Small Water System Operator Certification Manual

For Other Than Municipal and
Nontransient Noncommunity
Public Water Systems

Second Edition

Wisconsin Department of Natural Resources
Bureau of Drinking Water and Groundwater
PO Box 7921, Madison, WI 53707

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Introduction

One requirement of the 1996 amendments to the Federal Safe Drinking Water Act is that owners of all small public water systems must have a designated certified operator managing his/her system. The intent of this requirement is to ensure that the operators of these systems have the necessary knowledge and training to provide a safe and dependable supply of drinking water to their customers.

To meet this requirement, the Wisconsin Department of Natural Resources contracted with the Wisconsin Rural Water Association to produce this manual for small water system operators. It is intended to be used not only as a study guide for the certification exam, but also as a comprehensive reference manual containing information on all aspects of waterworks processes and procedures to assist drinking water providers in their day-to-day operations.

Small Water System Operator Certification

Wisconsin's Small Water System Operator Certification Program for Other Than Municipal and Nontransient Noncommunity water systems began March 2002 with training classes and exams held at different locations throughout the state. Currently, exams are offered twice per year in May and November at 6 city locations around the state.
The exam consists of approximately 50 multiple choice questions. An operator must correctly answer 75% or more of the questions to obtain state certification. Once certified, an operator must also acquire at least 6 hours of continuing education credits every 3 years to maintain certification. These credits are acquired by attending state approved training classes on subjects relating to the drinking water industry.

The production of this manual was a cooperative effort of staff of the Wisconsin Department of Natural Resources Bureau of Drinking Water and Groundwater and the Wisconsin Rural Water Association, with input from a Peer Review Committee consisting of individuals from all areas of the waterworks industry in Wisconsin. We would like to express our heartfelt appreciation to everyone who assisted in this process for his or her time and efforts.

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Chapter 1
Drinking Water Regulations

Drinking Water Regulations

The History of Drinking Water Regulations

Federal authority to establish drinking water standards was first enacted by Congress in 1893 with the passage of the Interstate Quarantine Act. The primary intent of this act was to prevent the spread of disease both from other countries into the U.S. and from state to state. The provisions of the Interstate Quarantine Act were enforced by the US Public Health Service (USPHS) and at the time, only applied to water systems that provided water to interstate means of transportation, such as boats and trains.

The USPHS developed more comprehensive standards for drinking water over the years, including some limits on chemical, physical, and bacteriological contamination. These standards were not mandatory, but they were usually adopted by those states that developed their own requirements for public water systems.

As technological advances were made in the 1960’s and 1970’s that allowed for better identification and detection of disease-causing organisms and chemicals in water, there was increasing pressure on the federal government to create uniform, nationwide drinking water standards for public water systems. The act that followed was called the ***Safe Drinking Water Act (SDWA)*** and was first passed by Congress in 1974. It has been amended twice since then, most recently in 1996. The SDWA not only sets water quality standards, but it also contains other regulations for the drinking water industry, which are important in protecting public health.

US Environmental Protection Agency

The federal agency responsible for establishing public drinking water standards and enforcing the requirements of the SDWA is the ***U.S. Environmental Protection Agency (EPA)***. However, the EPA can delegate enforcement authority to the states if the state elects to do so. This is called “***Primacy Authority.***” Most states have primacy authority to enforce the provisions of the SDWA in their state. If they do, they must establish requirements at least as stringent as those set by EPA.

Wisconsin Drinking Water Regulations

Wisconsin has long been recognized as a leader in the protection of natural resources and public health through stringent water regulations. Wisconsin has received approval from EPA to have primacy authority for enforcing public drinking water regulations in the state. These regulations are enforced by the Wisconsin Department of Natural Resources (DNR). In the DNR, the ***Bureau of Drinking Water and Groundwater*** is responsible for enforcing SDWA regulations.

The DNR not only enforces drinking water standards, such as those in the SDWA, but it is also responsible for establishing and enforcing standards and regulations for water system design, construction, operation and maintenance, well construction and placement, pumps, treatment processes, chemical addition, well abandonment, lab certification, and wellhead protection. To ensure water systems meet these state requirements, water system owners are responsible for obtaining plan approvals from the DNR for well construction, pump installation, well rehabilitation, chemical addition to water, water treatment, and new system capacity. ***Plan approvals*** help ensure that water suppliers provide a safe and dependable supply of water to their customers.

DNR personnel assure compliance with all appropriate codes and regulations by performing periodic on-site inspections of each system. These inspections are called ***Sanitary Surveys*** and their frequency depends upon the size and classification of the water system. During the sanitary survey, the DNR representative will review the system's compliance and monitoring records and inspect the water system facilities. Following the inspection, the system owner will receive a written report listing any deficiencies or violations found, and a time frame for the system to correct the problems.

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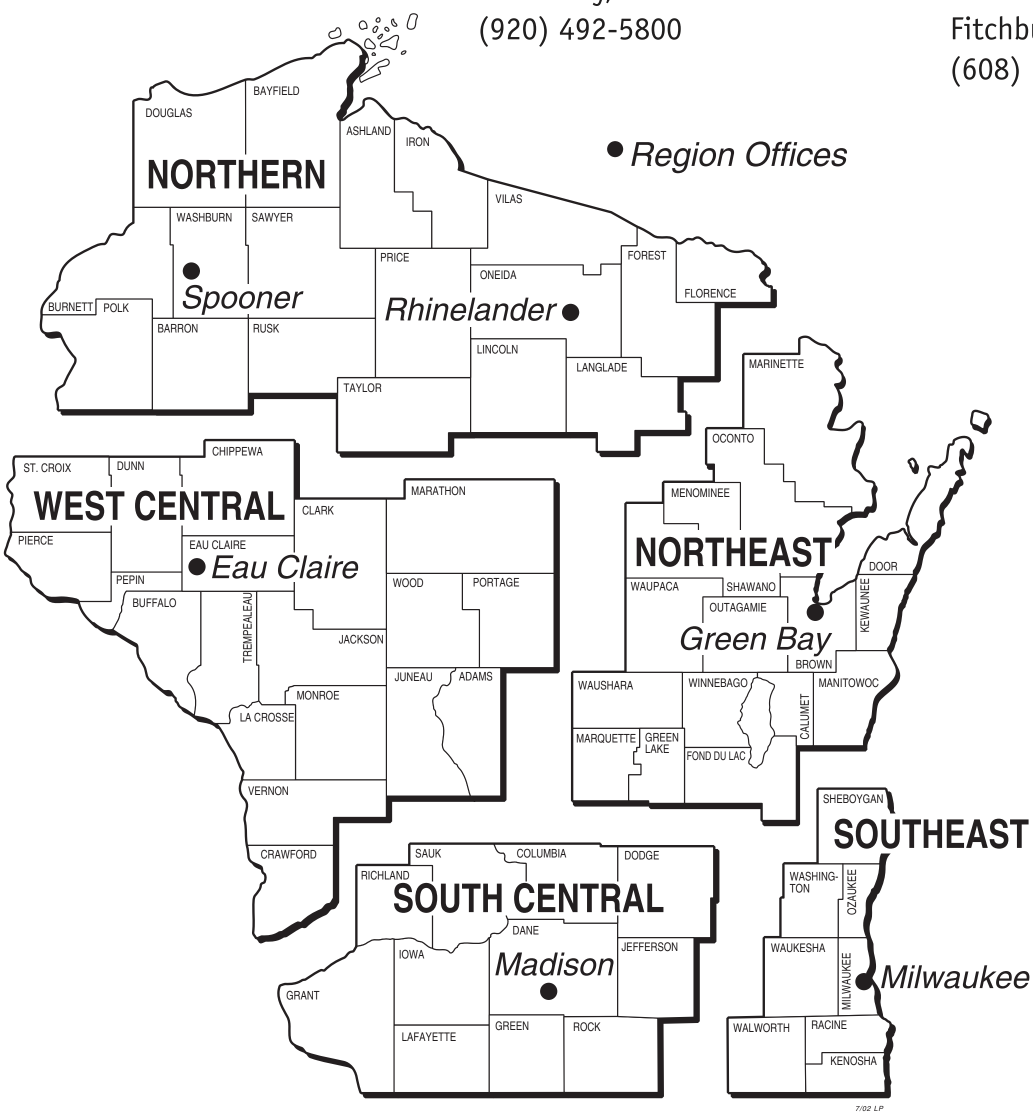


Public Water System Classification

SDWA regulations apply to all public water systems. The most basic definition of a ***public water system*** is any system that has at least 15 service connections or serves at least 25 persons at least 60 days per year. Public water systems may then be broken down into two major classes. These classes are community water systems that serve ***residential*** consumers and noncommunity water systems that serve ***non-residential or transient*** consumers.

Community Water Systems

Community water systems are divided into two sub-categories. A ***municipal water system (MC)*** is a water system that serves at least 25 year-round residents, or serves 15 or more service connections used by year-round residents. The water system is owned by a municipality such as a city, town, village, sanitary district, or a state, county or federal institution.

An ***other than municipal water system (OTM or OC)*** is a water system that serves at least 25 year-round residents or serves at least 15 service connections used by year-round residents. Anything greater than six months is considered "year-round". The water system is owned by an entity other than a municipality such as a subdivision, mobile home park, apartment complex or condominium association.

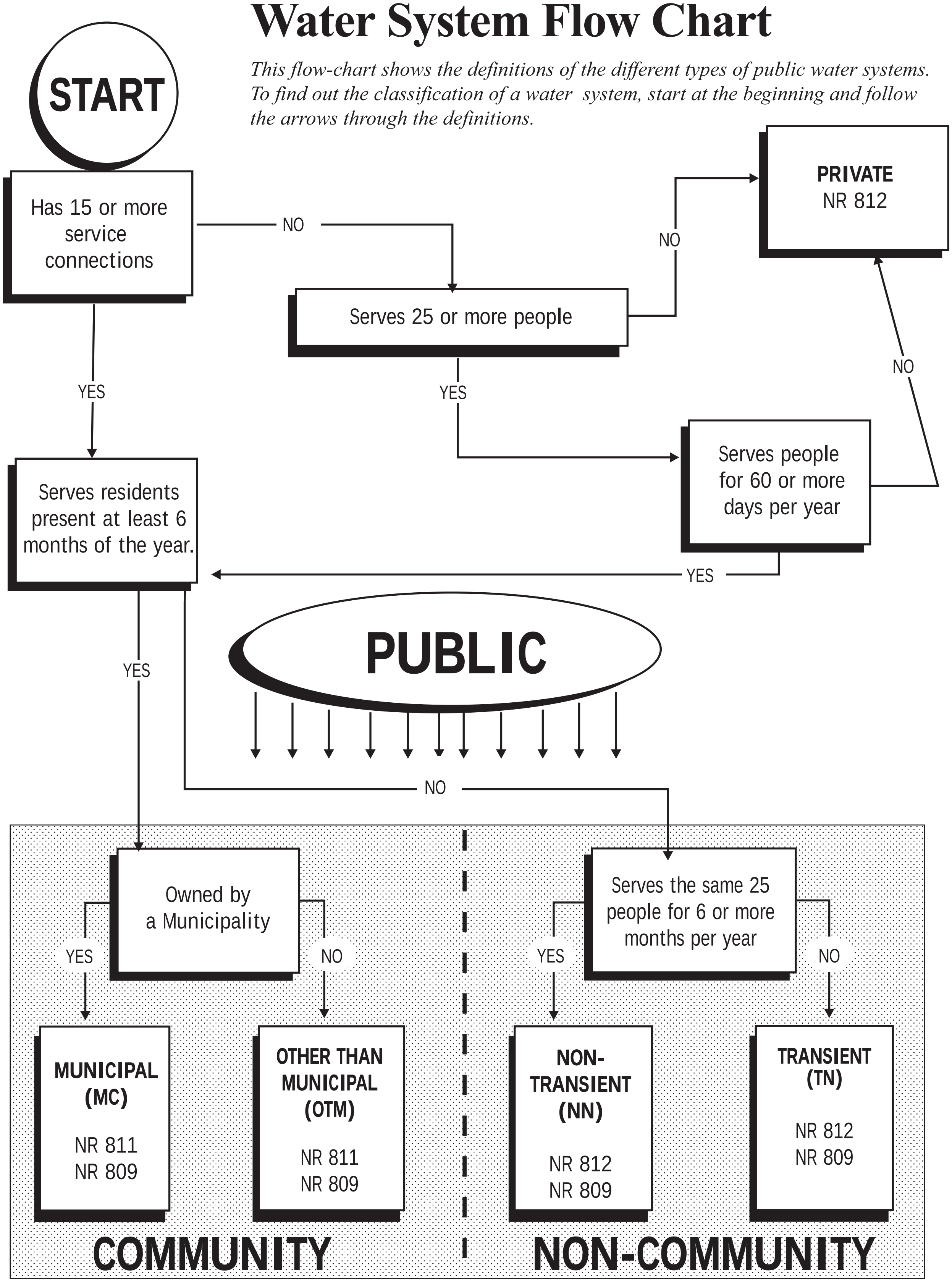
Noncommunity Water Systems

Noncommunity water systems are also divided into two sub-categories. A ***transient noncommunity water system (TN)*** is a water system that serves at least 25 people at least 60 days of the year, but those served change from day to day. Examples of TN systems include taverns, hotels, restaurants, churches, campgrounds, parks and gas stations.

A ***nontransient noncommunity water system (NN)*** is a water system that servers at least 25 of the sample people for 6 or more months of the year. Examples of NN systems include schools, day care centers, factories and businesses.

Water System Flow Chart

This flow-chart shows the definitions of the different types of public water systems. To find out the classification of a water system, start at the beginning and follow the arrows through the definitions.



Legal Definitions of Water Systems

Wisconsin Administrative Code Chapters NR 809, NR 811 and NR 812 are the primary State Codes used to implement the requirements of the SDWA in Wisconsin. They contain the following definitions:

NR 809.04(57) "Public water system" or "system" or "PWS" means a system for the provision to the public of piped water for human consumption through pipes or other constructed conveyances, if the system has at least 15 service connections or regularly serves an average of at least 25 individuals daily at least 60 days out of the year. A public water system is either a "community water system" or a "non–community water system".

A system:

(a) Includes any collection, treatment, storage, and distribution facilities under control of the operator of the system and used primarily in connection with the system.

(b) Includes any collection or pretreatment storage facilities not under the system's control which are used primarily in connection with the system.

(c) Does not include any "special irrigation district."

NR 809.04(4) "Community water system" or "CWS" means a public water system which serves at least 15 service connections used by year–round residents or regularly serves at least 25 year–round residents. Any public water system serving 7 or more homes, 10 or more mobile homes, 10 or more apartment units, or 10 or more condominium units shall be considered a community water system unless information is available to indicate that 25 year–round residents will not be served.

NR 811.02(20) "Municipal water system" means a community water system owned by a city, village, county, town, town sanitary district, utility district, public inland lake and rehabilitation district, municipal water district or a federal, state, county or municipal owned institution for congregate care or correction, or a privately owned water utility serving the foregoing.

NR 811.02(23) "Other–than–municipal water system" means a community water system that is not a municipal water system.

NR 809.04(47) "Non-community water system" or "NCWS" means a public water system that is not a community water system. A non-community water system is either a nontransient, non-community water system or a transient non-community water system.

NR 809.04(78) "Transient non-community water system" or "TNCWS" means a non-community water system that serves at least 25 people at least 60 days of the year. Examples of transient non-community water systems include those serving taverns, motels, restaurants, churches, campgrounds and parks.

NR 809.04(48) "Non-transient non-community water system" or "NTNCWS" means a non-community water system that regularly serves at least 25 of the same persons over 6 months per year. Examples of non-transient non-community water systems include those serving schools, day care centers and factories.

The classification of a public water system is important because it determines the level of regulation that a system must follow. In general, community water systems and non-transient non-community water systems are subject to stricter requirements than transient non-community water systems. State and federal regulations define **"serve"** as having water available for people to drink, and not the number of people who actually drink the water on a daily basis. This definition is important because even if a supplier provides bottled water for drinking but has plumbing fixtures supplied by a well, the water which comes out of those fixtures must meet drinking water standards.

Drinking Water Standards

Drinking water standards are divided into two categories. Health related drinking water standards are called ***Primary Drinking Water Standards*** and non-health related aesthetic drinking water standards are called ***Secondary Drinking Water Standards***.

Primary Drinking Water Standards

Primary drinking water standards are those dealing with contaminants that are known to have an adverse effect on human health. Each regulated contaminant that EPA has determined poses a public health risk is assigned a ***Maximum Contaminant Level (MCL)***. The maximum contaminant level or MCL is the maximum amount (concentration) of that particular contaminant in drinking water allowed by EPA. The EPA has determined that water containing amounts of a contaminant lower than the MCL do not pose a significant risk to public health. Some MCLs apply to all water systems such as those for bacteria and nitrate. Other MCLs only apply to community (municipal and other-than-municipal) and nontransient noncommunity water systems such as the MCLs for volatile organic compounds (VOCs) and synthetic organic compounds (SOCs). Public water systems must provide water that meets all applicable MCLs for their specific water system type.

Secondary Drinking Water Standards

Secondary drinking water standards deal with contaminants that affect the aesthetic quality of drinking water. These standards apply to such contaminants as iron, manganese, color, odor, and taste. As these contaminants have no known adverse health effects, public water systems are generally **NOT** required by state or federal drinking water regulations to meet these standards. The regulations do however give primacy agents authority to require corrective action when a secondary standard is exceeded and the resulting water quality is "*objectionable to an appreciable number of persons . .",* or " *detrimental to the public welfare . ."* .

Maximum Contaminant Level Goal

Before setting a maximum contaminant level (MCL) for any health related drinking water contaminant, the Safe Drinking Water Act requires EPA to set a ***Maximum Contaminant Level Goal (MCLG)***. The MCLG for a contaminant is the level at which there is no known or anticipated adverse health effect to humans. This level is expected to provide complete protection of public health, thus, in many cases the MCLG is set at zero. It is often significantly lower than the MCL because the MCLG does not take into account cost, treatability, or detectability of a contaminant.

Best Available Technology

Realizing that, in some cases, it is not technologically or financially feasible to achieve the MCLG for all contaminants, EPA establishes MCLs for all regulated contaminants in drinking water. In doing so, they take into account such factors as health risk assessments, cost-benefit analysis, and ***Best Available Technology (BAT)***, in establishing acceptable levels. The BAT refers to the technology available to detect and treat the contaminant of concern. EPA then sets the MCL as close to the MCLG as possible after taking all these factors into account. MCLs are the “drinking water standards” that all public water systems must meet. It is important to remember that as new health effects data becomes available, an MCL may be adjusted either up or down, depending on what the latest data shows.

Treatment Technique Requirement

For some contaminants, establishing a specific MCL is either not possible or too costly to mandate. For such contaminants, EPA may also choose to require specific water treatment practices called ***Treatment Technique Requirement (TTR),*** which, when implemented by the water system, would reasonably protect public health. Examples of TTR are corrosion control for reduction of lead and copper, and filtration for removal of particulates in surface water.

Variances and Conditional Waivers

If a water system cannot comply with a MCL, the SDWA allows states to grant ***variances*** and ***conditional waivers*** (or exemptions) in certain situations.

Variances

A variance can be granted by the state if the water system has already installed BAT and if there is no unreasonable risk posed to the public health. In granting a variance, the DNR must establish a schedule for the system to come into compliance and any additional measures the water system must undertake during the period of the variance. Only the nitrate standard applied to noncommunity water systems and community water systems serving a nursing home, prison or mental health facility may be considered for a variance at this time. Specific restrictions and requirements apply.

Conditional Waivers

The state may also consider granting a conditional waiver to a water system if the following three conditions exist:

- The water system is unable to comply due to compelling factors.
- No unreasonable risk to public health will exist as a result of the granting of the conditional waiver.
- The water system was in operation prior to January 1, 1989 or, if it is a newer system, there is no reasonable alternative drinking water source available.

In granting a conditional waiver, the state may require such conditions as increased monitoring, public notification, the installation of point-of-use treatment or filtration devices, or providing alternative water supplies to the customers. Conditional waivers are not generally granted for a period exceeding 3 years.

The difference between a variance and a conditional waiver

The main difference between a variance and a conditional waiver is that a water system does not have to install BAT before it applies for a conditional waiver. In either case, a variance or conditional waiver cannot be granted if there is an unreasonable risk to public health.

DNR Notification

Although the regulations contain many different requirements for water systems to notify their DNR representative depending on the situation and the type of treatment the system uses, the most important notifications the water supplier must remember are listed below.

As soon as possible, but no later than the end of the next business day when:

- There is a waterborne disease outbreak potentially attributed to the water system.
- There is an unsafe (positive) coliform bacteria water sample from any certified lab other than the State Laboratory of Hygiene.

Within 24-hours when:

- There is a failure to comply with any MCL, TTR, or monitoring requirement unless otherwise specified in drinking water codes.

Within 10-days of the end of a monitoring period:

- For all results of any monitoring which occurred during the specified monitoring period (month, quarter, year, etc.).
- For any monthly reports including the total monthly pumpage, static and pumping groundwater depth, and any other information on chemical addition (if applicable).

Record Keeping

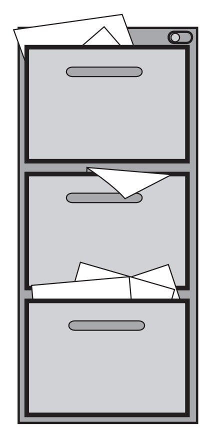
The owner or operator of a public water system must retain copies of their records for certain lengths of time. These records must contain certain information and must remain on the premises or at a convenient location near the premises.

