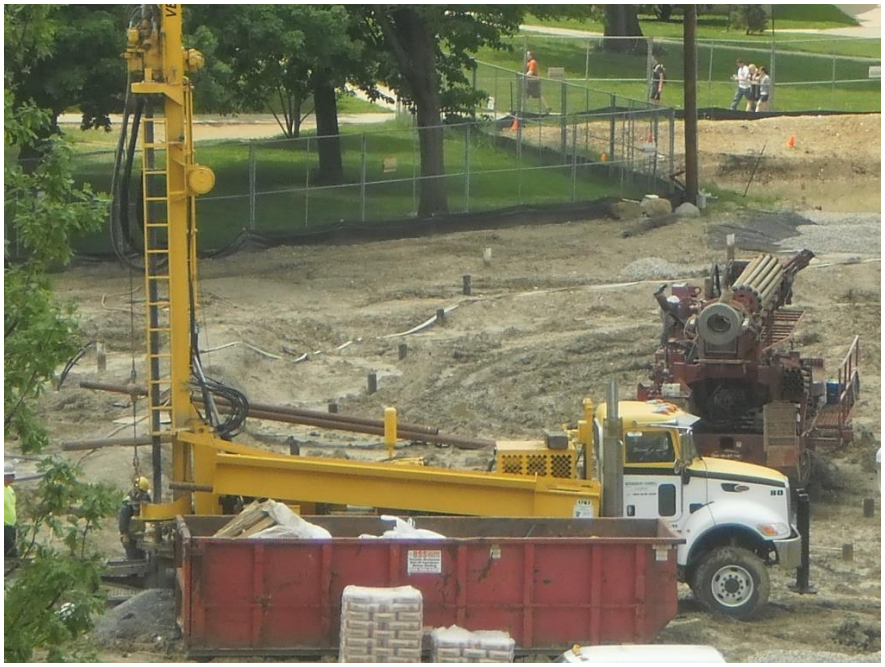
Ohio Groundwater Association
A Division of the Water Management Association of Ohio

Recommendations for Geothermal Heating and Cooling Systems

Guidance for Protecting Ohio's Water Resources

Final



February 2012
Updated September 2022

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Acknowledgements

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List of Abbreviations

BUSTR	Ohio Department of Commerce, Division of State Fire Marshal, Bureau of Underground Storage Tank Regulations
cm/sec	centimeters per second
gpd	gallons per day
GPS	Geographic Positioning System
HVAC	heating, ventilation, and air conditioning
NGWA	National Ground Water Association
NPDES	National Pollution Discharge Elimination System
OBBS	Ohio Board of Building Standards
OCILB	Ohio Construction Industry Licensing Board
ODH-BEH	Ohio Department of Health, Bureau of Environmental Health
ODNR-DGS	Ohio Department of Natural Resources, Division of Geological Survey
ODNR-DMRM	Ohio Department of Natural Resources, Division of Mineral Resources Management
ODNR-DWR	Ohio Department of Natural Resources, Division of Water Resources
Ohio EPA-DDAGW	Ohio Environmental Protection Agency, Division of Drinking and Ground Waters
Ohio EPA-DERR	Ohio Environmental Protection Agency, Division of Environmental Response and Revitalization
Ohio EPA-DSW	Ohio Environmental Protection Agency, Division of Surface Water
Ohio EPA-UIC	Ohio Environmental Protection Agency, Underground Injection Control Program
OMC	Ohio Mechanical Code
OUPS	Ohio Utilities Protection Service
USGS-OKI WSC	U.S. Geological Survey, Ohio-Kentucky-Indiana Water Science Center

Introduction

Public awareness of and education about the benefits of using green technologies, coupled with federal tax credits for energy efficiency, have created renewed interest in geothermal heating and cooling systems for residential and commercial buildings. This has, in turn, created resurgent growth in the industry. Industry experts estimate that approximately 5,000 to 6,000 residential systems and more than 500 commercial systems are now installed annually in Ohio.

Industry, in addition to state and local government agencies, have identified public health and environmental concerns related to the installation of geothermal heating and cooling systems. These concerns include the lack of recordkeeping on the location of these systems and impacts to ground water quality due to the absence of basic construction and sealing standards.

In 2012, to ensure that the installation of geothermal heating and cooling systems are protective of Ohio's water resources, the Ohio Water Resources Council (now the Ohio Water Resources Committee) tasked the State Coordinating Committee on Ground Water (now the Ohio Ground Water Association) with forming a workgroup representing industry and government to evaluate existing Ohio laws and rules, other state's guidance and regulations, and best industry practices. The workgroup was also tasked with developing any guidance and recommendations deemed necessary to ensure geothermal heating and cooling system installation is done in a manner that protects Ohio's water resources.

This document is intended for use by state and local government agencies and for the geothermal heating and cooling industry to use in overseeing the installation, operation, and decommissioning of these systems. The recommendations are intended to help ensure that geothermal heating and cooling systems are installed in a manner that will prevent groundwater contamination, will protect drinking water sources and public health, and help protect the owner's investments.

Geothermal Heating and Cooling Systems

A geothermal heating and cooling system transfers thermal energy between the earth, including ground water and a heat pump or heat exchanger, to heat or cool the interior of a building. The term, ground source heat pump system is sometimes used interchangeably with geothermal heating and cooling system. Below approximately 10 feet, the temperature of the earth or ground water varies from 50° to 55°F year-round. In winter, the relative warmth from the ground or ground water is transferred to the building, and in summer the process is reversed and the heat of the building is transferred to the earth or ground water.

The transfer of heat between the occupied space and the earth is accomplished by either passing a heat transfer fluid through piping, in a loop or series of loops buried underground, or by pumping ground water across a heat exchanger and discharging the water afterwards. Geothermal heating and cooling systems can be divided into two broad classes: open-loop systems and closed-loop systems.

Open-loop systems

An open-loop system withdraws ground water from an extraction (supply) well, passes it through a heat exchange system, and discharges the temperature-altered water either back to the ground in a return well (Figure 1) or to surface water (Figure 2).

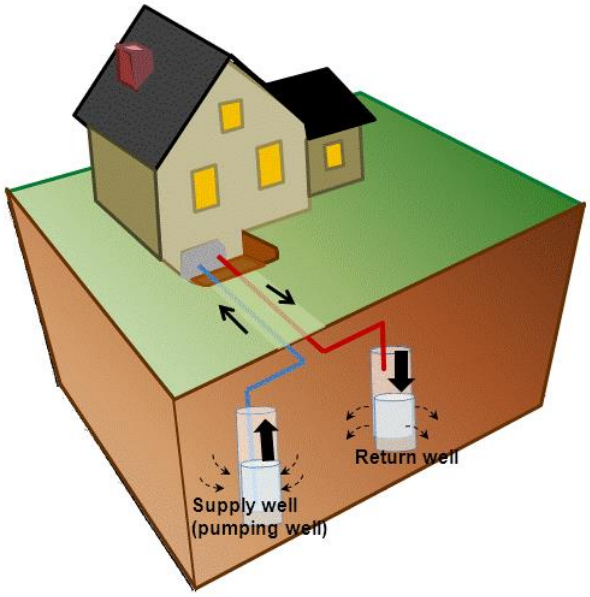

Figure 1 - An open-loop geothermal heating and cooling system discharging to ground water.

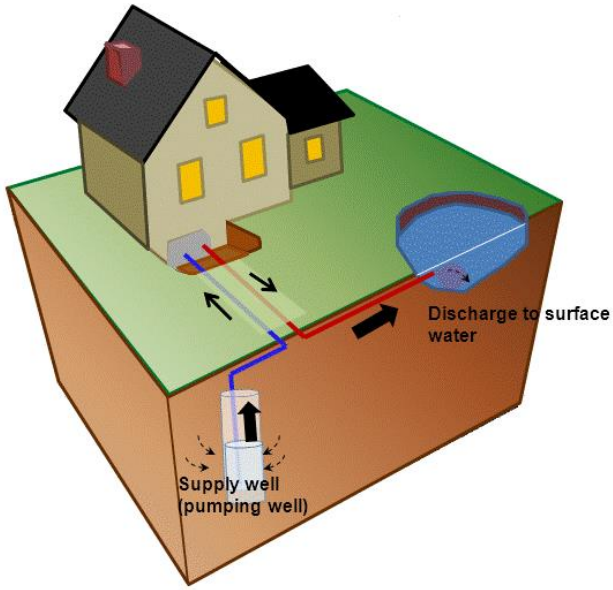

Figure 2 - An open-loop geothermal heating and cooling system discharging to surface water.

