a water right requires the individual, municipality, or organization to make an application to obtain a right to use a specific quantity of water for a stated beneficial use, pay a fee, and obtain a “permit” to build an intake structure to obtain water. Once the water is being used, in the quantity stated and for the beneficial use stated, the user provides the state with proof and obtains a documented right to use the water.

Municipalities

In some states, such as Oregon, a municipality may apply for and obtain a permit to use water in the future. The date the permit is issued determines where the municipality ranks in the appropriation.

Available Water

Obtaining a permit or a water right in an appropriation state does not guarantee the user will obtain water. During periods of low flow, the older rights have prior claims to the water. In addition, there may be more rights issued by the state than the stream can supply at low flow. While this problem is being addressed by most of the states, it is not unusual to find a stream has been over appropriated by two or three times its low flow.

Minimum Flow for Fisheries

In many of the western states, the state fisheries agencies have established minimum low flows on streams. These low flows are intended to provide a minimum supply of water to meet the needs of the aquatic life. A minimum flow in these states acts like a water right. Its priority in the system is the same as a water right issued on that date. The exception to this is the Endangered Species Act. Under this act, older water rights may be denied in order to provide adequate flow for fish that are classified as endangered.

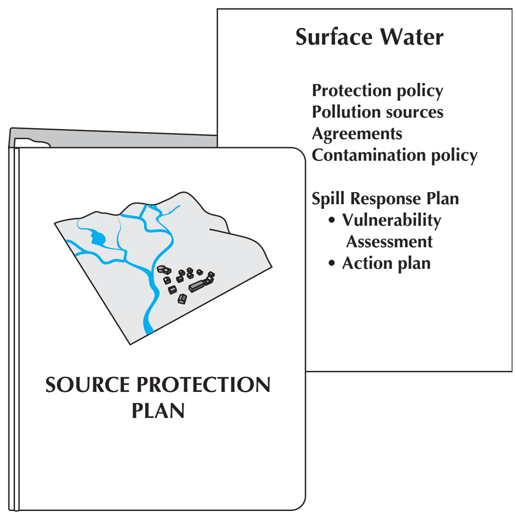
Management Responsibility

It is the responsibility of each utility that obtains surface water to have a registered water right and to know where this right ranks with all of the other rights and claims to the watercourse. The utility has a responsibility to secure enough water for the present and the future to meet the needs of the customers. If adequate supply is not available, the utility has a responsibility to notify the customers, present and future, of the limitation this poses to growth.

Source Protection

Why Develop this Plan?

Water Source Protection Plans are used to maintain good drinking water quality for the future, and to provide a means of educating the community about how their actions impact water quality.



Surface Water System

For surface water systems, the main source protection strategy is control of the activities in the watershed. If the watershed is large, as with the Yukon River, it is not possible to exercise complete control. The tools for protecting such a large watershed are as follows:

- A policy statement that protection of the source is a requirement. This policy is reflected in the utility ordinance and the comprehensive plan.
- Identification of major upstream sources of pollution that could impact the quality or quantity of the source.
- Agreements with those communities and industries upstream whose sewage, industrial discharge, and landfill drainage flows into the water source. These agreements contain provisions on the quantity and

quality of discharges allowed and notification procedures for accidental spills. *In each state the quantity and quality of the discharge is controlled through a discharge permit issued by a state agency.*

- Agreements with other potential polluters that they will notify the utility in case of a spill.
- Agreements with the agencies who regulate water quality, including provisions of what level of pollution is allowable.

Small Watersheds

If the watershed is small enough, the utility can either obtain ownership or develop written agreements with the landowners specifying the types of activities allowed in the watershed. This process must be provided for in the utility ordinance and addressed in the comprehensive plan. In addition, the land-use planning, as described in the comprehensive plan, should be designed to limit activities in the watershed to those that have the least potential to cause pollution or reduce the quantity of water.

Spill Response Plan

Purpose

One of the components of the source protection plan is an action plan for responding to spills of contaminants within the watershed. The plan is a written document containing step-by-step actions that will protect the customers from illness due to a spill.

Components

There are two major components to a spill response plan:

- Vulnerability Analysis
- Action Plan

The vulnerability analysis provides documentation of the potential sources of contamination and the probability of occurrence of a spill from each. The plan contains one or more action plans that address the specific actions to be taken to protect the customers from those contaminants that pose a health hazard and have a high potential to spill into the sources.

Not All Addressed

The plan does not address all possibilities or all sources of contamination. If there is a one in one million probability of occurrence of a specific contaminant, it may not be necessary to develop an action plan. However, if the contaminant provides a significant health risk, then an action plan may be desirable. The determination of which action plans to develop is based on the vulnerability analysis.

Routine Operation in the Watershed

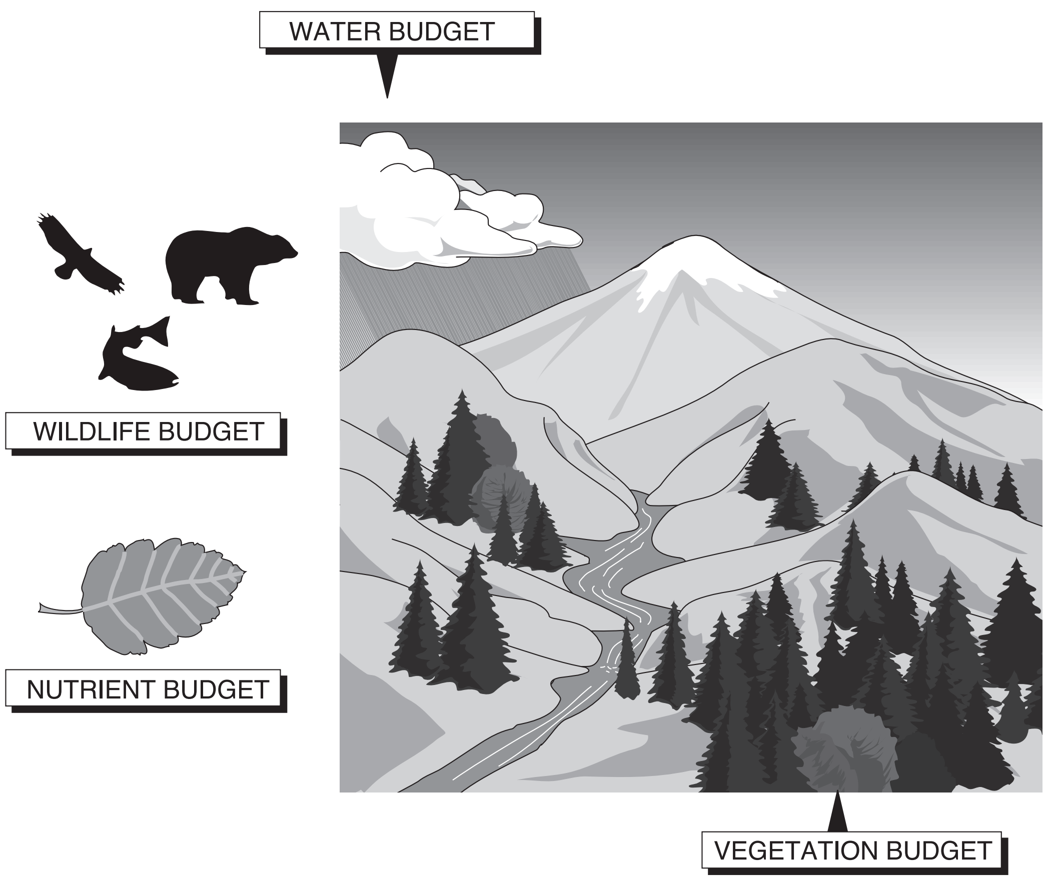
Impacts on the Drainage Basin

Budgets in General

The watershed and the water quality are impacted by a number of factors such as the amount and type of vegetation, wildlife, and water. These factors are called budgets. The following is a brief overview of the four major budgets that impact water quantity and quality in a drainage basin.

Vegetation Budget

The vegetation budget includes all of the vegetation in the watershed. The growth or removal of vegetation in the watershed can directly affect the amount of soil, organic material, or contaminants that are carried away during a rain storm or snow melt. The vegetation can also impact other components of the watershed including stream temperature and the quantity of nutrients that enter the water. The nutrient level directly affects **algae**[5] growth and, thus, dissolved oxygen levels and odor and taste considerations. Of special interest to the hydrologist is the vegetation next to the stream. This vegetation is called the riparian vegetation and has direct impact on the stream temperature and on holding the stream banks stable during high water.



[5] **Algae** - Microscopic plants which contain chlorophyll and live in water.

Nutrient Budget

The amount of nutrients in a watershed affects the growth of vegetation as well as impacting algae growth in streams and reservoirs. Algae growth in streams, rivers, and reservoirs can impact the level of dissolved oxygen and odor and taste of the water.

Wildlife Budget

Most watersheds are a delicately balanced ecosystem. The wildlife is a part of that ecosystem and can have positive and negative impacts on water quality. Wildlife can be a positive contribution to recreational activities while at the same time contribute to increases in pathogenic organisms such as Giardia.

Water Budget

Of all the budgets, the water budget has the greatest impact and is the most important to the waterworks operator. The water budget's two main components are precipitation and stream flows. In well run water systems that utilize surface water, both of these components are routinely measured and analyzed. Also, it is becoming common for systems utilizing groundwater to measure the precipitation in the recharge area.

Data Collection

Baseline Data

The initial gathering of physical information, observing the impact of the budgets, precipitation data, flow data, and water quality data are called baseline data. This data is essential for long term planning and determining the impact of activities in a drainage basin. Baseline data collection is part of a well run watershed management program.

Large Streams

The approach described below is based on the assumption that the watershed is small enough to be managed by the utility. If the utility is obtaining water directly from a large river such as the Mississippi, it is not feasible to apply this process as described. In this case, an attempt should be made to manage the water quality "one day" upstream from the intake. "One day" is the distance water will normally flow in a days time.

Physical Information

Using the Map

The development of a master map of the watershed is a part of initial baseline data collection. This map will contain much of the information needed to assist in managing the watershed. Below are some of the items that should be included on the map:

- Outline of the watershed.
- Order of the stream segments.
- Identification of the various owners of land within the watershed.
- All roads and railroads within the watershed are clearly marked.

- The intake marked
- Mark all locations used to collect chemical and bacteriological **raw water**[6] samples and note the GPS coordinates.
- Identification of all actual and potential sources of contamination. These sources should be marked as either natural or man-made. Typical sources are as follows:
  - ❑ Natural
    - ✓ Sources of high iron content, as observed by iron slime adjacent to or in the stream.
    - ✓ Sources of color, such as decaying organic material, runoff from muskeg ponds, etc.
    - ✓ Sources of turbidity, such as land slides, unstable ground, stream banks that have deteriorated, wildlife stream crossings, etc.
    - ✓ Sources of natural radioactivity or other minerals that may deteriorate the quality of the water.
  - ❑ Man-made
    - ✓ Roads
    - ✓ Mines
    - ✓ Logging activities
    - ✓ Fuel storage
    - ✓ Solid waste disposal
    - ✓ Sewage treatment plants
    - ✓ Septic tanks
    - ✓ Military sites, existing and abandoned
    - ✓ Agricultural areas

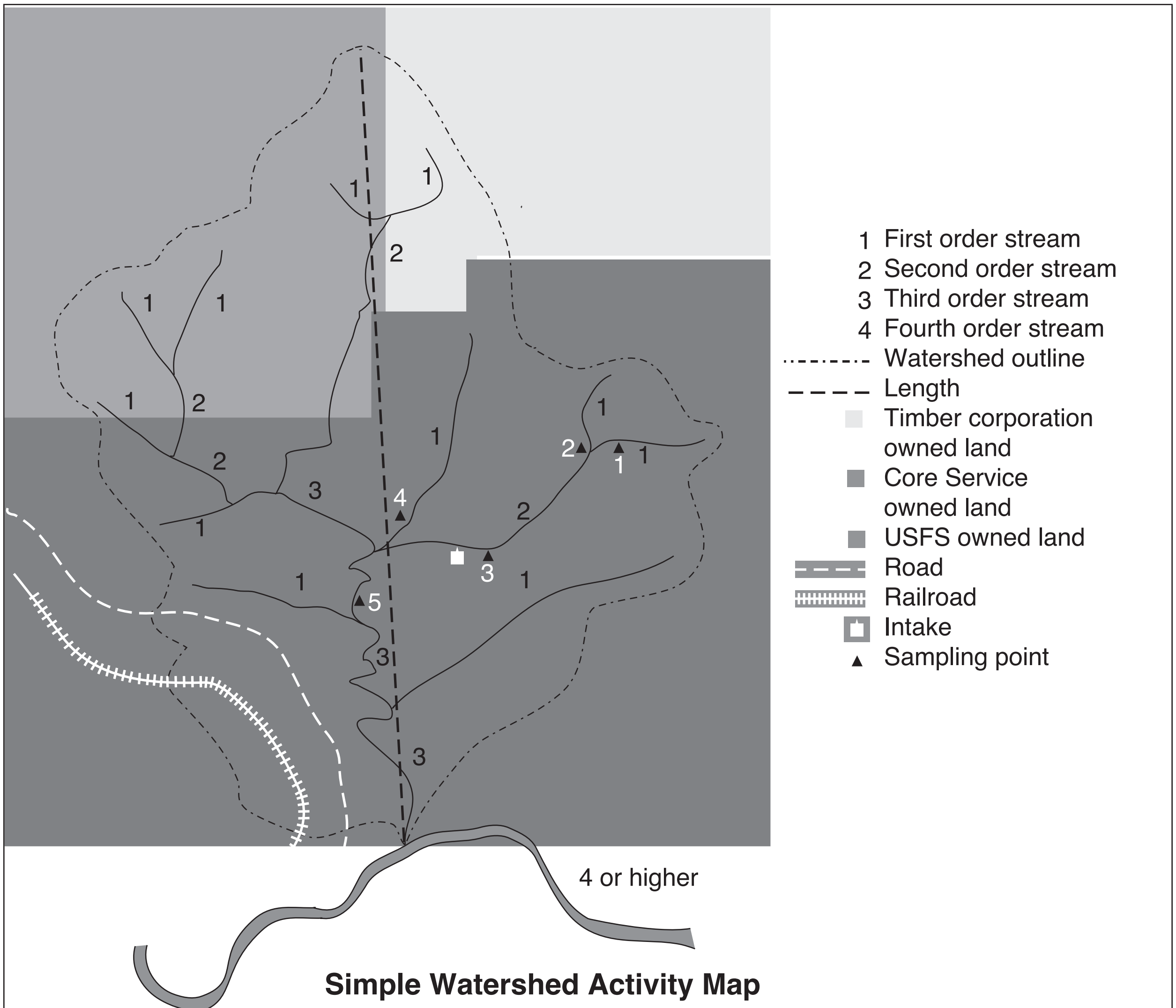
Support Document

A document containing key elements of the physical description should be developed along with the map. Some of the key elements in this document are:

- A written description of the watershed using the public land survey system.
- Calculation of the area of the watershed.
- The length, width, and slope of the watershed.
- A written physical description of the location of the intake using the public land survey system and the GPS coordinate system.

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

- A written description of any portion of the watershed not owned by the utility.



Simple Watershed Activity Map

Using GIS

The clutter resulting from a composite map may produce a confusing presentation. The confusion may be reduced by using plastic overlays for each major category of data or by placing this information in a GIS system and using different layers for the different categories of data.

Stream Condition

Evaluation Tool

Baseline data on the condition of most of the streams within a watershed should be obtained and analyzed. The same data should be collected once each year and compared to the baseline date. The U.S. Forest Service has developed a tool for evaluating the condition of streams for fisheries that is an excellent tool for the evaluation of streams used as a water source. This tool was selected on the basis that if a water source is good for fisheries, it is most likely a good potable water source.

What We Evaluate

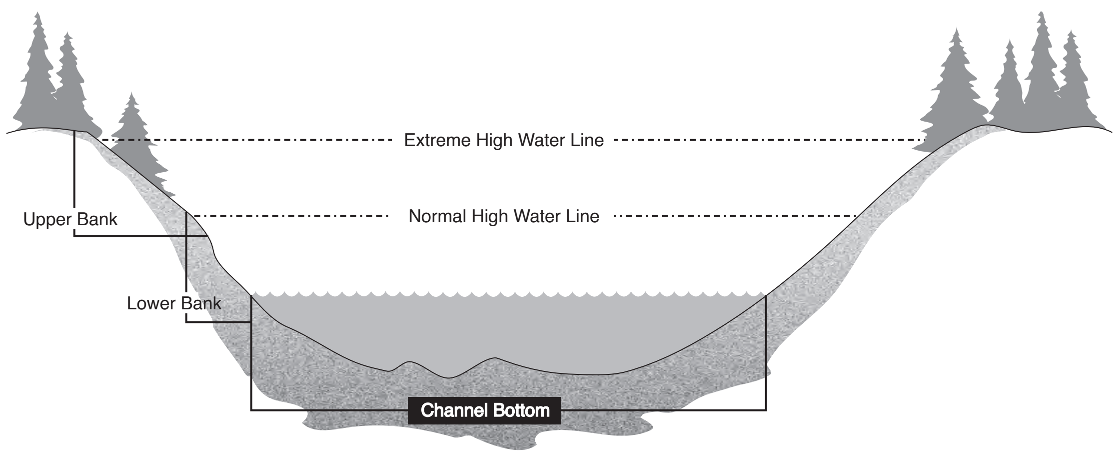
The tool is used by walking the stream and evaluating each **stream reach**[7] to determine how it will impact water quality. The condition of the upper bank, lower bank, and channel bottom are evaluated.

Upper Bank

The upper bank is the section of the bank between the normal and the extreme high water levels. This area is evaluated for vegetation, debris, and potential for contributing to turbidity.

Lower Bank

The lower bank is the area between the normal stream level and the normal high water level. This area is evaluated for flow restrictions, sediment, erosion, and stream capacity.



Channel Bottom

The channel bottom is evaluated for the condition and color of the rocks, amount of aquatic vegetation, size and distribution of rocks, and the quantity of debris.

