Wisconsin Department of Natural Resources
Drinking Water & Groundwater Program

WISCONSIN WATER WELL DRILLER LICENSE EXAM

STUDY GUIDE

Revised: 01/08/2024

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Wisconsin Water Well Driller License Exam Study Guide

Preface

This study guide is provided by the Wisconsin Department of Natural Resources to assist applicants in preparing for the Water Well Driller License Examination. Each section of this study guide includes objectives that should be reviewed and understood to achieve a passing grade on the license exam.

Preparing for the exam:

1. Study the material! Knowledge of objectives will be tested using a multiple-choice and true/false question format. Exam questions are taken directly from Study Guide Part 1 and Part 2 objectives.
2. Study Guide Part 1 "Administrative Code" sections list code related objectives. What is in code and why it is important is provided. Download chapters NR 146, NR 812 and NR 811 Wis. Adm. Code from the LICENSES AND REGISTRATIONS web page. These chapters of code and Part 1 of this study guide are the only references needed to prepare for code related exam questions.
3. Study Guide Part 2 "General Knowledge" sections list "key knowledge" objectives that a Wisconsin licensed water well driller is expected to know. These objectives are not code related and should be committed to memory for general knowledge related exam questions.

Taking the exam:

1. "Notice of Exam Eligibility" is required for a water well driller to apply for the license exam. To obtain an exam application, submit an email request to DNRDGLicensing@wisconsin.gov.
2. Visit the Operator Certification Exams web page for available exam dates and locations.
3. Copies of NR 146, NR 812 and NR 811 code references will be provided at the test center when you check in on the day of the exam. The packet will be sealed and must remain sealed until the proctor gives notice to start the exam. Personal copies of code cannot be used during the exam.
4. A current photo ID will be required.
5. There are 100 true/false and multiple-choice questions.
6. Time allowed for completion is 3 hours.
7. A score of 75% or higher is needed to pass.
8. Exam results will be available within 2 to 4 weeks of exam completion.

Acknowledgements

This Wisconsin Water Well Driller License Exam Study Guide is the result of a collaborative effort by department staff, with input from representatives of Wisconsin's water well industry through the Private Water Advisory Council. It was developed through the knowledge and efforts of the following department workgroup members:

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Part 1 - Administrative Code

Chapter 1 - NR 146: Licensing and Registration

Section 1.1 - NR 146.01: Purpose and applicability

1.1.1 Purpose and applicability

NR 146 establishes licensing and registration requirements that apply to water well drillers. Specific activities are listed to which license and registration requirements apply.

Section 1.2 - NR 146.02: Definitions

1.2.1 Definitions

This section provides important definitions that are necessary to understand license and registration requirements and how requirements are administered by the department.

Section 1.3 - NR 146.03(2)(a): Exceptions to water well driller license requirements

1.3.1 Exceptions to individual water well driller license requirements

A license is required to engage in the business of water well drilling under NR 146.03(1). NR 146.03(2)(a) lists the exceptions to this requirement.

Section 1.4 - NR 146.04(4): Water well driller business registration requirements

1.4.1 Water well driller business registration

A business registration is required for persons to engage in the business of water well drilling. The terms "persons" and "engaging in the business of" as defined in NR 146.02 need to be understood in order to grasp NR 146.04(4) intent. This section lists conditions required for water well driller business registration eligibility.

1.4.2 Exceptions to water well driller business registration requirements

NR 146.03(2)(b) provides exceptions to business registration requirements of 146.04(4). It lists the individuals who do not need a business registration in order to engage in the business of water well drilling as well as exceptions for persons drilling nonpotable water supply wells.

Section 1.5 - NR 146.04(4m): Supervisory responsibilities

1.5.1 Supervisory water well driller responsibilities

Areas of responsibility carried by the supervisory water well driller are laid out in this section. The extent of a supervisor's legal and financial responsibility includes the cost of corrections to noncomplying work done by the business or employees of the business. A supervisor must also be aware of all work-related activity done by drillers under their supervision.

Section 1.6 - NR 146.04(7): Engaging in the business of well filling and sealing

1.6.1 Well filling and sealing license and registration requirements

Licenses and registrations required to engage in the business of well filling and sealing are listed here.

Section 1.7 – NR 146.05(1): License and registration conditions

1.7.1 Conditions

Experience, qualifications and equipment are taken into consideration when a license, registration or renewal is issued. There are conditions that may be imposed on a license or registration to restrict activity if it is deemed necessary by the department.

Section 1.8 – NR 146.07: Renewals and continuing education requirements

1.8.1 *NR 146.07(1):* License and registration renewal application process

The license and registration renewal application processes are described here. Included are details on deadlines, fees, late penalties and required signatures. This section provides information on when a signature is required and who needs to sign the renewal application.

1.8.2 NR 146.07(2): License and registration renewal eligibility

Individuals who hold a valid license or registration on December 31st and have met continuing education requirements for the calendar year are eligible for renewal in the following year. This section lists reasons why a license or registration may not be in effect on December 31st. An individual whose license or registration is not renewed for the reasons listed must take and pass the appropriate exam to become licensed again.

1.8.3 NR 146.07(3): Continuing education requirements

This section discusses continuing education attendance and contains information on how many continuing education hours must be earned each year to renew a license or registration.

Section 1.9 – NR 146.08: Licensee and registrant responsibilities

1.9.1 Responsibilities

Responsibilities required of water well driller licensees and registrants are discussed here. Responsibilities include corrections to noncompliant work, advertising and business-related documents, contracts, leases, upgrades to noncomplying well components and systems and more. It is important to understand each as it applies to a specific license or registration.

Section 1.10 – NR 146.09: Suspension and revocation

1.10.1 Basis for suspension or revocation of a license or registration

A list of licensee or registrant actions that may result in suspension or revocation are listed under NR 146.09(1).

1.10.2 Limitations placed on suspended or revoked licenses and registrations

Following suspension or revocation, limitations are placed on individuals or persons who engage in the business of water well drilling. The requirements listed under NR146.09(2) must be met in order to engage in the business of water well drilling.

1.10.3 Reinstatement following suspension or revocation

Requirements for reinstatement are laid out in detail in NR 146.09(3). The steps required to reinstate a license or registration following suspension or revocation may include passing the license exam, reapplying after one year of revocation or demonstrating competency to the department under specific conditions.

Section 1.11 – NR 146.10: Well filling and sealing

1.11.1 Licensing and registration requirements for well filling and sealing

NR 146.04(7) states that a license or registration in required in order to engage in the business of well filling and sealing. NR 146.10 provides further detail on who can do well filling and sealing and under what conditions.

Section 1.12 – NR 146.11: Property transfer well inspections

1.12.1 Requirements

NR 146.11 and NR 812.44(1) provide information on who can inspect a well at time of a property transfer and what they may report regarding the well and its pressure system. Specific inspection tasks that require a license are listed.

Section 1.13 – NR 146.12: Citations

1.13.1 Appropriate action and stepped enforcement.

The enforcement process includes steps that are taken by the department prior to issuing a citation. These steps include a written warning that outlines the violation and provides opportunity to meet with the department in an enforcement conference. This section provides examples of specific violations that may result in a citation.

Chapter 2 - NR 811: Requirements for the operation and design of community water systems

Section 2.1 - NR 811.01: Applicability

2.1.1 When a water system is a community well

NR 811.01 explains when a well and water system is a community well, based on the number of dwelling units the water system serves. Community wells must meet the standards in NR 811 and require department approval before construction.

Section 2.2 - NR 811.08: General Requirements

2.2.1 Approval Requirements

This section lists requirements for submitting plans and specifications prior to receiving approval to construct wells for community water systems.

Chapter 3 - NR 812: Well construction and pump installation

Section 3.1 – NR 812.02: Applicability

This section outlines the relevant drilling, well construction and pump installing activities that are regulated under NR 812.

3.1.1 NR 812.02(1) to NR 812.02(2): Applicability to water systems and drillholes

Most new and existing water systems and drillholes are regulated by NR 812 with some listed exceptions.

Section 3.2 – NR 812.03: Cooperation with the department

This section specifies the expectations for cooperating with the department along with situations in which the driller or contractor should contact the department or other government entities.

3.2.1 NR812.03: Driller expectations to cooperate with the department

A water well driller must contact the department or other government entities prior to drilling in four distinct situations. This section of code explains those situations. One example is the requirement for water well drillers to contact a local water supply utility in order to determine whether the project is located within a wellhead protection area or within 400 feet of a municipal well.

Section 3.3 – NR 812.04: Contracts for noncomplying installations

This section specifies that well and heat exchange drillers, pump installers and well constructors must ensure that their work complies with NR 812, and bring noncomplying features of wells or water systems into compliance, and/or notify the owner and the department in writing of any known or apparent noncomplying features (even if no work was performed on them).

3.3.1 NR 812.04(1) to NR 812.04(2): Ensure work is conforming and exceptions

Licensed individuals must ensure that the construction and reconstruction of wells and water system conforms to NR 812 and may not agree to do noncomplying work and must inform the owner and the department of any noncomplying features of the system that are apparent or known in writing.

Section 3.4 – NR 812.07: Definitions

This section contains all the relevant definitions for terms used in NR 812.

3.4.1 NR 812.07(1) to NR 812.01(127): Well and water systems definitions

This section provides important definitions that are necessary to understand well construction and pump installation requirements and how requirements are administered by the department.

Section 3.5 – NR 812.08: Water well, reservoir and spring location

This section contains location requirements for wells, reservoirs and spring developments, especially separation distances from contamination sources.

3.5.1 NR 812.08(1) to NR 812.08(4) - Table A: Location requirements for Water Wells, Reservoirs and Spring Developments

A well must be located so that it and its surroundings can be kept in a sanitary condition, and the well is protected from surface water, flooding and is as far away from contaminant sources as possible.

It is important to understand the definitions relating to floodplains (found in NR 812.07) and be able to determine restrictions and prohibitions of constructing wells in floodplains.

Minimum separation distances from contaminant sources can be found in Table A. Wells may not be constructed less than the minimum separation distance from a contaminant source.

Section 3.6 – NR 812.09: Department approvals

Certain well construction and pump installation activities require approvals. This section provides a framework for determining which activities require approvals and the procedures for obtaining them.

3.6.1 NR 812.09(4): Activities requiring department approvals

Certain types of wells and drillholes require an approval by the department prior to construction. Examples include (but are not limited to) high capacity wells and wells constructed in a designated special well casing depth areas (SWCDA). Other approvals are required for water system features, such as well pits, spring development and a variance to a provision of NR 812.

3.6.2 NR 812.09(2) to NR 812.09(8): Application submission and approval

A well driller or well constructor must obtain written approval from the department in advance for activities requiring approval and must also give advance notification prior to starting construction under any approval. Modification of any approval must also be obtained in writing prior to starting construction. Noncomplying construction may result in denial or rescinding of an approval.

Section 3.7 – NR 812.091: General product and component approval information.

Certain products used to construct, develop, or treat a well or drillhole require prior approval from the department. This section provides an overview on Product and Component approvals and where to find the approved product and component lists.

3.7.1 NR 812.091: General product and component approval information.

Many products or components used to construct, develop, or treat a well or drillhole require department approval. NR 812.091 outlines the specific product categories requiring approvals, examples include well rehabilitation materials and grouting and sealing materials. The department may approve a product or component with additional conditions for use, which will be specified on the department-managed lists. The department may also prohibit the use of any product or component if there is evidence that the product poses a threat to groundwater. Additionally, there are situations in which an approval is not required by the department. These situations are specific to NSF/ANSI certified products and are dependent upon additional requirements as *outlined in 812.091(3). The department maintains categorized lists of all approved products which can be found here: https://dnr.wi.gov/topic/Wells/drillerPumpInstall.html*

Section 3.8 – NR 812.10: Well driller and well constructor requirements

This section provides the general requirements for well drillers and well constructors for constructing wells reporting to owners and the department, and addressing noncompliant, contaminated and problem wells.

3.8.1 NR 812.10(1) to NR 812.10(9): Responsibilities of well driller or well constructor prior to constructing a well

The well driller or well constructor must properly locate a well. They must use the proper equipment, materials and construction methods to construct a well.

The well driller or well constructor must also obtain any and all required approvals from the department and permits from counties or municipalities and consult with the department prior to constructing a well in areas with contaminated geologic formations or groundwater, or areas with residual contamination and continuing obligations.

If a noncompliant well is constructed, the well driller or well constructor must pay all costs for bringing the well into compliance or filling and sealing the well.

A well notification and any required permits must be obtained before construction begins.

3.8.2 NR 812.10(10) to NR 812.10(11): Water Sample Collection and Well Construction Report

A well driller or well constructor must collect water samples after construction of a well, and complete and submit a well construction report to the department for a list of well construction activities within the specified time period.

3.8.3 NR 812.10(12) to NR 812.10 (16): Responsibility of the well driller or well constructor to bring a noncompliant well into compliance or to fill and seal post-construction

A well driller or well constructor must return to a well site to address bacteria-positive results or correct problems within specific timeframes.

When a problem well has been identified by the department, the department may test or contract the well to be tested for damage or leaks.

A well driller who removes a well from service or constructs a replacement well must inform the property owner that the removed or replaced well must be filled and sealed.

Under certain situations, the well driller or well constructor must submit a well casing pipe depth verification report to the department.

Section 3.9 – NR 812.11: Well construction equipment and materials

This section provides general requirements for approved equipment and materials for constructing wells.

3.9.1 NR 812.11(1) to NR 812.11(16) - Tables B and C: Materials permanently installed in a well

All materials permanently installed in a well or used for the construction of the well by a well driller or well constructor must meet certain requirements of this section and in Table B. These include drill bit, tremie pipe, mud balance, liners, gravel packs, packers, screens, casing and casing shoe requirements (including dimensions, material and weights).