Here is a list of records that public water systems must retain along with the length of time that the records must be kept:

• Actions to correct violations	3 Years
• Bacteriological results	5 Years
• Chemical results	10 Years
• Sanitary surveys	10 Years
• Lead and Copper data	12 Years

Actual laboratory reports may be kept or the data may be summarized in a table provided that the following information is included:

- The name of the person who took the sample.
- The date, place and time of sampling.
- Identification of the sample (e.g., routine, check, raw water, entry point, etc.).
- The date of analysis.
- Laboratory and person responsible for performing analysis.
- The analytical method used.
- The results of the analysis.



Public Notification

The federal government realizes that an important element of public safety is keeping the customer informed about the quality of their drinking water. Two regulations that were enacted to help accomplish this goal are the ***Consumer Confidence Report*** and the *Public Notification Rule*.

Consumer Confidence Report

The Consumer Confidence Report (CCR) is a report that community water systems (OTM and MC systems) must provide or make available to their customers annually. The report is an important public relations tool that shows customers the efforts made by the water supplier to provide safe water. It is designed to inform the customers of the quality of the water they are drinking. It must include the following information:

- The source of water (groundwater or surface water).
- The name and phone number of the person that customers may contact if they have questions about the report or their water.
- The time, date, and location of any meetings that customers may attend.
- Definitions of the terms and abbreviations used in the report.
- Contaminants detected in the water (if any) and the levels found.
- Information on the health effects of the contaminants detected in the water and where additional information is available.
- Explanation of any violations, length of violations, potential health effects, and steps taken to address the violations.
- Compliance with other drinking water regulations.

The report must be made available to every customer of the water system *before July 1st of the following year* and must also be available in alternative languages if a significant number of the customers are non-English speaking.

Once the CCR has been completed and made available to the customers, the water system is required to complete a CCR Certification form detailing the efforts made to make the report available to the customers. Send the signed certification form and a copy of the CCR to the DNR.

CCR Instructions

Instructions and a template for creating a customized CCR for your system are available at:
www.dnr.state.wi.us/org/water/dwg/ccr/ccr_instructions.htm

Public Notification Rule

Whereas the CCR is designed to provide information to customers on an annual basis, the Public Notification Rule (PNR) specifies how and when water suppliers must inform their customers in the event of a violation or emergency situation. This rule specifies language, actions, time frames, and methods that must be used to notify the public.

Depending on the severity of the violation or situation, water suppliers have anywhere from 24 hours to one year to notify their customers. Public notices are divided into 3 *Tiers* to take into account the seriousness of the violation or situation.

Tier 1 Notice (within 24 hours)

For a Tier 1 notice, the water supplier must provide the notice to their customers within 24 hours of learning of the violation or situation. During this time period the water supplier must also contact the DNR to learn if additional requirements apply. For example, you may be required to provide repeat notices. Examples of situations that require a Tier 1 notice include violation of the MCL for total coliform, fecal or E. coli or nitrate and/or nitrite; a turbidity exceedance; a waterborne disease outbreak or an other waterborne emergency.

All public water systems must use one or more of the following methods to provide a Tier 1 notice to their customers:

- Radio
- Television
- Hand or direct delivery
- Posting in conspicuous locations

Tier 2 Notice (within 30 days)

For a Tier 2 notice, the water supplier must provide the notice to their customers within 30 days of learning of the violation. The water supplier must also issue a repeat notice every 3 months for as long as the violation persists. Examples of violations that require a Tier 2 notice include all MCL, Maximum Residual Disinfectant Level (MRDL) and treatment technique violations (except where a Tier 1 notice is required), and; monitoring and testing violations elevated to Tier 2 by the DNR.

Community water systems (OTM and MC systems) must provide a Tier 2 notice to their customers as follows:

- Mail or hand delivery.
- Any other method to reach persons served if they would not normally be reached by mail or hand delivery.

Non-community water systems (NN and TN systems) must provide a Tier 2 notice to their customers as follows:

- Posting the notice in conspicuous locations.
- Mail or hand delivery.
- Any other method to reach persons served if they would not normally be reached by posting, mail or hand delivery.

Tier 3 Notice (within 1 year)

For a Tier 3 notice, the water supplier must provide the notice to their customers within 1 year of learning of the violation. Tier 3 notices may be distributed individually or combined into an annual report. The water supplier must also issue a repeat notice annually as long as the violation persists. Examples of violations that require a Tier 3 notice include monitoring and reporting violations (except were a Tier 1 notice is required or the DNR determines a Tier 2 notice is required).

Community water sytems (OTM and MC systems) must provide a Tier 3 notice to their customers as follows:

- Mail or hand delivery.
- Any other method to reach persons served if they would not normally be reached by mail or hand delivery.
- CCR if the violations requiring a Tier 3 notice are less than 1 year old.

Non-community water systems (NN and TN systems) must provide the notice to their customers as follows:

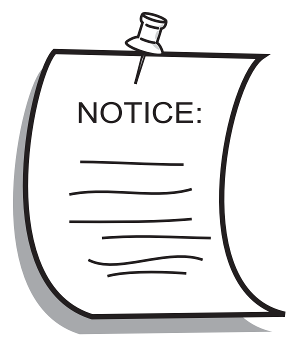
- Posting the notice in conspicuous locations.
- Mail or hand delivery.
- Any other method to reach persons served if they would not normally be reached by posting, mail or hand delivery.

Tier Determination

If you have a violation or situation and you're not sure which type of notice is needed (Tier 1 or Tier 2 or Tier 3) or what needs to be done, make sure to contact your DNR representative right away. Remember, "**when in doubt, call the DNR and find out**."

10 Elements of a Public Notice

Each public notice must include the following 10 basic elements:



1. Description of the violation or situation.
2. When the violation or situation occurred.
3. Any potential health effects including standard health effects language.
4. The population at risk.
5. Whether alternative water supplies (for example, bottled water) should be used.
6. Action consumers should take, if any.
7. What the system is doing to correct the problem.
8. When the system expects to resolve the problem.
9. The name, business address and phone number of the system owner or operator.
10. A statement to encourage distribution of the notice to others.

After Issuing a Public Notice

The water supplier must send a copy of the notice and a signed certification to their DNR representative within 10 days after providing the notice to their customers. Failure to do so means that the water system owner will receive a public notice violation.

Violations

Violations of regulations for public drinking water systems can generally be placed in one of three categories. They are *water quality violations, monitoring and reporting violations, and water system violations*. A listing of the regulations for public water systems in Wisconsin can be found in the Wisconsin Administrative Code Chapters NR 809, NR 811 and NR 812. The table of contents for these codes can be found in Appendix A.

Water Quality Violations

Water quality violations occur when the level of a contaminant exceeds its MCL. The severity of the violation, and the resulting action that needs to be taken by the owner or operator, is determined by the risk posed to public health. Minimum required actions may include public notification and a time frame for compliance. If the violation poses a significant risk to public health, immediate notification, immediate treatment, and/or fines for non-compliance may apply.

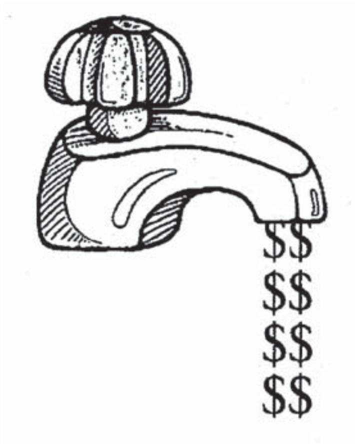
Monitoring & Reporting Violations

Monitoring and reporting violations (also called M/R violations) occur when the owner or operator of a public water system fails to collect their samples and/or report the results to the DNR as required. Monitoring schedules are mailed to all OTM and NN systems at the beginning of each year. These schedules list the contaminants that must be monitored and the time frame in which the monitoring must occur. A list of certified laboratories is included with the monitoring schedule. It is the responsibility of the system owner to make sure that all samples are collected at the appropriate location, within the appropriate time frame, analyzed by a certified laboratory, and that the monitoring forms are completed, signed and submitted to the DNR within 10 days of the end of the specified monitoring period. Failure to complete **any** of these actions is a monitoring and reporting violation and may result in increased monitoring, public notification and/or fines. The system owner or operator may also face substantial fines and/or penalties if he or she knowingly falsifies any monitoring or reporting data.

Water System Violations

Water system violations occur when a water system fails to meet code requirements for water system construction, operation, water pressure and flow. In most cases, violations of requirements for existing facilities are identified in sanitary surveys conducted by the DNR representative. Other violations occur when a water system owner fails to obtain the necessary DNR approval for facility upgrades, construction, and installation of water treatment. Violations of water system requirements will generally result in a compliance order listing the specific actions that must be taken and the time frame to complete the actions. Failure to take corrective action on a water system violation may result in substantial fines for the system owner or operator.

Capacity Development



Capacity development aims to help public water systems strengthen their ability to supply safe drinking water now and into the future. The program focuses on assisting system owners and operators, particularly small water systems, with improving their technical abilities, managerial skills, and financial resources to comply with the federal Safe Drinking Water Act (SDWA) requirements.

One of the goals of the Capacity Development Program is to help water systems improve operations and, most importantly, avoid contamination. The Capacity Development Program was authorized by the 1996 amendments to the SDWA, which established a strong new emphasis on preventing contamination.

Capacity, in this sense, does not mean just having enough safe water to drink. Rather, it means that a water system has the technical, managerial, and financial capability to ensure continuous delivery of safe drinking water to its customers.

Capacity can be broken down into three, interrelated types. They are *technical, managerial,* and *financial* capacity. Each type is further defined as follows:

Technical Capacity

Technical capacity is the physical and operational ability of a water system to meet the SDWA requirements. It refers to the physical infrastructure of the water system, including source water adequacy, infrastructure adequacy (including wells and/or source intakes, treatment, storage, and distribution system), and the ability of water system personnel to implement the necessary technical knowledge to safely operate the system.

Managerial Capacity

Managerial capacity refers to the water system's institutional and administrative capabilities. It refers to the management structure of the water system, including ownership accountability, hiring managing and training of water system staff and the overall water system organization.

Financial Capacity

Financial capacity refers to the financial resources of the water system. These resources include: revenue sufficiency (bill structures that take into account the need for future replacement of existing equipment), credit worthiness (the ability of the system owners to obtain and repay loans for needed capital improvements), and fiscal management (collection and management of sufficient revenues to safely operate and maintain the water system).

Wisconsin s Capacity Development Program

To assess these three areas, the EPA required the DNR to create a Capacity Development Program. The program was finalized in August 2000. It is meant to be a proactive means of evaluating and assisting water systems before problems occur, instead of dealing with problems after-the-fact.

The first phase of Wisconsin’s Capacity Development Program is to evaluate the “capacity” of each public water system. For new public water systems, the DNR evaluates system capacity prior to construction. For existing water systems, the DNR is using its inspection processes, namely sanitary surveys, to do this. Next, if capacity development problems are identified, the DNR uses different “tools” or activities to assist water systems. These tools will help public water systems comply with the SDWA requirements. Some of Wisconsin’s capacity development tools include:

One-on-one technical assistance from state and local government staff: Staff from municipal, county, and state government offer assistance to water systems owners and operators to help them understand the regulations.

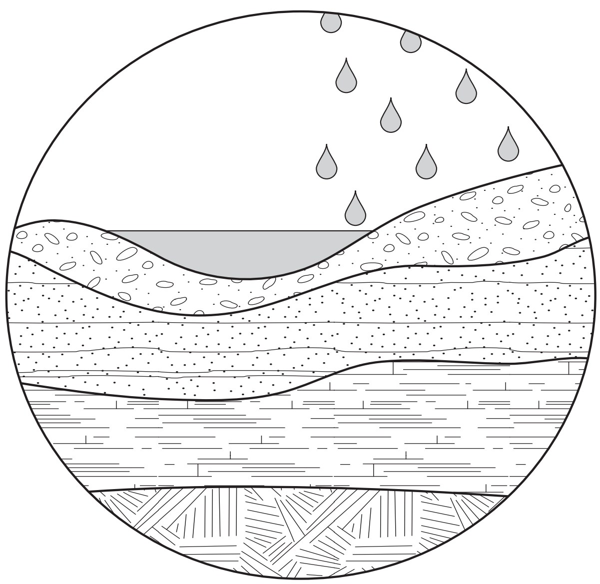
Operator Certification: The Operator Certification Program will help to ensure that water systems are run by appropriately trained and certified operators.

Technical assistance contractors: The DNR is working with contractors to provide technical assistance to OTM and NN systems. The contractors provide one-on-one assistance to water system operators, covering a variety of SDWA topics and issues.

Review Questions for Drinking Water Regulations

1. Name of the act that sets standards for drinking water quality?
2. What is the federal agency responsible for drinking water regulation?
3. What is the state agency responsible for drinking water regulations in Wisconsin?
4. What is the name of the authority given to states to enforce drinking water regulations?
5. What is the name of the on-site inspections conducted by DNR representatives to make sure systems are in compliance with drinking water regulations?
6. Name the two main classes of public water systems.
7. What are the two sub-categories of community water systems?
8. What are the two sub-categories of non-community water systems?
9. What's the main difference between a community water system and a non-community water system?
10. Name the two categories of drinking water standards.
11. What do the acronyms MCLG, MCL, TTR, and BAT stand for?
12. What is the difference between a variance and a conditional waiver?
13. What are the two regulations that are aimed at the customer's right to know about their water quality?
14. What is the name of the rankings established by the Public Notification Rule based on the severity of violations?
15. What are the three things used for assessing the capacity of a water system?

Chapter 2
Source Water



Source Water

For many years, when people wanted water, they simply picked a spot and drilled, dug, or pounded a well into the ground with little thought other than getting enough water to suit their needs. Those days are gone. These days, when people are looking for water, as much consideration must be paid to the quality of the water, as the quantity. This chapter explains the water cycle, water sources, water quality, and its characteristics. It also explains the actions well owners can take to protect the quality of the water they already have.

The Hydrologic Cycle

The hydrologic cycle is the continuous movement of water through the environment. Water undergoes physical, chemical, biological, and radiological changes due to different factors in the environment that affect its quality and characteristics.

Evaporation and Transpiration

Illustration 2-1 shows the hydrologic cycle. It starts with water entering the atmosphere through *evaporation* from surface water bodies such as ponds, lakes, rivers, and oceans. Evaporation is the changing of water from a liquid to a gaseous state called *water vapor*. Water also enters the atmosphere through *evapotranspiration* from plants. As plants take up water through their root system, it moves through the plant and returns to the atmosphere through tiny pores in its leaves.

Condensation

As water vapor enters the atmosphere it changes from water vapor to water drops. This process, caused by the cooling of water vapor, is called *condensation*. A good example of condensation is the liquid that forms on the outside of a cold glass of water on a hot summer day. As condensation occurs in the atmosphere, clouds are formed. Clouds are made up entirely of tiny water drops or ice crystals.

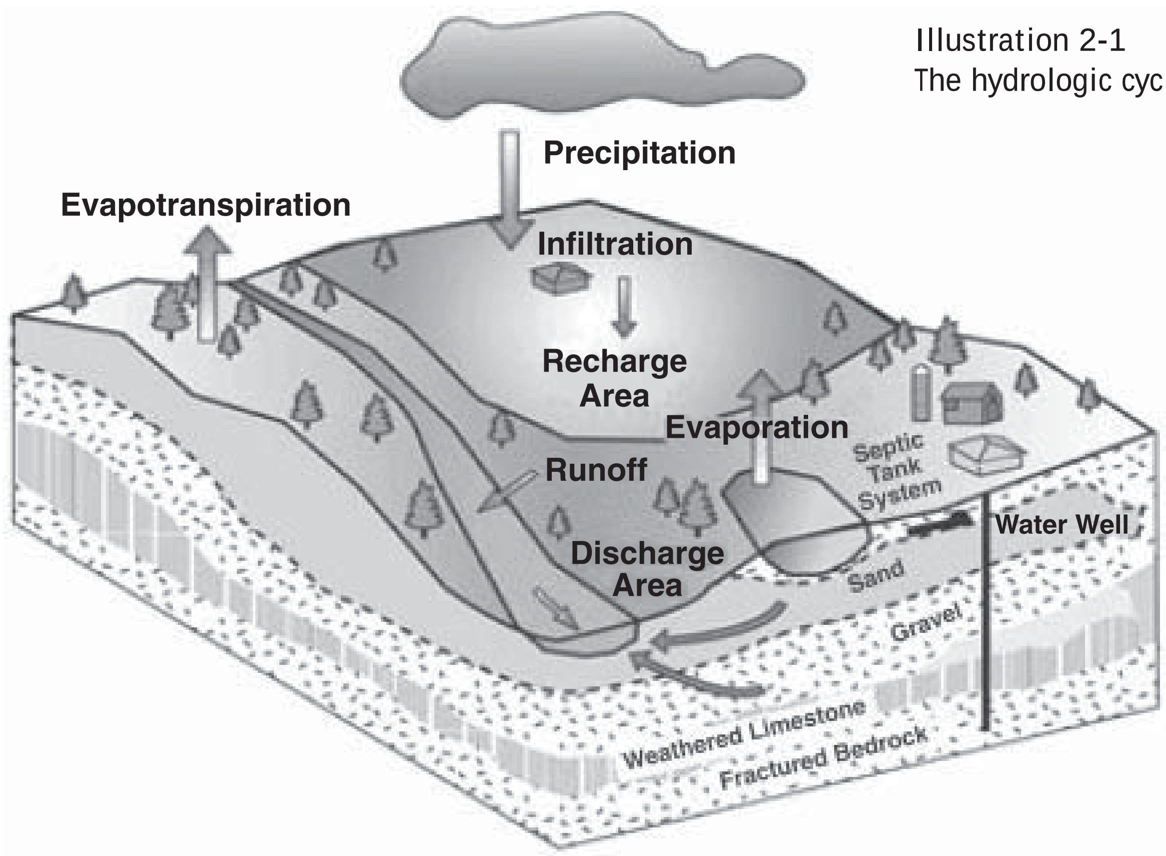


Illustration 2-1
The hydrologic cycle

Precipitation

As clouds absorb more and more water, they reach a point where they can hold no more and the water falls to the earth. This is called *precipitation*. In warm temperatures, it falls as drizzle or rain. In cold temperatures, it falls as hail, sleet, or snow.

Infiltration, Runoff, and Percolation

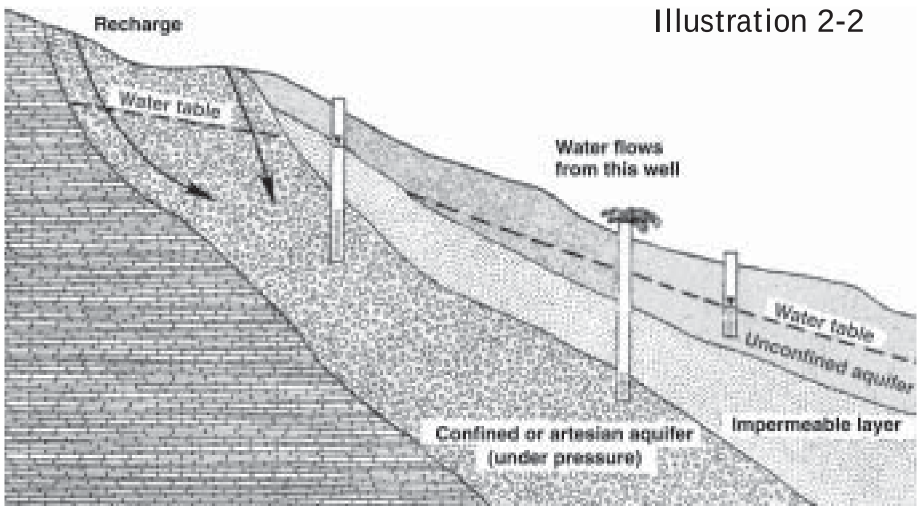
Once water reaches the earth's surface, some of it is absorbed by the soil. The process of water moving into the soil is called *infiltration*. Once water infiltrates into the soil, some is taken up by plant roots and re-enters the atmosphere through evapotranspiration. Some of the water moves further down through the soil. This is called *percolation*.

When soil can no longer hold any more water, it becomes *saturated*. If more precipitation falls, some of the water begins to flow across the ground. This is called *runoff*. Runoff flows into creeks, streams, rivers, and lakes and eventually re-enters the water cycle through evaporation.

Aquifers and Groundwater

Illustration 2-2 shows an aquifer and groundwater system. The water that infiltrates into and percolates down through the soil and rock eventually reaches a saturated zone called the *water table*. Below the water table is an *aquifer*. An aquifer is a water-bearing soil or rock formation below the earth's surface. The water contained in the aquifer is *groundwater*. There can be more than one aquifer below the surface in any one location. Aquifers fall into two broad categories, *unconfined* and *confined*.

Illustration 2-2



Unconfined and Confined Aquifers

An unconfined aquifer is located in a permeable formation where the water table is free to rise and fall, depending on factors such as the amount of rainfall and recharge. Confined aquifers or artesian aquifers are situated below an *impermeable layer* (confining layer) such as shale or clay. If an impermeable layer exists above the surrounding water table, a perched aquifer may form.

Consolidated and Unconsolidated Formations

Unconfined aquifers are often made up of sand and gravel formations. These formations are called *unconsolidated* because they are made up of loose materials that are not cemented together. Most unconsolidated formations are made up of glacial or river materials deposited thousands or millions of years ago. A *consolidated formation* consists of firm, coherent rock, such as sandstone, granite, dolomite, or limestone. Most consolidated formations were deposited hundreds of millions or billions of years ago.

