Wisconsin Department of Natural Resources
Drinking Water & Groundwater Program

WISCONSIN HEAT EXCHANGE DRILLER LICENSE EXAM

STUDY GUIDE

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Preface

This study guide is provided by the Wisconsin Department of Natural Resources to assist applicants in preparing for the Heat Exchange 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 and NR 812 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 heat exchange 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 heat exchange 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 and NR 812 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 80 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 Heat Exchange 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 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 heat exchange 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(2m): Exceptions to heat exchange driller license requirements

1.3.1 Exceptions to individual heat exchange driller license requirements

A license is required to engage in the business of heat exchange drilling under NR 146.03(1). NR 146.03(2m) lists the exceptions to this requirement.

Section 1.4 - NR 146.04(10): Heat exchange driller business registration requirements

1.4.1 Heat exchange driller business registration

A business registration is required for persons to engage in the business of heat exchange 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(10) intent. This section lists conditions required for heat exchange driller business registration eligibility.

1.4.2 Exceptions to heat exchange driller business registration requirements

NR 146.03(2m) provides exceptions to business registration requirements of 146.04(10). It lists the individuals who do not need a business registration in order to engage in the business of heat exchange drilling.

Section 1.5 - NR 146.04(10m): Supervisory responsibilities

1.5.1 Supervisory heat exchange driller responsibilities

Areas of responsibility carried by the supervisory heat exchange 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 146.05(1): License and registration conditions

1.6.1 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 1.7 – NR 146.07: Renewals and continuing education requirements

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

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.

1.7.2 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.

1.7.3. 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 1.8 – NR 146.08: Licensee and registrant responsibilities

1.8.1 Responsibilities

Responsibilities required of heat exchange 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 1.9 – NR 146.09: Suspension and revocation

1.9.1 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).

1.9.2 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 heat exchange drilling. The requirements listed under NR 146.09(2) must be met in order to engage in the business of heat exchange drilling.

1.9.3 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 1.10 – NR 146.12: Citations

1.10.1 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 812: Well construction and pump installation

Section 2.1 – NR 812.02: Applicability

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

2.1.1 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 2.2 – 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.

2.2.1 NR 812.03: Driller expectations to cooperate with the department

A heat exchange driller must contact the department or other government entities prior to drilling in four distinct situations explained in this section. One example is the requirement for heat exchange 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 2.3 – 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).

2.3.1 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 heat exchange drillholes conform to NR 812 and may not agree to do noncomplying work.

Section 2.4 – NR 812.07: Definitions

2.4.1 NR 812.07(1) to NR 812.07(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 2.5 – NR 812.09: Department approvals

Certain drilling activities require approvals. This section provides a framework for determining which activities require approvals and the procedures for obtaining them.

2.5.1 NR812.09(1)-(2) General approval criteria

The department shall complete any reviews for approvals within 65 business days after receipt of a complete application. All applications must be received in writing, except situations in which an immediate response is required. An application for approval must be signed by the owner of the property or by an authorized agent, such as a driller. Applications are expected to contain general information for the department to complete a review, these specific pieces of information are outlined in this section of code.

2.5.2 NR 812.09(4): Activities requiring department approvals

This portion of code explains how test drillholes can be constructed without prior department approval. In addition, heat exchange drillholes require department approval in certain situations. These situations vary and depend on the depth of drillhole(s), number of drillholes, total combined depth of all drillholes on a heat exchange project, and the distance to a municipal well. Heat exchange specific requirements can be found in 812.09(4)(x), (y), and (z).

2.5.3 NR 812.09(5) to NR 812.09(8): Application submission and approval

A 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 2.6 – NR 812.091: Product and component approvals

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.

2.6.1 812.091: General product and component approval information.

Many products or components used to construct, develop, or treat a well or drillhole require department approval. 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 2.7 – NR 812.10: Well driller and well constructor requirements

This section provides the general requirements for well drillers and heat exchange drillers for constructing wells and drillholes and reporting to owners and the department. It also addresses noncompliant and problem wells.

2.7.1 NR 812.10(1) to NR 812.10(9): Responsibilities of the heat exchange driller or well constructor prior to constructing a well or heat exchange system.

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

The heat exchange 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 or dirllhole in areas with contaminated geologic formations or groundwater.

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

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

2.7.2 NR 812.10(10) to NR 812.10(16): Responsibility of the *heat exchange* driller or well constructor to bring a noncompliant well or heat exchange drillhole into compliance or to fill and seal post-construction

The heat exchange driller must complete and submit a Well Construction Report (WCR) after construction of heat exchange drillholes. Specific instructions for filling out the WCR for heat exchange drillholes can be found in Part 2 of this study guide

Section 2.8 – NR 812.11: Well construction equipment and materials

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

2.8.1 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 drillhole or used for the construction of a drillhole by a heat exchange driller must meet certain requirements of this section and in Table B. These include drill bit, tremie pipe and mud balance.