Drilling water, grouting and sealing materials and drilling aids also must meet certain requirements that can be found in this section and in Table C.

Section 3.10 – NR 812.12: General drilled type well construction requirements

This section provides general requirements for planning, construction and post-construction activities for well construction.

3.10.1 NR 812.12(1) to NR 812.12(2): General requirements for well construction prior to construction

Prior to constructing a well, a well driller or well constructor must plan the well to meet specific requirements, including that the finished well is constructed appropriately for the geologic conditions and provides an adequate and contaminant-free water supply, while conserving groundwater and preventing groundwater contamination.

The design, materials and equipment must meet the requirements of the appropriate sections of NR 812.

3.10.2 NR 812.12(3) to NR 812.12(9): Construction of wells during the well drilling process

Construction of wells in special well casing depth areas and near quarries have special requirements outlined in this section.

General construction requirements for driving casing, well plumbness and alignment, upper enlarged drillholes, starter drillholes and liners are found in this section.

3.10.3 NR 812.12(10) to NR 812.12(14): Well construction post-drilling

Geologic samples must be collected for all potable school wells and for specific high-capacity potable and nonpotable wells. NR 812.12(10) identifies details for cutting sample collection and requires cutting samples to be submitted to the Wisconsin Geological and Natural History Survey within a specific timeframe after well completion.

The final well casing height must be at least 12 inches above the final ground grade, pumphouse or building floor, or any concrete or asphalt platform at or above the established ground surface.

Flowing, nonpotable wells must meet most of the requirements for low capacity potable wells.

3.10.4 NR 812.12(15) to NR 812.12(17) - Table D: Well construction finishing operations

After constructing or reconstructing a well, a well driller or well constructor must properly develop, perform a well pump test, disinfect and flush the well according to the requirements of this section. Table D contains information for preparing chlorine solution at the desired concentration for well disinfection.

Section 3.11 – NR 812.13: Drilled wells terminating in unconsolidated formations

This section provides more specific construction requirements for wells terminating in unconsolidated formations.

3.11.1 NR 81213(1) to NR 812.13(2): Drillhole diameter and casing depth requirements

This section specifies the minimum drillhole diameter based on nominal well casing size and minimum casing depths for all drilled wells in unconsolidated formations. Minimum casing depth varies depending on the static water level.

3.11.2 NR 812.13(3) to NR 812.13(6): Requirements for casing types and driving casing, material and installation of screens and gravel packs.

Steel or thermoplastic (PVC) casing may be used in unconsolidated formations with some exceptions as outlined in this section.

Steel casing may be driven or advanced in unconsolidated formations so long as the casing is fitted with a drive shoe or casing shoe, and clay slurry, sodium bentonite slurry or granular bentonite is maintained around the casing during advancement.

Screens for drilled wells in unconsolidated formations must meet the minimum requirements of NR 812.11, and be installed properly, including proper use of packers, shale traps and risers.

3.11.3 NR 812.13(7) to NR 812.13(9): Requirements for upper enlarged drillholes and grouting.

Depending on the casing joining method, the upper enlarged drillhole may be 2, 3 or 4 inches larger than the outside diameter of the casing.

Approved methods of keeping the hole open include the use of drilling mud and setting a temporary outer casing.

Cement grout may be used with steel and thermoplastic (PVC) casing.

An upper enlarged drillhole ≤20 feet deep may be grouted with clay slurry or mud and cuttings.

Approved grouting materials for all low capacity and nonpotable high capacity wells is neat cement, sand cement, sodium bentonite, and sodium bentonite-sand.

A well must be grouted so that it is not open to both an unconsolidated and a bedrock formation.

Section 3.12 – NR 812.14: Drilled wells in bedrock formations

This section provides more specific construction requirements for wells terminating in bedrock.

3.12.1 NR 812.14(1) to NR 812.14(2): Drillhole diameter and casing depth requirements

The minimum casing diameter for all bedrock wells is 6 inches.

Minimum casing depth for bedrock depends on the bedrock type and can be found in this section.

3.12.2 NR 812.14(3) to NR 812.14(4): Casing material requirements and restrictions when driving casing.

Either steel or thermoplastic casing may be used as permanent casing for bedrock wells, however thermoplastic casing use is restricted to only non-crystalline bedrock (limestone/dolomite, sandstone and shale).

A well driller or well constructor may drive or advance steel casing to the top of bedrock so long as depth to bedrock meets requirements found in this section. A drive shoe or casing shoe and the casing must be driven to a firm seat in the bedrock. Casing may not be driven or mechanically advanced through bedrock.

Thermoplastic casing may not be driven to a firm seat but may be held down mechanically within the upper enlarged borehole during grouting to prevent the casing from floating.

3.12.3 NR 812.14(5) to NR 812.14(6): Requirements for upper enlarged and lower drillholes

Depending on the casing joining method, the upper enlarged drillhole may be 2, 3 or 4 inches larger than the outside diameter of the casing.

Approved methods of keeping the hole open include the use of drilling mud, setting a temporary outer casing, and circulating air, water or drilling foam, depending on circumstances.

If an upper enlarged drillhole extends ≥5 feet into bedrock, the annular space must be grouted with neat cement or bentonite-cement.

A lower drillhole may not be drilled before grouting an annular space unless the casing is driven to a firm seat in bedrock. This section outlines specific restrictions to filling the open annular space with drill cuttings. If the annular space is grouted with cement, it must be allowed to set for at least 12 hours before drilling the lower drillhole.

3.12.4 NR 812.14(7) to NR 812.14(10): Requirements for grouting

Cement grout may only be used on steel casing and may not be used with thermoplastic (PVC) casing, except in flowing well situations as allowed in NR 812.15.

Approved grouting materials for all low capacity and nonpotable high capacity wells using steel casing with the upper enlarged drillhole extending less than 5 feet into bedrock require neat cement, sand cement, sodium bentonite, and sodium bentonite-sand.

Bentonite chips may be used when fractures, voids or caverns are encountered that prevent grout from coming up to the surface. This section specifies the process for *placing bentonite chips in these cases. A well must be grouted so that it is not open to both an unconsolidated and a bedrock formation (dual aquifer).*

Wells constructed or reconstructed to withdraw water from beneath the Maquoketa Shale formation must be cased and grouted into the Maquoketa Shale.

Section 3.13 – NR 812.15: Flowing wells

This section provides requirements for wells constructed in areas where the hydraulic pressure of the aquifer would make the water flow out of the well or drillhole without needing to be pumped.

3.13.1 NR 812.15(1) to NR 812.15(2): General requirements for the construction of flowing wells

When constructing a flowing well, the well driller or well constructor must confine the flow to the interior of the casing. If flow is not contained to the interior of the casing using the planned construction methods the well driller or well constructor must notify the department and do one of the following:

- *Reconstruct the well to contain the flow to the interior of the casing*
- *Reconstruct the well according to the requirements of NR 812.15(2) – (4)*
- *Fill and seal the well*

When constructed with an upper enlarged drillhole, all casing used for flowing wells (including thermoplastic (PVC) casing) must have the annular space grouted using neat cement. Specific restrictions on driving or advancing casing through the bottom of the upper enlarged drillhole apply.

3.13.2 NR 812.15(3): Requirements for constructing a flowing well in unconsolidated formations

If constructed within an unconsolidated formation, the drillhole must be 4 inches larger than the diameter of the casing, and the drillhole must be kept open by driving a temporary casing or circulating drilling mud. Additives approved under NR 812.091 may be used with the drilling mud.

Double cased wells have specific construction requirements for diameter, casing depth and grouting.

3.13.3 NR 812.14(4): Requirements for constructing a flowing well in bedrock formations

Minimum casing depth for flowing wells in bedrock formations depends on the depth to bedrock or confining bed in relation to minimum depth requirements when casing is driven or advanced. Casing set into an upper enlarged drillhole more than 5 feet into bedrock must be driven to a firm seat prior to grouting.

If constructed with an unconsolidated formation, the drillhole must be 4 inches larger than the diameter of the casing, and the drillhole must be kept open by driving a temporary casing or circulating drilling mud. Additives approved under NR 812.091 may be used with the drilling mud.

Double-cased wells have specific construction requirements for diameter, casing depth and grouting.

Section 3.14 – NR 812.152: Construction requirements for potable high capacity wells, potable school wells, and wastewater treatment plant wells

This section provides more specific construction requirements for potable high capacity, school and wastewater treatment plant wells.

3.14.1 NR 812.152(1) to NR 812.152(4): Minimum diameter, casing material, upper enlarged drillhole, and casing depth.

The minimum casing and lower drillhole diameter for potable high capacity wells, potable school wells, and wastewater treatment plant wells is 4 inches for unconsolidated formations and 6 inches for bedrock formations.

Only steel casing is allowed for potable high capacity wells, potable school wells, and wastewater treatment plant wells.

The upper enlarged drillhole must be at least 3 inches larger than the diameter of the casing or casing couplings (if used). The upper enlarged drillhole must be maintained at full diameter by circulating bentonite drilling mud or setting a temporary casing to the bottom of the drillhole or to the top of bedrock.

In unconsolidated formations, casing depth for potable high capacity wells, potable school wells, and wastewater treatment plant wells is either 60 feet, 100 feet, or 20 feet below the static water level depending on the static water level depth.

In bedrock, casing depth for potable high capacity wells, potable school wells, and wastewater treatment plant wells is either 60 feet or 100 feet, depending on static water depth or if supplying a wastewater treatment plant, and whether there is a treatment pond, lagoon or sludge beds on the property.

3.14.2 NR 812.152(5) to NR 812.152(6): Requirements for grouting and driving or advancing casing.

Only neat cement grout may be used to seal the annular space. If driving or advancing casing, the casing may be driven or advanced through the unconsolidated material to the top of bedrock.

3.14.3 NR 812.152(7) to NR 812.152(8): Requirements for screens and gravel packs.

Screens must be specific types and composed of stainless steel or lead-free brass. Gravel packs must be placed according to NR 812.16.

3.14.4 NR 812.152(9): Requirements for collecting geologic samples.

Geologic samples must be collected and submitted to the WGNHS for all potable school wells and high capacity potable wells when required by the department approval. The collection requirements must follow NR 812.12(11)(b).

Section 3.15 – NR 812.16: Gravel packs

Gravel packs are used with screened wells. This section provides the requirements for installing gravel packs.

3.15.1 NR 812.16(1) to NR 812.16(3): Requirements for constructing a screened well with a gravel pack.

Gravel packs may be placed in wells in unconsolidated formations, loose sandstone and badly fractured or decomposed bedrock.

Screens placed in gravel pack wells require centering guides at the top and bottom of the screen. The screen must be sized to retain 90% of the gravel pack and meet the material requirements of NR 812.11(11), and be welded or threaded onto the bottom of the casing.

3.15.2 NR 812.16(4) to NR 812.16(5): Requirements for gravel packs.

Gravel packs must be placed with a tremie pipe and surround the entire screen and extend above the screen with a minimum amount of sand seal above to separate the annular space sealing material from the gravel pack. For nonpotable high capacity wells the gravel pack may not extend too far above the top of the screen. The diameter of the upper enlarged drillhole must be sized to accommodate the thickness of the gravel pack sufficiently larger than the nominal radius of the screen.

Section 3.16 – NR 812.18: Welding procedures

This section describes how to determine proper welding procedures for joining casing and pitless adapters.

3.16.1 NR 812.18: Required welding procedures for steel well casing

Plain end steel casing must conform to the specifications of NR 812.11(6), be welded according to the American Welding Society manual for welding mild steel pipe and must be welded watertight.

Pitless adapters must be welded watertight according to the American Welding Society manual for structural welding of code steel.

Section 3.17 – NR 812.19: Well plumbness and alignment

This section describes the requirements to ensure the well is sufficiently aligned in the drillhole and sufficiently straight (plumb).

3.17.1 NR 812.19(1) to NR 812.19(2): Properly plumbed and aligned wells.

A well’s alignment may not deviate more than *75% of the well diameter per 100 feet of depth for well with casing at least 10 inches in diameter. The well must allow free passage of the pump installation to the depth of the pump plus 25%. The well must be aligned so it doesn’t cause damage to the bearings of a line shaft turbine pump.*

Section 3.18 – NR 812.20: Grouting and sealing

This section describes the requirements for properly grouting and sealing the annulus of a well.

3.18.1 NR 812.20(1) to NR 812.20(4): Procedures for grouting and sealing the annular spaces of wells

Tremie pipes must be placed on the outside of the casing string and must reach to the bottom of the upper enlarged drillhole and move freely in the annulus prior to grouting. The bottom of the tremie pipe must remain submerged in the grout as it is pulled back during grouting.

Grout must be placed from the bottom up in the annular space. Grout density flowing from the top of the annular space must be the same density as the grout being pumped into the annulus. Grout must be placed in one operation, unless the grout fails to come to the surface after pumping more than the calculated amount of grout required to fill the annulus. This section provides steps to take in that event, and the reason for the interrupted grouting operation must be noted on the WCR.

For low capacity wells cement grout must be allowed to set a minimum of 12 hours before continuing drilling operations.

This section lists four approved pressure grouting methods.

Non-pressure grouting may be used when the upper enlarged drillhole is shallow enough and sufficiently larger than the nominal diameter of the casing.

Section 3.19 – NR 812.21: Liners

Liners are generally lengths of casing-type pipe installed inside the well casing. This section specifies proper installation requirements for liners.

3.19.1 NR 812.21(1) to NR 812.21(5): Requirements, materials, methods and grouting requirements

Liners are usually installed to correct contaminated water supplies or to correct caving and sluffing bore holes. Liners installed to correct contamination are subject to more stringent requirements, such as installation of flanges or grout. It is your responsibility to understand these requirements.