Stream Beds Conditions

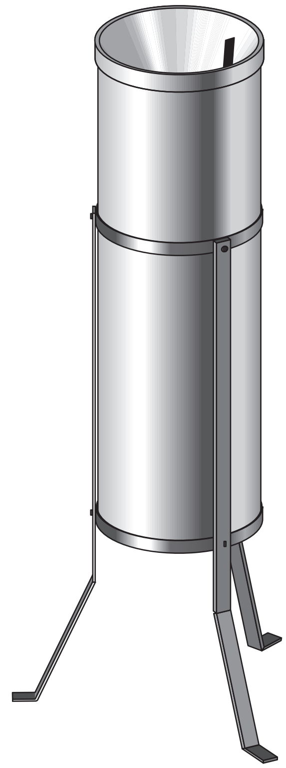
The quantity, size, and shape of rocks and silt in a stream bed is referred to as the **bed load**[8]. A high bed load would be a stream bed that moves easily during a high flow and a low bed load would be a stream bed that moves very little, even at high flow. High bed load streams can clog intakes and infiltration galleries, increasing operating labor costs.

[7] **Stream Reach** – A segment of a stream. There is no definite length to the segment. For the purpose of this evaluation, a reach is a segment of stream that is more-or-less uniform and can be seen from a single location in the stream.

[8] **Bed Load** - A measurement of the material on the bottom of the stream which can be moved by the force of the water, but is not suspended by the water.

Result

The result of this evaluation is a numeric score used to determine the probability of each reach of the stream in providing high quality water.



Can Type Rain Gauge

Precipitation

Hydrological Event

Precipitation, the melting of snow in the spring, and the seasonal low flow of a stream are **hydrological events**[9] that need to be tracked by the utility. Determining the frequency and magnitude of hydrological events within the watershed are typical activities of a well managed surface water source utility. The two most important data components required for a hydrological event are precipitation and the related steam flow.

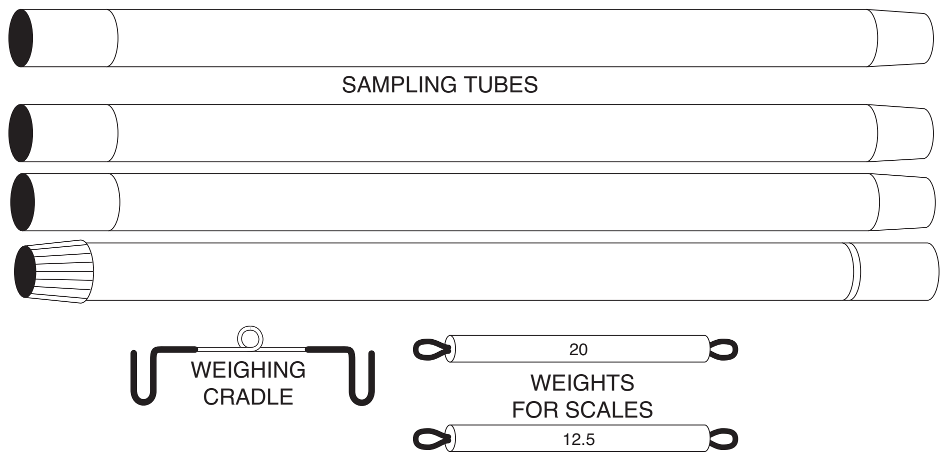
Precipitation Measurements

Precipitation in all of its forms is measured with a rain gauge. Rain gauges can be simple volume devices that are read manually or they can be automatic devices that electronically measure volume or weight. If the automatic equipment is not available, a simple "can type" rain gauge can be used to determine rainfall. A rain gauge should be installed at an easily accessible location within the watershed. If the watershed is large, more than one gauge will be desirable. Manual gauges must be read daily. Automatic gauges can collect data for months at a time or can be setup to transmit data to a satellite for retrieval from the utility office.

Snowpack Data

The measurements of the depth of a snowpack and the quantity of water it contains, like rain fall, are obtained either manually or electronically. Snowpack data can be collected by obtaining two pieces of data. First, measure the depth of each event. Second, measure the weight of snow after each event. This can be accomplished by simply gathering a sample of the snow using a piece of 2 inch thin wall pipe. The pipe is weighed, then pushed down through the snow until it touches the ground. The pipe and snow are carefully removed, any soil collected in the bottom of the pipe is removed, and the pipe with the snow are weighed. The difference between the two weights is the weight of the snow. The weight is converted to an equivalent amount of water.

[9] **Hydrologic event**—An event that is associated with precipitation. Typical events include rain storms, thunder storms, snow fall or snow melt.



Use of Snow Data

While this data is not directly usable to the operator, it can be very useful to a hydrologist in attempting to determine the amount of moisture available in the area. The collection of snowpack data is not normally part of the activities performed by the utility.

Evaluation of Data

A routine evaluation of precipitation, snow melt, and stream flow data would include a comparison of actual runoff to what was predicted using the U.S. Soil Conservation Service hydrologic soil type data. Below is an example of how total runoff can be estimated using this data.

Math Practice

A watershed is composed of 120 acres. A rain storm of 0.5 inches was measured in the watershed. If 15% of this rainfall becomes runoff, how many gallons of water are produced? (The 15% is obtained from U.S. Soil Conservation data)

120 acres X 43,560 ft^2/acre = 5,227,200 ft^2

0.5 inches of rain X 0.15 915% = 0.075 inches of water

0.075 inches/12 inches per foot = 0.00625 feet

5,227,200 ft^2 X 0.00625 ft = 32,670 ft^3 of water

32,670 ft^3 X 7.48 gal/ft^3 = 244,372 gallons

Flow Measurements

Introduction

The flow in a stream or river can be measured using a primary device such as a **weir**[10] or **flume**[11] on small streams or a secondary device called current meter on a larger stream.

Weirs

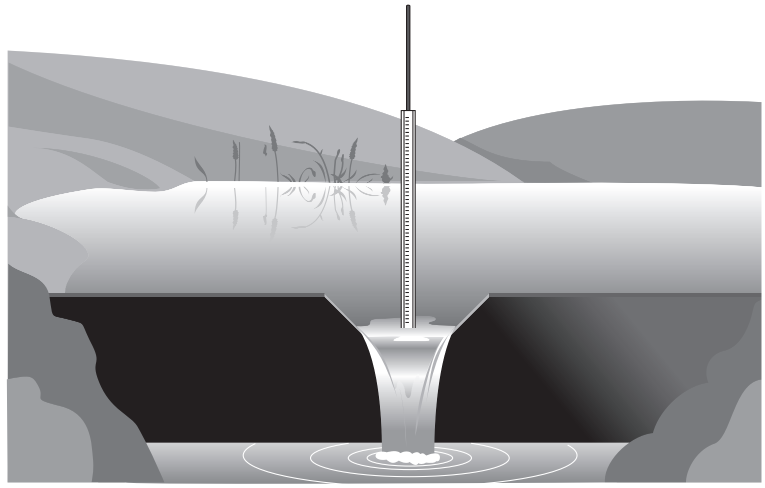
Weirs - Description

A weir is a plate made of wood or metal. The most popular weir plates used in small streams are made from three-quarter inch plywood. These plates are placed plumb and level in the stream. Because the

[10] **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.

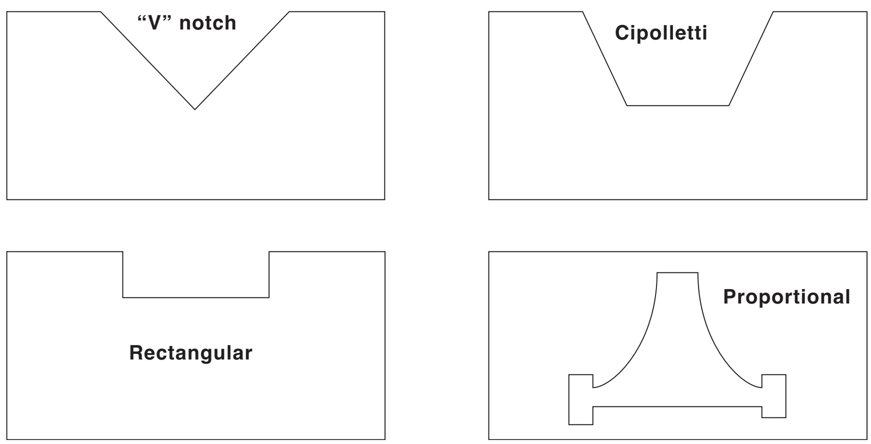
[11] **Flume** - An open conduit made of wood, masonry, or metal and constructed on grade, used to transport water or measure flow.

plates are typically only used during low flows, they are installed in a temporary manner, using rocks down stream of the plate to hold the plate and using Visqueen™ behind the plate as a seal on the stream bottom and the back of the plate.



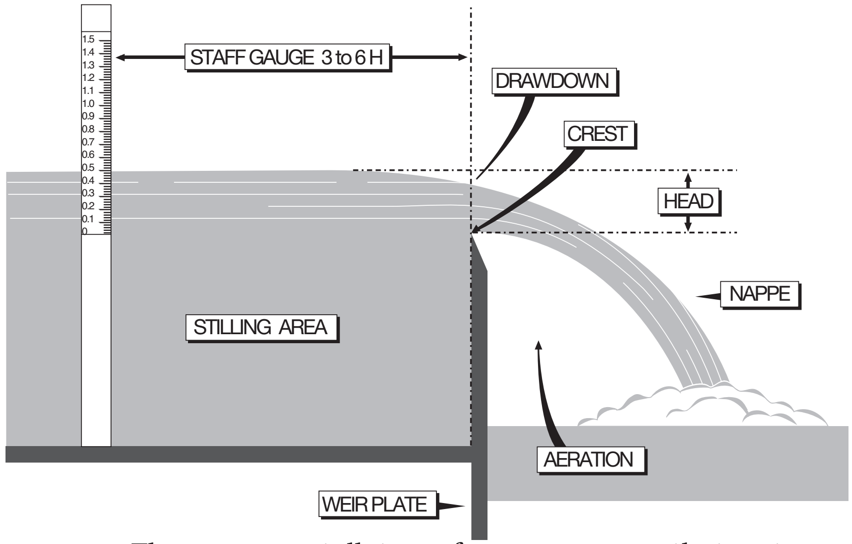
Weir Types

The weirs used in measuring stream flows are commonly called shape crested weirs. They are identified by their shape. Typical shapes are rectangular, “V’” notch, proportional, and cipolletti. The “V” notch and the cipolletti are the most common.



Weir Installation Components

The weir itself is called a weir plate. The top of the weir is the crest. The height of water above the weir is called the head (H). The device used to determine the head on a weir is called the staff gauge. The staff gauge is placed upstream from the weir plate to three to six times the maximum expected head. This is done to overcome the results of drawdown. Drawdown is the difference between the head upstream of the weir and the head directly over the weir plate. As water approaches the weir plate, the water level falls (the amount of the fall is called drawdown). The water that flows over the weir plate is called the nappe.



Weir Operation

The proper installation of a weir requires that certain dimensions be maintained. For instance, the stilling area behind the weir must have a length of at least six times the maximum head (height) of water expected over the weir plate. The water flowing over the plate must have sufficient fall to be aerated. The flow through a weir plate is determined by measuring the head (height) of water flowing over the weir. This measurement is normally taken from a staff gauge placed three to six times the maximum head expected over the weir back of the weir plate, The flow can then be determined using a formula or a table.

From Head to Flow

Staff gauges are usually marked off in feet and tenths of feet, not feet and inches. This makes it

Discharge of 90° V–Notch Weir

Formula CFS = 2.50 $H^{5/2}$ **MGD = CFS X 0.646317**

Head	0.00		0.01		0.02		0.03		0.04		0.05		0.06		0.07		0.08		0.09	
Ft	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD
0.1	.008	.005	.010	.006	.012	.008	.015	.010	.018	.012	.022	.014	.026	.017	.030	.019	.034	.022	.039	.025
0.2	.045	.029	.051	.033	.057	.037	.063	.041	.071	.046	.078	.050	.086	.056	.095	.061	.104	.067	.113	.073
0.3	.123	.080	.134	.086	.145	.094	.156	.101	.169	.109	.181	.117	.194	.126	.208	.135	.223	.144	.237	.153
0.4	.253	.163	.269	.174	.286	.185	.303	.196	.321	.207	.340	.219	.359	.232	.379	.245	.399	.258	.420	.272
0.5.	.442	.286	.464	.300	.487	.315	.511	.330	.536	.346	.561	.362	.587	.379	.613	.396	.640	.414	.668	.432
0.6	0.67	.451	.727	.470	.757	.489	.788	.509	.819	.529	.852	.550	.885	.579	.919	.594	.953	.616	.989	.639
0.7	1.02	.662	1.06	.686	1.10	.711	1.14	.736	1.18	.761	1.22	.787	1.26	.814	1.30	.841	1.34	.868	1.39	.896
0.8	1.43	.925	1.48	.954	1.52	.984	1.57	1.01	1.62	1.04	1.66	1.08	1.71	1.11	1.76	1.14	1.82	1.17	1.87	1.21
0.9	1.92	1.24	1.97	1.28	2.03	1.31	2.08	1.35	2.14	1.38	2.20	1.42	2.26	1.46	2.32	1.59	2.38	1.54	2.44	1.58
1.0	2.50	1.62	2.56	1.66	2.63	1.70	2.69	1.74	2.76	1.78	2.82	1.82	2.89	1.87	2.96	1.91	3.03	1.96	3.10	2.00
1.1	3.17	2.05	3.24	2.10	3.32	2.14	3.39	2.19	3.47	2.24	3.55	2.29	3.62	2.34	3.70	2.39	3.78	2.44	3.86	2.50
1.2	3.94	2.55	4.03	2.60	4.11	2.66	4.19	2.71	4.28	2.77	4.37	2.82	4.45	2.88	4.54	2.94	4.63	2.99	4.72	3.05
1.3	4.82	3.11	4.91	3.17	5.00	3.23	5.10	3.30	5.20	3.36	5.29	3.42	5.39	3.48	5.49	3.55	5.59	3.61	5.69	3.68
1.4	5.80	3.75	5.90	3.81	6.01	3.88	6.11	3.95	6.22	4.02	6.33	4.09	6.44	4.16	6.55	4.23	6.66	4.30	6.77	4.38
1.5	6.89	4.45	7.00	4.53	7.12	4.60	7.24	4.68	7.36	4.75	7.48	4.83	7.60	4.91	7.72	4.99	7.84	5.07	7.97	5.15
1.6	8.09	5.23	8.22	5.31	8.35	5.40	8.48	5.48	8.61	5.56	8.74	5.65	8.88	5.74	9.01	5.82	9.15	5.91	9.28	6.00
1.7	9.42	6.09	9.56	6.18	9.70	6.27	9.84	6.36	9.98	6.45	10.1	6.55	10.3	6.64	10.4	6.73	10.6	6.83	10.7	6.93
1.8	10.9	7.02	11.0	7.12	11.2	7.22	11.3	7.32	11.5	7.42	11.6	7.52	11.8	7.62	11.9	7.73	12.1	7.83	12.3	7.93
1.9	12.4	8.04	12.6	8.15	12.7	8.25	12.9	8.36	13.1	8.47	13.3	8.58	13.4	8.69	13.6	8.80	13.8	8.91	14.0	9.03
2.0	14.1	9.14	14.4	9.25	14.5	9.37	14.7	9.49	14.9	9.60	15.0	9.72	15.2	9.84	15.4	9.96	15.6	10.1	15.8	10.2

Stevens Water Resources Data Book 8th Ed much easier to use an equation or table to determine the flow. Below is a table providing flow through a 120° V-Notch weir. The table is based on the formula, CFS = 4.33 H $^{5/2}$Tables are produced for all the common weirs.

Using the Table

To read the table above first note the two axis. The vertical axis gives head over the weir in feet and tenths of feet. The horizontal axis gives head over the weir in hundreds of a foot. Flow is provided in CFS (cubic feet per second) and MGD (million of gallons per day).

Examples

Find the flow through a 120° sharp crested weir when the head is 0.54 feet.

Find the head of 0.5 feet along the vertical axis and 0.04 along the horizontal axis.