Springs and Artesian Wells

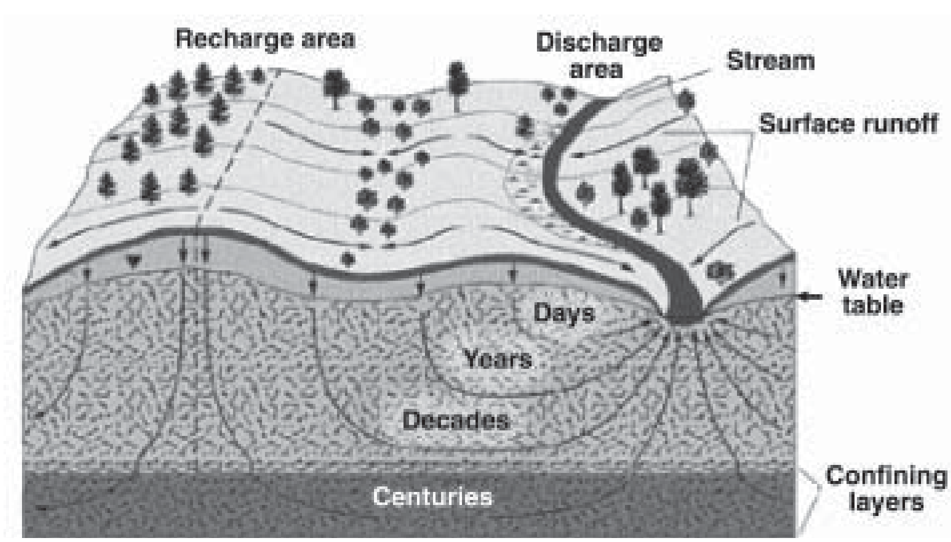
If a confined aquifer gets its water from a source at a higher elevation, it may be under pressure. If a well is cased through the confining layer, water in the well may rise above the aquifer - a further indication that it's under pressure. A well placed into this aquifer is called an *artesian* well. If water flows out of the well without being pumped, it is called a *flowing artesian* well (see Illustration 2-2).

Springs may form when an impermeable layer such as clay intersects a hillside. As water percolates down through the soil and intercepts the clay layer, the water flows along the top of the clay layer until it discharges on a hillside. Springs may also form when water-bearing fractured rock intersects a hillside.

Water Movement in Aquifers

Gravity and pressure control the movement of groundwater in aquifers. Like surface water, groundwater flows downhill. The natural movement of groundwater is from a point of high elevation (uplands) to a low one (lowlands), where it eventually discharges to a lake, stream, wetland, or spring. Near the coast, groundwater may discharge to the ocean.

Geology controls the rate of groundwater movement. In sand and gravel aquifers, groundwater may move hundreds of feet per year. In an aquifer made up primarily of silt and clay, groundwater moves only a few inches per year. Most groundwater moves a few feet per year. There are many factors that affect how groundwater moves including the permeability of the formation, fractures in the rock, the size and location of the recharge areas, and wells pumping from the aquifer. *Permeability* refers to the ability of rock or soil to transmit water. It is possible for groundwater to move at different speeds at different depths in the same aquifer.



Drinking Water Sources

Water exists in the environment in different forms and locations. The *source* of drinking water refers to where it's taken from. There are three main sources of drinking water in Wisconsin: *surface water*, *groundwater*, and *groundwater-under-the-influence of surface water*.

Surface Water

Water that is obtained from lakes, reservoirs, and rivers is called surface water. Surface waters are very susceptible to contamination. You name it - manure, gasoline, pesticides, fertilizers, industrial chemicals, bacteria, air pollution – it can enter surface waters. Because of their high susceptibility to contaminants, surface water sources must meet strict monitoring and treatment requirements.

While there are relatively few surface water systems in the world, they provide more water to more people than any other type of system. They are typically used by large cities that need a large volume of water to meet their needs (Milwaukee).

Groundwater

The water that is obtained from aquifers is called groundwater. Groundwater is generally less susceptible to contamination than surface water. Groundwater's susceptibility to contamination depends on the type and thickness of soil and rock layers, depth to the groundwater, and the type of contaminants. Some soils are very good at filtering out contaminants. Others are not. Groundwater in the central sands area and karst features of Wisconsin are very susceptible to contamination. In contrast, areas with thick, rich soil and a good depth to groundwater are generally less susceptible to contamination. In some areas of the state, groundwater may become contaminated with naturally occurring minerals in the soil and rock such as arsenic, lead, radium, radon gas and uranium. Groundwater systems generally have less restrictive monitoring and treatment requirements than surface water systems.

Groundwater Under the Influence of Surface Water

Water that is obtained from an aquifer that may be mixed with surface water is called "groundwater under the influence of surface water".

This situation may occur when a well is placed close to a lake or river. As the well is pumped, some of the water from the lake or river enters the groundwater, which, in turn, enters the well. In other words, the groundwater has a connection to the surface water. This connection makes the groundwater susceptible to the same types of contaminants as the surface water. Groundwater under the influence of surface water is covered by the same regulations as surface water systems.

Groundwater Sources In Wisconsin

The state of Wisconsin has a varied geology, which allows groundwater to exist in a variety of formations and aquifers. In Wisconsin, there are four principal aquifers: the *sand and gravel aquifer*, the *eastern dolomite aquifer*, the *sandstone and dolomite aquifer*, and the *crystalline bedrock aquifer*. These aquifers were formed by a variety of geologic processes including igneous intrusions, ancient oceans, and more recently, glaciers that covered 2/3 of the state during the Ice Age (see Table 2-1).

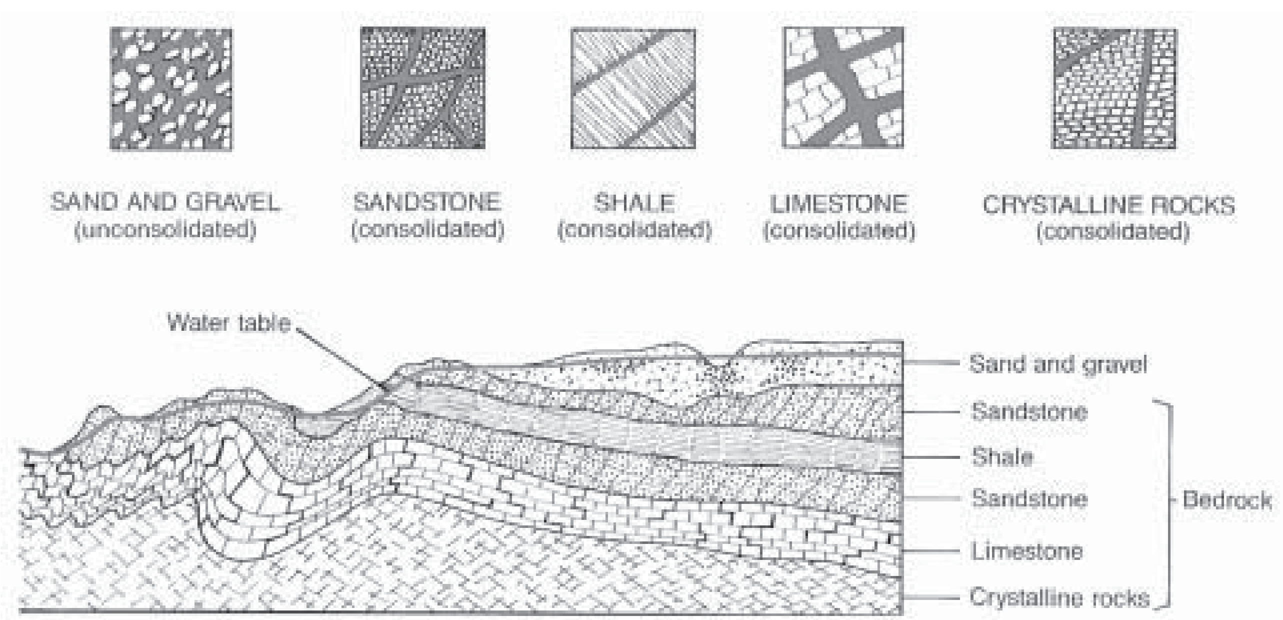


Table 2-1
Geologic Sections of Wisconsin Aquifers

<table>
<tr><th>System</th><th>Formation</th><th>Materials</th><th>Thickness</th><th>Water-bearing capability</th><th>Area of Wisconsin</th></tr>
<tr><td rowspan="2">Quaternary</td><td>Recent alluvium</td><td>Sand, gravel, peat, muck, marl</td><td>0'-100'</td><td rowspan="2">Small to large yields from sand and gravel regions</td><td rowspan="2">Majority of state except for west-southwestern</td></tr>
<tr><td>Pleistocene deposits</td><td>Boulder, clay, silt, sand, gravel</td><td>0'-500'</td></tr>
<tr><td>Devonian</td><td>Milwaukee and Theinsville</td><td>Dolomite, shale and limestone</td><td>50'-100'</td><td>Small</td><td rowspan="3">Eastern Lake Michigan coast</td></tr>
<tr><td>Silurian</td><td>Waubeka and Niagara</td><td>Dolomite</td><td>300'-825'</td><td>Small to moderate</td></tr>
<tr><td rowspan="4">Ordovician</td><td>Maquoketa shale</td><td>Dolomite shale</td><td>50'-540'</td><td rowspan="2">Small</td></tr>
<tr><td>Galena dolomite
Decorah shale
Platteville</td><td>Dolomite
Shale
Limestone</td><td>200'-350'</td><td rowspan="4">Eastern, western and south central areas of state</td></tr>
<tr><td>St. Peter</td><td>Sandstone</td><td>0'-330'</td><td rowspan="2">Small to moderate</td></tr>
<tr><td>Prairie du Chein</td><td>Dolomite</td><td>0'-200'</td></tr>
<tr><td>Cambrian</td><td>Trempealeau
Franconia
Dresbach
Eau Claire
Mount Simon</td><td>Sandstone</td><td>0'-1,000'</td><td>Small to large</td></tr>
<tr><td rowspan="2">Precambrian</td><td>Lake Superior</td><td>Sandstone, shale, basalt</td><td rowspan="2">Varies</td><td rowspan="2">Small</td><td>Northwestern</td></tr>
<tr><td>Basement complex</td><td>Crystalline bedrock</td><td>Entire state</td></tr>
</table>

The Sand and Gravel Aquifer

The sand and gravel aquifer covers most of the state, except for parts of southwest Wisconsin. Glaciers did not cover the southwestern portion of the state. This part of the state is known as the "Driftless Area." In Wisconsin, many sand and gravel formations are the result of the glacial movement and materials that were deposited as the ice melted. These shallow aquifers can be more than 300 feet thick in places and provide large volumes of groundwater. Because they are at or near the land surface and have little filtering capacity, they may be very susceptible to contamination.

The Eastern Dolomite Aquifer

The eastern dolomite aquifer, formed around 400 million years ago, is a narrow strip of Niagara dolomite over Maquoketa shale that exists along the easternmost part of the state, from Door County to the Illinois border. In some areas, the dolomite bedrock occurs at or near the surface leaving the shallow groundwater especially susceptible to contaminants. As dolomite is similar to limestone, groundwater resides in the interconnecting cracks and crevasses. Thus, the amount of water that can be obtained from a well is largely dependent on the cracks and crevasses it intersects. The Maquoketa shale is an impermeable rock layer formed from clay. It serves as a barrier between the eastern dolomite aquifer and the sandstone and dolomite aquifer below it.

The Sandstone and Dolomite Aquifer

The sandstone and dolomite aquifer formed from 425 to 600 million years ago. It covers most of the state, except in the northcentral Wisconsin. Along the eastern edge of the state, this aquifer exists below the Maquoketa shale. Throughout the rest of the state, it lies below the sand and gravel formations. As opposed to dolomite, the sandstone in this formation can produce substantial amounts of water, making it the principal bedrock aquifer for wells in the southern and western areas of the state.

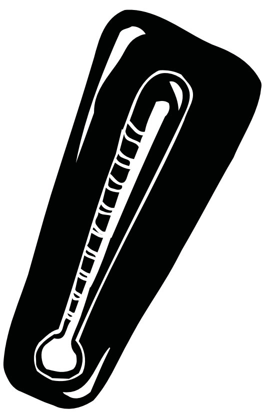
The Crystalline Bedrock Aquifer

The crystalline bedrock aquifer formed from 600 million to 4 billion years ago. It is made up of a granite-type crystalline structure that underlies the other aquifers throughout the entire state. As in the dolomite formations, water in the crystalline bedrock is contained mostly in cracks and crevasses.

Water Quality and Characteristics

The quality and characteristics of water are influenced by many factors including where it comes from and what it's exposed to as it travels through the hydrologic cycle. Water quality and characteristics are important to consider when choosing a water source. The four general categories of water characteristics are *physical*, *chemical*, *biological,* and *radiological*.

Physical Characteristics



Water *temperature* will affect how it tastes, how easily it dissolves things, and whether it's effective for other uses such as cooling. Generally, surface water sources are warmer than groundwater sources.

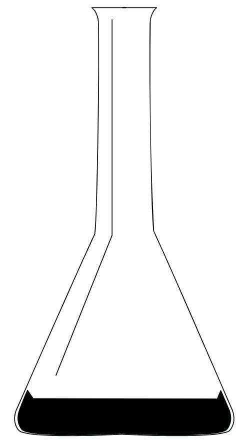
Turbidity is the cloudiness caused by matter or particles suspended in the water. This may include natural organic material, which is of aesthetic concern, but it may also include algae, bacteria, or microorganisms, which can cause serious health problems. Usually, the turbidity of groundwater is near zero due to the filtering characteristics of soil.

The *color* of water can be an important characteristic. Although color may be present in groundwater due to certain minerals or natural organic compounds, it is primarily of concern for surface water sources. Color is typically caused by the decomposition of organic materials such as leaves and plant remains.

The *taste* and *odor* of water can be caused by chemicals, minerals, decaying matter, or dissolved gases. The most common cause of odor in drinking water is the presence of hydrogen sulfide, iron, or sulphur-reducing bacteria. In a distribution system, the corrosion of pipe materials can also cause taste and odor. Even though taste and odor are more of an aesthetic concern than a health related one, their presence may be indicative of other contaminants that may be harmful to public health.

Chemical Characteristics

The chemical characteristics of water can be broken down into two main groups: organic and inorganic. Organic chemicals are carbon based, whereas inorganic chemicals are not.



Organic

Organic chemical characteristics in water come from the breakdown of naturally occurring materials, introduction of contaminants from human activities, and the reactions that occur during water treatment and distribution. The most common organic chemicals come from the breakdown of natural materials such as leaves and plants, aquatic decomposition, and other natural by-products. However, solvents, pesticides, herbicides and other commercial and industrial products are becoming more common in drinking water.

Inorganic

Inorganic chemical characteristics include such things as *pH*, *hardness*, *dissolved oxygen*, *dissolved solids*, and *electrical conductivity*.

pH

The pH of water is the level of its acidity or alkalinity. The pH scale is a numerical scale from 0 to 14. A pH of 7 is considered neutral. Generally, anything below 7 is considered acidic, and anything above 7 is considered alkaline. Acidic water has a tendency to corrode materials it comes into contact with. Conversely, alkaline water has a tendency to leave a scale buildup on the inside of plumbing fixtures.

Hardness

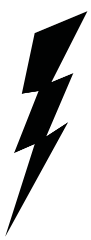
Hard water contains high amounts of calcium and magnesium ions. *Hard water* can be a problem because it requires more soap when washing and can lead to a buildup of calcium and magnesium on the inside of plumbing. This is especially true when hard water is heated, such as in a water heater. However, this scale buildup can have the beneficial affect of preventing lead and copper from leaching from plumbing fixtures into the water.

Dissolved Oxygen

Dissolved oxygen or DO is a common dissolved gas in water. Dissolved oxygen can enter the water from the air (aeration), by plants (photosynthesis), or introduced as part of a treatment process such as “air stripping”. High levels of dissolved oxygen in water can cause it to be corrosive, especially to metallic surfaces.

Dissolved Solids

Water is sometimes referred to as the “universal solvent” because it tends to dissolve minerals that it comes into contact with. Therefore, it may contain a variety of dissolved minerals. Some of these minerals such as arsenic, barium, lead, mercury and silver, can adversely affect human health, while others affect the aesthetic quality of water such as iron and manganese. The sum of minerals dissolved in water is referred to as *total dissolved solids* or TDS. Water with higher levels of dissolved minerals can cause problems with taste, odor, hardness, corrosion, and buildup. It can also cause problems when used in manufacturing processes.



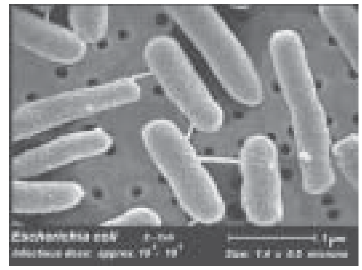
Electrical Conductivity

The electrical conductivity of water is its ability to conduct an electric current. Ions dissolved in the water cause electric current to flow. One way to determine the level of dissolved solids or TDS in water is to measure its electrical conductivity. Water with less dissolved solids will conduct less electricity than water with high levels of dissolved solids.

Biological Characteristics

Perhaps for drinking water the most important water characteristic is its biological quality. Microbial contaminants such as bacteria, viruses, and microscopic organisms pose the greatest health risk challenge for water system owners and operators. Mild to moderate illness lasting days to weeks can result from exposure to microbial pathogens. More serious health problems, even death, can result when people with weakened immune systems are exposed to pathogens. Microbial pathogens are present in human and animal feces, which can, in turn, contaminate drinking water.

Bacteria



The total coliform group of bacteria are found nearly everywhere in the environment, except in clean water. Some specific types of coliform bacteria are also associated with the digestive tracts of humans and many animals. While most forms of coliform bacteria are harmless, their presence in drinking water can indicate that either the water source or the distribution system has been contaminated by an external source. As such, the presence of total coliform in drinking water may be an indication that other more harmful bacteria, such as E. coli, are present. Fortunately, most forms of bacteria found in drinking water can be treated effectively with modern disinfection methods such as chlorine.

Viruses

Viral infection of drinking water supplies is another major concern in the protection of public health. Examples of waterborne viruses include enterovirus, rotovirus, and hepatitis. As with bacteria, the presence of viruses in drinking water may be associated with human wastes. If viruses are detected in drinking water, immediate steps must be taken to address the problem.

Microscopic Animals

Although most disease causing microscopic animals, or *protozoans*, are not naturally found in water, they can survive in water for a period of time. Examples of such animals include *Giardia* and *Cryptosporidium*. Their presence is also attributable to human and animal wastes, but unlike most bacteria and viruses, they can be particularly difficult to detect and treat in drinking water. That's because they are resistant to chlorine and can easily pass through inefficient filtration devices. Proper disinfection and/or filtration, system maintenance, and regular system upgrades are essential to protecting human health from these pathogens.

Radiological Characteristics

Although the presence of radiological elements, or *radionuclides*, in drinking water may be attributed to human activities, they are most often a result of dissolution of naturally occurring radioactive elements in rock formations such as granites. Examples of radionuclides found in drinking water include radium 226, radium 228, uranium, and radon. When consumed at high levels, these radioactive contaminants are known to cause cancer in humans.

Source Water Protection

For many years, people assumed that there is an unending supply of clean, safe water. However, we now know that many human activities can contaminate groundwater. That's why it's so important to prevent contamination whenever possible. Fortunately, there are many things water suppliers can do to protect the quality and quantity of their source water.

Water Conservation

One way to protect the quality and quantity of water is to limit the amount that is used. This is called *water conservation*. Although the earth contains adequate resources of water, it is disproportionately distributed. In some areas of the state, the amount of water available is decreasing at an alarming rate. As these supplies dwindle, either new wells must be drilled or existing ones drilled deeper. If you drill deeper, natural contaminants like arsenic and radioactivity may be encountered. If you pump too much water from existing wells, pesticides, gasoline or other contaminants may be drawn in from nearby sources. Any way you look at it, water conservation is a wise investment.

There are many ways to conserve water such as promoting the use of low-flow faucets, toilets, and showerheads. Industries can also be encouraged to recycle and reuse water in their processes. Perhaps the most effective means of promoting water conservation is public education. As customers become aware of the potential health risks of contaminated water and the high costs of treatment, they will learn to use water wisely and protect it as a valuable resource.