Liner material may be either steel or thermoplastic (PVC) casing. Liners must be at least 2” smaller than the diameter of the casing or drillhole.

The depth and interval of these liners is dependent on factors such as static water level, casing depth, and installation method, be sure to understand these requirements.

Section 3.20 – NR 812.22: Well rehabilitation and batch chlorination

This section describes the requirements for treating a well with bacterial contamination and yield or other problems, as well as disinfecting the well and system using a chlorine solution.

3.20.1 NR 812.22(1): Well rehabilitation

Redevelopment will follow the same procedure as for development of a well specified in NR 812. 12(15). Chemical conditioning of a well, pumps or intake screens shall be supervised by a licensed well driller or pump installer, respectively. Both may also be supervised by a Wisconsin registered professional engineer. Acidification of a well must use approved products and performed in a manner to prevent damage to the well, pump, system or hazards to humans or property. The acid must be inhibited and neutralized when removed from the well.

Wells may be physically conditioned using blasting, hydrofracturing, hydroflushing or mechanical brushing following the requirements of this section.

3.20.2. NR 812.22(2): Batch chlorination

The entire water system must be disinfected with a chlorine solution prepared according to Table D, shall be at least equal to the volume of standing water in the well, and be brought into contact with the entire inside of the casing by continuous circulation from the water system. The chlorine must be in contact with the system of at least 12 hours before being thoroughly flushed.

Section 3.21 – NR 812.23: Driven point wells

In unconsolidated formations with shallow potable groundwater, driven point wells can be a less expensive alternative to a drilled well. This section describes the requirements for constructing a driven point well.

3.21.1 NR 812.23(1) to NR 812.23(11): Requirements for construction of a driven point well.

Location requirements, materials, final casing height, pump installation and construction of flowing wells for driven point wells follow the same requirements and sections as for drilled wells.

The minimum casing size for driven point wells is 1 ¼ inches. Minimum casing depth (not including the screen) may depend on static water level in addition to standard minimum casing depth.

Adequate and compliant protection of driven point wells from frost/freezing is important, and requirements can be found in this section.

Pulling out the well casing pipe and replacing the well screen is considered new construction and must meet all the requirements of new well construction in NR 812. Shallow starter drillholes may be constructed to facilitate driving pipe.

Section 3.22 – NR 812.24: Dug type well design and construction

Wells constructed by simply digging down to groundwater are increasingly rare. If approved, a dug well must meet specific requirements due to the increased risk for contamination.

3.22.1 NR 812.24(1) to NR 812.24(3): Requirements for construction of a dug type well

> *The requirements for constructing a dug well are very specific and can be found in this section. Due to the risks to drinking and groundwater associated with dug wells, the DNR discourages their construction.*

Section 3.23 – NR 812.25: Springs

Springs may also be developed as a potable water source, although the department discourages this practice. If approved, the spring must meet specific requirements.

3.23.1 NR 812.25(1) to NR 812.25(3): The use of a spring as a source of potable water

> *Placement or driving of a casing pipe into an undeveloped spring accessible to the public is not allowed.*
>
> *The department discourages the use of springs as a source of potable water due to wide fluctuations in water quality and susceptibility to contamination.*
>
> *Obtaining approval for using a spring as a source of potable water shall follow the specific location, construction and water quality requirements in this section.*

Section 3.24 – NR 812.26 Well and drillhole filling and sealing

Filling and sealing is sometimes referred to as "abandonment." When a well is no longer being used, is contaminated, cannot be rehabilitated or reconstructed, or is otherwise noncompliant, it must be filled and sealed to prevent it from becoming a possible risk to human health and groundwater.

3.24.1 NR 812.26(1) to NR 812.26(4): Well and drillhole filling and sealing

> *Filling and sealing of wells may be performed only by a licensed well driller or pump installer, and heat exchange drillholes may only be sealed by a licensed heat exchange driller with only a few specific exceptions.*
>
> *This portion of the code explains the situations in which well sealing is required. There are certain situations which require the well owner to hire a licensed individual to fill and seal a well. An example is a well which is not being used. For most well types, a well that has not been used for any water supply purpose for more than 90 days must be filled and sealed. Seasonal or high capacity irrigation wells must be filled and sealed if they have not been used for more than 3 consecutive years. This portion of code also outlines the situations in which the department may require a well to be filled and sealed and the specific responsibilities of the pump installer when they receive notice from the department to fill and seal a well.*

3.24.2 NR 812.26(5) to NR 812.26(6): General requirements for filling and sealing wells and drillholes

Obstructions must be removed prior to filling and sealing. Sodium bentonite drilling mud may be circulated prior to filling and sealing in fractured or highly permeable formations. Filling and sealing material for any well or drillhole larger than 3 inches in diameter must be placed through a tremie pipe or dump bailer except when bentonite chips or bentonite pellets are used.

Liners with ungrouted annular spaces that cannot be removed must be perforated or ripped in place prior to filling and sealing according to requirements in this section.

In certain cases, the well casing may be removed and reused. Pits may be filled and sealed with clean native soil after all the equipment has been removed and the pit floor and at least one wall perforated or removed.

Neat cement, sand-cement, concrete, bentonite chips, bentonite pellets, drilling mud and cuttings and chlorinated pea gravel may be used in specific cases, and subject to certain restrictions specified in this section.

Wells and drillholes must be filled from the bottom up with a tremie pipe except where use of a tremie pipe is specifically exempted. Allowable filling and sealing materials are dependent on either well or drilhole is being sealed, diameter, and formation.

3.24.3 NR 812.26(7): Filling and sealing reports

Filling and sealing reports must be filed with the department electronically by the person performing the filling and sealing work.

Section 3.25 – NR 812.30: Vermin-proof well caps and seals

3.25.1 Requirements for well caps, seals and the conduit that encloses electrical wiring.

Well caps must be approved under NR 812.091 and meet the requirements of this section for seal, venting, conduit, as well as requirements for preparing the top of the casing for the cap. The details of seal types, well vents, hold-down devices, materials used and installation of electrical conduit are discussed.

Section 3.26 – NR 812.36: Pits

3.26.1 Requirements and specifications for pits and driveway ramps.

New well pits require approval under NR 812.09 prior to construction. This section describes the requirements for new well pits including conventional, alcoves and driveway ramps. All alcoves are pits. Valve pits are exempt from this section.

Section 3.27 – NR 812.37: Water treatment

3.27.1 Water treatment

This section describes the requirements for the treatment of potable private and noncommunity wells and water systems. It covers water treatment devices, but not disinfection or acidification which may be considered water treatment processes. General standards such as the requirement that treatment devices have plumbing *product approval in accordance with chs. SPS 382 and 384, a coliform free water supply must be present prior to treatment unless the department determines a coliform free water source is not available, requirements about how the equipment is installed and who can install it and specific technical requirements about the installation of treatment devices are covered in this section.*

Section 3.28 – NR 812.42: Criteria for evaluating and working on existing installations

NR812.42 outlines the specific requirements for evaluating existing wells for compliance. This section also provides requirements for completing work on existing well installations. Construction details, construction date, water quality, discharge piping arrangement, and sanitary condition all play a major role in both evaluating and working on existing systems.

3.28.1 NR 812.42(1): Location and well construction

A complying location depends on the requirements that were in place at the time of construction. Table E organizes separation distance requirements based on the date of installation. Well construction details are also based upon date of construction. Other construction details include the casing depth and the requirements based on geology and material, condition, and thickness of the well casing.

3.28.2 NR 812.42(1): Water quality

Existing wells need to meet water quality standards for bacteria and other regulated contaminants. The department may require water system upgrades or filling and sealing of wells which do not meet water quality standards.

3.28.3 NR 812.42(2) to NR 812.42(3): Pits and alcoves

This section describes the difference between an alcove, a pit, and a valve pit. It also describes the difference between basements, crawl spaces, and walkout basements. Existing wells in pits and alcoves and basements and walkout basements have different sets of requirements depending on the construction and installation date. Requirements specific to evaluating pre 1953 wells installed in a pit, alcove, basement, or walkout basement can be found in this section. These requirements are related to construction materials, sanitary condition, drainage, access, potential for flooding, and more. Newer pits and alcoves are subject to strict requirements as described in NR 812.36(2). This section also describes the requirements for filling and sealing noncomplying pits and alcoves. Basement wells (other than walkout basement wells) could not be installed after April 1, 1953.

3.28.4 NR 812.42(4): Reservoirs

This section goes into detail on determining compliance of existing reservoirs. Compliance depends on construction materials, access, sanitary condition and more. There are different requirements based on whether the discharge is pressurized or not. Requirements for abandonment of reservoirs are also specified in this section.

3.28.5 NR 812.42(5): Dug wells

Dug wells are more susceptible to contamination, which is why the department discourages use of dug wells. This section outlines the requirements for allowing the continued operation of dug wells. Compliance depends on curbing material, depth, cover specifications, and equipment placement.

3.28.6 NR 812.42(6): Pump and discharge piping evaluation

Pre-February 1, 1991 pump installations are subject to the evaluation criteria described in this section. The requirements will differ depending on type of well and how many families are served by the well. Criteria that need to be evaluated to determine compliance include pressurized and nonpressurized conduits, pitless units and adapters, check valve placement, pump type, and discharge location.

3.28.7 NR 812.42(7): Casing height & NR 812.42(12): Casing extensions

Required casing height is determined by factors such as date of construction and the location of well (pit/alcove, floodplain, pump room, basement, etc.). When work is done that involves entry into a well and the casing height is not compliant based on the previous factors, the casing must be extended. Casing height may only be extended under certain conditions related to the condition of the casing, casing thickness, distance to contaminant sources, and the casing depth. There are specific methods and materials requirements for extending the well casing outlined in this section of the code.

3.28.8 NR 812.42(8): Existing well caps and seals

This section lays out how to evaluate existing well caps and seals and when they must be replaced. It also describes the type of well cap or seal that may be installed and whom may install them.

3.28.9 NR 812.42(9): Basement wells

There are differences between basements, crawl spaces, and walk out basements. As of April 10, 1953, Basement wells may no longer be constructed; and as of July 1951, wells in crawl spaces under a building may no longer be constructed. There is a filling and sealing requirement for these wells if constructed after those dates. Requirements specific to evaluating and working on pre 1953 wells installed in basement or walk-out basement can be found in this section of code. These requirements are related to construction materials, sanitary conditions, drainage, access, water quality, potential for flooding, and more.

3.28.10 NR 812.42(11) through (12): Work on existing installations, reconstruction, and casing height extensions

These sections describe the requirements for reconstruction or extending the casing on existing wells. The casing may only be extended out of a pit or alcove if the casing depth meets the requirements at the time of construction. When working on existing installations; noncomplying well caps, sample faucets, and casing height all need to be considered and potentially brought into compliance depending on the extent of the work being completed, rather than just noting the noncompliance. Reconstruction (deepening, lining, screen replacement) may only be completed if the well meets current code *requirements. Additionally, sample faucets must be installed when completing specific types of work.*

Section 3.29 - NR 812.43: Variances

When strict compliance with the requirements of NR812 are not feasible, a variance can be requested. This section goes into detail on the requirements that must be met by both the applicant and the department.

3.29.1 NR 812.43(1): Responsibilities of the applicant

The applicant must clearly show why compliance with the code is not feasible. Additionally, this section lays out specific pieces of information needed with the variance request for the department to complete a review. The variance request must be signed by either the owner or an agent of the owner. Additionally, the variance request must be submitted in writing, though a verbal request may be acceptable in situations requiring an immediate response as determined by the department.

3.29.2 NR 812.43(1): Responsibilities and authority of the department

The department may grant a variance if the department determines the variance is justified. To determine this, the department has the authority to require additional information. The department may also require additional construction requirements or installation features as a condition of a variance approval to protect the well from contamination and to preserve the aquifer.

3.29.3 NR 812.43(1) (a) and (b): Landfill variances

Landfill variances may be requested by either the well owner or landfill owner, and both parties may appeal the variance approval. Landfill variances may be approved under the concept of comparable protection, which may be provided through additional construction and installation requirements. Additionally, the department is required to notify the owner of the landfill if the variance is approved.

3.29.4 NR 812.43(2): Variance to bedrock casing depth requirement

A variance to a casing depth requirement in bedrock formation may be granted if the well constructor can prove that water quantity or quality is not sufficient below the required casing depth. The department may require additional conditions.

Section 3.30 – NR 812.44: Property transfer well inspections

The buyer or seller of property with a private well may be interested in the condition of the well and the quality of water used for drinking. If an inspection is requested as part of a real estate transaction, there are requirements that apply.

3.30.1 NR 812.44 Scope and applicability

Well inspections at the time of property transfer are not required by law. However, NR 146.11 and this section of NR 812 list requirements that apply if inspection of a well and pressure system is requested. These requirements apply to water supply wells as defined in s. 280.30, Stats.

3.30.2 NR 812.44(1) Licensing requirements

NR 812.44(1) and NR 146.11 provide information on who can inspect a well at time of a property transfer and what they may report regarding the well and its pressure system. Specific inspection tasks that require a license are listed.

3.30.3 NR 812.44(2) through (4) Well pressure system inspection requirements

NR 812.44 subsections 2 thru 4 list inspection requirements pertaining to equipment, report forms and sample collection, analysis and reporting, and who shall receive the inspection report. Guidance is provided on what may accompany the required forms. Sample collection, analysis and reporting requirements are listed NR 812.46.