Discharge of 120° V–Notch Weir

Formula CFS = 4.33 H$^{5/2}$ **MGD = CFS X 0.646317**

Head	0.00		0.01		0.02		0.03		0.04		0.05		0.06		0.07		0.08		0.09	
Ft	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD
0.1	,014	.009	.017	.011	.022	.014	.026	.017	.032	.021	.038	.024	.044	.029	.052	.0.33	.060	.038	.068	.044
0.2	.077	.050	.088	.057	.098	.064	.011	.071	.122	.079	.135	.087	.149	.096	.164	.106	.180	.166	.196	.127
0.3	.213	.138	.232	.150	.251	.162	.271	.175	.292	.189	.314	.203	.337	.218	.361	.233	.385	.249	.411	.266
0.4	.438	.283	.466	.301	.495	.320	.525	.339	.556	.359	.588	.380	.621	.402	.656	.424	.691	.447	.728	.470
0.5	.765	.495	.804	.520	.844	.546	.886	.572	.928	.600	.971	.628	1.02	.657	1.06	.686	1.11	.717	1.16	.748
0.6	1.21	.780	1.26	.813	1.31	.847	1.36	.882	1.42	.917	1.48	.953	1.53	.990	1.59	1.03	1.65	1.07	1.71	1.11
0.7	1.78	1.15	1.84	1.19	1.90	1.23	1.97	1.27	2.04	1.32	2.11	1.36	2.18	1.41	2.25	1.46	2.33	1.50	2.40	1.55
0.8	2.48	1.60	2.56	1.65	2.64	1.70	2.72	1.76	2.80	1.81	2.88	1.86	2.97	1.92	3.06	1.98	3.15	20.3	3.24	2.09
0.9	3.33	2.15	3.42	2.21	3.52	2.27	3.16	2.33	3.71	2.40	3.81	2.46	3.91	2.53	4.01	2.59	4.12	2.66	4.22	2.73
1.0	4.33	2.80	4.44	2.87	4.55	2.94	4.66	3.01	4.78	3.09	4.89	3.16	5.01	3.24	5.13	3.31	5.25	3.39	5.37	3.47
1.1	5.50	3.55	5.62	3.63	5.75	3.72	5.88	3.80	6.01	3.88	6.14	3.97	6.28	4.06	6.41	4.14	6.55	4.23	6.69	4.32
1.2	6.83	4.41	6.97	4.51	7.12	4.60	7.27	4.70	7.41	4.79	7.56	4.89	7.72	4.99	7.87	5.09	8.03	5.19	8.18	5.29
1.3	8.34	5.36	8.51	5.50	8.67	5.60	8.83	5.71	9.00	5.82	9.17	5.93	9.34	6.04	9.51	6.15	9.69	6.26	9.86	6.38
1.4	10.0	6.49	10.2	6.61	10.4	6.72	10.6	6.84	10.8	6.96	11.0	7.09	11.2	7.21	11.3	7.33	11.5	7.46	11.7	7.58
1.5	11.9	7.71	12.1	7.84	12.3	7.97	12.5	8.10	12.7	8.24	13.0	8.37	13.2	8.51	13.4	8.64	13.6	8.78	13.8	8.92
1.6	14.0	9.06	14.2	9.20	14.5	9.35	14.7	9.49	14.9	9.64	15.1	9.79	15.4	9.94	15.6	10.1	15.8	10.2	16.1	10.4
1.7	16.3	10.6	16.6	10.7	16.8	10.9	17.1	11.0	17.3	11.2	17.5	11.3	17.8	11.5	18.1	11.7	18.3	11.8	18.6	12.0
1.8	18.8	12.2	19.1	12.3	19.4	12.5	19.6	12.7	19.9	12.9	20.2	13.0	20.4	13.2	20.7	13.4	21.0	13.6	21.3	13.7
1.9	21.6	13.9	21.8	14.1	22.1	14.3	22.4	14.5	22.7	14.7	23.0	14.9	23.3	15.1	23.6	15.2	23.9	15.4	24.2	15.6
2.0	24.5	15.8	24.8	16.0	25.1	16.2	25.4	16.4	25.7	16.6	26.1	16.8	26.4	17.1	27.0	17.3	27.0	17.5	27.3	17.7

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Run a line horizontally from the 0.5 feet and vertically from the 0.04 feet. At the intersection of these two lines the flow in CFS and MGD can be read.

The flow is 0.928 CFS or 0.600 MGD

Formulas and Tables

Formulas and flow tables are produced for each specific type of weir. (See the appendix for sources.)

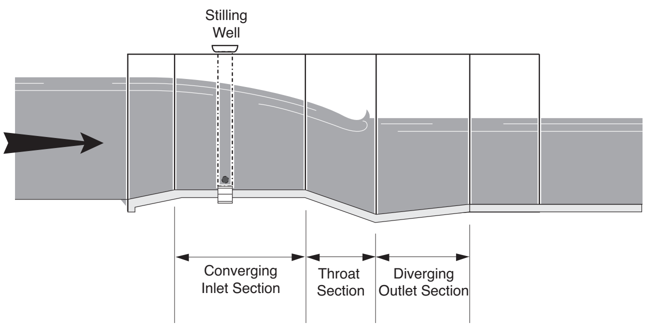
Flumes

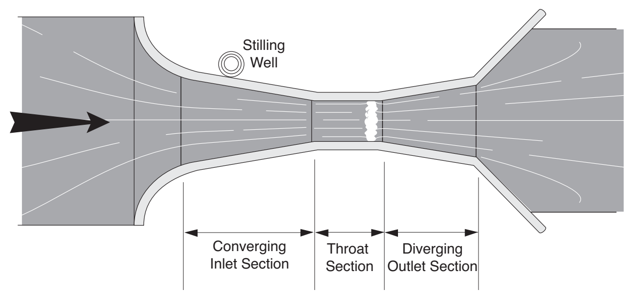
Advantages

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 an obstacle to the fish in 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**[12]. The Parshall flume is the most common and is also used in water and wastewater treatment plants to measure flow.





Staff Gauge

The quantity of water passing through the flume is determined by comparing the reading of a staff gauge located in the stilling well with a standard table. Because the table can be defined mathematically it is possible to obtain the head readings electronically and allow a computer to convert them to flow in cfs, MGD, gpd, etc.

Using the Table

To read the table on the next page, first note the two axis. The vertical axis gives head in the stilling well in tenths of feet. The horizontal axis gives the width of the throat of the flume in feet. Flow is provided in CFS (cubic feet per second) and MGD (million *of* gallons per day).

Examples

Find the flow through a 3 foot Parshall flume when the head is 0.26 feet.

Find the head of 0.26 feet along the vertical axis and throat size of 3 feet along the horizontal axis.

Run a line horizontally from the 0.26 feet and vertically from the 3 foot throat. At the intersection of these two lines the flow in CFS and MGD can be read.

The flow is 1.46 CFS or 0.94 MGD

Tables

Flow tables are produced for each specific type of flume.(See the appendix for sources of tables.)

[12] **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.

Flow through Parshall Measuring Flumes

Discharge through throat width, W of -

Head	2 ft		3 ft		4 ft		5 ft		6 ft		8 ft		10 ft	
Ft	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD	CFS	MGD
0.20	.66	.43	.96	.62	1.26	.81								
0.21	.71	.46	1.04	.67	1.36	.88								
0.22	.77	.50	1.12	.72	1.47	.95								
0.23	.82	.53	1.20	.78	1.57	1.01								
0.24	.88	.57	1.28	.83	1.68	1.09								
0.25	.93	.60	1.37	.89	1.80	1.16	2.22	1.43	2.63	1.70				
0.26	.99	.64	1.46	.94	1.91	1.23	2.36	1.53	2.80	1.81				
0.27	1.05	.68	1.54	1.00	2.03	1.31	2.50	1.62	2.97	1.92				
0.28	1.11	.72	1.63	1.05	2.15	1.39	2.65	1.71	3.15	2.04				
0.29	1.17	.76	1.73	1.12	2.27	1.47	2.80	1.81	3.33	2.15				
0.30	1.24	.80	1.82	1.18	2.39	1.54	2.96	1.91	3.52	2.28	4.63	2.99	5.74	3.71
0.31	1.30	.84	1.92	1.24	2.52	1.63	3.12	2.02	3.71	2.40	4.88	3.15	6.05	3.91
0.32	1.37	.89	2.01	1.30	2.65	1.71	3.28	2.12	3.90	2.52	5.13	3.32	6.36	4.11
0.33	1.44	.93	2.11	1.36	2.78	1.80	3.44	2.22	4.10	2.65	5.39	3.48	6.68	4.32
0.34	1.50	.97	2.22	1.43	2.92	1.89	3.61	2.33	4.30	2.78	5.66	3.66	7.01	4.53
0.35	1.57	1.01	2.32	1.50	3.05	1.97	3.78	2.44	4.50	2.91	5.92	3.83	7.34	4.74
0.36	1.64	1.06	2.42	1.56	3.19	2.06	3.95	2.55	4.71	3.04	6.20	4.01	7.68	4.96
0.37	1.71	1.11	2.53	1.64	3.33	2.15	4.13	2.67	4.92	3.18	6.48	4.19	8.02	5.18
0.38	1.79	1.16	2.64	1.71	3.48	2.25	4.31	2.79	5.13	3.32	6.76	4.37	8.37	5.41
0.39	1.86	1.20	2.75	1.78	3.62	2.34	4.49	2.90	5.35	3.46	7.05	4.56	8.73	5.64
0.40	1.93	1.25	2.86	1.85	3.77	2.44	4.68	3.02	5.57	3.60	7.34	4.74	9.09	5.88

Discharge Measurements

Many streams are too large to accommodate the use of primary measuring devices such as weirs and flumes. Stream flows in these larger streams are determined using a process called **discharge measurements**[13].

General Process

In this process the stream is divided into segments*. The depth, width, and **velocity**[14] are determined in each segment. By measuring the depth, width, and velocity, the flow in cfs for each segment can be calculated using the flow equation $Q = VA$. (Q is the flow in cubic feet per second (cfs), V is velocity in feet per second, and A is the area in square feet (A = depth X width)). The flows through all the segments are added together to determine the total flow of the stream.

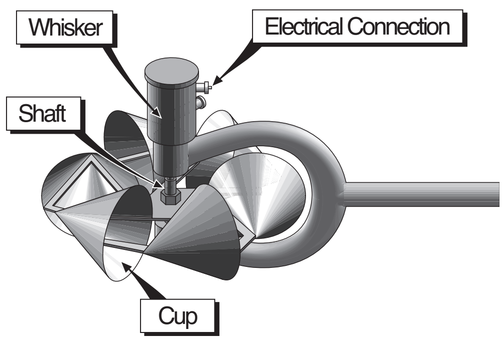
Velocity Meters

The device used to measure the velocity of each stream segment is called a velocity meter. There are electronic and mechanical velocity meters. The most common mechanical velocity meter is composed of a set of cups on a shaft mounted between two bearings. Flowing water fills the cups and causes the shaft to

* USGS prefers to divide the stream into 32 individual segments,working from one bank to the other.

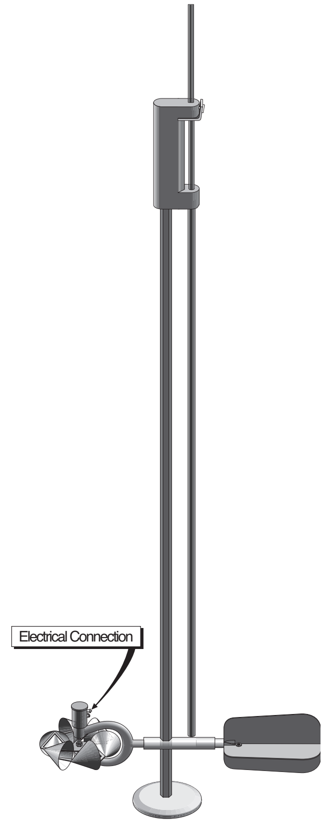
[13] **Discharge Measurement** - A process of measuring stream flow. The stream is divided into segments, at least 20. The average velocity for each segment is measured using a current meter and the flow through the stream calculated using the formula Q=VA.

[14] **Velocity** - The speed at which water moves, expressed in feet per second.

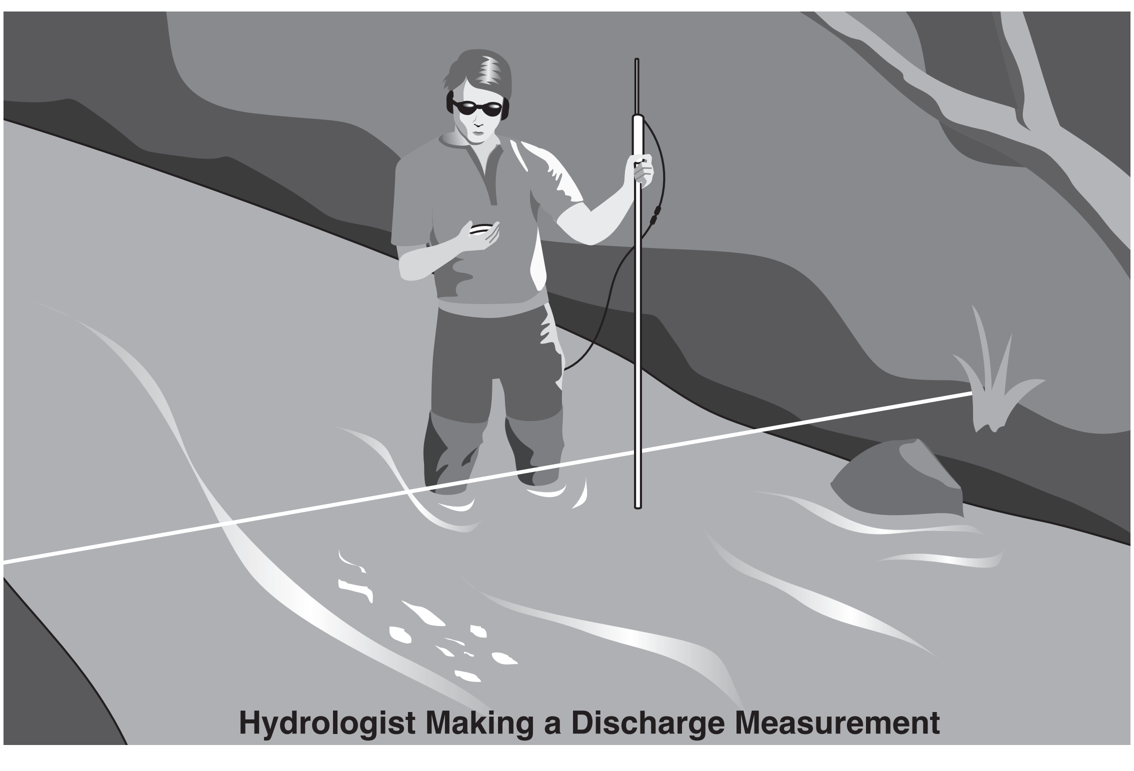


Price Current Meter

turn. There are two classic velocity meters that look much like a wind gauge. They are called "Price" and "Pygmy" meters. The Price is much larger and is shown on this page. The cups turn a cam that contacts a small wire called a whisker. A nine volt battery is connected between the cam and the whisker. When the cam contacts the whisker, a "click" is heard or a signal is used to move an electronic counter. The number of "clicks" within a set period of time is used, along with a table, to determine the velocity. The natural difficulty of making measurements accurately using these devices provided an opportunity for the development of solid state velocity meters. These devices sense the motion of the water and convert the data directly into a velocity reading.

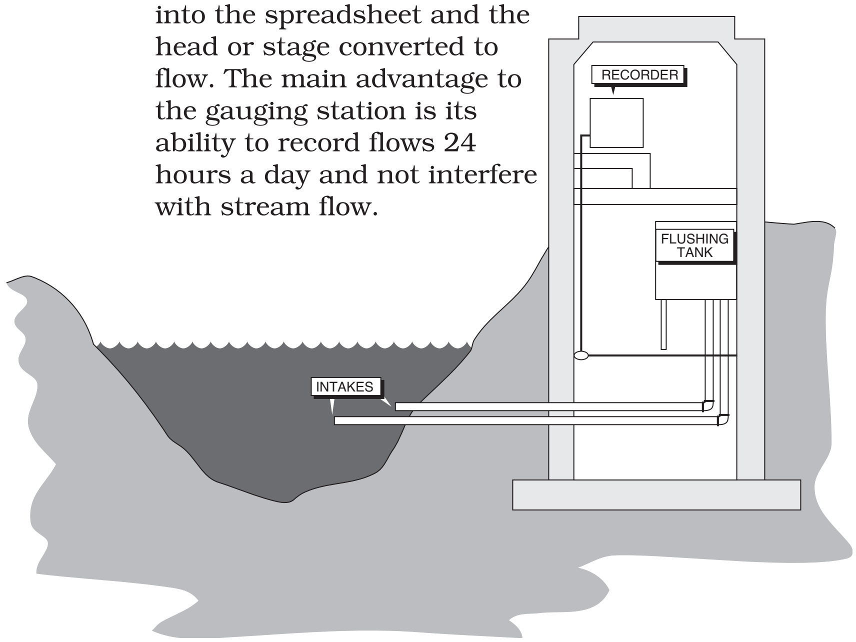


Price Current Meter & Wading Rod


Hydrologist Making a Discharge Measurement

Gauging Stations

Discharge measurements are made over time to determine the flow for various stream depths (called stages). Once sufficient measurements relative to the stream depths have been made, the process can be automated by using a gauging station that automatically records stream stage. The stream height (stage) is converted to flow by use of a formula derived specifically for the stream. Using a float system and a chart recorder or an electronic "data logger," the head over a weir or flume, or the stream stage is recorded. The electronic device is battery operated and can be set to gather data for weeks at a time. An electronic card containing the data is exchanged and inserted into a special reader where the data is transferred to a spreadsheet where the head or stage can be observed an read directly or the proper formula can be entered into the spreadsheet and the head or stage converted to flow. The main advantage to the gauging station is its ability to record flows 24 hours a day and not interfere with stream flow.



Graph of Data

If the discharge or the stream stage is plotted against time a graph is produced. This graph is called a **hydrograph**[15]. The hydrograph is a useful tool in analyzing the impact a hydrological event (rain storm or snow melt) has on stream conditions. On the next page is an example of a hydrograph based on a single hydrological event. The event, a rainstorm, is shown as a bar graph.

Hydrograph Terminology

The following terminology is used to describe the components of a hydrograph.

A – Discharge. This is the flow in cfs (cubic feet per second).This could discharge in cubic meters per second or stage height in feet or meters.

[15] **Hydrograph**—A record and graphical representation of discharge as a function of time at a specific location, for example, the discharge at a point in a stream or the discharge from a pumping well.

B – Time in hours – This could be minutes or days.