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 2.9 – NR 812.12: General drilled type well construction requirements

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

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

Prior to constructing a drillhole, a heat exchange driller must plan the drillhole to ensure the finished drillhole is constructed appropriately for the geologic conditions and for conserving groundwater and preventing groundwater contamination.

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

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

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

General construction requirements for drillhole plumbness and alignment, upper enlarged drillholes and starter drillholes are found in this section.

Section 2.10 – NR 812.151: Heat exchange drill hole location and construction requirements

This section is an overview of the only heat exchange-specific section of NR 812. For heat exchange drillers, most heat exchange requirements can be found in this section.

2.10.1 NR 812.151(1): License requirements

This subsection covers the general licensing requirements for heat exchange driller. The driller needs to know the licensing requirements for filling and sealing a heat exchange drillhole.

2.10.2 NR 812.151(2)-(3): Approvals and notification.

This subsection points to s. NR 812.09 (4) (w) through (z), which outlines the specific situations that require an approval from the department to drill heat exchange drillholes. This section also provides the expectation to acquire a notification permit at least 24 hours in advance.

2.10.3 NR 812.151(4): Location

This subsection explains required separation distances to contamination sources. An approval is required when a heat exchange project is sited within a certain distance of a municipal water supply well.

2.10.4 NR 812.151(5): Temporary casing

Temporary casing is often needed when constructing heat exchange systems. This section of code references s. NR 812.11(6) and (7) that are used to find specific material requirements for steel and thermoplastic casing pipe including wall thickness and weight.

2.10.5 NR 812.151(6): Pressure testing

Heat exchange loop pipe must be pressure tested with either potable water or an approved fluid according to manufacturer's specifications.

2.10.6 NR 812.151(7) through (10): Drilling fluids, surface protection, and grouting

This portion of NR 812.151 relates directly to protection of the aquifer. Grouting provides protection from vertical contamination of the aquifer. This portion of the code provides *requirements for selecting proper drilling fluids and department-approved grouting materials. The methods in which the grouting materials are installed are also addressed in this section of code.*

2.10.7 NR 812.151(11): Fusion welding

Fusion welding is typically used in joining heat exchange piping. This portion of the code provides the approved fusion types and methodology.

2.10.8 NR 812.151(12): Reporting

Heat exchange drillhole construction must be reported to the department on a required form. This section of code does not provide the specific instructions, but Part 2 of the study guide will provide in depth instructions for completing reports.

2.10.9 NR 812.151(14): Filling and sealing

Unused heat exchange loops and drillholes need to be filled and sealed. This section directs the reader to NR 812.26 for specific filling and sealing requirements, materials, and methods.

Section 2.11 – NR 812.26: Filling and sealing heat exchange drillholes

This section is an overview of the requirements for filling and sealing heat exchange drillholes.

211.1 NR812.26(3): License requirements

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.

2.11.2 NR812.26(4): Well and drillhole filling and sealing

This portion of the code explains the situations in which well and drillhole filling and sealing is required. There are certain situations which require the well owner to hire a licensed individual to fill and seal a heat exchange drillhole. An example is a heat exchange drillhole which will not be used as part of a heat exchange system. This portion of code also outlines the situations in which the department may require a heat exchange drillhole to be filled and sealed and the specific responsibilities of the driller when they receive notice from the department to fill and seal a heat exchange drillhole.

2.11.3 NR812.26(5) through (7): Methods and heat exchange-specific requirements

These portions of code outline the general requirements for filling and sealing as they pertain to the materials and methodology for different well types, geologies, and situations. NR 812.26(6)h, Wis. Adm. Code covers the specific materials and methods for filling and sealing heat exchange drillholes. There are situations in which the loop pipe must be removed and situations in which the pipe must be evacuated of all fluids and filled with neat cement.

2.11.4 812.26(7): Filling and sealing form

After filling and sealing, the heat exchange driller is required to submit a filling and sealing report. 812.26(7) provides the specific requirements and time frame for filling out the filling and sealing report. All filling and sealing reports are now required to be completed online.