Closed-loop systems

Closed-loop geothermal heating and cooling systems (Figures 3 and 4) circulate a heat transfer fluid through a loop or multiple loops of piping installed below ground or within a surface water body. A closed-loop system does not involve the withdrawal of ground water. In the winter, the earth's heat is absorbed by the heat transfer fluid within the piping and transmitted to the unit's heat exchanger and compressor to provide heating. In the summer, the cycle is reversed and the system removes heat from the building and transfers it into the earth to provide cooling.

Most closed-loop geothermal heating and cooling systems installed in Ohio circulate water with an antifreeze additive through multiple loops of polyethylene or cross-linked polyethylene pipe installed below ground. A vertical loop field is composed of borings 75 to 500 feet deep with a pair of pipes joined with a U-shaped connector at the bottom of the hole. The borehole is commonly filled with a bentonite grout to provide a thermal connection to the surrounding soil or rock to improve the heat transfer. Horizontal loop fields are long horizontal trenches deeper than the frost line with U-shaped or slinky coils placed into same trench. Pipe may also be installed through horizontal directional drilling, a steerable trenchless method of installing underground pipes with minimal impact on the surrounding area.

Direct exchange geothermal heating and cooling systems are a type of closed-loop system in which the refrigerant circulates through copper tubing placed in the ground. The refrigerant exchanges heat directly with the soil through the walls of the copper tubing. The copper tubing consists of a line set, a pair of manifolds, and several earth loops are installed in pits, trenches, or vertical borings. Refrigeration-grade copper is the only type of copper used in direct exchange systems.

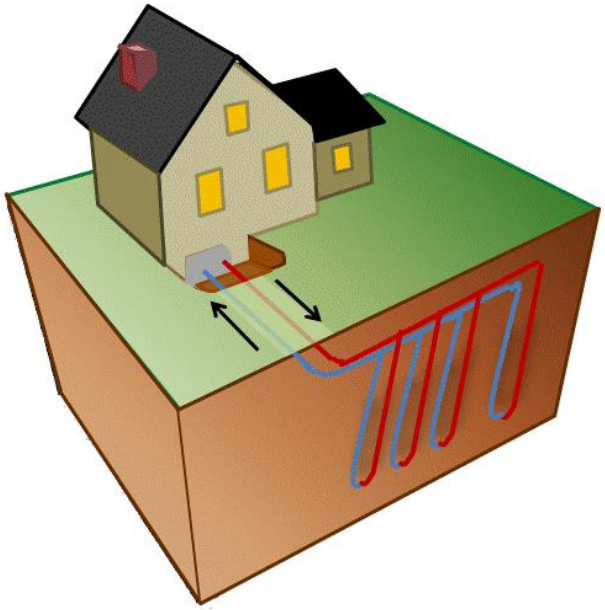

Figure 3 - A closed-loop geothermal heating and cooling system with vertical loops.

Arrows indicate the flow direction in the summer, when the system removes heat from the building and transfers it into the earth. In winter, the flow direction is reversed and the system removes heat from the earth and transfers it into the building.

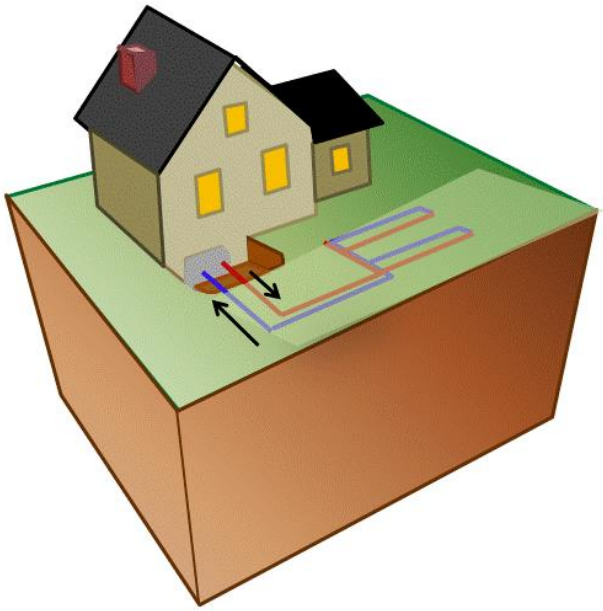

Figure 4 - A closed-loop geothermal heating and cooling system with horizontal loops.

Arrows indicate the flow direction in the summer, when the system removes heat from the building and transfers it into the earth. In winter, the flow direction is reversed and the system removes heat from the earth and transfers it into the building.

Geothermal Heating and Cooling System Best Practices

The following sections discuss the regulatory requirements and recommended best practices for geothermal heating and cooling systems installed in Ohio. This guidance is organized by system type: open-loop and closed-loop systems. Definitions, regulatory information, and references can be found in the appendices. This document does not discuss local building, construction, plumbing or health district codes or ordinances that may apply. Contact information for state agencies can be found in Appendix A.

Pre-design review

Prior to installing a geothermal heating and cooling system there should be a pre-design review of information about the property, surrounding properties and subsurface conditions. A pre-design review will help identify local conditions that may necessitate additional precautions during drilling or affect system design and installation (Figure 5). These conditions may include:

- karst and paleokarst;
- flowing or artesian conditions;
- coarse sand and gravel deposits;
- pre-existing ground water contamination;
- ground water with elevated total dissolved solids;
- ground water with high chloride concentrations (> 500 mg/l);
- other ground water conditions that may indicate the need for water treatment prior to discharge;
- underground mine shafts or rooms; or
- areas previously used for surface mining.

These conditions may necessitate changing drilling methods, revising plans for grout selection and placement or affect well or loop field location. The system designer or installer should include a review of information available about the local aquifer or aquifers, public records to identify contaminated zones in soil and ground water, past practices and other hazards that may complicate the process of system design, installation and operation.

Figure 5 - The importance of knowing the layout, history, and underlying geology of the project site.

The above photo shows multiple geysers created when air rotary drilling encountered paleokarst. The air forced ground water up previously drilled boreholes, and the project site quickly became mired in mud.

The copper pipes used for direct exchange systems can corrode over time, leading to leaks that are hard to locate and almost impossible to fix. In general, corrosion can be directly related to any one or even several factors, as many interrelated soil conditions are involved including elevated concentrations of sulfate or chloride or both in the soil, a combination of elevated sulfate or chloride content in the soil in conjunction with poor drainage, very low soil resistivity soils containing large quantities of organic matter particularly organic acids and organic soils supporting active anaerobic bacteria can produce sulfide. The pre-design review should attempt to identify whether any of these conditions may be present.

The pre-design review should also include contacting local government agencies regarding zoning, building, health and other codes that may affect the siting and installation of geothermal heating and cooling systems. Local ordinances may include siting and construction restrictions beyond those covered in this document. They may also include restrictions or prohibitions on:

- new well siting and construction;
- disturbances in riparian setback areas and flood plains, and
- construction based on local conditions such as slope and soil characteristics.

Coordination with local health districts is necessary to identify the locations of any existing or proposed private water systems or sewage treatment systems and their proposed replacement areas. If geothermal systems are proposed near a public water system, close coordination with the Ohio Environmental Protection Agency, Division of Drinking and Ground Waters (Ohio EPA-DDAGW) may be necessary.

Potential sources of information regarding geologic and ground water conditions, siting restrictions and water and wastewater infrastructure locations are included in Table 1. More specific information on how conditions, restrictions and existing infrastructure may affect system design, installation and operation can be found later in this document.