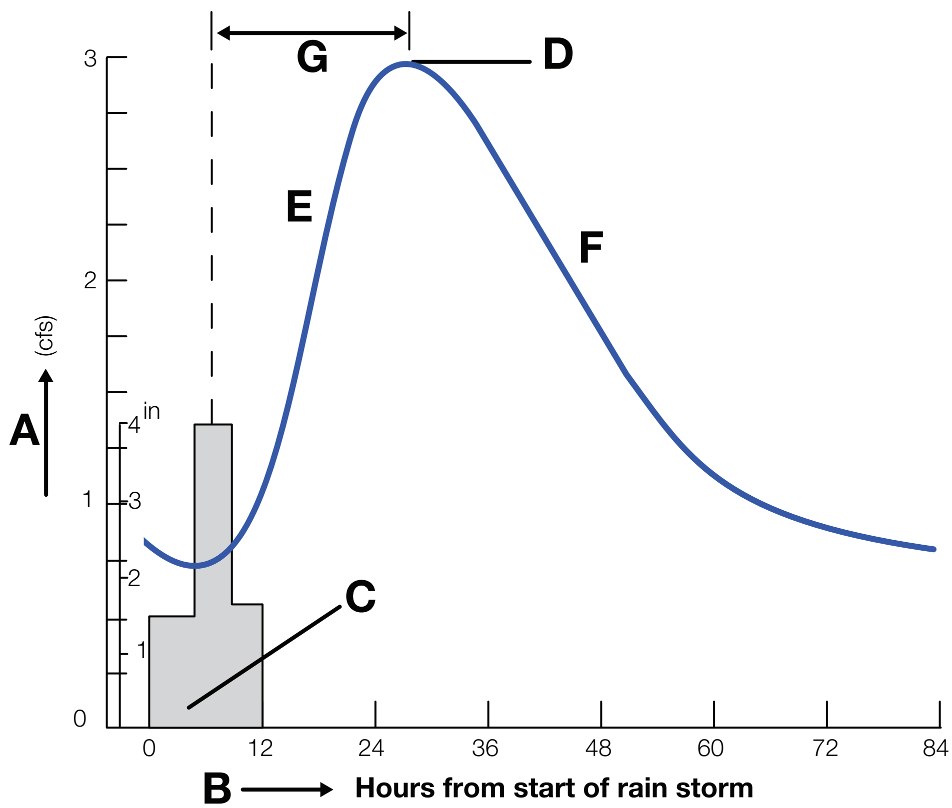
C – Rain fall in inches – This is the total accumulated for each period of time.

D – Peak Discharge. This is the very highest point to which the river discharge reaches.

E – Rising Limb. The discharge at this point is rising.

F – Recession Limb (or falling limb). The discharge at this point is falling.

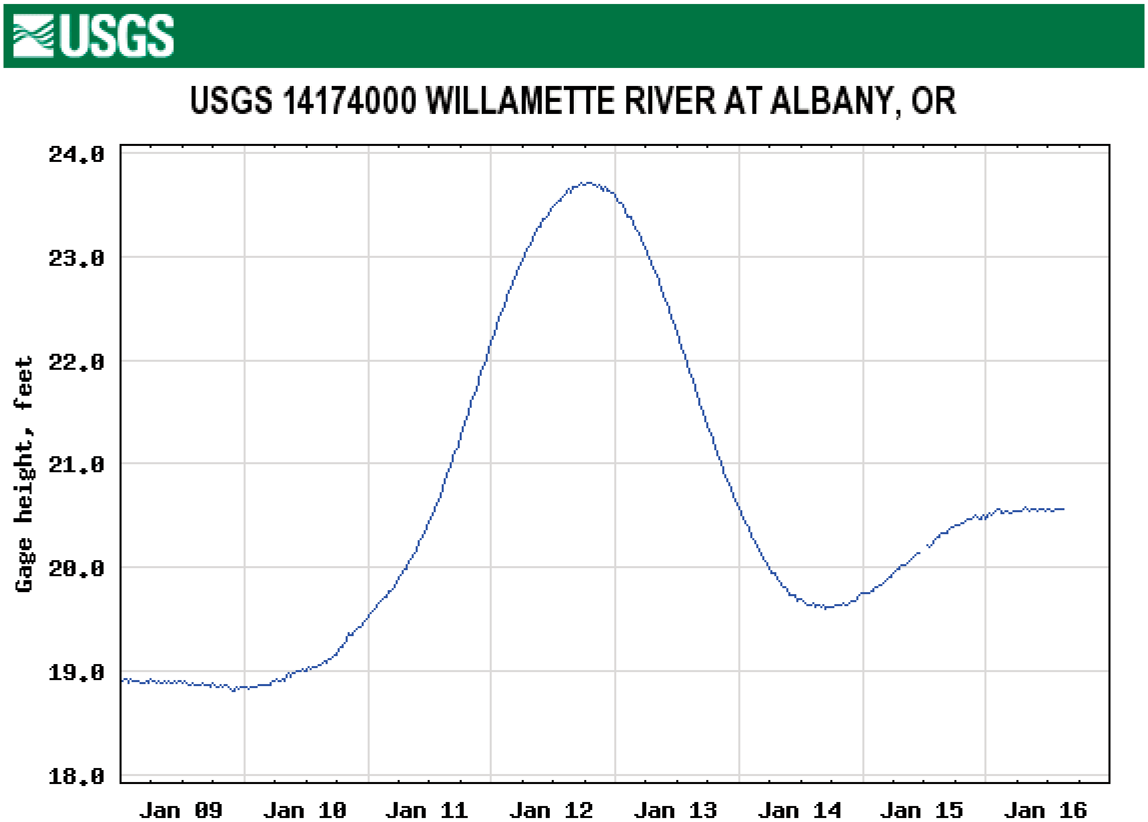
G – Time Lag (or Lag Time). The time between the peak of the hydrological event (rain fall) and the maximum discharge or gauge height. This is the time it takes for precipitation to run-off from where it has fallen to the river channel and flow to the point that the river stage is measured. Many factors can affect this, such as permeability of the soil, size, slope and shape of the watershed, and the quantity of interception from vegetation.



USGS Data

The U.S. Geological Survey maintains a system of “real time” recording stream gauge stations throughout the U.S., including Alaska, the Hawaiian Islands, and the U.S. territories. The data from these stations is observable and available from their web site.

Below is a USGS seven-day hydrograph for a river in Oregon. This hydrograph was taken directly from the USGS web site.



Hydrograph and Turbidity

One of the important operational issues associated with the hydrograph is the ability to predict the impact a hydrological event will have on raw water quality, especially turbidity. It is reasonable to assume turbidity will increase as the stream discharge increases. What is not normally known is the impact on turbidity during the recession limb of the hydrograph. As the stream height drops, it is common for the banks of the stream to cave into the stream. This can cause the turbidity to be greater than that observed during the rising limb. By accumulating hydrological event and stream flow data over a period of years it is possible to predict the impact on water quality of a normal hydrological event.

Math Practice

A channel is 12 inches deep and 15 inches wide. The water depth in a flume is 8 inches. The velocity is estimated at 0.75 ft per second. What is the flow in cfs and gpm?

Q = VA

A = H X W - The flume is 15 inches wide with 8 inches of water. First convert these dimensions to feet.

15"/12" per foot = 1.25 ft

8"/12" per foot = 0.667 ft

Multiply H X W = 0.667 ft X 1.25 ft = 0.8 ft^2

Q = 0.75 ft/sec X 0.8 ft^2 = 0.6 cfs

Since 1 cfs = 449 gpm

0.6 cfs X 449 gpm/cfs = 269 gpm

Water Quality Data

Introduction

Proper operation and management of a surface water source requires routine analysis of the quality of the raw water. The analysis includes a comparison of existing water quality to baseline data. Because surface water sources are more vulnerable to contamination, the frequency of sampling and the variety of tests run are greater than with groundwater sources.

Water Quality Divisions

Surface water, water quality measurements and observations can be divided into three categories: chemical, bacteriological, and **Benthic**[16]. Each category has its unique function in determining water quality.

Chemical Quality

Constituents

The items found in water that are not H_2O are called constituents. Iron, manganese, **pH**[17], alkalinity, and microorganisms are all called constituents. They are not referred to as contaminants or pollutants because some levels of many of these constituents are normally found in surface water and are important to aquatic life.

Comparisons

One of the major concerns associated with gathering raw water quality data is how to evaluate the data. The most common method of evaluating the data is to compare the data against the utility's needs and water quality criteria.

Water Quality Criteria

Water quality criteria specify concentrations of water constituents which, if not exceeded, are expected to result in an aquatic ecosystem suitable for specific uses of water. This includes the use of water by humans. Criteria are derived from scientific facts obtained from experiments or observations. Criteria are not regulations. One popular useful document containing water quality criteria is produced by EPA and is titled "Quality Criteria for Water."This document is available as a pdf file from the EPA web site. (See the reference in the appendix.) For each constituent a numeric value is provided plus some written rational that defends the numeric value.

[16] **Benthics** - Bottom dwelling macro-animals including: nymphs, larvae, snails, worms, and clams.

[17] **pH -** An expression of the intensity of the alkaline or acidic strength of a water. Mathematically, pH is the logarithm (base 10) of the reciprocal of the hydrogen ion concentration. pH may range from 0 to 14, where 0 is the most acid, 14 most alkaline, and 7 neutral. Natural waters usually have a pH between 6.5 and 8.5.

Water Quality Criteria Example

Below is an example of water quality criteria for alkalinity taken from the EPA manual "Quality Criteria for Water.'

ALKALINITY

CRITERION:
20 mg/L or more as CaC03 freshwater aquatic life except where natural concentrations are less.

INTRODUCTION:
Alkalinity is the sum total of components in the water that tend to elevate the pH of the water above a value of about 4.5. It is measured by titration with standardized acid to a pH value of about 4.5 and it is expressed commonly as milligrams per liter of calcium carbonate. Alkalinity, therefore, is a measure of the buffering capacity of the water, and since pH has a direct effect on organisms as well as an indirect effect on the toxicity of certain other pollutants in the water, the buffering capacity is important to water quality. Examples of commonly occurring materials in natural waters that increase the alkalinity are carbonates, bicarbonates, phosphates and hydroxides.

RATIONALE :
The alkalinity of water used for municipal water supplies is important because it affects the amounts of chemicals that need to be added to accomplish calculation, softening and control of corrosion in distribution systems. The alkalinity of water assists in the neutralization of excess acid produced during the addition of such materials as aluminum sulfate during chemical coagulation. Waters having sufficient alkalinity do not have to be supplemented with artificially added materials to increase the alkalinity. Alkalinity resulting from naturally occurring materials such as carbonate and bicarbonate is not considered a a health hazard in drinking water supplies, per se, and naturally occurring maximum levels up to approximately 400 mg/L as calcium carbonate are not considered a problem t o human h e a l t h (NAS,1974).

Alkalinity is important for fish and other aquatic life in freshwater systems because it buffers pH changes that occur naturally as a result of photosynthetic activity of the chlorophyll-bearing vegetation. Components of alkalinity such as carbonate and biocarbonate will complex some toxic heavy metals and reduce their toxicity markedly. For these reasons, the National Technical Advisory Committee (NATC, 1968) recommended a minimum alkalinity of 20 mg/L and the subsequent NAS Report (1974) recommended that natural alkalinity not be reduced by more than 25 percent but did not place an absolute minimal value for it. The use of the 25 present reduction avoids the problem of establishing standards on waters where natural alkalinity is at or below 20 mg/L. For such waters, alkalinity should not be further reduced. The NAS Report recommends that adequate amounts of alkalinity be maintained to buffer the pH within tolerable limits for marine waters. It has been noted as a correlation that productive waterfowl habitats are above 25 mg/L with higher alkalinities resulting in better waterfowl habitats (NATC, 1968).

SDWA

One of the other items used to evaluate raw water quality data is the Safe Drinking Water Act list of primary and secondary contaminants. When the raw water levels for these contaminants exceed the MCL established by the SDWA, the utility is assured that some form of treatment will be required to reduce the contaminant below the MCL.

Constituents and Criteria

The following are some of the common constituents that should be measured in the raw water, plus their accepted criteria.

Constituent	**Criteria**
Iron (Fe)	0.3 mg/L
Manganese (Mn)	0.05 mg/L
Hardness	Below 250 mg/L as $CaCO_3$
pH	6.5 to 8.5
Turbidity	Based on treatment capabilities
Temperature	Because of importance to water treatment and disinfection it must be recorded routinely
Alkalinity	20 mg/L - for treatment 80 mg/L
Organics	Compare to SDWA
Inorganics	Compare to SDWA

Dissolved Oxygen

One of the most important measurements of surface water quality is the level of **dissolved oxygen**[18] (D.O.) carried by a stream. Under natural conditions, the level of D.O. is inversely proportional to the temperature of the water. As the water temperature goes down, the D.O. will go up. Dissolved oxygen is a direct indicator of organic pollution; the higher the level of pollution the lower the level of oxygen. This is because microorganisms consume the pollution as food and at the same time multiply and consume oxygen, thus reducing the D.O.

Bacteriological Quality

Coliform

Raw water should be tested routinely for the presence of total coliform and fecal coliform bacteria. Coliform are our primary indicators used to determine the presence or absence of pollution. By knowing the coliform level the operator can estimate changes in chlorine demand and adjust feed rates appropriately. When the coliform level is high or the intake is downstream from a sewage treatment plant, fecal coliform sampling on a quarterly basis is also desirable. This data can be used to explain changes in chlorine demand.

Coliform Criteria

At the present time, there is no agreed upon criteria for coliform bacteria in the raw water supply. However, there is criteria for swimming and raising shellfish. The criteria for fecal coliform for swimming waters is 200 per 100 mL sample and for shellfish it is 14 per 100 mL sample.

[19] **Dissolved Oxygen** - The oxygen dissolved in water or other liquid, generally expressed in mg/L or percent of saturation. Usually designated as D.O.

Benthic Organisms

Description

Benthic organisms are macroanimals that live all or part of their lives on the bottom of a stream, either on the under side of rocks or in the silt. These include insects, insect larva, snails, sludge worms, and fresh water clams. The presence or absence of certain benthic organisms can be used as an indicator of water quality.

Use as Pollution Indicators

Benthic organisms are good indicators of pollution because some groups are more sensitive to pollution than others. In general, the larval stages of stoneflies, mayflies, and caddis flies are the most sensitive to pollution. Less sensitive are scuds, black fly larva, sow bugs, some snails, and clams. The most tolerant are sludge worms, bloodworms, and maggots.

Representative Bottom Dwelling Macroanimals

Sensitive

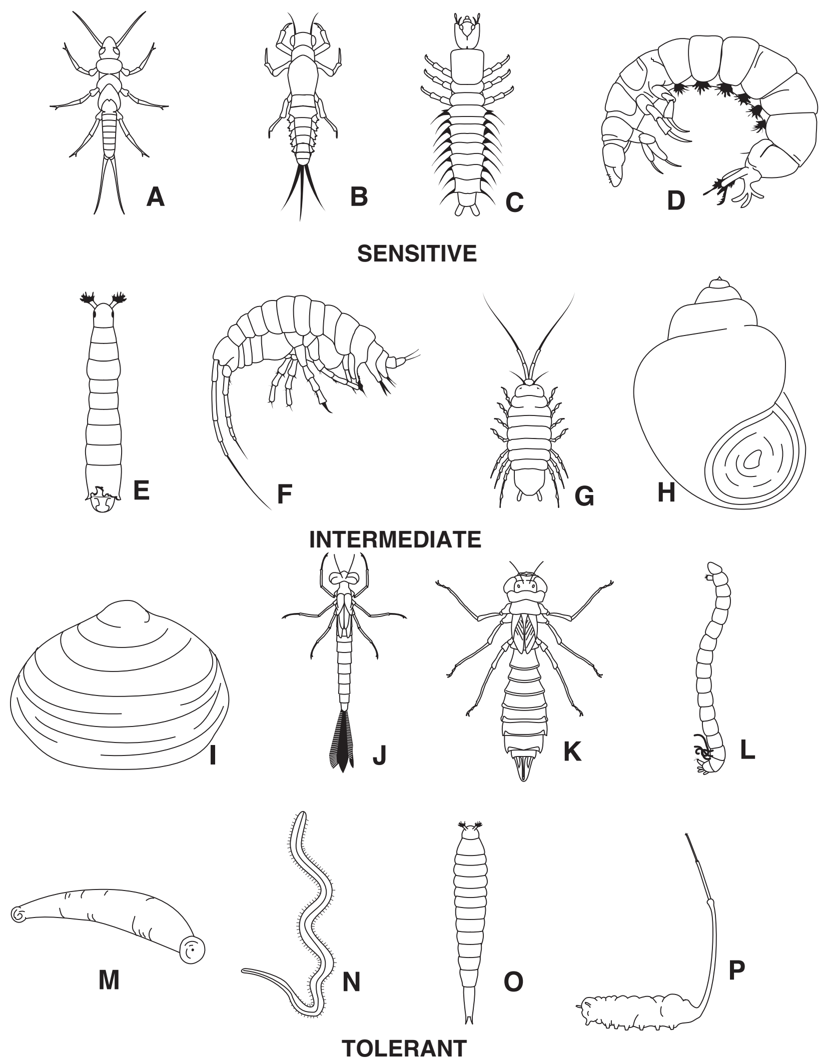
A Stonefly nymph
B Mayfly naiad
C Hellgrammite or Dobsonfly larvae
D Caddis fly larvae

Intermediate

E Black fly larvae
F Scud
G Aquatic sowbug
H Snail
I Fingernail clam
J Damselfly nymph
K Dragonfly nymph
L Bloodworm or midge fly larvae

Tolerant

M Leech
N Sludgeworm
O Sewage fly larvae
P Rate tailed maggot



Representative Bottom-Dwelling Macroanamals

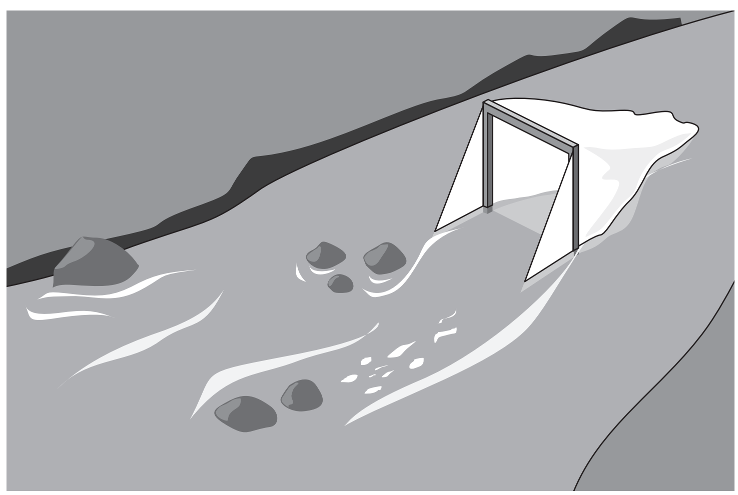
Drawings from Beckler, J., K.M. Mackenthun and W. M Ingram, 1963. Glossary of Comonly Used Biological and Related Terms in Water and Wastewater Control, DHEW, PHS, Cincinnati, Ohio, Pub. No. 999-WP-2.