Part 2: General Knowledge

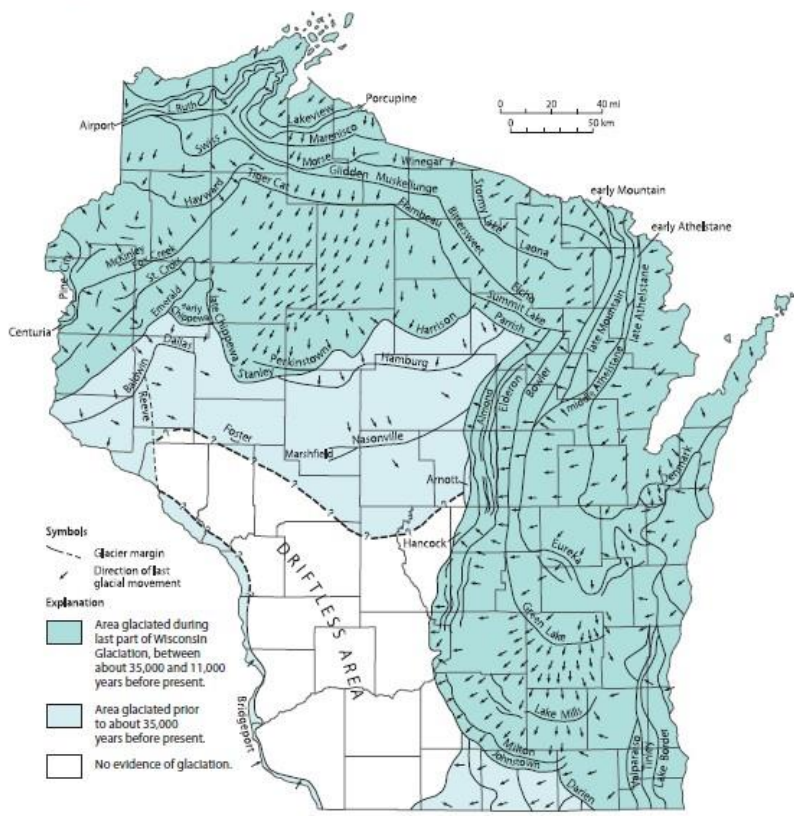
Chapter 3 – Geology of Wisconsin

Section 3.1 - Glacial geology

3.1.1 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



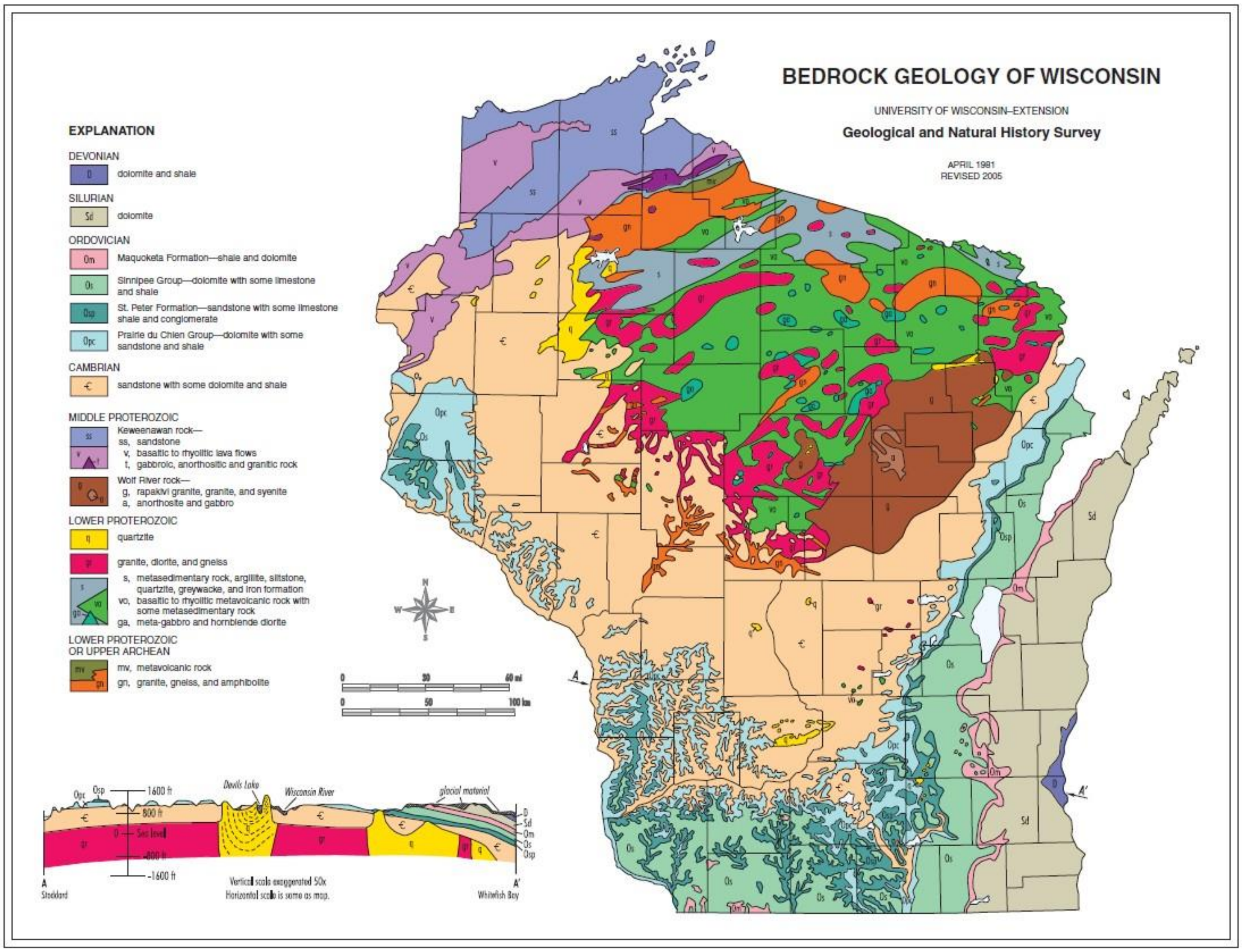
Ages of glaciation. In this map and the one on the last page, areas are distinguished by age: older or younger than about 35,000 years. Ages are determined using geochronology (radiocarbon and other dating techniques) and by studying features in the landscape. Younger glacial features are relatively 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 3.2 – Bedrock geology