Water Loss in Gallons

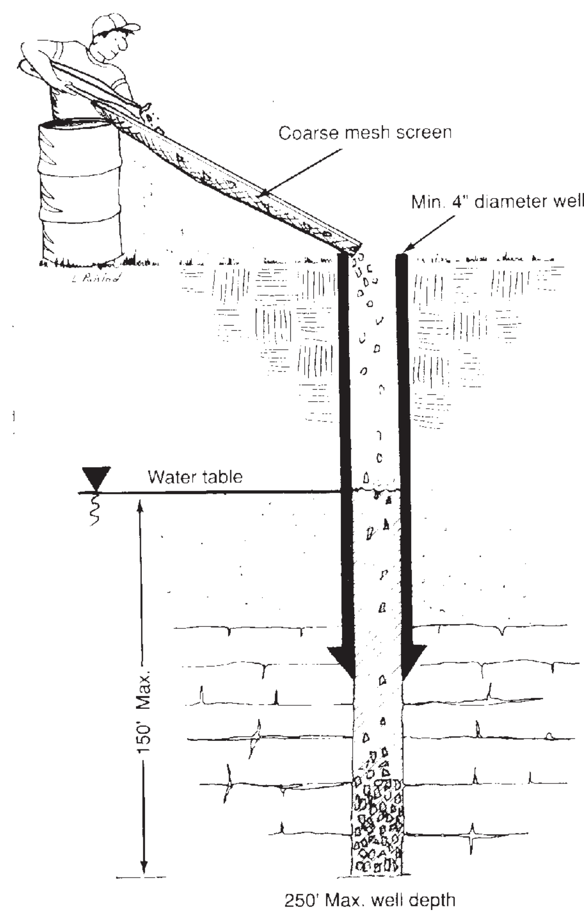
Leak this Size	Loss per Day	Loss per Month
●	120	3,600
●	360	10,800
●	693	20,790
●	1,200	36,000
●	1,920	37,600
●	3,096	92,880
●	4,296	128,980
●	6,640	199,200
●	6,984	200,520
●	8,424	252,720

Wellhead Protection

One way to protect the quality of water around your well is to limit the amount of contaminants that enter its recharge area. Although not currently required for other than municipal (OTM) and nontransient noncommunity (NN) wells, a Wellhead Protection Plan can be used to ensure you have a long-term source of clean groundwater. Wellhead protection planning involves identifying the area contributing water to the well (recharge area), inventorying potential contaminant sources within that area and developing a strategy or plan to protect the well from contamination. Your *Source Water Assessment* and *Vulnerability Assessment* contain the recharge area delineation and source inventory information that can be used to develop a wellhead protection plan to protect your well. This might include working with nearby businesses or activities that might impact groundwater or conducting a public education program to inform people about activities that may contaminate the groundwater. Visit the DNR's wellhead protection website at www.dnr.state.wi.us/org/water/dwg/gw/wellhead.htm for more information on wellhead protection planning.

Well Abandonment

Wells are a direct conduit to the groundwater and aquifers. It is important to properly abandon wells that are no longer in use, are contaminated, or don't comply with existing codes. Wisconsin's well abandonment requirements are listed in NR 811 and 812 of the Wisconsin Administrative Code.

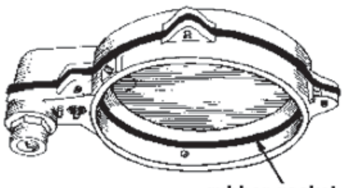


Review Questions for Source Water

1. What is the name of the cycle that explains how water moves through the environment?
2. What is the name of the process by which water changes from a liquid to a gaseous state?
3. Name the process where water moves into and down through the soil.
4. What is the difference between a permeable formation and an impermeable layer?
5. What factors can affect how water moves through an aquifer?
6. What is the difference between a confined aquifer and an unconfined aquifer?
7. What is the difference between a consolidated formation and an unconsolidated formation?
8. Name the three sources of drinking water.
9. Name the four main aquifers in Wisconsin.
10. Name the four main categories of water characteristics.
11. What are the four main physical characteristics of water?
12. What is the most common source of organic chemicals in water?
13. What chemical characteristics of water can affect its corrosivity?
14. What two biological contaminants in water are associated with human and/or animal wastes?
15. Name two protozoans that can be found in drinking water.
16. What is the most common health affect associated with radiological contaminants in drinking water?
17. Name four actions that an owner/operator can take to protect the quality of their water source.

Chapter 3
Wells

Wells



Virtually every small water system in Wisconsin obtains their water from a well. Wells are defined as any opening into the ground to obtain water where the depth of the opening is greater than the largest surface dimension. Depending on the depth to groundwater, the amount of water needed, and the water quality, wells can range from a few feet to thousands of feet deep. Most public wells in Wisconsin are 100 feet to 500 feet deep, depending on the formation used to obtain water. The methods used for constructing wells are ***dug, driven*** and ***drilled***.

Dug Wells

Dug wells are typically constructed in areas with very high groundwater levels (see Illustration 3-1). They utilize a constructed box or circular structure, which allows water to seep into the well where it can then be pumped out for use. These wells were widely used before modern drilling equipment was invented. An example of a common dug well is the "Wishing Well" with the rope and bucket attached to a hand crank. These wells often pose a safety hazard and are prone to contamination. The DNR strongly discourages their construction and use, hence they are no longer very common in Wisconsin. Dug wells may not be constructed without written approval from the DNR.

Driven Wells

Driven wells are constructed by driving a pipe with a point and screen into the ground (see Illustration 3-2). Because they are often installed in areas with sandy soils, they are also called "sand-point" wells. Due to the limitations in how deep they can be driven, they are generally used in areas that have a shallow groundwater level. In certain areas of Wisconsin, driven wells are still common for single-family residential wells. They are not allowed for use by public water systems and are only allowed for private residences and transient non-community system wells.

Drilled Wells

Almost all modern wells constructed for public use are drilled wells (see Illustration 3-3 and 3-4). They can be drilled using many different methods, but in Wisconsin the two most common methods are the *cable-tool (percussion) method* and the *rotary-drilling method*.

Cable-Tool (Percussion) Method

The cable-tool method uses a bit which pounds its way into the ground crushing the soil, material and rock it encounters. Periodically, the bit is removed and the crushed material is removed from the drill hole using a bailer. The bailer is a section of pipe, smaller in diameter than the casing, with a check valve at the bottom. As the bailer is lowered, the check valve is open and it fills with the crushed material. As it is lifted, the check valve closes and the material is lifted to the surface and discarded.

Rotary Drilling Method

The rotary drilling method uses a spinning drill bit that is lowered into the ground. Water or air is pumped down, either through the outside or inside of the drill bit. It cools the bit and carries the drilled materials to the surface. When constructing wells through loose materials or soft bedrock, clay can be mixed with the drilling water to provide a “slurry” that removes the drill cuttings and keeps the drillhole open and the drill bit lubricated.

Well Casing

In both the cable-tool and rotary drilling methods, steel casing is installed to keep the hole from caving in (see Illustrations 3-3 and 3-4). The casing lengths are welded or threaded and coupled together to form a continuous casing from the surface to the formation below. Casing not only serves to keep the well-hole open, but it also prevents contamination from entering the well and groundwater. It helps ensure that the well will produce bacteriologically and chemically safe water. In Wisconsin, casing pipe depth requirements are based on whether the well is constructed in a sand and gravel formation or bedrock. Because the top layers of some rock formations can be somewhat porous, the casing is installed into the rock formation to a depth where solid bedrock is encountered.

Grout

Openings or voids may be created around the casing during the drilling process. These voids, or annular spaces, are filled by the driller with a type of cement called “*grout.*” The grout acts as a seal to prevent contamination from moving down the casing to groundwater and also acts to stabilize the formation and protect the exterior of the casing from corrosion. For wells drilled into bedrock formations, the grout is installed from the surface to the bottom of the casing, whether it is at the top of the bedrock formation or deep into it.

Well Components and Constuction Methods

Illustration 3-1
Dug well

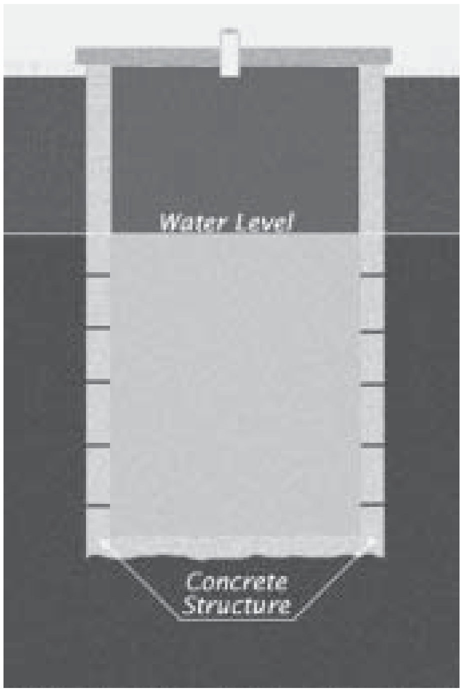
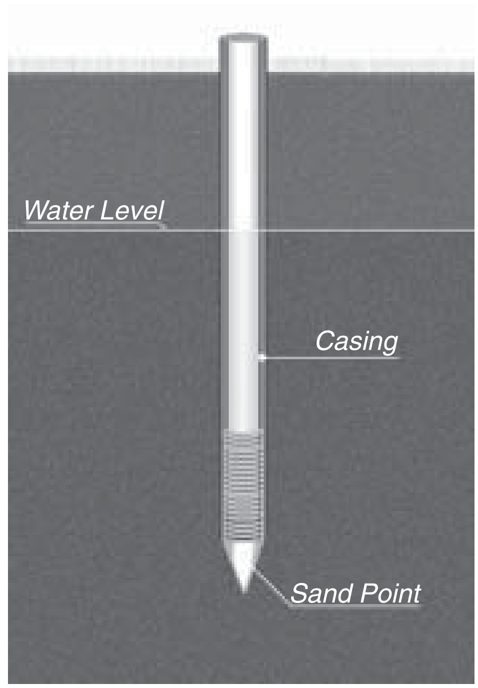


Illustration 3-2
Driven well



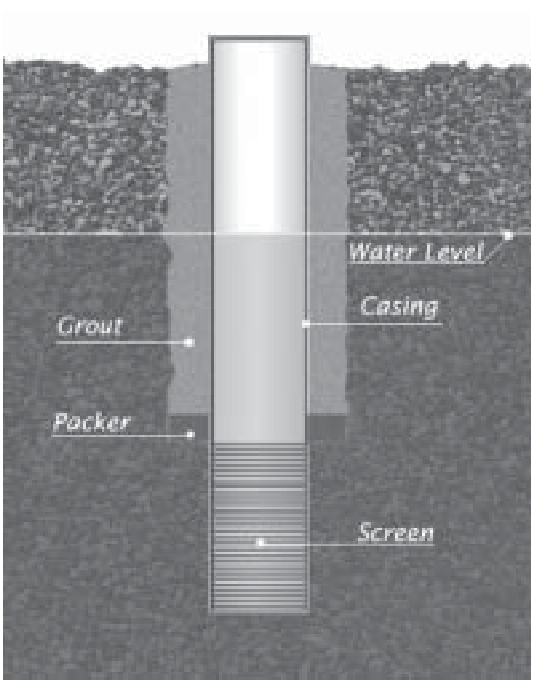


Illustration 3-3
Drilled well, sand and gravel formation

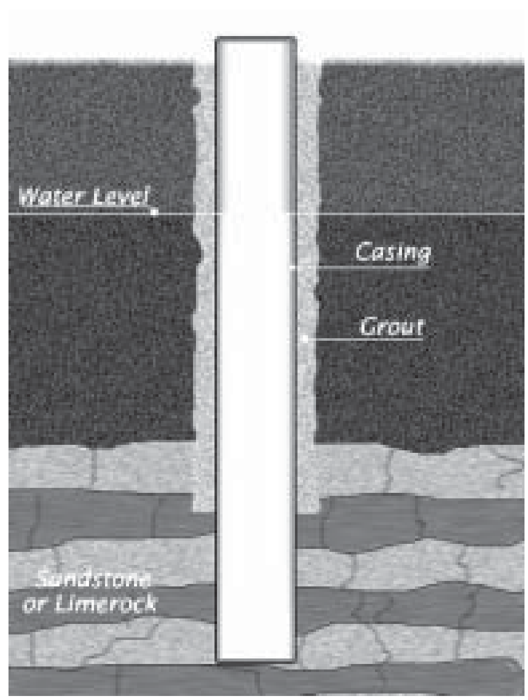


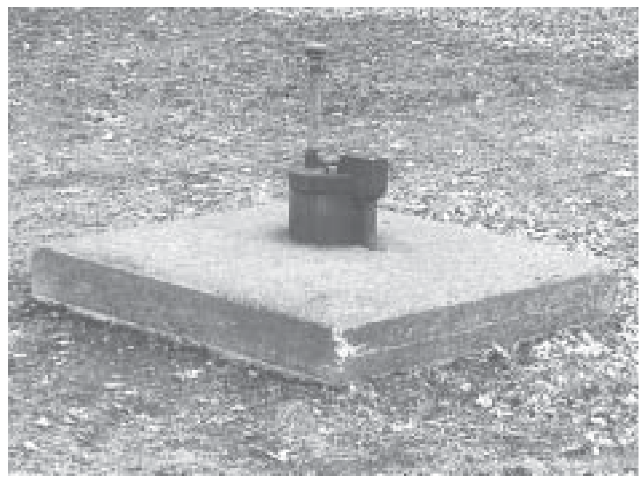
Illustration 3-4
Drilled well, bedrock formation

Gravel-Pack Wells

In wells where soft or very fine-grained sands are encountered, a gravel pack is used to prevent the sand from entering the well. For a gravel-pack well, a larger borehole is drilled and a screen is attached to the casing. A screen is a filtering device that allows water to enter a well, but not sediment. In a gravel-pack well, small stone or gravel is installed around the screen and casing. This gravel allows water to freely enter the well during pumping, but it prevents the formation sand from entering the well.

Vents

All wells must have vents to allow for the displacement of air during the pump starting and stopping cycles. Without a vent, a vacuum could be created which prevents the well from pumping water. Vents consist of a pipe installed in the well casing or well cap or seal to allow for the displacement of air between the casing and the pump column. When the pump starts, air is drawn into the casing as the water level drops. Conversely, when the pump shuts off, air is expelled through the vents as the water level returns to the static water level. All vents must have screens to prevent any solid material, vermin, and insects from entering the well.



Outside well with elevated vent pipe

Sources of Contamination

Because a well is a direct conduit from the surface to the groundwater below, care must be taken to prevent contamination from entering the well. It is important to place wells in high areas, out of floodways and storm water runoff areas, to prevent surface water from entering the well. Further, minimum separating distances must be kept between the well and other potential sources of contamination such as septic tanks, animal yards, buried petroleum tanks, etc. It is also important to make sure that the well cap or seal is in place and the vent pipe is screened to prevent access by vermin and insects. Well owners should inspect them frequently.

Pumps

There are two basic types of well pumps: the *vertical turbine pump* and the *submersible pump*. Along with the types of wells, there are several terms that water system operators should know and understand: *static water level*, *pumping water level*, *drawdown*, *well yield & specific capacity*, and *cone of depression*.

Vertical turbine pump.

Vertical Turbine Pump

The vertical turbine pump has a motor above ground connected by a shaft to the pump below. The motor assembly is secured to the top of the well casing. The pump itself has a series of impellers called bowl-assemblies which, when turned, push the water to the surface through a pump column (see Illustration 3-5). Each bowl-assembly provides a certain amount of lift; a sufficient number of bowl assemblies are needed to meet the lift requirements for the system being served.

Submersible Pump

The submersible pump has a motor and pump assembly attached at the bottom of the column, with an electric wire running from the surface to the motor below (see Illustration 3-6). This arrangement precludes the need for shafts to turn the impellers.

Static Water Level

The top of the water level in the well while the pump is not operating is called the static water level (see Illustration 3-7). In most cases, the static water level rarely fluctuates much over time as the aquifer is recharged through the hydrologic water cycle. But in some cases, due to excess pumpage from the aquifer over time, the static water level lowers as the aquifer becomes depleted.

Pumping Water Level

The top of the water level in the well while the pump is operating is called the pumping water level (see Illustration 3-8). This level is important because it is an indicator of the ability of the aquifer to supply water to the well.

Drawdown

The difference between the static water level and the pumping water level is known as the drawdown of the well (see Illustration 3-8). Drawdown is determined by the ability of the aquifer to replace the amount of water that is being pumped from the well. If there is an abundance of water in an aquifer and the water can move freely to the well, the drawdown will be fairly low, typical of sand and gravel formations. Conversely, if the water cannot move through the formation quickly enough to replace the water being pumped, the drawdown can be quite high.

Well Yield and Specific Capacity

Well yield and specific capacity are two terms that refer to the measurement of the amount of water a well can produce. Well yield is generally expressed in gallons per minute (gpm). Specific capacity is the rate of water that discharges from a well per unit of drawdown (usually feet). It is determined by dividing the well yield by the drawdown and is usually expressed in gallons per minute per foot (gpm/ft). For example, if a well pumps 100 gpm and it has a drawdown of 30 feet, its specific capacity at that flow rate is 3.33 gpm/ft. By tracking the specific capacity of a well over time, an operator can identify well and aquifer performance problems.

Cone of Depression

As water is pumped from the well, a depression in the water table forms in the shape of an inverted cone called the cone of depression (see Illustration 3-8). If the drawdown is low, the cone of depression may only extend for a short distance away from the well. Conversely, if the drawdown is high, the cone of depression can extend for quite a ways out from the well, in some cases for hundreds of feet. The cone will continue to enlarge until the rate of groundwater flow or recharge equals the pumping rate, or sufficient leakage occurs between formations to equal the pumping rate, or the cone intercepts a surface water body (lake, stream, etc), or some combination of these occur.

Pump Components and Water Levels

Illustration 3-5

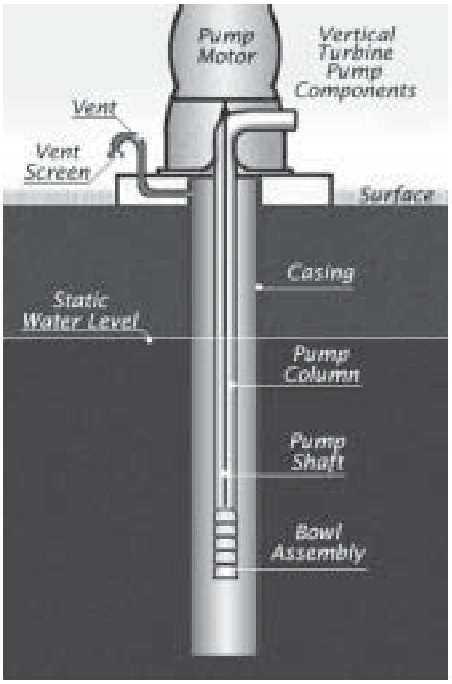
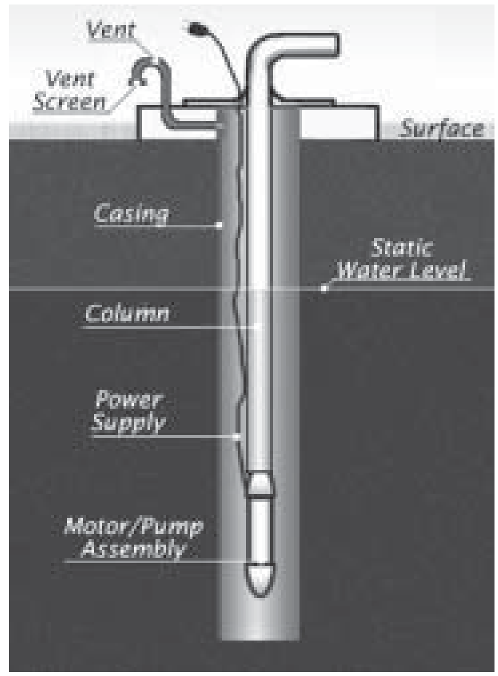


Illustration 3-6



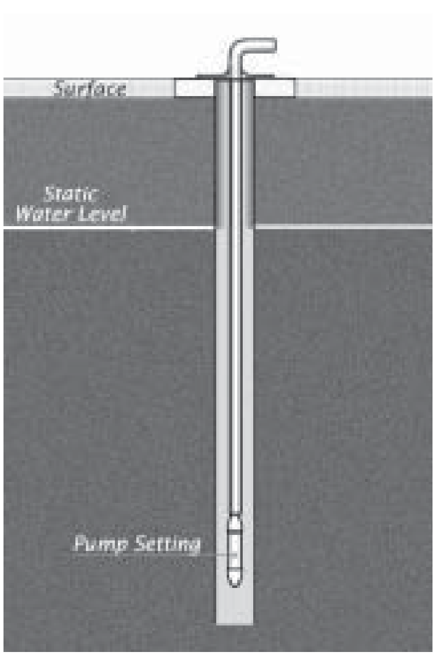


Illustration 3-7

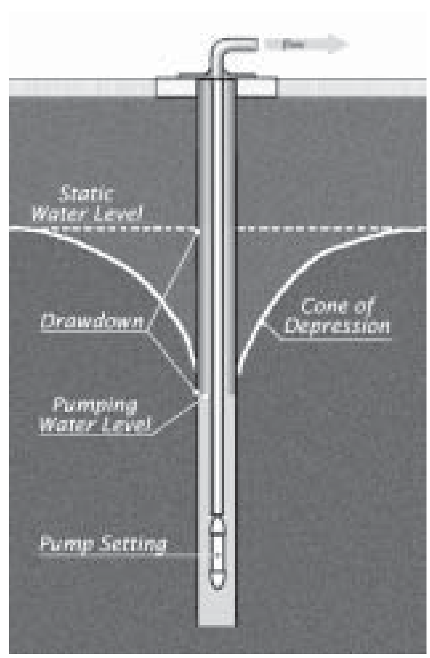


Illustration 3-8

Code Requirements

Wisconsin has strict code requirements for the placement, construction, and operation of public wells. Different wells have specific requirements based on their type, size, and use.

General Requirements

Chapters NR 811 and 812 Wiscsonsin Administrative Code includes general well construction requirements, many of which are provided below. This list is not all-inclusive.