Benthic Profiling

The process of making a census of benthic organisms can be quite simple. One method uses a piece of screen door screen attached to two broom handles. The handles are used by one person to hold the screen to the bottom. The screen is placed at a right angle to the flow. The top of the screen is tipped back at a 30 to 45 degree angle. A second individual standing upstream, simply scuffs up the stream bottom with there feet, or rocks can be picked up and scrubbed with a brush. The benthic organisms are washed down stream and collected on the screen. The screen is removed from the stream and the benthic removed from the screen and placed in a pan for counting and identification.

Square Foot Sampler

A more scientific method uses a device called a square foot sampler. This device is composed of two metal frames, each one-foot square. The frames are attached together at 90 degrees. A fine mesh cloth screen is attached to the device to collect the sample. The device is placed in the stream so one square foot of gravel is inside one frame and the other frame faces the flow of the stream with the screen trailing down stream. Each rock inside of the square foot frame is picked up and brushed with a small soft brush and then set aside. All benthics attached to the rocks are brushed off and collected by the screen. The sampler is removed from the stream and the benthics placed in a pan for identification and counting.



Square foot sampler installed in stream. Used to collect benthic organisms.

Interpretation

The organisms are separated into groups. The number in each group is counted and either weighed or their size noted. The presence of significant numbers of sensitive benthic organisms of typical size is a good indication of the lack of pollution. This process should be repeated quarterly and the results compared year to year. If the annual results change and there is no significant change in stream temperature, further investigation is needed to determine the cause of the change.

Normal Operations

Introduction

Normal operations of a surface water source is composed of making observations, planning for the future, collecting and analyzing data, and comparing the information to previous years. The process requires daily, weekly, and annual tasks.

Daily Tasks

The following tests should be performed on the raw water surface water on a daily basis:

- pH
- Temperature
- Turbidity
- Alkalinity

Ambient Conditions

Along with the raw water data, the **ambient**[19] conditions, temperature, sky conditions and winds should be measured or observed and recorded daily. As ambient conditions change, water conditions will be affected.

Weekly Tasks

Once a week the precipitation should be measured and recorded. During low flow periods the stream flow should also be measured and recorded weekly or continuously using a gauging station.

Annual Tasks

Sanitary Survey

The SDWA requires each regulatory agency to perform a sanitary survey of each community surface water system once every (3) years. This is a process of inspecting and documenting all actual and potential sanitary deficiencies in the system. In addition, it is desirable that each utility perform an internal sanitary survey once each year.

Water Quality Survey

Once each year, a water quality survey should be performed by the utility. A water quality survey is an in-depth look at the conditions and activities associated with the watershed that could impact water quality. This should not be confused with a sanitary survey. A sanitary survey is an overall review of the operations, maintenance, and management of a water system in an attempt to identify existing or potential sanitary risks that could adversely impact the quality of the water. The water quality survey is much more in depth than a sanitary survey and is focused specifically on the watershed.

Components of WQS

A water quality survey is composed of four steps:

- Data Collection - This includes all the water quality, physical, and activity data associated with the watershed, including a review of past surveys, the water use policies, and watershed use agreements.

[19] **Ambient** - The surrounding atmosphere.

- Observations - This requires a physical, on-site visit to the watershed. It requires observation of as much of the watershed and stream bed as is reasonable. The observations include looking for natural or man-made activities that can impact water quality.
- Evaluation - Evaluation of the WQS is an attempt to compare an analysis of the data from step one with physical observations. This is done in order to draw conclusions about the stability of the watershed and its ability to produce high quality water and produce the quantity of water required to meet customer needs.
- Documentation - The final phase of the WQS is the preparation of a report that summarizes the data findings and the evaluations. Most reports also include recommendations of actions that may improve water quality, as well as identification of items or areas that should be looked at closely in the future.

Inorganic Samples

Once each year a raw water sample should be collected and tested for inorganic constituents. The results should be compared against the SDWA contaminant list. Any levels above the existing MCLs will require treatment. If it is believed that the level of any of these constituents will vary from quarter to quarter, then this testing should be completed once each quarter.

Organic Samples

Once every three years for small systems and once each year for large systems a sample should be collected and tested for organic constituents. The results should be compared against the SDWA contaminant list. Any levels above the existing MCLs will require treatment. If it is believed that the level of any of these constituents will vary from quarter to quarter, then this testing should be completed once each quarter.

Analysis

If the test results for organic and/or inorganic constituents are above the MCL limits or the water quality criteria, a review of upstream activities should be initiated to determine the source of the contamination.

Agreements

Once each year the water use agreement and watershed management policies should be reviewed and updated as necessary.

Water Rights

Once each year it is advisable to review the water rights requirements and compare them to actual use. Most water rights require the holder of the water right to use a specific amount of water for a specific use.

Records

Storage of all records associated with water quality, any sanitary surveys completed on the water system, as well as water quality survey reports must be readily available and maintained for ten (10) years.

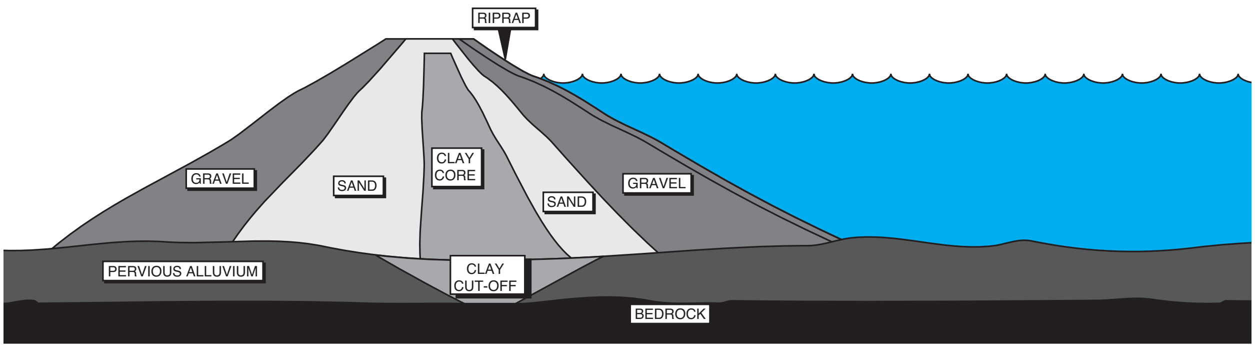
Storage Facilities

Description

Storage facilities used by small communities include natural lakes and man-made impoundments constructed with small (less than 30 feet high) masonry or embankment dams. The selection of the type of dam is dependent on three items: geology of the area, the availability of raw materials, and the engineer's preference.

Embankment Dams

Embankment dams are made from local raw materials and may include sand, gravel, clay, and rock. The embankment dam works because of an impermeable clay core. Permeable material, such as sand and rock, serves to hold the clay core in place.



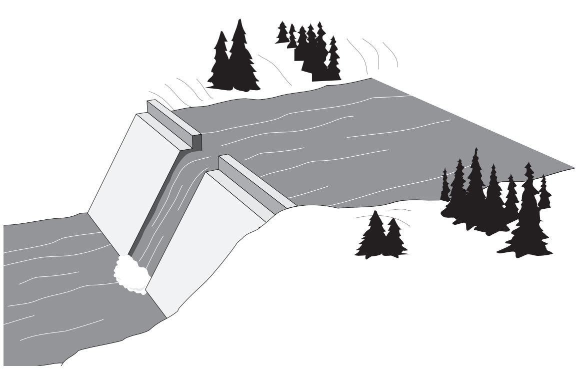
Small rock and sand filled embankment dam

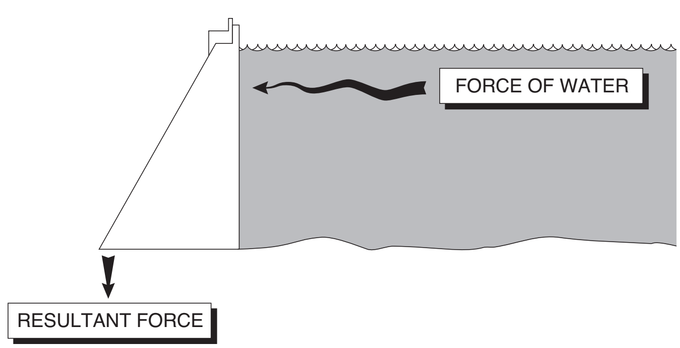
Masonry Dams

Masonry dams are constructed when the geology or availability of raw materials makes embankment dams impractical. There are three types of masonry dams. The choice of which dam to construct is based on the geology of the area.

Gravity Dams

Gravity dams are constructed so that the force of water behind the dam is transmitted to the floor. The gravity dam requires a solid rock base. Gravity dams are the most common dam used by small water systems.

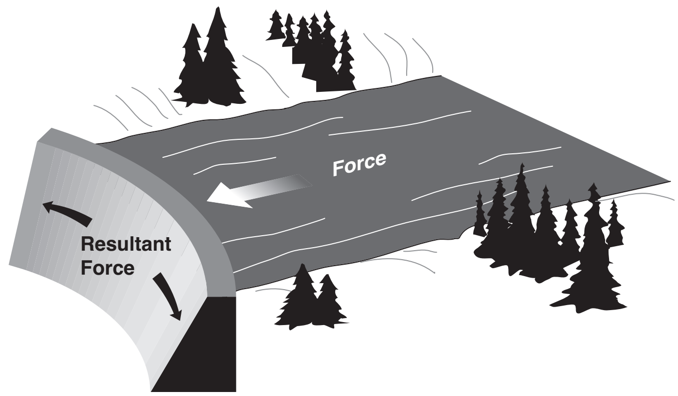




Arched Dams

Arched dams are used when the floor of the valley will not support the force associated with a gravity dam. The arched dam transfers the downward force to the walls of the valley. The City of Seldovia, Alaska, uses a 30 foot tall and 127 foot long arched dam. This dam withstood the 1964 earthquake.

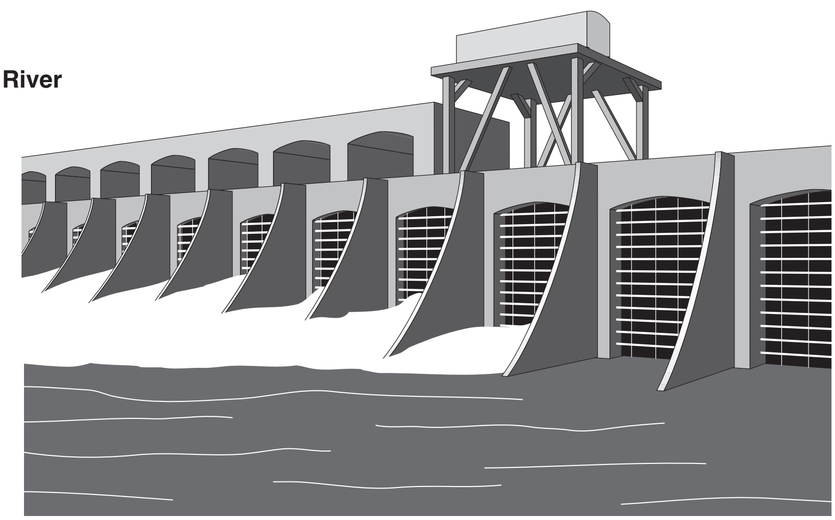
Arched Dam



Buttress Dams

Buttress dams are used when neither the floor or the walls of the valley will support the total force of the dam, but there are portions of the floor that will support considerable force. Buttresses are placed over these solid areas, and the force is transferred to them. One of the most famous buttress dams in the U.S. is the Bonneville Dam on the Columbia River.

Bonneville Dam, Lower Columbia River



Spillways

Protection

In order to prevent damage to the dam during high flows, each dam must have some type of spillway. There are three common spillway designs: the saddle, side channel, and drop inlet.

Saddle

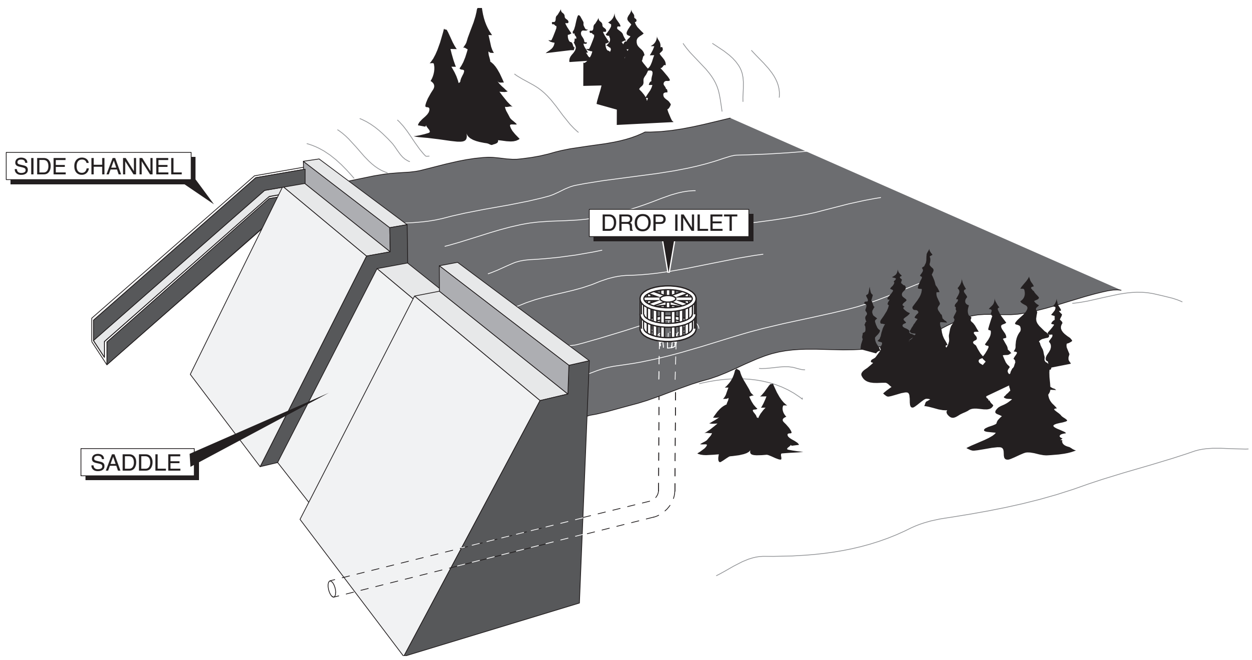
The saddle spillway is used primarily on gravity, arched, and buttress masonry dams. In some instances a saddle spillway is built out of concrete and used with an embankment dam.

Side Channel

The side channel spillway is usually used with embankment dams and can be constructed from native materials or cement.

Drop Inlet

The drop inlet spillway is used when conditions are not practical for a saddle or side channel spillways. This spillway can also be used as part of the intake structure. While somewhat unique, it does require additional maintenance to prevent plugging. An emergency spillway must be constructed to prevent damage to the dam in case of plugging or high flows.



Water Quality & Quantity

Overview

Although small, these storage facilities can be a major contributor to improvements and/or deterioration in water quality. Therefore, they should be managed in a manner that maintains or improves water quality as well as documenting the quantity of water in storage.

Quantity

The quantity of water in a reservoir is typically estimated in acre-feet. An acre-foot is the amount of water required to cover one acre, one foot deep. An acre is 43,560 ft^2; therefore, an acre-foot of water is 43,560 ft^3.

43,560 ft^3 X 7.48 gal/ft^3 = 325,829 gal in 1 acre-foot.

Loss of Quantity

The quantity of water in a reservoir will typically decrease with time due to the buildup of silt and debris on the bottom of the reservoir. With very small reservoirs (one million gallons or less), the reservoir may be drained once a year and the silt removed. With larger reservoirs it is necessary to determine the silt buildup at least once a year. Based on the rate of buildup, a management plan can be made on when and how to remove the buildup. In the development of this plan, the operational and financial considerations should be taken into account.

Common Quality Problems

There are several instances where well-meaning individuals have planted unwanted fish in a storage reservoir. In many cases these fish have contributed to a drastic change in water quality. In one case, catfish planted in the reservoir have contributed to higher than usual turbidity and increases in manganese. They do this by slowly moving their tails back and forth on the bottom of the reservoir, bringing sediments into solution.

Maintaining Water Quality

Sampling & Testing

In order to determine the quality of the water in the reservoir or lake, once every year, the water quality should be sampled and tested at the surface and at each 10 feet of depth. The sampling and testing should be completed for at least the following constituents:

- Temperature
- pH
- TSS
- Turbidity
- Iron & Manganese
- Alkalinity
- Dissolved Oxygen
- Algae Count
- Nutrients - Nitrogen and Phosphorous
- Color

The results should be compared to water quality criteria. In addition, a history of changes in this data can be very useful in predicting changes in water quality, as well as determining changes that may be necessary in the treatment process.

Stratification

Some storage facilities have bodies of water that are deep enough to stratify. Stratification occurs when the temperature of the layer of water on the bottom of the reservoir becomes significantly different than a layer of water on the top of the reservoir. A temperature profile of the water would show this sharp change. The upper layer of water is referred to as the **epilimnion**[20], the bottom layer is called the **hypolimnion**[21], and the layer that separates the two is called the **thermocline**[22].