Table 1 - Sources of information available during a pre-design review.
A list of the abbreviations used in this table can be found on page iii.

Area of concern:	Potential sources of information:
Local Geology	
Karst geology	ODNR-DGS, USGS-OKI WSC
Coarse sand and gravel deposits	ODNR-DGS USGS-OKI WSC
Local ground water conditions	
Flowing or artesian conditions	ODNR-DGS, USGS-OKI WSC
Ground water contamination	Ohio EPA-DDAGW; Ohio EPA-DERR; BUSTR
Other local ground water conditions	ODNR-DGS, Ohio EPA-DDAGW, USGS-OKI WSC, Local health districts
Well locations	
Public water system locations	Ohio EPA-DDAGW
Private water system locations	ODNR-DGS, Local health districts
Oil and Gas Wells	ODNR-DOGR
Other well locations	ODNR-DGS
Other local conditions	
Active and abandoned underground mines	ODNR-DMRM
Household sewage treatment primary and replacement areas	Local health districts
Small flow on-lot sewage treatment systems primary and replacement areas	Local health districts; Ohio EPA-DSW
Local ordinances	Local health districts, zoning boards or commissions and building departments
Mining activity	ODNR-DMRM
Buried utilities	OUPS

Reporting of Installation Details

Open-Loop and Dual Use Well Logs

The well log filing requirements found in Section 1521.05 of the Ohio Revised Code apply to both the extraction and return wells used in open-loop geothermal heating and cooling systems. The well log must include geographic positioning system (GPS) coordinates for each extraction or return well. A well log must be filed with the Ohio Department of Natural Resources, Division of Geological Survey (ODNR-DGS). A copy must also be filed with the local health district if the extraction well is dual-use for a private water system or with the Ohio EPA-DDAGW if it is dual-use for a public water system. The drilling contractor must provide the system owner with copies of all well logs filed with the ODNR-DGS.

Closed-Loop Borehole Logs

The well log filing requirements found in Section 1521.05 of the Ohio Revised Code should be followed with one modification. A minimum of one log should be filed with the ODNR-DGS per property unless significant differences in geology are noted across the site. If significant differences in geology are noted across the site, a well log should be submitted representing each area. The final log(s) should include a specific set of notes when covering multiple borings such as the number of wells the log represents and a minimum of two GPS points for reference.

If 20 or more borings are installed as part of a geothermal heating and cooling system, a minimum of five boring logs should be submitted, one representing each of the corners of the loop field and one for the centroid of the loop field. For these larger systems, the boreholes are typically installed in a grid with 15 to 20 feet between boreholes. Requiring the contractor to submit records for all boreholes would put an undue burden on the contractor to submit identical or almost identical well logs. Receiving five well logs per site will allow the state to characterize the geology of the site while delineating the geothermal borehole field layout. These logs should indicate any significant stratigraphic changes noted during drilling. Each log must meet the GPS location requirements for well logs.

The drilling contractor should provide the system owner with copies of all well logs filed with the ODNR-DGS.

System Construction Diagrams

As-built drawings of the loop field configuration should be filed with the permitting authority(ies) and provided to the system owner. These records should be retained in perpetuity. The installer should provide the system owner with as-built drawings that show sufficient detail to locate boreholes, trenches, loop fields and any piping, including supply and return lines. The diagram should , for each borehole, show the finished depth and actual heat exchanger length. All diagrams and schematics should be drawn legibly, with distances documented to key features, if possible, with a north arrow and indications of key nearby features such as buildings, septic systems, and water wells.

Record Keeping

Well logs filed with the ODNR-DGS, Ohio EPA-DDAGW and local health districts are kept on file permanently. The drilling contractor should also provide a copy of the log to the system owner. As-built drawings filed with permitting authority(ies) should be retained on file permanently. The property owner should maintain a copy of all as-built drawings and well logs in a safe location; these records should be retained permanently.

Open-Loop Geothermal Heating and Cooling Systems

The following sections outline Ohio's rules and regulations and recommended best practices that apply to open-loop geothermal heating and cooling systems. Standards and references may change, so the system designer or installer should always check with the appropriate state and local agencies prior to installing a system. Contact information for state agencies can be found in Appendix A.

Current Regulatory and Permit Requirements

A number of laws and rules apply to open-loop geothermal heating and cooling systems. These include requirements for installing wells in a manner that prevents contaminating ground water or providing a pathway for the migration of contaminants into ground water and between aquifers. The discharge of water used in open-loop geothermal heating and cooling systems, to ground water or surface water, is also regulated. Regulations for both well construction and water discharge are summarized in Figure 7. Other local laws and regulations may apply. The following requirements of Ohio law and rule are applicable to open-loop geothermal heating and cooling systems.

Water Withdrawal Registration

Any open-loop system with the capacity to withdraw 100,000 or more gallons per day (gpd) must register with the ODNR-DWR's Water Withdrawal Facilities Registration Program as required by Section 1521.16 of the Ohio Revised Code.

Great Lakes Water Resources Management

New or increased diversions of water out of the Great Lakes Basin are prohibited by the Great Lakes Compact, other than for certain specified exceptions. Therefore, rules applicable to Great Lakes water resource management are also applicable to open-loop geothermal heating and cooling system extraction wells and discharges. This means that ground water withdrawn within the Lake Erie Basin must be discharged within the Lake Erie Basin. In Ohio, the Lake Erie Basin includes all or part of 33 counties, with the drainage divide between Lake Erie drainage and the Ohio River drainage passing through 17 counties in northern Ohio as shown in Figure 6.

Ohio's laws covering Great Lakes water resource management are codified in Section 1522 of the Ohio Revised Code and are administered by the ODNR-DWR.

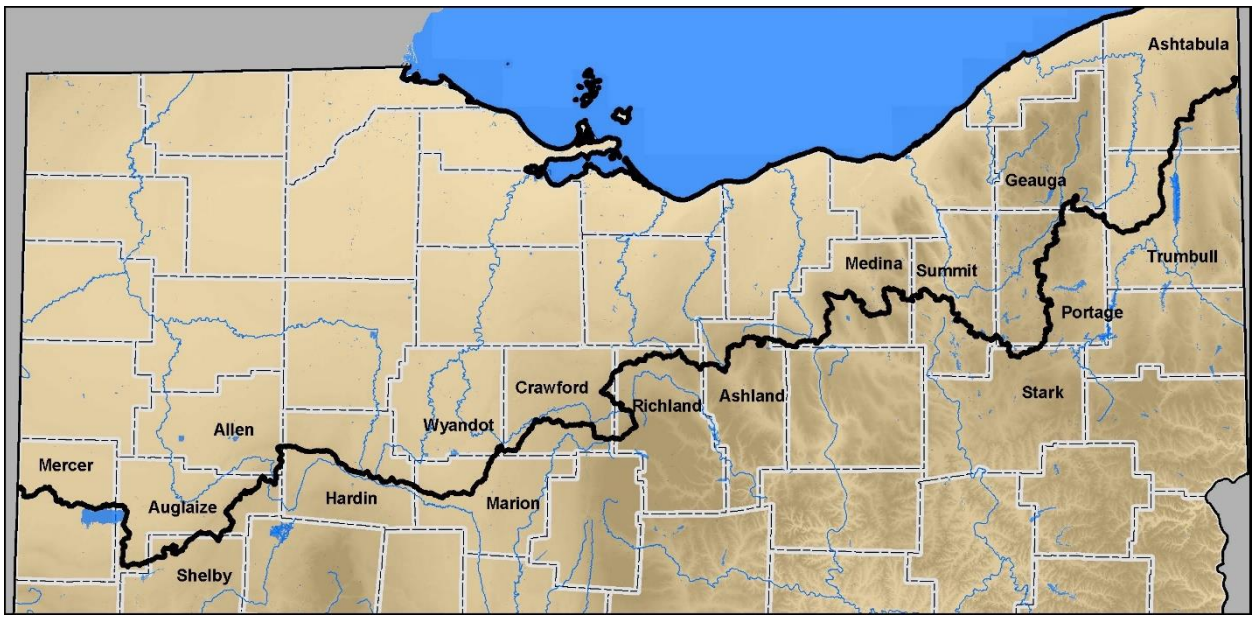

Figure 6 - The location of and counties crossed by the Lake Erie – Ohio River drainage divide.