3.2.1 Bedrock geology of Wisconsin:

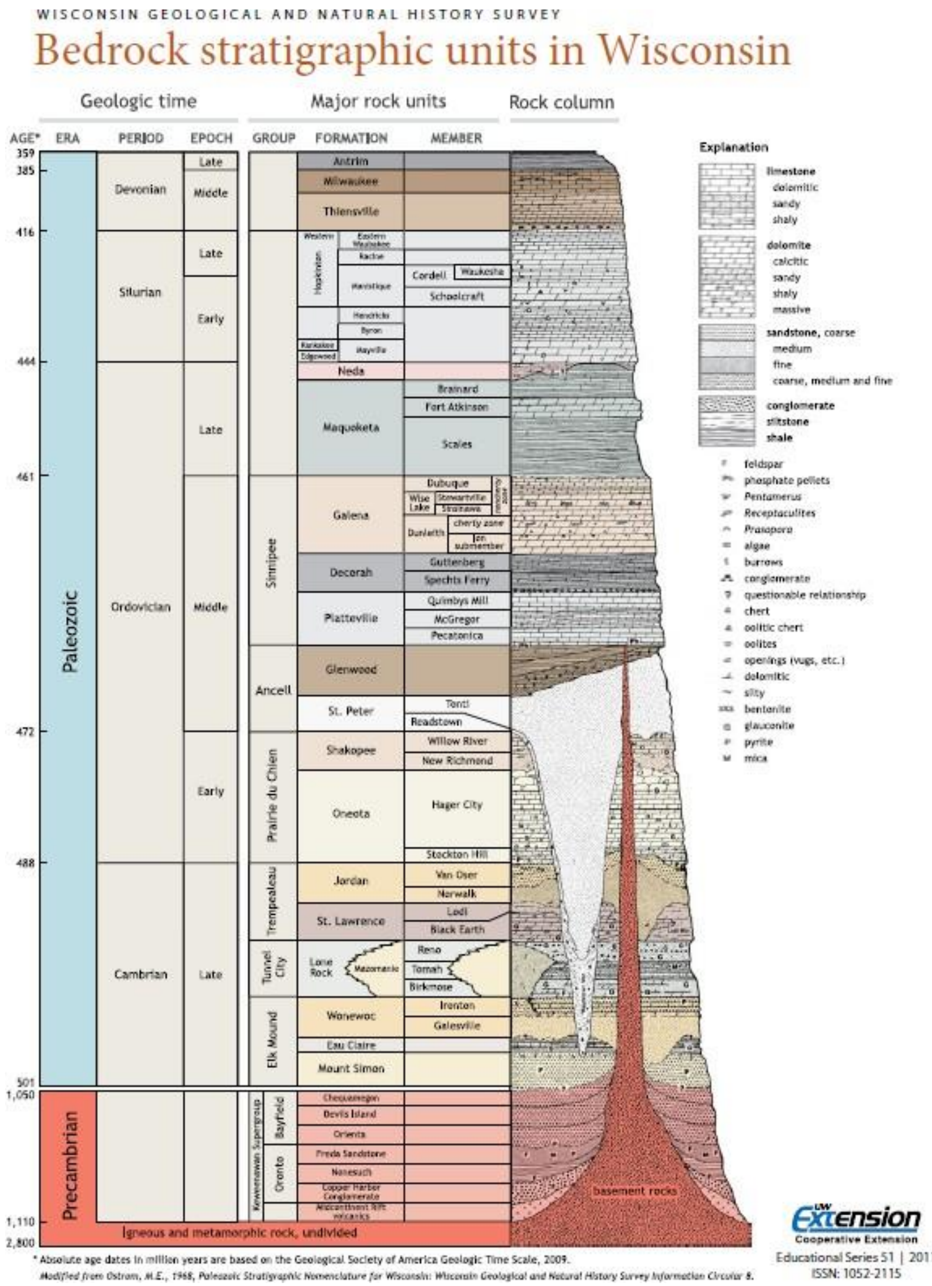
> *Wisconsin is home to relatively variable geology. This map view basically shows the surface extent of different bedrock types across the state. This map does not show glacial deposits or unconsolidated formations. Nor does it show which formations may be encountered at depth.* https://wgnhs.wisc.edu/pubs/000390/