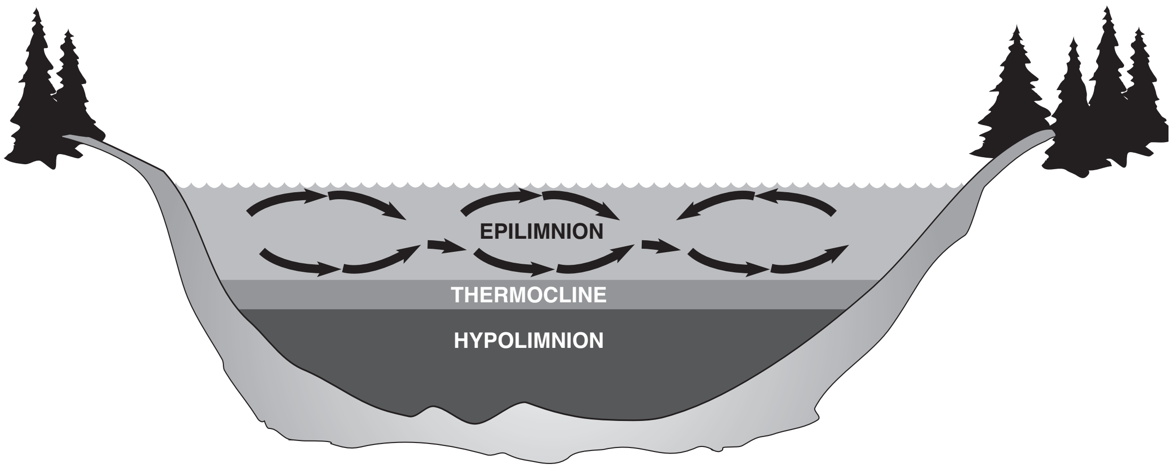
[20] **Epilimnion** - The upper layer of a stratified body of water. Commonly this layer is high, mixed by the wind, and is the warmest of the layers.

[21] **Hypolimnion** - The lowest layer in a thermally stratified body of water. In most cases this layer contains the colder and denser water. Normally no mixing occurs in this layer and the D.O. may be at or near zero.

[22] **Thermocline** - The middle layer in a thermally stratified body of water. The temperature will decrease rapidly from top to bottom through this layer. Also called the Metalimnion.

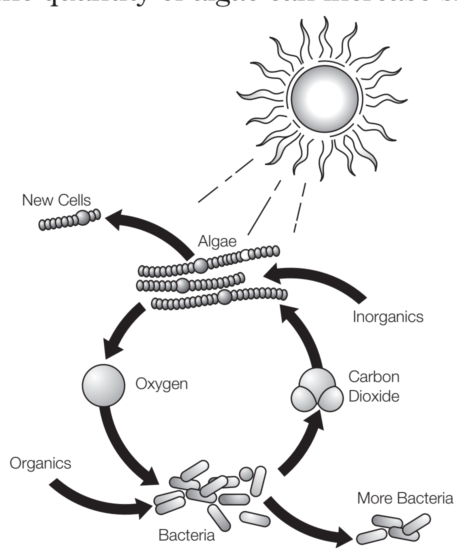
Epilimnion

The epilimnion, the upper layer, is usually mixed by the wind that blows across the surface and contains relatively warm water. This layer often contains a high quantity of dissolved oxygen. However, when there are sufficient nutrients in the water, algae will increase in quantity (called an algae bloom) and cause a deterioration of water quality.



Algae - Life Cycle

Under normal conditions, algae and bacteria that live in the water have a symbiotic relationship. The algae produce oxygen and consume carbon dioxide, while the bacteria consume oxygen and produce carbon dioxide. At night the algae use oxygen in order to stay alive. In a normal life cycle they consume about one-half of the oxygen they produce. When there is an excess quantity of nitrogen and phosphorous in the water, the quantity of algae can increase significantly.



The Result

High concentrations of algae can lower the dissolved oxygen in the water to a level that promotes the growth of anaerobic organisms. These organisms produce odor and taste by-products that impact water quality and treatment. In addition, several forms of algae produce significant odor and taste problems when they are killed using chlorine. When the nutrient level, and thus algae, and other aquatic plants increase to the point the water quality is undesirable, the water body is said to be **eutrophic**[23].

Hypolimnion

The hypolimnion, the lower layer, is commonly composed of lower temperature water. If the stratification remains long enough, or the algae growth in the epilimnion is sufficient to cut off the sunlight, the dissolved oxygen in the hypolimnion drops to near zero. When this happens the aerobic bacteria die off and the anaerobic bacteria thrive and facultative bacteria switch to an anaerobic condition. Anaerobic bacteria and anaerobic facultative bacteria produce methane and hydrogen sulfide and thus provide odor and taste problems. The low D.O. conditions in the hypolimnion also contribute to conditions that lower the pH of the water sufficiently to allow insoluble iron and manganese to be oxidized and brought into solution.

Ice

Stratification may not occur in lakes and reservoirs that are covered with ice several months of each year. However, there may be an overall reduction in water quality as a result of the lack of sunlight. One such reduction in water quality would be a decrease of the dissolved oxygen.

The Thermocline

The layer between the epilimnion and the hypolimnion is called the thermocline or metalimnion. Thermocline is the term used identify the temperate change between the two layers while metalimnion identifies the layer. The temperature gradient through the metalimnion is typically eight to ten degrees. The change is not sudden but gradual through the layer. Normally, greater the differences in temperature the thicker the layer.

Operational Considerations

Many reservoirs have outlets at various levels, allowing the operator to select the highest quality water. By performing water quality tests and analyzing the results, the operator can adjust the intake level to provide water that produces the best treatment results. For example, if there is a significant algae bloom in the first three feet of depth and water can be drawn from below this depth, odor and taste problems may be avoided.

[23] **Eutrophication** – The process where a body of water becomes enriched with nutrients that result in water quality characteristics undesirable for human use of the water as a drinking water source and/or recreation.

Control of Odor and Taste

From Anaerobic Conditions

Odor and taste problems associated with anaerobic conditions can be solved by portable aeration devices placed on the surface of the water. Long draft tubes extending nearly to the bottom of the water have proven to be very effective in treating small reservoirs and lakes. Lakes and reservoirs in some portions of the U.S. and Canada are covered with ice for several months of each year, making mechanical aeration impractical. The addition of potassium permanganate at the treatment plant, coupled with activated carbon can be an effective treatment. Prechlorination will typically cause an increase in customer complaints.

From Algae

The complaints associated with odor, taste, from algae are not normally the direct result of the algae, but the result of chlorine combining with oils released when the algae is killed. The results are very offensive odors and taste.

Other Algae Problems

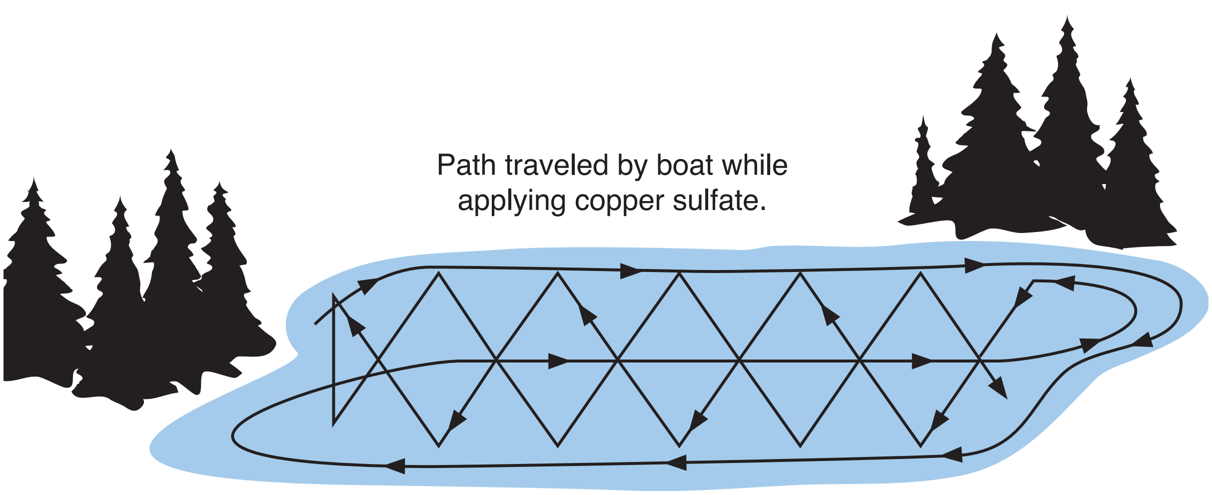
Besides causing odor and taste problems, algae can also plug filter media, causing very short filter runs and high headloss. Because of the problems from algae it advisable to control algae at the sources, rather than deal with it at the treatment plants.

Long Cold Winters

In northern climates, algae problems are very rare. The long winters and short summers do not contribute to conditions that allow algae to grow in great numbers.

Algae Treatment

There are two common algae control strategies, prevention and treatment. One prevention process is the use of some form of algaecide on the reservoir or lake just before a predicted algae bloom. The most common algaecide is copper sulfate (also called blue stone). Copper sulfate is applied as a liquid spray or as a powder. Copper sulfate is applied from a boat in some type of specific pattern that allows the majority of the lake surface to be treated.



Problems with Copper Sulfate

Historically, high populations of algae were managed by applying copper sulfate to the source water to kill the algae. As algae is killed, nutrients are released into the water which can contribute to a second bloom that is worse than the first. There are special problems associated with handling and disposing of copper sulfate containers because they are considered a hazardous waste. The secondary bloom and the difficulty of handling and disposing of a hazardous containers have caused many utilities to abandon this process in favor treatment or other prevention techniques.

Weed Control

Some utilities have had good success in reduction of algae concentrations by removing the aquatic weeds from around the edge of the lake or reservoir and, thus, reducing quiet water areas that can contribute to high algae bloom.

Treatment Techniques

Present treatment techniques used to control algae related order and taste require the addition of chemicals at the intake (often called pretreatment). The most common treatment techniques require killing the algae with potassium permanganate ($KMnO_4$) or chlorine dioxide (ClO_2) and oxidizing the oils released from their cells. A second method is to kill and oxidize the organisms and their by-products using chlorine or some other oxidant and then strip the offensive materials and the disinfection by-products using aeration. A third process is to use activated carbon in place of aeration to remove the offensive organic material that is produced as a result of chlorinating the algae.

Math Practice

A reservoir is 2,800 feet in length and approximately 350 feet wide. The average depth of water is estimated at 15 feet. How many acre feet and how many gallons does the reservoir contain?

Find the surface area in square feet.

2800 ft X 350 ft = 980,000 ft^2

What is the surface area in acres?

$$\text{Acres} = \frac{980{,}000\ \text{ft}^2}{43{,}560\ \text{ft}^2\ /\ \text{acre}} = 22.5\ \text{acres}$$

The average depth is 15 feet

22.5 acres X 15 feet = 337.5 acre feet

Find the volume in gallons

2800 ft X 350 ft X 15 ft = 14,700,000 ft^3

14,700,000 ft^3 X 7.48 gal/ft^3 = 109,956,000 gal

Dam Inspection

Federal Requirements

The Federal Guidelines for Dam Safety established in 1979 require all dams greater than six (6) feet in height be inspected by a qualified engineer at least once every five (5) years.

Annual Inspection

In addition to the Federal requirements, it is advisable for the utility to have a professional engineer perform an annual inspection of the dam and associated structures. This inspection should include:

- Condition of concrete
- Identification of any cracks, noting their length and width
- Presence of rust stains that could indicate internal corrosion of the rebar
- Exposure of the rebar
- Spalling
- Misalignment at joints
- Erosion of the floor of spillways
- Condition of valves and gates
- Condition of handrails and walkways
- Leakage of joints, under or around the dam
- Clarity of water from the weep hole drains

Routine Operation of Reservoirs

Introduction

Normal operation of a surface water reservoir is composed of making observations, planning for the future, collecting and analyzing data, and comparing the information to previous years.

Frequency

The frequency of inspection and data collection is dependent upon the vulnerability of the structure to vandalism and/or operational failure. Below is a suggested “typical” frequency of inspection, observation, and data collection for small dams.

Daily Tasks

The following inspections and tests should be performed on the dam and/or stored water on a daily basis:

- pH
- Temperature
- Turbidity
- Clarity (Clarity is tested using a Secchi Disk. This is a one foot diameter metal disk; one-half is panted black and the other half white. The disk is lowered until it cannot be seen and the depth recorded.)
- Vandalism

- Water level behind the dam
- Quantity of water going over the spillway

Weekly Tasks

In a very small system all of the daily tasks can be performed weekly.

Quarterly/Seasonally

At least once each season it is desirable to test the water quality by developing profiles (top to bottom at 10 foot intervals) at key locations in the reservoir for the following parameters:

- pH
- Temperature
- D.O.

Annual Tasks

At least once a year the following tasks should be performed: (In larger systems many of these tasks should be performed quarterly.)

- Inspect the condition of all concrete structures
- Photograph and describe any damage to the structure
- Identify the quantity of vegetation growth on the edges of the water. Or, remove all vegetation that could contribute to the deterioration of water quality.
- Exercise and lubricate all gates and valves
- Inspect the condition of walkways and handrails
- Inspect for the potential of ice damage at breakup
- Measure and document the quantity of silt buildup

Every 5 Years

Once each five years a qualified engineer must be hired to inspect the dam for structural integrity.

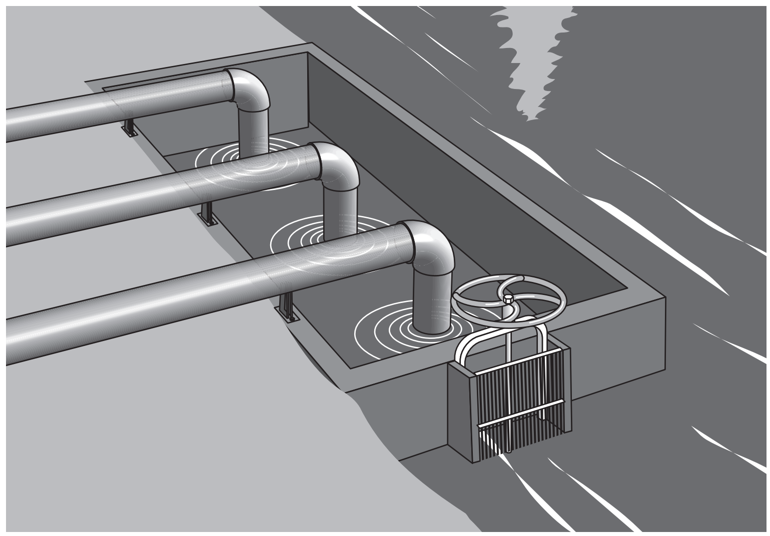
Intakes

Types

The type of intake structure depends on the nature of the source. Different intake structures are used with steams than are used with reservoirs and lakes; however, they all have similar components.

Collection Box

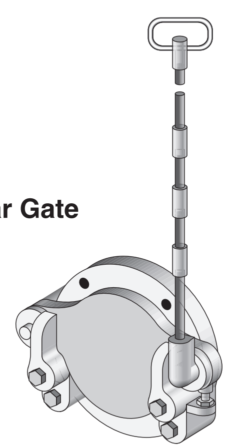
Most intakes have some type of intake box. This box is commonly a concrete box placed next to or into the stream, lake, or reservoir. At the entrance to the box is a bar screen used to keep large material from entering the collection box. Bar screens can be made from metal or concrete.



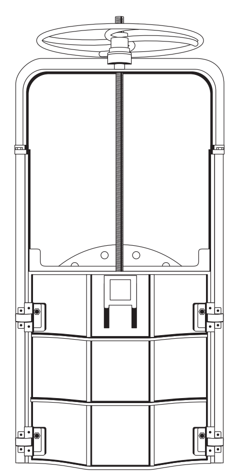
Valves

Behind the bar screen is commonly some type of valve that allows flow to the intake box to be shut off. Typical valves used for this are shear gates and sluice gates. A shear gate is a type of gate valve that is hinged on one side and opened and closed by lifting the other side using a long rod. Sluice gates are usually opened and closed by rotating a hand wheel. A threaded shaft is attached to the top of the gate and passes through the hand wheel.

Shear Gate



Sluice Gate

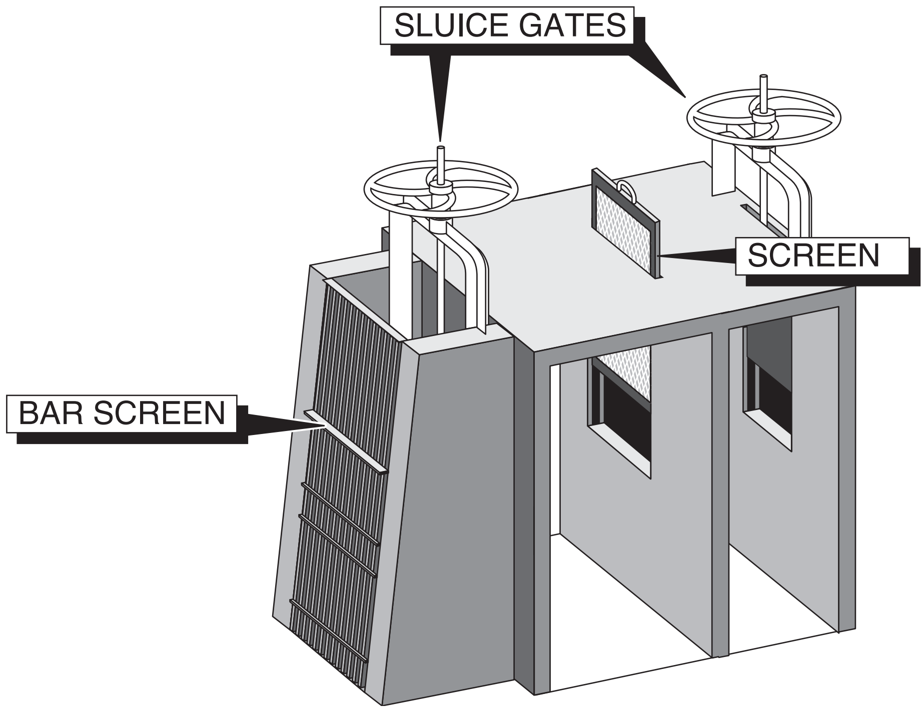


Dewatering

Sluice gates are often installed on the upstream side of small dams and allow the operator to dewater the dam so accumulated silt and rock can be removed.

Screens

Behind the shear or sluice gate may be one or more screens. Most of the time these screens are made of stainless steel. In order to allow the screen to be removed along with the accumulated debris, a trough is placed on the bottom of the screen. This trough catches the debris when the screen is removed. A typical routine process is to close the gate, remove the screen, dispose of the debris, replace the screen, and open the gate.