- DNR approval is required for the construction, reconstruction, or operation of a public water system well. Approval is required only for community water system wells, high capacity wells and school wells.
- The location of a proposed well must comply with the minimum separation distances to all contamination sources (see "Well Placement" or NR 812.08 and NR 811.16 for OTM systems).
- Wells must be planned and constructed so that they produce an adequate supply of safe water and are adapted to the geographic and geologic conditions of the site.
- Wells must meet DNR plumbness and alignment requirements.
- The top of the well casing must be at least 2 feet above the regional flood level and at least 12 inches above the ground surface.
- DNR approval must be obtained for any below ground style discharge for school, OTM and waste water treatment plant wells.
- Well casing must meet DNR thickness and material requirements.
- New wells must be sealed or covered with an approved weatherproof and vermin-proof compression type well cap or seal.
- Wells must have a screened downward facing well vent.
- Grout must be at least $1^1/_2$ inches thick around the entire casing and any casing couplings.
- A written well construction report must be submitted to the DNR within 30 days of completion of the well.
- Wells must be constructed by a Wisconsin-licensed well driller.

Specific Requirements

Chapters NR 811 and 812 of the Wisconsin Administrative Code also contain specific requirements for wells drilled and constructed in different formations (unconsolidated formations and bedrock), for different types of wells (radial collectors, dug wells, sandstone wells, limestone wells, gravel-packed wells, flowing wells and granite wells), and for wells serving different types of systems (school, community, noncommunity, high and low capacity, wastewater treatment plant). Familiarize yourself with these requirements and which ones apply to your situation. If you plan to hire a licensed well driller to construct or reconstruct a well, check to make sure that they follow the requirements listed in chapters NR 811 and 812.

Construction Application

To construct a new community well, school well or high capacity well in Wisconsin, an application for approval must be submitted to the DNR providing the following information:

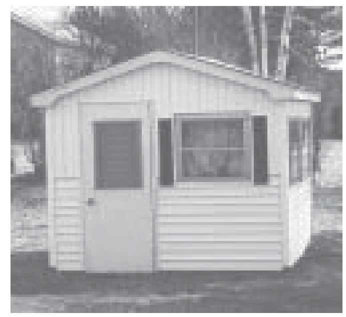
- The purpose of the well.
- The name and address of the individual, corporation, partnership or sanitary district that owns the property on which the well will be constructed.
- The name and address of the owner and/or operator of the well system.
- A written description and map of the entire property on which the well will be constructed.
- On the property map, the location of:
  - the proposed well and any other existing wells,
  - any nearby wells on other property, and
  - any wetlands within 300 feet of the proposed well.
- Any information on any other existing wells on the property.
- Details on the proposed well including:
  - Well depth
  - Depth, material, and thickness of casing
  - Type, material, and length of screen
  - Geological formation
  - Grouting material
  - Method used to construct the well
  - Name of well driller
  - Location of the sampling faucet
  - Distance from the well to any contamination source
  - Type and capacity of the pump, and how it's connected to the discharge piping
  - Type and design of the well cap
  - Pump discharge-piping information including check and shut-off valves & air relief

Siting, Placement and Abandonment

Well Siting

Due to the numerous factors that must be taken into account when choosing a site for a new well, it is important to utilize every available resource at your disposal. Fortunately, information is available from a variety of sources.

Well logs from other nearby wells are a valuable source of information on the underground geology of the area. These logs are required by Wisconsin Administrative code for any new well and must show the underground formations encountered and the depths at which they were found.



Other than municipal well building

Local well drillers are a valuable source of information. They are not only familiar with local geology, but also the quantity and quality of the water from the wells they have drilled.

Local, state, and federal natural resource agencies can provide valuable information on an area's geology, known sources of contamination, and regional water quality.

Water quality sampling results from testing done at wells in the area can provide valuable information on water quality at different depths of a formation. This sampling is required for all community and noncommunity wells.

Well Placement

A well should be located so that its surroundings can be kept in a sanitary condition. If possible, it should also be located at the highest point on the property so that it is protected from flooding and other contaminant sources. Wells should not be located downstream of any contamination source. They should be as far away from sources of contamination as possible.

Table 3-1 shows the minimum separation distances for OTM and NN system wells from some common contamination sources. These distances are specified in Wisconsin Adminstrative Code ch. NR 811 for community water systems (OTM and MC) and NR 812 for NN and TN system wells and residential wells. In special circumstances, the DNR may grant a variance to minimum separation requirements.

Table 3-1
Minimum Separation between Wells and Possible Sources of Contamination

Separation Distance	Community Water Systems	Nontransient Noncommunity Systems
2'		Building overhang
8'		Cistern Buried gravity flow sewer or drain Buried clear water waste drain or foundation drain Rainwater down spout outlet Nonpotable well Swimming pool Yard hydrant
25'		Edge of ditch Nonconforming drain or sewer pipe Buried grease interceptor or trap Buried pressuri ed sanitary sewer pipe Lake, river, stream, ditch, detention pond Septic tank or holding tank Buried residential fuel oil tank Wastewater sump
50'	Storm sewer main	Soil absorption unit <8000 gpd Privy Pet waste, animal shelter or animal yard Buried sanitary or storm sewer Cemetery grave sites Wastewater treatment plant effluent pipe Manure loading area
100'		Bulk surface storage tank >1500 gallons or any bulk buried storage tank Fertili er or pesticide storage tank Stormwater infiltration basin Wastewater treatment plant Lift station
150'		Temporary manure stack
200'	Residential fuel oil tank Sanitary sewer main or manhole Lift station	Soil absorption unit (school wells)
250'		Manure stack or storage structure Solid waste facility Salvage yard Salt storage area Sludge land spreading or storage
400'	Cemetery Septic tank Soil absorption unit receiving <8000 gpd Storm water drainage pond	
600'	Gasoline or fuel storage tank	
1000'	Land application of waste Manure storage Soil absorption unit receiving >8000 gpd Wastewater lagoon or storage structure	
1200'	Bulk fuel storage facility Coal or salt storage area Fertili er or pesticide storage facility Solid waste facility	Landfill Coal storage area >500 tons Ha ardous waste treatment facility

Well Abandonment

Unused and improperly abandoned wells are a significant threat to groundwater and aquifers. If not properly abandoned, wells can directly channel contaminants into groundwater. Wisconsin's well abandonment requirements are listed in sections NR 811.10, 811.17 and 812.26 of the Wisconsin Administrative Code. These sections of the code outline the requirements for permanently abandoning wells. An owner should abandon a well if any of the following conditions exist:

- The well is contaminated with microbial pathogens and 3 attempts at disinfection fail to eliminate the problem.
- The well is contaminated with a substance in exceedence of any drinking water standard.
- The well poses a hazard to health or safety.
- The well does not conform to construction or location requirements.
- The well was not constructed by the owner or a licensed well driller.
- The well has been out of service for 3 or more years.
- The well has been temporarily abandoned for 2 or more years.

Review Questions for Wells

1. What's the most common type of water source for water systems in Wisconsin?
2. Name the three most common methods of constructing a well.
3. What are the two most common methods of constructing a drilled well?
4. What is the name of the steel pipe that forms the outside of the well hole?
5. What is used to fill in voids around the casing of a well?
6. What must be installed in a well to allow air to displace the water that is pumped out?
7. Name the two types of well pumps.
8. What is the term for the water level in a well when the pump is not operating?
9. What is the term for the water level in a well when the pump is operating?
10. What is the term for the indentation in the water table that forms around a well as the pump is operating?
11. What are some of the items that must be included on a new well construction application?
12. Name a few of the informational resources available to someone constructing a new well.

Chapter 4
Contaminants

Drinking Water Contaminants And Monitoring

The following is a description of the contaminant sources, monitoring requirements, sampling procedures, health effects, and treatment options for the categories of primary contaminants regulated under the Safe Drinking Water Act.

Bacteriological

Bacteriological Contaminant Sources

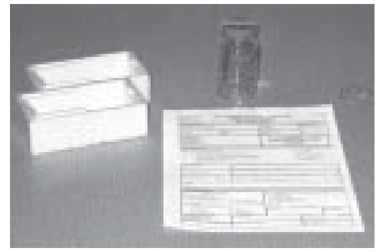
Coliform bacteria are common in the environment and most are not harmful. However, the presence of coliform bacteria in drinking water is usually the result of a problem with the well, the pressure tank, the treatment system, or the pipes that distribute water, and indicates that the water may be contaminated with germs or pathogens that can cause disease.

Drinking water must be monitored for certain bacteria that could indicate that the system is vulnerable to pathogens (disease-causing microbes). Many different pathogens may be present in water. It is not practical to test for them individually. Instead, water suppliers monitor for *indicator organisms*. The indicator organisms used for monitoring drinking water are total coliforms, fecal coliforms, and Escherichia coli (E. coli). They are usually not found in ground water. The presence of total coliform bacteria indicates that the water may be contaminated. If fecal coliform or E-Coli are detected, the water is likely contaminated with human or animal wastes (fecal matter).

Bacteriological Monitoring Requirements

Public water systems must sample for bacteria in their drinking water monthly, quarterly, or annually depending upon system size, population served, and system type.

Bacteriological Sampling Procedures

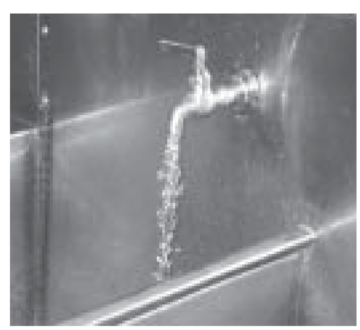


As you'll see in the following instructions, the basic steps for preparing to take a bacteriological sample are known as the three "F"s, *Flush, Flame, and Flush*. This is a simple way to remember the actions to take prior to collecting a sample.

1. Sampling sites must be DNR approved locations in the distribution system. Use metal faucets if at all possible. If you don't have metal faucets, seriously consider having them installed. Avoid rest rooms or any other sites with higher-than-normal chance of contamination if possible. If using a swivel faucet, do not adjust the swivel position once you begin the first flush. Do not sample from a dripping or leaking faucet.

   If mailing samples, determine when the mail leaves the post office and collect samples just prior to mailing. Plan to **mail early in the week** and guarantee next day delivery. Avoid Fridays, weekends and holidays. Plan sampling early in sample period (i.e. early in the month or quarter) to make sure enough time is available for resampling if there are errors or lost samples, and that the results are submitted to DNR before the sampling deadline.

2. Without opening it, inspect the sampling bottle. If the bottle is damaged in any way or the cap is not fastened securely, discard the bottle and choose another one. Make sure the bottle has been provided by a lab and is specifically for bacteriological samples. If your system adds chlorine for disinfection, make sure the bottle contains a neutralizing agent such as *sodium thiosulfate*. It is OK to use a sample bottle containing sodium thiosulfate even if you do not add chlorine to your water system.



3. Remove any attachments that may be connected to the faucet including any aerator/screen assembly and gasket. Turn on the water, using only the cold water. Allow the water to run approximately 5-10 minutes. The purpose is to flush out the line so you get a representative sample of water from the distribution system.

4. Turn off the water and sterilize the tap or faucet using a propane or butane torch. Hold the flame beneath the opening for 20 seconds, moving the flame continuously to prevent damage. The purpose of flaming is to kill any bacteria on the faucet that may otherwise contaminate the sample.

5. Turn on the cold water and allow it to run at a slow to medium stream for at least 5 minutes. **DO NOT change the flow rate or wash or wipe the faucet before sampling**. Write the name of your facility on the sample bottle label. This is much easier to do before you collect the sample than afterward. Remove the cap from bottle without touching the inside of the cap or bottle. Hold onto the cap and bottle with your fingers away from the inside edges and away from splashing water. DO NOT set the cap down. DO NOT rinse out the bottle.

6. Without allowing the bottle to touch the faucet, hold the bottle under the flow until the water is 1/2 inch from the top. Immediately replace the cap securely. If supplied with a plastic bag, place the filled bottle in the bag and close the bag.

Bacteriological Sample Reporting and Delivery

Fill out the lab analysis form that was included with the bottle, or provided by the DNR. Make sure the system name, system type (OC or NN), PWS ID number, county and owner/operator contact information are correct. If not, make the necessary corrections. Complete Section II "Sample Information" including the sample type, name of sampler, address where sample was collected, description of sample faucet, whether or not the water is chlorinated, and if so, the field results for free chlorine residual at sample location. Make sure you also include collection date and time. Place the sample and completed form in the package supplied and deliver it to the post office or lab. Bacteriological samples must be analyzed **within 30 hours** of collection. Check with your post office for the best and fastest way to deliver the sample, or use a different carrier to meet the 30-hour requirement.

Bacteriological Follow-Up Sampling

If any sample is total coliform positive (unsafe), the laboratory must then test the sample for fecal coliform or E-coli bacteria and the system owner or operator must report the results of both tests to the DNR within 24 hours. **Follow up sampling is required after any total coliform, fecal coliform or E-coli positive** compliance sample. Follow up samples must be collected within 24 hours after being notified of the original positive sample.

Collect samples from distribution system sites listed in the DNR approved sampling site plan. If you do not have a DNR approved sampling site plan, contact your DNR representative to discuss appropriate sampling locations.

Take 4 follow-up samples within 24 hours. The 4 follow-up samples consist of 1 check sample and 3 “repeat” samples. The check sample is collected from the same location as the original unsafe sample. Two of the repeat samples are collected from locations upstream and downstream of the original unsafe location. The third repeat sample is collected from another location in the distribution system.
It is best to work with your DNR representative to determine the best sampling locations for your water system. The results of the check and repeat samples will determine what additional steps are needed. Report the results to the DNR as soon as they are available to determine the next necessary actions.

During the next month, 5 additional samples will be required to confirm that your water system is safe. These samples are to be collected from any approved locations in the distribution system.

Bacteriological MCL Reporting Requirements

The water system owner or operator must report to the DNR within 24 hours the failure to comply with any bacteriological MCL or monitoring requirements, or treatment technique.

The DNR will accept analytical data only from SDWA certified labs. In addition, the DNR will accept only results obtained by an enzymatic substrate test method for bacteriological compliance monitoring. If your lab is not currently using an enzymatic substrate method, you will need to find another lab that uses the approved method.

Bacteriological Contamination Health Effects

The presence of disease-causing bacteria in water can cause symptoms such as nausea, cramps, diarrhea or headaches. For most people, these effects are short-term as their bodies can fight off microbes much the same way as they fight off germs. However, they can be dangerous or even deadly to infants, elderly, and those people whose immune systems are already weakened.

Bacteriological Treatment Options

If your system has long-term or reoccurring bacteriological problems, it is important to establish the source. Collect raw water bacti samples from the well to determine if it is the source of the contamination. If the well is the source, bailing, purging or jetting to remove sediment or debris from the well followed by shock chlorination and flushing of the system may correct the problem. Alternatively, the well and distribution system can be treated with biofilm treatment chemicals. Use of this option requires prior approval from DNR. If these treatment options don't correct the problem, installation of a new well may offer a long-term solution. If a new well is not an option, the DNR may allow installation of the following approved types of treatment:

- Continuous Chlorination
- Ultra-Violet (UV) Disinfection
- Continuous Ozonation

The use of any treatment device or technique requires prior approval from the DNR. Call your DNR representative for details if you are considering treatment for your system.

Nitrate

Nitrate Contaminant Sources

The most common sources of nitrates in drinking water are fertilizers, septic tanks, sewage, and decomposition of organic materials. Nitrate levels in groundwater may flucuate over time depending on the source of the nitrate. If your well has high levels of nitrates, this may be a sign that your well is susceptible to other contaminants, too.

Nitrate Monitoring Requirements

Public water systems must sample for nitrate in their drinking water annually or as determined necessary by the DNR. Sampling supplies may be obtained by contracting with a certified lab.

Nitrate Sampling Procedures

Sampling procedures for nitrates are similar to bacteriological samples, except that flaming the faucet is not necessary and the sample is collected at an entry point to the water system rather than the distribution system. An *entry point* is a location in the water system after treatment or chemical addition (if any) but before the distribution system.

Nitrate samples must be packed with ice immediately after the sample is collected. Place the sample in a plastic bag filled 3/4 full with ice. Fill out Section II of the lab form. The lab form should be placed in a separate plastic bag to keep it dry and included in the mailing container with the sample and ice.

Nitrate samples must be **analyzed within 48 hours** of collection. Check with your post office for the best and fastest way to deliver the samples to the lab or use a different carrier to meet the 48-hour requirement.

When an initial nitrate result indicates that the **MCL is exceeded** (10 mg/l or 10 ppm), the water supplier must notify the DNR and collect a *confirmation sample* within 24 hours of being notified of the original analytical result. Compliance with the nitrate MCL will be based on the average of the initial and confirmation sample results.

If the water supplier cannot collect the confirmation sample within 24 hours of receiving the initial nitrate result, the operator must immediately notify all consumers served by the system that the water exceeds the MCL for nitrate. Operators using this option **must** collect a confirmation sample and have it analyzed within 2 weeks of notification of the original nitrate sample result.

Nitrate Reporting Requirements

Upon receipt of the analytical results from the lab, check to make sure that the required testing was done (check the back of the lab form). Make a copy of the results and retain it for your records. If the samples were analyzed at the State Laboratory of Hygiene (SLH), the results are electronically sent to the DNR for you. If the samples were analyzed at a private certified laboratory, you will need to sign and date the lab form and submit it to the DNR within the following time frames:

- The first ten days following the month in which the result is received, **or**
- The first ten days following the end of the compliance period in which the monitoring was required, **whichever is sooner.**

  Example: You are required to monitor for nitrate in the first quarter (January - March) of 2004. You collect your sample on January 2nd and receive the results on January 30th. You must report the results to DNR no later than February10, 2004. However, if you collect your sample on March 1st and receive the results on March 20th, you must report the results to DNR no later than April 10, 2004.
- Report all MCL violations, monitoring and reporting violations, and public notice violations to DNR **within 24 hours** of the time you become aware of the violation.

Nitrate Health Effects

Water containing high levels of nitrate should never be fed to an infant under 6 months old. All infants under 6 months of age are at risk of nitrate poisoning, but premature babies and babies with other health problems are more susceptible than others. In young infants, nitrate can reduce the blood's ability to carry oxygen and cause a condition that doctors call methemoglobinemia or "*blue baby syndrome*" because the skin appears blue-gray or lavender in color. This color change is caused by a lack of oxygen in the blood. Infants suffering from "blue baby syndrome" need immediate medical attention because the condition can lead to coma and death if not treated promptly.

Nitrate Treatment Options

When a water system source becomes contaminated with nitrate above the MCL, the water system owner will be required to bring the system back into compliance. Generally, the preferred option is to reconstruct the existing well or drill a new well into a deeper, protected aquifer. When an alternative aquifer is not available, the DNR may allow installation of the following approved types of treatment:

- Ion Exchange
- Reverse Osmosis

The use of any treatment device or technique requires prior approval from the DNR. Call your DNR representative for details if you are considering treatment for your system.

Inorganic Compounds (IOC)

IOC Contaminant Sources

In most cases, the presence of inorganic chemicals in drinking water is caused by the dissolution of minerals in soil, rock and sediment.Their presence in water may also be a result of industrial discharges, mining activities, and other practices.

IOC Monitoring Requirements

Public water systems are required to sample for inorganic compounds every 3 years or as determined by the DNR. Sampling supplies may be obtained by contracting with a certified lab. The back of the lab form shows exactly which samples are required.

IOC Sampling Procedures

Prior to collecting any samples, read and follow all sampling instructions provided by the lab. IOC samples are collected at an *entry point* to the water system (first sampling point after any treatment but before the distribution system). If the entry point to be sampled is served by more than one well, make sure all of the wells are running when you collect your IOC sample. IOC samples should be collected early in the week (Monday, Tuesday or Wednesday).

1. If the sample faucet has an aerator, remove it.
2. Run water until cold, or for small systems, until the well pump goes on.
3. Write the system name or public water system identification number (PWS ID) and the entry point number on the bottle label.
4. Collect samples in appropriate bottles. Immediately preserve samples with appropriate preservatives according to the instructions provided by the lab.
5. Complete Section II of the lab form and place it in a sealed plastic bag and put it in the mailing container.
6. Follow the instruction provided by the lab for shipping the samples.

IOC Sample Reporting Requirements

Upon receipt of the analytical results from the lab, check to make sure that the required testing was done (check the back of the lab form). Make a copy of the results and retain it for your records. If the samples were analyzed at the State Laboratory of Hygiene (SLH), the results are electronically sent to the DNR for you. If the samples were analyzed at a private certified laboratory, you will need to sign and date the lab form and submit it to the DNR within the following time frames:

- The first ten days following the month in which the result is received, **or**
- The first ten days following the end of the compliance period in which the monitoring was required, **whichever is sooner.**
- Report all MCL violations, monitoring and reporting violations, and public notice violations to DNR **within 24 hours** of the time you become aware of the violation.

IOC Contamination Health Effects

The potential health effects associated with the presence of inorganic compounds in drinking water depend on the contaminant and the levels found. Effects may include increased risk of cancer, damage to the liver, kidney, and circulatory system, or damage to the intestines or central nervous system.

IOC Treatment Options

When a water system source becomes contaminated with an inorganic compound above an MCL, the water system owner will be required to bring the system back into compliance. Generally, the preferred option is to reconstruct the existing well or drill a new well. When an alternative aquifer is not available, the DNR may allow installation of the following approved types of treatment:

- Reverse Osmosis
- Ion Exchange
- Lime Softening
- Filtration

The use of any treatment device or technique requires prior approval from the DNR. Call your DNR representative for details if you are considering treatment for your system.

Lead And Copper

Lead and Copper Contaminant Sources

Although lead and copper are both inorganic compounds that occur naturally in the environment, the most common source in drinking water is household plumbing and fixtures.