3.30.4 NR 812.44(5) Well and pressure system evaluation criteria

NR 812.44(5) lists features that are to be inspected for property transfer well inspections. There are specific requirements that may apply depending on when the well was constructed and how it was used. A property transfer well inspection is a visual inspection that evaluates the listed criteria. When there are indications of potential violations, the inspector may identify the need for a more comprehensive search or additional research. This section lists examples of potential violations. All wells and pressure systems on a property are to be inspected when a property transfer well inspection is conducted.

Section 3.31 – NR 812.45: Citations

Citations may be issued by the department for certain violations of NR 812. This section describes the process for issuing citations, and the violations that are subject to their issuance.

3.31.1 NR 812.45(1) to NR 812.45(3): Issuance of citations for noncompliance

Prior to issuing citations for noncompliance, the department must issue a written warning outlining the violation and schedule an enforcement conference. Citations may still be issued if the alleged violator declines or fails to attend the enforcement conference. Citations may be issued for violations of license and registration requirements, sampling and reporting requirements, noncomplying systems installed before February 1, 1991, and well or drillhole filling and sealing requirements.

Section 3.32 – NR 812.46: Water sampling, analysis and reporting requirements

NR 812.46 summarizes water sampling, analysis and reporting requirements. It is important to know what circumstances require a water sample to be collected and the proper procedures for collecting a water sample and documenting the test results. Repeatedly failing to take water samples when they are required can result in receiving a citation and creates a risk to human health and groundwater.

3.32.1 NR 812.46: Water sampling, analysis and reporting requirements

This section identifies when a well driller is required to collect water samples for various activities regulated in NR 812. The section includes details on where to collect water samples, what contaminants to test for, sample collection and handling practices, which laboratories are allowed to do testing, and the well driller's responsibility to provide the *test results to the well owner. The section explains when a well driller can delegate the sample collection responsibility to someone else and indicates that collection of property transfer inspection water samples cannot be delegated. The section includes a list of laboratory responsibilities and explains the specific instances where water sample test results cannot be used for more than one purpose.*

Part 2: GENERAL KNOWLEDGE

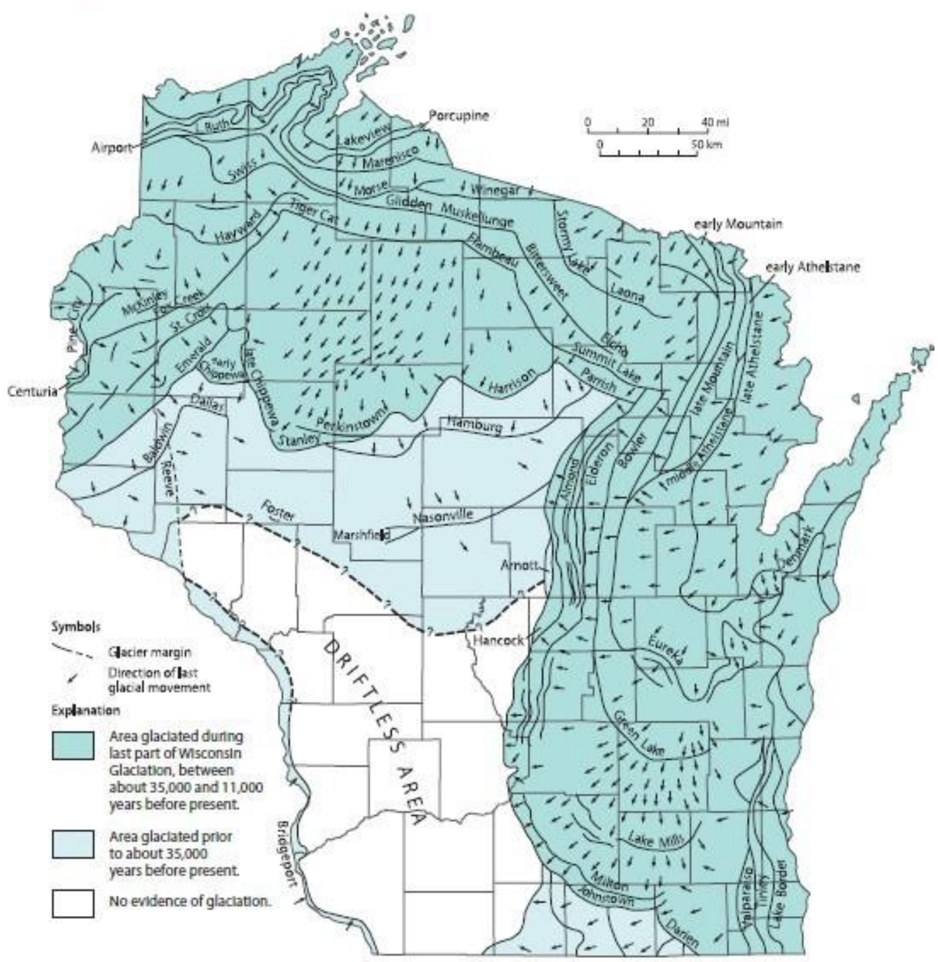
Chapter 4 – Geology of Wisconsin

Section 4.1 - Glacial geology

4.1.1 Glacial Geology of Wisconsin.

The last major glacial expansion in North America was called the "Wisconsin Glaciation" and started nearly 100,000 years ago. The ice sheet reached its maximum extent nearly 30,000 years ago and receded from Wisconsin about 11,000 years ago. Many prominent features in Wisconsin were formed by these glaciers. All of Wisconsin was impacted by glaciation, except for the Driftless Area in southwestern Wisconsin. https://wgnhs.wisc.edu/pubs/es0362011/

Phases of glaciation



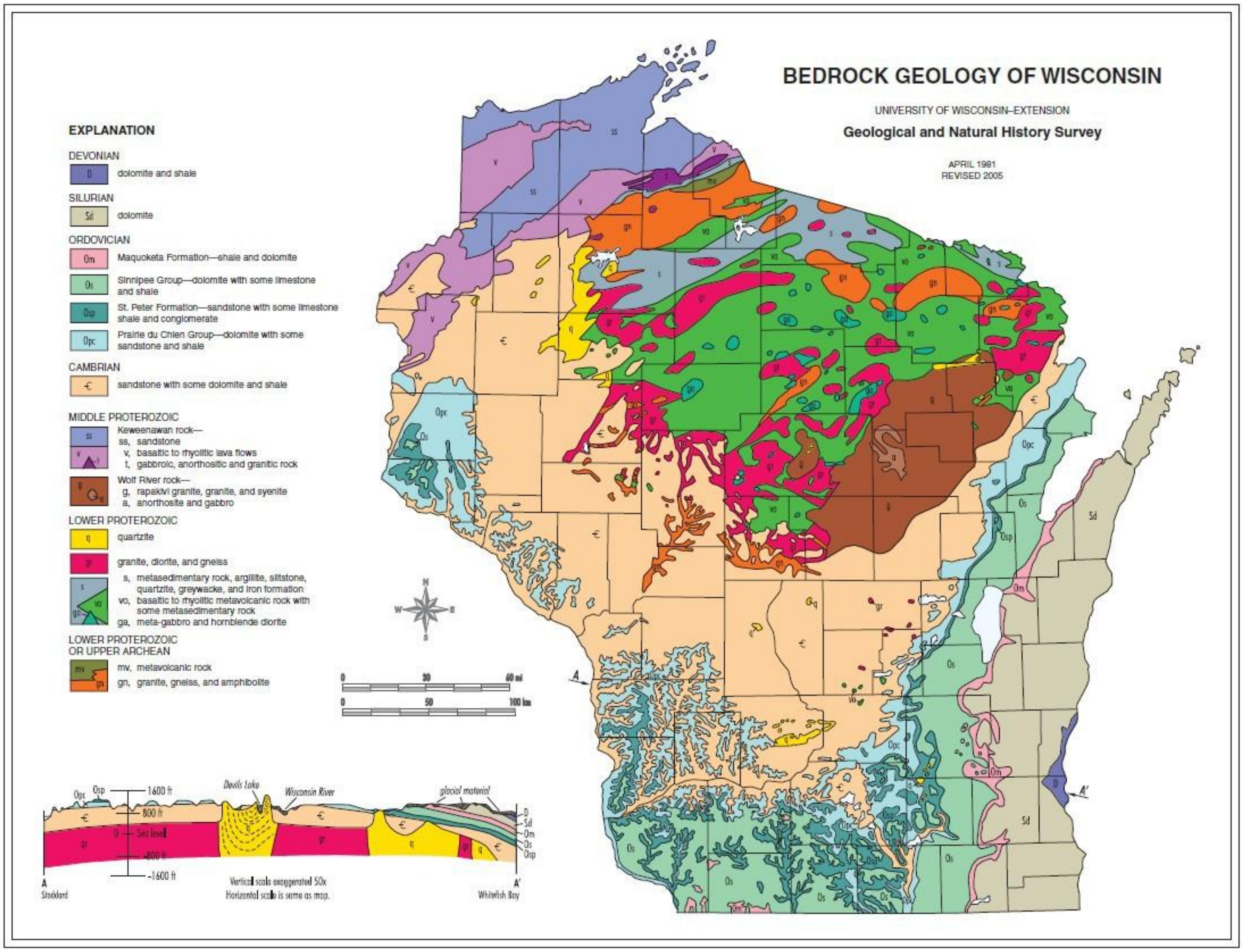
Ages of glaciation. In this map and the one on the last page, areas are distinguished by age: older or younger than about 35,000 years. Ages are determined using geochronology (radiocarbon and other dating techniques) and by studying features in the landscape. Younger glacial features are relatively fresh and uneroded; older glacial features are mostly or completely worn away.

A **phase** is a geologic event rather than a period of time. Most phases represent at least a minor advance of the edge of the Laurentide Ice Sheet. Each line marks the edge of the ice sheet during a phase of glaciation. For example, during the Johnstown Phase of the Wisconsin Glaciation, the southern edge of the Green Bay Lobe (see back page for lobe locations) of the Laurentide Ice Sheet advanced to the line marked "Johnstown" in southcentral Wisconsin. Only the most recent phase is shown at any location.

Section 4.2 – Bedrock geology

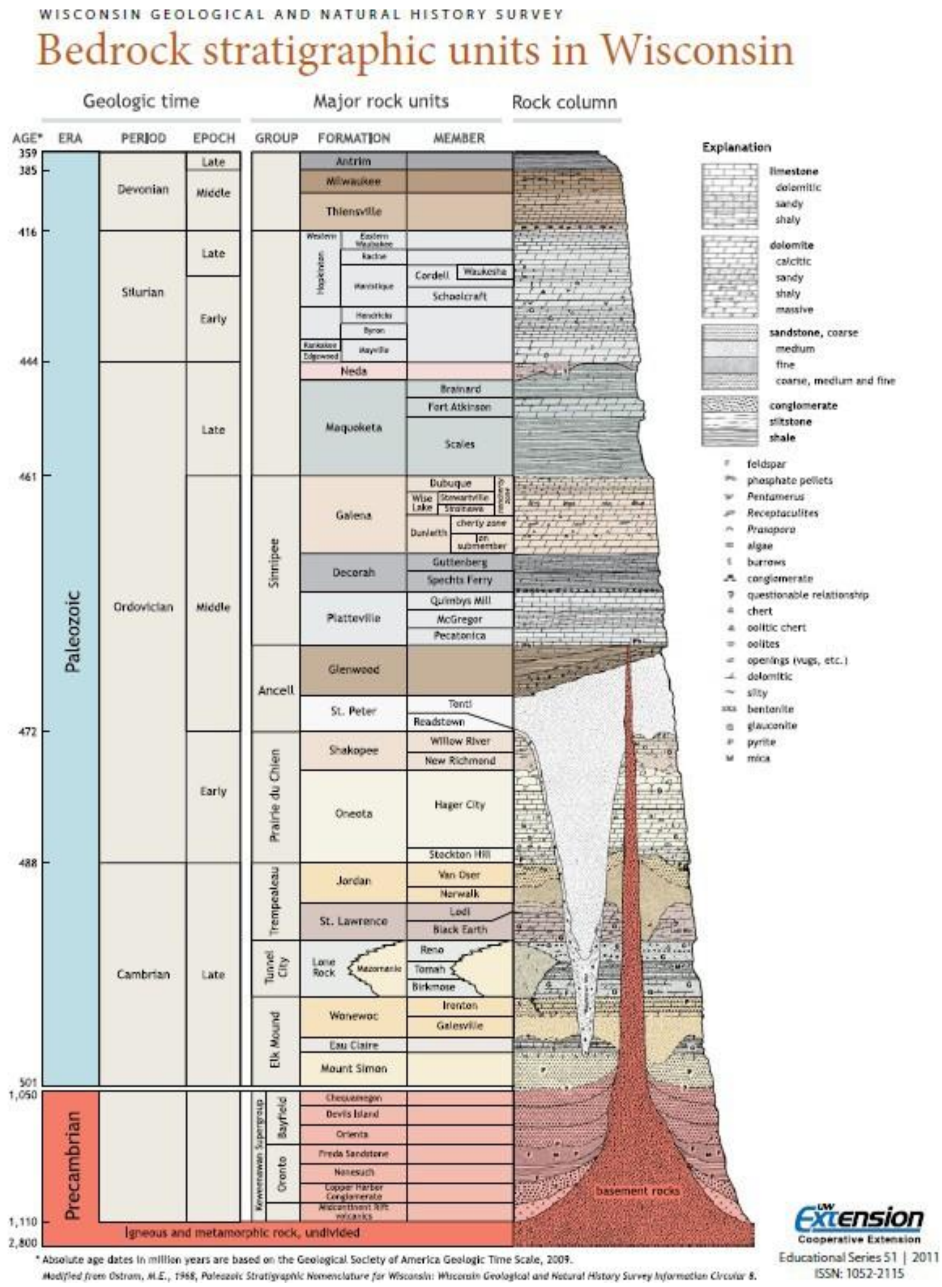
4.2.1 Bedrock geology of Wisconsin:

Wisconsin is home to relatively variable geology. This map view basically shows the surface extent of different bedrock types across the state. This map does not show glacial deposits or unconsolidated formations. Nor does it show which formations may be encountered at depth. https://wgnhs.wisc.edu/pubs/000390/



4.2.2 Stratigraphic bedrock units of Wisconsin.

Another way to view Wisconsin's bedrock geology is called a stratigraphic column, shown below. Rock types are listed in the legend on the right. This stratigraphic column shows the age and positioning of the bedrock. Younger rocks or positioned towards the top of the stratigraphic column and older rocks are towards the bottom. This also corresponds to depositional relationships. Younger rocks are typically deposited on top of older rocks. There is also a horizontal component to the stratigraphic column. Rocks that are more resistant to erosion extend further to the right horizontally, meaning the Precambrian igneous and metamorphic basement rock at the bottom of the column are the most resistant to erosion. https://wgnhs.wisc.edu/pubs/000200/



4.2.3 Limestone/Dolomite:

Limestone and dolomite are both creviced sedimentary carbonate rocks. Sedimentary rocks are formed from the deposition of smaller particles which eventually cemented together over time due to chemical or physical processes. Dolomite typically has finer grains and is more resistant to erosion and less water soluble than limestone. Limestone and dolomites are formed in marine waters from the accumulation and compaction of marine skeletal debris, such a shells and coral. They can also be chemically formed by the precipitation of calcium carbonate from sea or lake water.