Surface Water Discharges

The Ohio Environmental Protection Agency, Division of Surface Water (Ohio EPA-DSW) has issued a National Pollution Discharge Elimination System (NPDES) General Permit for non-contact cooling water, which includes open-loop geothermal heating and cooling systems discharging to surface water, under the provisions of Chapter 3745-1-05 of the Ohio Administrative Code. As with all NPDES General Permits, there are limitations to the covered discharges. These limitations include a maximum increase in water temperature of 10°F across the heating and cooling system for systems discharging more than 5,000 gpd, or 15°F for systems discharging 5,000 gpd or less; a prohibition on combining the system discharge with other discharges; and a prohibition on the discharge of certain chemicals, including antifreeze compounds. A list of all discharges prohibited under the general permit is located in Part I.C.2. of the permit.

Facilities that are designed to discharge less than 100,000 gpd are covered by the NPDES General Permit and not required to submit a Notice of Intent but are bound by the conditions of the permit. Owners of facilities that are designed to discharge 100,000 gpd or more must submit a Notice of Intent application for coverage under the general permit. An individual permit will be required if the discharge cannot meet applicable water quality standards or other conditions of the general permit, regardless of the quantity of water that passes through the system. An individual permit is also required for certain sensitive water classifications identified in the general permit.

A copy of the NPDES General Permit is available from Ohio EPA-DSW: ***NPDES General Permits***.

Ground Water Discharges

A return well for an open-loop geothermal heating and cooling system is a Class V injection well regulated under Chapter 3745-34 of the Ohio Administrative Code. Class V regulations are administered by the Ohio Environmental Protection Agency, Underground Injection Control Program (Ohio EPA-UIC).

Systems discharging non-contact heating and cooling water without chemical additives must register with Ohio EPA-UIC. The discharge must meet all drinking water and other health-based standards.

Systems discharging non-contact heating and cooling water with chemical additives must register with and be permitted by Ohio EPA-UIC. Plans for new systems discharging water with chemical additives must be submitted to and approved by Ohio EPA-UIC prior to drilling the return well. Wells converted from other proposes for use as a return well for water with chemical additives must be registered and permitted at the time of conversion. Systems converting to the use of chemical additives must be permitted at the time of conversion. In all cases the discharge must meet all drinking water and other health-based standards. Monitoring and monthly operating reports may also be required.

Extraction Well Construction

Except as noted in the following section, open-loop extraction wells must meet the construction requirements of Ohio Administrative Code Chapter 3745-9. These requirements are administered by the Ohio EPA-DDAGW. Additional information can be found in the Well Construction portion of this guidance.

Dual-use Extraction Wells

A dual-use well is a well used to provide both on-site potable water and water for heat transfer in an on-site, open-loop geothermal heating and cooling system. Dual-use wells must be constructed according to the appropriate standards for drinking water supply wells.

Private Water Systems

If the dual-use well will serve a private water system, it must be constructed in accordance with Chapter 3701-28 of the Ohio Administrative Code. These regulations cover the siting and construction of private water system wells and the registration of private water system contractors. Prior to installation of a new dual-use well or alteration of an existing well, an application must be submitted to the local health district and a permit for installation must be obtained. Dual-use wells are not permitted to be constructed with return water being discharged back into the private water system, such as a standing column well. Private water systems are permitted and overseen by the local health districts under standards established by the Ohio Department of Health, Bureau of Environmental Health and Radiation Protection (ODH-BEHRP).

Public Water Systems

If the dual-use well will serve a public water system, the well and distribution system must have engineering approval under Ohio Administrative Code Chapter 3745-9 from the Ohio EPA-DDAGW. Engineering approval covers the drilling, operation, maintenance, and abandonment of a well to prevent the contamination of the ground water. No person may construct or alter a public water system well until plans have been approved by the Director of the Ohio Environmental Protection Agency.

Well Siting

Wells should be sited to minimize the potential for the well to provide or create a pathway for the migration or spread of contaminants. Extraction and return wells should be sited at least 50 feet from a potential source of pollution. Potential sources of pollution include, but are not limited to, small flow onsite sewage treatment systems, household sewage treatment systems, underground storage tanks, and waste management facilities. In addition, wells should not be sited within 50 feet of the reserve location for a small-flow on-site sewage treatment system or household sewage treatment system.

Wells should also be sited to minimize the potential for interference with the operation of other wells. Extraction and return wells should be sited at least 50 feet from a private water system well or other well. The extraction and return wells should be sited outside of the sanitary isolation radius determined for a public water system well under Chapter 3745-9 of the Ohio Administrative Code. To avoid disrupting the efficient operation of the open-loop heating and cooling system, there should be a minimum spacing between the extraction and return wells of 50 feet in unconsolidated geologic formations and 100 feet in consolidated geologic formations. In addition, wells should not be sited within 50 or 100 feet, based on the nature of the aquifer, of an area that may be needed for installation of a backup or replacement well.

Under section 1521.17 of the Ohio Revised Code an operator could be liable for damage if the withdrawal of ground water causes excessive drawdown in nearby wells. Systems with the capability of withdrawing large quantities should conduct pumping tests to determine impacts to area water levels. As discussed earlier in this guidance, a pre-design review of information about the property, surrounding properties and subsurface conditions should be conducted prior to installing a geothermal heating and cooling system.

Well Construction

Extraction and return wells used for open-loop geothermal heating and cooling systems must be constructed to prevent contamination from occurring or spreading. This includes proper casing, grout materials and grout placement to prevent infiltration of surface water into the borehole or well. Extraction and return wells must also be constructed to prevent migration of fluids between geologic formations and aquifers.

Extraction Wells

Well construction requirements can be found in Chapter 3745-9 of the Ohio Administrative Code. The minimum extraction well diameter for an open-loop geothermal heating and cooling system is five inches.

Return Wells

In addition to the basic well standards, all construction standards found in Chapter 3745-34 of the Ohio Administrative Code for Class V injection wells apply to open-loop geothermal heating and cooling system return wells. In addition, return wells should be cased and grout placed to at least 25 feet below ground. Grout should meet a permeability standard of $1x10^{-7}$ cm/sec or lower.

Prior to placing a return well into service, the system designer should conduct slug or similar tests on the receiving formation to ensure it will accept the discharge at a rate that will prevent the well from overflowing. Whenever possible, return wells should be designed to minimize water cascading down open boreholes and within the casing. Controlling cascading helps protect water quality by limiting the turbidity caused by the tumbling of the water, limiting bacterial growth caused by increased oxygen in the return water and minimizing precipitation of minerals caused by increased oxygen in and changed temperature of the return water. Excessive bacterial growth and precipitation of minerals can result in natural plugging of the well.

A return well must be designed so that there is a sufficient screened interval in unconsolidated deposits or open borehole in consolidated deposits to accept water being pumped into it. Water discharge should occur below the static water level of the return well. The design of the well must be based on site-specific hydrogeology such as aquifer porosity and permeability.

If the casing and grout requirements cannot be met, the system designer should consider a closed-loop system.

Best Construction Practices - Supply and Return Lines

Supply and return well piping installation should be in accordance with all local and state water well regulations and, as applicable to the specific installation, the Ohio plumbing, mechanical or residential codes. Approved pitless adapters or pitless units meeting the requirements of Ohio Administrative Code Chapter 3745-9 must be used to provide a watertight connection with the supply and return line and the well casing. Sharp bends in piping should be prevented. The pipe between the well and building entry point must be buried at a depth, typically greater than four feet to help prevent freezing. Backfill should have no sharp-edged rocks or other material that would damage the piping.

The entry and exit points from a building should be made watertight and constructed to prevent leaks. Piping sleeves should be used at entry and exit points. Sleeves should extend a minimum of 12 inches out from the foundation and be constructed and installed in compliance with the Ohio plumbing, mechanical or residential codes and other ordinances as applicable to the specific installation. Sleeves serve to minimize shearing stresses from fill settling and help minimize damage to the foundation.