3.2.2 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 are 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/*](https://wgnhs.wisc.edu/pubs/000200/)



3.2.3 Limestone/dolomite:

Limestone and dolomite are both 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.*

3.2.4 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.

3.2.5 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.

3.2.6 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 3.3 - Cuttings identification

3.3.1 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.

3.3.2 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 most accurate 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. A screen or strainer works well for larger drill cuttings but does not capture silt and sand grains bound up in the drill tailings.

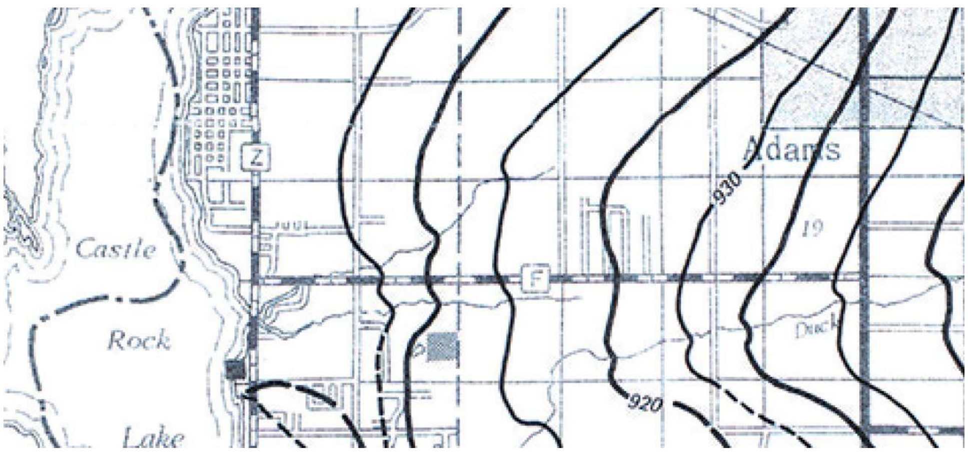
Section 3.4 - Hydrogeology

3.4.1 Groundwater flow.

Groundwater Flow is important to understand when constructing a well or drillhole near a contamination source. Groundwater typically flows from hydraulic highs (hills) to hydraulic lows (rivers or lakes). Because of this, groundwater elevation generally follows topography. It is best 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.

3.4.2 Groundwater flow map (water table elevation)

Below is a screenshot 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 4 – Heat exchange construction methods and reporting

Section 4.1 – Drilling methods

The main drilling method for constructing heat exchange drillholes in Wisconsin is the rotary method. There are several specific types of drilling within the Rotary method including: Mud Rotary, Air Rotary, Casing Hammer, and Dual Rotary.

4.1.1 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.*

4.1.2 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 drill 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 breaks the formation 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 circulated down hole. Air rotary 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.

4.1.3 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. The casing hammer method can be used to effectively set shallow temporary casing as an alternative to drilling an upper drillhole with mud rotary.

4.1.4 Dual rotary

Dual rotary is similar to the casing hammer method, 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 casing 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.

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 dual rotary method can also be used to effectively set shallow temporary casing as an alternative to drilling an upper drillhole with mud rotary.