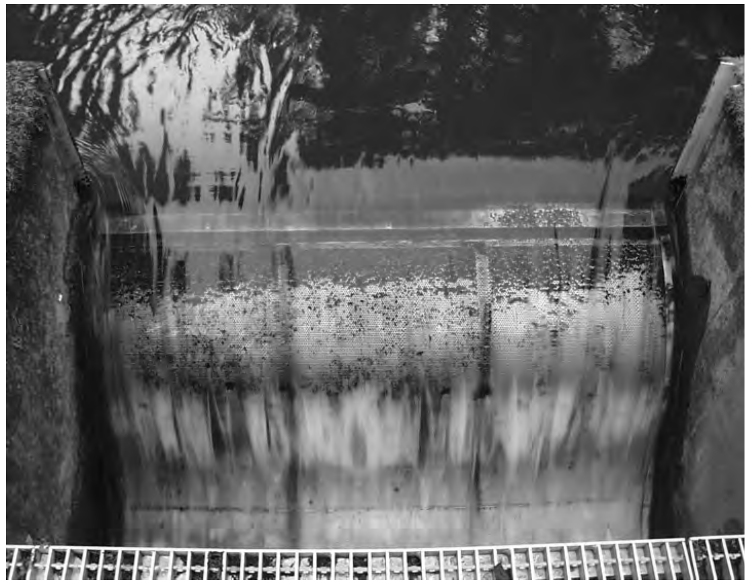
Automatic Screens

Some systems are fortunate enough to have self cleaning screens. These may be electrically operated continuous screens that use a high pressure nozzle for cleaning or screens that are rotated by the stream and cleaned by a water nozzle. If the flow is sufficient, large material may be prevented from being lodged on the screen by placing the screen at the appropriate angel in the stream. This allows the water in the stream to remove the debris.

Dewatering the Box

Properly designed collection boxes have provisions for dewatering so that they may be cleaned. This is commonly accomplished with a portable pump which pumps the water out of the screen box and into the stream. Entry into a collection box is to be considered as entry into a confined space, and the appropriate permit process and safety equipment must be utilized.

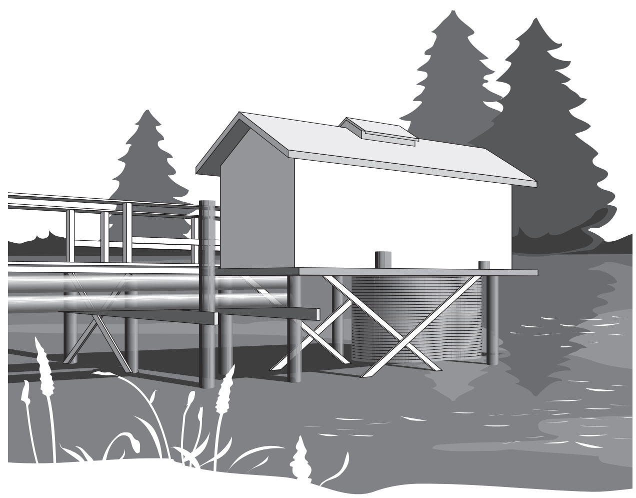
Self Cleaning Screen.
Rock Creek Treatment Plant Intake
Corvallis, OR



Multi- Level

With larger storage reservoirs it is desirable to have intakes at more than one depth. This allows the operator to select the best quality water. At different times during the year the water quality may shift. During high wind conditions the surface water may contain saturated dissolved oxygen or high turbidity. During periods of low flow the water at the bottom on the reservoir may be low in pH and D.O.

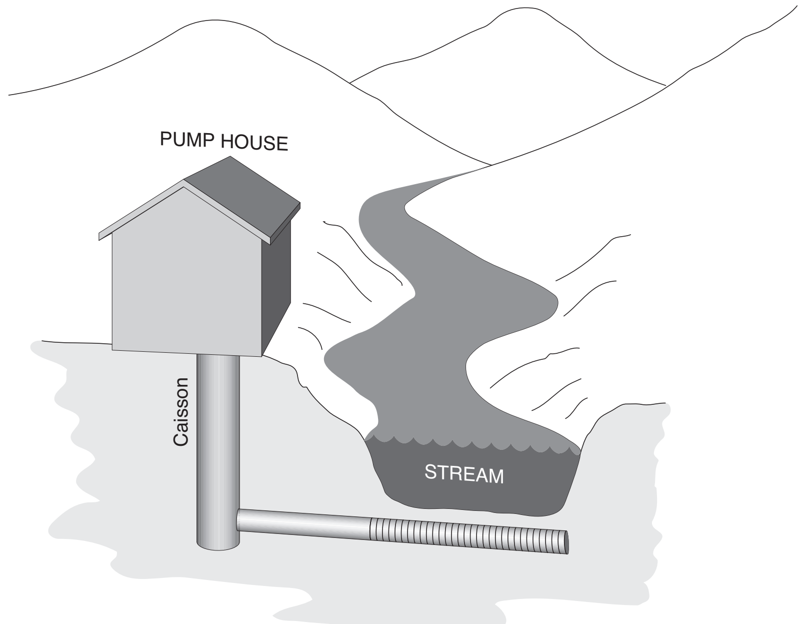
Intake structure in small reservoir. Lineshaft turbines are installed in caisson which has a screened intake at three different elevations. Each intake is controlled by a shear gate.



Infiltration Gallery

One of the common methods of removing water from a small stream is the use of an **infiltration gallery**[24]. With this intake the collection box is called the caisson and the inlet is through slotted or perforated pipe placed below the steam bed and covered with graded gravel. In many instances, a well screen is used for the collection pipe. It is desirable that the inlets into the caisson be controlled by valves and

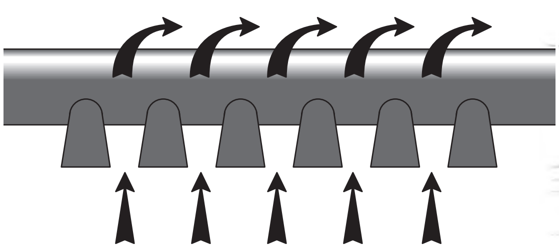
[24] **Infiltration Gallery** - A device used to obtain water from a water bearing strata. The device is typically composed of one or more perforated or screened pipes which lead to a central collection device called a caisson. Infiltration galleries can be used in the bed of a stream or as a means of collecting water from a spring.

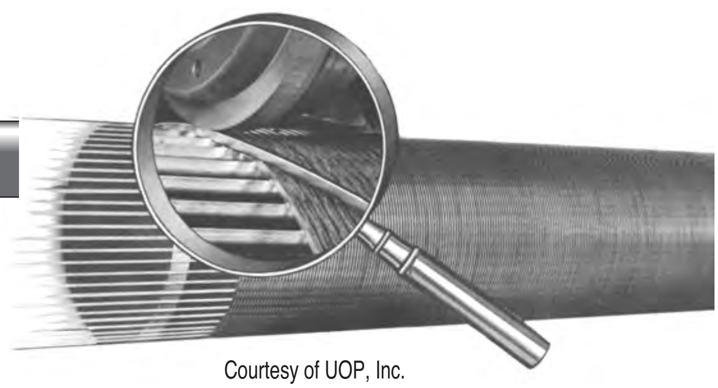


there be some means of dewatering the caisson so that it may be cleaned. Water is pumped from the caisson to the treatment plant.

Screens

There are a number of manufacturers of screens used in infiltration galleries, one of the most popular is the Johnson screen. This is a special design made by the Johnson Division, of US Filter. (Similar screens are manufactured by other companies.) These screens are made from various metals, stainless steel being the most popular. The Johnson screen uses a V-shaped wire that is wrapped around a series of vertical supports. The V-shaped wire forms a V-slot that allows any grain of sand barely smaller than the width of the opening to pass freely through the screen without plugging.


Cross-section of screen

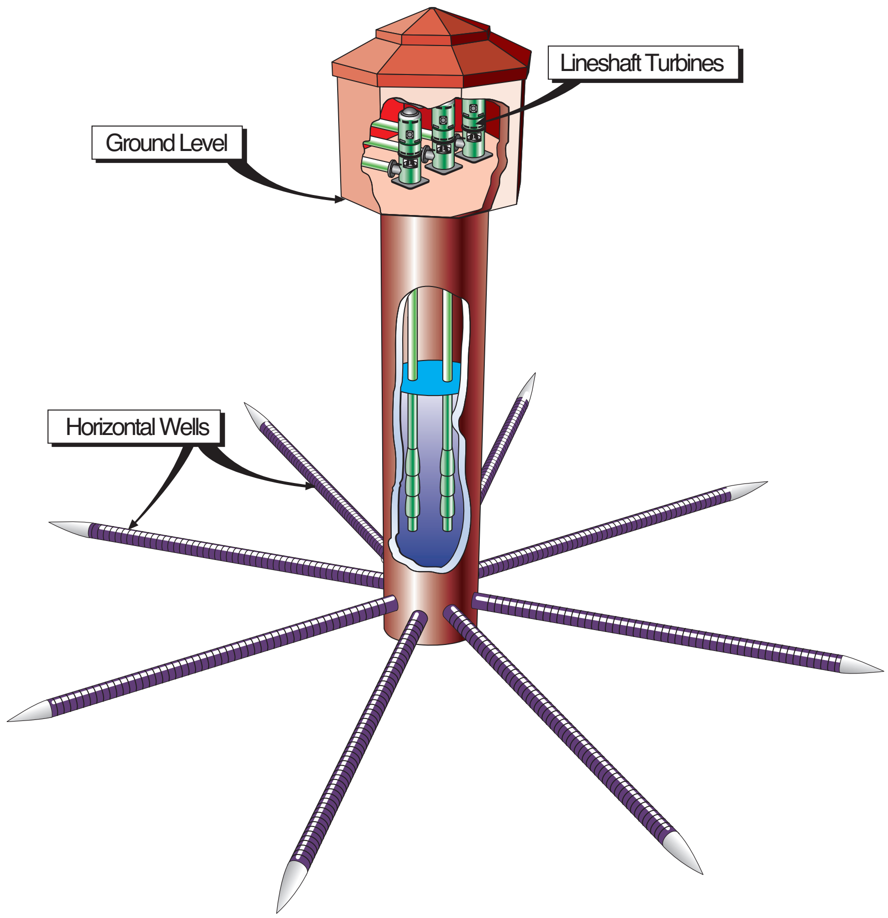

Courtesy of UOP, Inc.

Use of Well Screens

Well screens can be placed directly into the stream, lake, or reservoir. Often they are installed on a swing joint that allows the operator to raise and lower the screen to select the highest quality water and also to remove accumulated debris.

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 river bed water table. Water is pumped from the caisson to the treatment plant. A diagram of a Ranney collector is shown below.



Pumping Systems

Intakes for small systems often rely on pumping systems to move the water from the source to the treatment plant. These systems include end-suction centrifugal pumps, lineshaft turbines, and submersible turbines. Details on the operation and maintenance of these systems are found in the Pumping Systems section of this text.

Routine Operations – Intakes

Screens

Screens at the intake need to be cleaned as frequently as necessary to prevent them from becoming plugged. Where there is a large accumulation of fall leaves, cleaning may be one or more times a day. Self-cleaning screens should be inspected at least once a week and lubricated, based on the manufacturer's recommendation.

Shear Gates & Sluice Gates

Shear gates and sluice gates should be lubricated at least once each quarter with a water resistant grease. Lithium based #2 grease is a common water resistant grease.

Infiltration Gallery

The flow from the infiltration gallery into the caisson should be monitored monthly. The rate of the flow can be used to determine if the stream bed is clogging. Clogged stream beds can be cleaned by digging up the gravel over the pipes, washing the gravel, and replacing it back on top of the screen or perforated pipe.

Pumps & Motors

Pumps and their related piping should be inspected daily for leakage. Discharge pressure and flow should be observed and recorded on each visit, provided that the pump is running. Pump and motor noise and vibration should be noted as well as temperature. The two keys to finding bad bearings are vibration and temperature. With electric motors the amperage and voltage should be recorded once each quarter. With internal combustion engines, the engine oil and air filters should be changed, based on the manufacturer's recommended frequency, but at least once each quarter in which they operate.

Safety Considerations

When making electrical measurements, be sure to either use a licensed electrician, exterior panel voltage and amperage meters, or follow the prescribed precautions for making electrical measurements. These precautions include:

- The removal of all jewelry, watches, and metal rimmed glasses.
- Wear a shirt with tight fitting sleeves.
- Fasten the panel door open.

- Wear safety goggles.
- Have a second person standing by when making the measurements.
- Make all readings with one hand.

Remember: 120 volts from arm-to-arm can generate a current flow between 400 and 500 milliamps. A 200 milliamp current is sufficient to kill.

Confined Space

Valve pits, caissons, and collection boxes are confined spaces. These specific confined spaces may have low oxygen levels. OSHA requires the oxygen level in any work environment be at least 19%. Entry into a confined space requires following the existing permit system, using proper safety equipment, having two people present, testing the atmosphere, and having proper rescue equipment available.

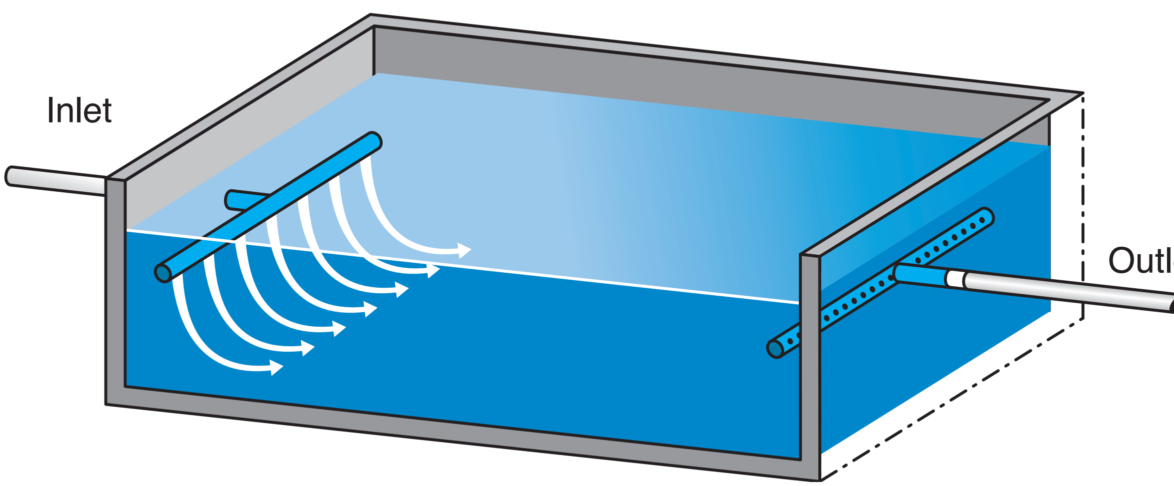
Settling Basins

Purpose

The hygrograph produced by a small stream often shows a sharp rise and fall as a result of a hydrological event. Treatment of the high turbidity produced by such events is very costly and time consuming. To reduce the impact on treatment, many small systems install settling basins prior to the treatment plant.

Description of Structure

Typical settling basins used for raw water are rather shallow, (less than 20 feet in depth) rectangular concrete structures open to the atmosphere. To reduce turbulence, special distribution piping or baffling is installed at the inlet and outlet.



Hydraulic Considerations

These basins are usually designed to allow the forward velocity of the water to drop sufficiently to allow suspended solids to be deposited on the floor of the basin. The surface of the basin is typically large in relationship to the depth, thus providing a low surface settling rate. Surface settling rate is the number of gallons per minute applied to each square foot of surface area. The design specifications of these basins are based on the source water quality conditions.

Operation Consideration

Test Clarity

The basin should be inspected routinely (daily or weekly depending upon system size) and the water clarity observed. Inlet and outlet turbidity should be measured and recorded.

Short Circuiting

When inlet and/or outlet piping is not properly designed, or the flow through the basin exceeds design criteria, or depth of accumulated silt and other debris on the bottom exceeds design limits, the flow may **short circuit**[25] through the basin. If short circuiting occurs, suspended material may be carried through the basin to the treatment plant.

Build-up of Silt

The silt buildup on the bottom of the basin should be checked at least monthly and removed when it reaches a depth equal to 10% of the total depth of water in the basin.

Structure Inspection

At least once a year the basin should be drained and the structure inspected for:

- Cracks
- Rust streaks indicating a deterioration of rebar
- Overall condition of the concrete
- Operation of valves and gates
- Condition of handrails and walkways

[25] **Short Circuiting** – A condition that occurs in tanks or ponds when portions of the water travel faster than the rest of the flowing water.

Springs

With some exceptions, springs are groundwater that is under the influence of surface water. While not a common municipal water supply, spring are used by a number of small to medium sized utilities. Production from a spring may range from a few gallons per minute to several thousand gallons per minute.