If at any point the return or supply line will cross a water line, the line should be enclosed in a sleeve until ten feet of separation is achieved. There should be a minimum separation of two feet between the return or supply lines and water or sewer lines.

Best Construction Practices - Backflow Prevention

Backflow prevention devices should be installed on all supply and return wells when the potential for backsiphonage into the well is present. A backflow prevention device is necessary for all dual-use wells. The following sections describe the backflow prevention requirements for facilities served by private and public water systems.

Private Water Systems

If an open-loop geothermal heating and cooling system is installed at a facility served by a private water system, the system must comply with the backflow prevention provisions of Chapter 3701-28 of the Ohio Administrative Code. An approved backflow prevention device is required between the private water system and any potential source of contamination such as the diversion of water into a geothermal heating and cooling system.

Public Water Systems

If an open-loop geothermal heating and cooling system is installed at a facility served by a public water system, the water system should be inspected to identify any hazards to water quality and the system must comply with the backflow prevention provisions of Section 3745-95 of the Ohio Administrative Code. The potable and non-potable supply piping must be completely, physically separated and an appropriate backflow prevention device installed at the service connection if a potential hazard still exists. Public water systems are regulated by the Ohio EPA-DDAGW.

A backflow prevention device should be installed on all open-loop geothermal heating and cooling systems discharging to surface water. Outfall piping for surface water discharging systems should be installed with the return water outfall located at least eight inches above 100-year flood level, have an appropriate air gap, or have backflow prevention device installed to prevent backsiphonage into the well.

If the system is commercial and requires any of the four mechanical licenses (HVAC, Refrigeration, Plumbing, Hydronics) regulated by the Ohio Construction Industry Licensing Board (OCILB), they would be required to be licensed. If the system is for residential in any of these trades, they are regulated by the local building and/or health departments. Most building and health departments require the State OCILB license for their residential, so local authorities should be contacted regarding their licensing requirements.

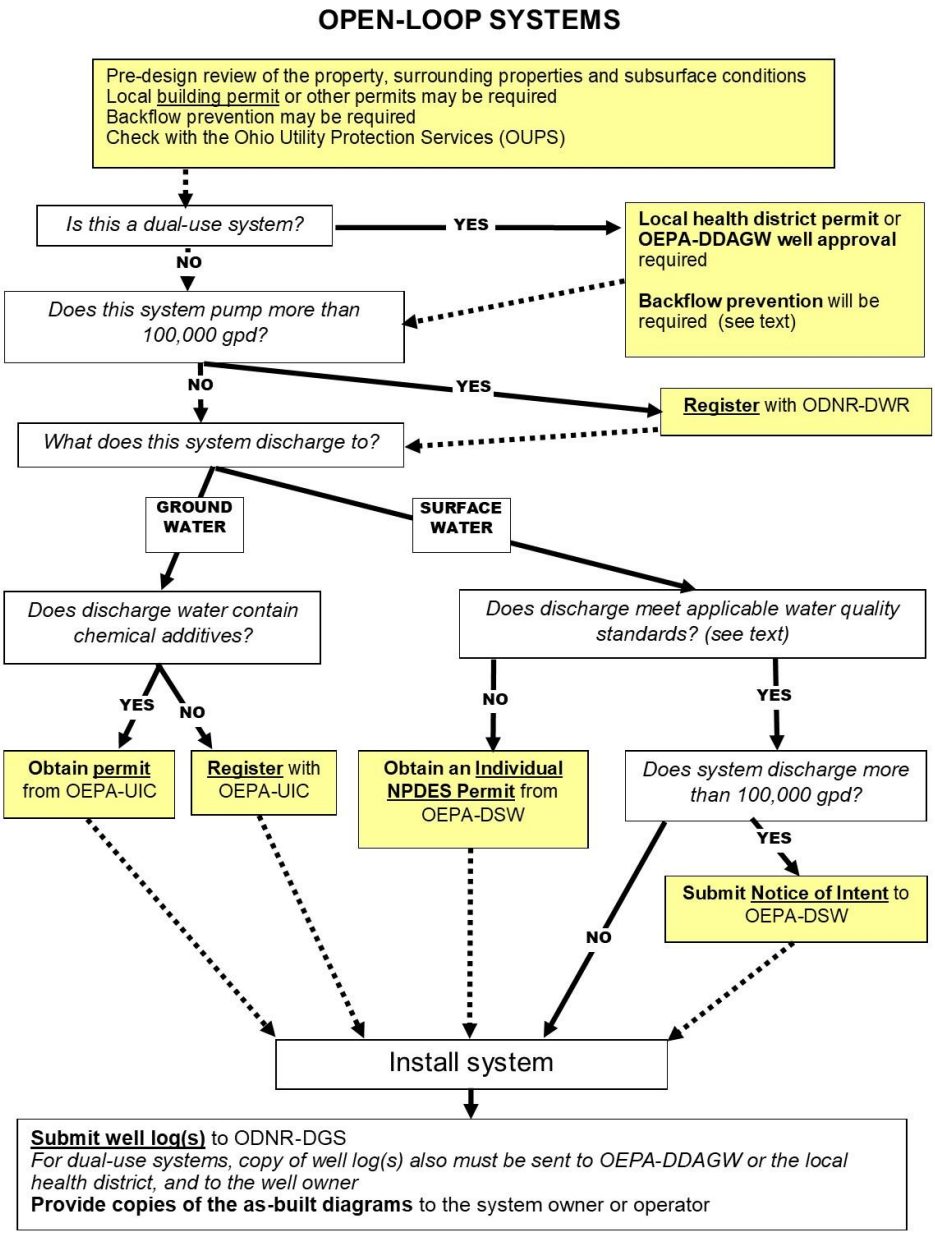

Figure 7 - Summary flowchart of existing laws, rules, and ordinances applicable to open-loop geothermal heating and cooling systems.

Closed-Loop Geothermal Heating and Cooling Systems

The following sections outline Ohio's laws and rules that apply to closed-loop geothermal heating and cooling systems. Where no applicable laws or rules are in place, best industry practices are recommended. Standards and references may change so the geothermal heating and cooling system designer or installer should always check with the appropriate state and local agencies prior to installing a geothermal heating and cooling system. These include the Ohio EPA-DDAGW, the ODH-BEHRP, the ODNR-DWR, the Ohio Board of Building Standards (OBBS) and local building, zoning, and health departments. Contact information for state agencies can be found in Appendix A.

As discussed earlier in this guidance, a pre-design review of information about the property, surrounding properties and subsurface conditions should be conducted prior to installing a geothermal heating and cooling system.

The following sections cover both vertical and horizontal closed-loop geothermal heating and cooling systems, including direct exchange systems.

Current Regulatory and Permit Requirements

An approval from the building department having jurisdiction is currently required for the installation of a closed-loop geothermal heating and cooling system serving a non-residential building. The design, installation, and testing of the piping system for non-residential buildings, including those portions of the system outside the building, must comply with the requirements of rule 4101:2-12-01 of the Ohio Administrative Code, Chapter 12 of the Ohio Mechanical Code. The design, installation, and testing of the heating, ventilation, and air conditioning (HVAC) equipment and ductwork serving non-residential buildings must comply with the requirements Division 4101:2 of the Ohio Administrative Code, the Ohio Mechanical Code. Plan approval will always be required for non-residential buildings. If the building is non-residential and there is no local building department with jurisdiction, then the plan approval should be acquired from the Department of Commerce, Division of Industrial Compliance.

The design, installation, and testing of the piping system, HVAC equipment, and ductwork serving residential buildings must comply with The Residential Code of Ohio, Division 4101:8 of the Ohio Administrative Code. These code requirements are uniform for all residential buildings constructed in Ohio. Local governments may elect to require the OBBS certification through their local building department. However, if they do not, the contractor and the construction of the system are still required to follow the state code but without the need for a permit, inspection or prior plan approval.