Lead and Copper Monitoring Requirements

Public water systems are required to sample for lead and copper every 6 months for initial base monitoring. Whenever possible, collect your lead and copper samples from the same locations each time you sample.

Systems not exceeding lead and copper action levels for two consecutive monitoring periods are eligible to reduce their monitoring frequency to once per year for 2 years. If results remain below action levels during both years, monitoring may be further reduced to once every 3 years.

Lead and Copper Sampling Procedures

Samples must be *first-draw* after water has been motionless in the plumbing for a **minimum of 6 hours**. An exception to the first-draw requirement can be granted to NN systems that operate 24 hours per day. They must document that they are a 24-hour operation and indicate the approximate length of time the water was motionless before the sample was collected.

1. Samples must be collected from cold, untreated water taps in the kitchen or bathroom of residential buildings. Non-residential building samples must be collected from taps where water is typically drawn for consumption. Taps connected to a softener or other point-of-use-devise are not recommended.
2. Collect compliance samples in 1 liter polyethylene bottles only. Preserve the samples according to the instructions provided by the lab.
3. Label the bottles and fill out Section II of the lab form so that the lab can identify the location where each sample was collected. Indicate the Tier of each sample location on the lab form as follows:

For OTM Systems:

- **Tier 1 sites** are single family residences with lead service lines or copper plumbing and lead solder constructed between January 1983 and September 1984.
- **Tier 2 sites** are multiple family buildings constructed in this same time frame.
- **Tier 3 sites** are single family residences constructed before 1983.
- **Exceptional sites** are constructed after 1984 or sites with water softeners. (Do not use sites with water softeners unless they are the only sites available for testing.)

For NN Systems:

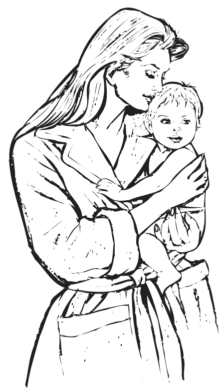
- **Tier 1 sites** are sites with lead service lines or copper plumbing and lead solder constructed between January 1983 and September 1984.
- **Tier 2 sites** are sites with copper plumbing and lead solder constructed before January 1983.
- **Exceptional sites** are sites constructed after 1984 or sites with water softeners. (Do not use site with water softeners unless they are the only sites available for testing.)

4. Place the sample bottles in a sealed plastic bag and put then into the mailing container.

Lead and Copper Sample Reporting Requirements

Upon receipt of the analytical results from the lab, check to make sure that the required testing was done. Make a copy of the results and retain it for your records. If the samples were analyzed at the State Laboratory of Hygiene (SLH), the results are electronically sent to the DNR for you. If the samples were analyzed at a private certified laboratory, you will need to sign and date the lab form and submit it to the DNR wihin the following time frames:

- The first ten days following the month in which the result is received, **or**
- The first ten days following the end of the compliance period in which the monitoring was required, **whichever is sooner.**
- Report all MCL violations, monitoring and reporting violations, and public notice violations to DNR **within 24 hours** of the time you become aware of the violation.



Lead and Copper Health Effects

Elevated levels of lead in the human body can cause serious damage to the brain, kidneys, nervous system and red blood cells. Those at highest risk are young children and pregnant women.

Although copper is an essential nutrient required by the body, elevated levels can cause stomach and intestinal distress, liver and kidney damage, and anemia. Also, persons with Wilson's disease may be more sensitive to the effects of copper contamination.

Lead and Copper Treatment Options

Lead and copper differ from most other contaminants in that they are not usually found in the source water. These contaminants enter drinking water when corrosive water comes in contact with lead or copper components in the distribution system. Therefore, treatment methods to reduce lead or copper are designed to adjust source water quality to make it less aggressive. The EPA has identified three acceptable treatment approaches for corrosion control:

1. pH adjustment
2. Addition of calcium
3. Addition of inhibitors (phosphates or silicates)

Any system that exceeds a lead or copper action level must first collect a series of water quality parameter samples to determine baseline water quality. The most appropriate treatment technique can then be selected after determining this baseline.

Some of the treatment options implemented for corrosion control include:

1. Injection of blended phosphates, polyphosphates, or orthophosphates
2. Injection of sodium silicates
3. Injection of sodium hydroxide
4. Lime contactors
5. Addition of soda ash
6. A combination of the above treatments

The use of any treatment device or technique requires prior approval from the DNR. Call your DNR representative for details if you are considering treatment for your system.

It is important to note that in some cases, a small, noncommunity system may be able to reduce lead and copper levels by replacing all plumbing or fixtures that may contribute to elevated levels in the distribution system. This would eliminate the need for constant corrosion control treatment.

Volatile Organic Compounds (VOC)

VOC Contaminant Sources

The presence of volatile organic compounds in drinking water is usually due to leaking underground storage tanks, discharges from chemical, industrial, or petroleum plants or from the improper disposal of products containing VOCs. The most common source of VOC contamination of drinking water in Wisconsin is leaking underground petroleum storage tanks.

VOC Monitoring Requirements

Public water systems are required to sample for VOCs quarterly for the first year and annually for years 2 and 3. After that, once every 3 to 6 years depending on results, well construction and susceptibility to potential contaminant sources. If VOCs are detected in the drinking water, increased monitoring is required. Sampling supplies may be obtained by contracting with a certified lab. The back of the lab form show exactly which samples are required.

VOC Sampling Procedures

VOCs samples are taken at an *entry point* to the water sytem. Prior to sampling, evaluate the area around the sample tap for possible extraneous VOC contamination. A loosely sealed or open gas can in a pump house could give off VOCs that could inadvertenly contaminate your sample. Check for cleaners, solvents, or degreasers, which could also taint a sample. Some other products that could possibly contaminate a sample are perfume, cosmetics, skin applied pharmaceuticals, suntan lotion, automotive products, crystalline bathroom/urinal deodorizers and plumbing compounds. If odors from any of these are present, air out the area prior to sampling. Better yet, don't store any products containing VOCs near any wells or sample taps.

1. Fill out the sample bottle labels before collecting the samples. Each sample vial should contain approximately 2 drops of 50% HCL (hypochloric) acid. Do not remove the acid from the vial. This is a strong acid so safety glasses and gloves are recommended when taking samples.

Water systems that chlorinate: If your system chlorinates (disinfects), it is necessary to add ascorbic acid to the samples. To add the ascorbic acid powder, give one push of the dispenser cap to deliver approximately 30 mg of acid into the sample vial. Ascorbic acid must be added to all vials including the trip blank.

2. If sampling faucet has an aerator, remove it. Run the water until cold. Reduce flow to a slow, thin stream.
3. Remove the cap ring from sample vial, making sure not to lose the Teflon liner. If the liner falls out, replace it in the cap ring, smooth-Teflon side down, and flush under running water for 30 seconds.
4. To minimize the formation of bubbles, tip the vial at a slight angle and allow a slow, steady stream of water to run down the inner wall of the vial. Fill the vial until you form a positive (convex) meniscus at the brim. Do not overflow excessively.
5. Replace the cap by gently setting it on the water meniscus, making sure that the white smooth side of the liner faces down. Tighten firmly, but do not over tighten; the vial can easily be broken.
6. Turn the vial over and check for air bubbles. If there is a bubble larger than the size of a small pea, add more water.
7. Complete Section II of the lab form and place it in a sealed plastic bag and put it in the mailing container. Samples must be shipped on ice according to the lab instructions.

VOC Reporting Requirements

Upon receipt of the analytical results from the lab, check to make sure all required testing was done. Make a copy of the results and retain it for your records. If the samples were analyzed at the State Laboratory of Hygiene (SLH), the results are electronically sent to the DNR for you. If the samples were analyzed at a private certified laboratory, you will need to sign and date the lab form and submit it to the DNR within the time frames listed below:

- The first ten days following the month in which the result is received, **or**
- The first ten days following the end of the compliance period in which the monitoring was required, **whichever is sooner.**
- Report all MCL violations, monitoring and reporting violations, and public notice violations to DNR **within 24 hours** of the time you become aware of the violation.

VOC Health Effects

The potential health effects associated with volatile organic compounds in drinking water vary depending on the contaminant and the level found. Health effects include the risk of cancer, anemia, liver or kidney damage, or damage to the nervous and circulatory systems.

VOC Treatment Options

When a water system source becomes contaminated with an VOC above the MCL, the water system owner will be required to bring the system back into compliance. Generally, the preferred option is to reconstruct the existing well or drill a new well. When an alternative aquifer is not available, the DNR may allow installation of the following approved types of treatment:

- Granular Activated Carbon
- Air Stripping

The use of any treatment device or technique requires prior approval from the DNR. Call your DNR representative for details if you are considering treatment for your system.

Synthetic Organic Compounds (SOC)

SOC Contaminant Sources

Synthetic organic compounds are non-volatile organic compounds commonly found in plasticizers, herbicides and pesticides. In Wisconsin, SOCs most commonly detected in drinking water systems are pesticides and herbicides or their breakdown products. These contaminants are commonly associated with pesticide storage and handling facilities but they may also be associated with agricultural applications of herbicides and lawn treatment chemicals in urban settings. Their presence in drinking water is usually due to the runoff or infiltration of such products into the groundwater.

SOC Monitoring Requirements

Larger systems are required to sample for SOCs twice in 3 years. Smaller systems once in three years. Sampling supplies may be obtained by contracting with a certified lab. The back of the lab form shows exactly which samples are required.

SOC Sampling Procedures

SOC samples are taken at an *entry point* to the water sytem.

1. Read and follow the sampling and shipping instructions provided by the certified lab.
2. Fill out the sample bottle labels before collecting the samples. Do not use plastic containers, funnels or hoses to collect the sample as they may inadvertenly contaminate the sample.
3. Run the water until cold.
4. Fill 1-liter amber bottles. If your system chlorinates its water, make sure the amber bottles contain *sodium thiosulfate* which dechlorinates the water. You will also need to fill 40 ml vials. These vials contain 1.2 ml of monochloroacetic acid. Do not remove the acid from the vials. If your system chlorinates its water, make sure to add sodium thiosulfate to the the vials to neautralize any chlorine. The 40 ml vials should be filled with no air bubbles.

5. Complete Section II of the lab form and place it in a sealed plastic bag and put it in the mailing container. Samples must be shipped on ice according to the lab instructions.

SOC Sample Reporting Requirements

Upon receipt of the analytical results from the lab, check to make sure all required testing was done. Make a copy of the results and retain it for your records. If the samples were analyzed at the State Laboratory of Hygiene (SLH), the results are electronically sent to the DNR for you. If the samples were analyzed at a private certified laboratory, you will need to sign and date the lab form and submit it to the DNR within the time frames listed below:

- The first ten days following the month in which the result is received, **or**
- The first ten days following the end of the compliance period in which the monitoring was required, **whichever is sooner.**
- Report all MCL violations, monitoring and reporting violations, and public notice violations to DNR **within 24 hours** of the time you become aware of the violation.

SOC Health Effects

The potential health effects associated with synthetic organic compounds in drinking water vary depending on the contaminant present and the level found. Health effects include the risk of cancer, anemia, damage to the eyes, liver, kidneys, and spleen, and problems with the cardiovascular, nervous, and reproductive systems.

SOC Treatment Options

When a water system source becomes contaminated with an SOC above the MCL, the water system owner will be required to bring the system back into compliance. Generally, the preferred option is to reconstruct the existing well or drill a new well. When an alternative aquifer is not available, the DNR may allow installation of the following approved types of treatment:

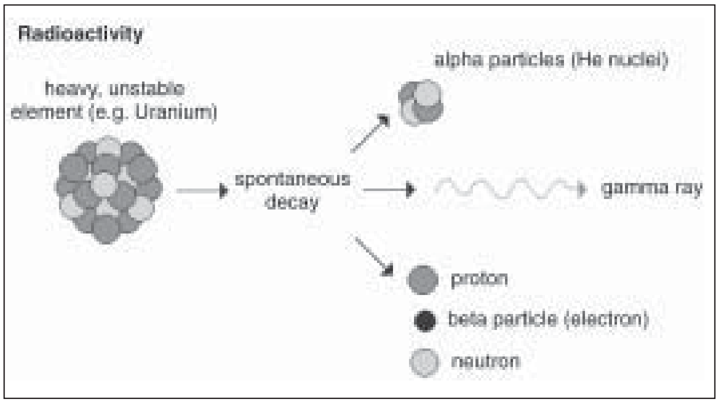
- Granular Activated Carbon

The use of any treatment device or technique requires prior approval from the DNR. Call your DNR representative for details if you are considering treatment for your system.

Radionuclides

Radionuclide Contaminant Sources

The presence of radioactive elements in drinking water is due to the dissolution of minerals that are naturally occurring in the environment.



Radionuclide Monitoring Requirements

Only community water system are required to monitor for radionuclides. Sampling supplies may be obtained by contracting with a certified lab. The back of the lab form show exactly which samples are required.

Radionuclide Sampling Procedures

There are several types of radionuclide samples that a system may be required to collect. They include: gross alpha grab, quarterly composite, radium grab, radium quarterly, radon and uranium. The procedures for collecting these samples follows.

Gross Alpha Grab Sample

Gross alpha grab samples must be collected from an *entry point* to the water system, which is after storage and treatment but before the distribution system. A new 1-liter polyethylene bottle, unpreserved is required.

1. Run water until cold.
2. Fill the sample bottle and securely tighten the cap.
3. Print the system name (or field number if desired) on cap and bottle label.
4. Complete Section II of the lab form.
5. Place the lab form and sample bottles in the mailing container and ship the samples according to the instructions provided by the lab.

Quarterly Composite Sampling Procedures

Quarterly composite samples must be collected from an *entry point* to the water system. Bottle required is a 1-gallon cubitainer for each composite sample. Each sample must be preserved with nitric acid.

1. Add the first quart of water to the cubitainer, using a 1-quart polyethylene bottle, followed by 25 mls of concentrated nitric acid. Be certain to add the acid only after the quart of water has been added to the cubitainer.
2. Add 1-quart of sample to the cubitainer every three months for the next nine months. The sample should be added without splashing. Rinse off any spatters immediately.
3. Complete Section II of the lab form.
4. Once the composite sample is collected, place the lab form and sample bottle in the mailing container and ship the sample according to the instructions provided by the lab.

Radium Grab (RG) and Radium Quarterly (QC) Sampling Procedures

Radium grab and quarterly samples must be collected from an *entry point* to the water system. Bottle required is a1-gallon cubitainer.

1. Run water until cold.
2. Fill the container.
3. Add one ampule of concentrated nitric acid preservative.
4. Complete Section II of the lab form.
5. Place the lab form and sample bottle in the mailing container and ship the sample according to the instructions provided by the lab.

Radon Sampling Procedures

For best results, radon samples should be collected after the well has pumped for a period long enough to allow collection of a representative sample of fresh water from the geologic formation. For small systems, the samples should be collected after the pump has cycled several times. Radon samples must be collected from an *entry point* to the water system. The radon test kit contains a 15-ml glass vial with a two-piece Teflon-lined cap. You will also need a bowl or other container that is at least 3 inches deep.

1. If sample faucet has an aerator, remove it.
2. Run water until cold.
3. Remove the cap from the sample vial, making sure that the liner does not fall out. If the liner does fall out, replace it in the cap so the white Teflon coated side of the liner is not visible when the vial is capped.
4. Place the bowl directly under the faucet and fill, being careful to keep the spigot opening under water after the bowl begins to fill.
5. Fill the bowl to the point of overflowing. Continue adding water for about a minute with the opening of the faucet still below the water level.
6. Submerge the vial in the bowl, open side up, until its fills. At this point, set the bowl down, and put the cap in the water, open end up. While still under water, replace the cap on the vial. Tighten firmly, but do not over-tighten.
7. Lift the closed vial out of the water. Turn the vial upside down and check closely for air bubbles. If there is an air bubble, empty the vial and the bowl and start again.

   NOTE: As a gas, radon prefers air to water. With even a small bubble in the vial, some of the radon leaves the water, leaving less radon in the water to measure.
8. Complete Section II of the lab form.
9. Place the vial and the lab form in the styrofoam mailer. Only the vial should be enclosed in the plastic bag provided. Secure the mailer with tape and attach the mailing label provided.
10. Ship the sample as soon as possible after the vial is filled to the lab, using the best and fastest delivery possible. The sample should be received by the lab no later than 2 days after sampling. The earliest possible receipt of the sample at the lab allows the most accurate radon concentrations to be obtained. Do not let sample freeze.

Uranium Sampling Procedures

Uranium samples must be collected from an *entry point* to the water system. Bottle required is a 1 gallon cubitainer. Sampling supplies may be obtained by contracting with a certified lab. The back of the lab form show exactly which samples are required.

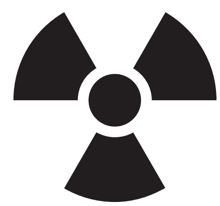
1. Extend the neck of the cubitainer by pulling up on the ring below the cap.
2. Collect the sample from the location specified by the DNR or run the water from an unsoftened tap for approximately one minute. Water softening removes radioactivity.
3. Collect the sample.

   For GRAB sample:

   a. Fill the 1 gallon cubitainer to within an inch of the top.

   For COMPOSITE sample:

   a. Add one quart of water to the 1 gallon cubitainer. Carefully add 10 mls of concentrated nitric acid, or the acid supplied to you. You only need to add acid to the cubitainer once. This is a strong acid so safety glasses and gloves are recommended.
   b. For the next 3 quarters, add one additional quart of water to the 1 gallon cubitainer. When complete, you should have 4 quarts or 1 gallon of sample.



4. Complete Section II of the lab form. Place the lab form into the plastic bag provided by the lab.
5. Place the plastic cubitainer and plastic bag into the cardboard mailing container and seal with tape. Attach the address label provided by the lab.
6. Send the sample to the lab within 72 hours of collection. The sample must be received at the lab within 5 days of collection, but overnight shipping is normally **not** required.

Radionuclide Sample Reporting Requirements

Upon receipt of the analytical results form from the lab, check to make sure that all required testing was done. Make a copy of the results and retain it for your records. Finally, sign and date the form and submit to the DNR within the following time frames:

- The first ten days following the month in which the result is received, **or**
- The first ten days following the end of the compliance period in which the monitoring was required, **whichever is sooner.**
- Report all MCL violations, monitoring and reporting violations, and public notice violations to DNR **within 24 hours** of the time you become aware of the violation.

Radionuclide Health Effects

The potential health affect typically associated with elevated levels of radioactive contaminants in drinking water is increased risk of cancer.

Radionuclide Treatment Options

When a water system source becomes contaminated with a radionuclide above the MCL, the water system owner will be required to bring the system back into compliance. Generally, the preferred option is to reconstruct the existing well or drill a new well. When an alternative aquifer is not available, the DNR may allow installation of the following approved types of treatment:

- Reverse Osmosis
- Ion Exchange
- Lime Softening

The use of any treatment device or technique requires prior approval from the DNR. Call your DNR representative for details if you are considering treatment for your system.

Disinfectants & Disinfection Byproducts (DDBP)

DDBP Contaminant Sources

Some water systems treat their water with a chemical disinfectant in order to inactivate any pathogens that may be present. While the benefits of disinfection are clear, they react with organic and inorganic matter in the water and form disinfection byproducts (DPBs), some of which pose health risks at certain concentrations.

DDBP Monitoring Requirements

Beginning January 1, 2004 systems that add a chemical disinfectant to their water must sample annually for total trihalomethanes (TTHMs) and five haloacetic acids (HAA5) for each treated well or combined entry point. Sampling supplies may be obtained by contracting with a certified laboratory. The back of the lab form shows exactly which samples are required.

DDBP Sampling Procedures

TTHM and HAA5 samples must be collected at the point of maximum residence time in the distribution system. For small systems, this is usually the furthest point away from where the chlorine or chloramines (disinfectants) was added to the system. Both the TTHM and HAA5 samples should be collected at the same time and from the same location. Make sure to add preservative to all of the sample bottles sent to you by the lab according to the directions in the sampling kit.

You must also measure and report the residual chlorine concentration for your system, at each location total coliform (bacti) samples are collected. The residual chlorine sample should be collected and measured at the same time you take your total coliform sample. The use of a color wheel to measure residual chlorine levels is **no longer allowed**. This measurement must now be done with a pocket colorimeter or other method that is specifically designed to measure residual chlorine. The LaMotte DC1200 or the HACH pocket colorimeter II are two instruments that can be used for this measurement. Other methods may be used as long as they can measure chlorine residuals to the nearest 0.1 mg/L in the range below 0.5 mg/L and to the nearest 0.2 mg/L in the range between 0.5 to 2.0 mg/L. Follow the instructions provided by the manufacturer when making this measurement.

DDBP Sample Reporting Requirements

Upon receipt of the analytical results from the lab, check to make sure all required testing was done. Make a copy of the results and retain it for your records. Then sign and date the form and submit to the DNR within the time frames listed below:

- The first ten days following the month in which the result is received, **or**
- The first ten days following the end of the compliance period in which the monitoring was required, **whichever is sooner.**
- Report all MCL violations, monitoring and reporting violations, and public notice violations to DNR **within 24 hours** of the time you become aware of the violation.

DDBP Health Effects

The potential health effects associated with disinfection byproducts in drinking water vary depending on the contaminants present and the levels found. Health effects include an increased risk of cancer and problems with the liver, kidneys or central nervous system.