Section 4.2 - Special well casing depth areas

4.2.1 Outagamie and Winnebago County arsenic area.

Special care must be taken when constructing heat exchange projects in Outagamie and Winnebago counties. Both counites are subject to a special well casing depth area due to arsenic issues in the Ordovician aquifer. This aquifer can contain lower pH water with a high metals count, which can break down bentonite-based grouts or not allow them to set properly. This can result in a poor annular seal which can introduce contaminants to the aquifer and inhibit the thermal properties of the grout. Neat Cement grout should be used in these areas. Any driller tasked with constructing a heat exchange drillhole in either of these counties should contact the department and obtain special approval.

Section 4.3 – Well construction reporting, drillhole location reporting, and Well Driller Viewer

4.3.1 Well construction reporting instructions

Heat exchange drillholes must be reported on a well construction report (WCR) form and submitted to the department within 30 days of completion. Instructions for filling out specific fields on the WCR's for heat exchange drillholes are included on the instructions page of the well construction report. One well construction report needs to be completed for every 20-heat exchange drillholes constructed. The reported location/GPS coordinate should be as representative as possible to show the project location. Though not required by the department, a site map with accurate measurements from buildings, property lines, roads and other property features should be given to the owner so each drillhole can be accurately located in the future.

4.3.2 Locating a well using Global Positioning System (GPS)

Many department forms require the latitude and longitude coordinates of a well or drillhole 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.

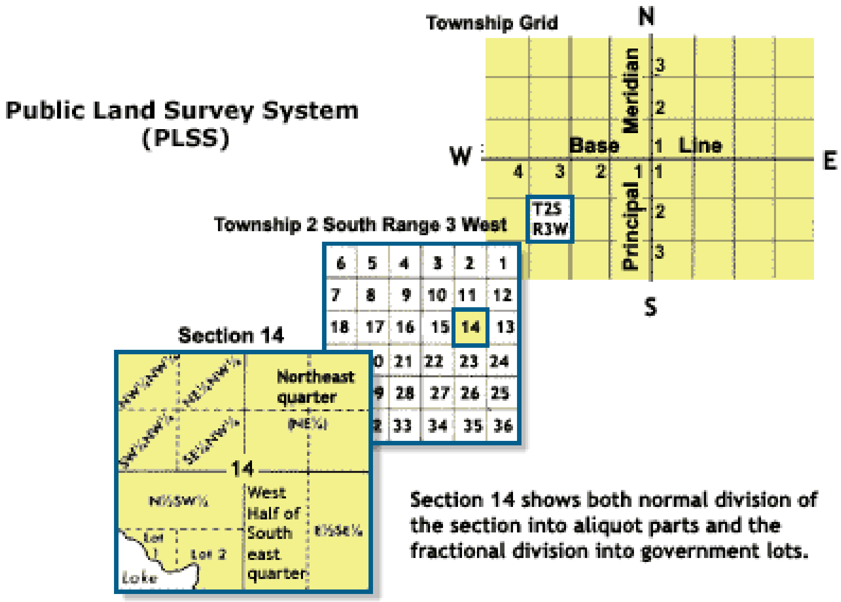
An example of correct reporting of GPS data is Latitude 43.4526 and Longitude 89.3805. In Wisconsin, correct GPS coordinates will have a latitude number between 42 and 47 degrees with a longitude value between 86 and 93 degrees. Any numbers outside of that range are incorrect. The longitude number is 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.

4.3.3 Locating a well using the Public Land Surveying System (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](#).

4.3.4 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

Chapter 5 – Drilling fluids

Section 5.1 - Types of drilling fluids

5.1.1 Water

Cuttings transport and removal is the primary function of drilling fluids. Water is the most commonly used well drilling fluid. 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.

5.1.2 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 can 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. 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.

5.1.3 Drilling foam

For 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.

Section 5.2 - Make-up water requirements

5.2.1 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. https://www.nationaldriller.com/articles/91492-whats-the-value-of-soda-ash-for-drilling-jobs

Chapter 6 – Grouting

Section 6.1 - Annular sealing - protection from surface contamination and co-mingling between aquifers.

6.1.1 Grouting uses and characteristics

Grout has many uses, but the most important is that it seals the annular space between the casing/geothermal loop 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. In heat exchange applications, the grout plays an additional role of providing thermal conductivity between the HEX pipe and the surrounding formation. Thermal conductivity (K Value) is the rate at which heat passes through a specified material. Put simply, heat exchange grouts provide both a seal and heat transfer from the loop pipe to the surrounding formation.