Some local governments may restrict the areas on a property available for siting the loop field. These may include current and proposed replacement areas for on-site sewage treatment systems and riparian setbacks. Additional information can be found in the Loop Field Siting section below. Regulations for closed-loop systems are summarized in Figure 8.

Underground Piping Best Installation Practices

Piping, fittings and joints must be compatible with the heat transfer fluid, antifreeze (or the refrigerant in the case of a direct exchange system) and must be corrosion resistant. As previously mentioned, all piping, fittings, joints and other materials used in closed-loop geothermal heating and cooling systems are required to comply with the Ohio Mechanical Code or the Residential Code of Ohio depending upon the type of building. Other recommended installation guidelines are published by the National Ground Water Association (NGWA) in its *Guidelines for Loop Wells for Vertical Closed Loop Ground Source Heat Pumps*. All underground piping joints should be either socket or butt joints, thermally fused according to the piping manufacturer's specifications. Glued or clamped joints should never be used below ground. Joints must not leak after assembly.

Flushing, air purging and pressure testing are part of the standard installation process for closed-loop geothermal heating and cooling systems. Pressure testing must be conducted at a minimum of 100 psi for at least 15 minutes with no observed leaks in accordance with the Ohio Mechanical Code or the Residential Code of Ohio (OMC Section 1210.10).

Underground piping should be installed following standards set by the International Ground Source Heat Pump Association (IGSHPA) in *Closed-Loop/Geothermal Heat Pump Systems - Design and Installation Standards*. Special attention should be paid to avoid sharp bends in piping and remove sharp-edged rocks or other material in the trench backfill. Either can cause damage to the piping, potentially causing loss of system integrity and fluids. Trenches should be constructed and backfilled in accordance with manufacturer's specifications. Backfill should be seeded and covered after settling has taken place. Filled excavations should be periodically monitored and erosion controls should be maintained until settling is complete and permanent ground cover is in place.

The Industrial Ground Source Heat Pump Association offers training (see training tab) for Certified Geothermal Inspector and for two different types of geothermal designers: ***IGSHPA - International Ground Source Heat Pump Association***.

All horizontal-loop trenches and horizontal boreholes must be constructed to prevent contamination from occurring or spreading to ground water. Underground loops should be installed parallel to surface contours whenever possible.

Loop Field Siting

Loop fields for both vertical and horizontal closed-loop geothermal heating and cooling systems should be sited in locations that will minimize the potential for the borehole or trench to provide or create a pathway for the migration of contaminants. Vertical loop fields shall not be sited within 50 feet of the primary or designated replacement area for a small-flow on-site sewage treatment system or household sewage treatment system. Horizontal loop fields shall not be installed within 10 feet of any component of a sewage treatment system or designated sewage treatment replacement area. In addition, loop fields should not be sited in area that may be needed for installation of a backup or replacement well. At a minimum, boreholes and trenches should be 50 feet from all other potential sources of pollution. Potential sources of pollution include, but are not limited to, underground storage tanks and waste management facilities.

Extension of horizontal borings beneath current and proposed soil absorption areas of sewage treatment systems is prohibited under OAC Rule 3701-29-06(G)(3)(a) and 3701-29-06(G)(3)(c).

Loop fields should not be sited within the sanitary isolation radius of a public water system well. Loop fields should not be sited within 50 feet of a private water system well unless the antifreeze is propylene glycol, in which case the loop field can be sited within 25 feet. Additional siting recommendations are based on the antifreeze additives used in the closed-loop geothermal heating and cooling system and can be found in the Heat Transfer Fluids section of this document.

Supply and Return Line Siting

The entry and exit points from a building should be made watertight and constructed to prevent leaks. Piping sleeves should be used at entry and exit points. Sleeves should extend a minimum of twelve inches out from the foundation and be constructed and installed in compliance the Ohio Building Code and Ohio Mechanical Code or the Residential Code of Ohio. Sleeves serve to minimize shearing stresses from fill settling and help minimize damage to the foundation.

If at any point the return or supply line will cross a water line, the line should be enclosed in a sleeve until ten feet of separation is achieved. There should be a minimum separation of two feet between the return or supply lines and water or sewer lines.

Heat Transfer Fluids

Geothermal heating and cooling systems must be designed to accommodate temperatures below the freezing temperature of water in northern climates like Ohio's. The fluid used in most closed-loop geothermal heating and cooling systems is a water/antifreeze mixture. In 2010, the most commonly used antifreezes in Ohio were methanol and ethanol, mixed with water (20% to 22% by weight).

The heat transfer mixture should comply with the Ohio Mechanical Code or the Residential Code of Ohio and standards referenced by the NGWA in its *Guidelines for Loop Wells for Vertical Closed Loop Ground Source Heat Pumps*. Antifreeze additives should be biodegradable, preferably food-grade fluids. Whenever possible, the system designer and contractor are encouraged to select the least toxic antifreeze additive.

If the closed-loop system will be located within a public water system's inner management zone, the designer and contractor should select non-toxic antifreeze. Information on the locations of drinking water source protection areas can be obtained from the Ohio EPA-DDAGW.

Sub-surface Loop Locations – Labeling and Accessibility

Conductive tracer wire (sometimes known as locator wire) should be installed so that borings and buried piping and equipment associated with the closed-loop geothermal heating and cooling system can be located prior to subsequent construction is planned near the loop field or if repairs to the loop field are required. Tracer wire is recommended because it responds to electromagnetic locating equipment above ground. The use of white tracer wire is recommended and should be laid in horizontal trenches and along the supply and return lines between the header and building. The wire should be laid in a continuous loop and be buried at least 24 inches deep. The ends of the wire must be accessible at the surface in a test port or terminated above final grade at the building foundation with a permanent label indicating the nature of the wires. Tracer wire access locations need to be clearly identified on the as-built drawings.

If available, place plastic tags or labels reading *Geothermal lines buried below* or plastic *Caution* tape in the backfill approximately 12 inches below the final surface elevation.

Vertical Closed-Loop Borehole Construction

During construction, steps should be taken by the owner and all contractors to minimize the potential for introduction of contaminants into an open borehole. During breaks in drilling, boreholes that are left open should be protected from direct precipitation, surface water inflow and access by animals and people. The contractor should ensure that any open borehole is securely covered to prevent the entrance of contaminants and prevent a safety hazard for animals and people if construction is not complete and the contractor must leave the well site. The borehole should be secured to prevent collapse if the drilling rig is to be removed from the site before borehole completion. Boreholes should not be left open for more than ten days and efforts should be made to avoid having multiple open boreholes on the site at one time.

All borings used for vertical closed-loop geothermal heating and cooling systems must be constructed in a manner that will prevent contamination from occurring or spreading.

The borehole diameter must be sufficient to accommodate the heat transfer fluid piping loop and tremie piping or any special grouting tools required by special geologic conditions. The usual range of borehole diameters is four inches for ¾ inch piping, five inches for 1 inch piping and six inches for 1¼ inch piping. This diameter is controlled by the radius of the u-joint needed for the pipe diameter.

Unique geologic conditions may require alternative construction practices. When necessary, a temporary casing should be used to maintain borehole stability in unconsolidated materials. Where flowing or artesian conditions are likely to be encountered, the contractor should take measures to control or eliminate upward flow in the borehole.

Vertical Closed-Loop Grout Selection

Grout should meet the requirements of Chapter 3701-28 of the Ohio Administrative Code for private water systems or Chapter 3745-9 of the Ohio Administrative Code, unless the system design indicates a thermally enhanced grout is needed. Grout should meet the industry permeability standard of $1x10^{-7}$ cm/sec or lower. Permeability must be adequate to prevent the migration of surface water and/or contaminants into the borehole and the migration of ground water between water bearing zones. Grout materials should meet public and private water well standards. Grout materials include bentonite, neat cement, concrete, and proprietary materials. Alternate materials may be used if water quality or aquifer conditions, such as elevated total dissolved solids or high chloride concentrations, prevent the use of standard materials. Under no circumstances should contaminated water be used in the grout mix. Grout designed to be compatible with copper pipe should be used when installing a direct exchange system.