Small Water System Operator Certification Manual
Disinfection Byproducts Addendum (03/07)
(Insert after page 80)

Why the Disinfection Byproducts Trihalomethanes and Haloacetic Acids are a Problem in Drinking Water

Long-term exposure to certain concentrations of disinfection byproducts, such as haloacetic acids and trihalomethanes, has been found to be harmful to humans. Toxicological and epidemiology studies have indicated that disinfection byproducts may pose a risk of cancer and reproductive or developmental problems.

The Dilemma

To prevent waterborne disease, most systems add chlorine or other chemical disinfectants to their water to kill or inactivate the pathogens. Unfortunately, while chemical disinfectants are effective at controlling many harmful microorganisms, they can react with naturally-occurring organic materials in the water (disinfection byproduct precursors) to form disinfection byproducts. Disinfectants can also dissociate, or break down, into other chemicals. Both reactions can form unintended byproducts. This presents a dilemma for systems: they must add chemical disinfectants to reduce the risk of waterborne disease outbreaks, but at the same time carefully control their use in order to avoid producing harmful byproducts.

How Trihalomethanes and Haloacetic Acids Form

Disinfectants, such as chlorine, react with naturally occurring organic and inorganic matter in natural water to form disinfection byproducts, such as, trihalomethanes and haloacetic acids.

Sampling Locations and MCLs for Total Trihalomethanes and Haloacetic Acids

Water systems that add a chemical disinfectant, such as chlorine, to drinking water must develop and follow a monitoring plan that describes specific locations and schedules for collecting total trihalomethanes and haloacetic acids samples.

Monitoring samples for the disinfection byproducts total trihalomethanes and haloacetic acids must be taken at the location representative of the maximum residence time of water in the distribution system during the month of warmest water temperature.

The point of maximum residence time is an “active” point (currently providing water to customers) in the distribution system where the water has been in the system the longest. This active point may not necessarily be the same as the most distant point from the well.

The maximum contaminant level or MCL for total trihalomethanes is 0.080 mg/L and the MCL for haloacetic acids is 0.060 mg/L.

Control Strategies for Total Trihalomethanes and Haloacetic Acids

Public water systems have choices in how to control the disinfection byproducts total trihalomethanes and haloacetic acids. Some of the most common ways are modifying treatment processes, changing source water, and forming a partnership with another system.

Modifying Treatment

Some practical ways of reducing disinfection byproduct formation include:

Decreasing contact time and/or the concentration of disinfectant (as long as adequate microbial protection is maintained!)

Changing disinfectants or using chloramines as a secondary disinfectant in conjunction with chlorine

Adjusting the pH of your water

Changing Source Water

If high levels of disinfection byproduct precursors in source water lead to high levels of disinfection byproducts in treated water, consider blending current source water with water from a source with lower precursor levels. The lower levels of precursors in the blended water may lead to lower levels of disinfection byproducts in the finished water.

Another alternative is abandoning a source and developing a new one. Developing a new water source is expensive, but it may in some cases be the most cost-effective way to lower disinfection byproduct levels in the long run. Before changing water sources, however, consider that a new water source may have lower levels of disinfection byproduct precursors but higher levels of other contaminants. In addition, switching from a ground water source to a surface water source will subject your system to additional regulations.

Partnerships with Other Water Systems

Small water systems face many of the same technical challenges larger systems face, but often lack their resources. Working with other water systems (for example, joining with one or more communities to form a consolidated system, consolidating management, or purchasing water from another established system) may allow water systems to lower costs, simplify management, and more consistently provide customers with safe drinking water.

Maximum Residual Disinfectant Level (MRDL) Defined and MRDLs for Chlorine and Chloramines

The maximum residual disinfectant level or MRDL is the maximum permissible level of disinfectant residuals in water delivered to a consumer. MRDLs are enforceable standards. Operators must assure that a disinfectant residual is maintained throughout the distribution system to assure effective pathogen removal; however, this has to be balanced with the fact that excess amounts of disinfectants may have adverse health effects for consumers of the water.

Residual chlorine and chloramines levels are measured at the same times and at the same locations as routine coliform bacterial samples are collected.

The MRDL for chlorine and chloramines are both 4.0 mg/L, measured as Cl_2 (chlorine).

Secondary Contaminants

Secondary contaminants refer to contaminants that affect the aesthetic quality of drinking water (taste, odor, color), but do not impact public health. The following are the secondary standards, aesthetics and treatment options for inorganic chemicals:

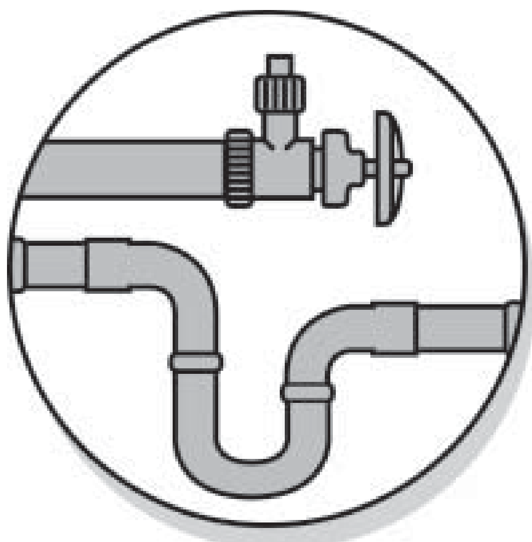
Contaminant	Standard (mg/l)	Aesthetics	Treatment Options
Aluminum	0.05 to 0.2	Discoloration of water	Ion exchange; RO
Chloride	250	Taste, odor	Ion exchange; RO
Color	15 units	Color	Ion exchange; RO
Copper	1.0	Staining	Ion exchange; RO
Corrosivity	non-corrosive	Corrosion	pH adjustment; addition of calcium or inhibitors
Fluoride	2.0	Mottling of teeth	
Foaming agents	0.5	Discoloration	Carbon filtration
Hydrogen sulfide	not detectable	Odor	Aeration
Iron	0.3	Taste, odor, color, staining	Filtration; chlorination
Manganese	0.05	Taste, odor, color, staining	Filtration; chlorination
Odor	3 (threshold odor #)	Odor	Filtration; chlorination
Silver	0.1	Discoloration of skin	Ion exchange; RO
Sulfate	250	Taste, odor	Ion exchange; RO
Total residue	500	Taste, corrosivity	RO
Zinc	5	Taste	Ion exchange; RO

RO = Reverse Osmosis

Review Questions for Contaminants and Sampling Procedures

1. What is the catch-phrase for the steps to take before collecting a bacti sample?
2. Where are bacti samples collected from - an entry point or the distribution system?
3. What is the one procedure that is done for bacti sampling that is not done for any other type of sampling?
4. If a system is adding chlorine, what must be present in the bacti sample bottle?
5. What is the time frame for which all bacti samples must be analyzed?
6. What does the presence of coliforms in water indicate may also be present?
7. What are the most common sources for nitrates in water?
8. What is the most common adverse health effect associated with higher levels of nitrates in drinking water?
9. Where are Lead and Copper samples collected from?
10. How long must the water be standing in the pipes prior to taking a Lead and Copper sample?
11. Where must VOC samples be collected?
12. What is an important action to take with the area around the sampling location before taking a VOC sample?
13. What is added to a VOC sampel bottle if chlorine is add to the water system?
14. Care must be taken to avoid what in a VOC sample bottle?
15. What are the common sources for SOC in water?
16. What is added to a SOC sample bottle if the system is adding chlorine?
17. What is the source of radionuclides in water?
18. Where should radiological samples be collected from - an entry point or the distribution system?

Chapter 5
Water Systems

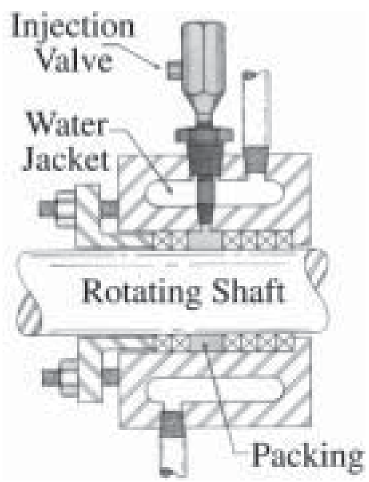


Water Systems

A water system is comprised of different components including the *well/pump, water storage facilities,* and the *distribution system*. The DNR enforces regulations for design, construction, installation, operation and maintenance of each of these three components of a water system. These regulations are found in the Wisconsin Administrative Code. The table of contents for chapters NR 809, 811 and 812 are included in Appendix A. The complete codes can be found on the internet at www.legis.state.wi.us/rsb/code.

Well / Pump

Each type of well or pump has specific maintenance and operation requirements that are not covered in this manual. The well owner and operator should consult with their well pump supplier and learn the maintenance requirements for their equipment. There are some general operation and maintenance principals that all operators should follow:



- Keep the area around the well clean and free of all potential sources of contamination. Do not store chemicals or petroleum products near the well.
- Inspect the well frequently. Make sure the well cap is securely in place and that there are no holes or gaps where insects can enter.
- Inspect the well vent screen and make sure it is securely in place.
- Listen to the well while it is operating. An experienced operator can identify and solve potential problems by simply listening to the well while it is in operation. In many cases, slight variances in noise are caused by wear to components that could cause system failure.
- For vertical turbine motors, grease pump and motor bearings per manufacturers specifications.
- Monitor the water quality. Some changes in water quality are caused by malfunctioning equipment.

Water Storage

Each water system has its own unique requirements for water storage. These depend on such factors as the system's pressure, normal water usage, low and peak demand, and fire protection requirements.

Water storage facilities come in different types including *ground storage*, *elevated tank*, *standpipe,* and *hydropneumatic tank* (pressure tank). Depending on their type, they are usually constructed of either steel or concrete. Their primary purpose is to store water during periods of low demand for distribution during periods of high demand. As with pumping equipment, each style and brand of storage facility has its own specific operation and maintenance requirements. Some general operation and maintenance tasks for all storage tanks are:

- Identify and repair storage tank leaks as soon as possible. In a water system, no leak ever repairs itself.
- Inspect the tank for corrosion. It is important to identify and eliminate any corrosion of storage tanks as soon as possible. Left unrepaired, corrosion can lead to failure of the tank and the need for replacement. The easiest way to prevent corrosion is to use protective coatings. Owners may also consider using an anti-corrosion method such as cathodic protection.
- According to Wisconsin Administrative Code, water storage tanks must be inspected every 5 years. Things to look for are cracks, chipped or peeling paint, leaking covers, screens on vents, leaking valves, improperly working gauges and low pressure in pressure tanks.
- Scheduled maintenance should be undertaken when it will least inconvenience customers. If this is not possible, notify your customers in advance.

OTM well, piping, and pressure tank


Outside ground storage water tank

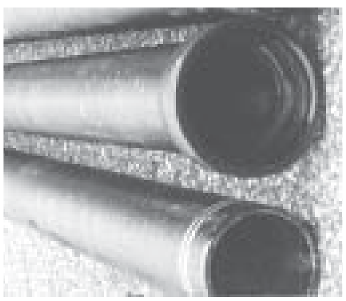

Outside water storage stand pipe

Distribution System

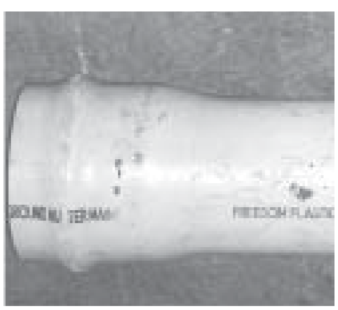
A water distribution system is made up of different components including *pipes, valves, hydrants, meters,* and *treatment equipment.*

Pipes And Mains

The common names for the pipes that act as conduits for water to travel through a distribution system are known as *water mains* and *water services*.



Ductile iron water main



PVC water main

Water Mains

Water mains are the pipes that carry water from the source to the storage facilities and throughout the distribution system. They can be made of different materials. The most common are *ductile iron* and *plastic*. However, many older mains are made of galvanized iron, cast iron, concrete, and even wood.

Factors to consider when choosing a main material are its durability, cost, installation, conductivity, and repair and ease of connection for future expansion or customer connection. The material must be approved by the DNR for use in a public water system. Wisconsin Administrative Code requires that pipes used for water mains must be cast iron, ductile iron, reinforced concrete, polyvinyl chloride (PVC), copper, or materials specifically approved by the DNR for restricted or experimental use. All pipes must meet American Water Works Association (AWWA) standards except if approved by the DNR for special low-pressure applications.

Another important factor in choosing water mains is their size. The size of the main will determine how well it transmits water throughout the system. Smaller pipes allow less water to flow due to their size restriction and the friction that is created between the water and the inside walls of the pipe. This loss in flow is called *friction loss*.

For main sizing, Wisconsin Administrative Code requires that:

- The minimum diameter pipe to provide water for fire protection and supply hydrants is 6 inches.
- The minimum flow required for water mains supplying hydrants is 500 gallons per minute (gpm) at 20 pounds-per-square-inch (psi) residual pressure.

- Water mains must be designed and operated to maintain a minimum residual pressure of 20 psi at ground level at all points in the system and under all flow conditions. Normal static pressure must be no less than 35 psi and no more than 100 psi respectively at ground level.
- Dead-end mains or other low flow portions of distribution system should be flushed annually or as needed to minimize water stagnation. Water stagnation can lead to unpleasant tastes and odors as well as positive (unsafe) total coliform samples.

Water Services

The pipes that carry water from the water mains to the customers are called *services* or *laterals*. Today, the most common water service materials are plastic and copper. Many older water services were made of galvanized iron and lead.

As with mains, the sizing of water services is an important factor, and they should be sized according to the needs of the customer. The higher the flows required, the larger the service needed and vice versa.

Pressure and Flow

One of the most commonly misunderstood areas for customers is the difference between *water pressure* and *water flow*. In many cases, a customer will notify the operator that they do not have any water pressure when, in fact, they are describing a low flow situation.

System pressures will generally fluctuate very little during normal operating conditions, although low pressure can be caused by high water demand somewhere else in the system or pump or pressure tank problems. Low flow problems can be caused by piping mineral build-up, valves partially closed, or the failure to adequately interconnect mains and pipe fittings such as elbows and tees which cause water to lose velocity as it changes direction. When an operator is faced with a problem dealing with a lack of water, it is important to first identify if it is caused by a lack of pressure or a lack of flow. Once determined, the problem can be fixed quickly and efficiently.

Leak Detection

The most common maintenance problem with water mains and services is leaks. Typically, leaks will occur at points where different pipes interconnect such as elbows, bends, tees, and fittings. However, it is also common for pipes to break due to the earth's natural movement, freezing, or improper installation.

In most cases where there is adequate pressure, water escaping from leaks will generally come to the surface near the location of the leak. However, this may not always be the case when leaks occur on hills, near underground rock crevices or sewer lines, or ground that is frozen. Modern leak detection devices are quite effective at locating such leaks. They typically employ sound-detection devices that locate the leak by detecting the noise that water makes as it escapes from pipes.

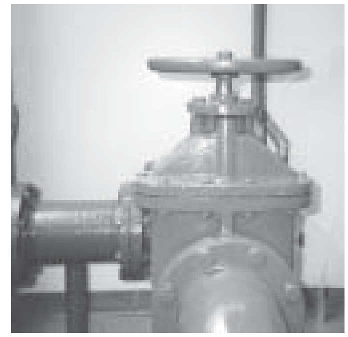
Water operator conducting electronic leak detector on fire hydrant

Water Hammer

Another cause of broken water pipes is called *water hammer*. Water hammer occurs when flowing water in a system is immediately stopped due to a valve or hydrant being closed too quickly. This creates tremendous force that can cause considerable damage. Always open and close valves and hydrants slowly.

Valves

The mechanical devices used to isolate water pipes are called *valves*. Valves come in a variety of styles, shapes and sizes, but their main purpose is to regulate or stop the flow of water. In a distribution system, there are two types of valves, *main valves* and *service valves*. As their names indicate, main valves are installed on water mains, and service valves are installed on service lines.


Wellhouse gate - valve

Main Valves

Main valves should be located so that shutting them off affects as few customers as possible. They are generally installed at tees or crosses where two or more mains intersect. In many cases they are used to make emergency repairs; therefore it is important to ensure they are accessible and in good working condition. To this end:


Water main gate valve

- Valves should be operated every 2 years.
- Valve boxes should be kept free of debris so access can be achieved when needed.
- Valves should always be operated slowly to prevent water hammer.

Service Valves

Another name for a valve used to isolate a water service line is a *curbstop valve*. They are installed on the service line between a water main and a building, usually near a street curb. As opposed to a main valve, which is used to isolate a section of the water system or main, the curbstop valve is used to isolate a single building. For service valves, operators should:


Water service line shutoff valve

- Make sure that the locations of curbstop valves are known. Their location should be measured from a nearby building or object.
- Make sure that the service valve boxes are free of any foreign materials and that they are working properly.

Fire hydrant

Flushing hydrant

Hydrants

In a distribution system, the device that allows water to flow quickly out of a main is called a hydrant. Hydrants are generally installed for two purposes, to fight fires and to flush water mains. As such, the hydrants are different.

Fire hydrants are equipped with fire hose connections. They are generally larger than flushing hydrants to allow large volumes of water to flow for fire fighting. They are strategically located throughout a distribution system for ready access in the event of a fire.

Flushing hydrants (or blow–off hydrants) are generally smaller than fire protection hydrants. They are installed on dead end lines and strategically throughout the system in low use areas. Many flushing hydrants are equipped with smaller nozzles unsuitable for fire hose connection.

Hydrant Styles

Regardless whether they are used for flushing or fire fighting, there are two styles of hydrants, dry-barrel and wet-barrel.

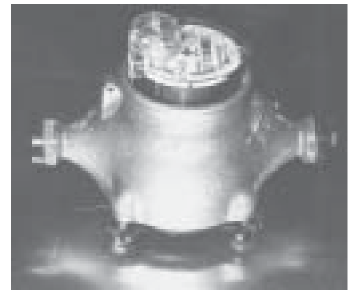
Wet-barrel hydrants have the operating valve at the top of the hydrant. The entire hydrant contains pressurized water.

Dry-barrel hydrants have a barrel that is empty of water, and the operating valve is located at the bottom of the barrel. This type of hydrant keeps the water below the frost line to prevent freezing. In Wisconsin, virtually every hydrant is a dry-barrel hydrant.

To ensure that hydrants are in working order, an operator should:

- Exercise hydrants every year and keep a record of these operations.
- Maintain hydrants in working order. Hydrants can become hard to operate and may require lubrication. If lubrication is required, follow the manufacturer's recommendations.
- Always open hydrants fully to close drain holes at bottom of barrel.
- Check hydrants in the fall to make sure they drain to prevent freezing.
- Operate hydrants slowly to prevent water hammer.

Meters



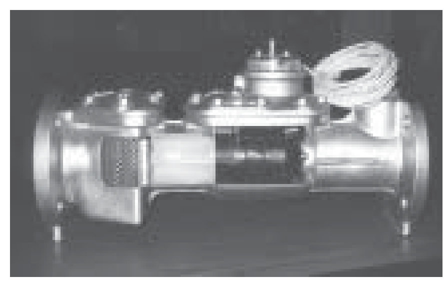
Positive Displacement Meter

The devices used to measure water flow and volumes used are known as *water meters*. There are different types of water meters including *positive displacement meters*, *turbine meters* and *compound meters*. Meters are always differentiated by size, with the size being the inside diameter of the entry and exit ports.

Positive Displacement Meters

Positive displacement meters measure water as it passes through a measuring chamber. The measuring chamber contains a piston or disc that rotates as the water passes through it. The piston or disc then turns a dial that records the amount of water used. This type of meter is used in normal and low-flow conditions and comes in sizes ranging from 5/8-inch to 2-inches. The 5/8-inch meter is most commonly used in single-family residential applications. The 3/4-inch meter is generally used for large residences, apartments, and businesses, where the service pipe is 1-inch. The 1-inch, 1.5-inch, and 2-inch meters are usually installed in businesses, large apartments, hotels, and industrial buildings, depending on water demand.

Turbine Meters



Cutaway version of a turbine meter

Turbine meters measure water much like a windmill, with the water turning fins or blades as it passes through it. They are generally used in high flow conditions and are not as accurate as positive displacement meters. Turbine meters come in sizes of 2 inches and larger, and are used in hospitals, very large hotels and large industry.

Compound Meters

A compound meter is a positive displacement meter and a turbine meter in one unit. The turbine unit is in the lower part of the meter housing and the positive displacement metering chamber is above it. For normal and low flow conditions, a valve closes and diverts the water through the upper meter. During high flow conditions the valve opens allowing the water to pass through the lower turbine unit. Compound meters come in sizes of 2 inches and larger and are normally used in schools or apartments where substantial fluctuations in water usage occur.

Choosing the Right Meter

In choosing the right meter, the operator must take into account the low flows, normal flows, and peak flows that the meter will encounter. The accuracy and life of the meter will depend on the type of meter chosen. It is also important to correctly size the meter. The meter should never be any larger than the pipe it is connected to. That's because the size of the pipe will determine the amount of water that can go through the meter.

Meter Reading Methods

Water meters can be read in a variety of ways, depending on the meter style. The most basic style is the *direct-read meter* where it is read by looking at the numbers on the top of the meter dial. The number from the previous reading is then subtracted from the present reading to determine the amount of water used between the two readings.

There is also the *generating meter* that relay the signal from the meter to a registering head mounted at a remote location. Both the direct-read and generating meter must be read manually (visually) to determine the water usage.

The newer generation of meter is called the *remote-read meter*. This meter generates a signal from the meter that is read by radio, telephone, or by a hand-held computer. These types of meters allow for readings to be obtained quickly and more efficiently than direct-read and generating meters.