Section 6.2 - Annular space and importance of straight and plumb drillholes

6.2.1 Straight and plumb drillholes

It is important for a drillhole to be straight and Plumb. Additionally, the casing or loop pipe should be as centered within the drillhole as possible. If the drillhole isn't straight, the casing or loop pipe can hug the drillhole wall which will reduce thermal conductivity in geothermal holes or result in a poor annular seal in both geothermal drillholes and water wells. Additionally, out of plumb drillholes can result in difficulty lowering tremie pipe for grouting.

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 heat exchange drilling in Wisconsin. For heat exchange drilling, the desired thermal conductivity (K value) often dictates the grout type.

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. Regarding heat exchange drilling, they do not offer as good of a K value (thermal conductivity) as other grouts, but they do work well when the geologic formation has a similar or lower thermal conductivity. 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. Graphite Based Grouts- Graphite based thermal grouts are a relatively new technology. They offer the best thermal conductivity values at a similar cost to two-step grouts. Depending on the product, graphite grouts are either a stand-alone one-sack product mixed with water, or an additive mixed with high solids bentonite grouts. Graphite based grouts have the added benefit of being easy to pump. *https://www.nationaldriller.com/articles/87744-an-overview-of-geothermal-grouts*

4. 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 with artesian flow, 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

Heat exchange drillholes are typically grouted with the pumped tremie pipe method. Tremie used in heat exchange drillholes 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 NR 812, the tremie pipe must remain submerged in grout.

Section 6.5 – Flowing drillholes

6.5.1 Artesian flow from heat exchange drillholes

In areas where there is potential for artesian flow from the annular space, special care must be taken. Typical thermal grouts may not be heavy enough to stop the flow and properly seal the annular space, and in these situations, neat cement may need to be used. If neat cement is used to grout a heat exchange drillhole, potable water or approved heat exchange fluid must be continuously circulated in the loop pipe to prevent potential loop pipe deformation.

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 General heat exchange calculations

Volume of a cylinder

Volume = V = π 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, 5-inch diameter drillhole with a 1-inch Single U-bend loop in it. (Two 1-inch pipes). The outside diameter (OD) of each 1-inch pipe is 1.315 inches.

***Step 1:** Volume of a 5-inch drillhole (remember to use the same units throughout):*

V = π r^2 h
r = 5.0 inches/2 = 2.5 inches
h = 500 ft. = 6,000 inches

V = 3.14159 X (2.5 inches)^2 X 6,000 inches = 117,750 inches^3

117,750 / 231 in^3 per gallon= 510 gallons.

***Step 2:** Volume of a single 1-inch pipe*

V = π r^2 h
r = 1.315 / 2 = 0.6575 inches
h = 500 ft = 6,000 inches
V = 3.14159 x (0.6575 inches)^2 x 6,000 inches = 8,145 inches^3 / 231 in^3 per gallon = 35 gallons.

***Step 3:** Annular volume*

5-inch drillhole volume (510 gallons) – volume of two 1-inch pipes (70 gallons) =

440 Gallons.

***Answer**: 440 gallons of grout needed to fill annular space.*

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*

Example 4: Below is a product guide for a commonly used thermal grout. This product is a thermal grout used exclusively in geothermal applications and requires mixing with silica sand. Calculate how many pounds of sand would be needed to grout 2,000 gallons of annular space.

BATCH RECIPE

TG Lite	1	bag
Silica Sand	250.0	lb
Fresh Water*	18.5	gal
Yield	32.6	gal

*Mix water must be suitable for human consumption

GROUT PROPERTIES

Target Thermal Conductivity	1.00	Btu/hr-ft-°F
Permeability	$<1\times10^{-7}$	cm/s
Density	13.9	lb/gal
Percent Solids	66.0	by weight
Percent Active Solids	24.5	by weight

Answer: *2,000 gallons / 32.6 gallon per bag = 61.35 bags of TG lite x 250 lbs of sand per bag = 15,338 pounds of sand needed.*

Example 5: How many gallons of heat exchange fluid are needed to fill a 350-foot-long, 1.25-inch u-bend loop pipe. Assume an internal diameter (ID) of 1.25 inches.

In this example, you need to calculate the volume of the loop pipe using the internal diameter of 1.25 inches.

350 feet x 12 inches/foot = 4200 inches.

V of pipe = $\pi r^2 h$ *= 3.14159 x (0.625 inches)*^{2} *X 4200 inches = 5,151* in^3 */ 231 cubic inches per gallon = 22.3 gallons x 2 pipes = 44.6 gallons*

Answer: *44.6 gallons of heat exchange fluid needed to fill a single u-bend loop pipe 350 feet long*

Wisconsin Heat Exchange Driller License Practice Exam

1. “Heat exchange drilling” means:
    a. The procedure employed in making heat exchange drillholes.
    b. The industry employed in making heat exchange drillholes.
    c. Both a and b.