4.2.4 Sandstone.

Sandstone is a sedimentary rock formed from small sand sized grains of quartz or feldspar. Sandstone is formed from the sedimentation and accumulation of sand which eventually is compacted by pressure of overlying material, and eventually cemented through the precipitation of minerals within the pore space of the sand grains. This process occurs over millions of years.

4.2.5 Shale.

Shale is also a sedimentary rock. The formation of shale is caused by very fine-grained material, such as mud or clay, which is then compacted by overlying material over a time frame of thousands to millions of years.

4.2.6 Precambrian basement rock.

Precambrian rocks are older than all the sedimentary rocks listed above. The Precambrian rocks in Wisconsin can be igneous or metamorphic. Igneous rocks are formed from the cooling of magma or lava. Metamorphic rocks are formed from melting and cooling of any type of existing rock. The Precambrian basement rocks in Wisconsin lie under the entire state and are the first rock type encountered in most places in the northern part of the state.

Section 4.3 - Cuttings identification

4.3.1 Importance of drill cuttings.

Cuttings identification is extremely important for several reasons. It is important to know which formations you're drilling through. Different formations have different characteristics, such as water quality, thermal conductivity, hydraulic conductivity, etc. Cuttings can help to identify potential naturally occurring water quality issues such as arsenopyrite and sulfide horizons, which can oxidize and cause high arsenic. Properly identifying cuttings is also important for filling out an accurate and useful well construction report. Drill cuttings are not always easy to identify and can easily be affected by different drilling practices. Cable tool drilling produces extremely clean and representative cuttings, while mud rotary makes cuttings identification more difficult.

4.3.2 Cuttings collection methods.

Many drillers use a screen to collect cuttings, which is generally effective, but does not provide the whole picture. Many small particles- like shale or sandstone- can pass through these screens. The best method to collect drill cuttings on a drill site is by using a 5-gallon bucket to collect the drill tailings. The bucket will be full of mud/water and the cuttings, so the driller should allow the cuttings to settle to the bottom, which usually takes a minute or two. Once those cuttings settle, they can be collected by the handful. This method allows for the driller to analyze the very fine-grained material along with the larger cuttings.

Section 4.4 - Hydrogeology

4.4.1 Aquifer

An aquifer is a water bearing geologic formation. The water resides in the pore space between grains in sand and gravel and sandstone formations and in the fractures of granite and dolomite formations. Wisconsin is home to four main aquifers. https://wgnhs.wisc.edu/water-environment/wisconsin-aquifers/

1. Sand and Gravel- The sand and gravel aquifers of Wisconsin were formed mainly from glacial outwash. They are not uniform throughout the state, but they can be found in nearly all the Wisconsin counties, especially in river valleys.
2. Eastern dolomite aquifer- This aquifer is on the eastern side of the state and is formed of the upper most and youngest dolomite rocks in the state. It is also known as the Silurian aquifer or the Niagaran aquifer. This aquifer extends from Door county in the north all the way to the Illinois/Wisconsin state line.
3. Sandstone and dolomite: This aquifer is also known as the Cambrian aquifer or the Cambrian-Ordovician aquifer. This aquifer underlies the sand and gravel and Silurian aquifers described above. This aquifer is made up of both sandstone and dolomite and is the target formation for most municipal wells throughout the state. This aquifer is absent in the north-central part of the state.
4. Crystalline Bedrock- This aquifer is also known as the Precambrian aquifer. This formation underlies the entire state, though it is only used as an aquifer in the northern part of the state where it is sometimes the only available aquifer. This aquifer is comprised of the oldest rock and Wisconsin and is comprised of igneous and metamorphic rocks. It is typically low yielding as the rocks are fine grained and less fractured than dolomite aquifers. Sometime hydrofracturing is necessary to enlarge the fractures enough to produce enough water.

4.4.2 - Specific capacity and well yield

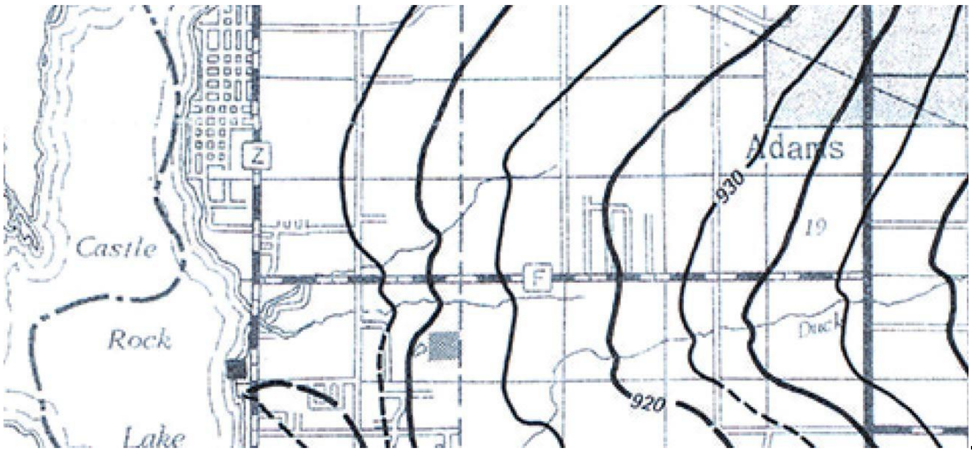
Specific capacity is a required field on the well construction reports. Specific capacity is the quantity of water a well can produce per unit of drawdown. It gives a general idea of how much water a well can produce. To calculate specific capacity, the yield (gpm) will be divided by the drawdown (in feet). For example, a well is pumping at 10 gallons per minute and has a draw-down of 20 feet during a pump test. The specific capacity of this well would be 0.5 gpm/ft. Specific capacity can be calculated regardless of the duration of the pump test, but a longer pump test will provide more accurate results. A pump test should run long enough for the draw down to reach steady-state conditions (a point at which drawdown no longer occurs).

4.4.3 Groundwater flow.

Groundwater Flow is important to understand when constructing a well or drillhole near a contamination source. Groundwater elevation typically follows topography and flows from hydraulic highs (hills) to hydraulic lows (rivers or lakes). It is always ideal to construct a well or drillhole up gradient or side gradient from contamination sources to protect both the water supply and the aquifer from contamination.

4.4.4 Groundwater flow map (water table elevation)

Below is an image of a portion of a Water Table Elevation map of Adams County. This water table map, along with many others, can be found on the Wisconsin Geological and Natural History Survey website. In the example below, you can see that groundwater flow is in a Westerly direction, towards Castle Rock Lake. The lines on this map are lines of equal water table elevation and the numbers are the water table elevation in feet above sea level. https://wgnhs.wisc.edu/pubs/mp811plate01/



Chapter 5 – Well construction methods and reporting

Section 5.1 – Well location

5.1.1 Siting a well

It is important to locate a well on the highest point of the property relative to the location of any contamination sources on and nearby the property, and relative to the topographic layout of the lot and its surroundings. If the well cannot be located on the highest point of the property, then it should not be sited directly down-gradient from a contamination source. Further, minimum separating distances must be maintained between the well and potential sources of contamination such as septic tanks, sewage absorption fields, buried petroleum tanks, animal yards, etc. Required separation distances from contamination sources can be found in ch. NR 812.08 and Table A.

Section 5.2 – Drilling methods

There are two basic methods for constructing wells; rotary methods and cable-tool (percussion) methods. Rotary methods are newer technology and are a little easier to understand. Mobile rotary drilling machines were developed in the oil drilling industry, where they were used to construct exploration drillholes in the oil fields. They have been used in Wisconsin since about the mid-1950s. Cable-tool (percussion) methods, in their present form, are a bit more rudimentary and have been around much longer, perhaps as long as 100 years or more, and remain in significant use today.

5.2.1 Rotary methods - mud circulation

For constructing drillholes through unconsolidated material (sand, gravel or clay) or soft bedrock, the driller can circulate a sodium bentonite clay slurry through the system. With rotary-mud drilling the geological formation is usually ground up using a tri-cone bit. Tri-cone bits were originally developed in the oil well drilling industry. Extremely hard tungsten carbide teeth are imbedded into the outside of each of the three cones. These teeth grind up the soil and bedrock material. The three cones rotate independently. The entire drill stem and bit also rotate. Mud rotary can be used to hold open caving formations without the need for casing. Mud rotary uses bentonite drilling fluid to build a filter cake on the walls of the drillhole. This minimizes communication between the drilling fluids and the surrounding formation – for this reason mud rotary is preferred in certain arsenic areas of the state. Because of the nature of the mud, it can lift cuttings out of the drillhole with modest upward velocities. It can also be a disadvantage that once mud is out of the hole it may not efficiently drop the cuttings before being pumped back down the hole. Although mud can be messy, it minimizes dust. Because drilling mud is made from clay, it can be difficult to distinguish formations with fines as the finer cuttings get mixed with the mud. Performance of the bentonite mud is greatly affected by the water quality of the water used to mix the mud and can also be affected by the water quality of the groundwater encountered.

5.2.2 Rotary methods - cuttings removal with air

When the driller encounters hard bedrock formations, he/she will often switch over from mud to air as the drilling fluid to remove the drill cuttings. When air is used the drilling bit is also often changed. Rather than using a tri-cone bit, the driller will switch to a down-the-hole hammer bit. The bottom of this bit has a single head and operates in a manner similar to a jack hammer by using compressed air under high pressure. Tungsten carbide buttons are embedded into the bottom of the head. The bit vibrates and rapidly separates and returns to the hammer at high frequency and simultaneously rotates. This hammering action chops the formation up into small pieces.

The compressed air blows out of holes in the bottom of the bit and lifts the cuttings between the outside of the drill stem and the inside of the drillhole up to the surface where they fall to the ground. The air also provides cooling for the bit. Small amounts of water and oil· are usually added to the air circulation system for lubrication and protection of the bit.

Air rotary also does not depend on the efficiency of the fluids ability to dump cuttings at the surface as fresh air is constantly pumped down hole. AR however requires high up-hole velocity to remove the cuttings. This can be impacted by things such as the hole diameter and the diameter of the drill rod. If the hole diameter is too large and the rod too small the air velocity may not be sufficient to lift cuttings without a larger compressor. Air rotary can also inject oxygenated air into surrounding formations which can cause problems if there is arsenic in the formation. Air rotary requires a source of water sufficient to complete the drilling as the water is not reclaimed and sent back downhole. However, air rotary will not be affected by the groundwater quality.

Air and foam (described below) may only be used in Wisconsin to construct a drillhole when drilling in bedrock, with one exception. If bedrock is encountered at shallow depth and the unconsolidated material above the bedrock is clay or a similar material that will stand open, air and foam may also be used in this material above the bedrock.

5.2.3 Cable-tool (percussion) advantages and drilling steps

Cable-tool rigs are generally older, smaller and less expensive drilling machines. The drilling rigs are smaller and can access sites otherwise too difficult to bring a larger rotary rig into. This can be a particular advantage when meeting separation distances is tricky. Cable tool has a reputation for drilling through soft sandstone without causing the formation to cave. The cable-tool method is in some ways more complicated than the rotary method because it involves a three-part process.

5.2.4 Step 1: Power chisel

The first step of the process involves constructing the drillhole with a chisel-type percussion bit.
Using the cable-tool machine, the method is similar to a power chisel. The long, blunt chisel-type bit is attached to a long string of tools and is dropped from a cable lifted high on a derrick (the cable/pulley mechanism is sometimes called the bull line). The bit and stem are repeatedly lifted and dropped into the drillhole to chop up the soil and rock material. In addition, with each stroke the bit rotates a quarter turn. This helps ensure that a straight, round hole is constructed. The drill stem may have an interlocking jars mechanism to allow the stem to slide by itself thus preventing damage.

5.2.5 Step 2: Bailer

In the second step of the process, the drill cuttings must then be removed from the drillhole. This is done in a manner much like dropping an old oaken bucket down a dug well. However, rather than using a bucket, a bailer connected to a cable on a separate pulley system on the derrick is dropped into the hole to pick up the cuttings. (This cable/pulley system is called the sand line or, sometimes, the calf line). A bailer is a long, hollow tube with a dart check valve installed at the bottom.