Meter Testing and Repair

In Wisconsin, requirements for the frequency and accuracy of testing for water meters are established and enforced by the *Wisconsin Public Service Commission (PSC)*. The regulations are important to ensure that both the owner and the customer are correctly compensated and charged for the amount of water used. Although there are conditions which can change the testing frequency, in general:

- Residential meters are to be tested once every 10 years.
- Remote outside meter and automatic meter reading systems are to be tested each time the meter is tested.
- Industrial and commercial meters are to be tested once every 1 to 4 years, depending on size.

- Station meters are to be tested once every 2 years. *Station meters* are used to measure the amount of water pumped into the distribution system. They should be installed on the inlet line of pressure tanks and storage reservoirs and not on the outlet lines.
- To test a meter, the meter is removed from the building and placed into a meter testing device through which flows a known amount of water. This is generally done using specifically sized tanks.

Important Note: When removing meters, always use a jumper cable to protect yourself. Most buildings' electrical systems are grounded to the plumbing system. Failure to use a jumper cable when removing a meter can result in serious injury or death.

The amount of water that the meter records is then compared to the known amount of water that passes through it. If the meter records the exact amount of water, it is 100% accurate. If not, it will record a lower percentage. Meters below 95% accuracy should be repaired or replaced.

Meter testing station

Treatment For Bacteriological Contaminants

Disinfection

Disinfection is a process of using chemical or physical methods to destroy or inactivate harmful pathogens that might be present in water. Disinfection is also used to protect the water in the distribution system from pathogen regrowth or recontamination. Disinfection can be accomplished using a variety of methods, the most common being chlorine, chloramines (chlorine combined with ammonia), chlorine dioxide, ozone, and ultraviolet (UV) radiation.

By far, the most common chemical used is chlorine. If UV or ozone are used, chlorine must be added to the water to establish a disinfectant residual.

Chlorination

Chlorine (Cl_2) is added to water in a variety of forms: *gas*, *liquid*, and *solid*. Chlorine disinfection systems typically use chlorine gas or sodium hypochlorite (NaOCl). Gas chlorination utilizes pressurized cylinders and regulators that control the amount of chlorine being added. Liquid or solid chlorination uses feed pumps that pump the chlorine or dissolved chlorine into the system. The length of stroke and number of strokes (speed) controls the amount of chemical fed by the chemical feed pump. Chlorine feed pumps should be cleaned and flushed with muriatic acid as needed. Hoses should be checked regularly for cracks and deterioration. In fact, routine servicing of all chemical feed equipment is necessary.

Chlorine Monitoring

When chlorine is added to the water system, you must monitor the amount of chlorine added and the levels of chlorine in the system. Common terms associated with monitoring chlorine levels are:

Dosage - Amount of chlorine added per unit volume of water (i.e. lbs/gallon or mg/liter).

Chlorine demand - Amount of chlorine that reacts with contaminants and inorganic (iron, manganese, etc.) and organic matter in the water.

Residual - Chlorine level remaining after the initial chlorine demand is satisfied.

Free chlorine residual - Amount of free chlorine remaining after the chlorine demand is met.

Combined chlorine residual - Free chlorine that has combined with ammonia or other nitrogen-containing organic matter.

Total chlorine residual - The sum of free chlorine residual and combined chlorine residual.

Chlorine Levels

Water systems that add chlorine must test for the residual amount at the ends of their distribution system a minimum of twice weekly. The amount of chlorine added must also be monitored daily, either by weight or by volume.

All systems that chlorinate must maintain a trace amount at the extremities of the system. Systems required to chlorinate must also maintain a minimum of 0.2 mg/L chlorine residual at the entry point to the system.

Systems required to perform emergency chlorination must reach a free chlorine residual of at least 0.5 mg/l within 4 hours of DNR notification and maintain it throughout the system.

Residual Chlorine Testing Methods

The use of the "color wheel" is no longer permitted for measuring residual chlorine. This measurement must now be done with a pocket colorimeter or other method that is specifically designed to measure residual chlorine. The LaMotte DC1200 or the HACH pocket colorimeter II are two instruments that can be used for this measurement. Other methods may be used as long as they can measure chlorine residuals to the nearest 0.1 mg/L in the range below 0.5 mg/L and to the nearest 0.2 mg/L in the range between 0.5 to 2.0 mg/L. Follow the instructions provided by the manufacturer when making this measurement.

Chlorine Safety

Chlorine is an extremely hazardous substance. Chlorine gas is especially dangerous and is not recommended for use by small water systems. Instead, consider using an electronic positive displacement chemical feed pump or a peristaltic chemical feed pump to deliver liquid chlorine (sodium hypochlorite) to your system. NSF approved chlorine must be used and delivered in properly labeled containers.

When using and handling liquid chlorine, be sure to always wear an apron and proper gloves and goggles. You should also have an emergency eye-wash station and shower nearby. It is recommended that the chemical feed equipment be housed in a separate room provided with forced air ventilation.

Additional precautions must be taken if chlorine gas will be used. The chlorine gas must be stored in a properly ventilated separate room. There must be one complete air change per minute whenever the room is occupied. Since chlorine fumes are heavier than air, the exhaust fan suction must be located near the floor. Make sure the exhaust fan discharges away from all building air inlets and other structures and that it is not blocked by snow or other obstructions. Chlorine gas scrubbers may also be required. The exhaust fan switch must be located outside the entrance to the chlorine room. Air inlets must be located near the ceiling. Self contained breathing appuratus must also be available.

Ultraviolet (UV) Disinfection

Ultraviolet disinfection is a method whereby water is passed through a device and exposed to ultraviolet light. The UV light is produced by low-pressure mercury vapor lamps. The amount of UV radiation that the water is exposed to is determined by the number of lamps used, the intesity of the UV light and the amount of time the water is in the device.

UV disinfection is effective at disinfecting water containing microorganisms such as protozoans that are resistant to chlorine. Its drawbacks include no residual in the distribution system, effectiveness depends on clarity of the water, limitations as to the amount of water that can be treated at one time, and the current inability to conveniently measure the treatment effectiveness.

O one Disinfection

Ozone disinfection utilizes the addition of ozone (O_3) to the water. Ozone must be generated on site. As ozone is a powerful oxidizer, it is effective at killing pathogens. In Wisconsin, it is more commonly used at surface water treatment facilities and at groundwater systems that have few options other than to treat unsafe groundwater. Like UV, its disadvantage is that it does not leave a disinfecting residual in the distribution system.

Treatment For Other Contaminants

Lime Softening

Lime softening is used to soften water by adding hydrated lime to precipitate out calcium carbonate and magnesium. These materials are removed by an upflow clarifier in the sludge. The water is then treated with carbon dioxide to balance the pH and is filtered.

Ion Exchange

Ion exchange includes cation and anion exchange. Cation exchange is used for water softening. Hardness-causing ions such as calcium and magnesium are exchanged with sodium ions, thus removing them from the water. Cation exchange is also used for removing radium.

Anion exchange is used for the removal of nitrate and uranium. It can also be used for arsenic removal; however, its effectiveness depends on the type of arsenic present and the chemistry of the source water.

Reverse Osmosis (RO)

Reverse osmosis (RO) is the process whereby water containing a high concentration of solids is pumped under pressure through a semipermeable membrane. The water that has passed through the membrane is low in solids, leaving behind a waste stream high in solids. Reverse osmosis is quite effective at removing most inorganic contaminants. Membranes with larger pore openings are available to reduce the cost of treatment when the solids content of the water to be treated is not as elevated.

Aeration

Aeration is a process whereby water is mixed with air in a chamber or tower filled with packing material or mechanism to disperse the water allowing for sufficient contact time. As the water trickles down over the material or mechanism, air is forced upward “stripping” the contaminants from the water. Aeration or “air stripping” is quite effective at removing volatile organic compounds (VOCs), hydrogen sulfide and radon gas.

Adsorption using Granular Activated Carbon (GAC)

Adsorption is the process whereby organic contaminants become affixed to the surfaces of granular activated carbon as it passes through the carbon bed. In some cases, this process is used in conjunction with aeration to increase the effectiveness of the organic chemical removal. Granular activated carbon is effective at removing many synthetic organic compounds (SOCs) and VOCs.

Corrosion Control

In a water system, corrosion of metallic materials can result from chemical or electrochemical processes. Chemical corrosion can be the result of water acidity (the lack of buffering minerals in the water) or the presence of such constituents as carbon dioxide, oxygen, hydrogen sulfide, hydrochloric acid, sulfuric acid and chloride. Corrosion can occur on any metallic surfaces throughout the water system. Electrochemical corrosion may be caused by the difference in electrical potential (electrolysis) between two dissimilar metallic surfaces or by the presence of a high level of dissolved solids in the water. Both types of corrosion will usually occur at joints or fittings where two dissimilar metals meet.

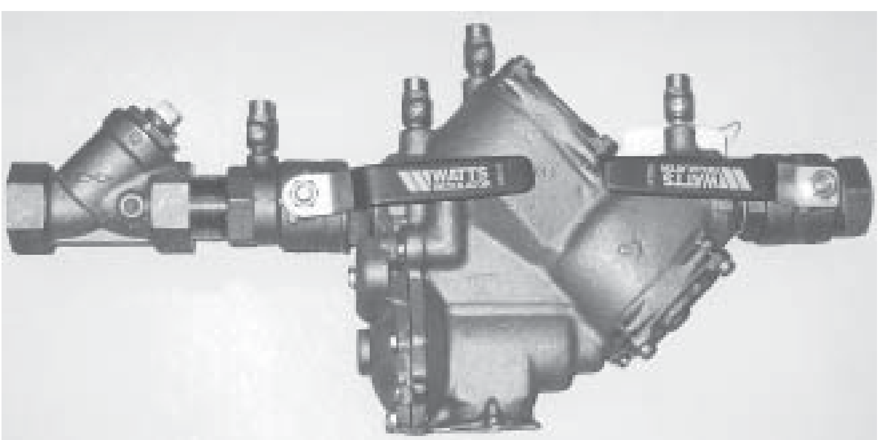
Methods used to control corrosion in a distribution system include pH adjustment (to make the water less acidic or neutral), the addition of phosphates, or both. Phosphates, such as orthophosphates and polyphosphates, act to create a microscopic coating on the interior linings of plumbing fixtures. This prevents the water from coming into contact with the metals that can be dissolved into the water. Phosphates can also be effective at sequestering elevated but not high levels of iron and manganese in the water.

Cross Connections

Cross connections are connections that link potable water (water suitable for human consumption) to nonpotable water (water not suitable for human consumption). Cross connections can cause contamination when a loss in water system pressure allows water to flow back into the distribution system from an outside source. This is called *back flow* or *back siphonage* and can occur during a water main break or when a main is shut down for repairs. *Backpressure* can also occur when a customer's water supply is at a higher pressure than the pressure in the water system. Examples of this could be a power washer or a boiler system.

Types of back flow prevention devices include *air gap separation*, *reduced pressure devices, double check valves, pressure vacuum breakers,* and *atmospheric vacuum breakers.*

A good cross connection program includes inspections of buildings to identify existing and addressing cross connections, testing of cross connection control devices, record keeping of corrections made, and follow-up inspections.



Reduced pressure backflow prevention valve

Water System Map

Water system operators should keep a map of their water system on hand. This can be especially useful when system repairs or upgrades are necessary. Maps do not need to be elaborate, but they should be accurate and up to date. Items that should be listed on maps include streets, valves, hydrants, laterals, water mains, wells and water storage facilities. If possible, sizes, depths and measurements of each item should be included on the maps.

Safety

All safety codes for privately-owned water systems are established and enforced by the *Occupational Safety and Health Administration (OSHA)*. Water system operators should know and follow all safety regulations and manufacturer recommended safety precautions.

Security

A water system may be significantly damaged due to an unforeseen event. A severe event may cause disruption of water service, contamination of water served, or damage to water works facilities. Efforts should be taken to keep facilities secure at all times. Operators should always be aware of security concerns and take necessary precautionary measures when appropriate. It is recommended that a plan be in place for responding to an emergency that includes a list of local and state emergency contacts.

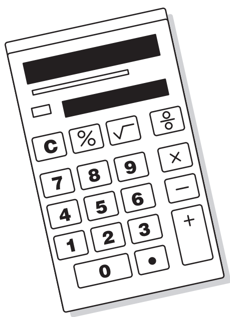
Other than municipal (OTM) water systems must have an up-to-date "Emergency Operations Plan" in place. This plan must include:

- A list of plumbers, electricians, or other contractors that would be available to respond in emergency situations.
- Procedures for obtaining a back-up water source in the case of an emergency.

Review Questions For Water Systems

1. Name the three main components of a water system.
2. Name four types of water storage facilities.
3. What are the different components of a water distribution system?
4. What are the two names for the pipes that carry water from the source to the customer?
5. What are the factors an operator should take into account when choosing pipes for a distribution system?
6. What is the difference between water pressure and water flow?
7. What is the name of the reaction that occurs in a water system when a valve or hydrant is closed too quickly?
8. What is the name of the device used in a distribution system to regulate or shut off the flow of water?
9. What are the two main uses for hydrants?
10. Name the three types of water meters and explain what each is designed for.
11. In Wisconsin, what agency regulates the metering of water?
12. Name the three most common methods used for disinfection.
13. What are the three forms of chlorine used for disinfection?
14. What is the name for the chlorine available in a water system after the demand?
15. What is the biggest drawback of UV and ozone disinfection?
16. Name two processes used for softening water.
17. Name two methods used for treating corrosion in a distribution system.
18. Name the agency responsible for safety codes at privately owned water systems.

Waterworks Math



Conversions

1 psi (pound per square inch)	= 2.31 feet of elevation
Minutes in a day	= 1,440
1 cubic foot of water	= 7.48 gallons
Weight of 1 cubic foot of water	= 62.4 pounds
Weight of 1 gallon of water	= 8.34 pounds
Liters of water in a cubic foot	= 28.317
Liters of water in a gallon	= 3.785
1 milligram per liter (mg/L)	= 1 part per million (ppm)
1 ppm or 1 mg/L	= 1,000 parts per billion (ppb)
1 ppb	= 0.001 ppm or 0.001 mg/L
1 million gallons per day (mgd)	= 694 gallons per minute (gpm)
1 cubic foot per second (cfs)	= 450 gallons per minute
Water per foot in a 1” pipe	= 0.041 gallons
Water per foot in a 2” pipe	= 0.163 gallons
Water per foot in a 4” pipe	= 0.653 gallons
Water per foot in a 6” pipe	= 1.469 gallons
Area of a square or rectangle	= Length x width
Area of a circle	= 0.7854 x diameter^2
Area of a circle	= 3.1416 x radius^2
Volume of a cylinder	= 0.7854 x diameter^2 x depth
Volume of a square of rectangle	= Length x width x depth
Pounds of chlorine needed	= Million gallons x ppm x 8.34

Examples

A well pumping 100 gallons per minute can pump how many gallons per day?
(1,440 x 100 = 144,000 gallons)

How many cubic feet are in 20 gallons of water?
(20 ÷ 7.48 = 2.67 cubic feet)

How many cubic feet of water are in a reservoir 20 feet long, 15 feet wide, and 10 feet deep?
(20 x 15 x 10 = 3,000 cubic feet)

How many gallons of water are in this same reservoir?
(3,000 x 7.48 = 22,440 gallons)

How many pounds of chlorine would it take to disinfect this same reservoir to a concentration of 0.5ppm?
(0.022440 x 0.5 x 8.34 = 0.09 lbs)

How many gallons of water are in a circular reservoir that is 30 feet across and 10 feet deep?
(0.7854 x 30^2 x 10 x 7.48 = 52,873 gallons)

With a well that pumps 50 gallons per minute, how long in minutes or hours will it take to fill this same reservoir?
(52,873 ÷ 50 = 1,057 minutes or 17.6 hours)

If you wanted 50 pounds of pressure at a given point of a water system with a gravity feed water reservoir, how many feet above that point must the water in the reservoir be?
(50 x 2.31 = 115.5 feet)

How many gallons of water are in a 2 inches water line that is 400 feet long?
(0.163 x 400 = 65.2 gallons)

If you wanted to flush out that same line through a faucet that flows at 20 gallons per minute, how many minutes would it take?
(65.2 ÷ 20 = 3.26 minutes)

A 2-gallon per minute leak loses how many gallons in a month?
(1440 x 2 x 31= 89,280 gallons)

5 parts per million is equivalent to how many milligrams per liter?
(5 mg/l)

5 parts per billion is equivalent to how many parts per million?
(0.005 ppm)

If you had to recoat the bottom of a circular reservoir 20 feet across, how many square feet would you be covering?
(.7854 x 20^2 = 314.16 square feet) or (3.1416 x 10^2 = 314.16 square feet)

References

An Introduction to Hydrant Operation and Maintenance- National Rural Water Association

Basic Math Handbook Training Guide- National Rural Water Association

Groundwater & Distribution Exam Review Course Guide- Wisconsin Rural Water Association

Groundwater and Wells (Second Edition) – Fletcher G. Driscoll

Minnesota Water Works Operations Manual- Minnesota Rural Water Association

Technical Guide (2000-2001)- Wisconsin Water Well Association

Water Distribution System Operation and Maintenance- California State University, Sacramento School of Engineering

Water Quality and Treatment- A Handbook of Community Water Supplies (Fourth Edition)- American Waterworks Association

Water Quality- Principles and Practices of Water Supply Operations (Second Edition)-American Waterworks Association

Water Sources- Principles and Practices of Water Supply Operations (Second Edition)- American Waterworks Association

Wisconsin Administrative Code

Appendix A

Table of Contents
Wisconsin Administrative Codes
Public Water Systems

Chapter NR 809
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Wisconsin Administrative Codes

Current versions of Wisconsin Administrative Codes are available on the Wisconsin State Legislature web site. The administrative codes below relate to public water systems. The chapter number, title and a brief description of the purpose and applicability of these codes are provided below along with the web site at which the full texts can be found.

Chapter NR 809

SAFE DRINKING WATER

The purpose of this chapter is to establish minimum standards and procedures for the protection of the public health, safety and welfare in the obtaining of safe drinking water. The provisions of this chapter shall apply to all new and existing public water systems as defined in this chapter.

Web site⟶ http://www.legis.state.wi.us/rsb/code/nr/nr809.pdf

Chapter NR 811

REQUIREMENTS FOR THE OPERATION AND DESIGN OF COMMUNITY WATER SYSTEMS

This chapter governs the general operation, design and construction of community water systems and the construction of any water system serving 7 or more homes, 10 or more duplexes, 10 or more mobile homes, 10 or more condominiums units or 10 or more apartments. The standards for design and construction shall be considered minimum standards for new facilities and the minimum standards to which existing facilities shall be upgraded when improvements are undertaken at those facilities. These standards may be imposed on a case-by-case basis to existing facilities when the department determines that a potential health risk exists.

Web site⟶ http://www.legis.state.wi.us/rsb/code/nr/nr811.pdf

Chapter NR 812

WELL CONSTRUCTION AND PUMP INSTALLATION

The purpose of this chapter is to establish uniform minimum standards and methods for: Obtaining or extracting groundwater for any purpose; and Protecting groundwater and aquifers from contamination through adequate construction and reconstruction of water systems. This chapter shall govern the location, construction or reconstruction and maintenance of private and non-community water systems, the abandonment of wells and drillholes and the installation and maintenance of pumping and treatment equipment.

Web site⟶ http://www.legis.state.wi.us/rsb/code/nr/nr812.pdf

Appendix B

Example Lab Analysis Forms

Bacteriological
Nitrate
Inorganic
Lead and Copper
Volatile Organic
Synthetic Organic
Radioactivity
TTHM
HAA5

Lab Analysis Forms

Lab analysis forms change frequently and are no longer provided in this manual. You may view, print or download sampling requirements and lab analysis forms for a specific water system from the DNR web site using the following instructions:

- Enter the following web site address in the "Address" line of your internet browser:

  Web site address→ http://prodoasext.dnr.wi.gov/inter1/pws2$.startup

- Press the <Enter> key or click on the "Go" button. You should see the **DNR Drinking Water System** web page.

- Enter either the water system name or the public water supply ID in one of the spaces provided and press the <Enter> key or click on the "Find" button. You should see the **Public Water Supply Systems** page.

- Click on the system name to access additional system information.

- Scroll down to the bottom of the system information screen and click on the "Sampling Requirements" link.

- The **Sampling Requirements** page will be displayed with a table of all the monitoring samples that are currently required for the system. For each Sample Group the table lists Source ID, Type, Status, # Required, # of Locations, Start Date and End Date.

- Click on a Sample Group in the table to see additional details.

- From this sample group detail page, scroll down to the bottom of the page and click on the "Print Sampling Form" button to view the sampling form.

Sampling forms are mailed directly to the designated sampler for the water system. Bacteriological sampling forms are included with sampling bottles. If you have any questions regarding sampling requirements or sampling forms contact your Regional DNR Representative.

Appendix C

National Primary Drinking Water Standards

National Drinking Water Standards

National primary and secondary drinking water standards change periodically and are no longer provided in this manual. You may view the current standards on the U.S. Environmental Protection Agency (EPA) web site.

Web site address→ http://www.epa.gov/safewater/contaminants

Provided is a table of regulated contaminants, the maximum contaminant level goal (MCLG), the maximum contaminant level (MCL), Potential Health Effects from Ingestion of Water, and Sources of Contaminant in Drinking Water. For most contaminants, clicking on the contaminant name will display a fact sheet with further information.