2. “Engage in the business of” includes which of the following:
    a. Advertising and bidding on drilling projects.
    b. Contracting and preparing plans on a drilling project.
    c. Preparing specifications and supervising a drilling project.
    d. All of the above.

3. A heat exchange driller license is not required for which of the following:
    a. An individual performing heat exchange work on property leased by that individual.
    b. An individual performing heat exchange work on property owned by that individual.
    c. An individual who is employed by a licensed individual heat exchange driller.
    d. All of the above.

4. Which of the following is not accurate with respect to renewal of an individual heat exchange 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 January 1st.
    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. All of the above are accurate.

5. Which of the following situations would require a prior written approval from the department?
    a. Constructing 15 heat exchange drillholes, each 300 feet deep.
    b. Constructing 5 heat exchange drillholes, each 450 feet deep.
    c. Constructing 8 heat exchange drillholes, each 350 feet deep.
    d. Constructing 1 heat exchange drillhole, 375 feet deep and 500 feet from a municipal well.
    e. a and b

6. You have a heat exchange project approved on February 2nd, 2021, when does this approval expire?
    a. February 2nd, 2022
    b. February 2nd, 2023
    c. February 2nd, 2025
    d. The approval does not expire

7. What requirement is specified in NR 812 for the water used to mix with grouting and sealing materials?
    a. The water must first be chlorinated before mixing with the grout.
    b. The water must be sampled prior to mixing with the grout
    c. The water must be clear water and obtained from an uncontaminated source
    d. The water must be treated with soda ash prior to mixing with the grout.

8. When grouting with neat cement, how many gallons of water per 94-pound sack are needed to result in a final grout density of 15.4 lbs/gallon?
    a. 5.0 gallons
    b. 7.0 gallons
    c. 5.5 gallons
    d. 6.0 gallons

9. How far in advance must a heat exchange driller obtain a well notification prior to the start of drilling?
    a. 36 hours
    b. One week
    c. 12 hours
    d. 24 hours

10. Which of the following is <u>not</u> true?
    a. A heat exchange drillhole must be installed at least 10 feet from a private well.
    b. A heat exchange drillhole must be installed at least 25 feet from a septic tank.
    c. A heat exchange drillhole must be installed at least 10 feet from a buried fuel storage tank.
    d. A heat exchange drillhole may not be constructed within 400 feet of a municipal well without prior written approval from the DNR.

11. A heat exchange driller must have a mud balance on site.
    a. True
    b. False

12. Drilling fluid may be denser than the grout to be pumped in the annular space of a heat exchange drillhole.
    a. True
    b. False

13. How long may a heat exchange drillhole remain open and ungrouted after drilling is completed?
    a. 48 Hours
    b. 72 Hours
    c. 24 Hours
    d. Indefinitely

14. Why is southwestern Wisconsin called the “Driftless Area”?
    a. It is the only area of the state which was not affected by glaciation.
    b. It is the flattest area of the state.
    c. It is the area of the state with the most glacial features.
    d. It is the only area in the state which was affected by glaciation.

15. Limestone, dolomite, sandstone, and shale are related in what way?
    a. They are all igneous rocks.
    b. They are all formed from shells and coral.
    c. They are all sedimentary rocks.
    d. They are all formed through a chemical process.

16. A screen or strainer is the most accurate way to collect <u>very fine</u> drill cuttings.
    a. True
    b. False

17. Groundwater elevation oftentimes follows topography.
    a. True
    b. False

18. Which of the following are true of using neat cement grout in heat exchange drillholes?
    a. Neat cement grout lacks filtration control.
    b. Neat cement does not work well in aquifers with high chlorides and high hardness.
    c. Neat cement provides for a very high thermal conductivity.
    d. The heat of hydration can potentially deform the heat exchange pipe.
    e. a and d

19. Calculate the volume, in gallons, of a 5” drillhole, 500 feet deep.
    Volume = $\pi r^2 h$ and 1 gallon = 231 cubic inches.
    a. 510 gallons
    b. 630 gallons
    c. 475 gallons
    d. 350 gallons

20. Calculate the volume of grout needed to grout the annular space of a 5” drillhole, 500’ deep, with a 1-inch U-Bend loop pipe. The OD (outside diameter) of each 1-inch pipe is 1.315 inches.
Volume = $\pi r^2 h$ and 1 gallon = 231 cubic inches.
    a. 600 gallons.
    b. 440 gallons.
    c. 350 gallons.
    d. 525 gallons.

Practice Exam Answer Key

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