As the bailer is dropped to the bottom of the hole, the dart at the bottom of the check valve opens up and allows the water and drill cuttings slurry to rush into the bailer. As the bailer is pulled up out of the drillhole, the dart falls, closing the check valve, thus preventing the slurry from dropping back out the bottom of the bailer. The bailer is then lifted up onto the derrick and dropped off to the side. The dart hits the ground or the bottom of a bucket, the check valve opens, and the slurry is dumped onto the ground.

5.2.6 Step 3: Pile driver

The third step of the cable-tool process involves the setting of the well casing pipe. After the drillhole has been constructed 10 to 20 feet into the ground and the cuttings have been removed with the bailer, a string of casing pipe is fitted with a collar-like device *called a drive shoe made of case-hardened steel. It is welded or threaded onto the bottom to assist in the driving of the casing and to prevent the casing from being damaged in the process. The casing is then inserted into the drillhole and driven below it with drive clamps to a depth necessary to obtain water and to line off the vertical zone of contamination. The drive clamps are bolted onto the top of the drill stem. Lengths of pipe can be either welded together or threaded with couplings. In this third part of the process, the cable-tool drilling machine operates much like a pile driver.*

This three-part cable-tool process is repeated until the well is deep enough to provide an acceptable quantity and quality of water in an unconsolidated formation or until bedrock is encountered. For unconsolidated formation wells, NR 812 requires a minimum casing depth setting of 25 feet or 10 feet below the static water level, whichever is greater. If bedrock is encountered at a shallow depth, an upper-enlarged drillhole must be constructed to at least the 40-foot depth (at least the 30-foot depth for sandstone) and the casing must be sealed in place with neat cement grout. If bedrock is encountered below these depths, the casing is driven to a firm seat in the top of the bedrock and a cement grout seal is not required. If limestone or dolomite is encountered above the 10-foot depth, the upper-enlarged drillhole and cement grout must extend to at least the 60-foot depth. In any case an open drillhole is then constructed into the bedrock formation below the bottom of the casing using the chisel-type cable-tool bit.

5.2.7 Casing hammer (combination rotary-percussion) method

The casing hammer method uses a combination of rotary and percussion methods that allows the driller to construct the drillhole and drive the casing in the same process. casing hammer is an accessory that is mounted on the derrick of a standard rotary-type drilling rig. Rotary bits are inserted inside to drill below the casing and the casing is also driven, so the process is both a rotary and percussion method. The drill cuttings are removed with compressed air during the drilling and driving, so the process is very fast and efficient.

5.2.8 Dual rotary

"Dual-Rotary" is similar to the casing hammer, but instead of the casing being driven, it is advanced into the earth by turning it with a second rotary drive unit mounted on the rig derrick. A standard rotary top head unit turns the drill stem and bit inside and below the bottom of the casing pipe in the same manner as a casing hammer rig. However, the second rotary drive unit-mounted on the derrick below the top head unit-grips onto the casing with powerful jaws and turns it into the ground. Pipe sizes up to 24 inches in diameter can be easily handled. A ring, having tungsten-carbide buttons imbedded into it, is welded onto the bottom of the casing to act as the casing bit. Both the top head unit and the lower casing unit are independently raised and lowered on the derrick by hydraulic cylinders. These units do not use chains, sprockets, cables, belts or clutches as do other rotary rigs, so maintenance problems are fewer.

As with the casing hammer system, a very large air compressor provides air to blow the drill cuttings up between the casing and the drill stem. The top head unit can also be *hydraulically tilted to make it easier, more efficient and safer to handle drill rod and casing pipe. This drill system works especially well in drilling through overburden composed of large gravel, cobbles and boulders. The biggest disadvantage of these rigs is that they are very large and very expensive.*

5.2.9 Screen installation

For unconsolidated formation wells terminating in sand and gravel formations, the well casing pipe is normally either set in a mud-filled upper-enlarged drillhole constructed with rotary methods or is driven with cable-tool methods to at least a depth where the aquifer will produce the desired amount of water. Once this depth has been reached, the well can be developed in a gravel formation through the open bottom of the casing; or if the formation is sand, a well screen can be installed at the bottom of the casing and sealed with a collar-like fitting called a K-Packer between the top of the screen and the inside bottom of the casing pipe.

The screen is installed to hold open the water-producing sand formation and to prevent the well from pumping sand. NR 812 requires a continuous-slot screen, usually made of stainless-steel or thermoplastic (PVC). Continuous-slot screens are quite expensive because they are engineered and manufactured with sophisticated technology to very exacting standards. They are made this way so that a maximum amount of open area is provided to allow as much water as possible to flow with ease into the well and thus produce an efficient well; and to prevent the screen from becoming plugged.

A screen can be set with the telescoping (pull-back) method or with the bail-down, wash-down, or jet-down methods. With the telescoping method the screen is set to the bottom of the casing. A K-packer forms a tight seal between the top of the screen and the well casing. The casing is then pulled back to expose the screen. In the bail-down, wash-down and jet-down techniques the screen is installed below the bottom of the casing pipe by constructing a drillhole below the bottom of the casing. The bail-down method involves removing formation material below the casing and the screen and bailing it out of the well, thus allowing the screen to settle into place. The wash-down and jet-down methods remove aquifer material with a high-pressure jet of water and allow the screen to settle down into place below the casing. A rubber-like neoprene K-Packer collar is placed around the top of the screen to provide a seal between the top of the screen and the bottom of the casing pipe to prevent sand from entering the well.

5.2.10 Well development

Well development is the process of removing the fine sediment particles and drilling mud residue from the aquifer formation surrounding the screen or the bottom of the casing.

All well drilling methods damage the aquifer formation thus reducing its ability to transmit water towards the well. Rotary mud-circulation methods usually plug the formation with drilling mud. In the process of driving the casing, percussion methods usually compact the formation and clog it up.

When done properly, well development will reassemble the formation particles closely surrounding the well so they become graded from larger to smaller sizes in a direction moving away from the screen. This creates a natural filter surrounding the screen and allows water to flow towards and into the screen with greater ease. Further, it prevents sand from entering the screen. Sand can be a nuisance and will usually reduce the life of the pump. Regrading of the formation particles also helps maximize the yield of water from the well and makes both the well and the pump more efficient, thus reducing both the amount of energy used and the cost to operate the pump.

5.2.11 Overpumping

There are several methods used for well development. The easiest method is to simply pump the well at a rate significantly higher than the rate of the pump to be permanently installed in the well. This is referred to as overpumping. Overpumping has limitations because it only causes water to move in one direction through the screen. This allows fine sediment to bridge and get trapped just outside the screen.

5.2.12 Surging

The most effective development methods force water both in and out of the screen-and the surrounding formation-at high velocity. Movement of water in and out keeps the formation sediment moving and allows the fine particles to find their way into the well where they can be removed. This is called surging. The easiest way to surge the well is to alternately pump the well and allow the pumped water to fall back into the well. This can be done with a submersible test pump or by airlift pumping. Air-lift pumping is done by injecting compressed air from the drilling rig compressor down a small diameter tube inserted down to the bottom of the well.

Surging with a surge block is an even more effective technique. This is accomplished by inserting a piston-like surge block into the well and moving it up and down within the casing like a plunger to move water in and out of the screen with force. This can also be done by raising and lowering a bailer in the well using a cable-tool machine, but this is not as effective.

5.2.13 Jetting

Perhaps the most effective method of development is jetting. A jetting tool is placed down inside the screen and high velocity streams of water are injected horizontally out this tool, through the screen, and into the surrounding formation. The jetting tool is rotated and moved up and down within the screen in order to get more complete agitation and rearrangement of the formation particles outside the screen. Jetting is most effective if it is done simultaneously with air-lift pumping. This is because the fine sediment that enters the screen is immediately removed up and out of the well and therefore cannot be forced back out the screen into the formation or fall to the bottom of the well.

Care must be taken when using development methods, especially surging and jetting. If they are done too vigorously at the beginning of the process when the formation is still quite plugged, significant differential forces can be applied on the screen. The development process must be started slowly and gently and then increased in intensity very gradually. If care is not taken, the screen can be damaged or can even collapse.

5.2.14 Blasting

Other development methods are used to try to increase the yield of water from low-producing crystalline bedrock wells such as the "granite" wells in northern Wisconsin. For many years the most common technique used was blasting. Dynamite was placed down into the open bedrock drillhole, the well was filled with water and/or sand, and the dynamite was detonated. Blasting should never be used on screened wells. This method had mixed results.

5.2.15 Acidification

Acidification is used primarily in granite and Limestone/Dolomite formations, it will dissolve precipitated calcite to open the fractures.

5.2.16 Hydrofracturing

Hydrofracturing is typically used in crystalline bedrock type aquifers such as granite to try to increase the yield of water from a well. It is also sometimes used in sedimentary bedrock aquifers like sandstone and limestone, but much less frequently. This technique can greatly increase the yield of crystalline bedrock wells that originally produced very low yields. It not only increases the size of the cracks and crevices in the aquifer but may also cause these fractures to be cleaned out and to become interconnected, thus allowing greater quantities of water to flow towards the well.

This technique involves the use of a cylindrical inflatable packer. The packer is inserted into the well to a specified depth in the open bedrock drillhole. The packer is then inflated with nitrogen gas to plug off the inside of the drillhole. A small diameter pipe extends down through the middle of the packer. Water under very high pressure--sometimes as high as 5,000 psi-is injected through the pipe into the open bedrock drillhole. This opens up, cleans out and creates fractures within the formation surrounding the well. Sometimes small amounts of sand or other inert material are injected along with the water to hold the cracks and crevices open after the pressure has been released. This technique has had great success in Wisconsin and in some of the Rocky Mountain states where low producing crystalline bedrocks are the only available aquifers.

Section 5.3 – Flowing wells and jetted well construction

5.3.1 Flowing wells

Flowing wells are wells that are constructed in areas that have an aquifer under a positive head. These are sometimes referred to as "artesian" wells. If uncontrolled, the water can flow unrestricted from the aquifer. It is important that the well be constructed in order to keep the flow inside the well casing and prevent the flow from following the casing up the annular space, or otherwise finding a way to reach the surface outside the casing. If the well is under so much pressure that the flow from the well cannot be contained by a properly capped well, the well must have proper drainage of the well overflow to prevent undesired environmental issues, such as erosion. These wells require extra care in planning and construction and have specific code requirements for proper construction.

To address the unique issues around constructing flowing wells, techniques such as using an upper enlarged drillhole rather than driving casing, double casing the well and using heavier neat cement grout may be used.

5.3.2 Jetting methods

Jetting is normally done for small diameter (usually 2-inch) wells, this method uses water under high pressure forced down at high velocity through a hollow tube out the bottom of a bit. The water breaks up the formation and washes the cuttings up to the ground surface. The bit is raised and lowered periodically, and the drill stem rotated so that a straight, round drillhole is constructed. As with rotary-mud drilling, the water used for jetting is circulated in a continuous system. When the water and drill cuttings reach the surface, they are allowed to flow into a pit or tank where the cuttings fall out and the water is recirculated.

Jetting too vigorously at the start can cause air/water to come up alongside the outside of the casing and compromise the annular space seal.

After the drillhole is extended to a given depth, the drill stem is removed. A string of casing pipe-installed with a drive-shoe on the bottom-is then inserted into the hole and driven in a manner similar to the cable-tool method into the formation.

Section 5.4 - Special well casing depth areas

5.4.1 Special well casing depth areas described

For most areas of Wisconsin, the well casing pipe depth setting requirements described in ch. NR 812 are adequate to obtain uncontaminated groundwater and to prevent contamination of the aquifer. However, there are areas throughout Wisconsin where groundwater has been contaminated to significantly greater depths either from anthropogenic sources or naturally occurring contaminants like arsenic or manganese. In these areas, the standard required depths of casing do not extend deep enough to get below the vertical zone of contamination to prevent wells from becoming contaminated. As a result, a greater depth of casing setting is required.

For example, in Door County in the northeastern part of the State, the entire county rests on a Silurian (Niagara) Dolomite escarpment (i.e., A high cliff plus it's gradual backslope). The dolomite is highly fractured and creviced and lies at a shallow depth below very thin soil. As a result, it is very prone to groundwater contamination. In the early 1970's the entire county was designated as a special casing pipe depth area.

Section 5.5 - Types of drilling fluids

5.5.1 Water

Cuttings transport and removal is the primary function of drilling fluids. Water is the most commonly used drilling fluid during construction of water wells. Additives in the water to help improve its performance. The most commonly used additive is sodium bentonite. The geology and drilling method usually dictate the additives used in well construction. Fluids are designed for hole cleaning and drillhole stability, and to minimize damage to the formation.

5.5.2 Sodium bentonite slurry

Sodium bentonite is a clay mineral formed naturally from chemically altered volcanic ash. It is mined mostly in South Dakota and Wyoming. Powdered bentonite is shipped in 50-pound bags. When mixed with water at the drilling site it has the ability to provide a slurry with a viscosity high enough to remove the drill cuttings, to keep the drillhole open and to lubricate the drilling bit. Yet, it has a density (weight) low enough to be easily pumpable and not create too great a hydrostatic head (pressure down the hole) to cause the hole to collapse. (* Viscosity is simply the internal resistance of a fluid to flow. For example, water has a low viscosity, molasses has a high viscosity).*

Bentonite slurry also has a rather unique property called thixotropy. Thixotropy is the characteristic of some fluids to develop a gel structure when not in motion. This gel structure tends to hold the cuttings within the drilling mud slurry when it is not being circulated. This helps prevent the cuttings from sinking to the bottom of the drillhole and reduces the chances of bits getting stuck down the hole.