If mineshafts, fractures, or caverns are encountered in consolidated material, the borehole should be packed or sealed above and below the void. Other methods may be used as needed and are available to preserve borehole stability. When drilling through caves, mines, or other cavities the lower portion of the casing should be grouted in accordance with design specifications and a packer or similar bridging device used to facilitate grouting above the cavity. If rapid loss of grout material occurs during placement, coarse material such as sand, gravel, crushed stone, dry cement, or other bridging materials approved for use may be used in the zones in which the loss is occurring. The remainder of the annular space should be grouted in accordance with grout manufacturers and design specifications. Casing should be installed, as necessary, in the case of voids which may cause the loss of excessive amounts of grout.

Vertical Closed-Loop Grout Placement

At a minimum, grout should be installed per Section 3701-28 of the Ohio Administrative Code for private water systems and/or Section 3745-9 of the Ohio Administrative in all other cases. Cuttings should not be returned to the borehole.

The borehole should be grouted immediately after pipe installation, ideally within 24 hours and in accordance with the grout manufacturer's mixing and installation requirements. Drilling fluids will be flushed from the borehole prior to pipe installation, with the exception of boreholes where ground water exhibits artesian conditions.

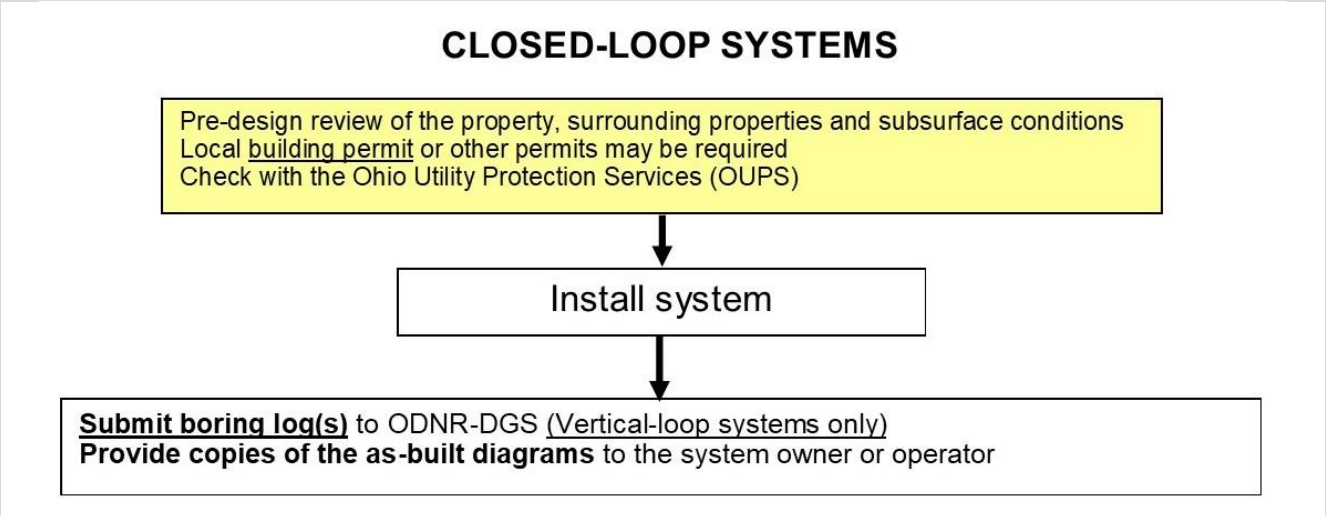

Figure 8 - Summary flowchart of existing laws, rules, and ordinances applicable to closed-loop geothermal heating and cooling systems.

System Decommissioning

The extraction and return wells of an open-loop geothermal heating and cooling system must be abandoned in a manner consistent with Ohio rules for water wells. A well sealing permit must be obtained from the local health department for the sealing of all dual-use private water system wells. A well sealing form must be filed with the ODNR-DGS and either the local health department for dual-use private water systems or the Ohio EPA-DDAGW for all other open loop systems. Dead end water lines should be avoided when removing a geothermal service connection from an existing private or public water system.

When all or a portion of a closed-loop geothermal heating and cooling system is decommissioned, all heat transfer fluids and other wastes should be removed and disposed of properly. The local health district should be notified of the system's removal from service. Just as an approval is required from the building department having jurisdiction for the installation of a new geothermal heating and cooling system, an approval is also required for any alterations to or removal of existing geothermal heating and cooling systems serving nonresidential buildings and for those systems located in jurisdictions with certified residential building departments. For vertical loop systems, decommissioning should include fusing and sealing the ends of abandoned loops with the ends terminated a minimum of two feet below ground surface before backfilling any excavations made to access the piping.

Appendix A - State Agency Contact Information

Ohio Department of Commerce, Division of Industrial Compliance, Ohio Board of Building Standards
Phone: 614-644-2613
Email: bbs@com.state.oh.us

Ohio Department of Commerce, Division of Industrial Compliance, Ohio Construction Industry Licensing Board
Phone: 614-644-3493
Email: dic.ocieb@com.state.oh.us

Ohio Department of Commerce, Division of State Fire Marshal, Bureau of Underground Storage Tank Regulations
Phone: 614-752-7938
Email: websfm@com.state.oh.us

Ohio Department of Health, Bureau of Environmental Health and Radiation Protection
Phone: 614-466-1390
Fax: 614-644-2909
Email: BEH@odh.ohio.gov

Ohio Department of Natural Resources, Division of Water Resources
Phone: 614-265-6610
Email: water@dnr.ohio.gov

Ohio Department of Natural Resources, Division of Geological Survey
Phone: 614-265-6740
Email: geo.survey@dnr.ohio.gov

Ohio Department of Natural Resources, Division of Mineral Resources Management
Phone: 614-265-6633
Fax: 614-265-7998

Ohio EPA, Division of Drinking and Ground Waters
Phone: 614-644-2752
Fax: 614-644-2909
Email: whp@epa.ohio.gov

Ohio EPA, Division of Surface Water
Phone: 614-644-2001
Fax: 614-644-2745

Ohio EPA, Underground Injection Control Program
Phone: 614-644-2752
Fax: 614-644-2909

Ohio EPA, Division of Environmental Response and Revitalization
Phone: 614-644-2924
Fax: 614-644-3146

U.S. Geological Survey
Ohio-Kentucky-Indiana Water Science Center
Phone: 614-430-7700
Fax: 614-430-7777

Appendix B - Definitions

The definitions included below are derived from various technical guidance documents and state regulations and are presented with specific reference to geothermal systems."

Antifreeze — A substance, often a liquid such as ethylene glycol or alcohol, mixed with another liquid to lower its freezing point.

Cascading well — A well that allows water to cascade down an open borehole.

Closed-loop system — A low-temperature geothermal heating and cooling system that circulates a heat transfer fluid, usually water with an antifreeze additive, through a loop or multiple loops of piping installed below the ground surface or within a surface water body. A closed-loop system does not involve the withdrawal of ground water. In the winter, the earth's heat is absorbed by the heat transfer fluid within the piping and transmitted to the unit's heat exchanger and compressor to provide heating or cooling. In the summer, the cycle is reversed and the system removes heat from the building and transfers it into the earth.

Direct exchange system — A type of closed-loop geothermal heating and cooling system that uses loops of copper piping installed in pits, trenches, or vertical borings in the earth, through which a refrigerant is circulated.

Dual-use well — A well used to provide both on-site potable water and water for heat transfer in an on-site geothermal heating and cooling system.

Geothermal heating and cooling system — A mechanical system for space heating or cooling that relies on the transfer of thermal energy between the earth, including ground water, and a heat transfer fluid and consists of a heat pump, a heat exchange well or loop, and a heat distribution network.

Ground water discharge — The direct or indirect discharge of water used as a source of, or reservoir for, heat in an open-loop geothermal heating and cooling system to ground water. Ground water discharge may occur within aquifers or anywhere below land surface, where percolation may ultimately reach ground water.

Inner management zone — The surface and subsurface area around a public water system well that will provide water to the well within one year, as delineated or endorsed by the Ohio Environmental Protection Agency under the wellhead protection program and the source water assessment and protection program.