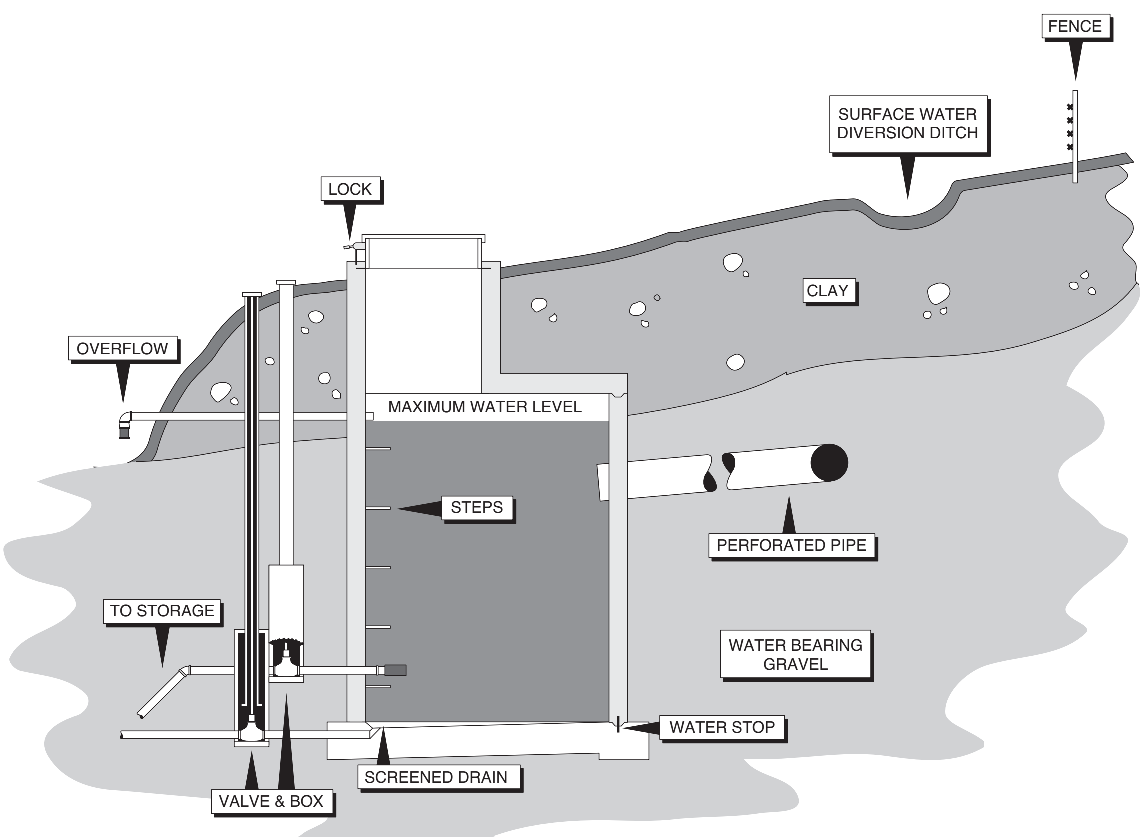
Components

Intake

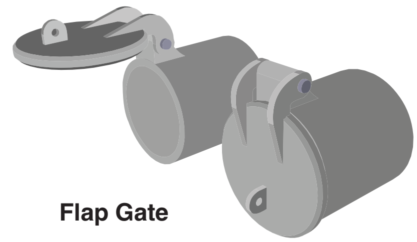
The intake structure commonly used to collect water from a spring is composed of either perforated pipe or well screen. One or more pipes are buried into the water bearing strata. A second method used, where the water bearing material is fractured rock or the slope is too steep for digging, is the insertion of horizontal well screens. A specially designed well rig is used to drill a hole horizontally in the bank. A well casing and well screen are grouted into the bank and water collected.

Spring Box

The water from the intake structure is piped into a concrete spring box. The box is equipped with a vandal resistant, shoe-box type lid. The lid should remain locked except when the box is being entered by a member of the utility crew. The outlet from the box should be off the floor and valved. A vent and overflow are typically installed in the box and are



protected from outside contamination by a #22 mesh screen. A valved drain should be installed, flush with the floor and the end of the drain line protected from contamination with a screen or flap gate. Caution: springs boxes are typically permit required confined spaces.



Surface Protection

To protect the source from surface contamination, a clay cap should be placed over the perforated pipe. A diversion ditch should be placed above the water bearing strata and designed in such a way as to channel any surface runoff away from the intake. To prevent contamination by livestock and wild animals, an appropriate fence should be placed above the intake structure.

Routine Operations

Water Quality

The chemical and biological water quality from the spring should be sampled and tested in the same manner and frequency as any other surface water source. The recommendations for sampling and testing are provided above.

Inspection & Cleaning

The spring box should be drained, inspected, cleaned with clean water, and disinfected once each year. The disinfection can be accomplished by mixing one (1) gallon of household bleach with water in a five (5) gallon bucket. The solution can be sprayed or mopped onto the walls and floor of the basin.

Screens

The screens on the vent, overflow, and drain should be inspected once each year. Any damaged or deteriorated screens should be replaced.

Hatch

The hatch, like the screens, should be inspected annually and replaced or repaired as necessary.

Valves

All valves should be located and exercised once each month.

Above Intake

The area above the intake should be inspected for damage to the diversion ditch and fence once a year. This area should also be inspected for activities that could contaminate the water source.

Recharge Protection

The recharge area for the spring should, if possible, be identified and the procedures described above in the performance of a water quality survey applied to this area.

Roof Catchment

Introduction

While not popular with large water systems, roof catchment systems are used in the U.S. Virgin Islands, Hawaii, central plains of the U.S., South Pacific, Western Pacific, arid regions of the Western U.S., and Southeast Alaska. This is one of the few effective means of collecting rain water. The basic concept is to collect the rain water from the roof of a structure and pipe it directly into some type of holding basin.

Components

Diversion Box

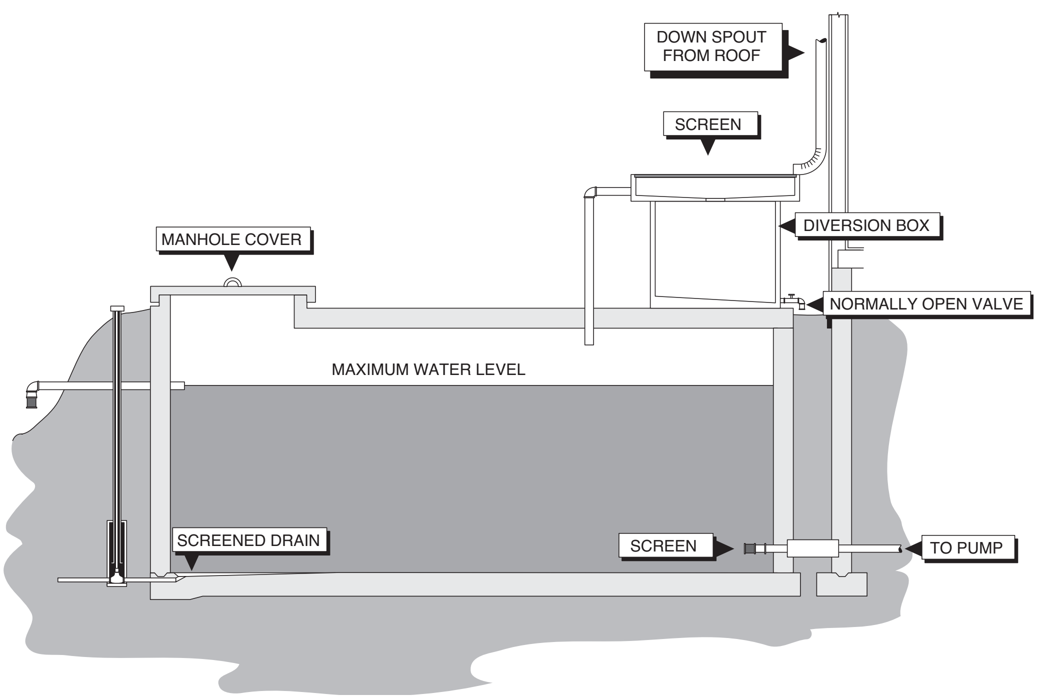
One of the safest and most effective designs of a roof catchment includes a screened diversion box. The water must fill the diversion box before any water enters the catchment. This allows the first water from the roof to be piped to waste and thus reduces the amount of debris carried into the catchment. A screen on top of the diversion box catches large material.

Inlet

Once the diversion box fills to the top, water is directed into the catchment box.

Catchment

The catchment box may be concrete, plastic, wood, or metal. Any commercial container should be NSF approved. The catchment box is designed in much the same way as a spring box or storage reservoir. The entrance is protected with a shoe-box type hatch that is kept locked except for inspection and maintenance. The overflow, drain, and vent are screened with #22 mesh, non-corrosive screen. The outlet is screened and up off the floor. A valved drain is flush with the floor and allows dewatering and cleaning of the basin.



Typical Roof catchment system on the island of Majuro in the Republic of the Marshall Islands

Roof catchment system. At an elementary school on the island of Peleliu in the Republic of Palau.

Routine Operations

Water Quality	The chemical and biological water quality from the catchment should be sampled and tested in the same manner and frequency as any other surface water source. The recommendations for sampling and testing are provided above.
Inspection & Cleaning	The roof catchment should be drained, inspected, cleaned with clean water, and disinfected once each year. The disinfection can be accomplished by mixing one (1) gallon of household bleach with water in a five (5) gallon bucket. The solution can be sprayed or mopped onto the walls and floor of the basin.
Routine Disinfection	Disinfection can be maintained by adding one (1/4) cup of bleach to each 500 gallon tank of water.
Screens	The screens on the vent, overflow, and drain should be inspected once each year. Any damaged or deteriorated screens should be replaced.
Hatch	The hatch, like the screens, should be inspected annually and replaced or repaired as necessary.
Roof	The roof of the building should be inspected once each year for sources of contamination. As various roof materials deteriorate, they can contribute to increased levels of contaminants.
Valves	All valves should be located and exercised once each month.
Primitive Sites	In locations where electricity or technology are limited, the entire catchment system may be located above ground, with a gravity flow outlet.

Source Water Assessment Program (SWAP)

Purpose

Virtually every stream, lake, river and aquifer in the U.S. is used as a drinking water source. As a result, protecting these source waters from contaminants is key to protecting public health through ensuring a clean, safe drinking water supply. The protection of source water is one of the barriers to entry of waterborne disease into the drinking water system. In addition, protecting the source water or improving its quality reduces treatment cost.

SDWA

The Source Water Protection Program defined in the 1996 Amendments to the Safe Drinking Water Act, required each state to develop and implement a Source Water Assessment Program (SWAP). This program is composed of six steps:

- Delineation of the drinking water source protection area.
- An inventory of known and potential sources of contamination within these areas.
- Determination of the susceptibility of the water system to these contaminants.
- Notification and involvement of the public by providing them with information on the contaminant source inventory and what the findings of the inventory mean to their water system.
- Implementation of management measures to prevent, reduce, or eliminate threats posed by the contaminates identified in the inventory.
- Development and implementation of a contingency (emergency response) plan to deal with water supply contamination or service interruption emergencies.

Sources Affected

This plan addresses both groundwater and surface water systems and incorporates the activities and components found in a “well head protection program.”

Components in this Text

The delineation, inventory of contamination, and determination of susceptibility have been addressed in some detail in this text. The inventory of actual or potential contamination as well as an assessment of water quality are addressed in depth. The need for a contingency plan is also addressed. However, the development of the plan is considered a management practice and thus not addressed in this text.

Management Practices

The activities described in this chapter address all but two of the six steps. The two not addressed are: public notification and involvement, and implementation of management practices to prevent, reduce, or eliminate threats with contamination. As these are both considered management practices they have not been addressed in this text. However, the watershed management practices described in this text are key components in the implementation step of the SWAP.

Most Positive Component

One of the most positive aspects of the SWAP program is the management requirement it provides. Water purveyors now have the tools necessary to control (to some extent) activities in a watershed that could have a negative impact on water quality. In order to effectively protect public health, water purveyors should utilize every tool and measure available to them as a means of protecting the quality and quantity of water.

Surface Water Worksheet

1. One of the functions of watershed management is the annual completion of two surveys. They are _________________ _________________ survey and the ________________ survey.

2. When the utility does not own the watershed, watershed management practices would include a _________________ ________________ with land owners describing details on allowable _________________.

3. The two common watershed management policies are _____________________ _________ policy and the _______________ _____________ policy.

4. The "Natural Flow" rule is part of the __________________ doctrine of water rights.

5. First in time, first in line, is a summary of the ___________________ doctrine of water rights.

6. The water rights based on Spanish law are called _________________ water rights.

7. In most jurisdictions, ____________________ use is considered the highest priority beneficial use of water.

8. Minimum low flows established for fisheries act like a water right in which doctrine?

9. A source protection plan contains three key elements. They are a ___________________ statement, ______________ of major sources of _________________, and _____________ with upstream communities, potential polluters, and agencies.

10. A spill response plan is based on a _____________________ assessment or analysis.

11. The quality and quantity of water flowing from a watershed is impacted by four major watershed budgets:

    a. _________________________ b. _______________________

    c. _________________________ d. _______________________

12. Background water quantity and quality data that are used to determine the impact of activity in a watershed is called ____________________ data.

13. Potential sources of contamination in a watershed can be divided into two general categories: ______________________ and _________________ made.

14. The U.S. Forest Service stream condition evaluation tool provides guidelines for evaluating three components of the stream: the __________________ bank, _______________ bank, and ________________ bottom.

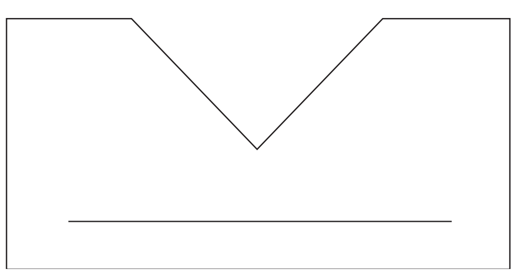
15. In hydrology terms, a rain storm is called a ____________________ event.

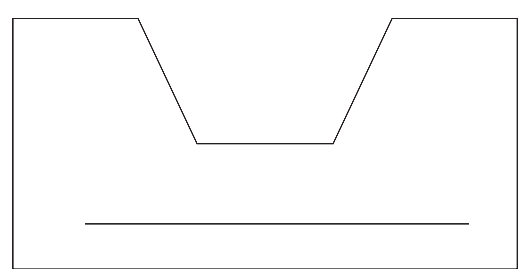
16. In watershed management, rainfall should be measured and recorded once each __________.

17. A watershed is composed of 320 acres. A rain storm of 0.5 inches is measured in the watershed. If 8% of this rainfall becomes runoff, how many gallons of water are produced?

18. Two common, primary measuring devices that can be used to measure stream flow are __________________ and _________________.

19. Identify by name the two weirs shown below:





20. The device used to measure the head over a weir plate is called a ________________ gauge and is placed __________ to _______ times the maximum head upstream of the weir plate.

21. The water spilling out of a weir is called the _______________.

22. A flow of 4 cfs is how many gallons per minute?

23. A ______________________ measurement uses an instrument to measure the velocity of a segment of a stream.

24. A _______________ station is a permanent structure for recording stream stages.

25. A rectangular culvert is 24 inches deep and 36 inches wide. The water level in the culvert is 8 inches deep. The velocity is estimated at 0.25 ft per second. What is the flow in cfs and gpm?

26. Macroanimals such as stonefly nymphs, clams, and caddis fly larvae are called ________________ organisms.

27. Alkalinity, pH, and iron are examples of _____________________ and are not classified as pollutants or contaminants.

28. Raw water quality data is compared against water quality _______________ and the EPA ________________ to determine required treatment strategies.

29. One of the most important measures of water quality is the ____________ __________ level in the stream.

30. It is desirable that raw water quality not exceed these limits:

Iron ____________ mg/L   Manganese ______________ mg/L

pH _________ to ________   Hardness below _____________ mg/L

31. Knowing the total coliform levels in a raw water supply can assist the operator in adjusting _________________ dosage.

32. Ambient conditions refer to ________________, _____________ and _____________ conditions.

33. Proper operation of a surface water source calls for daily sampling and testing the following chemical and physical parameters:

    a. ____________________ b. ____________________

    c. ____________________ d. ____________________

34. A water quality survey is composed of four steps:

    a. ____________________ b. ____________________

    c. ____________________ d. ____________________

35. In a properly operated surface water system, organic and inorganic samples should be collected from the sources and tested ___________________________ (frequency).

36. Water quality data, sanitary surveys, and water quality surveys should be maintained by the utility for _____________ years.

37. Small raw water storage facilities can contribute to the __________________ or ____________________ of water quality.

38. How many gallons of water are contained in 4 acre-feet?

39. One of the primary causes of deterioration of water quality in a storage reservoir is the build up of ___________________.

40. The upper layer of water in a stratified reservoir is called the ___________________ or the __________________ zone.

41. Water quality in a reservoir should be tested every ________ feet of depth.

42. Algae blooms usually occur in which layer of a stratified reservoir: hypolimnion or epilimnion?

43. An increase in nutrients in a reservoir can cause an _____________ bloom, which will result in a drop in ___________ __________ and thus a deterioration in water quality.

44. Low D.O. conditions at the bottom of a reservoir can allow anaerobic bacteria to produce ________________ ______________ gas, which causes odor and taste. In addition this condition can cause the pH to be reduced, thus allowing insoluble ____________ and/or ______________ to be oxidized and brought into solution.

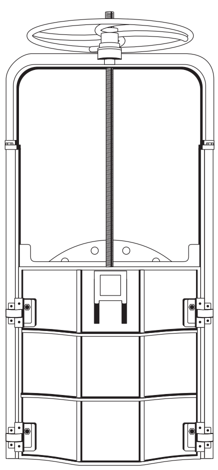
45. One method of treating algae in an open reservoir is the application of __________ __________.

46. An annual inspection of a storage facility dam focuses on the condition of the _______________. In addition, the operation and condition of all ____________ and ____________ should be checked.

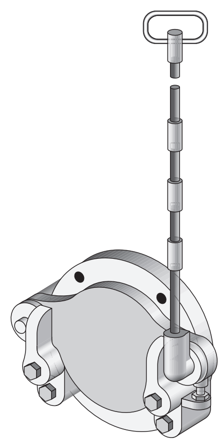
47. The Federal Guidelines for Dam Safety established in 1979 require all dams greater than _____ feet or higher to be inspected once every _____ years by a __________ engineer.

48. The clarity of water in a reservoir can be checked physically with a black and white disk called _________________ disk.

49. Identify the two types of valves used to control water into and out of a surface water intake:



a. ____________________



b. ____________________

50. An _________________ gallery is a system used to collect water from under a stream.

51. Intake structures and equipment should be inspected ______________ (frequency) in most systems.

52. One of the major problems with raw water settling basins is ________________ ________________. This condition causes the water exiting the basin to be of less than desirable quality because it has not been in the basin long enough for suspended materials to settle out.

53. Spring boxes should be cleaned and disinfected at least __________________ per year.

54. The lid on a spring box should be the _____________ box type and locked.

55. Roof catchments should be cleaned and inspected at least ________________ per year.

56. The SWAP was included in the 1996 Amendments to the SDWA because protecting the water source is one of the ______________ to entry of _____________ _____________ and protecting the source water or improving its quality will reduce ______________ cost.