The powdered drilling mud bentonite is normally mixed with water to make a slurry using a jet-venturi hopper mixing system. The mud slurry is pumped through the mixer into a mud tank or a mud pit. It is then pumped out of the mud tank using a mud pump that is usually mounted on the drilling rig. It flows through a hose up to the rotary top drive, down through the hollow drill stem, out through the tri-cone bit, up the annular space between the drillhole and the drill stem and then back into the mud pit. The mud is thus circulated in a completely continuous process. (Figure 4.) The' drill cuttings settle out of the mud into the pit and are then removed from the pit by shoveling them out or by other mechanical means.

5.5.3 Drilling foam

For very deep, large diameter drillholes it is often necessary to add drilling foam to the air system to help lift the cuttings up to the surface and keep the drillhole from eroding when circulating high volumes of air under high pressure. Drilling foam is a specifically designed anionic surfactant, which is simply a fancy term for a liquid soap. Surfactants *are used as an ingredient in many shampoos and dishwashing detergents. Only approved foam products may be used for drilling in Wisconsin.*

5.5.4 Other additives

Some important additives to consider:
1. PAC polymers are essential to use in unconsolidated formations such as sand, gravel or cobble.
2. Clay and shale inhibitors are important additives when encountering swelling clays.
3. Drilling detergents work well to make fluid "wetter," and to help prevent bit balling and sticky conditions.
4. Gel-strength enhancers are available for adding to fluids when cuttings are hard to lift out of the drillhole.

Section 5.6 - Product selection relative to soil type

5.6.1 Considerations for drilling fluid and additive selection

Water by itself is unlikely to perform as well as bentonite drilling slurry, bentonite/polymer fluid or even drill foam in air-drilling operations, especially in unconsolidated formations. The water by itself also can wash out the drillhole, making it larger than desired. The water is going to mix with whatever soil is downhole and become a type of "drilling mud." There are several questions to be asked when deciding what should be used for any particular drilling application.

The water first should be checked for the pH level. Bentonite, polymers and foams work well in a pH range of 8.5 to 9.5. Many water sources range from 5.5 to 7.5. This is too low for good drill fluid mixing and proper yield. Soda ash can be added to the water at rates of 1⁄4 pound to 1⁄2 pound per 100 gallons to raise the pH and precipitate out any calcium that would be causing hard water. Make-up water for drill fluid is much like water we use to shampoo our hair. If the water is too hard, it will take more product, and the yield of the product will be considerably less. Treating make-up water is essential to good, efficient drilling fluid.

https://www.nationaldriller.com/articles/88664-drilling-fluids-designing-a-drilling-fluid-for-successful-well-completions

Section 5.7 - Make-up water requirements

5.7.1 Make-up water description and requirements

Make-up water (also called drilling water) is water added to bentonite mud to dilute the slurry to the proper viscosity. NR 812 requires that all water used for mixing grouting or sealing material is clear water from an uncontaminated source and must be disinfected with chlorine (see NR 812.10(14) and (15)). It is also important and often overlooked for make-up water to have the proper pH prior to mixing with drilling mud. Most drilling muds perform best with the make-up water pH between 8.5 and 9.5, while most source water *has a pH around 7. Soda ash is an important product to have on site to inexpensively increase the pH of the make-up water.*

Section 5.8 – Reporting requirements

5.8.1 Well construction reporting

A well construction report (Form 3300-077A) must be submitted to both the department and the well owner within 30 days of any of the following activities:

- *Well construction*
- *Well reconstruction*
- *Constructing or replacing a driven point well*
- *Construction of a dry drillhole or unsuccessful well if not immediately filled and sealed*
- *Replacing a screen if set more than 5 feet above or below the depth of the original screen*
- *Replacing the screen of a driven point well, regardless of depth.*

Starting January 1, 2023, all Well Construction Reports must be submitted to the department electronically.

If a Well Construction Report is returned for correction by the department, it must be corrected and re-submitted within 15 days.

5.8.2 Well filling and sealing reporting

A well and drillhole filling and sealing report must be submitted to the department within 30 days after filling and sealing the well or drillhole. This report must be submitted electronically.

5.8.3 Sampling reporting

Well drillers and well constructors must submit samples to laboratories that are certified under chs. ATCP 77 and NR 149 for the following contaminants and activities:

- *Coliform bacteria only – pump installing in a new well (if the pump installer is different than the well driller), replacing a pump or pressure tank on an existing system when no entry into the well is required, pump installing activities involving entry into the well when arsenic and nitrate samples have been collected within the last 6 months by the same pump installer, entering the well to diagnose a well feature or problem, property transfer well inspections (nonpotable only), or after corrective action for a bacteria-positive test.*
- *Coliform bacteria and nitrate – Initial well construction, reconstruction, redevelopment or physical conditioning.*
- *Coliform bacteria, nitrate and arsenic – entering the well to perform pump installation activities, chemical conditioning and property transfer well inspection (potable wells only)*

Forms 3300-077 for first water quality test and 3300-265 Water Quality - Pump Work test are the forms used.

5.8.4 Well compliance inspection report

A well compliance inspection report (Form 3300-305) must be submitted to the well owner whenever a well or system is inspected prior to any construction, reconstruction, *or equipment installation on a system with any noncomplying features that are apparent or known, within 10 days of the evaluation. In addition, the form must be completed and provided to the well owner prior to adding treatment and when required to measure casing depth.*

5.8.5 Property transfer well inspection report

Form 3300-221 must be used by the inspector to report the results to the person who requested the inspection. The form lists all potential noncomplying features that an inspector is responsible for checking. The inspection form is provided to the person requesting the inspection. The form is not submitted to the department and use of the form does not imply department approval of the well and pressure system.

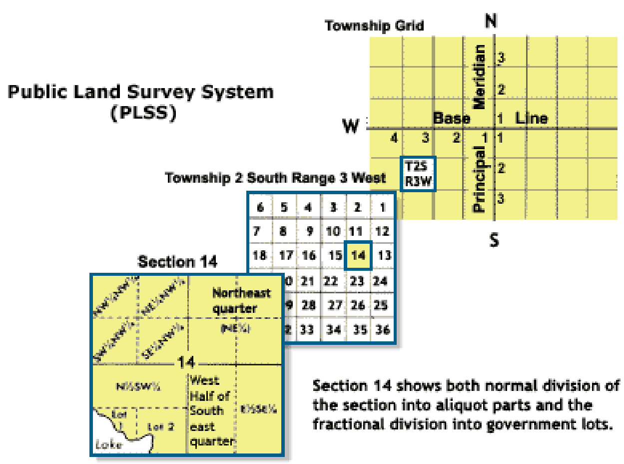
Section 5.9 – Locating a well using the Public Land Survey System

5.9.1 Description of the PLSS

Department forms require the Public Land Survey System (PLSS) location of a well to be reported. When Wisconsin was first surveyed, it was divided into a grid of boxes that are each 36 square miles. This grid system is known as the Public Land Survey System (PLSS). The PLSS is one standardized method that can be used to describe a well location. An example of a legal description using the PLSS is given below.

NE 1/4 NE 1/4, S14, T2S, R3W

The descriptions are generally read from front to back. For example, the description above would be read "The northeast quarter of the northeast quarter of section 14, township 2 south, range 3 west." Refer to the figure below for the derivation of the naming. Note that all townships in Wisconsin are N (north).



TOWNSHIPS OF THE PUBLIC LAND SURVEY SYSTEM. SOURCE: NATIONAL ATLAS OF THE UNITED STATES.

For a more detailed explanation of using the PLSS, refer to [a department Tutorial on Public Land Survey System Description](#).

Section 5.10 - Locating a well using Global Positioning System and the Well Driller Viewer

5.10.1 Description of using GPS to report a well location

Department forms also require the latitude and longitude coordinates of a well to be reported. Determining the latitude and longitude requires information from devices that locate using the Global Positioning System (GPS). Devices that can be used to gather GPS coordinates include commercial GPS units, Internet search engines, smart phones or department map viewers such as DNR's Well Driller Viewer. The department requires GPS coordinates to be reported in "decimal degrees" format rounded to four digits after the decimal point. Be sure your device is set to record in decimal degrees.

An example of correct reporting of GPS data is Latitude 43.4526 and Longitude 89.3805. In Wisconsin, correct GPS coordinates will have a latitude number between 42 and 47 degrees with a longitude value between 86 and 93 degrees. Any numbers outside of that range are incorrect. The longitude number is technically a negative value, but reporting exists as positive or negative in practice. For more detail, refer to a department web page on Accurately locating wells and drillholes for applications and reports.

5.10.2 Well Driller Viewer

The well driller viewer was created by the DNR to help contractors. There are tools in the viewer to plot GPS coordinates, measure distances, draw shapes, locate DNR landfill buffers, locate contaminated properties, special well casing depth areas, etc. Another key feature of the well driller viewer is the ability to view surrounding well construction reports to determine geology. The department recommends that any contractor planning a well or heat exchange drillhole to review the area on the driller viewer for potential sources of contamination or special casing depth area requirements. The department also suggests verifying PLSS and GPS coordinates to ensure the reported location is accurate on the well construction report. The link to the well driller viewer is found here: https://dnrmaps.wi.gov/H5/?viewer=Well_Driller_Viewer

Section 5.11 – Disinfection

5.11.1 Disinfection

New wells and wells that produce bacteriologically unsafe water should be disinfected. Disinfection is usually performed using a chlorine solution to kill any bacteria in the well and system. Mechanical methods may also be required to ensure the well is adequately disinfected.

For severe bacterial infestations perhaps involving a biofilm, like an iron or sulfate reducing bacterial slime, more aggressive approaches may be necessary. These approaches include a more concentrated chlorine solution, measures to control the pH of the solution, or the addition of salt (NaCl) or other department approved products. Sometimes it is also necessary to revert to physical rehabilitation methods such as scrubbing the inside of the well with a brush or using a surge block to help remove slime or mineral buildup that can harbor the bacteria.

5.11.2 Bleach concentration and controlling pH of disinfection solutions

Another factor that may be contributing to persistent bacteria positive water test results when attempting to disinfect a water system is the pH of the solution. Additional details about this subject are available in a department document. Chlorine solutions like bleach are basic (higher pH than 7). The effectiveness of bleach to disinfect a well or water system is highly influenced by the pH of the disinfectant solution. Even when very high bleach concentrations are used, their effectiveness to kill bacteria is limited by the pH of the solution. Disinfectant solutions with higher bleach concentrations will have higher pH values.

The best pH to strive for is a value of about 7 (Neutral). There are many inexpensive meters or test papers that can be used in the field to monitor the pH of disinfection solutions. Simple acids like vinegar or phosphoric acid can be used to lower the pH of a disinfection solution when it becomes too high. Introducing the acid solution will lower the pH of disinfection solutions that have pH numbers that are too high (above 8).

Section 5.12 – Water sampling

5.12.1 Removing Residual Chlorine

Water samples collected and sent to a laboratory for bacteria analysis must be free of any residual chlorine remaining from the disinfection process. All drinking water samples are screened for the presence of chlorine upon arrival at the laboratory and will be rejected if residual chlorine is detected. Proper system flushing for a sufficient time is essential when purging the disinfectant solution from a water supply system. If your sense of smell can detect any odor of chlorine in the water you intend to sample or the water sample tests positive with a chlorine test strip, the well system should be purged for a longer time before collecting a sample for bacteria analysis.

5.12.2 Arsenic and Metals Sampling

A water sample collected for arsenic analysis can produce high arsenic test results that do not reflect the groundwater levels of arsenic, depending on how the water sample is collected. Particulate matter included in a water sample collected for arsenic analysis can increase the arsenic test results. Two causes of particulate matter are; 1) disturbing the water sampling tap when sampling and 2) not purging the water system enough or not allowing sufficient time to pass following the disinfection and purging before collecting a sample.

Well water that is oxygenated through the disinfection process, high rate of purging at, or disturbance of, the sample faucet or from recent well drilling activities may also produce a higher arsenic sample result. Avoid over chlorinating and allow the well water to stabilize for several days to a week or more may result in a lower arsenic result than a sample that is collected immediately following drilling or disinfection.

In addition, Wisconsin has sulfide deposits in certain bedrock formations that have been economically important in the past. Although it is uncommon, these mineralized zones can inadvertently be drilled into for the construction of drinking water wells. When these deposits become oxidized from well installation or well use, arsenic and other potentially harmful metals can be introduced to groundwater at levels that exceed Federal drinking *water health standards. Water supply specialists at the department can help determine what formation a well is constructed in. This metals screening analysis is available from many certified laboratories.*

Section 5.13 – Why filling and sealing is important

5.13.1 Why filling and sealing is important

Wells and drillholes require filling and sealing for a number of reasons. Wells that cannot be adequately decontaminated, cannot be brought into regulatory compliance, or have been unused for a long period of time all need to be filled and sealed. Among the issues filling and sealing addresses are:

- *The well is a vertical conduit that can allow shallow contaminants to migrate into a deeper aquifer.*
- *Surface drainage, vermin and debris could gain direct access to an unsealed well and contaminate groundwater.*
- *It can be a physical safety hazard (e.g., small animals or children could fall into it).*

5.13.2 Stuck pump removal

NR 812.26(5)(b) discusses the removal of obstructions prior to filling and sealing. When a pump is stuck in a well the code states "a reasonable attempt shall be made using the best available technology to pull it out." As a recommendation, this can be interpreted as using a hydraulic jack, winch or other mechanical device to attempt to free the stuck pump. This applies to pumps that have some practicable way to attach a wire cable, chain or other pulling attachment.