Karst — A suite of landforms caused by the dissolution of limestone and to a lesser extent dolomite and gypsum. Features of karst terrain include fissures, sinkholes, underground streams and caverns.

Local health department — A department organized by county, city or a combination of counties and cities that work closely with the Ohio Department of Health and Ohio Environmental Protection Agency to address environmental health issues, including private water systems and small flow on lot sewage treatment systems.

Notice of Intent — Written notification to a regulatory agency or other government body of the intent to act on a legal right. In this document Notice of Intent is specific to the written notice a geothermal heating and cooling system owner or operator must provide to the Ohio Environmental Protection Agency that a system discharging to surface water will be installed or operated under the National Pollution Discharge Elimination System (NPDES) General Permit for Non-Contact Cooling Water.

Non-contact heating and cooling water — Water used for heating or cooling which does not come into contact with any raw material, product, by-product or waste.

Non-residential building — Any building that is not a one-, two-, or three-family dwelling.

Open-loop system — A geothermal heating and cooling system that withdraws water from an extraction well or body of water, passes the water through a heat exchange system, and discharges the temperature-altered water either into the ground in a discharge or return well or to the ground surface or into surface water.

Paleokarst — A buried carbonate unit exhibiting typical karst fractures such as large, interconnected fractures and voids.

Private water system — Any water system, other than a public water supply system, for the provision of water for human consumption, if the system has fewer than fifteen service connections and does not regularly serve an average of at least twenty-five individuals daily at least sixty days each year. A private water system includes public water systems that are defined as exempt in Section 6109.02 of the Ohio Revised Code and use hauled water storage tanks as their only source of water. (Ohio Administrative Code Chapter 3701-28; Ohio Department of Health, Bureau of Environmental Health and Radiation Protection)

Public Water System — A system which provides water for human consumption through pipes or other constructed conveyances and has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least sixty days out of the year. A public water system is either a community water system or a non-community water system. (Ohio Administrative Code Chapter 3745-81; Ohio EPA, Division of Drinking and Ground Waters)

Refrigerant — A substance, such as air, ammonia, water, or carbon dioxide, used to provide cooling either as the working substance of a refrigerator or by direct absorption of heat.

Residential building — Any one-, two-, or three-family dwelling.

Standing column well — A semi-open-loop geothermal heating and cooling system consisting of a vertical boring from which ground water is withdrawn and into which ground water that has passed through a geothermal heating and cooling system is discharged.

Surface water discharge — The direct or indirect discharge of water used as a source of or reservoir for heat in an open-loop geothermal heating and cooling system to streams, lakes or ponds.

Vertical closed-loop system — A set of grouted borings containing sealed pipe installed in the earth in boreholes in a vertical, angled, or diagonal configuration, for the purpose of transferring heat between a building space and the earth, including ground water, in a geothermal heating and cooling system.

Well — Has all of the following definitions:

A. any excavation by digging, boring, drilling, driving, or other method for the purpose of removing ground water from an aquifer, except a private water system well or a monitoring well (Ohio Administrative Code 3745-9; Ohio EPA, Division of Drinking and Ground Waters).
B. any excavation greater than ten feet below the ground surface regardless of design or method of construction that is done or used for any of the following purposes:
    a. Removing ground water for the provision of water for human consumption; or
    b. Determining the quality, quantity, or level of ground water in or the stratigraphy of an aquifer, excluding borings for instrumentation in dams, dikes or levees or highway embankments (Ohio Administrative Code 3701-28; Ohio Department of Health, Bureau of Environmental Health and Radiation Protection).
C. any excavation, regardless of design or method of construction, created for any of the following purposes:
    a. Removing ground water from or recharging water into an aquifer, excluding subsurface drainage systems installed to enhance agricultural crop production or urban or suburban landscape management or to control seepage in dams, dikes, and levees;

b. Determining the quantity, quality, level, or movement of ground water in or the stratigraphy of an aquifer, excluding borings for instrumentation in dams, dikes, levees, or highway embankments;
c. Removing or exchanging heat from ground water, excluding horizontal trenches that are installed for water source heat pump systems (Ohio Revised Code 1521.01; Ohio Department of Natural Resources, Division of Geological Survey).

Appendix C - Existing State Laws and Rules

The following existing regulations are applicable to all or part of a geothermal heating and cooling systems.

Ohio Administrative Code § 3745-9 - Well standards
Administered by the Ohio EPA, Division of Drinking and Ground Waters

These rules cover the siting and construction of most open-loop extraction wells and all open-loop return wells. The primary exception is for dual-use wells serving private water systems. This set of regulations covers specifications for proper casing and grout materials, grout placement, well siting and well abandonment

Ohio Administrative Code § 3701-28 – Private Water Systems Rules Well standards
Administered by the Ohio Department of Health, Bureau of Environmental Health and Radiation Protection

These rules cover the siting and construction of private water system wells and are primarily applicable to for dual-use wells serving private water systems. This set of regulations covers specifications for proper casing and grout materials, grout placement, well siting and well abandonment. Geothermal systems will not need a permit from this program area/under these rules.

Ohio Administrative Code § 3701-29 – Sewage Treatment System Rules
Administered by the Ohio Department of Health, Bureau of Environmental Health and Radiation Protection

These rules cover the siting, construction, and maintenance of sewage treatment systems. Geothermal systems will not need a permit from this program area/under these rules, but an on-site sewage system location and designated replacement area must be part of the siting process to maintain required isolation distances.

Ohio Revised Code § 1521.05 - Well construction logs - well sealing reports
Administered by the Ohio Department of Natural Resources, Division of Water Resources

This law requires persons constructing a well file a log of the well construction and report the proper abandonment of a well with Ohio Department of Natural Resources. Logs are required for all open-loop extraction wells, open-loop return wells and vertical closed-loop borings.

Ohio Administrative Code § 3745-33 and 3745-38 - National Pollutant Discharge Elimination System (NPDES) permit
Administered by the Ohio EPA, Division of Surface Water

These rules allow the agency to issue general NPDES permits for activities such as discharge of non-contact cooling water used in open-loop geothermal heating and cooling systems.

Ohio Administrative Code § 3745-34 Underground Injection Control
Administered by the Ohio EPA, Division of Drinking and Ground Waters

These rules cover the permitting, siting and construction of open-loop return wells.

Ohio Administrative Code § 4101:2 - Ohio Mechanical Code
Administered by the Ohio Department of Commerce, Ohio Board of Building Standards

These rules cover the design, installation, and testing of geothermal heating and cooling piping systems, heating, ventilation, and HVAC equipment for non-residential buildings.

Ohio Administrative Code § 4101:8 - The Residential Code of Ohio
Administered by the Ohio Department of Commerce, Ohio Board of Building Standards

These rules cover the design, installation, and testing of geothermal heating and cooling piping systems serving residential buildings.

Ohio Revised Code § 1521.16 - Registering facilities capable of withdrawing more than 100,000 gallons a day
Administered by the Ohio Department of Natural Resources, Division of Water Resources

This law requires facilities with the capacity to withdraw water at a quantity greater than 100,000 gallons per day to register with Ohio Department of Natural Resources.

Ohio Revised Code § 1522 Great Lakes - St. Lawrence River Basin Water Resources Compact
Administered by the Ohio Department of Natural Resources, Division of Water Resources

This law, applicable to Great Lakes water resource management, is also applicable to open -loop geothermal heating and cooling system extraction wells and discharges. Ground water withdrawn within the Lake Erie Basin must be discharged within the Lake Erie Basin.

Ohio Revised Code § 1521.17 - Determination of reasonableness of use of water
Administered by the Ohio Department of Natural Resources, Division of Water Resources

This law provides authority to the Ohio Department of Natural Resources to investigate water use conflicts.

Appendix D - Referenced Standards

Guidelines for Loop Wells for Vertical Closed Loop Ground Source Heat Pumps, National Ground Water Association

Closed-Loop/Geothermal Heat Pump Systems - Design and Installation Standards, International Ground Source Heat Pump Association