5.13.3 Calculating bentonite chip volume

Calculating the volume of material required to fill and seal a well or drillhole is important because it can identify when bridging, a downhole obstruction or some other unknown condition is present that may need to be addressed. A table like the one below can be used to estimate the number of bags of bentonite chips that are required to fill and seal a well or drillhole. For example, to calculate the number of bags of chips required to fill a 6-inch diameter well that is 150 feet deep, run down the first column on the left until the 6-inch diameter hole is located, then run across the row to the right until the column for the number of feet filled by one bag is found. This number (3.5) is the number feet filled by one bag. Dividing 150 feet by this number results in 150/3.5= ~ 43 bags.

Number of 50 lb. Bags of Bentonite Chips to Fill a Well

Hole Dia (Inches)	Hole Volume (Ft3/Ft)	Pounds of Bentonite Chips to Fill 1 Ft	Feet Filled by One Bag of Bentonite Chips	Bags of Bentonite Chips to Fill 100 Ft
4	0.087	6.3	7.9	12.6
4 1/2	0.11	7.9	6.3	15.8
5	0.136	9.8	5.1	19.6
5 1/2	0.165	11.9	4.2	23.8
6	0.196	14.1	3.5	28.2
6 1/2	0.23	16.6	3	33.2
7	0.267	19.2	2.6	38.4
7 1/2	0.307	22.1	2.3	44.2
8	0.349	25.1	2	50.2
8 1/2	0.394	28.4	1.8	56.8
9	0.442	31.8	1.6	63.6
9 1/2	0.492	35.4	1.4	70.8
10	0.545	39.2	1.3	78.4
11	0.66	47.5	1.1	95
12	0.785	56.5	0.89	113
15	1.227	88.3	0.57	176.6
18	1.767	127.2	0.39	254.4
20	2.182	157.1	0.32	314.2
25	3.409	245.4	0.2	490.8
30	4.909	353.4	0.14	706.8

Chapter 6 – Grouting

Section 6.1 - Annular sealing - protection from surface contamination

6.1.1 *Grout Uses and Characteristics*

Grout has many uses, but the most important is that it seals the annular space between the casing and the upper enlarged drillhole. The most important characteristic of grout is that it is less permeable than the surrounding geologic formation. This characteristic prevents contaminants form migrating vertically into the drillhole, as well as preventing water from different aquifers from co-mingling.

Section 6.2 - Annular space and importance of straight and in gage drillhole

6.2.1 Straight and In Gage Drillhole

It is important for a drillhole to be straight and in gage. Additionally, the casing pipe should be as centered within the drillhole as possible. If the drillhole isn't straight, the casing can hug the drillhole wall which will result in a poor annular seal in water wells. In water wells, a drillhole that isn't straight can also result in issues installing the pump.

Section 6.3 - Sealant materials and properties

6.3.1 Types of Sealant Materials

Many different types of grouts are approved for use in Wisconsin depending on drillhole type, geology, drillhole depth, etc. Below are the main types of grout used for well drilling in Wisconsin.

1. Bentonite Based Grouts- Bentonite based grouts are manufactured using a naturally occurring clay material called sodium bentonite. There are several types and brands of bentonite grouts, but they all share the same general characteristics. They offer a low permeability with no heat of hydration. Bentonite based grouts are also not ideal in aquifers with high hardness or high chloride concentrations as these attributes can reduce the bentonite's ability to swell. https://www.nationaldriller.com/articles/87744-an-overview-of-geothermal-grouts

2. Bentonite/Sand mixed Grouts (Two Step Grout)- Bentonite and sand mixed grouts are commonly used in heat exchange drillholes. They provide the benefit of a low permeability seal with the bentonite and a higher K value because of the silica sand. In Wisconsin, the driller is allowed to mix sand and bentonite at a ratio of 5 to 1 clean silica sand to bentonite grout. The silica sand must consist of silica sand with 80 percent or more of the sand smaller than 0.0117 inch (US Sieve #50) in size. The correct size of the sand and the correct amount of water is critical to ensure the bentonite can properly suspend the sand to avoid issues with sand settling. https://www.nationaldriller.com/articles/87744-an-overview-of-geothermal-grouts

3. Neat Cement Grout- Neat cement grout is non-reactive and is the best grout to use in areas where bentonite may be affected by water chemistry (high chloride, high hardness areas). It is also a good tool to use when trying to grout drillholes on flowing wells, due to the heavier weight. There are a few disadvantages to using neat cement grout. Neat cement has a relatively low thermal conductivity in comparison to thermally enhanced grouts. The other disadvantages are lack of filtration control and heat of hydration. With lack of filter control, the neat cement grout can dehydrate, which can affect the bonding *between the loop or casing. It can also dehydrate in porous formations, which requires the annular space to be "topped off". Heat of hydration can have several negative effects, due to expansion of the grout and contraction of the loop pipe, a micro annulus can form- which effects thermal conductivity and can create a vertical conduit for surface contamination of the aquifer. Additionally, enough heat of hydration can potentially deform the loop pipe. https://www.nationaldriller.com/articles/87744-an-overview-of-geothermal-grouts*

Section 6.4 - Grout placement methods

6.4.1 Tremie Pipe Method

Tremie Pipe Pumped – Drinking water wells are typically grouted with the pumped tremie pipe method. Tremie pipe used is typically 20-foot lengths of steel or black poly pipe on a hose reel. The tremie is inserted into the bottom of the annular space and the grouting material is then pumped down the tremie and up the annular space until it rises to the surface. Per NR812 Wis. Adm. Code, the tremie pipe must remain submerged in grout.

6.4.2 The Bradenhead Method

The Bradenhead method of grouting is exclusive to water wells. It utilizes a bradenhead with two valves welded to the top of the casing pipe. One valve is a pressure relief valve while the other allows grout and water into the tremie pipe which is installed on the inside of the casing and extends nearly all the way to the bottom of the casing. The casing is then filled with water until it comes out of the pressure relief valve. The pressure relief valve is shut, and the well driller lifts the casing off the bottom by about a foot. The driller then begins to pump the grout, which has no place to go other than up the annular space, as the water within the casing is incompressible. Once the grout flows to the surface, the casing is placed back to the bottom, and the tremie is flushed with water.

6.4.3 Grout Shoe Method

The grout shoe method is also exclusive to water wells. It utilizes a pre-made and drillable "shoe" installed at the bottom of the casing. The grout shoe contains a one-way valve in which the tremie pipe can be seated. The tremie pipe is first inserted into the valve, the casing is then lifted. Once lifted, the driller starts pumping grout until it rises to the surface from the annular space. Once complete, the casing is placed back to the bottom of the drillhole and the tremie is removed.

Chapter 7 - Calculations

Section 7.1 - General calculations

Well and heat exchange drillhole construction requires a basic understanding of math and making calculations. It is important to be able to accurately calculate the amount of product needed to create accurate bids and estimates. There are many tools available on the internet to complete these calculations, but they still require a basic understanding of the underlying calculations.

7.1.1 Grout Calculation

Volume of a cylinder

Volume = V = $\pi r^2 h$
π = pi = 3.14159
r = radius = ½ Diameter
h = height = Casing Length

Conversions

1 gal = 231 cubic inches= 0.1337 cubic feet
1 foot= 12 inches

Example 1: In gallons, calculate the volume of grout required to fill the annular space of a 500-foot-deep, 10-inch diameter drillhole with a 6-inch casing. Outside diameter (OD) of the casing pipe is 6.625" inches.

Step 1: *Volume of a 10-inch drillhole (remember to use the same units throughout):*

$V = \pi r^2 h$
π = pi = 3.14159
r = 10.0 inches/2 = 5 inches
h = 500 ft. = 6,000 inches

V = 3.14159 x (5 inches)^2 x 6,000 inches= 471,239 Inches^3

471,223 / 231 in^3 per gallon= 2,040 gallons.

Step 2: *Volume of 6.625-inch pipe*

$V = \pi r^2 h$
r = 6.625 / 2 = 3.3125 inches
h = 500 ft = 6,000 inches
V = 3.14159 x (3.3125 inches)^2 x 6,000inches = 206,830 Inches^3 / 231 in^3 per gallon= 895 gallons.

Step 3: *Annular volume*

10-inch drillhole volume – volume of 6-inch pipe = 2,040 gallons – 895 gallons = 1,145 gallons of grout needed.

Example 2: Assuming one sack of mixed cement with a slurry density of 15.2 lbs/gallon has a volume of 9.6 gallons, exactly how many sacks would be required to fill the annular space of a 10-inch upper enlarged drillhole with 6-inch casing to a depth of 200 feet. The outside diameter (OD) of 6-inch casing is 6.625".

V of drillhole = $\pi r^2 h$ = 3.14159 x (5 inches)^2 x 2,400 inches = 188,400 inches^3 / 231 in^3 per gallon= 816 gallons.

V of Casing = 3.14159 x (3 inches)^2 x 2,400 inches = 67,824 inches^3 / 231 in^3 per gallon = 294 gallons.

Volume of Annular space = 816 gallons – 294 gallons = 522 gallons

Answer: *522 gallons needed / 9.6 gallons per sack = 54.4 sacks of cement.*

Example 3: Below is a product mixing chart for a commonly used high solids bentonite. For an annular space that requires 250 gallons of grout, how many

sacks of product would be needed when 20% solids grout is required?

Recommended Treatment: Add one 50-lb sack of material to appropriate amount of make-up water to obtain the desired solids content:

% Solids Grout	15	20	23
Water, gallons	33	24	20
Water, liters	125	91	76
Yield Volume, gallons	35.3	26.3	22.3
Yield Volume, liters	133.6	99.6	84.4

Answer: 250 gallons / 26.3 gallons per sack = 9.51 *mixed sacks of grout needed*.

Wisconsin Water Well Driller License Practice Exam

1. The definition of well drilling includes activities that change the characteristics of a drilled well.
    a. True
    b. False

2. The definition of “engaging in the business of” well drilling includes which of the following:
    a. Advertising and bidding on drilling projects.
    b. The industry employed in drilling water wells.
    c. Preparing specifications and supervising a drilling project.
    d. All of the above.

3. A water well driller or pump installer license is required for which of the following:
    a. An individual performing water well drilling on property leased by that individual.
    b. An individual constructing a driven point well with pipe and casing diameter smaller than 3 inches.
    c. An individual who is employed by a licensed individual water well driller.
    d. An individual conducting a property transfer well inspection.

4. A homeowner may fill and seal a well on property he/she owns.
    a. True
    b. False

5. A water well driller or pump installer license is not required for which of the following:
    a. Well filling and sealing.
    b. Property transfer well inspections.
    c. Obtaining a water sample when not for a property transfer well inspection.
    d. All of the above.

6. Which of the following is accurate with respect to renewal of an individual water well driller license each year?
    a. The licensee must earn six continuing education hours by attending department approved continuing education sessions between January 1st and December 31st.
    b. The licensee must submit a renewal application on a form specified by the department on or before December 31st.
    c. Only one renewal fee of $25.00 is paid if the licensee holds both a heat exchange driller license and water well driller license.
    d. Both a & b are accurate.

7. A new condominium under construction is initially built with 10 units but plans to eventually expand to 25 units all served by the same well. Which is true?
    a. The well and facilities must be constructed in accordance with ch. NR 812 (well construction and pump installation) standards and no prior written approval from the department is needed.
    b. The well and facilities must be constructed in accordance with ch. NR 812 standards and prior written approval from the department is required.
    c. The well and facilities must be constructed in accordance with ch. NR 811 (community water system) standards and prior written approval from the department is required.
    d. The well and facilities must be constructed in accordance with ch. NR 811 (community water system) standards and no prior written approval from the department is needed.

8. A valve pit may contain a pressure tank.
    a. True
    b. False

9. Which of the following does not require a minimum separation distance from a well?
    a. Manure sewer
    b. Building overhang
    c. Lake shoreline
    d. Privy

10. Construction of both potable and nonpotable high capacity wells requires prior written approval from the WDNR.
    a. True
    b. False

11. A well construction report does not need to be submitted to the department when:
    a. A pump is installed
    b. A screen is replaced within 5 feet of original screen depth
    c. A liner is installed
    d. All of the above

12. A lower drillhole in bedrock may be constructed using a drill bit up to 5/16” smaller than the nominal diameter of the drillhole to be constructed.
    a. True
    b. False

13. Which of the following is a correct ending to this sentence? A well may be constructed less than 500 feet from a quarry without a variance if:
    a. An additional 10 feet of upper enlarged drillhole and casing is used over standard bedrock requirements
    b. The annulus is grouted with bentonite
    c. The quarry is no longer used and is filled with water
    d. All of the above

14. A well may be grouted with mud and cuttings if the upper enlarged drillhole is less than or equal to 30 feet in depth.
    A. True
    B. False

15. A new well terminating in sandstone must have a minimum of 30 feet of casing.
    A. True
    B. False

16. Which of the following is considered a percussion drilling method?
    A. Mud rotary drilling
    B. Dual rotary drilling
    C. Cable tool drilling
    D. Driving a driven point well

17. A well may not be disinfected with a chlorine solution that contains an algicide.
    A. True
    B. False

18. What is the most commonly used drilling fluid in Wisconsin?
    A. Bentonite slurry
    B. Mud and cuttings
    C. Water
    D. None of the above

19. Drilling foam is best used for:
    A. Constructing wells in high arsenic areas
    B. Constructing deep, large diameter drillholes
    C. Constructing wells in unconsolidated formations
    D. All of the above

20. Water used for constructing a well does not need to be obtained from an uncontaminated source so long as the well is properly disinfected after the well is constructed.
    A. True
    B. False

Practice Exam Answer Key

1. a
2. d
3. d
4. b
5. c
6. a
7. c
8. b
9. b
10. a
11. b
12. b
13. c
14. b
15. a
16. c
17. a
18. c
19. b
20. b